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SOILS OF THE KINGSTHORPE FIELD STATION

EASTERN DARLING DOWNS

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

The 16 ha Kingsthorpe Field Station is located 6 km south-west of Kingsthorpe township on a very gently inclined alluvial fan/pediment derived mainly from basalt.

Soil profiles were described and bulked surface soils sampled on a 50 x 100 m grid across the Field Station. Soils were mapped at 1:25 000 scale and three representative soil profiles were taken for analysis.

Only one soil type, the Craigmore clay was found to be present, including an eroded phase and a gypseous subsoil variant.

Soils were classified as black earths (Stace *et al.* 1968), as an Ug 5.15 principal profile form (Northcote 1979), as an Udic Pellustert (Soil Survey Staff 1975) and as a Pellic Vertisol (FAO 1979).

Soil chemical and physical analyses reveal that the block in general has adequate to high levels of all available nutrients, except nitrogen. One corner of the station has low DTPA zinc while organic carbon levels are low when compared to other available data for a similar soil. Clay percentages are high at 70 to 80% and the clay mineral present is probably smectite. Plant available water capacity is high while the soils are both non-saline and non-sodic in the upper 0.8 m.

A compacted plough pan occurs just below the surface across the entire Field Station. The whole area should also respond to nitrogen fertiliser and in some places to zinc. Phosphorus, sulphur and trace elements (eg. copper and manganese) occur in adequate amounts throughout. Apart from zinc (and deep subsoil features) there was no major difference observed between bays on the Field Station. Differences in subsoil features below one metre are unlikely to affect plant growth.

INTRODUCTION

This soil survey was carried out following a request from Research Stations Branch. Some workers had observed differences between bays on the Kingsthorpe Field Station (hereafter called the field station) and a 1:25 000 soil survey was undertaken to assess soil variability.

The field station with a total area of 12 ha is located some 6 km south-west of Kingsthorpe on the Darling Downs, south-east Queensland (Figure 1).

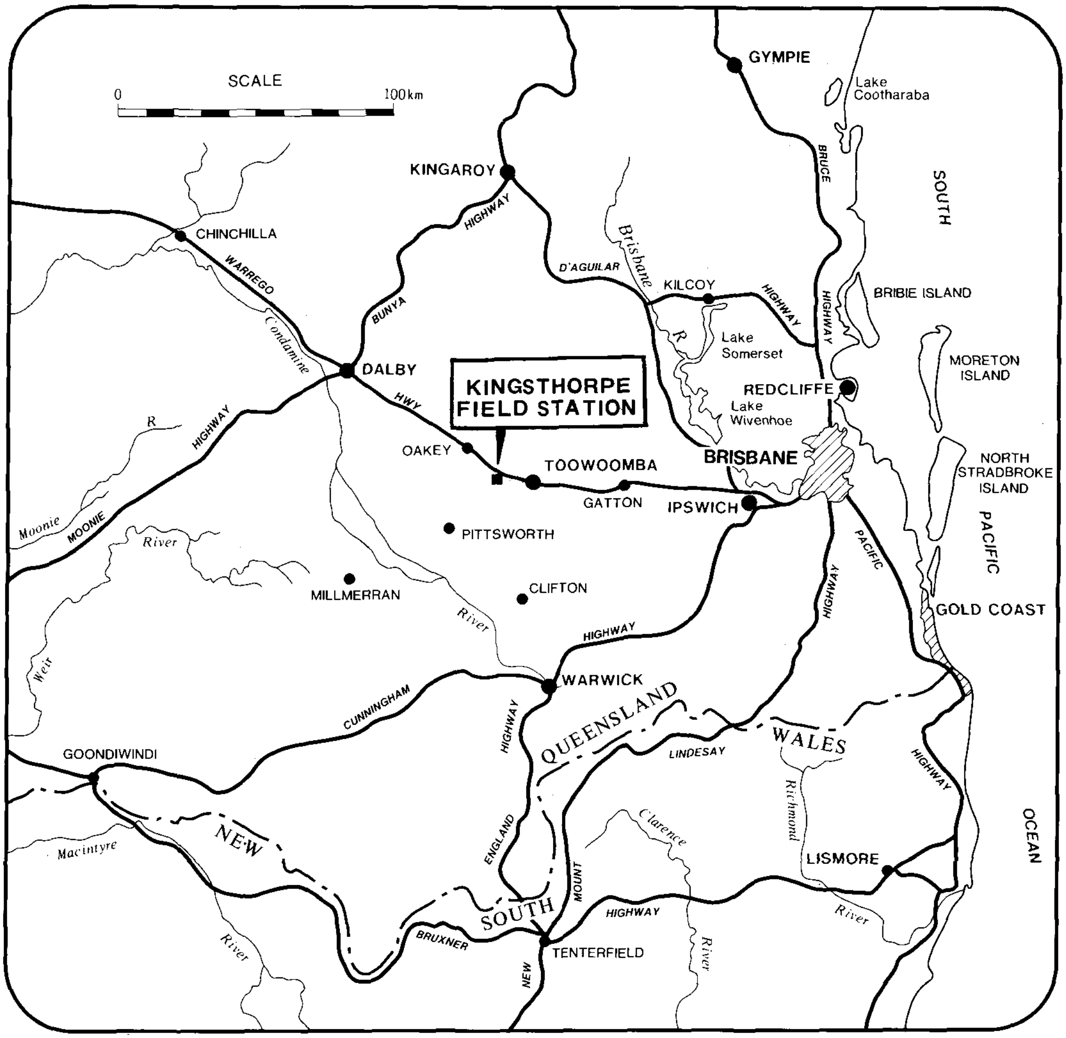

Figure 1. Locality plan

PHYSICAL RESOURCES

Climate

Climatic data for nearby Gowrie Junction and Dalby are summarised in Table 1. Rainfall is summer-dominant with 67% falling between October and March. There is a secondary peak in the winter months of June and July.

Summer temperatures average 31 to 32°C maxima and high temperatures in excess of 35°C may be experienced from October to March. Average winter temperatures drop to 4 to 6°C minima with an average of 29 frost days occurring from May to September.

Table 1. Climatic data summary (Australian Bureau of Meteorology)

Climatic factor	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Mean rainfall (mm) (Gowrie Junction)	94	79	65	38	34	46	41	29	35	59	68	91	679
Mean daily pan evaporation (mm) (Dalby)	7.7	6.9	6.8	5.3	3.8	2.7	2.7	3.3	4.7	5.5	7.2	7.9	
Mean daily maximum temperature (°C) (Dalby)	31.8	31.1	29.6	26.6	22.6	19.4	18.8	20.7	24.1	27.5	30.2	31.6	
Mean daily minimum temperature (°C) (Dalby)	18.4	18.2	16.4	12.2	8.1	5.5	4.1	5.2	8.4	12.5	15.6	15.6	
Mean no. of days over 35°C (Dalby)	6	4	1	0	0	0	0	0	0	1	3	5	
Mean no. of frost days (Dalby)	0	0	0	0	2	6	12	7	2	0	0	0	

Geology and landform

The field station is situated on a very gently inclined alluvial fan/pediment derived from Main Range Volcanics (Cranfield *et al.* 1976) which consist mainly of olivine basalt. On this landscape, the alluvial fan of a local drainage line gradually merges with the adjacent pediment and the geomorphic origin of the field station could not be clearly distinguished.

The slope on the field station averages 1.5% and soil conservation works have been implemented to control runoff. Despite this, erosion gullies were evident in some bays and the more deeply eroded areas are shown on the soil map as an eroded phase.

LAND RESOURCES SURVEY METHOD

Soils on the field station were described, classified and sampled at 28 sites located on a 50 m x 100 m grid. Soils were mapped at a scale of 1:2 500 using the soil series names of Thompson and Beckmann (1959). Profile data were recorded in code (McDonald *et al.* 1984) and stored on hard disk at the Land Resources Branch, Agricultural Research Laboratories, Indooroopilly.

A bulked 0-0.1 m surface sample was collected from each grid site for fertility assessment. In addition, three representative profiles were sampled for analysis. The location of representative profiles (S1, S2 and S3) are shown on the soil map. Depths sampled and analyses carried out are listed in Table 2. Methods of soil analysis are described in Bruce and Rayment (1982).

Plant available water capacity (PAWC) of the three soil profiles analysed was estimated by the regression equations of Shaw and Yule (1978) using their -15 bar method as recommended by Ahern (1988).

SOILS - MORPHOLOGY AND CLASSIFICATION

Morphology

Only one soil type (the Craigmore clay) was identified on the field station, although an eroded depression phase and a gypseous variant were also mapped. The Craigmore clay is a black earth with clayey soil texture, dark upper horizons over brown to red-brown calcareous subsoils. The boundary between the dark upper horizon and the brown to red-brown horizon below varies from gradual to clear and dark tongues of clay can be seen intruding into the brown to red-brown horizon. These are probably cracks which have been infilled with dark clay from above.

Table 2. Analytical determinations of sampled profiles

Depth	Analytical determinations
Bulked 0-0.1 m	pH; electrical conductivity (E.C.); chloride (Cl); acid extractable phosphorus (P); bicarbonate extractable (bicarb P); DTPA Copper (Cu), Zinc (Zn), Manganese (Mn) and Iron (Fe); organic carbon (C); total nitrogen (N); extractable potassium (K); sulphate-sulphur (SO_4-S).
Profile 0-0.1 m	pH, E.C.; Cl; exchangeable cations*; cation exchange capacity (C.E.C.)*; total P; total K; total Sulphur (S); total N; organic C; % air dry moisture (A.D.M.); particle size analysis (P.S.A.); -15 bar moisture; dispersion ratio; sulphate sulphur (SO_4-S).
Profile 0.2-0.3 m 0.5-0.6 m, 0.8-0.9 m	As for profile 0-0.1 m plus bicarb P.
Profile 1.1-1.2 m	As for profile 0-0.1 m minus -15 bar moisture and dispersion ratio.
Profile 1.4-1.5 m	pH, E.C.; Cl; organic C; total N; bicarb P; SO_4-S.

* Alcoholic 1M NH_4Cl extraction

Distinguishing attributes of the forms of Craigmore found on the field station are described in Table 3 and a detailed description is provided in Appendix I. A notable feature of these soils is the presence of a plough pan 0.03 to 0.07 m below the self-mulching surface.

The variable depth to calcareous brown or red-brown clay probably relates to former gilgai microrelief, but there is no clear evidence to support this contention. In terms of soil morphology, the entire field station is considered to have low variability with minimal differences between soil bays.

The presence of gypsum in the profile of the Craigmore-gypseous variant is an unusual feature in this region. It suggests that the soil is not totally derived from olivine basalt (a low sulphur rock) and that parent material probably includes the Walloon Coal Measures. However, no exposures of Walloon Coal Measures have been mapped in the catchment area above the field station.

Beckmann and Thompson (1959) examined this area in detail (Mt Gowrie area) and mapped the field station as a Waco clay. The soils of the field station do not clearly fit the typical Waco clay in having a medium self-mulching surface (3-10 mm surface granules), brown to red-brown subsoils, and in some cases subsoil gypsum. In addition, their uncertain alluvial-colluvial origin indicates that they could belong to another soil type, possibly the Craigmore clay. The typical Craigmore clay has a coarser self-mulching surface compared to Waco and this was the basis on which the soil was identified.

Table 3. Major distinguishing attributes of soils

Soil series	Major distinguishing attributes	Great soil group	PPF
Craigmore* (Cm)	Strongly self-mulching 3-10 mm granular surface, dark medium to heavy clay to 0.45 to 0.9 m over calcareous brown to red-brown light clay to heavy clay.	Black earth	Ug5.15
Craigmore - eroded depression phase (CmEp)	As above dark clay extends to 0.4 to 0.55 m.	Black earth	Ug5.15
Craigmore - gypseous variant (CmGv)	As above but dark clay extends to 0.9 to 1.35 m over gypseous and calcareous red-brown clay.	Black earth	Ug5.15

Classification

Craigmore is classified as belonging to the black earth great soil group (Stace *et al.* 1968), with a Principal Profile Form of Ug5.15.

In Soil Taxonomy (Soil Survey Staff, 1975) it is classified as an Udic Pellustert and in FAO-UNESCO (1974) as a Pellic Vertisol.

Soil variability

Variability in morphological expression of the Craigmore clay on the Field Station is presented in Appendix I. The upper profile of these soils is consistently dark medium to medium-heavy clay of similar structure. The depth to the brown or red-brown calcareous subsoil varies between 0.45 to 0.90 m over most of the field station but its effect on plant growth is not clear. Crop growth patterns associated with gilgai mounds and depressions and the variable depths of their subsoils usually appear for about 10 years after initial cultivation but then mostly disappear (Thompson and Beckmann 1982).

SOILS - CHEMICAL AND PHYSICAL PROPERTIES

Results of laboratory analysis are presented in Appendix II and data for three profiles are compared in Tables 4 and 5. The results of the bulk surface samples collected by grid sampling are presented in Figures 2, 3, 4 and 5.

Fertility

The block has a history of fertilisation and the results reported give the fertility status as at September 1986. The results for the grid sampling shown in Figures 2, 3, 4 and 5 show fertility to be high over the majority of the field station. Trends across the block are shown for pH, DTPA-Zn, organic carbon (OC) and bicarbonate phosphorus (bic-P) as contours on Figures 2, 3, 4 and 5 respectively.

Phosphorus (bic-P) levels are high and no response would be expected to applied fertiliser for values greater than 30 ppm (Rayment, 1983). Similarly, exchangeable potassium would not be expected to be deficient with values well above the critical level of 0.4 meq/100 g (Young, 1976).

Values of copper, manganese and iron indicate that these trace elements are in adequate supply. Figure 2 however, shows some evidence of zinc deficiency. For one site, a DTPA-Zn value of 0.3 ppm was recorded for a soil of pH 7.7, indicating that it is deficient in zinc (Rayment and Bruce, 1982).

Surface OC levels are low for most sites (maximum value 1.6%). These levels are lower than the range (2.5 to 3.7%) recorded by Reeve *et al.* (1960) for Craigmore black earths. Stubble retention or green manuring are methods of increasing levels of OC. C/N ratios range from 10 to 13 (Table 5) and are typical values for black earths in Queensland.

White *et al.* (1981) and Rayment (1983) found sulphate sulphur (SO_4-S) contents in the profile of 3.5 ppm (0-0.8 m) and 6 ppm (0-0.1 m) respectively, indicated sufficiency. SO_4-S contents for these soils exceed critical levels established by White *et al.* (1981) and Rayment (1983) indicating no deficiency exists for these soils at present.

Table 4. Analytical data for selected soil profiles.

Soil Profile Class/Depth in metres	pH 1:5 H_2O	E.C. 1:5 dS/m	Water Sol. Cl % % (A.D)++	Exchangeable Cations$ Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CEC m. equiv/100 g (A.D)	ESP	Total P %	Total K % % (A.D)	Total S %	PO_4=Ext.S mg/kg (A.D)++	Particle Size Analyses % (O.D)+ Coarse	Fine	Silt	Clay	Air Dry Moisture %	Ratios R_1	CEC/clay
Site (S1)																				
Bulk 0-0.1	7.5	0.14	0.003															10.2		
0-0.1	7.6	0.10	0.002	31	28	1.1	1.6	71	1.6	0.08	0.80	0.02	5	1	13	17	71	9.1	0.48	1.1
0.1-0.2	7.7	0.12	0.005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1	-	-
0.2-0.3	7.7	0.14	0.009	34	26	1.8	.89	71	2.5	0.05	0.75	0.02	15	<1	15	18	71	10.4	0.56	1.1
0.5-0.6	7.7	0.23	0.024	32	27	2.6	.58	71	3.7	0.04	0.69	0.02	15	1	12	17	74	10.5	0.55	1.1
0.8-0.9	8.0	0.28	0.022	30	28	3.3	.50	70	4.7	0.04	0.70	0.02	21	1	12	17	74	9.9	0.60	1.0
1.1-1.2	8.0	1.1	0.020	32	26	3.7	.85	67	5.5	0.07	0.81	0.14	725	1	11	17	76	8.8	0.57	1.0
1.2-1.3	7.7	3.0	0.019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.4-1.5	8.4	0.87	0.018	27	27	4.5	1.0	60	7.5	0.09	0.77	0.09	475	2	11	13	77	9.6	0.55	0.86
Site (S2)																				
Bulk 0-0.1																				
0-0.1	7.6	0.13	0.002	31	26	1.4	1.3	70	2.0	0.06	0.72	0.02	7	1	13	20	71	9.9	0.48	1.1
0.2-0.3	8.0	0.19	0.006	31	27	2.6	.52	72	3.6	0.05	0.68	0.02	11	1	12	19	72	12.1	0.57	1.1
0.5-0.6	8.6	0.32	0.011	29	26	3.9	.61	71	5.5	0.05	0.75	0.03	24	1	11	12	72	11.5	0.65	1.1
0.8-0.9	8.8	0.37	0.011	25	27	4.7	.71	60	7.8	0.09	0.89	0.03	42	1	12	17	75	12.3	0.57	0.9
1.1-1.2	8.7	0.54	0.024	26	29	5.6	1.0	62	9.0	0.09	0.87	0.03	150	1	10	15	79	12.0	0.51	0.87
1.4-1.5	8.6	0.77	0.059	27	29	5.9	1.0	66	8.9	0.07	0.79	0.04	250	2	11	13	78	9.0	0.53	0.88
Site (S3)																				
Bulk 0-0.1																				
0-0.1	7.8	0.17	0.001	38	31	1.7	1.5	86	2.0	0.05	0.62	0.02	8	1	10	15	80	11.2	0.47	1.2
0.2-0.3	8.5	0.17	0.001	37	31	3.0	.65	80	3.8	0.04	0.63	0.02	15	1	9	12	80	15.0	0.51	1.2
0.5-0.6	8.8	0.28	0.002	36	35	4.9	.75	76	6.5	-	-	-	22	1	8	13	81	14.1	0.63	1.1
0.8-0.9	9.1	0.30	0.003	29	31	5.7	.93	70	8.1	-	-	-	25	1	10	12	79	13.3	0.64	1.0
1.1-1.2	9.0	0.37	0.004	27	33	6.1	1.0	69	9.7	0.07	0.78	0.02	36	1	10	13	79	12.6	0.60	1.0
1.4-1.5	8.9	0.41	0.012	28	33	6.9	1.1	64	9.3	0.07	0.78	0.02	58	2	8	12	81	11.6	0.60	1.0

+ = oven dry $ = by alcoholic 1M NH_4Cl at pH 8.5 ++ = air dry

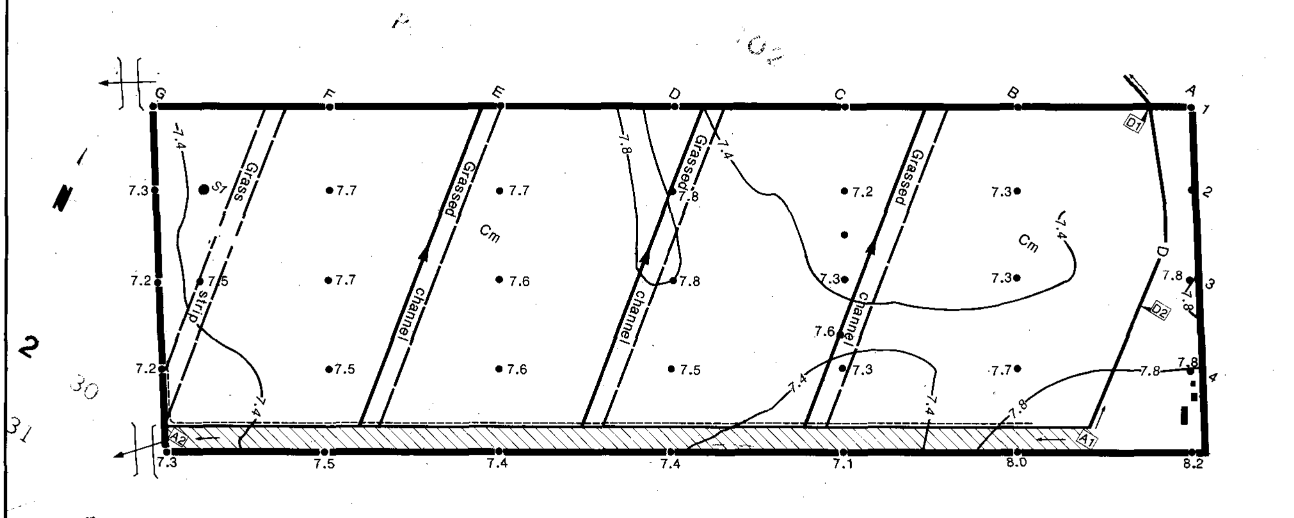

Figure 2. pH values and contours (0–0.1m)

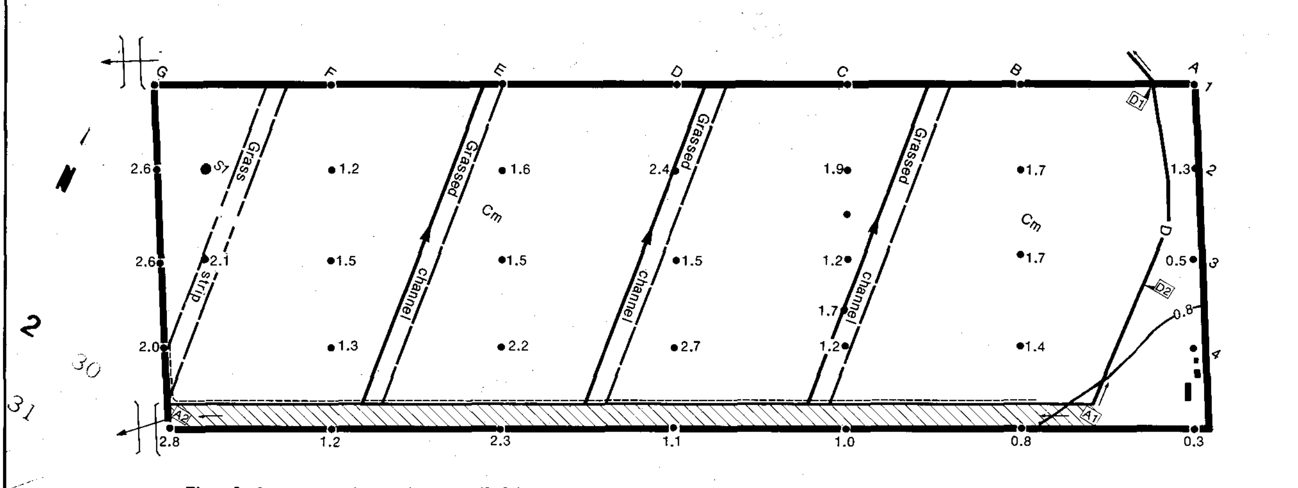

Figure 3. DTPA zinc values and contours (0–0.1m)

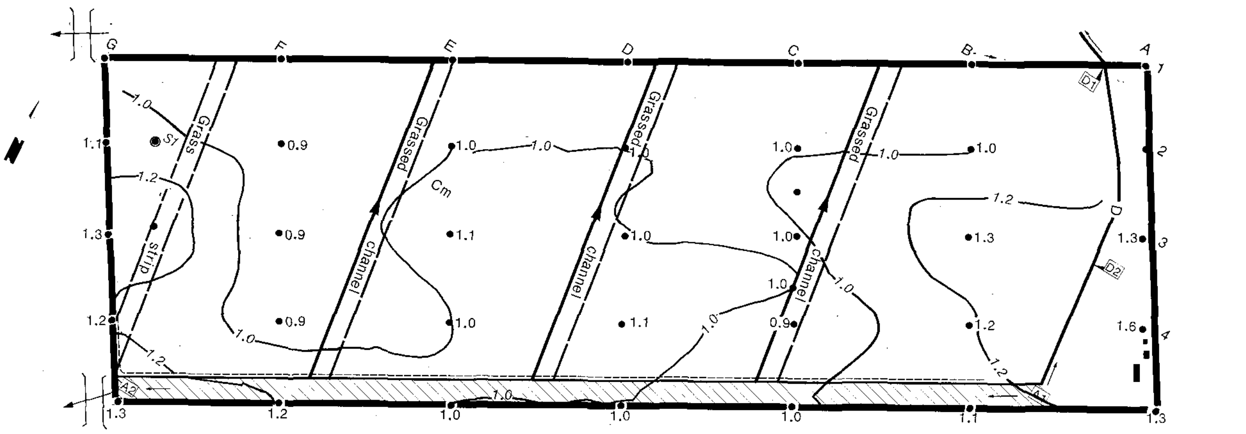

Figure 4. Organic carbon values and contours (0–0.1m)

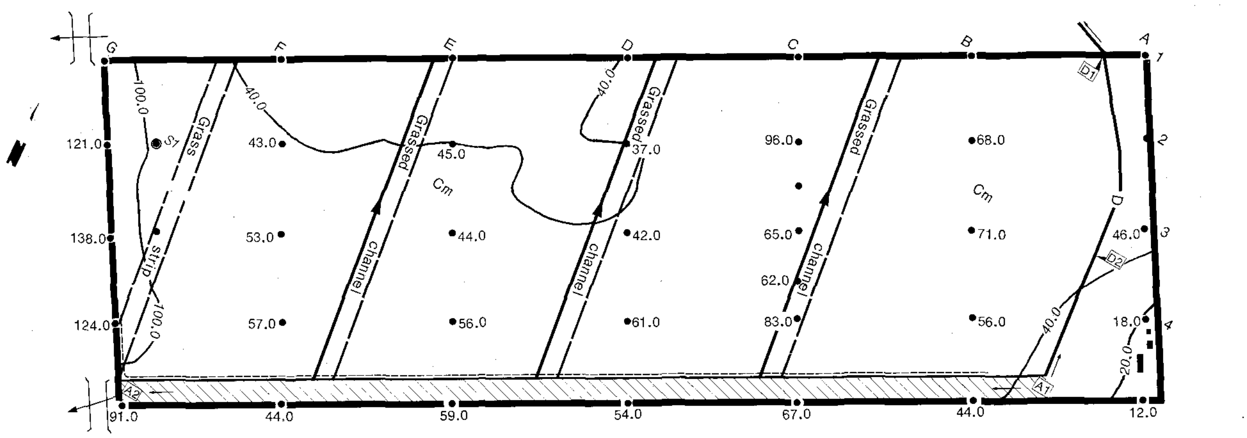

Figure 5. Bicarbonate P values and contours (0–0.1m)

Table 5. Surface soil fertility of representative soil profiles

Site and depth (m)	ppm Extr. P acid (mg/kg)	Bicarb (A.D.)	Org. C (W + B) %C (A.D.)	Tot. N %N (A.D.)	DTPA Trace Elements Fe	Cu (mg/kg)	Mn	Zn (A.D.)	Ratio C/N**
Site (S1)									
Bulk 0–0.1	226	86	1.3	0.10	21	2.6	18	2.1	13
Site (S2)									
0–0.1	145	54	0.9	0.09	27	2.9	23	1.3	10
Site (S3)									
0–0.1	118	58	1.3	0.10	20	2.3	14	1.2	13

** Carbon to nitrogen ratio

Baker (1982) observed that most crops grow well when soil pH is in the range from 5.5 to 7.5. Most surface soils at the station have pH's about 7.5 (Fig. 2).

Physical properties

Clay activity (CEC to clay ratio, CCR) values range from 1.2 in the surface to 0.85 at depths below approximately 1.0 m. Data from Reeve *et al.* (1960) show CCRs ranging from 1.4 to 1.1 for Craigmore black earths in the same district. However, these values are believed to be overestimates because the CEC method was probably inflated due to soluble calcium.

CCRs of >0.8 indicate that a high activity clay mineral is dominant, probably smectite. Clay contents are high ranging from 70 to 80% in the profile.

Profile plant available water capacity (PAWC) was estimated as high (144 mm). For similar black earths of the eastern Darling Downs, Mullins (1981) gave a range of field measured PAWC to 0.9 m of 138 mm to 170 mm (mean 159 mm).

The dispersion index values (R_1) in Table 4 indicate that the soils have a low tendency to disperse (Thompson, 1977). R_1 values range from 0.48 to 0.65 in the profile.

Sodicity ratings are based on exchangeable sodium percentage (ESP) values (Northcote and Skene, 1972). ESP was calculated by the formula exchangeable sodium to cation exchange capacity ratio expressed as a percentage. In all three profiles surface soils are non-sodic (ESP <6) whereas subsoils are sodic (ESP 6 to 14) at depths 0.9 m or deeper. With these properties no structural or profile wetting problems are expected in these soils (Smith and McShane, 1981). For all soils pH was strongly related to exchangeable sodium (r = 0.91, n = 18).

Profile S_2 and S_3 are rated as non-saline (Northcote and Skene, 1978) whereas the gypsum rich horizon of profile S_1 at 1.3 m makes this soil saline at depth (see Table 4). Chloride represents between 30% to 60% of the soluble salts in profiles for all depths except site (S_1) where gypsum accounts for greater than 90% of the EC at 1.3 m. This salinity is unlikely to affect plant growth.

Cation exchange capacity (CEC) and exchangeable calcium and magnesium

CEC values are high (60 to 85 meq/100 g) throughout the profiles. Calcium and magnesium are major cations in these soils with calcium dominant in the upper 0.6 m and magnesium dominant below this depth (Table 4). Calcium to magnesium (Ca/Mg) ratio ranged from 1.3 in the surface 0-0.1 m to around 0.85 at depth. Results from Reeve *et al.* (1960) show comparable Ca/Mg ratios of 1.2 in the surface horizon to 0.68 at depth.

For the 0-0.1 m samples CEC is larger than the sum of cations. OC present in these horizons inflates the CEC. This is the result of organic matter increasing the CEC values.

Total phosphorus (P), potassium (K) and sulphur (S)

The total P, K and S values of all 3 profiles are similar (Table 4). Using the ratings of Bruce and Rayment (1982), total P and K are medium to high whereas S is low. Total K levels are of the same order throughout the profiles but are all less than 1%.

LAND USE

Although these soils have high PAWC, moisture is the major limiting factor for crop production. High evaporation, erratic rainfall distribution and high intensity storms with high runoff rates reduces the effectiveness of rainfall to about half the total precipitation (Douglas 1977).

The entire field station is affected by a compacted plough pan just below the surface. This is a common feature of cultivated black earths in south-east Queensland. The effects of this compaction on plant yields are uncertain but restricted root penetration is a commonly observed feature. Deep ripping when relatively dry may help break up this layer whereas irrigation may aid compaction by reducing drying and any consequent deep cracking.

Even though slopes are less than 2%, erosion gullies have formed in some bays (see map). Cover crops are recommended during the summer storm period to control soil erosion. Incorporation of stubble should also reduce erosion and help reduce the density of the compacted plough layer.

From the results of soil analysis, the entire field station should respond to nitrogenous fertilisers and some areas to zinc (Figure 3). All other nutrients measured were rated as having high or adequate levels over the whole field station. Differences in nutrient values between bays observed in Figures 4 and 5 are probably the result of different fertiliser regimes in the past. However, these differences would not be expected to show up as differences in crop performance, as all values are above critical levels.

Chemically and physically the soils of the field station are considered to be uniform in the upper metre of the profile, apart from differences in DTPA zinc levels.

Morphological soil differences relate to the depth to the brown or red-brown calcareous subsoil. These may need to be evaluated experimentally to determine their effect on crop performance. Differences between soils below 1 m depth such as the Craigmore gypseous subsoil variant are unlikely to affect crop growth.

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Agricultural Chemistry Branch who carried out soil chemical and physical analysis.

Ms Lyn Landers of Land Resources Branch typed the final manuscript.

Mr S.E. Macnish edited the manuscript.

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APPENDIX I. DETAILED MORPHOLOGICAL DESCRIPTIONS OF SOIL TYPES

Notes:

(i) The most commonly observed range of profile attributes is described, together with less frequent variations outside this range.

(ii) The soil profile diagram indicates upper and lower depth limits of each horizon.

(iii) Horizon nomenclature: As per McDonald and Isbell (1984).

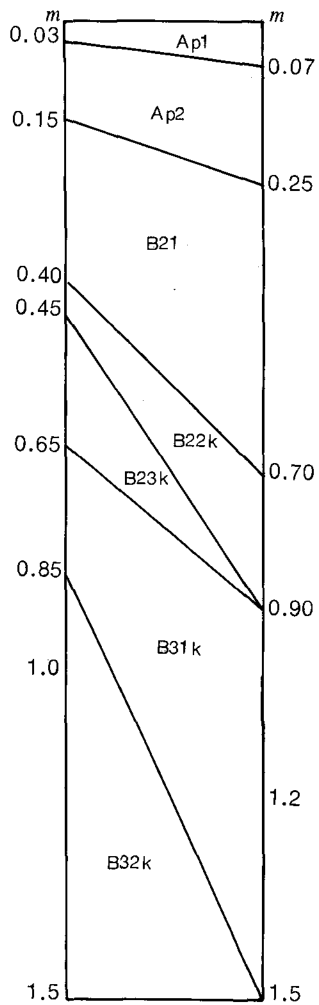
(iv) Colour: Moist colours were recorded using the revised Standard Soil Colour Chart (Oyama and Takehara 1967).

(v) Texture: As per McDonald and Isbell (1984).

(vi) Structure: As per McDonald and Isbell (1984).

(vii) Consistence and horizon boundaries: As per McDonald and Isbell (1984).

Soil Type	P.P.F.	Profile Diagram	Description
Craigmore	Ug5.15	Black earth	Surface condition: strongly self-mulching, seasonally cracking



Ap1 horizon: Dark (10YR 2/1-2); medium to medium-heavy clay; strong 3-15 mm granular; moderately fine (moderately moist). Clear or abrupt to -

Ap2 horizon (plough pan): Dark (10YR 2/1-2); medium to medium - heavy clay; moderate 20 - 50 mm fragments; moderately weak (moist). Clear to -

B21 horizon: Dark (10YR 2/1-2); medium - heavy clay; moderate 20 -50 mm lenticular; moderately weak (moist). Clear or gradual to -

B22k horizon: Dark (7.5YR - 10YR 2/2, 3/2, 3/2); medium to medium - heavy clay; moderate 20 - 50 mm lenticular; moderately weak (moist); 1-10% carbonate nodules. Clear or gradual to -

B23k horizon: Brown (7.5YR 3/3-4) to red brown (5YR 3/3-4) occasional dark mottle; medium to medium - heavy clay; moderate 20 - 50 mm lenticular, very weak (moist); 1-10% carbonate nodules. Clear or gradual to -

B31k horizon: As for above but with occasional red mottle, light - medium clay, 2 - 10 mm polyhedral primary peds; very weak (moist). Clear to -

B32k horizon: As above but may contain more carbonate and veins of manganese. It may also include medium - heavy clay and lenticular structure

Variants: gypseous variant - contain gypsum in B3 horizons. These profiles have B22 horizons to 1.35 m deep.

: carbonate variant - contain carbonate throughout profile. These could be old gilgai mound profiles, but brown subsoils do not occur close to surface as would be expected.

APPENDIX II. MORPHOLOGY AND ANALYSIS OF REPRESENTATIVE PROFILES

Notes:

Soil profile morphology: As per notes (iii) and (vii) in Appendix I.

Chemical data: All soil chemical data presented are on oven dry (O.D.) basis, except for pH, E.C. and fertility data.

SOIL TYPE: Craigmore
SITE NO: S3
A.M.G. REFERENCE: 379 529 mE 6 955 940 mN ZONE 56

GREAT SOIL GROUP: Black earth
PRINCIPAL PROFILE FORM: Ug5.15
SOIL TAXONOMY UNIT: Udic Pellustert
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1.5 %
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Gently undulating rises

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 680 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Periodic cracking, self-mulching

HORIZON	DEPTH	DESCRIPTION
AP1	0 to .05 m	Brownish black (10YR2/2); medium heavy clay; strong 5-10mm subangular blocky; dry very strong. Clear to-
AP2	.05 to .17 m	Brownish black (10YR2/2); medium heavy clay; moderate 20-50mm fragment; moist moderately weak. Clear to-
B21	.17 to .45 m	Brownish black (10YR2/2); medium heavy clay; moderate 20-50mm lenticular; moist moderately weak. Gradual to-
B22	.40 to .65 m	Brownish black (10YR2/2); medium heavy clay; moderate 20-50mm lenticular; moist moderately weak; very few medium carbonate nodules.
B23	.65 to .90 m	Dark brown (7.5YR3/3); very few medium distinct dark mottles; medium clay; moderate 20-50mm lenticular moderate 5-10mm lenticular; moist moderately weak; very few medium carbonate soft segregations. Gradual to-
B31	.90 to 1.05 m	Dark brown (7.5YR3/4); light medium clay; moderate 20-50mm lenticular moderate 5-10mm polyhedral; moderately moist very weak; very few medium carbonate soft segregations. Clear to-
B32	1.05 to 1.50 m	Dark reddish brown (5YR3/4); very few fine faint red mottles; light medium clay; strong 10-20mm lenticular strong 2-5mm polyhedral; moderately moist very weak; few coarse carbonate nodules, very few fine manganiferous veins.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	% @ 105C				m.eq/100g						%		% @ 105C				
.10	7.8	.17	.001	01	10	15	80	86	38	31	1.7	1.5	0.05	0.62	0.02	11.2		37	.47	
.30	8.5	.17	.001	01	09	12	80	80	37	31	3.0	.65	0.04	0.63	0.02	15.0		40	.51	
.60	8.8	.28	.002	01	08	13	81	76	36	35	4.9	.75				14.1		41	.63	
.90	9.1	.30	.003	01	10	12	79	70	29	31	5.7	.93				13.3		39	.64	
1.20	9.0	.37	.004	01	10	13	79	69	27	31	6.7	1.0	0.07	0.78	0.02	12.6		42	.60	
1.50	8.9	.41	.011	02	08	12	81	74	28	33	6.9	1.1	0.07	0.78	0.02	11.6		42	.60	

Depth	Org.C	Tot.N	Extr. Phosphorus		Rep.	DTPA-extr.			
	(W&B)		Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
.10	1.3	.10	118	58	1.2	20	14	2.3	1.2

SOIL TYPE: Craigmore
SITE NO: S2
A.M.G. REFERENCE: 379 358 mE 6 955 823 mN ZONE 56

GREAT SOIL GROUP: Black earth
PRINCIPAL PROFILE FORM: Ug5.15
SOIL TAXONOMY UNIT: Udic Pellustert
FAO UNESCO UNIT:

SURFACE COARSE FRAGMENTS: Very few coarse pebbles, rounded tabular basalt, very strong

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1.5 %
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Gently undulating rises

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 680 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Periodic cracking, self-mulching

HORIZON	DEPTH	DESCRIPTION
AP1	0 to .03 m	Brownish black (10YR2/2); medium heavy clay; strong 2-5mm granular; moderately moist moderately firm. Clear to-
AP2	.03 to .15 m	Brownish black (10YR2/2); medium heavy clay; moderate 20-50mm fragment; moist moderately weak. Clear to-
B21	.15 to .50 m	Brownish black (10YR2/2); medium clay; moderate 20-50mm lenticular secondary, moderate 2-5mm lenticular primary; moist moderately weak. Clear to-
B22	.50 to .75 m	Brownish black (10YR3/2); medium clay; moderate 20-50mm lenticular secondary, moderate 5-10mm lenticular primary; moist moderately weak; few medium carbonate nodules. Diffuse to-
B31	.75 to .95 m	Dark brown (7.5YR3/4); very few fine faint red mottles; light medium clay; moderate 10-20mm polyhedral secondary, moderate 2-5mm polyhedral primary; moist very weak; very few medium carbonate soft segregations. Clear to-
B32	.95 to 1.50 m	Dark reddish brown (5YR3/4); very few fine distinct red mottles; light medium clay; strong 50-100mm lenticular secondary, strong 10-20mm polyhedral primary; moist very weak; few medium carbonate nodules, very few fine manganiferous veins.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	% @ 105C				m.eq/100g					%			% @ 105C				
.10	7.6	.13	.002	01	13	20	71	70	31	26	1.4	1.3	0.06	0.72	0.02	9.9		32	.48	
.30	8.0	.19	.006	01	12	19	72	72	31	27	2.6	.52	0.05	0.68	0.02	12.1		35	.57	
.60	8.6	.32	.011	01	11	12	72	71	29	26	3.9	.61	0.05	0.75	0.03	11.5		36	.65	
.90	8.8	.37	.011	01	12	17	75	60	25	27	4.7	.71	0.09	0.89	0.03	12.3		36	.57	
1.20	8.7	.54	.024	01	10	15	79	62	26	29	5.6	1.0	0.09	0.87	0.03	12.0		36	.51	
1.50	8.6	.77	.037	02	11	13	78	66	27	29	5.9	1.0	0.07	0.79	0.04	9.0		36	.53	

Depth	Org.C	Tot.N	Extr. Phosphorus		Rep.	DTPA-extr.			
	(W&B)		Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
.10	0.9	.09	145	54	1.1	27	23	2.9	1.3

SOIL TYPE: Craigmore - gypseous variant
SITE NO: S1
A.M.G. REFERENCE: 379 065 mE 6 955 826 mN ZONE 56

GREAT SOIL GROUP: Black earth
PRINCIPAL PROFILE FORM: Ug5.15
SOIL TAXONOMY UNIT: Udic Pellustert
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1.5 %
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Gently undulating rises

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 680 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Periodic cracking, self-mulching

HORIZON	DEPTH	DESCRIPTION
AP1	0 to .07 m	Brownish black (10YR2/2); medium heavy clay; strong 5-10mm fragment; moderately moist moderately weak. Clear to-
AP2	.07 to .15 m	Brownish black (10YR2/2); medium heavy clay; moderate 20-50mm fragment; moist moderately weak. Clear to-
B21	.15 to .90 m	Brownish black (10YR2/2); medium heavy clay; moderate 10-20mm lenticular secondary, moderate 2-5mm lenticular primary; moist moderately weak. Clear to-
B22	.90 to 1.20 m	Brownish black (10YR2/2); medium heavy clay; moderate 20-50mm lenticular secondary, moderate 5-10mm lenticular primary; moist moderately weak; very few medium carbonate nodules. Diffuse to-
B31k	1.20 to 1.30 m	Dark brown (7.5YR3/4); medium clay; moderate 10-20mm polyhedral secondary; moderately moist very weak; common medium carbonate nodules. Clear to-
B32y	1.30 to 1.40 m	Dark brown (7.5YR3/4); medium clay; moderate 2-5mm polyhedral primary; few medium gypseous crystals. Clear to-
B33	1.40 to 1.50 m	Dark reddish brown (5YR3/4); very few fine faint red mottles; medium clay; strong 10-20mm polyhedral secondary, strong 2-5mm polyhedral primary; moderately moist very weak; very few medium carbonate nodules.

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl %	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m.eq/100g CEC	Ca	Mg	Na	K	Total Elements % P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp.Ratio R1	R2
Bulk .10	7.5	.14	.003													10.2				
Bulk .10	7.3	.34	.025																	
.10	7.6	.10	.002	01	13	17	71	71	31	28	1.1	1.6	0.08	0.80	0.02	9.1		33	.48	
.20	7.7	.12	.005													10.1				
Bulk .20	7.3	.33	.019																	
.30	7.7	.14	.009	00	15	18	71	71	34	26	1.8	.89	0.05	0.75	0.02	10.4		34	.56	
.60	7.7	.23	.024	01	12	17	74	71	32	27	2.6	.58	0.04	0.69	0.02	10.5		34	.55	
.90	8.0	.28	.022	01	12	17	74	70	30	28	3.3	.56	0.04	0.70	0.02	9.9		34	.60	
1.20	8.0	1.1	.020	01	11	17	76	67	32	26	3.7	.85	0.07	0.81	0.14	8.8		35	.57	
1.30	7.7	3.0	.019																	
1.50	8.4	.87	.018	02	11	13	77	60	27	27	4.5	1.0	0.09	0.77	0.09	9.6		36	.55	

Depth metres	Org.C (W&B) %	Tot.N %	Extr. Phosphorus ppm Acid	Bicarb.	Rep. K m.eq%	DTPA-extr. ppm Fe	Mn	Cu	Zn
Bulk .10	1.3	.10	226	86	1.3	21	18	2.6	2.1
Bulk .10	1.3	.10	246	87	1.4	25	15	2.7	2.1
Bulk .20	1.2	.10	251	84	1.3	30	14	2.7	4.7