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PROJECT REPORT

SOILS OF THE QUEENSLAND WHEAT RESEARCH INSTITUTE EXPERIMENTAL FARM ,WELLCAMP EASTERN DARLING DOWNS

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SUMMARY

The 24 ha Wellcamp Experimental Farm is located 9 km south-west of Toowoomba on a very gently inclined alluvial fan of basaltic material.

A soil survey was carried out on a 100 m square grid and representative soil profiles analysed to assess the soil resources of the farm. Three soil types, one phase and one miscellaneous group of soils were mapped at 1:2 500. The two main soil types identified were Craigmore and Irving, both heavy clay black earths with brown to red brown calcareous clay subsoils. The Irving soil has a finer surface self mulch than the Craigmore soil which is related to higher exchangeable calcium: exchangeable magnesium ratio in the surface soil. Agronomically the soils are expected to perform similarly except for a coarse self mulching phase of Craigmore where germination may be hindered due to poor soil-seed contact. Gypsum application may improve germination on this soil.

Most soils were classified as belonging to the black earths great soil group (Stace *et al.* 1968), the Ug5.15 or Ug5.11 principal profile forms (Northcote 1979), the Typic Pellusterts (Soil Survey Staff 1983) and the Pellic Vertisols (FAO 1979).

Soils were neutral to alkaline in the surface and alkaline at depth. Salinity and sodium levels were low suggesting good internal drainage. Plant available soil water capacity was consistently high (14-15 cm in the upper 0.9 m) but soil fertility was variable. All soils appear to need maintenance applications of zinc and sulphur while phosphorus status appears to be variable, possibly due to gilgai patterns. In general, the more alkaline surface soils (e.g. Irving) tend to be low in phosphorus.

A compacted plough pan was observed at 0.05 to 0.10 m deep. The effects of this layer on yield are uncertain, but restricted barley root penetration was observed during the survey. Deep ripping is recommended to break up the plough pan.

INTRODUCTION

The Queensland Wheat Research Institute (Q.W.R.I.) Wellcamp Experimental Farm of 24 ha is located on the Drayton-Wellcamp Road, some 9 km south-west of Toowoomba (Figure 1).

The experimental farm will be used for a variety of trials, many involving soil fertility - plant nutrition aspects of winter cereal crop production. Because of the possible effects of soil variability on trial results, Q.W.R.I. requested Land Resources Branch to carry out a very high intensity soil survey of the farm and report on soils, chemical properties and likely management problems.

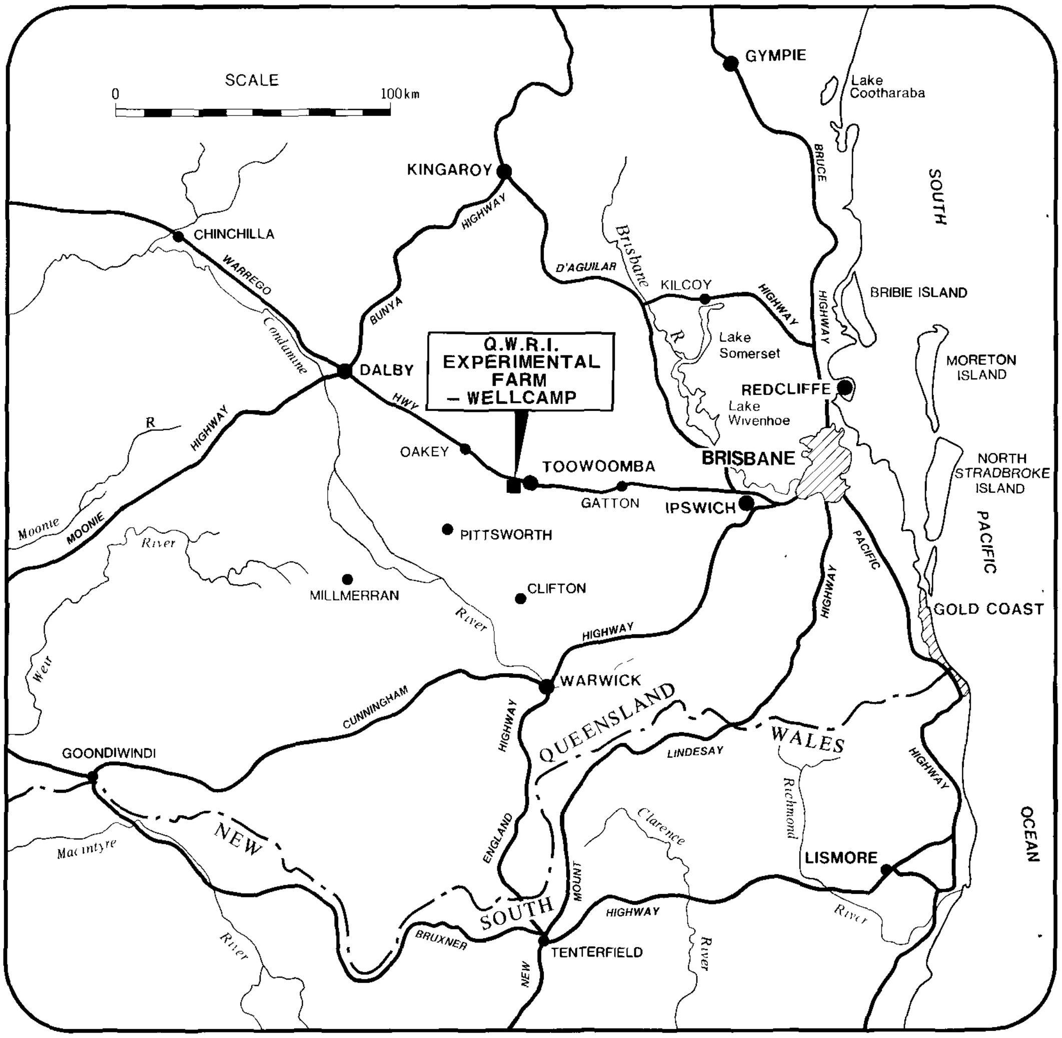

Figure 1. Locality plan.

PHYSICAL RESOURCES

Climate

Table 1 summarises climatic data for recording centres in the area.

The experimental farm is positioned in a rain shadow area and has lower annual rainfall than Toowoomba (refer Gowrie Junction). Rainfall is summer dominant with 67% falling between October and March, although there is a secondary peak in the winter months of June and July. Approximately 36% of the winter half year rain falls in these 2 months.

Summer temperatures average 26.9^{o}C maximum while winter temperatures average 5.7^{o}C minimum. Frosts are possible from May to October inclusive, but most common during June, July and August.

Geology and landform

The experimental farm is situated on a very gently inclined alluvial fan out of part of the Main Range Volcanics (Cranfield and Schwarzbock 1971). These rocks consist predominantly of olivine basalt.

The slope of the fan averages 1.5% and soil conservation works have been implemented in the form of contour banks, grassed waterways and grass strips.

Linear gilgai microrelief is a feature of these landscapes but surface features have been obliterated by cultivation.

Soils

The area has been previously mapped by Thompson and Beckman (1959) as the Charlton - Craigmore soil association. This association is described as shallow and deep heavy clay soils, some with linear gilgai, very dark brown and dark grey in colour, alkaline reaction. Detailed soil chemical data are also available (Reeve, Thompson and Beckmann 1960) for soils of the region.

Table 1. Climatic Data Summary

Climatic Factor	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Mean rainfall (mm) (Gowrie Junction)	94	80	65	38	34	46	41	29	35	59	68	91	680
Mean rainfall (mm) (Toowoomba)	134	124	101	61	56	61	54	41	49	74	89	121	970
Mean no. of raindays (Gowrie Junction)	6	5	5	3	3	3	3	3	3	4	5	6	49
Mean no. of raindays (Toowoomba)	12	11	11	8	8	8	7	6	7	8	10	11	107
10% probability of receiving (mm) or greater (Decile 9) (Toowoomba)	282	264	204	130	117	161	118	84	97	136	158	228	1 322
50% probability of receiving (mm) or greater (Decile 5) (Toowoomba)	125	90	90	52	41	41	42	32	44	63	80	105	953
90% probability of receiving (mm) or greater (Decile 1) (Toowoomba)	41	31	20	11	7	5	5	7	9	22	21	40	618
Mean monthly pan evaporation (mm) (Oakey)	235.6	204.4	186.0	150.0	108.5	78.0	93.0	117.8	156.0	192.2	222.0	251.0	1 994.6
Mean daily maximum temperature (°C) (Toowoomba)	27.0	26.4	25.3	23.2	19.5	17.0	16.2	17.8	20.6	23.4	26.0	27.3	22.5
Mean daily minimum temperature (°C) (Toowoomba)	16.6	16.7	15.4	12.5	8.6	6.2	4.8	6.0	8.3	11.5	13.9	15.7	11.4
Frost (days/month) (Toowoomba)	0	0	0	0	3	7	12	8	3	1	0	0	34
Humidity % 9 a.m. (Toowoomba)	74	78	76	72	74	76	69	67	64	66	67	68	71

LAND RESOURCES SURVEY METHOD

Soils on the experimental farm were described and classified at 34 sites located on a 100 m square grid. Soils were mapped at a scale of 1:2 500 into soil types compatible with the soil series identified by Thompson and Beckmann (1959). The term soil type is defined as a three dimensional soil body such that any profile within the body has a similar number and arrangement of major horizons whose morphological attributes are within a defined range (McDonald, unpublished). The term is not based on the soil type definition of Soil Survey Staff (1951) although at this map scale it is approximately the equivalent. Additional profiles were examined where necessary to delineate soil boundaries.

Gilgai patterns were confirmed by examining several profiles spaced approximately 0.3 m apart and noting the depth to the black-brown clay horizon boundary.

Sampling for laboratory analysis was carried out on four representative soil profiles. Profiles were sampled in 0.1 m depth increments at 0.3 m intervals to 1.5 m. In addition a bulk of nine 0 to 0.1 m samples was collected at each site. Analyses in Table 2 were carried out according to the methods described by Bruce and Rayment (1982).

Table 2. Analytical determinations for 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; (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

SOILS - MORPHOLOGY AND CLASSIFICATION

Morphology

Three soil types, one phase and one miscellaneous group (see Table 3) have been identified and mapped, and are described in full in Appendix I.

Table 3. Major distinguishing attributes of the soils

Soil Type	Major Distinguishing Attributes	Great Soil Group	PPF's
Craigmore (Cm)	Strongly self mulching 3 to 10 mm granular surface, dark medium to medium heavy clay to 0.95 to 1.25 m over alkaline brown to red brown medium to medium heavy clay.	Black earth	Ug5.15
Craigmore-coarse self mulching phase (CmCp)	Strongly self mulching 5 to 15 mm granular surface	Black earth	Ug5.15
Irving (Iv)	Strongly self mulching 2 to 5 mm granular surface, dark medium to medium heavy clay to 0.8 to 1.15 m over alkaline brown to red-brown medium to medium heavy clay.	Black earth	Ug5.15
Yargullen-deep variant (Yg)	Strongly self mulching 2 to 4 mm granular surface, dark alkaline medium heavy clay to 0.85 m over marly clay.	Black earth	Ug5.11
Miscellaneous-recent alluvium (Ml)	Strongly self mulching 2 to 10 mm granular surface, dark medium to medium heavy clay to 0.45 to 1.35 m over alkaline dark to brown D horizons or buried soils.	Black earths and prairie soils	Ug5.17 Uf6.32

Soils (black earths) were difficult to separate. The landscape is fairly uniform and subsoil colour in both major soil types (Craigmore and Irving) is usually brown to red-brown. The main difference betweem Craigmore and Irving is in the size of the granules making up the surface self mulch. Craigmore has a dominantly 3 to 10 mm granular surface while Irving has a finer 2 to 5 mm granular surface. A coarse self mulching phase of Craigmore with 5 to 15 mm granular surface was mapped in the north-eastern corner.

Several variants of the black earths were found, the most common being either grey colour of the subsoil, or lighter texture of the deep subsoil, or variable depth to the coloured subsoil. The last feature is probably due to gilgai patterns.

A small area of Yargullen was mapped; however this is a deep variant of the typical Yargullen identified by Thompson and Beckmann (1959). At 0.84 to 0.86 m a white strongly calcareous (marly) clay is found, possibly the result of frequent saturation by carbonate rich waters. The soil cracks when dry and is a black earth, not a rendzina.

A miscellaneous group of soils made up of black earths and prairie soils was mapped along the edge of the southern fence and is probably the result of alluvial deposition from the adjacent creek.

Agronomically, all soils are expected to perform similarly except for the coarse phase of Craigmore where germination problems may be encountered due to poor soil-seed contact.

Long term cultivation has obliterated linear gilgai features, however surface carbonate was observed in many areas, indicative of a former gilgai surface. The distribution of brown subsoils and carbonate accumulations also suggests a former linear gilgai pattern with curving tongues (Thompson and Beckmann 1982).

Classification

In the map reference, soils are classified into great soil groups (Stace *et al.* 1968) and principle profile forms (Northcote 1979). Soils have also been classified to Soil Taxonomy subgroup level (Soil Survey Staff 1983) and the FAO-Unesco soil unit (1979) (Table 4).

Table 4. Classification of Wellcamp soils in Australian and international systems

Soil Type	Great Soil Group	Principle Profile Form	Soil Taxonomy Subgroup	FAO-Unesco Soil Unit
Craigmore	Black earth	Ug5.15	Typic Pellustert	Pellic Vertisol
Irving	Black earth	Ug5.15	Typic Pellustert	Pellic Vertisol
Yargullen deep variant	Black earth	Ug5.11	Typic Pellustert	Pellic Vertisol

Soil horizons were classified for engineering purposes according to the Unified Soil Classification (Olson 1973) (Table 5). All horizons were found to be CH except for the D horizons of both the miscellaneous recent alluvium and occasionally the lower B horizons of the Craigmore clay profiles which are SM, SC, CL or GM. These soil materials have gravelly and sandy layers deposited at depths of 0.6 m to 1.5 m below the surface.

Table 5. Unified soil classification of Wellcamp soils

Horizons	Soil Types			
	Craigmore	Irving	Yargullen - deep variant	Miscellaneous recent alluvium
Ap	CH	CH	CH	CH
B2	CH	CH	CH	CH
B3k	CL,SC	-	-	-
D	-	-	CH	SM,SC,CH, CL,GM

CH - inorganic clays of high plasticity, high shrink swell, high liquid limit
CL - inorganic clays of low to medium plasticity, low liquid limit, includes gravelly clays, sandy clays and silty clays
SC - clayey sands and sand and clay mixtures
SM - silty sands, sand and silt mixtures
GM - silty gravel, gravel, sand and silt mixtures.

SOILS - CHEMICAL AND PHYSICAL PROPERTIES

General

Four soil profiles were sampled for detailed laboratory analysis. With each profile, a bulked 0 to 0.1 m surface sample was also collected for fertility assessment. Analyses carried out (Table 2) and general interpretations of data are detailed in Bruce and Rayment (1982) (see Appendix III).

Representative profile descriptions complete with detailed profile analysis are presented in Appendix II. Due to variability of the soils, a grey subsoil variant of the Irving soil was sampled for analysis. Apart from poorer subsoil drainage characteristics, this soil profile is considered to be within the range of the Irving soil type.

Conclusions and interpretations of soil laboratory data are only applicable to the Wellcamp Experimental Farm and without further work, cannot be extrapolated to areas outside the farm.

pH

Surface soil laboratory pH varies from neutral to strongly alkaline. There is an apparent relationship between alkalinity and fineness of surface self-mulch. The coarse self mulching phase of Craigmore is neutral, the typical Craigmore is moderately alkaline while the fine self mulching Irving is strongly alkaline. Nutrient availability, notably phosphorus and zinc, is likely to be reduced on the more alkaline surface soils. Such strong alkalinity in the surface is not typical for the Irving soil which elsewhere is commonly neutral. Strongly developed mound dominant gilgai patterns possibly account for this feature as alkaline gilgai mounds are mixed with depressions by cultivation.

All soils show strongly alkaline pH trends down the profile associated with high base saturation due to magnesium, calcium and sodium carbonates and bicarbonates.

Salinity

Very low chloride levels (<0.01%) were detected in all profiles to 0.9 m (Table 6). Below this depth, only the Craigmore self mulching phase showed a significant chloride increase to medium values (0.03 to 0.06%).

Table 6. Chloride and sodicity levels in analysed profiles at selected depths

Soil Type	% Chloride (oven dry) 0-0.1 m	0.8-0.9 m	Sodicity (ESP) 0-0.1 m	0.8-0.9 m
Cm(B3)	0.002 very low	0.002 very low	0.3 non-sodic	1.8 non-sodic
Cm(D2)	0.002 very low	0.003 very low	0.7 non-sodic	3.3 non-sodic
CmCp	0.002 very low	0.009 very low	1.2 non-sodic	3.8 non-sodic
Iv	0.003 very low	0.003 very low	0.5 non-sodic	-

Electrical conductivity levels were also very low in the upper profile but tended to increase relatively more than chloride in the subsoil (Figure 2). This suggests that sodium and chloride are not the dominant salts, and that other ions are also present.

The shape of the salt profile with depth (Figure 2) reflects the hydraulic properties of the soil and the degree of deep drainage (Shaw and Dowling 1985). The Irving and Craigmore curves indicate minor salt accumulation while the coarse phase of Craigmore shows a moderate accumulation and therefore implies slower deep drainage. All profiles show a gradual increase in salinity with depth, which suggests a depth of wetting greater the 1.5 m deep and the ability of vegetation to remove water to at least 1.5 m.

Exchangeable cations, CEC, sodicity and dispersion

Cation exchange capacity (CEC) was determined chemically after using alcoholic 1M NH_4Cl at pH 8.5 to extract exchangeable cations. CEC levels are high in all soils (42 to 82 m equiv/100 g) especially in the main root zone, the upper 0.9 m (64 to 82 m equiv/100 g). At depth the CEC tends to decline as clay contents decrease. The high CEC's show that the soils have a high capacity to retain nutrient cations and implies high soil water holding capacity.

Soils are strongly base saturated (80 to 100%) with calcium and magnesium the dominant cations on the exchange complex. In the upper profile calcium is dominant or calcium/magnesium are codominant. Down the profile, magnesium becomes progressively more dominant with calcium subdominant, a common feature of many eastern Darling Downs black earths (Reeve, Thompson and Beckmann, 1960).

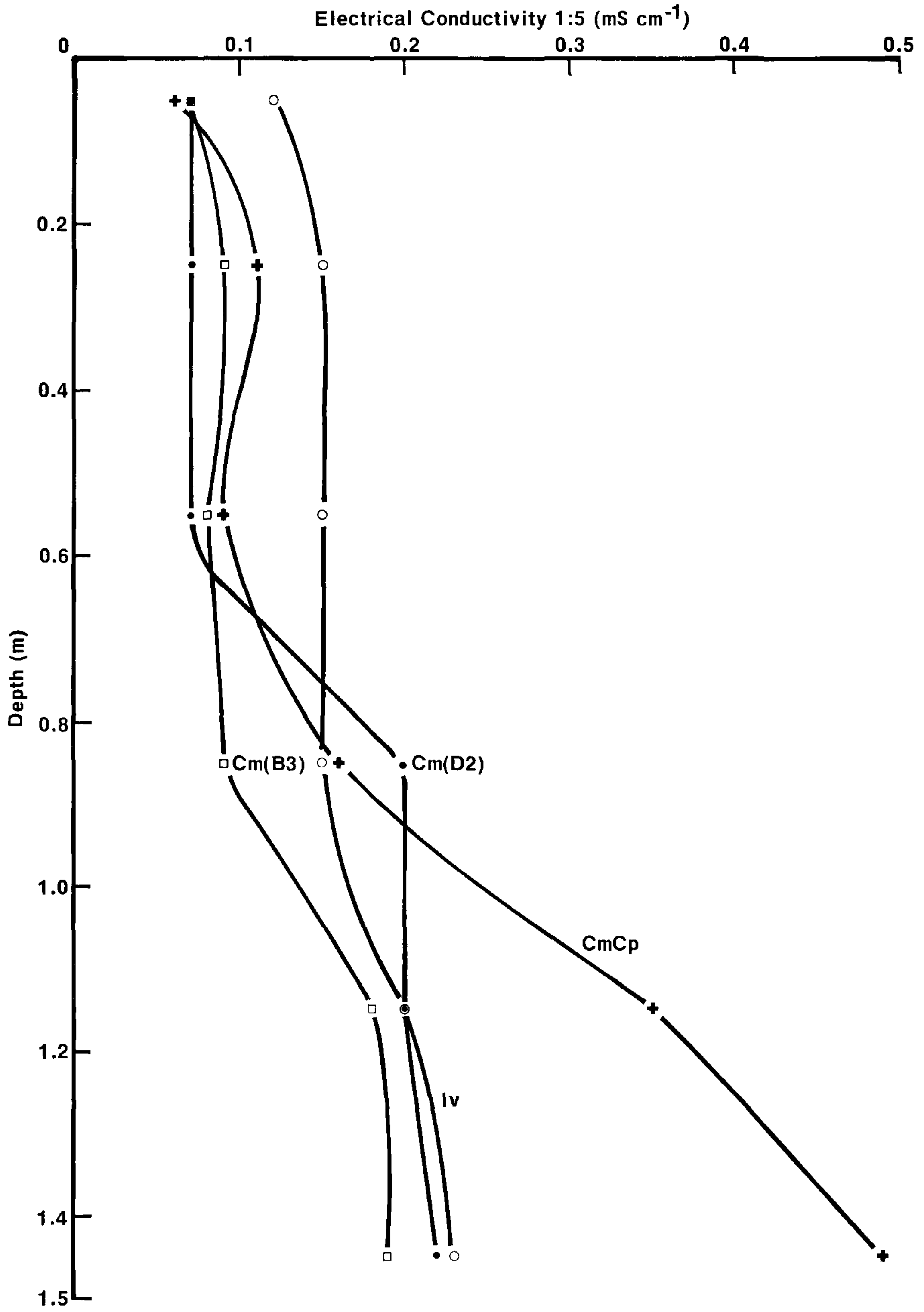

Figure 2. Salt profiles for Wellcamp soils.

An increase in calcium relative to magnesium in the surface seems to result in finer self mulching granules. The fine self mulching Irving surface has high calcium relative to magnesium (Ca:Mgz 2.4) where as the Craigmore coarse self mulching phase has almost equal proportions of calcium and magnesium. The normal Craigmore soil is in between these two extremes.

Exchangeable sodium levels are generally low (Table 6) with soils being classed as non-sodic (Northcote and Skene 1972), although there is a trend towards increasing sodicity with depth. Clay soils elsewhere in Queensland have shown a relationship between exchangeable sodium percentage (ESP) and soil pH (Baker *et al.* 1983, Powell *et al.* 1985). However for these black earths the relationship does not apply as soil pH's can be quite high due to high carbonate and bicarbonate levels yet sodicity remains low.

Salt profiles in Figure 2 suggest that Irving and Craigmore have better deep drainage than the Craigmore coarse self mulching phase. When the ESP's of soil profiles below a metre are compared, Irving and Craigmore range from 2.5 to 4.5, while Craigmore coarse self mulching phase is 7.6. The difference in sodicity appears to be the main factor contributing to slower drainage and greater salt accumulation. However this level of salt accumulation is not considered to be a limiting factor in crop production.

Estimates of the tendency to disperse (dispersion ratio R1) give an overall indication of soil structural stability and these are low (<0.6) in 3 of the sampled profiles. The exception is Craigmore site B3 which has moderate dispersion (0.6 to 0.8) in the subsoil, but this soil did not show any visual differences in soil structure.

The available data point to the conclusion that these soils have favourable structural properties for cereal crop production except for the Craigmore coarse self mulching phase.

Plant available water capacity

Mullins (1978) indicates that generally the Irving and Craigmore soils are able to store available soil water to at least 1.5 m. He suggests that total available soil water capacity to 0.9 m (the main root zone) varies from 14 to 19 cm .

Plant available water capacity (PAWC) was estimated for four soil profiles using a modified method of Shaw and Yule (1978) using regression equations between field measured maximum (Wmax) and minimum (Wmin) gravimetric soil water and CEC for each 0.1 m depth increment. PAWC was calculated as the difference between Wmax and Wmin after conversion to a volumetric figure using the bulk density formula $B.D. = \frac{0.95}{0.3774 + Wmax}$ (Shaw, pers. comm.). As CEC was measured only at standard depths (Table 2), the sum PAWC for the 0.9 m profile was estimated as: $PAWC_{0-0.1\ m} + 3\ (PAWC_{0.2-0.3\ m}) + 3\ (PAWC_{0.5-0.6\ m}) + 2\ (PAWC_{0.8-0.9\ m})$.

Soils at Wellcamp were found to store 14 to 15 cm of plant available water in the top 0.9 m. In comparison, cracking clays at Emerald had a PAWC of 7.4 to 13 cm (Shaw and Yule 1978) while the Burdekin cracking clays store 10.4 to 12.8 cm of plant available water (Gardner and Coughlan 1982). These eastern Darling Downs black earths appear to have superior PAWC in comparison to most cracking clays. This capacity to retain plant available water is the major reason for successful grain cropping on these soils.

Particle size distribution and clay activity

Clay content for the Irving soil is high throughout the sampled soil profile (74 to 82%). In contrast, Craigmore is high in clay (64 to 70%) in the top 1.2 m, but may decline rapidly below this depth to (38 to 55% clay). The change occurs at the B_2 to B_3 horizon boundary and B_3 horizons have correspondingly higher fine sand contents as clay content drops. Measured clay contents were found to approximately match field texture clay estimates.

Silt contents are generally higher in the Craigmore soil (15 to 22%) than in the Irving soil (11 to 17%).

Clay activity (CEC/% clay) ratios of 1.0 to 1.18 are found in the clay rich horizons (>55% clay) of all soils sampled. However the lower clay B_3 horizons of sites D2 and F1 have higher clay activities (1.24 to 1.37). All ratios suggest smectite dominant clay minerals are present. The higher ratios are similar to results obtained in the Lockyer Valley (Ahern *et al.* 1984) and Fassifern Valley (Powell 1979) for alluvial plain subsoils. These high CECs are considered to be due to the presence of partially weathered plagioclase feldspars in the silt and fine sand fractions (Wilson 1976).

Total phosphorus, potassium and sulphur

Total phosphorus levels are very high for all 0 to 0.1 m surface soils except the Craigmore coarse self muching phase (site F1) which is high (0.089%). Thompson and Beckmann (1959) suggest that phosphorus contents in these soils reflects phosphorus in parent materials. The coarse self mulching Craigmore thus appears to be developed from different parent material although still in the basaltic range.

Total phosphorus gradually declines with depth, probably as organic phosphorus and fertiliser levels decline, except in the type Craigmore profiles. These show an increase in the carbonate rich B_2 horizons.

For all 0 to 0.1 m surface soils, total potassium levels are in the medium range. However the Craigmore coarse self mulching phase profile is lower in total potassium than the other soils, which is further evidence of different parent material.

Total sulphur, a poor indicator of available sulphur, is medium in the surface 0.1 m and low at depth.

Soil fertility

Surface soil pH is neutral to weakly alkaline for all sampled soils except the Irving which is strongly alkaline (pH 8.7). Alkalinity may result in lower solubility and hence availability of certain essential plant nutrients. It was noted that Irving had low bicarbonate extractable P (bicarb P) (10 ppm) and low DTPA extractable zinc (0.3 ppm) (Table 7). This is despite a high total P level (0.162%). In contrast, Craigmore soils have much higher levels of bicarb. P and slightly higher DTPA zinc levels and pHs of less than 8.2.

Acid extractable P values (Table 7) are unreliable indicators of fertility for these alkaline soils, although the very high levels of acid P recorded suggest calcium phosphates are present. Bicarb P on the other hand is strongly correlated with cereal responses on Darling Downs soils (Whitehouse 1971).

Doughton (pers. comm.) has found evidence of considerable short distance variability in bicarb P status (15 to 76 ppm) on Craigmore surface soils. This could be due to former gilgai patterns with lower P on the mounds and higher P in the depressions (Thompson and Beckmann 1982).

All soils investigated show very high extractable potassium values (Tables 7 and 8) and deficiencies are unlikely.

Copper and manganese levels appear adequate but all soils show probable zinc deficiency, with the alkaline Irving profile having the lowest levels of DTPA extractable Zn.

Using the weighted average sulphate sulphur technique for established siratro pastures (Rayment 1983), potential sulphur deficiencies were assessed for these soils. For Craigmore, weighted average sulphate sulphur levels were less than 4 ppm, suggesting a likely sulphur response. In Irving however, adequate profile sulphur levels are present, but maintenance of existing levels is desirable. In all profiles, the presence of sulphates down the profile is indicated by medium levels of sulphate sulphur at 1.5 m (Table 8).

Total nitrogen levels in the surface are borderline between low and medium and decline with depth more rapidly than organic carbon levels (Tables 7 and 8).

Carbon to nitrogen ratios range from 10 to 12.6 in the surface but the ratio increases in the subsoil.

Table 7. General fertility and ratings for the surface 0.1 m (40°C air dry basis)

Soil type	Phosphorus		Extractable K	DTPA Extractable			Total Nitrogen	Organic Carbon	Total Sulphur	Sulphate Sulphur
	Acid P ppm P	Bicarb P ppm P	m. equiv. %	Copper ppmCu	Zinc ppmZn	Manganese ppmMn	%	%	%	ppm S
Cm(B3)	535 very high	61 high	1.4 very high	2.2 medium	0.5 low	12 medium	0.18 medium	2.0 medium	0.030 medium	3 very low
Cm(D2)	510 very high	45 high	1.4 very high	1.9 medium	0.4 low	7 medium	0.16 medium	1.8 medium	0.027 medium	1⁻ very low
CmCp(F1)	475 very high	83 high	1.4 very high	2.9 medium	0.7 low	20 medium	0.18 medium	2.1 medium	0.031 medium	2 very low
Iv(C5)	255 very high	10 low	1.1 very high	1.7 medium	0.3 low	5 medium	0.15 medium	1.6 medium	0.026 medium	4 very low

After Bruce and Rayment (1982)

Table 8. Profile trends of selected fertility data (40°C air dry basis)

Depth m	Organic Carbon %				Total Nitrogen %				Phosphorus-Bicarb. extr. P ppm				Sulphate-Sulphur S ppm			
	Cm(B3)	Cm(D2)	CmCp(F1)	Iv(C.5)	Cm(B3)	Cm(D2)	CmCp(F1)	Iv(C.5)	Cm(B3)	Cm(D2)	CmCp(F1)	Iv(c.5)	Cm(B3)	Cm(D2)	CmCp(F1)	Iv(C.5)
0-0.1	1.8	1.7	1.9	1.9	0.18	0.16	0.18	0.15	60	42	84	14	3	1	2	6
0.2-0.3	1.5	1.4	2.0		0.12	0.11	0.15		8	15	71		5	1	3	7
0.5-0.6	1.4	0.9	1.5	1.1	0.08	0.08	0.11	0.08	4	10	77	5	3	1	2	5
0.8-0.9	1.2	0.7	1.1		0.06	0.04	0.08			8	36		3	3	7	7
1.1-1.2	0.5	0.2	0.2	0.9	0.03	0.01	0.01	0.05		10	12	2	7	3	10	13
1.4-1.5	0.3	0.2	0.2	0.4	0.01	0.01	0.02	0.02	7	9	10	2	8	15	5	15

LAND USE

Soil moisture

From the figures in Table 1 it can be seen that moisture (water availability) is the major limiting factor to crop production. The combination of high evaporation, erratic rainfall distribution and sometimes high intensity rainfall with associated high runoff, tends to reduce the effectiveness of rainfall to about half the total precipitation (Douglas 1977).

Due to these features and in spite of the summer dominant rainfall, crop production in the area is based on winter growing cereals. This is possible because of the ability of the clay soils to store summer rainfall under bare cultivation.

Soil management

In all profiles examined a compacted plough pan 0.1 to 0.2 m thick was observed 0.05 to 0.1 m below the surface. The effects of compaction on yield are uncertain, but restricted barley root penetration was observed during the survey. Deep ripping through the relatively dry plough pan may help break up this layer allowing improved root penetration and water infiltration. Irrigation may aid compaction as the soils may not get the opportunity to dry out sufficiently for deep cracks to develop and break up the plough layer.

The coarse self mulching phase of Craigmore is expected to cause low germination due to poor soil-seed contact. The application of gypsum may reduce the self mulching granule size and improve germination.

Even though slopes are gentle (1 to 2%), erosion gullies are forming in some areas. The use of cover crops to control soil loss from the interbank areas is recommended during the summer storm period. Incorporation of organic matter should also assist in reducing erosion as well as helping to reduce the density of the compacted plough layer.

From the soil analysis, all soils should respond to zinc and nitrogen fertilisers. Irving and Yargullan are expected to respond to P application and Craigmore soils also need P to overcome any short distance variability. Craigmore is also likely to show a sulphur response although all soils will require maintenance applications of sulphur.

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REFERENCES

Ahern, C.R., Shaw, R.J. and Thorburn, P.J. (1984), 'Difference in chemical and physical properties between soil layers of dark earths on alluvia in the Lockyer Valley, Queensland.' *Proceedings of the National Soils Conference,* . Brisbane, Australia p. 180 Queensland.

Baker, D.E., Rayment, G.E. and Reid, R.E. (1983), 'Predictive relationships between pH and sodicity in soils of tropical Queensland'. *Communications in Soil Science and Plant Analysis,* Volume 14, 11 : 1063-1073.

Bruce, R.C. and Rayment, G.E. (1982), 'Analytical methods and interpretations used by the Agricultural Chemistry Branch for soil and land use surveys', *Queensland Department of Primary Industries*, Bulletin QB82004.

Cranfield, L.C., Schwarzbock, H. and Day, R.W. (1976), 'Geology of the Ipswich and Brisbane 1:250 000 sheet areas'. *Queensland Department of Mines, Geological Survey of Queensland Report Number 16.*

Douglas, N.J. (1977), 'Jondaryan Shire Handbook. An Inventory of the Agricultural Resources and Production of Jondaryan Shire, Queensland', Queensland Department of Primary Industries.

FAO-Unesco (1974), *'Soil map of the world. 1:5 000 000 Volume 1 Legend'.* Food and Agricultural Organisation of the United Nations.

Gardner, E.A. and Coughlan, K.J. (1982), 'Physical factors determining soil suitability for irrigated crop production in the Burdekin-Elliott River area'. *Queensland Department of Primary Industries, Agricultural Chemistry Branch, Technical Report Number 20.*

McDonald, R.C. (unpublished), 'Soil type proposal'.

McDonald, R.C. and Isbell, R.F. (1984), Soil profile in *Australian Soil and Land Survey Field Handbook* (McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S.) (Inkata Press, Melbourne).

Mullins, J.A. (1978), 'Description and Management of the soils of the Eastern Darling Downs', *Queensland Department of Primary Industries, Division of Land utilisation, Technical Bulletin Number 33.*

Northcote, K.H. (1979). *A Factual Key for the Recognition of Australian Soils*, 4th Edition (Rellim Technical Publications: Glenside, South Australia).

Northcote, K.H. and Skene, J.K.M. (1972), 'Australian soils with saline and sodic properties', *CSIRO Division of Soils, Soil Publication Number 27.*

Olson, G.W. (1973), 'Soil survey interpretation for engineering purposes', *FAO Soils Bulletin Number 19.*

Oyama, M. and Takehara, H. (1967), *Revised Standard Soil Colour Charts,* (Fujihira Industry Co. Ltd.: Tokyo).

Powell, B. (1979), 'Soils of the Kalbar district, south-east Queensland'. Queensland Department of Primary Industries, *Agricultural Chemistry Branch, Technical Report Number 16.*

Powell, B., Baker, D.E. and Christianos, N.G. (1985), 'Soils of the Mutdapilly Research Station', *Queensland Department of Primary Industries Bulletin* QR85001.

Raupach, M and Tucker, B.M. (1959), 'The field determination of soil reaction', *Journal of the Australian Institute of Agricultural Science* 25, 129-133.

Rayment, G.E. (1983), 'Prediction of response to sulphur by established Siratro/grass pastures in south-east Queensland', *Australian Journal of Experimental Agriculture and Animal Husbandry* 23, 280-287.

Reeve, R., Thompson, C.H. and Beckmann, G.G. (1960), 'The laboratory examination of soils from the Toowoomba and Kurrawa areas, Darling Downs, Queensland' *CSIRO Australia, Division of Soils,* Divisional Report 1/60.

Shaw, R.J. and Dowling, A. (1985), 'Principles of landscape, soil and water salinity - processes and management options'. In 'Landscape, soil and water salinity Lockyer-Moreton regional workshop'. *Queensland Department of Primary Industries Conference and Workshop Series* QC85004.

Shaw, R.J. and Yule, R.F. (1978), 'The assessment of soils for irrigation, Emerald, Queensland', *Queensland Department of Primary Industries, Agricultural Chemistry Branch, Technical Report Number 13.*

Soil Survey Staff (1951), 'Soil Survey Manual', *United States Department of Agriculture, Agriculture Handbook Number 18* (United States Government Printer: Washington DC).

________________ (1975), 'Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys', *United States Department of Agriculture, Agriculture Handbook* 436 (United States Government Printing Office: Washington DC).

Stace, H.C.T., Hubble, G.D., Brewer, R., Northcote, K.H., Sleeman, J.R., Mulcahy, M.J. and Hallsworth, E.G. (1968), *A Handbook of Australian Soils*, (Rellim Technical Publications: Glenside, South Australia).

Thompson, C.H. and Beckmann, G.G. (1959), 'Soils and Land Use in the Toowoomba Area, Darling Downs, Queensland', *CSIRO Australia, Division of Soils, Soils and Land Use Series Number 28.*

_________________________________ (1982), 'Gilgai in Australian Black Earths and some of its effects on plants', *Tropical Agriculture (Trinidad)*, 59, 149-156.

Thorburn, P.J. and Shaw, R.J. (in prep.). Comparison of routine particle size analysis methods.

Whitehouse, M.J. (1971), 'Queensland Wheat Research Institute Annual Report 1970-71', p. 31-33.

APPENDIX I

Detailed morphological descriptions of soil types

Notes:

General: Soil types are presented in the same order as in the map reference.

Soil Profile Morphology:

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

(ii) Self mulch: fine = 2 to 5 mm diameter granules
medium = 3 to 10 mm diameter granules
coarse = 5 to 15 mm diameter granules

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

(iv) Horizon Nomenclature: As per McDonald and Isbell (1984).

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

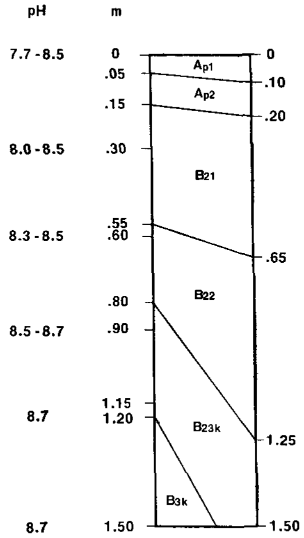
(vi) Texture: As per McDonald and Isbell (1984).

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

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

(ix) Field pH: As per Raupach and Tucker (1959) and Soil Survey Staff (1951).

Soil Type	P.P.F.	Profile Diagram	Description of the Soil Type	Landscape Unit
		Black earth:		
Craigmore	Ug5.15		Surface condition. strongly self mulching (medium to coarse), few to common basaltic cobbles in patches	Very gently inclined alluvial fan.



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

Ap2 horizon (plough pan): Dark (10YR 2/1, 3/1); medium to medium heavy clay, weak 20-50 mm blocky, hard (moist). Clear or abrupt to -

B21 horizon. Dark (10YR 1/1, 2/1); medium to medium heavy clay; moderate 10-20 mm blocky, slightly hard (moist). Clear or gradual to -

B22 horizon: Dark (10YR 1/1, 2/1, 3/1) occasional deeper brown mottles; medium to medium heavy clay; moderate to strong 10-50 mm lenticular, slightly hard (moist). None to small amounts of soft and concretionary carbonate. Colour and carbonate sub horizons common. Abrupt to -

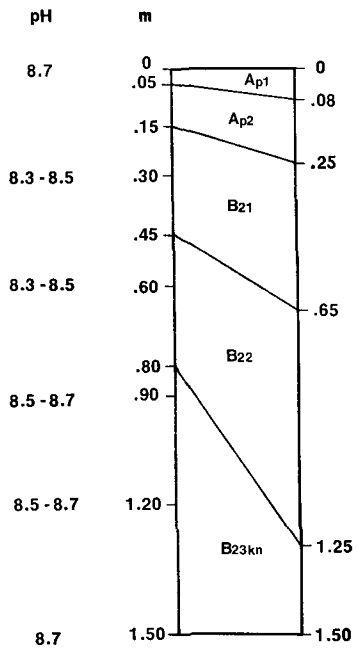
B23k horizon: Brown (7.5YR 3/3, 4/3, 4/4) to red-brown (5YR 3/3, 4/3, 4/4); medium to medium heavy clay, moderate to strong 10-50 mm lenticular, slightly hard (moist). Small to moderate amounts of soft and concretionary carbonate and commonly manganese (B23kn). Sub horizons due to colour, mottling, texture common.

B3k horizon Light to light medium clay, strong 10-20 mm lenticular or blocky; 2-15% basalt and/or ferruginous fragments. Then as above.

Variants:
- Ap1 - 10YR 2/2; light medium clay
- Ap2 - 10YR 2/2
- B21 - 10YR 2/2, lenticular structure, abrupt to
- B22 - Upper boundary 0.70 m, lower boundary 1.40 m
- B23k - 7.5YR 3/2 (Ug5.1), 7.5YR 5/3 (Ug5.16), 10YR 4/2 (Ug5.16) Occurs closer to surface (mound) probably as curving tongues (see Thompson and Beckmann, 1982). 2-15% basalt and ferruginous fragments.
- B3k - Sandy clay, strong prismatic

Note: Variation in soil properties is presumed to relate to linear gilgai patterns. Surface gilgai features have been obliterated by long term cultivation.

Soil Type	P.P.F.	Profile Diagram	Description of the Soil Type	Landscape Unit
Irving	Ug5.15	Black earth:	Surface condition: strongly self mulching (fine); occasional carbonate nodules; few to common basaltic cobbles in patches	Very gently inclined alluvial fan



Ap1 horizon: Dark (10YR 2/1, 3/1); medium to medium heavy clay; strong 2-5 mm granular; slightly hard (slightly moist). Abrupt to -

Ap2 horizon (plough pan): Dark (10YR 2/1, 3/1); medium to medium heavy clay; weak 10-50 mm blocky; hard (moist). Gradual or abrupt to -

B21 horizon: (Dark (10YR 1/1, 2/1); medium to medium heavy clay; moderate 10-50 mm blocky; slightly hard (moist). Clear or gradual to -

B22 horizon: Dark (10YR 1/1, 2/1); medium to medium heavy clay; moderate 10-20 mm lenticular; slightly hard (moist). Trace amounts of soft carbonate. Clear to -

B23kn horizon: Brown (7.5YR 4/3) to red brown (5YR 4/3, 4/4); medium to medium heavy clay; moderate 10-20 mm lenticular; slightly hard (moist). Small to large amounts of soft carbonate and manganese. Occasional basalt and bole fragments more often associated with red brown colour.

Sub horizons due to colour, texture, structure and fragments common.

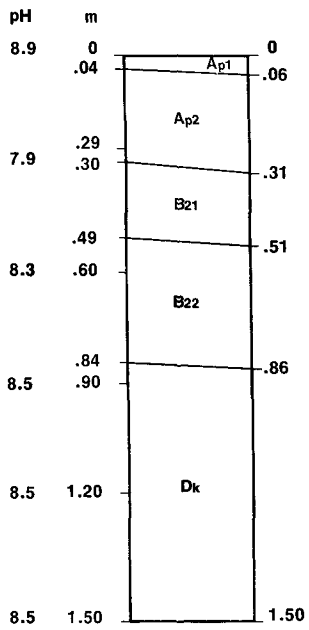
Variants:
- B21 - 10YR 3/2; trace soft carbonate
- B22 - 7.5YR 4/3; lower boundary 1.5 m; grey mottle at depth
- B23kn - light clay; occurs closer to surface (mound), probably as curving tongues (see Thompson and Beckmann 1982); grey (10YR 4/2) with dark mottle

Note: Variation in soil properties is presumed to relate to linear gilgai patterns. Surface gilgai features have been obliterated by long term cultivation.

Soil Type	P.P.F.	Profile Diagram	Description of the Soil Type	Landscape Unit

Black earth:

Yargullen deep variant — Ug5.11



Surface condition: strongly self mulching (fine); carbonate nodules common

Ap1 horizon: Dark (10YR 3/1) medium heavy clay; strong 2-4 mm granular; slightly hard. Clear to -

Ap2 horizon (plough pan): Dark (10YR 3/1) medium heavy clay; moderate coarse blocky; slightly hard. Trace amounts soft carbonate. Clear to -

B21 horizon: Dark (10YR 2/1) medium heavy clay; moderate blocky; slightly hard. Trace amounts of soft carbonate. Gradual to -

B22 horizon: Dark (10YR 2/1) with grey mottle; medium heavy clay, moderate lenticular; slightly hard. Small amounts of soft carbonate. Clear to -

Dk horizon: Brownish Yellow* (7.5YR 8/4) with red mottle; light medium clay; strong lenticular; slightly hard. Large amounts of soft carbonate (marly clay).

Note: Typical Yargullen soil is shallower than this with marly clay at 0.35-0.65 m.

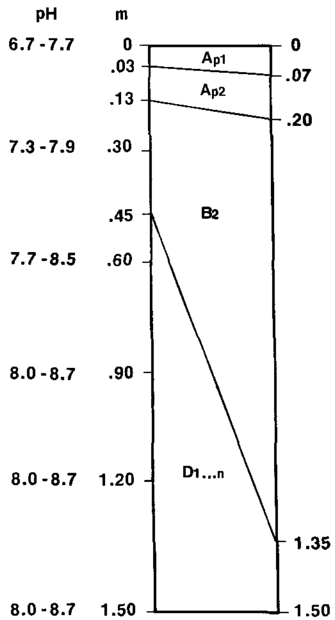
Landscape Unit: Very gently inclined alluvial fan

* Coventry and Robinson (1981)

Soil Type	P.P.F.	Profile Diagram	Description of the Soil Type	Landscape Unit

Black Earths and Prairie Soil:

Miscellaneous - recent alluvium Ug5.17 Uf6.32



Surface condition: strongly self mulching (medium)

Ap1 horizon: Dark (10YR 2/1, 3/1); medium to medium heavy clay; strong 2-10 mm granular; slightly hard (slightly moist). Clear to -

Ap2 horizon (plough pan): Dark (10YR 2/1, 3/1); medium to medium heavy clay; weak 20-50 mm blocky; hard (moist). Clear to -

B2 horizon: Dark (10YR 1/1, 3/1-3); medium to medium heavy clay; moderate 10-20 mm blocky to lenticular; slightly hard (moist). Trace amounts concretionary carbonate. Sub horizons due to colour, texture and structure common. Clear or gradual to -

D1...n horizons: Dark (7.5YR 3/2) to brown (7.5YR 3/3); coarse sandy loam to medium clay; single grain to prismatic or blocky; slightly hard (moist). Trace amounts concretionary carbonate and manganese. Occasional basalt and bole gravel or fragments. Sub horizons due to colour, texture and structure common. Buried soils (AB profiles) may be evident.

Landscape Unit: Very gently inclined alluvial fan

APPENDIX II

Morphology and analysis of representative profiles

Notes:

Soil Profile Morphology: As per notes (ii) and (iv) to (ix) in Appendix I.

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

Soil Type: Craigmore

Great Soil Group: Black earth

Parent Material: Basaltic alluvium-colluvium

Topography: 0.5% lower slope of very gently inclined alluvial fan

Map Unit: Cm

Soil Taxonomy: Typic Pellustert

A.M.G. Ref: 387625 mE,6950105 mN

Location: Q.W.R.I. Experimental Farm, Wellcamp

Site No: B3

P.P.F.: Ug5.15

Vegetation: None

Profile Morphology: Surface: strongly self mulching (medium); basalt cobbles common

Ap_1	0-0.07 m	Dark (10YR 3/1); medium clay; strong 3-10 mm granular; slightly hard (slightly moist). Abrupt to -
Ap_2 (plough pan)	0.07-0.15 m	Dark (10YR 3/1); medium clay; weak 20-50 mm blocky; hard (moist). Clear to -
B_{21}	0.15-0.6 m	Dark (10YR 2/1); medium clay; moderate 10-20 mm blocky; slightly hard (moist). Clear to -
B_{22}	0.6-1.1 m	Dark (10YR 2/1); medium heavy clay; moderate 10-20 mm lenticular; slightly hard (moist). Abrupt to -
$B_{23}kn$	1.1-1.4 m	Brown (7.5YR 4/3); medium heavy clay; moderate 10-20 mm lenticular; slightly hard (moist). Moderate amounts of soft carbonate and manganese. Clear to -
B_3kn	1.4-1.8 m	Red-brown (3YR 3/3); light medium clay; moderate 10-20 mm lenticular; soft (moist). Moderate amounts of soft carbonate and manganese; 2-15% basalt and ferruginous fragments.

Laboratory Data:

Lab.No.	Depth m	pH 1:5	E.C.(1:5) $mScm^{-1}$	Cl %	Dispersion Ratio (R_1)	C.S.	F.S.	Si	C	C.E.C.	Ca^{++}	Mg^{++}	Na^+	K^+	P	K	S	Moisture % A.D.	Moisture % 15 bar
						Particle Size % O.D.				Exch. Cations m. equiv/100 g O.D.					% O.D.				
7293	0-0.1	8.0	0.07	0.002	0.52	2	13	17	66	74	36	27	0.19	1.8	.152	0.83	.030	13.0	32
7294	0.2-0.3	8.3	0.09	0.002	0.52	1	13	15	69	81	41	30	0.41	0.77	.156	0.77	.027	14.2	36
7295	0.5-0.6	8.5	0.08	0.002	0.62	1	13	19	68	72	35	33	0.83	0.63	.147	0.82	.019	14.9	37
7296	0.8-0.9	8.7	0.09	0.002	0.70	1	13	21	65	75	28	42	1.4	0.74	.119	0.77	.019	13.2	37
7297	1.1-1.2	9.0	0.18	0.002		5	19	21	55	55	14	39	1.7	0.42	.155	0.72	.008	10.1	
7298	1.4-1.5	9.2	0.19	0.002															

Lab.No.	Depth m	Org. C %	Tot. N %	Acid Extr. P ppm	Bicarb Extr. P ppm	Extr. K m.equiv/100g	Fe	Mn	Cu	Zn	SO_4-S ppm S
							D.T.P.A. Extr. ppm				
7292	0-0.1	2.0	0.18	535	61	1.4	18	12	2.2	0.5	3

Soil Type: Craigmore

Great Soil Group: Black earth

Parent Material: Basaltic alluvium-colluvium

Topography: 1.5% lower slope of very gently inclined alluvial fan

Vegetation: None

Map Unit: Cm

Soil Taxonomy: Typic Pellustert

A.M.G. Ref: 387800mE, 6950250mN

Location: Q.W.R.I. Experimental Farm, Wellcamp

Site No: D2

P.P.F.: Ug5.15

Profile Morphology: Surface: strongly self mulching (medium); occasional carbonate nodules.

Ap1	0-0.1 m	Dark (10YR 2/1); medium heavy clay; strong 3-10 mm granular; slightly hard (moist). Abrupt to -
Ap2 (plough pan)	0.1-0.2 m	Dark (10YR 2/1); medium heavy clay; weak 20-50 mm blocky; hard (moist). Clear to -
B21	0.2-0.6 m	Dark (10YR 2/1); medium heavy clay; moderate 10-20 mm blocky; slightly hard (moist). Clear to -
B22	0.6-0.8 m	Dark (10YR 2/1); medium heavy clay; moderate 10-20 mm lenticular; slightly hard (moist). Clear to -
B23	0.8-0.97 m	Dark (10YR 3/1); medium heavy clay; moderate 10-20 mm lenticular; slightly hard (moist). Small amounts of soft carbonate. Abrupt to -
B24 k	0.97-1.2 m	Brown (7.5YR 4/3); medium clay; moderate 10-20 mm lenticular; slightly hard (moist). Moderate amounts of concretionary carbonate. 2-15% basalt and ferruginous fragments. Clear to -
B31 k	1.2-1.6 m	Red-brown (5YR 3/3); light clay; moderate 10-20 mm blocky; soft (moist). Moderate amounts of concretionary carbonate. 2-15% basalt and ferruginous fragments. Clear to -
B32	1.6-1.8 m	Brown (7.5YR 4/3); light medium clay; strong 10-20 mm blocky; soft (moist). 2-15% basalt and ferruginous fragments.

Laboratory Data:

Lab.No.	Depth m	pH 1:5	E.C.(1:5) $mScm^{-1}$	Cl %	Dispersion Ratio (R_1)	C.S.	F.S.	Si	C	C.E.C.	Ca^{++}	Mg^{++}	Na^+	K^+	P	K	S	Moisture % A.D.	15 bar
						Particle Size % O.D.				Exch. Cations m. equiv/100 g O.D.					% O.D.				
7279	0-0.1	8.1	0.07	0.002	0.42	1	13	18	70	75	37	28	0.53	1.7	.148	0.85	.027	12.1	32
7280	0.2-0.3	8.3	0.07	0.003	0.43	1	12	18	71	70	33	35	0.73	0.78	.137	0.80	.021	13.2	36
7281	0.5-0.6	8.6	0.07	0.003	0.56	1	14	21	66	70	24	39	1.2	0.69	.129	0.89	.014	12.3	34
7282	0.8-0.9	8.9	0.20	0.003	0.59	4	14	21	66	71	18	44	2.4	0.54	.116	0.72	.010	11.9	33
7283	1.1-1.2	9.2	0.20	0.002		13	31	20	38	52	11	36	2.6	0.30	.149	0.68	.004	7.8	
7284	1.4-1.5	9.2	0.22	0.002															

Lab.No.	Depth m	Org. C %	Tot. N %	Acid Extr. P ppm	Bicarb Extr. P ppm	Extr. K m.equiv/100g	Fe D.T.P.A. Extr. ppm	Mn	Cu	Zn	SO_4-S ppm S
7278	0-0.1	1.8	0.16	510	45	1.4	12	7	1.9	0.4	1

Soil Type: Craigmore - coarse self mulching phase **Map Unit:** CmCp **Site No:** F1

Great Soil Group: Black earth **Soil Taxonomy:** Typic Pellustert **P.P.F.:** Ug5.15

Parent Material: Basaltic alluvium-colluvium **A.M.G. Ref:** 387975mE, 6950385mN

Topography: 1.5% lower slope of very gently inclined alluvial fan

Location: Q.W.R.I. Experimental Farm, Wellcamp

Vegetation: None

Profile Morphology: Surface: strong self mulching (coarse)

Ap1	0-0.1 m	Dark (10YR 2/1); medium clay; strong 5-15 mm granular; slightly hard (moist). Abrupt to -
Ap2 (plough pan)	0.1-0.2 m	Dark (10YR 2/1); medium clay; weak 20-50 mm blocky; hard (moist). Abrupt to -
B21	0.2-0.6 m	Dark (10YR 2/1); medium clay; moderate 10-20 mm blocky; slightly hard (moist). Clear to -
B22	0.6-1.0 m	Dark (10YR 2/1); medium clay; moderate 20-50 mm lenticular; slightly hard (moist). Abrupt to -
B23k	1.0-1.15 m	Brown (7.5YR 4/3); medium clay; moderate 20-50 mm lenticular; slightly hard (moist). Small amounts of soft and concretionary carbonate. Clear to -
B3k	1.15-1.6 m	Brown (7.5YR 4/4) with 5% dark mottle; light medium clay; moderate 10-20 mm blocky; soft (moist). Small amounts of soft and concretionary carbonate; 2-15% ferruginous fragments. Clear to -
D1	1.6-1.7 m	Brown (7.5YR 4/4); coarse sandy clay loam; moderate 10-20 mm prismatic; soft (moist). Trace amounts of soft manganese 15-50% basalt fragments. Clear to -
D2	1.7-1.8 m	Brown (7.5YR 4/3); light medium clay; strong 10-20 mm lenticular; soft (moist). Trace amounts of soft manganese.

Laboratory Data:

Lab.No.	Depth m	pH 1:5	E.C.(1:5) mScm⁻¹	Cl %	Dispersion Ratio (R1)	C.S.	F.S.	Si	C	C.E.C.	Ca++	Mg++	Na+	K+	P	K	S	Moisture % A.D.	15 bar
						Particle Size % O.D.				Exch. Cations m. equiv/100 g O.D.					% O.D.				
7272	0-0.1	7.1	0.06	0.002	0.47	2	11	20	70	79	31	29	0.94	1.8	.089	0.53	.031	10.3	33
7273	0.2-0.3	7.7	0.11	0.003	0.47	1	17	22	64	72	33	29	0.78	0.63	.078	0.51	.025	9.7	32
7274	0.5-0.6	8.0	0.09	0.003	0.56	2	11	20	69	77	28	36	1.6	0.67	.069	0.48	.019	11.6	36
7275	0.8-0.9	8.6	0.16	0.009	0.59	4	13	18	64	74	24	46	2.8	0.67	.065	0.49	.016		
7276	1.1-1.2	8.9	0.35	0.025		13	31	19	42	52	11	38	4.0	0.43	.064	0.45	.015	12.2	36
7277	1.4-1.5	9.0	0.49	0.047															

Lab.No.	Depth m	Org. C %	Tot. N %	Acid Extr. P ppm	Bicarb Extr. P ppm	Extr. K m.equiv/100g	Fe D.T.P.A. Extr. ppm	Mn	Cu	Zn	SO_4-S ppm S
7271	0-0.1	2.1	0.18	475	83	1.4	34	20	2.9	0.7	2

Soil Type: Irving (grey subsoil variant)

Map Unit: Iv

Site No: C.5

Great Soil Group: Black earth

Soil Taxonomy: Typic Pellustert

P.P.F.: Ug5.16

Parent Material: Basaltic alluvium-colluvium

A.M.G. Ref: 387670 mE, 6950370 mN

Topography: 1.5% lower slope of very gently inclined alluvial fan

Location: Q.W.R.I. Experimental Farm, Wellcamp

Vegetation: None

Profile Morphology: Surface: strongly self mulching (fine); carbonate nodules common

Ap1 0-0.05 m Dark (10YR 3/1); medium heavy clay; strong 2-5 mm granular; slightly hard (moist). Abrupt to -

Ap2 0.05-0.15 m (plough pan) Dark (10YR 3/1); medium heavy clay; weak 20-50 mm blocky; hard (moist). Clear to -

B21 0.15-0.65 m Dark (10YR 1/1); medium heavy clay; moderate 20-50 mm blocky; slightly hard (moist); trace amounts of soft carbonate. Clear to -

B22 0.65-0.8 m Dark (10YR 1/1); medium heavy clay; moderate 10-20 mm lenticular; slightly hard (moist). Trace amounts of soft carbonate. Clear to -

B23 0.8-1.25 m Dark (10YR 2/1) with 10% grey mottle; medium heavy clay; moderate 10-20 mm lenticular; slightly hard (moist); small amounts of soft carbonate. Abrupt to -

B24 kn 1.25-1.8 m Grey (10YR 4/2) with 10% dark mottle; medium heavy clay; moderate 10-20 mm lenticular; soft (moist); large amounts of soft carbonate and manganese.

Laboratory Data:

Lab.No.	Depth m	pH 1:5	E.C.(1:5) $mScm^{-1}$	Cl %	Dispersion Ratio (R_1)	C.S.	F.S.	Si	C	C.E.C.	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	P	K	S	Moisture % A.D.	Moisture % 15 bar
						Particle Size % O.D.				Exch. Cations m. equiv/100 g O.D.					% O.D.				
7286	0-0.1	8.7	0.12	0.003	0.39	3	9	17	74	85	60	25	0.40	1.7	.162	0.88	.026	13.1	38
7287	0.2-0.3	8.4	0.15	0.005	0.37	1	7	14	82	97	57	33	0.41	1.1	.136	0.75	.024	14.1	45
7288	0.5-0.6	8.7	0.15	0.004	0.58	3	8	12	76	89	43	43	0.75	0.70	.126	0.81	.015	19.1	42
7289	0.8-0.9	8.8	0.15	0.004	0.53	3	8	12	79						.120	0.89	.009	18.4	44
7290	1.1-1.4	8.9	0.20	0.004		5	8	11	74	86	20	57	2.1	0.75	.107	0.58	.006	15.7	
7290	1.4-1.5	9.1	0.23																

Lab.No.	Depth m	Org. C %	Tot. N %	Acid Extr. P ppm	Bicarb Extr. P ppm	Extr. K m.equiv/100g	Fe D.T.P.A. Extr. ppm	Mn	Cu	Zn	SO_4-S ppm S
7285	0-0.1	1.6	0.15	255	10	1.1	6	5	1.7	0.3	4

APPENDIX III

General ratings used for interpretation of soil chemical analyses (after Bruce and Rayment, 1982)

Analysis		Rating				
		Very Low	Low	Medium	High	Very High
EC	(mS cm^{-1})	<0.15	0.15-0.45	0.45-0.90	0.90-2.0	>2.0
Cl	(%)	<0.01	0.01-0.03	0.03-0.06	0.06-0.20	>0.20
P_A	(ug g^{-1})	<10	10-20	20-40	40-100	>100
P_B	(ug g^{-1})	<10	10-20	20-40	40-100	>100
Exch. K	(m. equiv. 100 g^{-1})	<0.1	0.1-0.2	0.2-0.5	0.5-1.0	>1.0
Extr. K	(m. equiv. 100 g^{-1})	<0.1	0.1-0.2	0.2-0.5	0.5-1.0	>1.0
Cu	(ug g^{-1})	<0.1	0.1-0.3	0.3-5	5-15	>15
Zn pH >7:	(ug g^{-1})	<0.3	0.3-0.8	0.8-5	5-15	>15
pH <7:	(ug g^{-1})	<0.2	0.2-0.5	0.5-5	5-15	>15
Mn	(ug g^{-1})	<1	1-2	2-50	50-500	>500
B	(ug g^{-1})	<0.5	0.5-1	1-2	2-5	>5
Total N	(%)	<0.05	0.05-0.15	0.15-0.25	0.25-0.50	>0.50
Org. C	(%)	<0.5	0.5-1.5	1.5-2.5	2.5-5.0	>5.0
SO_4-S	(ug g^{-1})	<5	5-10	10-20	20-100	>100
Total S	(%)	<0.005	0.005-0.02	0.02-0.05	0.05-0.10	>0.10
Total P	(%)	<0.005	0.005-0.02	0.02-0.05	0.05-0.10	>0.10
Total K	(%)	<0.1	0.1-0.5	0.5-1	1-3	>3
Sodicity	(ESP)	Non-Sodic		Sodic		Strongly sodic
		<6		6-14		>15