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Soils Investigations in the Sugar-Cane Producing Areas of Bundaberg

By NORMAN J. KING, Director of Sugar Experiment Stations, Division of Plant Industry.

SUMMARY

Three major soil series—designated the Woongarra, the Gooburrum and the Burnett series—and an unusual minor type (Kepnock Yellow Soil) have been recognized following a survey of the Bundaberg district cane-growing areas.

The chemical and physical properties of the various series and their component types are described.

Soil moisture relationships, as deduced from standard determinations and a series of field investigations, are described for the major types and the suitability of the soils for irrigation purposes is discussed.

The nutrient status of each type is considered in relation to chemical analysis and the results of field fertilizer trials. Results of some trials with molasses and other soil amendments are given.

INTRODUCTION

Soil survey work in the sugar-cane producing areas of Queensland was inaugurated in 1930 when the writer made a reconnaissance survey of most of the districts from Mossman to Childers. Sugar cane is grown in this State from Mossman (lat. 16.5° S.) to Beenleigh (lat. 27.7° S.). Since coastal Queensland is geologically complex and the average annual rainfall varies from 40 inches in some of the southern producing areas to over 150 inches in some of the northern districts, it is not surprising to find a wider variety of soil types than is found in any other sugar-cane growing country in the world. Further and more intensive survey work was delayed until 1936-37 in the northern areas, but intermittent studies were made in the Bundaberg and surrounding districts in the south over several years. It has now been decided to publish the data available for the Bundaberg area and to proceed with further work in the other districts.

Sugar production in Queensland is one of the State's largest primary industries, the 1939 and 1947 returns for raw sugar being in excess of £14,000,000 and the 1948 crop returning £25,000,000. Some idea of the relative position of the Bundaberg district within the industry may be gleaned from the fact that in 1948 the five Bundaberg mills crushed 15 per cent. of the total crop.

The gross acreage assigned for sugar-cane growing within the five mill areas of Bundaberg is 60,572, but not all of this was covered by the survey. The Gin Gin mill area was excluded, and also that part of the Bingera mill area which extends west of Bullyard.

The area is bisected by the main North Coast railway line and stretches from the coast west to Bullyard, and from the Elliott River on the south to north of the Kolan River. The commercial centre of the area is the city of Bundaberg (lat. 24° 53″ S.; long. 152° 21″ E.), situated approximately nine miles from the coast, on the Burnett River.

PHYSIOGRAPHY

Starting from the coast, the first topographical feature of note is the development of elevated volcanic land, the centre and origin of which is the Hummock (308 ft.), stretching from the Burnett to the Elliott River, and in a westerly direction almost to the city of Bundaberg. West and north of the elevated area the country is remarkably flat and featureless, except for the alluvial deposits caused by the Elliott, Burnett and Kolan Rivers and their subsidiaries, and a further small volcanic outcrop near Bingera which rises to 241 ft. At Bucca, north of the Kolan River, some hilly country of minor agricultural importance exists. All three major topographical developments—(1) the red volcanic lands, (2) the very extensive forest flats, and (3) the river alluvium—contribute largely to the agricultural production of the area. The line of hills just west of Bullyard forms a natural though not economic boundary between the Bundaberg and the Gin Gin areas.

The red volcanic loams are developed from Late Tertiary basalts, the Woongarra formation at Bundaberg and the Hill End flow near Bingera being only two of the several along this section of the coastal belt. The extensive sandy loams of the forest country, on which a great deal of sugar cane is grown, are formed on fresh-water sediments of the Burrum series of Cretaceous age, while the alluvial soils of the Burnett and Kolan Rivers occupy flood plains and river terraces in restricted areas. These alluvial soils are, in the main, of recent age, though the Fairymead group is possibly Pleistocene.

NATURE OF THE INVESTIGATION

During recent years a considerable amount of detailed work has been carried out on the Bundaberg soils, and maps have been prepared showing the location and soil type of each cane farm and plantation in the district. The work is a soils investigation and is not restricted to survey procedure. In some respects it differs from the conventional survey which is used in conjunction with possible land use. In this case the land surveyed is already being utilized for cane growing. Under the legislation governing sugar-cane growing, a given acreage of land is assigned for cane production to a given mill. The sugar cane grown must be produced on that assigned acreage irrespective of whether the grower owns a large acreage of unassigned land or not. He is not allowed to rotate the acreage except to the extent that only 75 per cent. of the gross assigned acreage may be harvested in any one year. It will therefore be seen that soil survey work on unassigned land has no purpose at present and this work was concerned only with classifying the existing assigned areas.

AGRICULTURAL DEVELOPMENT

The area is primarily, and almost solely, one of sugar cane production. It produces the bulk of the cane supply for the Qunaba, Millaquin, Fairymead and Bingera mills, which collectively have an average annual capacity of approximately 800,000 tons of cane. On the marginal lands some mixed farming, including dairying, is practised, but in the bulk of the area sugar cane is grown to the exclusion of all other crops. The method of assignment of land to a sugar mill—under the "Regulation of Sugar Cane Prices Acts, 1915-1948"—brought about close settlement of suitable areas and a relatively high acreage value for assigned land. Farm areas are consequently small, the average being about 40 acres. The first land to be cleared and planted in the early days of sugar production was the red volcanic soil between Bundaberg and the coast, settlers being attracted by the rich soil with its excellent rain-forest cover. Agricultural development of the alluvial flats along the Burnett and Kolan Rivers soon followed, and after a considerable lapse of time the better class land on the flat forest country was cleared and planted with sugar cane. Over-production of sugar and consequent legislation limiting the areas which could be assigned for growing cane put a stop to further clearing of these forest areas. Some attempt has been made in more recent years to extend the tobacco and cotton growing industries on these soils, but no major development has taken place.

Since 1932, when a severe drought affected the area, more consideration has been given to the irrigation potentialities of the area. A weir on the Burnett River impounded sufficient water for the irrigation of the extensive Bingera Plantation and of many adjacent farms. The Fairymead Sugar Company installed many plants which pumped from subterranean supplies on several of their plantations. These large-scale installations were rapidly followed in the succeeding decade by the introduction of pumping units to a considerable number of individual farms, and it is estimated that there are upwards of 200 irrigation units in the district, 90 per cent. of which are pumping from underground water-bearing beds. The amount of water required for sugar-cane growing in this area is considerable, and it is calculated that in an average year nearly one million gallons of water per acre are required in addition to normal rainfall.

CLIMATE

Though sugar cane is a highly adaptable crop capable of being grown under a wide range of climatic conditions, best results are obtained when the period of heaviest rains coincides with that of highest temperatures and longest days, since, for prolific growth, the plant requires a high mean temperature, a high relative humidity, and large quantities of available moisture. It follows, therefore, that a district with summer rainfall is required for successful production of this crop. Climatic data for Bundaberg are give in Table 1. An analysis

Table 1.

CLIMATIC DATA FOR BUNDABERG.

	No. of years	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Mean monthly rainfall (in.)	55	8.55	6.53	5.18	3.27	2.55	2.85	1.84	1.27	1.57	2.12	2.69	5.08	43.50
Mean no. of wet days ..	—	10	10.5	10.2	8.4	7.0	5.8	5.6	3.4	4.2	6.9	8.4	10.9	91.3
Mean precipitation per wet day (in.)	—	.855	.622	.508	.389	.364	.491	.328	.374	.374	.307	.320	.466	.476
Mean maximum temperature (°F.)	30	85.9	85.7	84.2	81.2	76.6	72.4	71.7	73.5	77.1	80.4	83.2	85.6	—
Mean minimum temperature (°F.)	30	69.6	69.4	67.1	62.3	55.6	51.7	49.0	50.3	55.6	60.8	65.1	68.7	—
Relative humidity at 9 a.m. (per cent.)	30	69	71	72	71	72	74	72	70	65	63	63	65	—

Table 2.

RAINFALL RELIABILITY—BUNDABERG AND FAIRYMEAD.

Locality	No. of Years	Chances of receiving rainfall less than									
		10in.	15in.	20in.	25in.	30in.	35in.	40in.	50in.	60in.	70in.
		Summer									
Bundaberg ..	55	—	1/10	3/10	3/7	3/5	3/4	4/5	9/10	19/20	29/30
Fairymead ..	57	—	1/10	1/4	2/5	3/5	3/4	5/6	11/12	19/20	all
		Winter									
		4in.	8in.	12in.	16in.	20in.	24in.	28in.	32in.		
Bundaberg ..	55	—	1/5	1/2	7/10	5/6	14/15	all	all		
Fairymead ..	57	1/30	1/6	2/5	7/10	6/7	14/15	all	all		

of incidence of monthly rainfall shows that the normal* summer rainfall (October to March) is 27 inches for Bundaberg and for Fairymead, while the normal winter precipitation is 12½ inches for Bundaberg and 13 inches for Fairymead. Rainfall reliability figures computed by the Commonwealth Bureau of Meteorology are given in Table 2. These figures, though indicating a definite summer rainfall period, make evident the fact that the summer normal of 27 inches is of only about 50 per cent. reliability. Recorded extremes—outside the normal range—are 12.53 inches in 1901-02 and 86.38 inches in 1892-93.

Under the heading of climatic data, Bundaberg may be classified as having a Meyer ratio of 181, this figure being the ratio of precipitation to saturation deficit (P/s.d.), obtained by dividing rainfall in inches or centimetres by the deficit from the saturation value of the atmospheric water vapour pressure, measured also in inches or centimetres of mercury.

VEGETATION

Broadly, the vegetation-type boundaries coincide with those of the major soil series, but in view of the flatness of much of the country rather broad transition regions, or ecotones, sometimes occur.

On the red volcanic loams of the Woongarra series the vegetation is described as closed forest or "monsoon" forest, as distinct from the true rain-forest which develops in areas with a rainfall in excess of about 50 inches per annum. It really represents the survival of hardier rain-forest species on richer moisture-retaining soils in lower rainfall areas with a pronounced dry season. The species composition is very complex: more than 90 different tree species occur in the small remnants of natural vegetation. This "monsoon" forest vegetation is closely confined to the boundaries of the one soil series which occurs in the Woongarra and at Hill End.

On the Gooburrum series of sandy loams, the vegetation is a mixed eucalyptus forest. The canopy trees include the pink and white bloodwoods (*E. intermedia* and *E. trachyphloia*), yellow stringybarks (*E. carnea* and *E. umbra*), blue gum (*E. tereticornis*) and rusty gum (*Angophora costata*). The under-story consists of many species of *Melaleuca, Acacia, Casuarina* and *Grevillea*. Drainage is an important factor in local appearance of the forest, and on more poorly drained sections the individual trees become sparser and tea-tree (*Melaleuca leucadendron*) and grass-tree (*Xanthorrhaea* sp.) play a more prominent part in the under-story.

The ancient alluvial soils (Burnett series Type II) carry a blue gum forest association. This is usual on heavy clay flats such as characterize this soil type. The predominating species is blue gum (*E. tereticornis*); others which occur include tea-tree, she-oak (*Casuarina glauca*) and black wattle (*Acacia cunninghamii*).

* The "normal" used in this discussion is taken as the central value (approx.) of the range of most frequently obtained rainfalls. This value is generally different from the "average" since it is unaffected by abnormally low or high falls, which are so rare as to be of little consequence.

On the Type I soils of the Burnett series, which consist of recent alluvium, the canopy is higher than on the "monsoon" forest of the Woongarra series. The growth is better, since it depends more on soil moisture from adjacent streams than on rainfall. Typical species are black bean (*Castanospermum australe*), weeping myrtle (*Eugenia ventenatii*) and giant water gum (*E. francisii*).

On the sandy coastal soils, which are of very minor importance in sugar-cane production, a Moreton Bay ash (*Eucalyptus tesselaris*) forest exists.

DESCRIPTION AND CLASSIFICATION OF SOIL TYPES

In the area under discussion, three soil series are clearly defined; they have been named, according to location of major occurrence, the Woongarra series, the Gooburrum series and the Burnett series.

THE WOONGARRA SERIES

In the Woongarra series two soil types have been defined and mapped —the Woongarra red loam and the Woongarra brown clay loam.

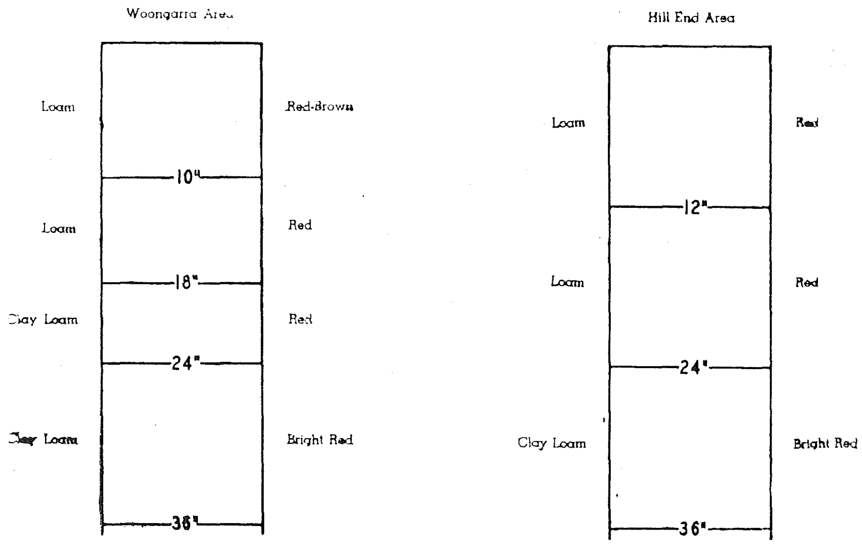

Figure 1
Soil Profiles—Woongarra Series, Type I.

The Woongarra red loam (*see* Fig. 1 for profiles) is of a deep red colour and has been developed on basalt—classified as an olivine-augite-plagioclase basalt—of Late Tertiary age. It is usually of considerable depth, the parent rock frequently being as much as 50 feet below the surface. As is to be expected of a volcanic soil where the basaltic flow merges into adjoining formations, and where the topography is undulating, the depth of soil overlying the parent material varies considerably. At the site of the Sugar Experiment Station (Por.

49 Par. Kalkie) there is approximately 10 feet of red soil, 40 feet of very decomposed basalt which can be penetrated by a post-hole digger, two feet of solid basalt, and then the underlying deposit. At Qunaba Plantation—some four miles distant (Por. 31, Par. Barolin)—22 feet of red soil overlies a honeycomb formation which is succeeded by solid basalt at 47 feet, while on still another portion of the Woongarra 11 feet of red soil overlies 99 feet of solid basalt.

The soil in certain areas contained, in the natural state, considerable amounts of boulders, indicating a stony phase, but as these were removed during early agricultural development there is no means of mapping such a phase. Though the type is described as a loam, mechanical analysis discloses a large proportion of clay particles. The texture is loamy and the soil is highly permeable to moisture; it is regarded as the best drained type in the district. There is no distinct profile delineation in the true red loam. Sections of this soil which have been under grass cover ever since the clearing of the original scrub have a slightly defined organic horizon, but below 9 inches there is no visible change in colour or texture. No hard-pan is evident, the only evidence of the soil-forming process being the presence throughout the soil of small "shot" (spherical nodules of silica, iron and alumina). These concretions reach 4 mm. in diameter, and on analysis have the composition shown in Table 3.

Table 3.

WOONGARRA SERIES TYPE I—ANALYSIS OF CONCRETIONS.

—	—	>3 mm.	<3 mm.
	per cent.	per cent.	per cent.
Moisture	4.28	4.32	4.17
Loss on ignition	9.19	11.05	10.18
Mn_3O_4	0.69	3.09	3.08
Fe_2O_3	50.53	27.02	32.33
SiO_2	18.12	26.62	26.00
Al_2O_3	12.53	21.86	18.05
TiO_2	2.52	4.75	5.27
P_2O_5	2.52	0.47	0.47
CaO	0.10	< 0.05	< 0.05
MgO	0.20	0.41	0.43
K_2O	0.09	0.18	0.14
Na_2O	0.02	not determined	not determined
	100.79	99.82	100.17

In some areas—generally towards the borders of the type—deposits of an ironstone gravel exist at varying depths. Occasionally these are found under one or two feet of soil. The gravel is fairly regular in size, approximating one half-inch in diameter. This soil type is notable for the remarkably fine tilth which it retains even when much abused. In the virgin condition it has an excellent crumb structure. This deteriorates progressively with constant cultivation, but even after 60 or 70 years of intensive cultivation the physical condition remains excellent. Despite the high proportion of clay particles shown by mechanical analysis, the texture is loamy, due no doubt to the content of free ferric hydroxide.

When dry, this soil type is quite loose, of open structure, and contains very few lumps. When squeezed in the wet state, it is plastic but retains its characteristic tilth. The coarse and fine sand set out under the mechanical analysis consist of mineral fragments from the basalt and include no quartz sand. On a very small area on the western slope of the Hummock some quartz sand is found associated with the soil, indicating a more acid lava flow of small proportions at this point.

The brown type (*see* Fig. 2 for profile) merges rather gradually into the red without any sharp line of demarcation. The type is, in general, located in the lower-lying parts of the area, but some of the occurrences are elevated. The principal points of difference from the red type are (1) colour is a grey-brown, (2) shot-like concretions are far more plentiful, (3) moisture-

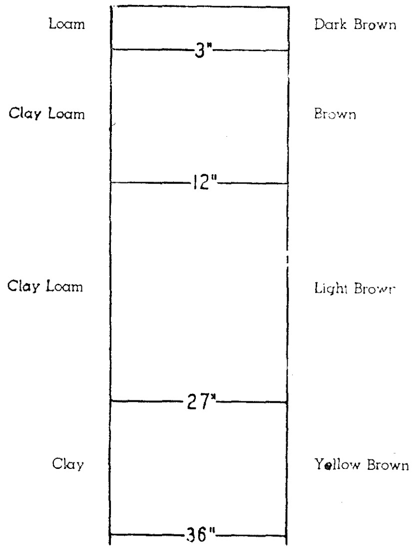

Figure 2
Soil Profile—Woongarra Series, Type II.

holding capacity is greater, (4) behaviour is more like that of a clay-loam than a loam, (5) ironstone pans are more common, and (6) the crumb structure is not so well defined. The soil has the reputation of being poorer than the red type, but it has been proved that adequate fertilization makes it an equal if not superior producer because of its better moisture-holding capacity. It is possible that the brown colour was developed under wetter soil conditions in depressions and less well-drained locations. Certain uncleared areas of this brown type carry a preponderance of tea-tree, a water-loving species usually found in badly drained locations.

There are no considerable depths of this type such as are found with the red type; but the soils are relatively shallow, merging at 10 to 20 feet into a highly decomposed basalt which, though retaining the structure and steam holes of the original rock, can be penetrated by a pick. This decomposed rock stage is generally of a mottled grey-brown colour.

No apparent differences exist in pH or plant food supplies in the two types. The pH of both is in the slightly acid to neutral range, with occasional samples slightly alkaline. Both types are well supplied with available phosphate and are deficient in available potash.

Though situated in a belt of 43-inch annual rainfall, with a reasonably good summer distribution, the volcanic soils have a reputation for droughtiness which cannot be entirely explained by the very free drainage. An investigation into the moisture relationships of the soil was conducted over a period of years.

Table 4.

WOONGARRA SERIES—SOIL MOISTURE PERCENTAGES AT CESSATION OF GROWTH OF FOUR CANE VARIETIES (PLANT CROP).

Depth (in.)	Variety			
	P.O.J.234	Q.813	Co.290	P.O.J.2725
0–3	15.1	14.1	16.3	15.5
3—6	18.4	19.9	19.6	18.8
6—12	20.0	21.2	20.9	21.1
12—18	21.2	25.5	23.6	23.0
18—24	22.9	25.3	25.7	23.6
24—30	23.0	25.0	23.5	23.3
30—36	23.3	25.5	24.3	23.6
36—42	23.0	25.5	23.5	23.7
42—48	24.0	25.5	23.8	23.2

Table 5.

WOONGARRA SERIES—SOIL MOISTURE PERCENTAGES AT CESSATION OF GROWTH OF FOUR CANE VARIETIES (RATOON CROP).

Depth (in.)	Variety			
	P.O.J.234	Q.813	Co.290	P.O.J.2725
0—3	18.0	18.1	17.2	17.0
3—6	19.1	19.2	18.3	18.1
6—12	20.1	20.5	20.7	19.9
12—18	22.8	22.6	23.0	22.1
18—24	24.5	24.5	25.7	24.7
24—30	25.2	25.1	26.4	25.3
30—36	26.2	26.7	27.0	26.0
36—42	28.3	27.4	28.5	27.7
42—48	27.9	30.3	31.5	34.1

Soil moisture determinations at different levels, in combination with sugar-cane growth measurements, indicated that the Woongarra red and brown types have a maximum field capacity of 30-32 per cent. and a wilting percentage of 20-21 per cent. Moisture equivalent was found to be approximately .91 of the maximum field capacity.

Table 6.

WOONGARRA SERIES—EFFECT OF VARIOUS TREATMENTS ON SOIL MOISTURE CONTENT.

Treatments : (1) Bare fallow ; (2) Surface hoed to 3 inches ; (3) Trash mulch : (4) Bag cover.

——	April 7				April 9				April 11				April 15				April 18			
Depth (in.)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
0— 3 ..	25.9	22.8	Not determined	30.2	19.9	15.0	26.2	34.2	18.0	15.8	26.9	28.6	18.0	15.2	26.0	24.6	15.0	19.8	25.0	26.0
3— 6 ..	23.8	30.3		29.6	28.1	27.8	26.9	30.0	26.0	22.8	27.7	28.2	23.8	23.9	25.9	24.6	22.4	24.0	25.1	26.9
6— 9 ..	32.2	31.1		31.0	29.0	29.2	27.5	30.5	28.0	28.6	28.3	27.7	26.5	26.4	26.4	27.3	25.6	26.6	26.5	26.6
9—12 ..	32.9	31.1		31.8					28.3	29.6	28.6	28.6								
12—15 ..	31.0	32.3		30.6	28.6	26.9	28.5	29.8	26.7	27.7	27.4	27.8	26.8	27.1	27.3	26.6	26.6	26.6	26.2	26.3
15—18 ..	29.8	30.0		28.9					27.5	27.3	27.6	27.2								
18—21 ..	28.8	28.3		28.6	27.5	28.1	27.0	28.0	27.0	27.1	27.5	28.4	26.0	27.3	26.1	26.0	26.2	26.1	26.1	27.1
21—24 ..	28.5	28.2		28.0					26.7	27.0	27.2	27.0								
24—30 ..	28.3	28.3		28.0	27.2	27.5	27.7	27.6	28.0	26.7	26.4	26.2	25.8	26.2	25.6	26.5	25.9	25.3	26.0	26.2
30—36 ..	28.9	28.5		28.6	26.8	27.3	27.7	27.4	28.6	27.7	26.6	26.6	26.6	26.3	26.2	26.3	25.6	26.3	26.0	26.8
26—42 ..	28.8	28.7		28.6	28.0	27.7	27.0	27.2	27.4	28.6	26.9	26.8	25.0	25.6	26.2	27.2	26.5	26.5	26.1	26.3
42—48 ..	27.9	29.1		28.9	28.0	28.1	27.4	27.8	28.2	29.4	27.4	27.7	25.8	25.7	26.8	27.3	26.3	27.9	26.6	27.2

	April 20				April 22				April 25				April 27				May 2			
Depth (in.)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
0— 3	13.1	11.2	24.6	24.9	14.2	12.5	24.3	20.5	14.5	12.0	22.7	23.2	14.8	12.8	22.6	21.4	14.5	12.0	21.1	19.8
3— 6	21.0	22.9	25.6	25.0	22.2	22.2	25.8	24.6	23.0	22.2	26.5	26.2	21.8	21.8	26.3	25.5	20.0	20.7	21.4	22.2
6— 9	26.0	26.7	26.3	26.5	26.3	26.9	27.3	25.6	24.3	25.6	25.8	27.3	25.4	26.3	25.6	26.4	23.0	24.4	24.1	25.5
9—12																				
12—15	26.4	25.9	25.8	26.4	26.4	26.6	27.3	27.1	25.8	26.2	26.6	26.4	26.1	26.4	26.0	26.3	25.3	26.1	25.2	26.2
15—18																				
18—21	26.2	25.7	25.6	26.0	27.2	26.5	26.6	27.0	26.6	26.3	26.6	27.7	27.0	25.9	26.5	26.7	25.4	25.9	25.9	26.0
21—24																				
24—30	26.5	26.2	26.3	26.4	27.2	27.0	26.3	26.7	26.2	26.6	26.2	26.3	26.9	26.9	26.0	26.5	25.5	25.9	25.9	25.7
30—36	26.3	26.7	26.1	26.9	26.6	27.1	25.8	26.6	26.4	26.4	25.2	27.3	26.8	26.8	25.6	27.2	26.1	26.1	24.4	26.2
36—42	26.2	27.1	27.0	27.3	26.5	27.2	26.1	28.1	26.7	26.0	26.3	27.3	26.6	26.3	26.1	27.5	26.9	26.6	24.3	27.4
42—48	26.7	26.7	26.1	28.3	26.4	26.8	26.3	27.5	26.0	26.0	27.0	26.9	26.1	26.5	26.8	27.3	26.6	27.3	25.4	26.2

The wilting percentage was determined from growth measurements on sugar cane recorded simultaneously with soil moisture determinations at different levels to four feet over a period of years. Since the principal root zone of sugar cane is from 6 to 12 inches, the moisture in the 6-12 inch zone when growth ceased was taken as the wilting percentage. The figures in Table 4 are for soil moisture content at the time of minimum growth rate with four varieties of sugar cane.

A further series of determinations made a year later on the ratoon crop, also at a time when growth measurements indicated that stalk elongation had ceased, are as shown in Table 5.

It will be seen that subsoil moisture was at a far higher level in the second series than in the first, but that the moisture content of the 6-12 inch layer at the time of cessation of growth was virtually the same in both years.

Studies were also made of the much discussed farm practice of surface cultivation to conserve soil moisture, a practice which takes the form in the Bundaberg district of light scarifyings after rains to break the surface soil into a friable mulch. Table 6 shows figures obtained as the result of soil moisture studies under four different surface treatments. In treatment No. 1 the land was hand-hoed to a depth of two inches to maintain a surface mulch; in treatment No. 2 the land was left undisturbed, but weeds were hand-picked to

Table 7.

WOONGARRA SERIES TYPE I—FUSION ANALYSIS.

	per cent.	
Moisture	2.73	
Loss on ignition	13.68	
SiO_2	37.02	Fe_2O_3 19.6
R_2O_3	45.23	Mn_3O_4 0.5
P_2O_5	0.17	$Al_2O_3 + TiO_2$ 25.1
CaO	0.59	
MgO	0.17	
Na_2O	0.18	
K_2O	0.19	

Table 8.

WOONGARRA SERIES TYPE I—ANALYSES AT VARIOUS DEPTHS.

Depth (in.)	0—12	12—24	24—48	48—72
	per cent.	per cent.	per cent.	per cent.
Coarse sand	4.7	2.3	2.5	
Fine sand	7.0	7.6	8.6	⅓ soil
Silt	12.6	10.9	14.7	⅔ weathered
Clay	74.0	77.8	73.8	rock
Moisture	4.65	4.00	5.69	6.88
Loss on Ignition	13.18	12.00	11.14	12.00
Carbonates	.01	.01	.01	.01
Organic carbon	1.67	1.08	0.51	0.25
Nitrogen	.175	.128	.058	.030
C/N Ratio	9.5	8.4	8.8	8.3
pH*	6.7	6.6	6.5	5.2
SiO_2/R_2O_3 (clay fraction)	1.37	1.17	1.34	—

* Glass electrode.

maintain comparable conditions with bare fallowing; in treatment No. 3 a close cover of cornsacks was applied in an attempt to prevent surface evaporation; and in the fourth section a cane trash cover was applied to measure its efficiency as a mulch in comparison with the bag and soil mulches. Borings were made on each section every two or three days to a depth of four feet and the moisture determined in 3-inch and 6-inch sections over the total depth. The experiment was started immediately after April rains and continued until May 2, during which period no rain fell.

The results showed that the sack cover retained the most moisture in the surface soil, though there was no significant difference between sacks and trash

Table 9.

WOONGARRA SERIES—ANALYSES OF SAMPLES FROM VARIOUS LOCALITIES.

Type I. (Woongarra District).

No.	2166	2167	2168
Depth (in.)	0—12	12—24	24—36
	per cent.	per cent.	per cent.
Coarse sand	11.5	7.0	7.4
Fine sand	9.0	8.5	7.9
Silt	22.0	22.4	19.7
Clay	54.6	60.9	61.8
Moisture	5.4	5.0	4.9

No.	927	928	929
Depth (in.)	0—9	9—18	18—27
	per cent.	per cent.	per cent.
Coarse sand	3.4	1.9	1.7
Fine sand	7.8	7.4	10.9
Silt	26.6	21.2	22.3
Clay	53.9	63.6	62.6
Moisture	7.7	5.8	5.3
Loss on ignition	14.9	12.6	11.5
Carbon	3.4	1.8	1.2
Nitrogen	0.33	0.19	0.14

No.	B.108	B.109	B.110	B.111
Depth (in.)	0—10	10—18	18—24	24—36
	per cent.	per cent.	per cent.	per cent
Coarse sand	10.26	13.26	9.11	8.77
Fine sand	7.42	5.38	5.10	4.70
Silt	12.09	10.75	11.95	12.01
Clay	68.85	66.64	71.90	75.33
Moisture	5.12	4.22	4.21	3.63
pH*	6.30	6.60	6.80	7.00
Carbon	2.77	2.61	2.25	1.90
R_2O_3	31.88	29.20	33.62	35.18
Loss on acid treatment	2.02	2.05	1.79	1.68

* Glass electrode.

Table 9—*continued*

Type I (Hill End District).

No.	B.100	B.101	B.102
Depth (in.)	0—12	12—24	24—36
	per cent.	per cent.	per cent.
Coarse sand	5.0	4.5	3.9
Fine sand	19.0	18.0	18.3
Silt	14.1	16.1	14.5
Clay	56.7	57.8	60.1
Moisture	3.2	3.2	2.9
Carbon	1.36	.88	.49

Type II

No.	B.103	B.104	B.105	B.106	B.107
Depth (in.)	0—3	3—12	12—27	27—31	31—36
	per cent.	per cent.	per cent.	per cent.	per cent.
Coarse sand	32.62	19.91	26.98	23.27	27.08
Fine sand	7.09	7.79	8.99	9.55	8.86
Silt	9.03	10.28	11.10	11.38	12.40
Clay	47.87	59.56	53.06	56.60	55.17
Moisture	3.86	3.96	3.41	3.36	3.80
pH*	6.40	6.70	5.95	5.75	5.60
Carbon	2.77	2.43	1.76	1.68	1.66
Loss on acid treatment	1.42	1.43	1.12	0.50	0.30

* Glass electrode.

Note.—The considerably higher percentage of coarse sand particles in the brown phase is caused by the content of shot-like concretions referred to on page 000.

in the aggregate of the first two feet; the bare sections, hoed and undisturbed, lost appreciably more moisture than the former two.

Table 7 sets out the results of a complete fusion analysis of a sample of Type I. The outstanding figures in this analysis are the very high sesquioxide content, the low silica, the low sodium, and the high loss on ignition.

Monolith profiles taken from this soil type on Por. 49 Par. Kalkie were examined to a depth of 72 inches; the results are given in Table 8.

Further mechanical analyses (Table 9) of this soil type were made on samples from various parts of the Woongarra and Hill End areas. The analysis of profile samples Nos. 927 and 929 were supplied by the Waite Agricultural Research Institute.

The presence of a small area of virgin rain forest on this series allowed comparison of virgin and cultivated soils of the series to be made. The results are shown in Table 10.

The serious loss of soil organic matter, as demonstrated by the lowered total carbon, total nitrogen and moisture equivalent in the cultivated soil, prompted an attempt to investigate the possibility of regenerating the soil, or, at least, checking the deterioration.

The incorporation of organic matter into sugar-cane soils, without serious interference with normal practices, can be achieved by application of molasses, by ploughing-in of green manure crops, and by conserving cane crop residues. Accordingly, a similar cultivated soil from the Experiment Station, belonging to the same type as No. 2091, was used for a series of pot tests. The treatment included incorporation in the soil of (1) 5 per cent. by weight of molasses; (2) 5 per cent. by weight of ground dry cane trash; and (3) 5 per cent. by weight of dry Poona pea leaves. The pots were kept moist until no visible traces of the organic materials remained; then soil samples from each pot were worked up to optimum moisture content and the percentage determined. Field peas were then grown in all pots to a stage approaching maturity, the soil surface being covered to minimize evaporation losses. At this stage water was withheld until the plants began to wilt, and the moisture content of the soil in the root zone was determined. The figures are given in Table 11.

The results indicate that there is little to choose between the three amendments in increase in carbon content, available moisture or moisture equivalent. The use of 5 per cent. of organic material is a very heavy dressing and beyond practical attainment on a farm scale. The fact that the moisture equivalent has been raised only from 25.1 to 27.6 per cent. in the best treatment indicates the magnitude of the task of returning this soil to virgin condition; in Table 10 it is shown that the virgin soil has a moisture equivalent of 34.9.

Comparisons of various features of soils of the Woongarra series with the corresponding characteristics of other soils in the area are given in Tables 17-24.

THE GOOBURRUM SERIES

The extensive sandy loam development of the forest area has, during the past 25 years, become a major sugar-producing type. These soils have been formed on the freshwater sediments of the Burrum series, and prior to cultivation were covered by a fairly heavy hardwood forest growth. Cane planting on this soil series lagged considerably behind the cultivation of the red volcanic loams, the early settlers having shown a decided preference for the "scrub" land and a disregard for the forest soils. The more important developments of this soil series occur at South Kalkie, Alloway, Clayton, Gooburrum, Oakwood, Bingera, Ten Mile Road and Pine Creek. In these areas, compact cane-growing communities exist, but several hundred sugar-producing properties are scattered over the same series in the more sparsely settled sections.

In general, but particularly in the South Kalkie—Alloway—Clayton areas, the topography is remarkably level. On the north side of the Burnett River and at Pine Creek it is slightly undulating, but the similarity in the physical and chemical nature of the soils, the natural vegetation, the soil profile and the underlying strata indicates that they belong to the same series. A considerable depth of soil is one of the characteristics of the series, 20 to 25 feet being

Table 10.

WOONGARRA SERIES—ANALYSES OF CONTIGUOUS CULTIVATED AND VIRGIN SOILS.

Lab. No.	Soil	pH (water)	pH (KCl)	Avail. P_2O_5 p.p.m.	Replaceable K^+ m.e. per 100 g.	Replaceable Ca^{++} m.e. per 100 g.	Total Carbon per cent.	Organic Matter per cent.	Total Nitrogen per cent.	Moisture Equivalent 1,000 g. per cent.
2090	Virgin	8.0	7.7	249	.89	26	4.5	7.8	.478	34.9
2091	Cultivated	7.9	7.2	225	.54	13	2.1	3.6	.220	26.2

pH was determined with the quinhydrone electrode; available P_2O_5 in extracts with $N/100\ H_2SO_4$.

Table 11.

WOONGARRA SERIES—EFFECT OF INCORPORATION OF ORGANIC MATTER.

—	Total Carbon	Optimum Moisture	Wilting Point	Available Moisture	Moisture Equivalent 1.000 g.
	per cent.	per cent.	per cent.	per cent.	per cent.
Soil + 5 per cent. cane trash ..	2.68	31.85	20.25	11.6	27.63
Soil + 5 per cent. molasses ..	2.67	31.85	20.20	11.65	26.77
Soil + 5 per cent. Poona pea leaves	2.62	31.65	20.05	11.6	26.90
Control	2.19	30.1	20.2	9.9	25.10

normal over a large portion of the area. A reddish colour, varying in intensity from a light reddish brown to the dark red of the volcanic series, is typical of these lands, and the sandy loam texture is a distinguishing feature of the series as a whole. The series extends considerably beyond the boundaries of the sugar-cane producing lands, but this paper is concerned only with such areas as are utilized for sugar production. The red phase, on which cane production has developed, probably owes its colour and its reasonably good base status to volcanic ash which was deposited at the time of the nearby basaltic flows. Though minor colour variants exist within the series, they are associated largely with surface soils only (*see* Fig. 3 for typical profiles), and subsoil strata generally conform to the red phase. For this reason, the series has not been

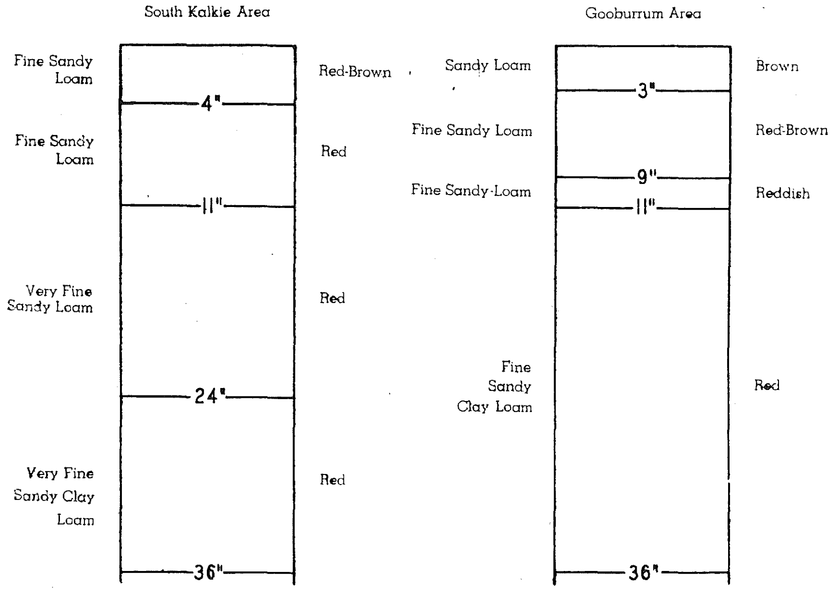

Figure 3
Soil Profiles—Gooburrum Series.

divided into types, as would be the procedure if distinct variants with clearly defined differences existed. Texture variants usually occur where this soil is contiguous with another series; at Bingera, for instance, every gradation exists from the sandy loam to the true volcanic loam, and it is common in the Oakwood—Gooburrum sections for the normal sandy loam phase to grade off on the margins to a sandier type. It is not unusual at Bingera, where the forest sandy loam series is adjacent to the volcanic series, to find layers of volcanic soil underlain and overlain by the sandy loams. This occurrence is obviously the result of decomposition *in situ* of basaltic sills which intruded into the fresh-water deposits. The normal depth of such decomposed sills is about four feet from the surface and they are usually from six inches to two feet in thickness.

One of the characteristics of this series is the exceptionally low phosphate content of the soils. Though the land carries a good growth of hardwood forest in its natural state, the soils have proved, when cleared and planted with sugar cane, to be incapable of producing even one crop without the application of phosphatic fertilizers. According to the system of soil analysis employed by the Bureau, these soils contain, in the natural state, less than 25 parts per million of available P_2O_5, whereas the minimum requirement for satisfactory cane growth is 40 parts per million.

Agriculturally, this series is a valuable one. The soil texture is very satisfactory for sugar-cane growing, being sufficiently light to permit of good drainage and of such a free-working nature as to make good tilth easy of attainment. There is no very pronounced crumb structure, and there is a tendency, after years of intensive cultivation of sugar cane, for the structure to deteriorate. This is particularly noticeable after the use of pulverizing implements such as the rotary hoe, which convert the soil into too fine a state and result in the fine mass "running together" after heavy rain and then setting into a hard surface cake on drying out. Working the soil when it is holding excess moisture similarly results in drying into cement-like clods, and the constant irrigation of these soils appears to be hastening the process of deterioration. This effect is no doubt contributed to by the relatively low divalent base status of the soils and is found to be alleviated by applications of lime. The series is very acid and the majority of farms on this forest type benefit from applications of pulverized limestone or dolomite.

Though the content of replaceable bases and phosphate is rather low, and that of replaceable hydrogen in relation to pH 7.0 rather high, the other qualities of the soil make it suitable for cane growing. The moisture-holding capacity is good, and a high outlay on lime and fertilizer is amply justified for such a high-value crop as sugar cane. The maximum field capacity in this series is from 23 to 25 per cent. and the wilting point is 11 to 13 per cent. The higher amount of available moisture accounts for the fact that during dry periods cane crops on this soil show less distress than those on the adjacent Woongarra soils.

Fusion analyses of two samples of this series are given in Table 12, and mechanical analyses of several selected profiles in Table 13. The series has a well-defined profile with a pronounced organic horizon. In the natural state the surface is generally a dark grey-brown, but on cultivation the organic matter is rapidly oxidized and the reddish colour soon becomes apparent.

Additional analytical data are given in Tables 17-24.

THE BURNETT SERIES

The alluvial series is the third in order of importance in the Bundaberg district. It is restricted to the flats and terraces of the Burnett and Kolan Rivers and their tributaries and to the older flood plain occupied by the Fairymead Plantation. These soils were cultivated very early in the history of the sugar industry, the pioneers being attracted by the luxuriant rain-forest vegetation and the fertile loams, silt loams and clay loams built up by centuries of flood deposits from the rivers along which they were formed. As is the case with all alluvial and deltaic formations, the deposits are extremely variable. The velocity of the flood water governs the particle size of the deposit at any particular point, and consequently variations exist from almost pure sand to silts and heavy clays, with all possible intermediate gradations. Sandy loams with clay loam subsoils occur alongside deep silt deposits, and sandy knobs occur in fields which are otherwise of a clay loam texture. In the absence of a detailed soil survey, which was not considered essential for this soil investigation, the series has been divided into two main types.

Table 12.

GOOBURRUM SERIES—FUSION ANALYSES.

——	Parish Gooburrum		Parish Kalkie	
	per cent.		per cent.	
Moisture	0.87		1.40	
Loss on ignition ..	4.97		9.40	
SiO_2	82.62	Fe_2O_3 3.8	65.23	Fe_2O_3 6.8
R_2O_3	11.41	Mn_3O_4 0.355	23.37	Mn_3O_4 0.116
P_2O_5	0.04	Al_2O_3 7.2	0.05	Al_2O_3 16.2
CaO	0.43		0.39	
MgO	0.03		0.11	
Na_2O	0.05		0.01	
K_2O	0.06		0.02	

Table 13.

GOOBURRUM SERIES—MECHANICAL ANALYSES.

No.	B.1	B.2	B.3	B.4	B.47	B.48	B.49	B.50
Depth (in.)	0—4	4—11	11—24	24—36	0—6	6—12	12—23	23—36
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Coarse sand ..	13.59	12.18	11.22	9.23	21.61	21.22	14.08	17.85
Fine sand ..	23.98	24.26	23.53	19.09	36.83	32.55	31.32	26.00
Silt	9.86	7.36	7.46	4.86	13.04	12.22	10.48	7.18
Clay	45.04	50.93	55.17	65.75	23.70	30.26	41.84	47.82
Moisture	3.23	3.34	2.49	2.89	1.77	1.76	1.88	2.32
pH*	5.95	6.00	6.40	6.90	6.20	6.00	5.35	5.15
R_2O_3	17.92	17.32	18.14	20.74	8.10	10.38	14.62	15.56
Loss on acid treatment	0.65	1.11	2.46	1.07	0.81	1.49	0.36	0.86

* Glass electrode.

Type I includes all those soils of recent origin along the immediate river flats. They are grey soils of silty loam or clay loam texture in the main (*see* Fig. 4 for profiles), with good structure and of exceptionally high fertility. In the sandier gradations mica particles are frequent, and water penetration and drainage vary according to the texture. Topographically, the type is undulating and in places broken by creeks and gullies. In some parts, developments of this type exist within 6 to 10 feet of the normal river level, whereas in others they are elevated some 30 or 40 feet. The major cultivation developments are in the tidal sections of the rivers, but on both the Burnett and Kolan Rivers extensive areas exist above the tidal reaches.

From the cane-growing aspect this type is very important and valuable. It is extremely fertile, has high moisture-holding capacity and a good base status, and is only slightly acid. A good tilth is usually obtainable even in the less tractable phases of the type, but such soils tend to set hard under the influence of wetting and drying. The exceptional qualities of some of these soils were demonstrated subsequent to a record flood in 1942, when several high-class farms were very seriously eroded. A depth of up to four feet of the soil was removed from several acres on one farm. Though it was considered that the exposed subsoil would take some years to be built up into arable farm land, the owner merely graded the new surface, ploughed it up and planted

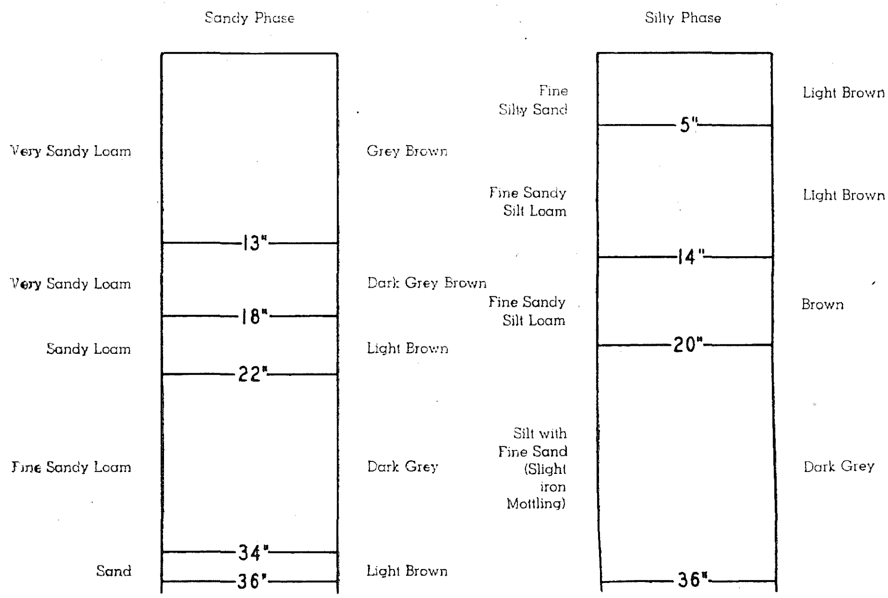

Figure 4
Soil Profiles—Burnett Series, Type I.

it within a few months. The newly-exposed soil yielded equally as well as the remainder of the property with the addition only of nitrogenous fertilizer. Several analyses of the silt and sand deposits left by the 1942 flood were made just after the land had dried out sufficiently for sampling, and if it is assumed that previous flood deposits were of similar fertility it is not remarkable that the lower soil levels were capable of immediate production.

The principal occurrences of Type I are found on both sides of the Kolan River above and below Bucca crossing, at Tegege, Avondale, Booyan and Moorlands, while on the Burnett River the principal producing areas are

Electra, South Bingera, Bonna, Millbank and Rubyanna on the southern bank and at The Cedars, Bingera, Sharon, North Bundaberg and Tantitha on the northern bank. Further extensive areas occur in the Gin Gin and Wallaville districts, which are further up the Burnett River and outside the scope of this investigation.

Type II is restricted to the ancient flood plain, the major portion of which is farmed by the Fairymead Sugar Company. It is quite distinct from Type I, the soils of which are of recent age, and may possibly be a Pleistocene deposit. Type II soils are characterized by a shallow surface soil of grey colour with a clay loam texture (*see* Fig. 5 for profile). This surface soil may be from 6 to 10 inches in depth. It is underlain by a very heavy clay subsoil several feet in depth, which in turn rests on a water-bearing drift sand. The physical condition of Type II is not good, and it is a difficult matter to obtain a tilth suitable

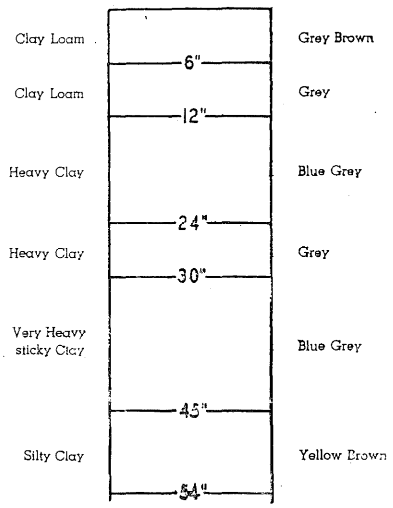

Figure 5
Soil Profile—Burnett Series, Type II.

for sugar-cane planting. The surface clay loam is a sticky, highly deflocculated type which sets hard on drying and tends to break up into large clods if cultivated either too wet or too dry. The structure is poor and the type has not such a good moisture-holding capacity as Type I. The heavy clay substratum makes drainage a major problem, as this soil type is topographically extremely level in the main. Most of the 3,000 acres of this type which are planted with sugar cane are surface drained, feeding into a complex system of open drains which are located along the block headlands so as not to interfere with cultivation. These in turn deliver into a main drain, and the large quantity of drainage water is thus led away from the plantation. The type is among the oldest cultivated of the Bundaberg cane-growing lands, and the 70 years of intensive cultivation on this intractable type have undoubtedly contributed to the poor physical condition of the soil to-day. The condition has been accentuated in recent years by the use of irrigation water containing varying amounts of sodium chloride and having an unfavourable figure of merit. Type II soils are normally quite acid in reaction, but are well supplied with both available phosphate and potash. The acidity is so high on some portions of the area that pulverized limestone at the rate of three to six tons per acre has been applied to raise the pH to a figure more favourable to cane growth. Such treatment also produces some amelioration of the physical condition, and pot tests have indicated that gypsum likewise could be used to improve the texture and structure of the soil.

Fusion and mechanical analyses of soils of the Burnett series are given in Tables 14 and 15, respectively, and other data are contained in Tables 17-24.

KEPNOCK YELLOW SOILS

The yellow soil of the Kepnock area, though unimportant as a type on account of its restricted area, is interesting pedologically. Sharply defined as to boundaries, the Kepnock soil meets the red volcanic Woongarra series Type I on the east, the sandy Gooburrum series on the south, and to the west and north merges into a poor uncultivated podsol under forest cover. It is yellow-brown in colour (*see* Fig. 6 for profile), of considerable depth, well drained, contains no rock, has a level topography, and maintains a hardwood forest vegetation. No underlying rock strata have been encountered when sinking wells to water-bearing drifts below this soil. The boundary between the yellow Kepnock type and the Woongarra red volcanic type is marked by a watercourse, one bank of which is stony and forms the western edge of the basaltic flow. The yellow type is characterized by general poverty in plant nutrients, low replaceable base status, and low pH (*see* Tables 17-24). Moisture-holding capacity is not high, and cropping is successful only if considerable amounts of fertilizer and irrigation water are applied. The effects of liming are not yet clear-cut despite the high degree of acidity of the soil type. A mechanical analysis is given in Table 16.

Table 14.

BURNETT SERIES—FUSION ANALYSES.

——	Type I		Type II	
	per cent.		per cent.	
Moisture	0.52		1.75	
Loss on ignition ..	2.56		7.70	
SiO_2	77.52	Fe_2O_3 3.1	63.38	Fe_2O_3 4.4
R_2O_3	13.82	Mn_3O_4 .056	21.04	Mn_3O_4 .048
P_2O_5	0.08	Al_2O_4 10.3	0.355	TiO_2 4.21
				Al_2O_3 12.3
CaO	1.41		1.66	
MgO	0.51		0.78	
Na_2O	2.04		2.13	
K_2O	1.99		1.68	

Table 15.

BURNETT SERIES—MECHANICAL ANALYSES.*

Type I

No.	B.18	B.19	B.20	B.21
Depth (in.)	0—5	5—14	14—20	20—36
	per cent.	per cent.	per cent.	per cent.
Coarse sand	12.19	21.54	10.32	3.13
Fine sand	47.97	44.95	48.79	40.50
Silt	13.78	12.55	14.66	23.16
Clay	22.36	19.57	22.13	30.46
Moisture	2.89	2.31	2.34	3.37
pH	5.80	5.70	5.80	5.70
R_2O_3	9.74	8.04	8.34	10.56
Loss on acid treatment	0.87	1.28	2.22	2.13

Type II

No.	3892	3893	3894	3895	3896	3897
Depth (in.)	0—6	6—12	12—24	24—30	30—45	45—54
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Coarse sand	0.7	0.7	0.7	0.6	0.4	0.5
Fine sand	6.7	6.1	6.1	7.0	8.6	10.6
Silt	13.7	13.6	13.4	11.7	14.1	22.0
Clay	64.6	64.2	65.0	67.2	64.0	54.3
Moisture	10.7	11.2	12.3	11.8	10.8	9.4
Loss on acid treatment	3.5	3.4	3.5	3.8	7.0	7.7
Loss on ignition	11.9	10.7	8.9	7.8	8.2	7.7

No.	3914	3915	3916	3917	3918
Depth (in.)	0—6	6—12	12—24	24—36	36—48
	per cent.	per cent.	per cent.	per cent.	per cent.
Coarse sand	2.5	2.4	2.7	2.9	2.1
Fine sand	5.8	6.3	5.7	6.8	15.7
Silt	10.1	11.7	10.7	13.9	22.1
Clay	59.8	65.1	66.7	63.7	47.3
Moisture	16.1	10.0	13.8	13.3	10.8
Loss on acid treatment	2.3	1.8	1.4	0.6	0.7
Loss on ignition	15.1	14.3	11.1	10.5	10.3

No.	3902	3903	3904	3905	3906
Depth (in.)	0—6	6—12	12—24	24—27	27—36
	per cent.	per cent.	per cent.	per cent.	per cent.
Coarse sand	1.3	0.8	0.5	1.8	6.9
Fine sand	7.8	7.2	6.6	8.6	14.7
Silt	30.0	30.7	26.2	23.9	20.5
Clay	48.1	48.5	51.9	55.6	51.3
Moisture	8.5	7.8	11.8	7.9	6.1
Loss on acid treatment	1.3	1.4	1.2	1.1	0.7
Loss on ignition	9.9	10.2	8.9	8.6	8.5

* The above analyses were carried out by Mr. Crabtree, formerly of Fairymead Sugar Co., at the Waite Agricultural Research Institute.

REPLACEABLE BASES

An examination of Tables 17-21 demonstrates the differences in base content between the Woongarra series on the one hand and the Gooburrum series and the Kepnock yellow soils on the other. In the latter case the major distribution of total replaceable bases lies between one and eight milliequivalents per cent., whereas in the Woongarra series the values lie principally between 10 and 18 milliequivalents per cent. The soils of the Burnett series, by virtue of their texture variability, do not show any particular concentration in the distribution table, but the number of soils in the 14 to 22 range indicates that in the heavier textured samples the replaceable base status is high.

The values for the individual replaceable bases are shown in Table 18 not only as milliequivalents per cent. of the soil but also as percentages of the total replaceable bases. So far as calcium is concerned, there is little dif-

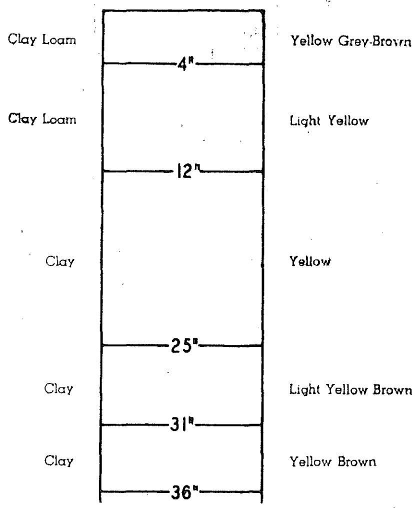

Figure 6.
Soil Profiles—Kepnock Yellow Soil.

ference between the Woongarra, Gooburrum and Burnett series, but the Kepnock yellow soils have a lower percentage. The proportion of magnesium to the other bases in the Kepnock soil is, on the other hand, appreciably higher than in the other types, but the percentage of replaceable calcium and magnesium combined is not significantly different as between the soil types. The proportion of sodium in the replaceable bases does not vary much in the different types, but there is a suggestion that the heavier Type II of the Woongarra series is richer in sodium than is Type I. The Burnett series shows the influence of periodic floodings in its higher proportion of potassium.

The exchangeable hydrogen to pH 7.0 was measured for a number of surface soils in each soil series, and Table 21 shows this figure in relation to total replaceable bases and total carbon. The total exchange capacity to pH 7.0

in the final column suggests a grouping in the Woongarra and Gooburrum series and in the Kepnock yellow soils. The difference in the Burnett series Type I and Type II soils is shown in Table 18; the older Type II soils are much higher in replaceable magnesium and lower in calcium, but there is no appreciable difference between the two types in the potassium and sodium content.

Table 16.

KEPNOCK YELLOW SOIL—MECHANICAL ANALYSES.

No.	B.80	B.81	B.82	B.83	B.84
Depth (in.)	0—4	4—12	12—25	25—31	31—36
	per cent.	per cent.	per cent.	per cent.	per cent.
Coarse sand	9.42	7.95	7.46	6.98	7.52
Fine sand	24.88	25.26	20.86	20.61	17.10
Silt	30.17	31.19	31.04	31.25	24.89
Clay	31.05	33.31	35.57	40.51	48.71
Moisture	2.12	2.02	2.03	1.90	2.16
pH	5.55	5.55	5.40	4.90	4.75
Carbon	1.89	1.65	1.56	1.41	1.29
R_2O_3	11.90	10.86	11.10	12.80	16.61
Loss on acid treatment	1.33	1.07	0.73	0.83	0.78

SOIL TYPES IN RELATION TO PRODUCTION AND IRRIGATION

The productive capacity of the soils of the several series can be compared under either dry farming or irrigated conditions.

Without irrigation, but with adequate fertilizing, the order of productivity is:—

(a) Burnett Series Type I.

(b) Woongarra Series Type II.

(c) Woongarra Series Type I.

(d) Gooburrum Series.

(e) Burnett Series Type II.

(f) Kepnock Yellow Soils.

The Burnett series Type I is given pride of place partly on account of its exceptional fertility but principally because of its good moisture supply in dry periods. Despite the fact that the soils of the Gooburrum series hold more available moisture than those of the Woongarra series and crops growing thereon show less distress in dry periods, the Woongarra soils have a much higher productive capacity under good seasonal conditions. In fact, when rainfall is ample, the growth on the Woongarra series is probably faster than on any other soil type. This is doubtless contributed to by the excellent tilth and crumb structure, first-class aeration, and higher base status.

The order of productivity under irrigation is not clear-cut but is approximately as follows:—

Table 17.

BASES SOLUBLE IN HYDROCHLORIC ACID.

	CaO	MgO	K_2O
	per cent.	per cent.	per cent.
Woongarra Series Type I—			
No. B.108 0—10 in.	.48	.43	.12
B.109 10—18 "	.61	.88	.10
B.110 18—24 "	.51	.58	.08
B.111 24—36 "	.57	.39	.10
Woongarra Series Type II—			
No. B.103 0—3 in.	.64	.62	.09
B.104 3—12 "	.60	.73	.11
B.105 12—27 "	.51	.56	.12
B.106 27—31 "	.49	.43	.07
B.107 31—36 "	.54	.31	.06
Gooburrum Series—			
No. B.1 0—4 in.	.24	.08	.17
B.2 4—11 "	.17	.06	.16
B.3 11—24 "	.26	.12	.15
B.4 24—36 "	.15	.07	.11
No. B.47 0—6 "	.17	.10	.15
B.48 6—12 "	.10	.13	.04
B.49 12—23 "	.06	.13	.04
B.50 23—36 "	.07	.08	.04
Burnett Series—			.30
No. B.18 0—5 in.	.36	.18	.25
B.19 5—14 "	.32	.30	.26
B.20 14—20 "	.36	.31	.30
B.21 20—36 "	.48	.34	
Kepnock Yellow Soil—			04
No. B.80 0—4 in.	.06	.19	.02
B.81 4—12 "	.10	.32	.04
B.82 12—25 "	.05	.37	.03
B.83 25—31 "	.03	.29	.04
B.84 31—36 "	.05	.10	.

Table 18.

REPLACEABLE BASES.

Woongarra Series Type I Surface Soils.

No.	Milliequivalents per cent.					Per cent. of total				†H to pH 7.0 m.e. per cent.
	Ca.	Mg.	Na.	K.	Total	Ca.	Mg.	Na.	K.	
B.74	11.9	2.8	0.60	0.50	15.80	75.3	17.70	3.8	3.2	4.2
B.75	9.7	1.3	0.47	0.17	11.64	83.3	11.2	4.0	1.5	3.6
B.76	12.3	1.1	0.69	0.19	14.28	86.2	7.7	4.8	1.3	3.0
B.77	15.5	2.7	1.10	0.50	19.80	78.3	13.6	5.6	2.5	3.0
B.78	13.8	2.8	0.60	1.00	18.20	75.8	15.4	3.3	5.5	3.0
B.79	10.7	1.1	0.48	0.95	13.23	80.9	8.3	3.6	7.2	1.6

Woongarra Series Type II Surface Soils.

No.	Milliequivalents per cent.					Per cent. of total				†H to pH 7.0 m.e. per cent.
	Ca.	Mg.	Na.	K.	Total	Ca.	Mg.	Na.	K.	
B.97	12.8	2.1	1.14	0.21	16.25	78.8	12.9	7.0	1.3	5.2
B.98	11.3	1.0	1.21	0.15	13.66	82.7	7.3	8.9	1.1	4.1
B.99	2.2	0.3	0.64	0.58	3.72	59.1	8.1	17.2	15.6	3.7
B.100	8.8	0.4	0.67	0.34	10.21	86.2	3.9	6.6	3.3	3.2
B.101	18.6	1.1	0.95	0.13	20.78	89.5	5.3	4.6	0.6	3.2
B.102	5.8	0.5	0.65	0.25	7.20	80.6	6.9	9.0	3.5	3.4

Table 18—*continued*

Gooburrum Series Surface Soils.

No.	Milliequivalents per cent.					Per cent. of total				†H to pH 7.0 m.e. per cent.
	Ca.	Mg.	Na.	K.	Total	Ca.	Mg.	Na.	K.	
B.70 ..	4.3	0.5	0.42	0.23	5.45	78.9	9.2	7.7	4.2	4.1
B.71 ..	5.0	0.4	0.22	0.52	6.09	81.3	6.6	3.6	8.5	2.7
B.85 ..	3.2	0.6	0.29	0.23	4.32	74.1	13.9	6.7	5.3	6.3
B.86 ..	4.3	0.8	0.28	0.56	5.96	72.2	13.4	4.7	9.7	5.4
B.87 ..	2.0	0.5	0.30	0.17	2.97	67.4	16.8	10.1	5.7	5.8
B.88 ..	6.7	0.6	0.22	0.36	7.88	85.0	7.6	2.8	4.6	4.4
B.89 ..	5.5	1.0	0.30	0.26	7.06	77.9	14.2	4.2	3.7	4.4

Burnett Series Type I Surface Soils.

No.	Milliequivalents per cent.					Per cent. of total				†H to pH 7.0 m.e. per cent.
	Ca.	Mg.	Na.	K.	Total	Ca.	Mg.	Na.	K.	
B.64 ..	11.8	1.7	0.92	0.90	15.32	77.0	11.1	6.0	5.9	2.3
B.65 ..	11.7	1.5	0.60	1.70	15.50	75.4	9.7	3.9	11.0	2.9
B.68 ..	4.4	1.5	0.47	1.73	8.10	54.3	18.5	5.8	21.4	1.9
B.69 ..	8.4	1.0	0.72	1.20	11.32	74.2	8.8	6.4	10.6	2.4

Burnett Series Type II Surface Soils.

No.	Milliequivalents per cent.					Per cent. of total				†H to pH 7.0 m.e. per cent.
	Ca.	Mg.	Na.	K.	Total	Ca.	Mg.	Na.	K.	
——	6.2	5.0	0.33	1.02	12.55	—	—	—	—	4.7
——	5.8	4.8	0.44	0.92	11.96	—	—	—	—	5.1
——	6.7	5.3	0.28	0.87	13.15	—	—	—	—	4.1
——	5.4	4.5	0.51	1.12	11.53	—	—	—	—	4.6

Kepnock Yellow Soil Surface Soils.

No.	Milliequivalents per cent.					Per cent. of total				†H to pH 7.0 m.e. per cent.
	Ca.	Mg.	Na.	K.	Total	Ca.	Mg.	Na.	K.	
B.55 ..	1.6	0.7	0.30	0.10	2.70	59.3	25.9	11.1	3.7	5.8
B.56 ..	1.3	0.6	0.20	0.10	2.20	59.1	27.3	9.1	4.5	6.5
B.57 ..	3.8	1.5	0.30	0.20	5.80	65.5	25.9	5.2	3.4	5.5
B.51 ..	1.9	0.1	0.46	0.28	2.74	69.3	3.7	16.8	10.2	7.4
B.58 ..	5.4	0.6	0.46	0.95	7.41	72.9	8.1	6.2	12.8	6.1
B.59 ..	3.8	0.5	0.44	0.52	5.26	72.2	9.5	8.4	9.9	4.0

† Determined by p. nitro-phenol method.

Table 19.

TOTAL REPLACEABLE BASES (M.E. PER CENT.)—DISTRIBUTION TABLE.

Soil Series	0—2	2—4	4—6	6—8	8—10	10—12	12—14	14—16	16—18	18—20	20—22	22—24
Woongarra Series	—	—	—	4	1	6	9	15	7	2	1	—
Kepnock Yellow Soils	6	2	—	—	—	—	—	—	—	—	—	—
Gooburrum Series	23	34	32	31	11	2	1	—	—	—	—	—
Burnett Series	2	2	2	3	4	2	—	3	4	2	4	1
Total	31	38	34	38	16	10	10	18	11	4	5	1

Table 20.

pH OF SURFACE SOILS—DISTRIBUTION TABLE.

	4–4.5	4.5–5	5–5.5	5.5–6.0	6.0–6.5	6.5–7.0	7.0–7.5	7.5–8.0
Woongarra Series ..	—	—	1	8	27	3	3	4
Kepnock Yellow Soils ..	2	6	—	—	—	—	—	—
Gooburrum Series ..	3	13	59	65	9	3	—	—
Burnett Series	—	1	4	20	19	9	—	—
Total	5	20	64	93	55	15	3	4

Table 21.

TOTAL CARBON AND TOTAL EXCHANGE CAPACITY TO PH 7.0.

Soil Type	No.	* Total Carbon per cent.	Replac. Bases m.e. per cent.	† Lime Require. (H to pH 7.0) m.e. per cent.	Total Exchange Capacity m.e. per cent.
Kepnock	B.55	1.59	2.7	5.8	8.5
"	B.56	1.74	2.2	6.5	8.7
"	B.57	1.98	5.8	5.5	11.3
"	B.51	2.03	2.8	7.4	10.2
"	B.58	2.76	7.5	6.1	13.6
"	B.59	1.61	5.2	4.0	9.2
Burnett Series —					
Type I	B.64	1.97	15.3	2.3	17.6
"	B.65	1.73	15.5	2.9	18.4
"	B.68	0.81	7.9	1.9	9.8
"	B.69	1.53	11.3	2.4	13.7
Burnett Series —					
Type II ..	—	1.84	12.6	4.7	17.3
"	—	1.62	12.0	5.1	17.1
"	—	1.71	13.2	4.1	17.3
"	—	1.23	11.5	4.6	16.1
Gooburrum Series	B.85	1.67	4.3	6.3	10.6
"	B.86	1.86	6.0	5.4	11.4
"	B.87	1.37	3.0	5.8	8.8
"	B.88	1.59	7.9	4.4	12.3
"	B.89	1.94	7.1	4.4	11.5
Woongarra Series	B.74	2.16	15.8	4.2	20.0
"	B.75	1.80	11.7	3.6	15.3
"	B.76	2.10	14.3	3.0	17.3
"	B.77	2.06	19.8	3.0	22.8
"	B.78	2.28	18.2	3.0	21.2
"	B.79	1.43	13.3	1.6	14.9

* Organic carbon, Walkley and Black values.

† Determined by p. nitro-phenol method.

Table 22.

REPLACEABLE HYDROGEN IN SURFACE SOILS (M.E. PER CENT.)—DISTRIBUTION TABLE.

	1.5–2.5	2.5–3.5	3.5–4.5	4.5–5.5	5.5–6.5	6.5–7.5	7.5
Kepnock Yellow Soils ..	—	—	1	2	14	1	1
Burnett Series	14	1	—	—	—	—	—
Gooburrum Series ..	—	1	12	8	1	—	—
Woongarra Series	1	15	7	1	—	—	—
Total	15	17	20	11	15	1	1

Table 23.

AVAILABLE P_2O_5 IN SURFACE SOILS (P.P.M.)—DISTRIBUTION TABLE.

Soil Series	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550
Woongarra Series	—	20	18	4	1	1	3	—	1	—	—
Gooburrum Series	171	87	16	8	2	—	—	—	—	—	—
Kepnock Yellow Soils ..	4	5	—	—	—	—	—	—	—	—	—
Burnett Series	1	3	3	7	11	9	9	1	1	1	2
Total	176	115	37	19	14	10	12	1	2	1	2

Table 24.

AVAILABLE K_2O IN SURFACE SOILS (M.E. per cent.)—DISTRIBUTION TABLE.

Soil Series	0–.1	.1–.2	.2–.3	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1
Woongarra Series	8	24	10	7	3	2	—	—	—	—	—
Gooburrum Series	141	114	19	6	—	—	—	—	—	—	—
Kepnock Yellow Soils	7	2	—	—	—	—	—	—	—	—	—
Burnett Series	3	5	12	11	4	6	7	2	1	—	2
Total	159	145	41	24	7	8	7	2	1	—	2

(a) Woongarra Series Type I.
(b) Gooburrum Series.
(c) Burnett Series Type I.
(d) Kepnock Yellow Soils.
(e) Burnett Series Type II.

The development of irrigation has been most marked on the Gooburrum series soils, which are underlain by extensive water-bearing drift strata. Since the early 1930's the number of irrigation plants has steadily increased and has by no means reached its peak. The Woongarra series probably occupies second place in order of acreage irrigated, but development on this type has slowed down appreciably owing to the cost of reaching the water supplies through thick basalt layers and to the fact that some tapped supplies are not of a quality suitable for irrigation. The soils of the Burnett series Type II are next in order of importance, as a very large area is irrigated from subterranean water supplies by the Fairymead Sugar Company. Irrigation is extending on the Kepnock yellow soils, but the area is not economically important. Because of unsuitable topography, very little irrigation is practised on Type I of the Burnett series, so it has not been possible to gauge on a wide scale the effects of this practice. On farms that are irrigated on this type, several difficulties have been experienced on the heavier phases, the tilth of the soil being adversely affected and water penetration showing a tendency to fall off with time. The crop increases with irrigation have not been as spectacular on this type as on soils of other series.

No irrigation is practised on the small areas of Woongarra series Type II.

RAINFALL PENETRATION

Percolation tests on the Woongarra series were inaugurated in an attempt to measure the depth to which a given fall of rain would raise the soil to maximum field capacity. It was found that the driving of percolation cylinders altered the natural soil structure and allowed faster penetration around the cylinder periphery, and accordingly it was decided to measure percolation during natural rainfall.

Moisture determinations were carried out on every 3-inch section of the borings to a depth of 24 inches and on every further 6-inch section to a maximum depth of 48 inches. The moisture determinations, together with careful observations during boring, enabled the depth of penetration to be calculated fairly accurately to one or two inches. All borings were made in the middle of the interspace so as to be at a regular distance from the plants.

Table 25 shows rainfall data for the period of the measurements and also the moisture figures obtained.

It will be noted that 204 points of rain on April 2-3 penetrated the soil to between the 15- and 18-inch levels and the extra 466 points on April 4

Table 25.

WOONGARRA SERIES TYPE—RAINFALL PENETRATION DATA.

Date	Rainfall in.	Depth in.	Date of moisture determinations										
			Mar. 28	Apr. 3	Apr. 5	Apr. 7	Apr. 10	Apr. 12	Apr. 19	Apr. 21	Apr. 24	Apr. 26	Apr. 28
			per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
April 2	1.06	0—3	20.3	30.2	32.4	27.4	24.2	20.0	19.8	19.4	14.3	15.1	18.3
,, 3	0.98	3—6	19.5	31.2	31.9	29.4	27.3	24.6	21.0	23.5	21.0	22.8	20.0
,, 4	4.66	6—9	20.4	31.8	31.7	30.9	27.7	26.3	25.1	24.3	23.5	23.8	23.0
,, 5	0.16	9—12	20.7	32.1	32.0	31.1	28.4	26.8	26.2	25.8	23.5	24.6	23.1
,, 16	0.05	12—15	23.1	29.9	31.4	31.1	27.4	28.6	28.1	27.2	26.0	25.1	25.6
,, 17	0.19	15—18	23.9	25.6	30.3	29.6	28.0	27.6	27.8	28.4	27.3	26.2	27.3
,, 26	0.06	18—21	24.2	24.1	30.1	30.1	28.0	27.6	28.1	28.1	26.2	26.3	26.5
		21—24	24.3	23.8	29.7	28.6	28.1	27.4	28.0	28.1	27.6	26.6	26.7
		24—30	23.3	23.4	29.9	29.8	28.0	27.6	27.9	28.1	26.5	26.0	26.6
		30—36	23.6	23.5	29.6	29.1	28.0	27.4	28.2	28.3	26.6	26.2	26.2
		36—42	24.5	23.4	29.9	29.7	27.0	27.4	28.0	28.9	27.4	26.6	26.0
		42—48	25.3	23.4	30.6	30.7	29.3	28.8	28.6	27.0	27.0	26.8	25.9

raised the whole 48-inch depth of soil to optimum moisture content of approximately 30.8 per cent. The average moisture content of the four feet of soil on March 28 before the rain was 22.8 per cent., whereas on April 5 the average was 30.8 per cent., the increase being equivalent to 4.25 acre inches. Since 5.70 inches had fallen in the intervening period the deficiency to be accounted for is 1.45 acre inches. This could have been in part taken up by cane roots, lost by drainage below the 48-inch level, lost by evaporation from the soil surface, and lost by run-off during rainfall. The figures indicate that if this soil type contains 20 per cent. moisture—which is the stage at which moisture available to the plant is depleted—it may be raised to maximum field capacity of approximately 30 per cent. moisture by rainfall of 1.33 inches per foot depth of soil.

FIELD TRIALS AND THE FERTILITY STATUS OF SOIL TYPES

From the year 1901 a very large number of Bundaberg cane-growing soils were submitted to analysis but there was little detailed information available regarding the responses of the various soil series and types to the separate fertilizer ingredients. The method of complete agricultural analysis by hydrochloric acid digestion gave a measure of total nutrients in the soil but no indication of availability, while the citric acid method for estimating available nutrients did not give reliable data. In particular was this latter method quite inaccurate on the red basaltic loams, the manganese dioxide in which oxidized the citric acid. During 1929 the relatively new method of field experimentation was used for the first time in the sugar-producing areas and within a short time Latin square fertility trials were scattered throughout the sugar districts on a variety of soil types. Immediate results were obtained and the application of statistical methods of analysing the figures enabled the significance of these results to be measured. The qualitative trials were followed by quantitative Latin squares and these in turn gave way later to factorial type trials.

However, in a sugar industry the size of Queensland's, where 8,000 individual farms are located in settlements along a thousand miles of coastline from south of Brisbane to north of Cairns and where a large number of soil types exist, some method of soil quality evaluation other than the field trial had to be found. It was required to develop some form of soil analysis which would give a reasonably accurate measure of the available soil nutrients. As an initial step in this investigation a certain analytical procedure was adopted tentatively for the estimation of available phosphate, available potash and total exchangeable bases. The details of these methods and of the correlations obtained between soil fertility measured by this procedure and responses to fertilizers in controlled field experiments have been fully discussed by Kerr and von Stieglitz (1938). The various Bundaberg soil types were utilized, as were those of all other areas, in the laying down and harvesting of these fertilizer trials. The first 10 years of field experiments clarified very decisively the qualitative plant food deficiencies and responses and gave a fund of information on quantitative requirements of the various types under certain conditions. The failure to define more accurately the quantitative fertilizer requirements of a crop was related to seasonal variation, the response to higher levels of fertilizer being obtained only in above-average seasons or under irrigated conditions, while responses even at lower fertilizer levels may not be obtained in drought years when moisture becomes the limiting factor in crop production.

Table 26.

SUMMARY OF RESPONSES TO PHOSPHATE AND POTASH.

Soil classification		Response to P. Tons per acre	Response to K. Tons per acre
Woongarra Series	Plant	0.3	2.5
	Ratoon	1.3	4.5
Gooburrum Series	Plant	2.5	0.9
	Ratoon	5.9	3.4
Burnett Series	Plant	0.9	1.6
	Ratoon	—	—

A summary of field trials carried out during the past 19 years is given in Table 26, where the responses to P or K or both are indicated.

Responses to nitrogen have not been included in the table, as all Queensland cane-producing soils respond to the application of nitrogenous fertilizers. Bundaberg soils irrespective of series react positively to sulphate of ammonia applications on all ratoon crops and on such plant crops as are not preceded by the ploughing-in of a leguminous crop. Periodic floods, which submerge more or less of the Burnett series, contribute in no small degree to the high plant food status of these soils and it is not usual to obtain payable returns from applications of phosphatic and potassic fertilizers. This applies to the extensive Fairymead plantation, which is located in the main on Type II of the Burnett series.

In the Woongarra series, phosphatic fertilizers give no significant returns. Although this is a volcanic loam with high iron and alumina content—a type in which phosphate fixation is often reported to be a serious problem—there is no evidence that a phosphate problem exists in the Woongarra series. Though the soils have been intensively farmed for some 70 years, the phosphate supply is apparently still adequate for normal crop production and is not a limiting factor in growth. Many plantations, including one which is irrigated and an outstanding example of high productivity, never use phosphatic fertilizers. The formation of insoluble phosphates of iron and aluminium as a result of the application of water-soluble phosphates to the soil is a natural reaction. It must be concluded, therefore, that the matter of phosphate fixation is not of economic significance on these soils and that the colloidal phosphates formed are readily available sources of plant food for sugar cane.

IRRIGATION

As mentioned earlier in this paper, the 1932 drought was followed by an awakening by sugar-cane producers to the necessity of irrigation as an insurance against dry periods. The first development of importance was the construction by Messrs. Gibson and Howes of a weir across the Burnett River near the Bingera Mill to impound a water supply for the large-scale irrigation of their 1,200-acre plantation. This very successful venture was practically concurrent with the Fairymead Sugar Company's installation of an irrigation system of a different type. The Fairymead plantation, though also situated near to the Burnett River, is within tidal influence and it was decided in this case to exploit the subterranean water resources of the plantation. This Type II soil of the Burnett series is underlain by drift sand and gravel deposits which are fresh-water bearing, and capable of delivering very large quantities of water suitable for irrigation. On the eastern margin of the plantation, where the Type II soils merge into Type I soils of the same series, water of increasing salinity is encountered, as the Type I soils form the recent flood plains and alluvial deposits of the Burnett River in its tidal reaches. This experience is almost uniform on Type I soils where the river is tidal. In some cases good quality waters are located at shallow depths, but in general the deeper drift strata are more or less saline and give rise to waters unsuitable for irrigation of crops.

The supplies of suitable irrigation waters in the Bundaberg district are very closely allied to the soil type below which they occur (King, 1948). The largest development of irrigation has taken place on the Gooburrum soil series. These soils, developed from freshwater sediments, are all underlain by extensive sand and gravel drift beds carrying large quantities of excellent quality water. The Woongarra series has not been extensively investigated for irrigation, though several large plants and a number of smaller ones have been installed. Irrigation installations here are very costly owing to the depth of rock to be penetrated, but drift sand of varying quality is usually located. Briefly, it may be stated that excellent quality waters in large quantity underlie the Gooburrum series and the Kepnock yellow soils; the Woongarra series subterranean waters are of variable quality and quantity; the Burnett series Type I soils overlie saline waters where the river is tidal; and the Type II soils cover extensive water-bearing strata of fair to good quality.

SOIL AMENDMENTS

The use of molasses as a soil amendment is peculiar to the sugar industry. This is due to the fact that its fertilizing properties were first appreciated in this industry and also to the high transportation cost involved in moving the product any considerable distance from a sugar mill. Molasses is a by-product of raw sugar manufacture and contains approximately 80 per cent. of total solids. The major portion of this is comprised of various sugars which are not recoverable in the manufacturing process. The average plant food composition of molasses, obtained from a large number of analyses, is as follows:—

Nitrogen 0.9 per cent.
P_2O_5 0.3 per cent.
Potash (K_2O) 3.0 per cent.

It is not practicable to apply to the soil less than 5 tons per acre of this viscous material and an application of this magnitude contains the equivalent of approximately:—

500 lb. sulphate of ammonia
168 lb. superphosphate
560 lb. muriate of potash.

So far as is known, the first large-scale use of molasses as a fertilizer on sugar cane was at Bingera Plantation in 1922, and it has been more or less standard practice on that property since that time. Trials were carried out

Table 27.

Results of Molasses Application Trial.

	Plant Cane			First Ratoon		
	4 tons	6 tons	8 tons	4 tons	6 tons	8 tons
Cane (tons per acre)	12.8	13.4	13.3	20.9	23.7	24.6
C.C.S. of cane (per cent.)	15.4	15.2	15.5	16.3	16.2	16.6
C.C.S. (tons per acre)	1.97	2.04	2.07	3.40	3.84	4.08

Table 28.

Results of Molasses and Fertilizer Equivalent Application Trial.

Treatment	Cane per acre	C.C.S. of cane
	tons	per cent.
Control	16.1	16.1
10 tons molasses per acre	22.7	15.9
5 tons molasses plus fertilizer equivalent of 5 tons molasses per acre	24.9*	16.3
Fertilizer equivalent of 10 tons molasses per acre ..	22.9	16.0

* Significantly exceeds all other treatments.

on the Woongarra series Type I soils in the Bundaberg area owing to their potash deficiency. The first trial measured the response to a 10-ton application of molasses. This resulted in an increase of 32 tons per acre over two crops, or 3.2 tons of cane per ton of molasses applied. This was followed by a quantitative trial designed to define more accurately the precise amount of molasses which would be the most economic application. Dressings of four, six and eight tons per acre were applied to the soil prior to planting and no other fertilizer was used on either plant or ratoon crop. A drought was experienced in the first year and moisture was the limiting factor in crop production. However, an average season for the ratoon crop gave an indication that a 6-ton application would supply the needs of crops of the magnitude grown. The details are shown in Table 27.

In trials subsequently carried out, using 10 tons of molasses as one treatment and half the molasses tonnage plus the fertilizer equivalent of the other half as another treatment, it was demonstrated that the latter was superior to molasses alone. The results of one such experiment are given in Table 28.

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