

QUEENSLAND.

Bureau of Sugar Experiment Stations

Division of Soils and Agriculture

---

FARM BULLETIN No. 6.

---

## Value of Different Forms of Lime

By H. W. KERR and C. R. Von STIEGLITZ

and

## Intensive Cane Production

By H. W. KERR and E. J. R. BARKE



Issued by direction of the Hon. F. W. BULCOCK,  
Minister for Agriculture and Stock.

---

BRISBANE:

By Authority: Frederick Phillips, Government Printer.

## Factors Governing the Value of Different Forms of Lime.

By H. W. KERR and C. R. VON STIEGLITZ.

EARLY records show that the value of lime as a soil improver was known to agriculturists over 800 years ago, and its use has persisted as a standard practice through the intervening centuries. It is only quite recently, however, that its true functions have been clearly understood. Lime is, strictly speaking, an essential plantfood, and in its complete absence the soil is quite sterile. The relative needs of various plant species for this nutrient vary widely, however. Lucerne and many other legumes appear to thrive only in soils abundantly provided with this plantfood. Sugar-cane, on the other hand, is not a lime-loving plant, and the employment of lime on the cane soils of the State must be traced to its virtues in other important respects.

These may be listed briefly as follows:—

- (1) Neutralisation of harmful soil acids;
- (2) Provision of an environment more favourable to the helpful soil bacteria;
- (3) Rendering plantfoods in the soil more readily available to the crop;
- (4) Enabling fertilizers to exert their full influence on cane yields;
- (5) By continued use on clays and clay loams, tending to improve their physical state and favouring the production and maintenance of good tilth.

Under our conditions, lime is employed primarily for its influence on soil acidity. In regions of high rainfall continued leaching results in the rapid removal of lime, and often induces an acid condition in the soil; in extreme cases the soil becomes so intensively acid that crop growth is completely suspended. Such lands actually exist in localised areas in North Queensland. It is the destruction of the poisonous acids by liming which promotes also increased activity among the soil microbes—those tiny inhabitants of the soil, which feed on the soil organic matter and yield valuable plantfoods as the by-product of their life processes. Certain of these little workers also, which normally effect the necessary conversion of fertilizer to a form in which it is absorbed by the crop roots, are unable to function under intensively acid conditions. Further, results are on record which show that sulphate of ammonia may actually reduce crop yields on soils of this nature. Following an application of lime, the same soils gave pronounced results from the use of this valuable fertilizer.

A confusion of terms appears to have arisen out of the use of the words "sour" and "acid" to describe the condition of certain soils. The farmer frequently applies lime to heavy, wet, ill-drained lands which he describes as "sour." The use of this material frequently facilitates the drying out and "sweetening" of the soil, as the farmer expresses it. It should be clearly understood, however, that the "acid" soils so far discussed comprise many of our best-drained lands such as the alluvial loams of the Innisfail and Babinda areas. The function

of the lime on these lands is essentially to neutralise the soil acids; and though the heavier soils of this type are markedly improved in tilth following the use of lime, this is rather incidental.

#### KINDS OF LIME.

When a grower proposes purchasing lime, he is frequently perplexed by the range and variety of materials from which he may make his choice. A brief description of the important forms of lime may clarify the position, and indicate the several factors to be considered.

Lime occurs naturally in the form of deposits which vary considerably in their physical state. All have, however, the same chemical composition—*carbonate of lime*, or agricultural lime as it is popularly known in its marketed form. Marble, limestone, coral lime, and earth lime (or marl) all contain this compound as their active ingredient, though they may show a wide range of incidental impurities in the form of clay or earthy matter which reduce their monetary value. Coral and marble are usually very pure forms of lime, while earth lime frequently contains as little as 40 per cent. of this constituent. On the other hand, certain earth lime deposits which are exploited in Queensland show as high as 95 per cent. of lime carbonate.

Another form of lime which is frequently employed is known as *burnt lime*. This form does not exist naturally, but as the name indicates it is manufactured from carbonate of lime by the process of burning. If we should burn 100 lb. of pure limestone or marble, we would obtain 56 lb. of burnt lime. The proportion which is lost (44 lb.) consists of carbonic acid gas or carbon dioxide, which passes into the atmosphere. Burning therefore results in a concentration of the active material, none of which is lost in the process. If a compact lump of burnt lime should be exposed to the air, it will be found that it slowly increases in size, and gradually crumbles to a very fine white powder. The action of the atmosphere in this respect is simply a reversion of the burning process, and the "air-slaking" as it is called results in the re-absorption of 44 lb. of atmospheric carbon dioxide by every 56 lb. of burnt lime, to give once again 100 lb. of carbonate of lime.

Now it is a well-known fact that the different forms of lime exhibit pronounced differences with respect to the speed with which they effect their beneficial influence on the soil. Burnt lime is consistently superior in this regard; and though the caustic action of the fresh material is often considered a serious objection, this effect may be largely minimised by air-slaking prior to spreading. It may appear somewhat difficult for the farmer to understand why the carbonate of lime which is again produced by slaking is so definitely superior to other forms of carbonate of lime. The explanation lies in the fact that the speed of action depends entirely on the fineness of the product. Lime does not readily dissolve in the soil moisture, as do soluble mineral fertilizers, and the rate at which it reacts with the solid acid substances in the soil depends on the degree of intimacy with which the lime and soil particles can be brought together. If the grower expects quick results from liming, the necessity for having the lime finely powdered will be readily appreciated. Air-slaking of burnt lime actually effects this desired condition most effectively, but the practical difficulties associated with the mechanical disintegration of limestone generally result in a marketed product which, though apparently well pulverised, still contains particles which are exceedingly coarse when compared with the particles of air-slaked lime.

#### EXPERIMENTAL.

This consideration is of the greatest importance in the evaluation of a sample of agricultural lime; and to provide a clearer picture of the influence of fineness of grinding on the speed of neutralisation of soil acids, an interesting series of tests was carried out in our laboratory.

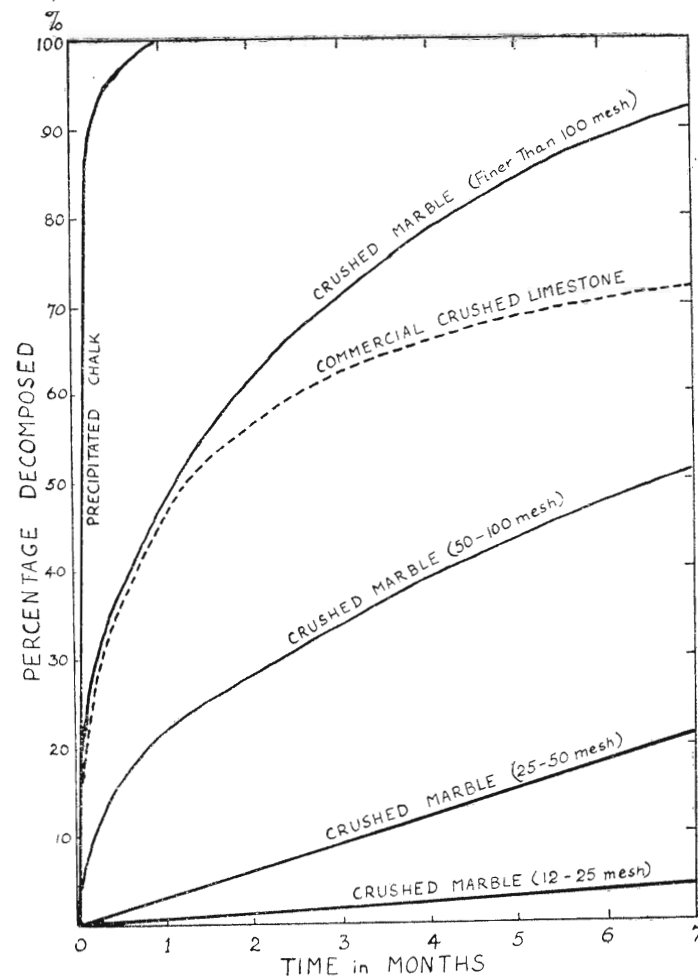


FIG. 1.

The graph shows that the finely-divided precipitated chalk had completed its work within a month of mixing. The high-grade commercial lime showed only about 70 per cent. decomposition after seven months, while the material of particle size 1/12-1/25 inch diameter was practically worthless.

A number of liming materials of varying particle size was selected as follows:—

- (1) Precipitated chalk—an extremely finely divided form of carbonate of lime, comparable with air-slaked lime.

- (2) Pulverised marble—particles fine enough to pass a sieve with 100 meshes to the inch.
- (3) Pulverised marble—particles passing a 50-mesh sieve, but coarser than 100 mesh.
- (4) Pulverised marble—particles passing a 25-mesh sieve, but coarser than 50 mesh.
- (5) Pulverised marble—particles passing a 12-inch sieve, but coarser than 25 mesh.
- (6) A sample of commercial crushed limestone, regarded as high grade; 90 per cent. was fine enough to pass a 50-mesh sieve, and the sample contained a large proportion of very fine particles.

As a suitable soil for the purpose a highly acid alluvial clay loam from our South Johnstone Station was selected. Six equal samples were weighed out and submitted to an application of lime at the rate of 6 tons per acre, employing each of the above grades of material.\* The soil and lime were mixed thoroughly, and water added to bring the mass to a condition of optimum moisture. The samples were then covered, set aside in the laboratory and stirred from time to time to enable the material to react. Portions of the soil were withdrawn at regular intervals, and the amount of carbonate of lime remaining unchanged was determined. In all, the process was continued over a period of seven months.

The accompanying graph brings out very clearly the relative values of the lime, as governed by particle size; and the results demonstrate in no uncertain manner that if the influence of liming is to be felt within a reasonable period, a large proportion of the material used should be fine enough to pass through a 100-mesh sieve. The sample of high-grade crushed limestone which was included in the tests was found to react quite rapidly, and 50 per cent. of the material had done its work within a month of mixing. This undoubtedly constituted the finest particles, and the coarser material then reacted with the soil acids at a markedly reduced rate.

The fact that "coral sand"—undoubtedly a very pure form of lime—produces so frequently a very disappointing result when applied at, say, 2 tons per acre, is due entirely to the fact that it is usually marketed in a condition which is far too coarse to ensure a reasonable speed of action. In other words, the coarse material gives the farmer his money's worth in lime, but not in added cane yield; and the unchanged grains of lime may remain practically inert in the soil for many years.

#### CONCLUSION.

We may now summarise the conclusions to be drawn from the preceding remarks and experimental results. In choosing a suitable liming material, the following facts must be considered:—

- (1) Burnt lime, even after air-slaking, will give most rapid results, due to the completeness with which it may be mixed with the soil particles.

\* Though this may seem an excessive dressing, it was barely sufficient to neutralise all the acids in this particular soil.

- (2) One ton of pure burnt lime is equal in lime value to  $1\frac{3}{4}$  tons of pure agricultural lime; this is an important point, where freights and haulage charges constitute an appreciable proportion of the cost of lime on the farm.

- (3) Other things being equal, the finer the condition of the agricultural lime, the quicker will favourable results be obtained. Particles coarser than one-twentieth of an inch in diameter are practically worthless, and in a country where lime costs are so high, the farmer should pay particular attention to this consideration.

In general, an initial application of burnt lime is to be recommended for highly acid soils. Where growers are able to obtain good quality agricultural lime at a reasonable price, the use of this material is recommended, as a subsequent practice, to maintain the soil in an acid-free condition. On many soils of the humid northern areas, it has been found that an application of 2 tons of agricultural lime may be employed profitably each time the land is replanted. Under these conditions, the lime should be spread broadcast following the final ploughing, and lightly harrowed into the land.

We would again point out that it is our pleasure to assist cane-growers in determining the need for lime, due to excessive acidity in their soils. Samples should be forwarded to the Director, Bureau of Sugar Experiment Stations, Brisbane; or where growers are situated in closer proximity to our South Johnstone Station, samples should be consigned to that address. A covering letter should express the desire for an opinion on the lime requirement of the particular soil.

# Intensive Cane Production.

By H. W. KERR and E. J. R. BARKE.

AS a means of reducing production costs of agricultural crops, the importance of intensive cultivation under our Queensland conditions has been repeatedly stressed. Before this can be effected, it is essential for the farmer to have a clear understanding of the chief factors influencing crop yields. For sugar-cane, the following are the more important:—

- (1) A continuous supply of soil moisture in a well-drained soil;
- (2) An adequate supply of available plant food;
- (3) High temperatures combined with a humid atmosphere;
- (4) Absence of harmful substances in the soil, such as intensive acidity;
- (5) Freedom from the influence of diseases and pests.

In our several cane districts these various factors enter in greater or lesser degree to influence crop production. In the central and southern areas it is generally conceded that soil moisture deficiencies are the most serious causes of reduced yields, while in the humid north plant food deficiency is usually blamed for crop limitations. It is well to investigate these questions more closely, however, and learn by actual experiment the relative importance of these factors both individually and collectively.

During the past few years we have carried out extensive observations on the relationship between climatic factors and crop growth. Selected cane stalks growing in the field under observation are subjected to systematic periodical measurement, and from the records obtained it is possible to trace clearly the manner in which the crop has grown. Fig. 1 illustrates a growth rate curve constructed from data secured at our South Johnstone Station in 1929-1930. It will probably come as a surprise to most growers to find that even in this region of heavy rainfall the distribution is far from ideal; the cane does not make even growth, and the production rate is greatly influenced by the incidence of rainfall. The maximum growth rate is sustained for only a brief period following rain, and during rainless spells it falls to a small fraction of the maximum.

Repeated fertilizer experiments on this Station show very clearly that the soils of the heavy rainfall belt are highly leached, deficient in available plant foods, and often in need of liming to neutralise acidity. Heavy applications of lime or additions of appropriate mixed fertilizer up to one-half ton per acre result in very definite increases in crop yield, and these results prompt the question—What would be the maximum cane yield were we to remove all controllable factors limiting cane growth? Given an adequate supply of moisture and plant food at all times, how many tons of cane per acre could be produced under natural conditions of temperature and atmospheric humidity?

## Experimental.

By the nature of the problem and the difficulties involved in fulfilling the prescribed requirements, the experiment had necessarily to

be performed on a small scale. Actually a single row 25 feet in length was employed. The soil was excavated to give a trench 3 feet wide and 3 feet deep. Soil and subsoil were carefully separated. As the land was strongly acid the soil was limed liberally, and also treated to a heavy application of stable manure and mixed fertilizer before being replaced in the trench. The cane was planted in this excellent seed-bed in April, 1931. In order to ensure that the plant food and moisture supply to the crop should not limit cane production, the following treatments were made throughout the growing period of the crop:—

*Fertilizer.*—Every month the cane received a dressing at the following rate per acre:—

100 lb. sulphate of ammonia.

50 lb. superphosphate.

20 lb. muriate of potash.

*Irrigation water* was applied as follows:—

Winter—Two inches per acre per week.

Spring—Four inches per acre per week.

Summer—Six inches per acre per week.

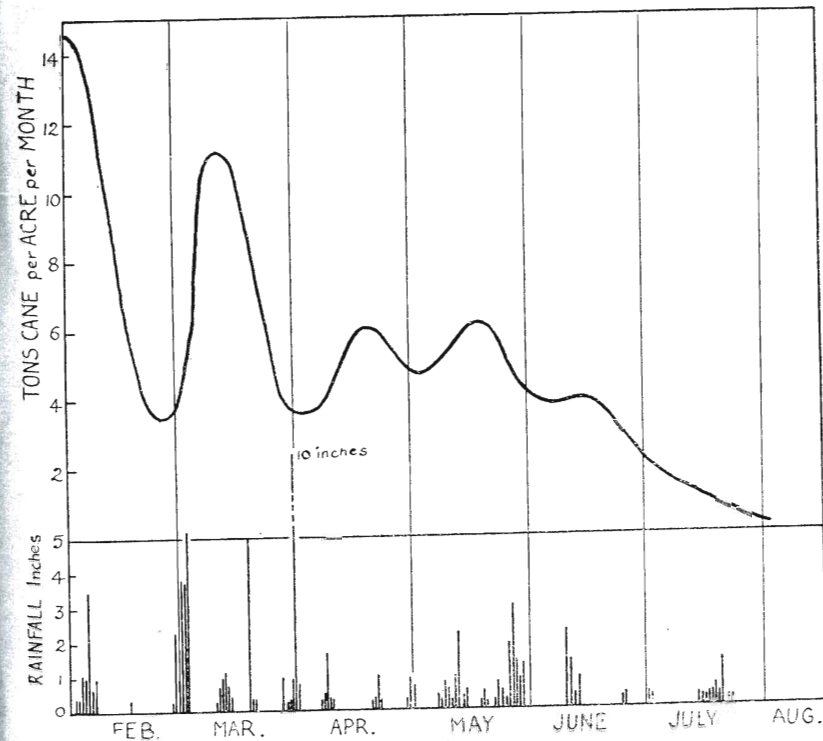


FIG. 1.

Showing the erratic nature of crop production under natural rainfall conditions at South Johnstone. The fluctuations in the growth curve lead to considerable reductions in crop yield.

Twenty-five secondary shoots were selected in July, and growth measurements on these were made at regular three-day intervals until the crop was harvested. It was thus possible to trace the course of crop production and, finally, to determine the relative proportions of the crop produced during individual growing months.

For purposes of comparison, a second trench was prepared in a manner entirely similar to the above, but the planting of this line was deferred until August, 1931. Under the conditions of the experiment it was thus possible to gauge the relative influence of time of planting on crop production.

In August, 1932, the crops were harvested. Each had made exceptionally good growth, particularly that planted in April; the stools were very heavy, and the average length of stick in the early plant Badila was over 11 feet. From the cane yields the following tonnages were calculated, assuming a field of similar cane with rows at 5-feet interspaces:—

Planted.	Harvested.	Age of Crop.	Tons of Cane per Acre.	C.C.S. %	Tons C.C.S. per Acre.
1931.	1932.	Months.			
April	August	16	143.9	15.9	22.9
August	August	12	58.3	15.8	9.2

Now it is not suggested for one moment that under field conditions the enormous crop of 144 tons of cane per acre could be produced; the above conditions were as nearly as possible ideal, and with the single row border effects were eliminated. Nor could a c.c.s. value of 15.9 per cent. be realised where under natural conditions such a crop would be a tangled mass of lodged cane with low sugar content. But there are valuable lessons to be learned by studying the various factors instrumental in the production of this heavy crop which could profitably be considered in conjunction with normal farm practice. It is proposed to study these influences and discuss their applicability.

As a basis for discussion the growth rate has been reproduced graphically in Fig. 2. The solid blocks represent by their area the tons of cane produced in each calendar month; the small numbers in the circle indicate the actual monthly tonnages. Curves representing variations in the relative periods of daylight and mean atmospheric temperatures are included also.

#### Time of Planting.

Under the conditions of our experiment we sought to remove the limiting factors—moisture and plant food supply—from the consideration. Any variations in crop growth rate should then be dependent chiefly on (1) air temperature and (2) hours of daylight. Fig. 2 shows very definitely that this is the case. The maximum growth rate was attained when the days were longest and the temperatures the highest—that is, in the month of December. This fact is one of very great importance in its relationship to normal farm practice. Where the cane was planted in April it utilised the cooler months of the winter in

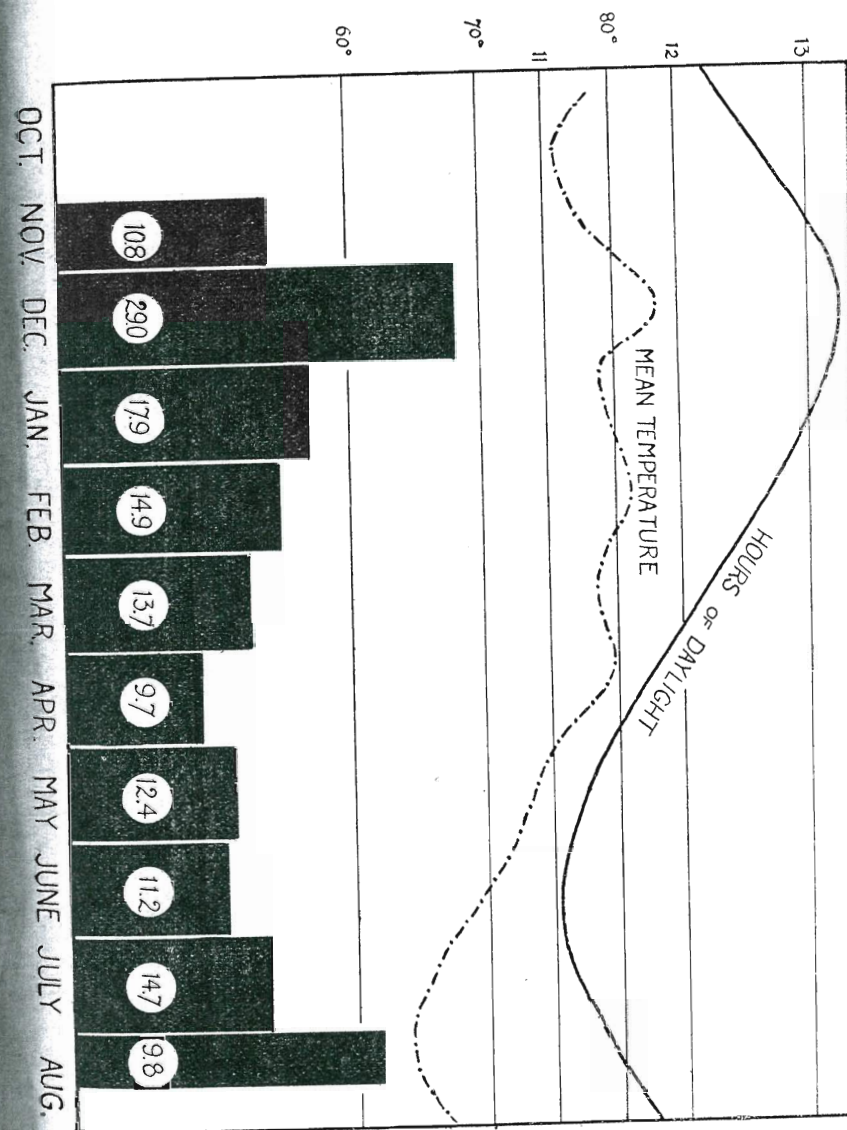


FIG. 2.

The solid blocks represent the tons of cane per acre produced under optimum conditions during each calendar month. The curves for hours of daylight and mean temperature fit very well with the growth rate, and show the particularly favourable growth conditions of December, provided that moisture and plant food are available.

becoming established and producing a heavy stool of vigorous shoots. Temperatures during this period were quite adequate for the purpose, and with the advent of the warmer spring months the growth rate speeded up, so that by early November millable cane was showing. During December this crop put on cane to the extent of 29 tons per acre, and from this maximum value the growth rate declined through the cooler and shorter days of late summer and autumn, but even in the coldest month (June) the rate was still about 10 tons per acre per month under the favourable growing conditions provided.

Contrast these figures with those from the spring planted crop. The highly favourable days for cane production of November and December were utilised in enabling the crop to become established, and millable cane was not in evidence until the latter part of January. This is a period when growing conditions, though still quite favourable, are on the decline. It should be pointed out that the discrepancy in crop yields between the autumn and spring planted cane was not entirely due directly to the time of planting. The spring planted cane was severely damaged by top-rot disease which seriously checked its growth and undoubtedly resulted in a marked reduction in crop yield. It is very significant that the autumn planted cane was quite free from the disease, though growing in close proximity to diseased cane. This provides a vivid example of the influence of planting time on the incidence of top-rot, and supports the recommendations of our pathologists that in areas subject to this disease early planting should be practised whenever possible. Assuming that the crop had been disease-free, and taking the growth rate of the autumn plant, the crop would still be inferior to the latter to the extent of 50 tons per acre.

#### Plant Food Supply.

Although no direct evidence was obtained from this experiment to indicate the influence of the added fertilizer on the growth of the crop, this was undoubtedly most important. During its growing period the early planted cane received about 2,700 lb. per acre of mixed fertilizer in the monthly applications, over and above that applied to the seed-bed. Excessive though this may appear, it was not capable of supplying the full plant food requirements of the 144-ton crop. It has been calculated that the plant food removed by 1 ton of cane is equal to that contained in 25 lb. of mixed fertilizer, and on this basis the above crop would require 3,600 lb. per acre. These facts emphasise the absolute necessity for the consistent application of heavy dressings of fertilizer if the farmer would harvest heavy tonnages of cane per acre while maintaining his soil in a highly productive state. This is particularly true of soils in the districts of heavy rainfall where the soil in its natural state has been robbed of its plant food reserves by the leaching action of the excessive rains over many centuries.

#### Irrigation.

Finally, we have to consider the influence of an adequate moisture supply in a well-aerated soil. The importance of this factor cannot be over-emphasised. The accompanying illustration (Fig. 2) shows that, even with low winter temperatures, cane can maintain an appreciable growth rate provided that moisture is available to it at all times. It is unfortunately true that September, October, and November are the

driest months of the year, and at this time the crop often suffers severely from lack of soil moisture even in the humid North. The severe check which the crop receives at this time seriously retards its development and prevents it from taking full advantage of the favourable cane-producing conditions usually associated with the long, hot, and rainy days of December. The average wet season rains are also relatively poorly distributed, as is demonstrated by the growth rate curve of Fig. 1.

The obvious remedy for this defect is the exploitation of irrigation possibilities to their fullest extent. To growers in the central and southern areas this cannot be too strongly advocated; while growers in the far north, who are so frequently situated in close proximity to permanent streams of the highest quality water, could in many cases double their crop yields by judicious irrigation. It will be argued that irrigation adds to farming costs; the important question is, however, will it reduce the cost of production per ton of cane? If so, then it is in the grower's best interests to adopt the practice. It may also be suggested that the added tonnage will still further embarrass an already depressed sugar market. This is, of course, entirely the grower's affair. The maximum area of land which he is permitted to bring under cultivation is limited by his assignment, but the lower limit is subject to his discretion. If he chooses to produce his present tonnage from one-half of the area now harvested, and in so doing he reduces his costs of production, then the principle is highly sound and economical.

At the present time the Burdekin district is the only one where irrigation is practised consistently. The results which are obtained there should afford strong evidence of its importance on crop growth. During recent years this area has made marked progress in the development of more efficient water application methods, and the better farmers of the district have repeatedly produced 50 and 60 ton crops. Certainly this area possesses some of the richest cane soils in Queensland, but there are others which are relatively difficult to work and in need of artificial manures. In other respects also conditions are not ideal. The land surface is practically level throughout the district, and the slight irregularities in the topography are just sufficient to make it more difficult to provide an even distribution of water. The favourable gentle slopes of other districts would make the process of irrigation simple by comparison. For a great proportion of the year, also, the area is subjected to the unfavourable influence of hot, drying winds, which rapidly remove soil moisture by evaporation and distress the crop. The latter does not flourish under these conditions, and much energy is expended in an attempt to sustain the unusually rapid evaporation loss from its leaves. These difficulties are cited to demonstrate the fact that other cane areas, both to the north and south, are much more favourably situated with respect to many conditions which would make for heavy crop yields, given an abundance of soil moisture. The Bundaberg district in particular is one which would again occupy a very prominent place in our sugar world, and it is pleasing to note that irrigation on an intensive scale is being practised at Bingera plantation this season. There can be no doubt as to the results which will follow. When it is remembered that the summer days are longer in the southern areas than in those districts lying nearer the equator, and air temperatures are equally favourable during this season, the production of a 50-ton crop requires but a few months of favourable growing conditions, and fertilizer and irrigation water will do the rest. The taller crops will be

subjected to less damage from frosts in the winter, while a moist soil is characteristically a better conductor of heat than a dry one, so that the severity of frosts is again minimised by watering. The red volcanic soils of the Bundaberg area are probably the most suitable lands for irrigation that could be found, being almost identical with the better class irrigated areas of the Hawaiian Islands, which are famed for their productivity.

There is another aspect of irrigation which should appeal to growers in those areas where cane grubs are active. A continuous supply of soil moisture will provide conditions best suited to the rapid replacement of roots as they are chewed off by this pest, and though the severe check in growth will not be eliminated the crop will be saved. This suggestion is worthy of serious consideration by growers in the Gordonvale area, for example, where an abundant supply of water from the Mulgrave River could be diverted for the purpose.

This whole question is one which should not be turned aside lightly by any grower fortunately situated with respect to water supply. In times of economic stress it is easy for the primary producer to fall into unsound practices in an attempt to reduce costs. One most frequently employed is a reduction in the purchase of fertilizer—the material so essential to the maintenance of the plant food supply of soil and crop. Under this policy the assets of the farm are rapidly dissipated, and its effects are only too clearly illustrated by the unfortunate circumstances which surround certain of the older cane-producing areas. Their pioneering days came at a time when the value of artificial manures was not appreciated, so that to-day the land has been reduced to such a low level of fertility that in many instances cane production under natural climatic conditions is economically impossible. It should be evident to every grower that to farm a smaller area intensively, and give the remainder of the land a prolonged rest under grass, is the surest method of maintaining a fertile soil. This policy enables Nature to continue with her process of building up plant food reserves in the soil—a process which was rudely interrupted when the soil was devoted to continuous cane cultivation.

#### FARM BULLETINS ISSUED TO DATE.

- 
- No. 1.—FARM FERTILITY TRIALS, 1930.
  - No. 2.—PAPERS ON CANE CULTURE, DISEASE AND PEST CONTROL.
  - No. 3.—FARM FERTILITY TRIALS, 1931.
  - No. 4.—CHILDERS CANE BEETLE.
  - No. 5.—SOILS IN THEIR RELATIONSHIP TO SUGAR-CANE CULTURE.