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Sugar Plantations, Cane Growers and Sugar Mills.

ISLAND AND NAME.		MANAGER.	POSTOFFICE.
OAHU.			
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Ewa Plantation Co	*	G. F. Renton	Ewa
Waianae Co	***	Fred Meyer	Waianae
Waialua Agricultural Co	*	W. W. Goodale	Waialua
Kahuku Plantation Co	x*	Andrew Adams	Kahuku
Waimanalo Sugar Co	**	G. Chalmers	Waimanalo
Oahu Sugar Co	x	E. K. Bull	Waipahu
Honolulu Plantation Co	**	Geo. Ross	Aiea
Laie Plantation	x*	S. E. Wooley	Laie
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Wailuku Sugar Co	**x	C. B. Wells	Wailuku
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Onomea Sugar Co	**x	J. T. Moir	Hilo
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KEY.	HONOLULU AGENTS	
*	Castle & Cooke	( )
**	W. G. Irwin & Co	(8)
***	J. M. Dowsett	(1)
x	H. Hackfeld & Co	(9)
*x	T. H. Davies & Co	(8)
**x	C. Brewer & Co	(6)
x*	Alexander & Baldwin	(6)
x**	F. A. Schaefer & Co	(2)
x*x	H. Waterhouse Trust Co	(2)
††	Hind, Rolph & Co	(2)
xx	Bishop & Co	(1)

THE HAWAIIAN PLANTERS' MONTHLY

PUBLISHED FOR THE

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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SUGAR PRICES FOR MONTH ENDING DEC. 13, 1907.

			Centrifugals.	Beets.
November	15,	1907	3.80¢	9s 5¼d
"	22,	"	3.70¢	9s 3d
"	29,	"	3.625¢	9s 4½d
December	6,	"	3.625¢	9s 6¾d
"	13,	"	3.85¢	9s 8¼d

Messrs. Willett & Gray in the issues of their "Weekly Statistical" of November 27 and December 5, report as follows:

Raws.—Conditions have improved somewhat during the week under review, and some business has transpired, although at the expense of values, sales including shipment from Cuba at 2 3-16c. c. & f. for 94° test, which, at 1-32c. per lb. per degree up figures 3.61c. for 96° test. On a better feeling in the New Orleans market, resulting in an advance there, a sale was made here of 10,000 bags Centrifugals, ex store, to the Arbuckle refinery at 3.65c. per lb. duty paid, basis 96° test, followed by sales of about 40,000 bags prompt shipment from Cuba at 2 5-16c. c. & f. 96° test, equal to 3.67c. per lb. duty paid.

At the close, in spite of the steadier indications and sales at better prices, it appears that the market is still without material support, and on pressure the market gave way 4½ points, sales from store being made at 3⅝c., basis 96°. American was the buyer and Howell, for plantation account, the seller.

No stock belonging to importers now remains in warehouse, and any local business must necessarily be from one refinery to another.

The situation in New York at this time is quite abnormal and the circumstances existing may have an important influence on the market a little later on. For instance, last season when sugars were required to finish out the year's meltings, it was easy to bring them from the European markets, because American and European markets were at a parity.

On the contrary, this year there is a wide difference in this regard, our spot quotation being 30½c. per 100 lbs. below the parity of European beet sugar. Naturally, any needed supplies for the remainder of the year would come from the New Orleans market, where 96° test is now quoted at 3⅜c., but it so happens from financial conditions combined with freight conditions by steamer from New Orleans north, that some difficulty exists in bringing forward large supplies from that market. Should requirements become urgent in December and January, owing to any increased demand for refined sugars, shipments from New Orleans to meet such demand would have to be made within the next few weeks, while, from present appearances, such shipments, to any material extent, are well nigh impossible, although a few steamers are said to be under engagement. In the meantime, with the stocks in refiners' hands and a few cargoes of Javas still to arrive before the end of the year, the contingency of short supplies which occurred last season and was met by imports from Europe, may not exist this year to the same extent. This will depend largely upon the demand for refined sugars from the East. Suplies of refined sugars at the middle and distant West can be readily met by the domestic beet sugar factories in those sections. .

Europe during the week has fluctuated but slightly down to 9s. 3d., which is the closing quotation.

The cargo of Java sugars noted last week due to arrive here still remains unsold and bids thereon are solicited.

The weather in Europe continues favorable for field work.

Cuba conditions remain unchanged, rain being wanted in some parts.

The Permanent Commission of the Brussels Convention is still considering the position of Russia, which we note elsewhere in this paper.

There seems no doubt now that the acute stringency of the financial disturbance in the United States has been passed and improvement will steadily follow,. even if slow.

December 5.

There has been no change in quotations during the week under review principally for the reason that there are no sugars offering for sale. Quotations remain nominally basis of 3.625c. for 96° test.

The tone of the market has shown increased strength because of an important rise which went on in the European beet sugar markets for most of the week with an net advance of 2¼d., due to expected decrease in beet crop estimates.

The New Orleans market has advanced 1-16c. to 3 7-16c. for 96° test. Some of the purchases made there for shipment north have already arrived and others will follow in larger quantities, until approximately 40,000 to 50,000 tons are transferred before the end of the campaign.

The small balance of the old Cuban crop is held in strong hands and not offering even at 2.31c. c. & f., 95°, which might possibly be obtained. No business in new crop is reported, buyers' views being around 2⅜c. c. & f., 96° test. Latest weather reports from Cuba are rather more favorable. It is just possible that a few centrals will begin grinding this month, but the harvesting will not be general until January.

The unsold cargo of Javas, reported afloat last week, has arrived and been ordered into store for importers' account.

Reports from Europe by cable are received this week, stating that Russia has been admitted to the Brussels Convention, which should give a firmer tone to the market generally.

RUSSIA ADMITTED TO BRUSSELS CONVENTION.

Press reports state: Brussels, Dec. 4.—By the conditions under which Russia is admitted to the sugar convention that country is empowered to export a maximum of 300,000 tons from December 1, 1907, to August 31, 1909, and 200,000 tons during each succeeding year until August 31, 1913, with the understanding, however, that the total exportation during the whole period must not exceed 1,000,000 tons.

Russia agrees not to export into German or Austria-Hungary, as the supply in those countries is in excess of the demand, but as an offset to the loss of this market she is authorized to export any amount she desires into Finland and Persia. Russia is permitted to retain her fiscal and tariff legislation relating to sugar on condition that she does not give her producers advantage in the nature of a bounty.

Evidently the above date of December 1, 1907, for the beginning of exports, is in error, as we have received a special cable from London, dated December 5th, stating that "Russian sugars remain excluded until September, 1908."—(W. & G.)

EXPECTED REDUCTION IN EUROPEAN ESTIMATES.

Special cable received by us, dated London, December 3, 1907: "It is expected that a reduction of 150,000 tons will be made in the estimates of European Beet crops, the recent working of German and French beet roots being disappointing."

WEST INDIAN AGRICULTURAL CONFERENCE.

In January, 1907, the West Indian Agricultural Conference was held at Kingston, Jamaica, and the report of the proceedings thereof is contained in a recent bulletin of the Imperial Department of Agriculture. It is interesting to note that while the meeting was discussing the sugar industry, and during the reading of a paper on sugar cane experiments at Barbados, the disastrous earthquake that caused so much damage in Kingston occurred, and the proceedings were resumed on board ship during the journey to Barbados.

Some of the papers read at the conference are of considerable importance, and in this issue we are republishing F. A. Stockdale's paper on "Breeding Hybrid Sugar Canes," and that by S. F. Ashby entitled "The Nitrogen Cycle of Soil Organisms," which we think will be of interest to our readers.

IMMIGRATION.

The annual report of the Commissioner-General of Immigration for the year ended June 30, 1907, has just come to hand and is replete with valuable and interesting information and statistics.

The total of immigration to the United States for the year under review reached the unprecedented figure of 1,285,349, as against 1,100,735 for the preceding year. Commenting on this and the increase of immipration since 1820 the report says:

"Chart 2 shows the wave of immigration into the United States from the various countries since 1820. It is interesting to note that the successive periodical increases, receding less each time, coincident with periods of financial depression, only to reach a greater height with the next ascending wave, and passing a million and a quarter, the highest point in history, during the present year. Thus the three periods of depression following, 1857, 1873 and 1893, stand out prominently. This periodical rise and fall well represent the relative prosperity of the country, while the general average increase from decade to decade, may be taken as an index to the country's development and growth, and its capacity to employ larger quantities of the alien element.

"What will be the effect if the present phenomenal immigration continues is a question that is constantly being asked. With regard more particularly to quantity the question may be answered by the following illustration: China proper is the thickly populated portion of the Chinese Empire, and is the country popularly thought of as representing the limit of density of population. With a net increase to our population by immigration of 1,000,000 per annum, which is less than the present rate, and the present rate of natural increase (14.66 per cent. per decade), the United States would reach the density of China proper in about four generations, or, more particularly, in one hundred and thirty-four years, at which time we would have a population of 950,000,000. This is in no sense an estimate of future population; it is simply an illustration of the present pace."

Commenting upon the efforts of various sections of the country, including Hawaii, to obtain immigrants through specially created Boards of Immigration, the report says:

"The desire of particular sections of the country for immigration, and the discussion of ways and means for securing it, especially in the Southern States, have engaged the attention of the Bureau to a considerable extent in the past year. The position taken by it has been that two leading considerations point to the propriety, if not necessity, of an encouragement of this desire, and assistance, so far as possible in its fulfillment—first the indirect, but powerful, influence that the establishment of a part of the arriving aliens in such sections must eventually exert upon the congested conditions existing in our northern and eastern cities, and second, the fact that Congress, recognizing that many of the States and Territories were in need of settlers, made in the law a special exception in favor of such States and Territories, advertising the facilities and inducements they offer to settlers. The Bureau has not hesitated, therefore, so far as lay in its power and within what it conceived to be the lawful limits of its duties, to offer encouragement and assistance in the furtherance of the plans of the immigration commissions appointed in several of the States and Territories. In doing this it has given advice concerning the meaning and intent of the law, always being careful to caution those making inquiries that no plan could be countenanced that included within its scope any indirect furtherance of schemes on the part of labor employers to obtain cheap labor, or any violations of the provisions of the law relating to alien contract labor; and has arranged for the prompt examination of aliens brought from abroad under the auspices of, and in response to, advertisements by States or Territories. Two prominent instances of this kind have occurred:

"The State of South Carolina, early in the year made arrangements for the settlement therein of a number of Belgians—mostly weavers and mill operatives—for which class of labor there was a heavy unfilled demand among the cotton mills of the state. "On November 4, 1906, the North German Lloyd steamship 'Wittekind' entered the port of Charleston with 473 aliens aboard, coming in response to advertisements made in Europe by the immigration commissioners of the State, who accompanied the party on the voyage over. The Commissioner-General was present with a selected corps of employees, detailed from Baltimore, Philadelphia and New York, and the examination of the aliens under the immigration laws was promptly conducted. They were found to be, in the main, an excellent lot of men and women; and undoubtedly, if they are made to feel contented and to prosper in their new homes, they will exert a powerful influence upon the future settlement of the State.

"The other instance occurred in the Territory of Hawaii. On April 24, 1905, the Legislature of that Territory passed an 'Act to provide for a board of immigration,' in pursuance of which two commissioners were appointed in the summer of 1906 to proceed to Europe and secure white settlers for the Islands. They chartered a boat, the *Suveric,* and brought to Honolulu about 1,300 Portuguese, who were landed on December 1 and 2, 1906. Later, two other shipments were brought—the *Heliopolis* landing on April 26, 1906, with 2,300 Spanish aliens, and the *Kumeric* reaching Honolulu on June 27, 1907, with about 1,100 more Portuguese. Thus there has been added to the white population of the Islands almost 5,000 settlers whose influence upon the future of the Territory can hardly be foretold or imagined. The Commissioner-General was present when the *Suveric* arrived, and was very favorably impressed with the appearance of the aliens and with the reception accorded them by the people of Honolulu."

The Chinese immigration question occupies a very considerable part of the report, and the suggestions made by the Commissioner-General, and the general manner in which this subject is treated, show perhaps that the trend of public opinion in the United States desiring a more liberal treatment of Chinese, is affecting official circles. The report says:

"The Chinese Government has always asserted a desire to keep her coolie class at home; and as her resources are opened up, there should be more need than ever for the maintenance of this policy upon her part. On the other hand, considerable dissatisfaction is indicated among the Chinese everywhere with the existence in this country of laws that they think are too broadly directed at the Chinese people as a race. Under these circumstances is there not sufficient to be granted by way of mutual concession, to form the basis of a treaty, so plainly drawn and so comprehensive, as to be effective of the desires of both countries, permitting of a more liberal attitude on the part of the United States toward the Chinese and at the same time affording an assurance that the coolie class will not be permitted to enter this country?

"Whatever may be thought as to the desirability and feasibility of adopting a new treaty on this subject, in the Bureau's opinion one thing is certain, viz., that present conditions, some of which have already been alluded to and others of which will be mentioned hereinafter, cannot be allowed to continue indefinitely with any credit to our Government. If the exclusion laws, as they now stand upon the statute books, are just and reasonable, they should be enforced in all of their provisions; if they are not just and reasonable and are not therefore to be enforced in detail, they should be repealed."

ACIDITY OF SOILS.

By Isaac Phillips Roberts.

LIMING TO CORRECT ACIDITY OF THE SOIL.

No recent experiments with lime have attracted more attention than those made at the Rhode Island Station, and since they are destined to be far-reaching in their results, it is a pleasure to quote them freely. Of necessity, but brief extracts can be made, yet it is hoped that the student will become sufficiently interested to re-read the full text of the publication. The facts reached are doubly valuable, since they give the results secured in both field and laboratory, and the only regret is that space does not permit making fuller and more connected quotations.

"So far as we have been able to ascertain, no one in this country has thus far definitely called attention to the existence of an injurious degree of acidity in uplands or naturally well-drained soils, and at the same time pointed out a simple and practical means for its recognition. American agricultural chemists appear not only to have been of the opinion that an injurious degree of soil acidity is to be found only in muck and peat swamps, and in spots where stagnant water occurs but they make no mention of making tests for acidity as a means of recognizing a deficiency of carbonate of lime."

* * * * * * * *

"E. W. Hilgard, in the course of his work upon the soils of the southern states, particularly in connection with the sandy pine lands of Mississippi, has called attention to their need of lime, though we can find no mention of tests for acidity having been made in connection therewith; he states, however, in a private communication, that the recognition of their acidity was what led to his recommendation of the application of this substance. He furthermore says: 'You are doubtless right in thinking that attention should be more definitely called to the importance of soil acidity as an unfavorable agent in agriculture outside of swamp or marsh lands.' A. Volecker says that, 'There is a ready test for ascertaining whether a soil is likely to contain an injurious constituent. All that is necessary is to put a strip of litmus in contact with wet soil; if the blue color of the test paper turns rapidly red, the soil is certain to contain something injurious to plant life.' The soils which he appears particularly to have examined were reclaimed marshes, muck, etc., or what would be termed unusual soils. Several French writers refer to the acid soils of Brittany, Limousin, and other sections, which in many instances have been wonderfully benefitted by the use of lime. Many of the soils referred to appear to have been upland, or well drained. Schultz-Lupitz, in speaking of the sandy soil of his section, in Germany, refers to its being poor in lime, and, therefore, becoming sour and unfit for the economical production of plants; he makes, however, no reference to the use of litmus paper nor of any other means of definitely ascertaining its acidity, but appears to infer that it was acid from the beneficial action of lime upon it. E. W. Hilgard says: '"Saurer Sandboden" is the expression I have frequently heard applied in Berlin to the uplands of that region and the Mark Brandenburg at large.' W. Detmar states distinctly that not all soils which are excessively rich in humus are acid, and, on the contrary, that sandy soils sometimes give an acid reaction; and he mentions in the same connection the value of the litmus paper tets as an indicator of this condition. Th. Hubener likewise calls attention to the frequent acidity of sandy soils.

"S. W. Johnson states that 'a soil that is fit for agricultural purposes contains little or no free acid except carbonic acid, and oftentimes gives an alkaline reaction with test papers,' while Storer asserts that 'cultivated soils, though sometimes neutral to test papers, as a rule exhibit a faint acid reaction; and experience with water culture has shown that slightly acid solutions are favorable for the growth of plants. But any excess of soluble acids in the soil would be highly detrimental.' Jas. F. W. Johnston, in speaking of soils which are moist and where much vegetable matter abounds, says that 'the effect of this superabundance of acid matter is, on the one hand, to arrest the further natural decay of the organic matter, and, on the other, to render the soil unfavorable to the healthy growth of young or tender plants.' Voelcker says regarding the action of soil upon litmus paper: 'If the blue color of the test paper turns rapidly red, the soil is certain to contain something injurious to plant life. All good and fertile soils either have no effect upon red or blue litmus paper, or show a slight alkaline reaction; that is to say, in a wet condition they restore the blue color to reddened litmus paper.' A. Mayer states that the so-called sour humus is really somewhat sour, and that on this account is, without doubt, injurious to plants. Shultz-Lupitz, as heretofore cited, speaks of sandy soils becoming sour and unfit for the profitable production of plants. Mulder claims that 'a good soil should turn a red litmus paper blue,' (that is, it should be alkaline, and not acid). A. Stutzer says that 'a large amount of acid in soils is injurious to all cultivated plants.' Th.

Hubener states that 'hardly anything has so great an influence upon the character of the vegetation as the conditions of the humus.' In this respect plants may be divided into three classes: one which thrives best where the humus is sour, another which refuses to grow where sour humus is present, and a third and the largest class, the individuals of which can accommodate themselves to either condition; and also that where a soil is recognized by means of litmus paper as being sour, the acidity must be overcome by the use of marl or lime. * * * * * *

"Certain cultivated plants have been found to nearly or quite succumb until lime has been applied, after which they have made a magnificent growth; characteristic among these may be mentioned common red clover, spinach, lettuce, beets and timothy (Phleum pratense). Upon sour soil, when left to itself for some time, certain plants seem eventually to predominate, while others gradually disappear. Considering that the soil contains no carbonate of lime, to the absence of which, together with other basic compounds, its acidity is apparently due, it will be obvious, in connection with what has been said above, that the natural vegetation would be of a type suited to such a soil. Having observed, therefore, what plants thrive here naturally, the recognition of similar plants elsewhere would lead to the natural conclusion that there similar conditions may also exist. Those plants which have appeared particularly characteristic of acid soil in our immediate vicinity are the following: Birdfoot violet (Viola pedata), wild or beard grass (Andropogon scoparius), species of St. John's-wort (Hypericum), common or soft rush (Juncus effusus), wood rush (Luzula compestris), and several mosses; the appearance of common sorrel (Rumex Acetosella) is common as soon as the soil is cultivated. In addition to one or two of the plants above mentioned, Ruffin speaks of the pine as a plant which thrives best upon soil poor in lime. Various French and German writers state that clover fails to thrive upon land deficient in carbonate of lime, and, as above stated, we have found the same to be true of timothy; so that by observing not only those plants which thrive, but also those which fail to thrive, indirect evidence of the needs of the soil may be, in a measure, afforded. In the course of observations upon the nature of the wild plants, cultivated grasses and clover, not only in many parts of Rhode Island, but also in some parts of Massachusetts and Connecticut, the soil appears to be probably in somewhat the same condition as our own; quite marked changes in this respect are noticeable as one travels westward from Boston. At a distance of twenty or thirty miles, clover and timothy are, in certain sections, found to largely disappear, and farmers in such sections have stated that clover cannot be made to grow, and that timothy runs out quickly. In fact, statements to the same effect have recently come to our notice from New York, Connecticut and several of the eastern seaboard states."

The Rhode Island report makes the following summary of the literature:

"The removal of plants from the soil, and the use of certain fertilizers, doubtless exhaust the lime and other basic ingredients of the soil more rapidly than would be the case were nature allowed to take her course.

"That an acid condition is liable to result, in consequence of the above-mentioned operations, particularly in the case of soils derived from rocks deficient in basic ingredients, we believe to be a reasonable assumption.

"While some plants, like clover, timothy and beets, appear to be injured by a lack of carbonate of lime or by the resulting acidity of the soil, others appear to thrive best under such conditions.

"A strongly marked reddening of blue litmus paper seems to be a simple and effective indication of the condition of a soil in the above-mentioned particulars.

"The value of a satisfactory method for determining the relative acidity of soils would seem to be great.

"A dangerous degree of acidity, or at least a fatal lack of carbonate of lime, appears to exist in upland and naturally well-drained soils, and is not confined to muck and peat swamps and very wet lands, as most American and many other writers seem to assume, in view of which it appears that the test for acidity should be more generally applied to such soils.

"That this condition of upland soils has not been more fully recognized heretofore is not surprising, for the reason that the failure, or partial failure, of certain crops, has been attributed to winter-killing, poor germination of seeds, drought, excessive moisture, or attacks of insects or fungi. Upon soils where certain plants are injured only to a limited extent by acidity, others would be expected to thrive best of all, in consequence of which it is not surprising that the cause for the partial failure of certain crops upon them has not been suspected.

"The inefficiency of land plaster, as compared with air-slaked lime, in the culture of beets, and in overcoming the ill effect of sulfate of ammonia, as well as the highly beneficial results from the use of caustic magnesia and carbonate of soda, all tend to further strengthen the position that the fault of the soil in question is a lack of basic ingredients, to which the presence of noxious compounds, which may partly or wholly give rise to the acid reaction, is attributable."

By the courtesy of Professor H. J. Wheeler, of the Rhode Island Station, I am permitted to make extracts from a paper recently read by him at Washington:

"Soon after the establishment of the Experiment Station, at Kingston, R. I., it became noticeable that the farmers, at least in the southern portion of the state, grew but little, if any clover, and upon inquiry among them, it was stated that it could not be grown, owing to the fact that it winter-killed. The only place where clover could be seen to any extent was in a few fields near stables and upon an occasional farm where wood ashes had previously been used. Timothy failed to endure for more than one or two years, while red top and Rhode Island bent were the two grasses most universally found. On seeding land upon the college farm with clover and mixed grass seed, it was found to be practically impossible to secure a stand of timothy and clover, though a fair crop of Rhode Island bent and red top could be obtained. It was observed that with an increased application of ammonium sulfate, the crop of Indian corn was lessened instead of increased, and where the full ration of nitrogen in this form was used, the yield was much less than on an adjacent plat treated the same in other respects, but where nitrogen was not applied. This condition has continued uninterruptedly up to the present time.

"In searching for a cause for the ill effect of the ammonium sulfate, non-nitrification, and in consequence of a poisonous effect of the ammonium sulfate or of compounds produced by its reaction within the soil, were considered. All of the conditions essential to nitrification seemed to be right, provided the nitrifying organisms were present, unless perhaps the difficulty was due to an unusual acidity or alkalinity of the soil, which reaction was already well known to exert a marked influence upon nitrification in various media. An examination of the soil by means of blue litmus paper revealed the fact that it was decidedly acid. In consequence, the idea of the use of lime naturally suggested itself.

"In recognition of the writings of American agricultural chemists, in which they note the effect of sourness upon the growth of plants in lowlands or wet meadows, as well as those of European writers, some of whom do not confine their reference to swamp lands exclusively, and to lowlands naturally wet, the idea suggested itself that the acidity of the upland soil at Kingston might be sufficient to exert a marked influence upon the growth of various agricultural plants. Accordingly, in 1893 an experiment was begun which has been continued since without intermission, in which nearly 150 different varieties of plants have been tested in this particular. In order to eliminate in this experiment, so far as possible, the influence of the acidity of the soil upon nitrification, sodium nitrate was employed upon two plats in connection with muriate of potash and dissolved boneblack, one of the plats receiving an additional application of air-slaked lime. In the course of the experiment, some of the most striking differences not only in members of the same family of plants, but also even in species belonging to the same genus, have been observed. When fresh applications of lime had been made rye was benefited little, if at all, and sometimts apparently injured, while oats showed a slight benefit, wheat a very marked one, and barley even more than wheat. Serradella, lupines and one or two other leguminous plants have been invariably injured by liming, while red clover, peas and certain others have been benefitted decidedly thereby. One of the most remarkable instances is that of watermelons and muskmelons. The former in two trials were injured by liming, and in the second trial in a most serious degree; while the latter were a total failure where lime was not applied." * * * * * * * * * * * *

"In the course of these experiments it has been found that calcium sulfate does not prevent the ill effect of ammonium sulfate, while air-slaked lime does it effectually. Magnesium sulfate fails likewise, while caustic magnesia is highly effectual."

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"From the foregoing it will be seen that there is great probability that the larger portion of the state of Rhode Island is suffering from a deficiency of carbonate of lime, a fact which in many instances would not have been surmised from a determination of calcium oxid in a hydrochloric acid extract of the soil, for in the soil of the Experiment Station at Kingston there was found upon the hill, by this method, .45 per cent. of calcium oxid, and upon the plain .57 per cent., in both of which cases one would have been disinclined to believe that such a serious deficiency of carbonate of lime existed. In one experiment at the Rhode Island Experiment Station, gypsum was applied at such a rate that the equivalent of .2 per cent. of calcium oxid was present in the soil, yet without overcoming the ill effect of ammonium sulfate. In another experiment, gypsum representing about .13 per cent. of calcium oxid failed to have the same beneficial effect upon the growth of beets and barley as an equivalent amount in form of air-slaked lime. It must be obvious, therefore, *that in certain instances soils may contain even a high percentage of lime, all of which may be in such combination within the soil that an acid reaction is possible,* whereby plants are injured, even if nitrates are supplied, in which case calcium carbonate or other alkaline agents are efficient remedies. It will be seen, furthermore, that where such soil-conditions exist, a test for acidity gives a better indication of the needs of the soil in respect to lime than an analysis of the hydrochloric acid extract, and in view of the fact that many soils, not only in Rhode Island, but some also from Connecticut, Massachusetts, New York, Virginia and other states, have been tested in our laboratory and found acid, and in view of the actual demonstration of the value of lime in the culture of beets in various parts of Rhode Island, it must be obvious that agricultural chemists should give more attention to this important factor in their examinations of soils. Most of the soils upon which lime has proved so beneficial in connection with the culture of beets, and several where clover has likewise been benefited in a most wonderful manner, belong essentially to that group of soils which would be considered as upland and naturally well drained, and would not be classed, under any circumstances, as naturally wet, or be spoken of as 'swamps' or 'morasses.' It will be seen, therefore, that the question of the occurrence of acidity in upland or naturally well-drained soils, even though it is almost unmentioned by American agricultural writers as a matter of importance, is deserving, in certain sections of this country, of perhaps even more attention that it has received in Europe."—The Fertility of the Land.

THE IMPROVEMENT OF SUGAR CANE BY SELECTION AND BREEDING.

By V. O. Townsend,

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It is the purpose of this report to consider briefly the progress that has been made in the improvement of sugar cane in those countries in which this plant is grown commercially, and to establish, if possible, a general foundation upon which future reports may be based.

Sugar cane belongs to the natural order of grasses and is divided by Cordemoy into three species, namely, *Saccharum officinarum, Saccharum violceum*, and *Saccharum sinense*. Most authorities agree that all cultivated canes are derived from the first species named. The second one is found in Hawaii, while the third is the Chinese cane. At each joint and underneath the leaf is the bud or eye, which was thought for many years to be the only means by which cane could be propagated and which is still the principal means of propagating this plant commercially. This bud is about the size of a pea or a little larger, and varies in size and shape on different canes. The head of the cane, commonly called the arrow, consists of large white or gray clusters of flowers, a panicle of soft silky spikelets carried on an elongated peduncle. The spikelets are made up of three scale leaves, two exterior and one interior. The two outer ones are called the glumes and the interior one the palea. Within this covering is the flower, consisting of three stamens and one pistil. The ovary is ovoid and sessile, and contains only one ovule. It carries two styles of a reddish color, which in turn carry a large number of stigmas. The time of flowering varies from eight to fifteen months, but the cane is not fully ripe until from two to three months after flowering.

The composition of sugar cane varies with the species and with the conditions of growth. The limits of composition of cane as given by Dr. Deerr in his work on Sugar and Sugar Cane is as follows:

	Per Cent.
Water	69 to 75
Sugar	10 to 18
Glucose	0 to 2
Fiber	8 to 16
Ash	3.10 to 8.10
Organic non-sugar	½ to 1

What is here called fiber refers to the insoluble matter and not alone to true cellulose.

One of the strongest incentives to the improvement of the quality of sugar cane has been the development of its rival as a sugar plant—the sugar beet. It is therefore only within comparatively recent years that earnest systematic efforts have been made to improve cane as a sugar-producing plant.

Two general methods have been employed in improving the size, quality and habits of sugar cane. One method may be designated as vegetative or bud selection, and the other as breeding. The former undoubtedly has been carried on by cane growers either consciously or unconsciously from the time this plant was found to be of economic value, even without having in mind a definite type of cane to be produced. Vegetative selection is based upon bud variation, in which peculiar or desirable characters have been recognized by the grower; as for example, size of cane, color, ability to stand erect, size of nodes, length of internodes, ability to ratoon, etc. Some effort has been made to improve cane by chemical selection, and, while considerable progress has undoubtedly been made along this line, it has been largely because the desirable internal qualities of cane correspond to some extent with the desirable external qualities. The difficulties in the way of chemical selection under the vegetative plan of breeding are similar to those of other plants. The soil and climatic conditions, as well as methods of cultivation, cause considerable variation in the sugar content of the cane. As an instance of the variation in sugar content due to external conditions it is stated that the crop in Demerara in 1900 consisted of one variety only. The canes grown on virgin soil contained less than eleven per cent. sugar, while the small variety growing on older land produced fourteen per cent. or more. This fact has been observed repeatedly in connection with sugar beets, and it is undoubtedly a general rule that the composition of the plant varies within wide limits depending upon soil and climatic conditions. Likewise, the part of the cane tested as well as the age of the cane causes variation in the results obtained. The lower part of the cane, for example, contains considerably more sugar and less glucose than the upper part. The following data from a table prepared by Bonane establishes this fact:

A. Plant imperfectly ripe and still in full vegetation. The lower part contained 13.74 per cent. of sugar and 1.78 per cent. of glucose; the middle part contained 14.11 per cent. of sugar and 2.44 per cent. of glucose; the upper part contained .85 per cent. of sugar and 4.11 per cent. of glucose; and the white top contained 4.01 per cent. of sugar and 6.57 per cent. of glucose.

f. Plant very ripe, 14 months old. The lowest fourth contained 22.68 per cent. of sugar and .51 per cent. of glucose; the lower middle fourth contained 22.68 per cent. of sugar and .52 per cent. of glucose; the upper middle fourth contained 22.68 per cent. of sugar and .52 per cent. of glucose; the upper fourth contained 22.03 per cent. of sugar and .53 per cent. of glucose; and the white top contained 16.84 per cent. of sugar and .70 per cent. of glucose.

The other plants used by Bonane were mostly ratoons, which showed a marked decrease in the sugar from the base upwards and a corresponding increase in glucose. It is important therefore in comparing canes for the purpose of establishing a higher sugar content that the sample be taken from the same part of each cane tested. It has been ascertained that over-ripe canes rapidly deteriorate, hence the exact time of making the test is important. Inasmuch as different varieties of cane ripen at different ages, it is difficult to make tests that are comparable, and especially is this true since the later ripening variety may be subjected to weather conditions during the ripening period that are entirely different from the weather conditions that obtained while the earlier varieties were ripening. It is also true that the buds on the lower nodes of the cane are less active than those at the upper nodes. For these reasons it is customary in some localities to use the upper three or four nodes for planting, while the lower part of the cane is used for sugar production. Whether or not the practice of using buds from that part of the cane poorest in sugar and richest in glucose will not eventually cause the canes to deteriorate can not be determined from any of the reports examined. The fact that the buds are practically independent of the canes so far as germination and growth are concerned would lead to the conclusion that the quality of the cane produced from the bud would be but slightly influenced by the quality of the cane upon which the bud was borne. This can be determined with certainty only upon investigation.

The improvement of cane by seminal breeding has been confined to the past two decades. For many years it was supposed that the seed of cane was infertile. Although we find some references to the production of seedling canes in India, no importance was attached to these statements by cane producers. Darwin, in his work on the variation of animals and plants under domestication, cites cane as one of the plants which does not produce seed. He bases this statement upon the record of various observers in the principal sugar countries of the world. De Candolle in his Origin of Cultivated Plants, states that the seed of cane has never been described nor figured. For the reason stated, the buds on the joints of cane were considered the seeds of this plant and were, as already stated, looked upon as the only means of reproduction. In 1858 it was found by J. W. Parris, of Barbados, and in 1860 and 1861 by F. B. Carter, of that Island, that a few of the seeds produced by sugar cane were fertile, but they were so few in number and the difficulties that arose in trying to produce canes from seeds were so great that the idea was abandoned. It seemed to be the purpose of those who discovered fertile seeds in early days to do something in the way of producing commercial cane from seeds, while very little attention seems to have been given to the production of improved strains or varieties at that time by seminal variation. In 1887 fertile seeds of sugar cane were again discovered almost simultaneously by Professor Soltwedel, Director of the Samarang Station, in Java, and by Mr. J. B. Harrison, Island Professor of Chemistry and Agricultural Science at Barbados, in conjunction with Mr. T. R. Bovell, Superintendent of Dodd's Reformatory. The flowers of cane were figured by Professor Soltwedel probably for the first time, and it is claimed by some writers that his discovery of fertile seed and the production of seedling canes therefrom slightly antedates the discovery of Messrs. Harrison and Bovell. The two investigators last mentioned, however, made the most practical use of this discovery, or rather rediscovery of fertile seeds of cane. The method of their discovery is briefly as follows: The canes were planted in thirty-six plats of eighteen varieties, so arranged that two sets of each kind were planted side by side. The plats were noticeable for the number of arrows sent up by some of the varieties. Mr. Harrison gave strict orders to the laborers to call his attention to any peculiar or unusual grasses that appeared among the canes during the season. Accordingly his attention was called to a few tufts of grass toward the end of January. He states in his report that a great deal of difficulty was experienced in keeping these plants alive as they quickly shriveled under the influence of the sun's rays. However, by keeping them shaded and constantly watered he succeeded in saving upwards of sixty of the plants. This probably is the beginning of the breeding of sugar cane, at least so far as we have any record of this phenomenon.

In 1887 Dr. Soltwedel tried to cross one of the cultivated varieties with one of the wild kinds. It was not possible to ascertain whether or not the cross-fertilization was successful. Fertilization was observed in twenty varieties of cane other than the variety used, and fertile seed was produced in eleven of these varieties. The number of seeds produced varied from thirty-one per cent. to less than ¼ of one per cent. A very large number of Dr. Soltwedel's seedlings perished. In fact, he obtained strong seedlings from only one variety, the Yellow Hawaii. These attained a height of 2½ meters. The fact that Dr. Soltwedel and Messrs. Harrison and Bovell worked independently upon this interesting problem and obtained practically identical results would lead us to the conclusion that both parties are entitled to great credit for this discovery, which undoubtedly means much for the future of the cane industry.

The principal difficulties in the way of the improvement of sugar cane either by vegetative selection or breeding are due to several general conditions, such as confusion of names, non-stability of characters, and size and position of flowers. The confusion of names of existing varieties is due in part to our lack of knowledge of the origin of cane and in part to the tendency on the part of planters to give old varieties new names when they are introduced into new localities. Some writers claim that the original home of the cane is China; others find strong evidence that it originated in India, while still others claim that it is a native of the Pacific Islands. Without the original type plant we are unable to determine what are variations and what are true characters. Again, a cane introduced into Louisiana from Hawaii, for example, may receive in Louisiana the name of the planter who first grew it. If taken to Queensland, it may receive still another name, all of which tends toward great confusion in regard to the true name and to the number of existing varieties.

As has already been indicated it is difficult to fix upon any characters which may be sufficiently stable to establish a basis for varieties. Among the important points towards which cane breeders aim may be mentioned the following: (1) Good yield. (2) High sugar content. (3) Upright growth. (4) High fertility. (5) Freedom from disease. (6) Fair fiber in megass. (7) High percentage of juice. (8) Early maturity. (9) Ease of crushing. (10) Easy clarification of juice. (11) Flinty rind. (12) Satisfactory ratooning. These characters may all be summed up in the one statement that the cane most desired is the one that will yield the largest quantity of sugar per acre with the greatest certainty and with the least expense. The value of nearly all these characters is self-evident. It is of prime importance that a good yield of cane rich in sugar be produced. A tendency in the cane to fall down produces not only crooked canes that are hard to handle but canes that are low in sugar and rich in glucose. The fiber in the megass is of especial importance in those localities where this material is used as fuel.

One of the most common characters which has been used to distinguish varieties is that of color. To this have been added size of nodes, length of internodes, general characters of arrows, and habit of growth. In regard to color as a varietal distinction, Professor Stubbs in his work on the cultivation of sugar cane divides all the varieties found in Louisiana into three classes according to color. In the first class he places all white, green and yellow canes; in the second class, all the striped canes; and in the third class, canes having solid color other than in class one. He then divides the canes under the varietal classes into groups, the number of canes in each group varying from one to nine. All the members of the same group are, according to Professor Stubbs, identical. Whether or not canes retain their color under the various soil and climatic conditions in Louisiana, Professor Stubbs does not state, but according to Professor Eckart color is not a staple character, at least with some varieties. He has made a study of a large number of varieties, and states that between White Bamboo and Yellow Caledonia there seems to be no difference and after four years' trial it is impossible to distinguish one from the other. This arrangement by Professor Stubbs is made for the purpose of bringing order out of chaos regarding the names of the varieties of cane. Several years ago the Louisiana Station inaugurated a plan whereby the different varieties of cane grown in various countries could be exchanged and compared for the purpose of determining which are identical. This will undoubtedly do much toward solving the problem of varieties, providing the influence of soil and climate has not already produced marked changes in the imported varieties so that they can no longer be recognized as belonging to the type from which they originated.

In conclusion it may be said that much has been accomplished in improving sugar cane in spite of the many difficulties and discouragements that attend the selection and breeding of this important plant. Not only has the yield of sugar per acre been greatly increased, both by increased yield of cane and by a higher sugar content, but varieties more or less resistant to disease have been produced, thus making the crop more profitable and more certain. Furthermore, varieties suited to different soil and climatic conditions have in some instances been developed in this manner, greatly increasing the acreage. That much may still be done to improve the quality of sugar cane and the quantity that may be produced per acre is certain, but it will take years of patient painstaking work to approach the desired goal. In our own country much has been accomplished by the Louisiana Experiment Station. It has not been possible in this country to produce canes from home grown seed owing to the fact that cane grown in this country does not produce fertile seeds. Imported seeds have been produced, some of which are very promising along several lines of improvement. In Java a great deal has been accomplished in producing canes immune to disease as well as in producing improvements along other lines. Likewise in Australia, Hawaii, and other sugar-producing countries, the methods of improving sugar cane have been inaugurated along right lines, and the future is full of promise for good results. The most satisfactory results have been attained in the British West Indies, where improvement by seminal variation was first successfully started and where it has been carried on continuously for nearly twenty years. While the vast majority of seedlings produced have been rejected for good reasons, a few have been more or less satisfactory, and are now being grown in nearly all cane-growing countries of the world. The methods of selecting and hybridizing are fully described in Professor Stockdale's report of last year.

BREEDING HYBRID SUGAR CANES.

By F. A. Stockdale, B.A., (Cantab.),

Experiments in the raising of seedling sugar canes by hybridization under control were commenced at Barbados in 1904. The flowers of one variety were emasculated while young, covered in a muslin bag, and then pollen from another variety was transferred to them. As the result of this work, five stools of hybrid canes of known parentage were obtained and were under investigation during last season. One of these stools suffered very severely during the drought, but two cuttings were obtained from it. At the present time, there are 166 plants growing from the five hybrids obtained, and laboratory tests will be made later to ascertain the saccharose content of their juices. Four pedigree hybrid sugar canes have also been raised in Queensland, and it is reported that during 1905-6, owing to a favorable season, over 600 hybrids were obtained at the Harvard Experiment Station, Cuba.

In a paper by Sir Daniel Morris, K.C.M.G., and myself, that was communicated to the International Conference on Genetics, held under the auspices of the Royal Horticultural Society during July and August, 1906, a concise account was given of the different methods by which improved varieties of sugar cane had been obtained by selection and hybridization. Some of the results obtained by those working in this direction were given, together with the individual advances made by some of the more important cane-growing countries. It was pointed out that attempts to procure an improved race of sugar canes centered around breeding from the best varieties, but it was suggested that in the future the best results were likely to be obtained by first carefully analyzing the different characteristics of the different varieties under cultivation, in the hope that it might be possible to pick out desirable qualities from one variety and combine them with other desirable qualities of another variety. The necessity of adopting a method of breeding for definite objects has been brought conspicuously to the front, by the fact that it has repeatedly been pointed out that the breeding ability of the various mother plants varies considerably. Frequently a variety, which is low down in the list in respect to saccharose yield per acre, gives seedlings that are of much more value than a similar race of seedlings produced from a cane that is much higher in the list, or in other words, a cane of comparatively low value often gives a much greater percentage of subsequently selected seedlings than a cane which, in itself, is of a much higher value. In the one case, we have what has been described as a strong "projected efficiency," and in the other a weak "projected efficiency." This variability noticed amongst the offspring has led to considerable confusion, for the plant has been considered as a whole; when each separate character, if taken alone, may be found to obey definite simple laws. Single characters must be treated as distinct, and the composition of individual plants must be considered as much by their progeny as by their ancestry.

In raising new varieties by selection, advantage is taken of the fact that plants raised from seed are never exactly like the parent, while hybridization is often held by some to awaken the sum total of variation in the two parents, with the result that the seedlings thus obtained present many variations. The raising of new and improved races of plants depends upon this circumstance of variability, and it would appear that the differences between separate members of one family are of two kinds: (a) individual differences, usually quantitative, between the various members, such as differences in size of plants or in size of any particular part of a plant—for example a fruit; and (b) definite or qualitative differences, existing between different strains of plants. It is from these definite differences, by a process of hybridization, that new varieties of plants of increased value can be raised.

It has been shown that hybridization of the sugar cane under control can successfully be carried out. Therefore, instead of depending on raising seedlings by planting arrows from the better varieties, by which only the seed-bearing parent is known with certainty, and instead of making a considerable number of crosses indiscriminately with the hope of obtaining some improvement, hybridization experiments on definite lines have been laid out, in which the different useful characteristics of the several varieties are carefully considered. By this means, the possibility of an individual deviating to a marked degree toward a desired type becoming pollinated with pollen from less desirable varieties is eliminated, and by the careful selection of the varieties to be experimented with there is little chance of a reduction of the standard of perfection already attained.

During recent years, it has been conclusively shown that a general knowledge of the characteristics of different varieties is of the utmost importance, as by such knowledge it is often possible to confine the work to a small number of varieties possessing those desired qualities which are not to be found in other sorts. The physiology of heredity—the manner in which different useful characteristics are handed over from parents to offspring—is becoming more fully understood, and has lately been the subject of exact scientific inquiry. The results, so far obtained, tend to show the value of the technical methods that have been developed by the experience of practical men.

Kobus in Java, in reports issued between the years 1898 and 1901 on the crossing of Java canes, as seed-bearing parents, by natural hybridization with the East Indian variety Chunnee, as pollen-bearing parent, states that "in some cases the fecundating power of the Chunnee variety is so strong that more than 95 per cent. of the hybrids resemble the male parent," and Professor Harrison in a report on the Agricultural Work in the Botanic Gardens and the Government Laboratory, British Guiana, for the years 1896-1901, states that it was being found that "while the seedlings of the older varieties with but few exceptions show marked tendency to variation, the seeds of canes from seedling canes do not possess this property to anything like the same extent, and in many of these the offspring appears to come fairly true to parentage." Such records as these on the raising of seedling canes show that some varieties possess characteristics that are transmitted to their offspring, while others do not.

In reference to many other plants it has repeatedly been noticed that when two varieties, which differ by definite characters, were crossed together, the offspring of such a cross partakes to some extent of the different characteristics of either parent, and frequently all to an equal extent. It was further found that if these offsprings were crossed amongst themselves or allowed to self-fertilize, a large number of forms arose in the next or second generation. This was not fully understood until 1901 when the discovery of experimental work carried out by Mendel gave an explanation of the hereditary processes with which the breeder is concerned.

MENDEL'S WORK ON INHERITANCE IN PEAS.

Mendel experimented with the crossing of a large number of peas and centered his attention not on the plant as a whole, but upon its simplest characters, such as shape of seed, color of flowers, length of stem, etc., and traced in detail the behavior of each character in the hybrids, keeping the records of these simple characters, singly, separate from all others; for he held that "in order to discover the relations in which the hybrid forms stand towards each other and also towards their progenitors, it appears to be necessary that all members of the series developed in each successive generation should be, without exception, subjected to observation."

The exact nature of Mendel's work may possibly be made clear by taking one or two examples from it.

Two varieties of pease were chosen, one of which possessed smooth, round or roundish seeds, while the other possessed seeds that were irregularly angular or deeply wrinkled. These were cross-fertilized. The plants arising from this cross possessed round seeds entirely, of such a form that differences could not be detected between them and the round seeds from one of the parents. It appeared, therefore, that a character of one parent was transmitted complete or almost complete in hybridization to the exclusion of the corresponding character of the other parent. This constituted the character of the hybrids of the first generation, which may be designated by the sign (F. 1). The character which is transmitted is said to be *dominant* to that which is excluded, and the latter may be called *recessive*—roundish form of seeds *dominant* to the wrinkled or angular form.

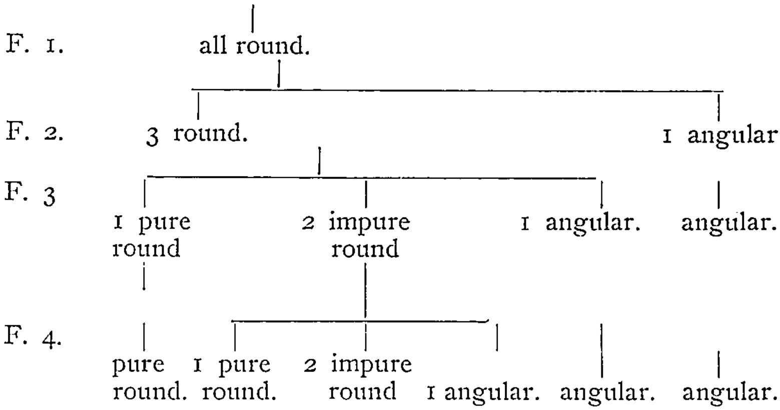
Now, if plants of the first generation (F. 1) were allowed to self-fertilize themselves and a further generation (F. 2) raised from the seed they produced, the recessive character—the angular form of the seed—appeared. Twenty-five per cent. of the seeds in this second generation (F. 2) were angular, while 75 per cent. were round or roundish—or a proportion of 3 dominants to 1 recessive.

In this third generation (F. 3), the offspring from the angular seeds of (F. 2) bore nothing but angular seeds, thus showing that the recessive character was constant; while in the offspring from the roundish seeds of (F. 2), which are all so much alike as far as external appearances go, it was noticed that twenty-five out of seventy-five (i. e., 1 out of 3) produced the round character purely, whilst fifty produced both round and angular seeds in the proportion of 3 of the former to 1 of the latter, i. e., 3 dominants to 1 recessive. From this it was seen that some of the round seeds of the second generation (F. 2) bred true to round, while others did not. The former were therefore "pure" round and the latter "impure" or "hybrid" round. It was proved that the "pure" rounds through many generations kept true, and showed no reappearance of the angular recessive character. The "hybrid" rounds, however, produced pure round, hybrid round, and pure angular, just as their parents did.

It was moreover seen that 100 plants from the progeny of the hybrid of (F. 2) consisted of twenty-five pure recessive, twenty-five pure dominant, and fifty similar in constitution to the hybrid form, since they gave offspring of the same character in the same proportions.

This can be shown diagramatically as follows:

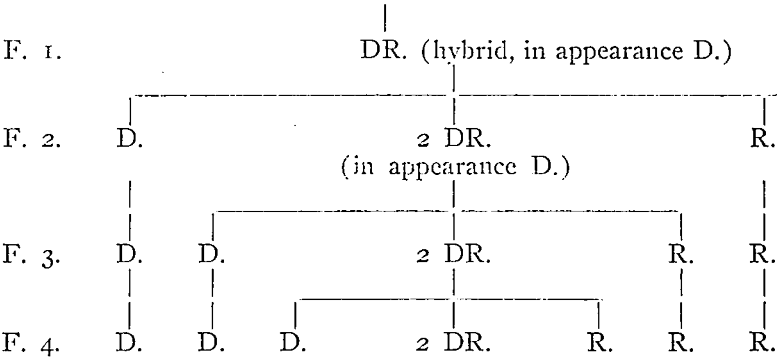
ROUND × ANGULAR (OR *vice versa*).



In further generations a similar result was obtained and other characters were found to behave in a like manner. In peas it was found that tallness is dominant to the dwarf habit, the round shape of the seeds dominant to the angular form, etc.

The exact results may be given in the abreviated form—D. being written for the dominant character and R. for the recessive—and is applicable for any pair of similar characters:

D CROSSED WITH R.



Experiments subsequently conducted by Bateson, Saunders and others for the Evolution Committee of the Royal Society, and by Biffen and others on wheat breeding have given similar results. It is, therefore, concluded that the *gametes*—the male and the female germ-cells—are pure with respect to the characters they carry, and assuming that an approximately equal number of pollen grains and egg-cells carry either one or other of the characters, the numercial relations observable in the progeny of the hybrids find a simple explanation; for according to the law of probability, when self-fertilization occurs in a DR. form, if the gametes bear either one of the characters in approximately equal numbers, the chances are that a D. pollen grain may meet with a D. or R. egg-cell, giving rise to a form either with dominant characters alone or to a hybrid, i. e., a D. or a DR.; while an R. pollen grain may meet with an R. or a D. egg-cell and give rise to R. or DR. forms. No other combinations are possible, and therefore, the progeny would be represented by a series of individuals of the following forms:—D. + 2 DR. + R.

The D. and R. forms breed true, as their gametes carry only dominant or only recessive characters, whilst the DR. forms produce on self-fertilization the D. + 2 DR. + R. series again.

We have considered, as yet, only varieties different in simple characters; but varieties differing in two or three pairs of characters have been experimented with, and it has been found that the gametes carry each of these characters pure.

If a plant having seeds round and yellow were crossed with a variety having seeds angular and green, definite results would be obtained. We may indicate roundness of seeds by A. and the angular character by a., as roundness is dominant to the angular form, and yellowness by B. and greenness by b., as the yellow character is dominant to the green one. We may consider the first character (shape of seed) and get in F. 2, A + 2Aa + a, while if we consider the second character (color of seed) we get in F. 2, B + 2Bb + b. Now the total number of combinations that the gametes can make will be obtained by multiplying together (A + 2Aa + a) and (B + 2Bb + b); the result of which is AB + Ab + aB + ab + 2ABb + 2AaB + 2Aab + 2 ABb + 4AaBb.

There are, therefore, nine types possible, but externally they appear as four, namely, round yellow, round green, angular yellow, and angular green, in the proportion of 9 : 3 : 3 : 1; as AB, 2aB, 2ABb, and 4AaBb, have the appearance AB = 9; Ab, and 2Aab, are of the appearance Ab = 3; aB, and 2aBb are of the appearance aB = 3; and ab = 1.

Mendel next tested the truth of his hypothesis that both male and female cells were pure, by crossing the first cross hybrid with pure dominant and pure recessive forms, respectively. It was found that DR. crossed with D. gave DD.: DR. as 1 : 1, and that DR. crossed with R. gave DR.:RR. as 1 : 1.

EXPERIMENTS IN BREEDING SUGAR CANES.

In cases that follow Mendel's Law, the processes of plant breeding are definite and exact, viz., the characters existing in the parents are transferred in their full intensity to descendants of the hybrids, recessives bred true from the moment of their appearance but only one-third of the individuals showing the dominant character breed true, and a further generation has to be raised before the pure dominants can be picked out. A number of example have been noticed which do not behave along exactly similar lines. The characters may blend, giving an intermediate form, which may breed true or may give the parent forms among its offspring in the second generation. Other instances have occurred in which a totally new character has made its appearance which may or may not follow Mendel's Law, while whole series of new forms, apparently not combinations of visible parental characters, may appear.

The problem we have to face is this—Can the breeding of the sugar cane be conducted upon the same lines as the breeding of new varieties of peas or wheat; is it possible, so to speak, to pick out the valuable characters from different varieties, and gradually build up an ideal type? This, of course, can only be shown by experiments, and consequently a series of experiments is being started in which definite crosses will be made with a view to ascertaining how the different characters desired are transmitted to the offspring. The sugar cane is built up of a series of characters, the inheritance of which must be traced independently of each other.

A thorough knowledge of the varieties to be experimented with is the first requisite, and then it is necessary to decide what characters are to be worked with. Only those varieties of sugar cane that have been tested under varying conditions of soil and climate have been chosen for experiment, for the securing of good parents is very important as the number of varieties for experiment has to be limited. Only those characters which are of economic value, and which appeal to the planter, will be considered at the outset. It is hoped before long that definite results will be obtained, and that some knowledge will be gained of the different characters that will be considered in the experiments, viz., tonnage of cane per acre, richness of juice, and resistance to disease.

TONNAGE EXPERIMENTS.

For the tonnage experiments, six varieties, that have been under test for some time, have been chosen, viz., B. 1,753, B. 4,164, B. 4.028, B. 3,390, D. 95, and Queensland Creole. The first four have shown themselves to give a large tonnage per acre, while the last two are small tonnage canes. These varieties have been planted in four rows, twenty-five holes deep, and arranged according to a definite plan, so that any single variety can be crossed with any other. There will therefore be 100 holes of each variety. The rows run in the following order: B. 1,753, D. 95, B. 4.164, Queensland Creole, B. 4.028, B. 3.390, B. 4,164, B. 1,753, D. 95, B. 4,028, Queensland Creole, B. 3,390, B. 1,753, Queensland

Creole, B. 4,164, B. 4,028, D. 95, B. 3,390, B. 1,753, B. 4,028, Queensland Creole, D. 95, B. 4,164, B. 3,390.

It will be possible, therefore, if the varieties arrow, to make the following crosses: large tonnage crossed with large tonnage, large tonnage crossed with small tonnage, and small tonnage crossed with small tonnage. In this way it is hoped to ascertain whether tonnage of cane is a character that is transmitted to the offspring and whether certain varieties are of greater value in this respect than others.

It is expected that the sugar cane can be considerably improved in the direction of increased tonnage, especially when it is held that a larger tonnage of cane per acre depends largely upon increased vigor of the cane, for hybrids are generally more vigorous than their parents.

JUICE EXPERIMENTS.

Cousins, Jamaica, holds that "beyond a certain point—24 per cent. saccharose in the juice—any increase in richness involves a reduction in agricultural yield," but as only a few of the varieties now under experiment possess over 20 per cent. saccharose in the juice, maximum productiveness has not been obtained, and therefore experiments to inquire into the quantity of saccharose in the juice as a distinctive character of the sugar cane have been laid out on the same plan as the tonnage experiments. Six varieties, viz., B. 3,675, B. 208, B. 3,922, T. 24, B. 3,746, and B. 4,164 have been chosen for the experiments, the first four possessing rich juice and the last two poor juice. Each of the varieties has been planted in four rows—twenty-five holes deep—and arranged in the following order: B. 3,675, B. 3,746, B. 208, B. 4,164, B. 3,922, T. 24, B. 208, B. 3,675, B. 3,746, B. 3,922, B. 4,164, T. 24, B. 3,675, B. 4,164, B. 208, B. 3,922, B. 3,746, T. 24, B. 3,675, B. 3,922, B. 4,164, B. 3,746, T. 24. These varieties have been laid out on a plan similar to that of the tonnage experiments and have been arranged so that different crosses can be made—rich-juice canes with rich-juice canes or with those having poor-juice, and the poor-juice canes among themselves.

DISEASE EXPERIMENTS.

A similar plan of experiments has been laid out to inquire into the disease-resistant power of various varieties, as it is possible that increased vigor of a plot of canes as reflected in larger yield of sugar is accompanied by greater immunity from disease. The root disease is probably the one that, at the present time, is causing a considerable amount of damage in the West Indies. Large losses have certainly been incurred by this disease in Barbados, and therefore it is the one to which attention will be paid. Four varieties, viz., B. 6,048, B. 1,529, B. 3,289, and B. 208 have been chosen as those which are either entirely immune or suffer little from the attacks of the fungus that causes this disease, and will be arranged with two others, B. 3,668 and B. 3,696 that appear to suffer severely from this cause.

These are planted on precisely the same plan as the tonnage and the juice experiments, in the following order: B. 6,048, B. 3,668, B. 1,529, B. 3,696, B. 3,289, B. 208, B. 1,529, B. 6,048, B. 3,668, B. 3,289, B. 3,696, B. 208, B. 6,048, B. 3,696, B. 1,529, B. 3,289, B. 3,668, B. 208, B. 6,048, B. 3,289, B. 3,696, B. 3,668, B. 1,529, B. 208. The offspring of the crosses made will be tested for resistance against the root disease, and if sufficient disease is not present for tests from natural infection, artificial inoculations or injections will have to be resorted to.

COMBINATION—TONNAGE AND JUICE—EXPERIMENTS.

The above three series of experiments have been established for the purpose of investigating different characters singly, but an effort will be made to examine closely a combination of two characters, with a view of obtaining definite knowledge as to the behavior of these characters in several different varieties of sugar cane on hybridizing. Owing to the small space available for the conduction of these experiments and to the limited time during which it is possible to carry out the emasculation of the flowers, only twelve varieties have been chosen, and 100 holes of each variety set out. The canes are planted in chess-board fashion in rows twenty-five holes deep, and arranged so that any variety can be crossed with two others. The following varieties have been chosen: B. 1,753, B. 3,289, B. 3,922, B. 6,048, B. 1,529, B. 4,844, B. 4,164, B. 208, B. 1,566, B. 3,390, B. 3,675. Table I gives an outline of the crosses that it is proposed to make. An analysis of the characters of the different varieties chosen is also given, where R = rich juice, r = poor juice, T = large tonnage, and t = small tonnage.

Of course, it must be clearly understood that the different characters put forward in this table are not of the same value, for they vary slightly in different years, but they are held to be comparative. For example, B. 1,753 gave in 1903-5 an estimated yield of canes of 50.17 tons while B. 3,289 only gave 42.34 tons; but these tonnage yields must be considered large against 28.92 tons of B. 1,529 and 29.88 tons of B. 4,844. The first are, therefore, designated by T. while the last are indicated by t. The same is the case with the juice of the different varieties.

TABLE I.

Combination—Juice and Tonnage—Experiments.

B. 1,753 (r T)	to be crossed with	B. 6,048 (R T) B. 1,566 (r T)
B. 3,289 (R T)	" " "	B. 6,048 (R T) B. 3,675 (R t)
B. 3,922 (R t)	" " "	B. 4,844 (r t) B. 1,529 (R t)
B. 6,048 (R T)	" " "	B. 1,753 (r T) B. 3,289 (R T)
B. 1,529 (R t)	" " "	B. 3,922 (R t) B. 4,164 (r T)
B. 4,769 (r t)	" " "	B. 3,390 (R t) B. 4,844 (r t)
B. 4,844 (r t)	" " "	B. 4,769 (r t) B. 3,922 (R t)
B. 4,164 (r T)	" " "	B. 3,390 (R t) B. 1,529 (R t)
B. 208 (R t)	" " "	B. 3,675 (R t) B. 1,566 (r T)
B. 1,566 (r T)	" " "	B. 208 (R t) B. 1,753 (r T)
B. 3,390 (R t)	" " "	B. 4,164 (r T) B. 4,769 (r t)
B. 3,675 (R t)	" " "	B. 3,289 (R T) B. 208 (R t)

The planting of the varieties in chess-board fashion has been practiced in order to make crossing as easy as possible, and the following table illustrates the arrangement adopted:

TABLE II.

Chess-board Planting taken from the Combination—Juice and Tonnage—Experiments.

B. 1,753	B. 6,048	B. 1,753	B. 6,048	B. 1,753	B. 1,566	B. 1,753	B. 1,566
x	x	x	x	x	x	x	x
B. 6,048	B. 1,753	B. 6,048	B. 1,753	B. 1,566	B. 1,753	B. 1,566	B. 1,753
x	x	x	x	x	x	x	x
B. 1,753	B. 6,028	B. 1,753	B. 6,048	B. 1,753	B. 1,566	B. 1,753	B. 1,566
x	x	x	x	x	x	x	x
B. 6,048	B. 1,753	B. 6,048	B. 1,753	B. 1,566	B. 1,753	B. 1,566	B. 1,753
x	x	x	x	x	x	x	x
Continued to twenty-five holes deep.							

The varieties have all been carefully studied and have been chosen as being the best we have on hand at the present. Careful systematic work, conducted along definite lines, is to be carried out in order to analyse the different qualities of the sugar cane and to incorporate as many of the best characteristics as can possibly be brought together in a single variety in order to fulfil a certain and definite purpose. Arrows of the various varieties will also be bagged separately to obtain self-fertilized seedlings, in order to investigate, if possible, the dominant characteristics more fully, for it is suspected that some, if not many, of the varieties chosen may be impure or hybrid types. This will considerably complicate matters, but difficulties will have to be met.

Small numbers of seedlings can only be obtained owing to mechanical difficulties in emasculation and cross-pollination, on account of the small size of the flowers and the height of the arrows above the ground, to the varied time of arrowing and often to a total lack of arrows, as well as to unfavorable climatic conditions. It is hoped, however, that in a few years, canes will be built up, character by character, that will stand the rigorous test of field selections and analyses in the laboratory.

A systematic investigation of the material on hand in order that something definite may be learned about the unit characters with which we intend to deal, their dominance, and their combination and correlation with other characters is to be undertaken. With this fundamental work accomplished, it may be possible to deal with varieties, concerning whose characteristics something definite is known, and to prosecute the work of sugar cane breeding in definite directions and to secure results previously planned for.

OTHER EXPERIMENTS FOR PRODUCING HYBRIDS.

The difficulties of obtaining large numbers of hybrids by hybridization under control have been mentioned previously, and, as the access of pollen from an unknown source must be recognized as being detrimental to advancement in hybridization work and as it would lead to entirely erroneous conclusions, a series of experiments by which it is hoped to obtain hybrids by what may be called natural hybridization has been started.

It has been well known for some time that certain varieties of the sugar cane produce much fertile pollen while the pistil is normal, and others produce little or none. Advantage of this fact has been taken by the experimentalists in Java, and large numbers of hybrids have been obtained by planting in alternate rows varieties that arrow at the same time—one of which may be called "male," possessing much fertile pollen, and the other "female," possessing a very small proportion of fertile pollen. The arrows from the "female" variety alone are cut, and the resulting seedlings must be the result of a cross or of self-fertilization, and the chances, under Java conditions, are such that the "male" variety planted in the adjoining rows is generally held to have provided the pollen.

With the high winds that prevail in the West Indies it is thought that such a method cannot be satisfactorily practiced, but it is hoped that, if varieties "male" and "female" be planted in chess-board fashion and an arrow producing much normal pollen be bagged with an arrow producing little fertile pollen at an early stage, before outside pollen from an unknown source can be blown upon the stigmatic plumes of the "female" variety, a number of seedlings can be obtained of known parentage. After a sufficient time has elapsed for pollination the "male" arrow would be taken out and only the "female" arrow sown.

It is possible that some seedlings would be the result of self-fertilization, as sometimes the "female" canes produce a new normal pollen grains; but in these varieties the chances of self-fertilization are reduced to a minimum and, therefore, if fertile seeds are produced by these canes they will almost certainly be the result of hybridization. By this method, access of pollen from an unknown source cannot take place, and the risk of obtaining large numbers of seedlings of less value than the female parent will be largely reduced.

At the Dodds Experiment Station, Barbados, plots have been laid out to test this method. Canes that have stood the stringent test for a number of years have been selected. B. 376 has been planted chess-board fashion with B. 208, and White Transparent is to be crossed with B. 3,289; 2½ acres have been planted in all. White Transparent and B. 376 produce little fertile pollen, and therefore, any seedlings obtained from them should be the result of crossing, and an advance made in the desired direction.

It is hoped that this method may give results that would justify its adoption on a larger scale, and be the practical method of gradually improving the sugar cane along scientific lines.

CONCLUSION.

In conclusion, it will be seen that definite plans have been laid out by this Department for the breeding of hybrid sugar canes, as it is expected that considerable improvement can be made. The experiments have been started on a small scale, as it is necessary to become as fully acquainted as possible with the characters of different chosen varieties, in order that the inherent tendencies for utility may be understood, and so that the life forces of the best varieties may be directed into useful channels. Records of pedigrees, relative values of hybrids, dominance of characters, etc., will have to be kept and arranged in such a way that the value of any individual may be seen at a glance. It is possible that, in hybridization, totally new characters may make their appearance which may prove of value and possibly different characters of the parents may show blending, but until experimental evidence is obtained nothing can be said of what results will follow. Several years must elapse before sufficient varieties have been raised and submitted to rigorous field and laboratory tests, before recommendations can be made to the planters. Plant breeding has been put upon a definite basis, for it has been shown that, with the proper understanding of the inheritance of the unit characters, new varieties can be built up with certainty, by picking out and combining together characters already existing in other varieties. Improvements can be made by picking out a desirable feature here, another there, and combining them together. It is expected that hybridization will be the means of making rapid improvement in the sugar cane, and it is hoped that among the hybrids there will be some that will not be found wanting when the final tests are made.

*THE NITROGEN CYCLE AND SOIL ORGANISMS.**

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During the last twenty years much has been done towards clearing up the changes which the element nitrogen suffers in its relation to the soil and vegetation. It was until quite recently believed that the inert gas which constitutes four-fifths of the air was practically a changeless reservoir of indifferent matter which was brought into combination with oxygen in occasional trifling amounts during electric discharges. This combination was supposed to make good, slight losses whereby the element might, under unknown conditions, become free again, so that the fund of combined nitrogen in the world remained constant, working round in a cycle through the organic and inorganic kingdoms practically independent of the great free reservoir in the air.

Thanks, however, to the work of agricultural chemists, and plant physiologists, as well as that of microbiologists, it is now known that the free nitrogen of the air is constantly being brought into combination on a large scale through the agency of certain organisms, and that it is also being set free again on a large scale by the agency of other organisms.

It is the amount of combined nitrogen in the soil which, given suitable physical conditions, determines in a large measure the yields of our crops, and it has always been one of the objects of a successful agriculture, though in an unconscious way, to encourage and turn to account this process of combination, and as far as possible to combat and discourage the process which turns the nitrogen back into the air as free gas again. Broadly speaking, this has been achieved by the growth of legumes for animal food or for green manuring, and by drainage and rational cultivation of the soil.

To understand the working of these two end processes, a short account of each of the main changes undergone by nitrogen will be necessary.

In the first place, a few words may be said about the organisms of the soil. These consist, in addition to the familiar green plants visible to the unaided eye, of various forms of green plants, called algae, which can be seen only with the aid of the microscope. The vast number of soil organisms are, however, colorless; mostly bacteria, a few moulds, and still fewer yeasts.

From the standpoint of the nitrogen cycle, all these organisms are important; but in virtue of their numbers, kinds, and activities, the bacteria easily take the first place. They consist of

* From Proceedings of West Indian Agricultural Conference.

single cells which multiply by simple division, and are as a rule either spherical or rod-shaped. They are extremely small, rarely exceeding 1/5000 inch in length, and are often not more than 1/25000 inch, so that one need not be surprised to hear that an ounce of a good soil to a depth of 1 foot contains about ten millions. At a depth of 3 feet they are much less numerous, and at 6 feet are often entirely absent, the soil acting as a filter. If some soil is heated for an hour or more at 250° F. in contact with steam, the organisms are all killed out. The same end can be attained, though with more difficulty, by treating the soil with poisons like corrosive sublimate or carbolic acid, or with the vapors of chloroform, carbon bisulphide, etc.

By treating soils in one of these ways to kill the life in them, it has been possible to prove that none of the changes about to be described, take place by purely chemical means, but only when the bacteria and other organisms are alive and active.

We can now turn to the first step in the nitrogen cycle—the bringing into combination of free nitrogen gas.

THE BRINGING INTO COMBINATION OF FREE NITROGEN GAS.

Nearly twenty years ago, Hellriegel and Wilfarth published their results on vegetation experiments from which one could only conclude that leguminous plants, such as peas, beans, clover, etc., are able to get their nitrogen from the air.

It has now been proved, beyond doubt, that it is the bacteria living in the nodules on the roots of these plants which bring the atmosphere nitrogen into combination. Maze and Golding have been able to cause these bacteria, separated from the plant, to fix nitrogen from the air in an artificial culture liquid. Special cultures of these organisms have proved of great value both in the United States and Germany for inoculating seed or soil, where virgin land has been broken up, for sowing alfalfa or serradella. In soil which has been long under cultivation they are generally present, and inoculation would probably only be profitable where a leguminous plant new to a country was being introduced. Under ordinary conditions leguminous plants are rarely without root nodules, and, consequently, the bacteria which fix the nitrogen.

By this means, an enormous amount of nitrogen is being annually obtained from the air by one of the largest and most widely distributed of all orders of plants. In Jamaica, it is easy to see that the leguminous order provides a large part of the vegetation, from great trees down to herbaceous weeds.

In all tropical countries, where the people are mainly vegetarian, the seeds of legumes, always rich in meat equivalents, are one of the most valued food staples; for instance, the gram peas and soy beans of the East. It is certain that the bulk of the nitrogen in these seeds comes from the air. In the tropics, where the rainfall is not sufficient for high forest and formation of humus, nor so scanty as to induce desert conditions, vegetable matter decays very rapidly, especially in the lighter soils which are easily exhausted of their combined nitrogen. Under these conditions, the fixation of nitrogen by legumes, in conjunction with the nodules bacteria, is a property which greatly favors the development of these plants.

At about the same time as nitrogen fixation was observed in the above mentioned case, the French chemist Berthelot was able to prove that uncropped soils, when kept moist and exposed to the air, showed, after several months, considerable gains in combined nitrogen, and as this did not occur when the microbes have been killed in them, he concluded that certain soil organisms must be able to bring nitrogen into combination quite independent of any green plant. A few years later, a bacterium which was capable of growing in a sugar solution, containing no combined nitrogen, and, in the absence of oxygen, of fixing small quantities of nitrogen gas, was isolated from soil. The sugar was broken down into butyric acid, carbonic acid, water, and hydrogen, and for every 1,000 parts so decomposed about 2 parts of nitrogen were fixed.

About four years ago another organism was obtained from soil which grew vigorously in sugar solution when in the presence of abundant oxygen, but in the absence of combined nitrogen. The sugar was oxidized to carbonic acid and water, and for every 1,000 parts so broken down as much as 10 parts of nitrogen were fixed. The writer has repeatedly isolated this organism from English arable soils, once from an Egyptian soil, and an allied variety from East, and South African soils, the latter differing from the other by producing a blue and finally golden yellow diffusible pigment.

An organism quite similar to the English type has been isolated by him from a Jamaican cane soil, with similar nitrogen-fixing properties. It has been impossible, however, up to the present, to find this organism in old pasture and old meadow land showing an acid reaction, but it is always abundant in cultivated soil containing carbonate of lime.

For obtaining it from the soil, a solution of the following composition has been found very favorable:

Mannite or Glucose	12 grammes.
Di-potassium phosphate	.2 "
Magnesium sulphate	.1 "
Sodium chloride	.1 "
Distilled water	1 litre.

If about 100 c.c. of this solution, to which ½ gramme of precipitated carbonate of lime has been added after sterilization, is put into a flask in a shallow layer, inoculated with a gramme of fresh arable soil, and exposed to a temperature of 80-90° F., in the dark or in diffused sunlight, a strong film of the organism will develop in about three days, which is never quite pure. Isolated colonies can be obtained by transferring some of this film on to an agar of the same composition.

In pure cultures the fixation of nitrogen is never so large as in the first crude culture from the soil. The organism is an unusually large coccus, two-to-four-thousandths of a millimeter in diameter, often occurring in the film as diplococci, and staining a fine red-brown with iodine in potassium iodide. It takes up aniline stains with great intensity, and is consequently very rich in albuminous matter. An old film on a liquid, or the growth on agar becomes brown, and finally often black. This organism from the soil is very feebly motile, and only shows that property in young cultures.

Beijerinck, the discoverer of the bacterium, has named it *Azotobacter chroococcum*, and he has also described another species *Azotobacter agilis*, which he found in a canal water, but distinguished by its larger size and intense motility. The writer has also found this species forming an almost pure film on the surface of a marked mixture of dunder and molasses which had been set up for a butyric fermentation six months earlier, after being sterilized and inoculated with a pure culture of a butyric organism. Rain had, however, got in and doubtless brought this organism with it. There was no longer sugar present, but only the calcium salts of lactic, butyric, and acetic acids. That these salts were undergoing rapid oxidation by the *Azotobacter* was shown by the continuous separation from the liquid of a calcium carbonate precipitate.

The first visible product of nitrogen fixation is the albuminous substance of the organism itself, neither ammonia nor oxidized nitrogen being present in the medium. The organism obtains the energy for fixation from the oxidation of the sugar, which yields an amount of energy enough to fix more than ten times as much nitrogen as has ever been obtained in artificial cultures. In the case of the leguminous plants, the sugar formed in the leaf is the source of energy for the nitrogen fixed by the bacteria of the nodules, which show, otherwise, no resemblance to the *Azotobacter* species.

It is easy to show that soils contain also butyric organisms capable of fixing nitrogen in sugar solutions, by using the same sugar solution as that for the culture of *Azotobacter*, but exposed to an atmosphere of nitrogen (best obtained by absorbing the oxygen with alkaline pyrogallate) at a temperature of 90-100° F. An active fermentation sets in, but less than one-third of the nitrogen is fixed for the same amount of sugar decomposed, as in the case of the *Azotobacter*.

As yet, one knows very little with regard to the amount of nitrogen practically brought into combination by these free living organisms in soils, and one is, therefore, not in a position to estimate their value for agriculture.

Mr. A. D. Hall at the Rothamsted Experiment Station, England, has recently found that two soils which had been allowed to run wild for twenty years had gained very greatly in combined nitrogen during that period to a depth of at least a foot, the gain being much the greater, however, in the one containing much calcium carbonate from which the writer obtained *Azotobacter* abundantly, than in the other where carbonate of lime was absent, and from which only butyric bacteria could be cultivated.

Several observers have remarked a considerable increase of combined nitrogen in the surface layers of soils on which an abundant growth of microscopic green algae had formed, and it was concluded, somewhat hastily, that they also had the power to fix nitrogen from the air. Pure cultures of the algae have, however, shown no such ability, but fixation has occurred when they were allowed to grow in conjunction with soil bacteria. This suggests a symbiosis between the green algae and the bacteria of the *Azotobacter* type, similar to that between the green leguminous plants and its nodule bacteria, the sugar formed by the algae with the aid of sunlight becoming available for oxidation by the bacteria with consequent fixation of nitrogen by the latter.

Under whatever conditions the nitrogen of the air becomes combined, the first visible product is always the albuminous matter constituting the bodies of the active organisms, and indirectly, of the leguminous plant. On the death of these bodies, this matter undergoes great changes, due to the activity of other soil organisms, and this brings us to the next step in the nitrogen cycle.

THE BREAKING DOWN OF ALBUMINOUS MATTER.

This takes place under two broad conditions, in the presence of abundant air, and, consequently, of oxygen, and in the absence, or in a very restrictive supply, of air. In the first case, one speaks of decay, in the latter case of putrefaction. Decay of albuminous matter takes place in the well aerated surface soil which is frequently stirred by agricultural implements, and is characterized by the production of ammonia, carbonic acid, and water. This process is entirely the work of hacteria and moulds, mainly of the former. If one inoculates a one-part-per-thousand solution of peptone with a little soil, and then exposes it to the air in a shallow layer at about 80° F., one will find that after a few days, at least half the nitrogen of the peptone has been converted to ammonia, and the liquid is strongly clouded by countless bacteria. If air had been excluded, putrefaction would have set in and been characterized by the production of evil-smelling substances, ammonia being formed only very slowly. Decay is, therefore, a greatly more rapid and more effective process than putrefaction. Ammonia, however, does not accumulate in a cultivated soil, but suffers a change under the influence of bacteria. This brings us to the next step in the nitrogen cycle.,

NITRIFICATION.

This consists in the oxidation of ammonia to nitrate in two stages by two quite distinct species of bacteria. The ammonia is first converted by the one species to a nitrate, and the latter then oxidized by the other species to a nitrate. This process can only occur when there is an abundant supply of air, and is therefore most active near the surface of the soil. The writer has found that, under English conditions, nitrification is nearly as active at a depth of 8 inches as at 4 inches, but only about half as active at a depth of 12 inches from the surface.

In order that the process may go forward, some basic substance must be present in the soil. This is usually carbonate of lime. This converts the ammonia into carbonate, which is then oxidized to nitrate of ammonia which reacts with more carbonate of lime with the formation of calcium nitrate and ammonium carbonate, the latter being again nitrified.

Neutral solutions of ammonium salts, like the sulphate and chloride, undergo no nitrification whatever when inoculated with a little soil, but the process can be started by the addition of a little carbonate of lime. The writer has found that ferric hydrate or iron rust can replace the carbonate to a certain extent.

In acid soils nitrification cannot occur. The author found this to be the case with the acid turf of an old meadow down to 8 inches, but in the mineral soil below, at 12 inches, nitrification was fairly active, and was even taking place at a depth of 28 inches.

These two nitrifying bacteria are remarkable for the fact that they will grow and nitrify in a purely mineral medium, as they are both able to use the energy set free by the oxidation of ammonia and nitrate, respectively, to decompose the carbonic acid in the air, the carbon entering into the organic substance of their bodies.

If a little fresh soil is used to inoculate a solution containing ½ gramme of ammonium sulphate in a little distilled water to which potassium phosphate and magnesium sulphate have been added, together with some carbonate of lime, then, in the course of a fortnight, at a temperature of 80-90° F., nitrate will be found in the liquid, which, after increasing in amount for some days, will begin to diminish, and finally disappear, giving place to nitrate. The latter will only begin to appear when the ammonia has been largely oxidized to nitrite. This is due to the fact that ammonia prevents the nitrate organism from oxidizing the nitrate formed by the other bacterium. The writer has found, however, that ammonia prevents the growth of the nitrate organism, but when the latter has multiplied abundantly, even large amounts of ammonia have no effect on oxidation.

In the soil where both organisms are abundantly present, nitrates never accumulate, as they are oxidized to nitrate as fast as they are formed. The nitrate formed in this way is the commonest form in which all crops (the legumes however only in part) obtain their nitrogen, and its preservation is therefore of very great importance in agriculture. It can, however, be lost to them in two ways. Firstly, by being washed into the subsoil by rain and thus carried beyond the range of their roots; and secondly, by being decomposed through the activity of certain bacteria, and having its nitrogen returned to the air as free gas, thus completing the nitrogen cycle. This latter process is called denitrification.

DENITRIFICATION.

This process can only occur where nitrates are accompanied by easily soluble non-nitrogenous organic matter, especially in an alkaline medium. It was formerly thought that air, i. e., free oxygen, must be absent, but this is now known to be an unnecessary condition. The freeing of nitrogen gas from the nitrate does not, however, always occur, but is often accompanied by reduction to nitrates and ammonia, an action exactly the reverse of the nitrifying one.

The writer found that if a sugar such as glucose is added to a purely mineral solution originally containing ammonia which has been completely nitrified to nitrates by the organisms conveyed in a little soil, an abundant bacterial growth forms, and in the course of twenty-four hours, at a temperature of 80-90° F., nitrates will be found in the liquid. After another day, ammonia will often be abundantly present, and the original nitrates will have completely disappeared.

In another case, after the preliminary formation of nitrates no ammonia can be found, but all the nitrogen will have disappeared from the solution; in this latter case true denitrification has taken place, and the nitrogen has escaped into the air as the free gas. This has taken place where air had free access to the liquid, and was not the work of the nitrifying bacteria, which can only convert ammonia into nitrate, but of other organisms which were present in the soil originally inoculated, but which could only develop when the medium had been rendered suitable by the addition of the sugar.

Both true denitrification and the back action to ammonia are always preceded by a reduction of the nitrate to nitrite, and in fact very many bacteria can reduce nitrate to nitrite and can carry the action no further. One of the commonest soil bacteria (the so-called earth bacillus), *Bacillus mycoides*, which is very active in the breaking down of albuminous matter to ammonia during decay, is also able in the presence and absence of air, to reduce nitrates to nitrites and ammonia, so that an organism which is active at one stage of the nitrogen cycle can also be an effective worker at another stage. At the same time, as much as 20 to 30 per cent. of the nitrate nitrogen can be assimilated by the active organisms and converted into the albuminous matter of their bodies.

In some recent experiments made in Germany with soils heavily dunged with stall manure and receiving at the same time nitrate of soda were annually supplied to the same crop, have not peared as free gas or was taken up by the bacteria as body substance, and rendered non-available to the crop.

On the other hand, long-continued experiments at Rothamsted, England, in which both moderate quantities of dung and nitrate of soda were anually supplied to the same crop, have not made evident, by affecting the crop yield, that much loss has taken place through the above mentioned causes. Although denitrification can undoubtedly occur with free access of air, yet it is still more likely under conditions where air is excluded, or the supply greatly diminished. This can easily be shown by saturating a soil rich in organic matter with a solution of a nitrate; after a few days no nitrate will be found in the water extracted from the soil.

In Japan, some recent observations have shown, that for rice grown in soils largely water-logged and richly dunged with faeces, sulphate of ammonia is a much more effectual manure than nitrate of soda, owing to partial denitrification of the latter.

On the other hand, some of the river waters of Jamaica which are known to be contaminated by sewage along part of their course, very often show no trace of nitrates, although the water before contamination must have contained them. These streams flow along very shallow and rocky channels, and must be very effectually aerated, yet the soluble or organic matter brought in by the sewage has enabled bacteria to denitrify the nitrates originally present. The very low figures obtained for oxidizable organic matter in these waters go to support this conclusion, and show that in the self-purification of rivers in tropical climates, the organic matter and nitrates are mutually destructive under the influences of bacteria.

The circulation of nitrogen has now been followed along the main channel, through direct fixation of the free element, decay, and putrification, nitrification, and finally denitrification which completes the circle.

Almost no attention has, however, been given to two side channels which tap the main current at one point, only to return to it at another. One of these is that portion of green vegetation which obtains its nitrogen from the nitrates of the soil, builds them into the albuminous matter of its living structure, which, after death, is again returned to the soil to be again broken down by decay, and the successive bacterial processes of the main current.

Before, however, the return to the soil is made, a portion both of this vegetation, and of the nitrogen-fixing legumes have to pass the animal body. This vegetable albumen is transformed to a small extent into animal albumen, but the greater portion, over 90 per cent., is almost immediately rejected again in a simplified form, in the case of the higher animals, by the urine. In man and the carnivorous mammals this is mainly as urea; among the herbivorous as hippuric acid; and by birds, reptiles, and fishes mainly as uric acid.

Urea is acted on very rapidly by many bacteria and converted completely into carbonate of ammonia; hippuric acid, though a more complex substance, is also broken down, at first into benzoic acid and glycocoll, and the latter again into carbonate of ammonia and water. Uric acid suffers the same fate through the instrumentality of soil bacteria, so that in all these cases the nitrogen excreted by animals finds its way back into the main current of the nitrogen cycle as ammonia, to undergo the further successive changes.

It is evident, then, that the total amount of animal life is determined by the amount of combined nitrogen available for nutrition. Under natural conditions there is no reason to believe that the total amount of combined nitrogen would tend to increase, i. e., that nitrogen fixation would be in excess of denitrification. On the other hand, with agriculture and its constant endeavor to increase crop production by creating conditions favorable to nitrogen fixation and unfavorable for denitrification, it appears most probable that the natural balance has been upset, and that the total of combined nitrogen in the world is probably on the increase.

Significant in this respect is the great extension of soil area during the last half century devoted to leguminous crops. It is, of course, impossible, as yet to estimate the extent to which nitrogen fixation is taking place through the energy of free living soil organisms, under agricultural conditions, and the same holds also for denitrification.

The few data to hand are for temperate conditions, the problem of the relation of soil organisms to crop production having, as yet, received no serious attention in the tropics.