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SOILS OF THE REDLANDS HORTICULTURAL RESEARCH STATION

by
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Queensland Department of Primary Industries

Queensland Government Technical Report

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SOILS OF THE REDLANDS HORTICULTURAL RESEARCH STATION

B. Powell

1. INTRODUCTION

The Redlands Horticultural Research Station occupies a 60 ha block on the corner of Finucane Road and Delancey Street, Ormiston.

One third of the station consists of krasnozems which are the prime horticultural soils of the area, and from which the Redlands district takes its name. Most horticultural research is carried out on these soils. Beckmann (1967) named and mapped these and associated minor soils as the Redlands soil association.

The remaining two-thirds of the station carries red and yellow podzolic soils of the Woodridge soil association (Beckmann 1967). These soils are less favourable for horticulture but are representative of the 'grey' horticultural soils used in the district. The local name of "grey soils" comes from the colour of the surface soil. Although less suitable for cropping, some soils are better than others.

The station is soon to be the site for expansion of facilities for other branches of the Department of Primary Industries. To aid decisions on locating facilities and experimental plots, a survey was needed to identify and map the different soils.

2. PHYSICAL ENVIRONMENT

2.1 Climate

The Redlands Research Station has a summer dominant rainfall pattern with two-thirds of the annual precipitation usually falling from November to April inclusive.

Although Table 1 shows a mean of 1322 mm rainfall per year, precipitation has varied from 596 mm in 1957 to 2480 mm in 1974.

Because of its close proximity to the coast, temperatures are mild. Only on rare occasions do temperatures exceed 32°C or drop below 5°C. Terrestrial minimum temperatures of minus 2 or 3°C are recorded once or twice a year. Frost damage to tender crops occasionally occurs in the lower areas, but only once in the history of the station have crops on the higher parts been damaged.

TABLE 1

Mean climatological data for the Redlands Horticultural Research Station

Month	Rainfall mm	Temperatures °C Atmospheric Maximum	Atmospheric Minimum	Terrestrial Minimum	Approximate Pan Evaporation mm
January	175	27.9	19.8	17.0	160
February	198	27.9	19.8	16.9	150
March	179	27.2	18.6	15.7	120
April	107	25.3	15.6	12.4	100
May	89	22.6	12.2	8.3	75
June	95	20.6	9.7	6.3	70
July	69	19.6	8.0	4.3	70
August	45	20.9	8.2	4.2	90
September	43	22.7	10.8	7.3	105
October	97	24.7	14.2	11.0	140
November	93	26.3	16.8	13.6	170
December	132	27.6	18.6	15.6	195
Annual	1322				1410

2.2 Geology and Topography

Small scale maps by Cranfield *et al.* (1976) at 1:250 000 and Willmott *et al.* (1978) at 1:100 000 show three geological units on the Research Station.

The oldest rocks occur as convex low hills derived from the Woogaroo Subgroup of the Bundamba Group. These are pre-weathered sandstones, siltstones, shales and conglomerates of Triassic - Jurassic age. The low hills are mainly of sandstone with 5-10% slopes and a relative relief of 22 m.

The Woogaroo Subgroup is separated from Tertiary basalt by Hilliards Creek. The Tertiary basalt is deeply lateritized and appears as krasnozems on broadly convex low hills with 3-6% slopes and 15 m relative relief.

Along most of its length in the research station, Hilliards Creek hugs closely to the edge of the basalt and has formed a narrow creek flat extending into the Woogaroo Subgroup.

Soils developed on the Quaternary alluvium of the creek flat have similar morphology to some of the soils derived from the Woogaroo subgroup (Queen and Woodridge). This suggests that the Woogaroo subgroup is the main source of the creek flat alluvium. However the high sodium content of the subsoil clay of the alluvium and the fine sandy to silty nature of the soil texture also suggest an estuarine influence. The creek flat was designated as Cainozoic estuarine sediments in the geology maps. These are sediments of mud, silt, clay, fine grained sand and gravel, with minor peat and coral debris, which were deposited behind the coastal dunes and in the lower sections of major river valleys and up creek lines, probably during periods of fluctuating sea level in the Pleistocene (Willmott *et al.* 1978).

The station is close to Moreton Bay and only 37 m above sea level at its highest point (on sandstone), and 15 m above sea level at its lowest point on the Hilliards Creek flat.

2.3 Vegetation

Common and scientific names of all species are given in Appendix 1 for quick reference.

Most of the research station is still natural woodland with only 12 ha cleared and cropped, mostly on the more productive krasnozems.

The small remnants of native vegetation that remain on the krasnozem (Redlands) consist of open forest. The tree layer (20 - 25 m) is dominated by scribbly gum (*Eucalyptus signata*) with pink bloodwood (*E. intermedia*) subdominant and patchy occurrences of narrow-leaved ironbark (*E. crebra*). Underneath is a low tree layer (15 m) of sparse black sheoak (*Casuarina littoralis*) and occasional smudgee (*Angophora woodsiana*) and rusty gum (*A. costata*).

The ground layer is dominated by blady grass (*Imperata cylindrica* var. *major*) and bracken fern (*Pteridium esculentum*) with wire grass (*Aristida calycina*) and *Lomandra multiflora* common.

Other species include kangaroo grass (*Themeda australis*) native grape (*Cissus opaca*), red ash (*Alphitonia excelsa*), *Entolasia stricta* and *Desmodium rhytidophyllum*.

On the yellow podzolic soils (Woodridge and Queen), woodland dominated by scribbly gums 10-15 m tall occurs. Smudgee, red mahogany (*E. resinifera*) and small-fruited bloodwood (*E. trachyphloia*) are also present.

A patchy tall shrub layer (3 - 6 m) of black sheoak is evident.

The ground layer contains at least twelve species with a sedge (*Ptilanthelium deustum*), kangaroo grass, *Tricoryne elatior, Hibbertia stricta* sens lat. and *Entolasia stricta* the most frequent species. Also present are queen of the bush (*Pimelea linifolia*), sundew (*Drosera sp.*), *Goodenia rotundifolia* and *Acrotriche aggregata*.

On the gradational red and yellow podzolic soils, a tall woodland community is present. Occasional 30 m-tall tallowwoods (*E. microcorys*) tower over the remaining 10 - 20 m tall trees. Small fruited bloodwoods and scribbly gums are most frequent with minor numbers of pink bloodwoods, swamp mahogany (*Tristania suaveolens*) and brush box (*T. conferta*) evident.

A 2 - 3 m shrub layer of black sheoak is seen very occasionally. Red ash (*Alphitonia excelsa*) and geebung (*Persoonia cornifolia*) occur sporadically.

Most frequent ground cover species are kangaroo grass, bracken fern, blady grass and *Lomandra multiflora*. Also present are *Hibbertia stricta* sens lat., *Entolasia stricta*, and *Lomatia silaifolia*.

The sandy yellow podzolic soils with deep A-horizons (Delancey) have plant communities intermediate between the woodland and tall woodland described above.

The poorly drained gleyed soloths bordering Hilliards Creek support a woodland plant community of stunted trees (5 - 10 m) and water-loving species.

Swamp mahogany, rusty gum and paperbark tea trees (*Melaleuca sieberi, M. quinquinervia*) are the most frequent species. Scribbly gums (5 - 10 m), small fruited bloodwoods (15 m), narrow-leaved red gum (*E. seeana*) (15 m) and smudgee are occasionally seen.

Broad-leaved banksias (*Banksia robur*) are frequent in drainage line depressions.

Ground cover species include a wild may (*Leptospermum flavescens*), blady grass, long-leaved mat rush (*Lomandra longifolia*), kangaroo grass, *Velleia spathulata* and *Pimelea linifolia*.

3. SOIL SURVEY METHOD

Descriptions were made of 74 soil profiles located on a 100 m square grid. Six soil profile classes were identified and mapped at a scale of 1:5 000.

Soil profile classes were given names of local significance or the Beckmann (1967) soil association name where the soil description reasonably matched the dominant soil e.g. Redlands, Woodlands.

Sampling for laboratory analysis was carried out on 4 soil profiles. Profiles were sampled in 10 cm increments to 150 cm and a bulk of ten 0 - 10 cm samples was collected with each profile. Analyses were carried out according to the methods described by Bruce and Rayment (1982) as follows:-

Bulked 0 - 10 cm	:	Organic C, total N, acid P, bicarb. P, extr. K, DTPA Fe, Mn, Cu, Zn.
All profile samples	:	pH, chloride, E.C.
Profile 0-10 cm, 20-30 cm, 50-60 cm, 80-90 cm, 140-150 cm	:	Dispersion ratio, particle size, CEC, exchangeable cations, total P, K and S, A.D. moisture, $^1/_3$ and 15 bar water.
Profile 110 - 120 cm	:	as above minus dispersion ratio, $^1/_3$ and 15 bar water.
Profile 10 - 20 cm	:	Organic C, total N, acid P, bicarb. P, extr. K.

4. SOILS - MORPHOLOGY AND CLASSIFICATION

4.1 Morphology

Detailed soil profile class descriptions are given in Appendix 2. The general features of the soils are described below.

4.1.1 Krasnozems

Redlands is a typical krasnozem in having a brown moderately to strongly structured clay loam A_1 horizon grading into a deep, acid, red, strongly structured clay subsoil. Variable amounts of ferruginous or ferromanganiferous nodules are found occasionally in the profile. Faint yellow, red and grey mottling occurs at depth in some lower slope positions. Occasionally horizons of lighter texture (loam to clay loam) occur at depth in the profile.

The surface of virgin krasnozems is usually a brown strongly structured clay loam but under cultivation it becomes redder, cloddy, weakly structured, and heavier in texture (light-medium clay).

4.1.2 Red and yellow podzolic soils

The podzolic soils derived from pre-weathered Jurassic sediments (the Woogaroo subgroup) have hardsetting light grey surfaces when dry, with occasional outcrops of hard ferruginous and siliceous weathered rock fragments. Soils on sandstone have sandy A horizons while those on shale are finer textured (loam to clay loam).

All soils have weakly structured or massive A horizons and usually include a conspicuously bleached A_2 horizon. Occasionally this A_2 horizon hardens to form a fragipan. Deep yellow A_3 horizons are common in the better drained soils (Coburg and Delancey).

Woodridge and Queen are yellow podzolic soils which show poorer drainage characteristics, compared to Delancey (a yellow podzolic soil) and Coburg (a red podzolic soil). The former soils have an A horizon 10 - 50 cm deep clearly overlying a yellow moderately structured clay B horizon while the latter two soils have A horizons to 40 - 70 cm gradually overlying a yellow or red loam to clay B horizon.

The B horizons of all three yellow podzolic soils become yellow and red, or grey and red mottled and often heavier textured with depth. In contrast, the red podzolic soil (Coburg) B horizon becomes redder and lighter textured with depth.

Soils are generally very deep (>120 cm) except where rocks outcrop (see map) and where moderately deep (90 - 120 cm) Delancey profiles occur.

The grey and red mottled clay material in the lower subsoil resembles the mottled zone of a laterite profile. Occasionally a virtually mottle free pallid zone occurs below the mottled zone.

4.1.3 Silty soloths

The very poorly drained silty soloths (Hilliards) of the Hilliards Creek flat also have hardsetting light grey surfaces when dry, with massive silty or fine sandy A horizons. There is a conspicuously bleached A_2 horizon clearly or abruptly overlying a grey or yellow-brown clay B horizon becoming mottled with depth. The B horizon is commonly underlain by a buried soil profile with a massive conspicuously bleached A_2 horizon and mottled yellow and grey clay B horizon.

In some areas of the silty soloths there are low hummock formations 20 to 40 cm apart with tussock sedges growing on the peaks. Several explanations can be suggested for this, including fauna (freshwater cray fish), flora (fibrous mat of roots combined with siltation), or differential siltation and erosion during prolonged seasonal flooding. In northern Australia these phenomena are termed Debil-Debil.

4.2 Classification

In the map legend, soils are classified into great soil groups (Stace *et al.* 1968) and principal profile forms (Northcote 1979).

Hilliards has the morphological features compatible with a gleyed podzolic soil but has been classified as a soloth because of its high subsoil exchangeable sodium (ESP of 25). In comparison, a gleyed podzolic sampled on alluvium on nearby Epripah Creek had a subsoil ESP of only 2 - 3% (Beckmann and Reeve 1972).

Reference soil profiles analysed in the laboratory and described in Appendix 3 are also classified to Soil Taxonomy subgroup (Soil Survey Staff 1975).

In Appendix 3 soil horizons have been classified for engineering purposes according to the Unified Soil Classification (Olson 1973). All krasnozem horizons are MH whereas the yellow podzolics and soloths have SM or ML A horizons, CL or MH B horizons, and GC or GP C horizons.

5. SOILS - CHEMICAL AND PHYSICAL PROPERTIES

Profile descriptions and analytical results are given in Appendix 3 while interpretations are those of Bruce and Rayment (1982).

5.1 Fertility

The native fertility of the soils sampled is very low particularly the podzolic soils and the soloth. This would be expected for soils or their parent materials that have been exposed to considerable weathering and leaching. Most soils in this study had features resembling parts of the laterite profile (see glossary) which also suggests intensive leaching. Beckmann (1967) proposed that "All the sedimentary materials in the region have been through at least one cycle of weathering, erosion and deposition, and many may have been through several such cycles. As a result of this the parent materials of many of the soils have been progressively reduced in nutrients".

He also added that "Even the weathered basalts appear to be lower in nutrients than are many such materials of southern Queensland. This may partly be due to lateritizing processes, but may be partly the result of a low level of certain constituents in the unaltered rock".

The krasnozem is slightly more fertile than the podzolic soils and the soloth with adequate calcium and magnesium, medium nitrogen (0.2% total N) and medium potassium (0.42 m. equiv./100 g extr. K). With cropping this initial fertility will be lost and fertilizer needed. Sulphur, manganese, copper and zinc are also at medium levels in the krasnozem and generally higher than in the other soils.

The organic matter level of the krasnozem surface soil is high (4.0% organic C) compared to the podzolic soils (1.6 - 1.7%) and the silty soloth (2.0%). Accordingly the surface soil structure is also stronger in the krasnozem.

Podzolic soil profiles are strongly to medium acid (pH 5.3 - 6.1), and the krasnozem and soloth medium acid (pH 5.5 - 6.0).

Salt levels are very low throughout the profiles of all soils.

5.2 Physical Properties

Generally, clay activity (see Glossary) is <0.24 indicating that a low activity clay mineral, probably kaolinite, is the dominant clay mineral. An appreciable amount of sesquioxide is probably also present in both krasnozem (Redlands) and red podzolic (Coburg) B horizons. The B horizon of the Woodridge yellow podzolic has clay activity up to 0.34, which suggests the presence of other clay minerals.

The estimated available soil water capacity of the soils varies considerably. The krasnozem holds a low 6 - 9% gravimetric water throughout the profile. The Coburg red podzolic holds 11% water in the surface but only 5 - 7% at depth. The Woodridge yellow podzolic holds a high amount of available water in the surface (16%) and a fair amount at depth (9 - 12%). The latter figure is probably the result of clay minerals with a greater surface area for water retention. The Hilliards silty soloth has a very high available water (21%) at the surface with a fair amount at depth (10 - 11%). Organic matter is responsible for the higher surface available soil water.

All soils except the silty soloth have a low to moderate tendency to disperse. The soloth however, with an ESP of 25% shows a high tendency with dispersion ratios ranging from 0.79 to 0.94.

5.3 Exchangeable Cations

The krasnozem has a highly saturated clay B horizon, magnesium being the dominant metal cation, with moderate amounts of calcium present.

As found by Beckmann and Reeve (1972), the yellow podzolic soil (Woodridge) is acid (pH 5.3 - 5.5) with low cation exchange capacity in the clay B horizon (10 - 17 m. equiv/100 g soil). The dominant cations are usually hydrogen and magnesium with more sodium than calcium on the exchange complex. Base saturation of the B horizon is 34 - 56% which is higher than the 15 - 30% found by Beckmann and Reeve.

The Coburg red podzolic soil is similar to the yellow podzolic soil in that it is also acid (pH 5.3 - 5.9) and has very low B horizon cation exchange capacity (3 - 4 m. equiv./100 g soil). Magnesium is the only metal cation present in significant amounts and the cation exchange capacity is fully base saturated. Chemically and morphologically, Coburg closely resembles the 'podzolic' red earths of Beckmann and Reeve.

The Hilliards soloth is also acid (pH 5.4 - 5.6) with low cation exchange capacity (4 - 6 m. equiv./100 g soil) and high base saturation, magnesium being the dominant cation. Sodium is also higher in the B horizon with an ESP of up to 25%. As suggested in section 2.2, an estuarine influence may be responsible for the sodicity and high base saturation.

The meadow podzolic soil of the Eprapah soil association belonging to a similar landscape position (Beckmann and Reeve) has many similarities with Hilliards but has low base saturation and virtually no sodium. This may be due to weathering of the meadow podzolic soil since deposition and its subsequent elevation as a terrace. Meadow podzolic soils are the equivalent of the gleyed podzolic soils described in Stace *et al.* (1968).

Additional information on the soil chemical features of the region may be obtained from Beckmann and Reeve (1972).

6. SOIL SUITABILITY FOR CROPPING

The Redlands krasnozems have long been recognised as soils suitable for most crops. Before housing development took over in the district, these soils produced a substantial supply of Brisbane's market garden produce.

Although well drained, these soils have only a low available moisture range and require irrigation for good yields. Fertility is also low for the major essential plant nutrients.

Of the podzolic soils, Woodridge and Queen are least desirable from the point of view of good drainage. Their internal drainage is extremely variable and dependent on the depth to clay subsoil (10 - 50 cm). Delancey is better drained with a more uniform 40 - 65 cm of A horizon above the clay. The best drained soil however is Coburg with 50 - 70 cm of soil over a friable, very permeable clayey B horizon.

Queen would be slightly better for cropping than Woodridge as its finer A horizon would be expected to retain more moisture.

The low fertility levels of all podzolic soils indicate that heavy fertilizer inputs are required.

The silty soloths (Hilliards) have very poor internal and external drainage and are unsuitable for cropping. In addition their fine sandy or silty surface has a high tendency to crust and fertility levels are very low.

Summing up, the soils are ranked for their crop suitability as follows:

1. Redlands, 2. Coburg, 3. Delancey, 4. Queen, 5. Woodridge, 6. Hilliards.

7. GLOSSARY

Available soil water capacity: The amount of water (on a weight, volume or depth basis), between the moisture content of field capacity and permanent wilting point.

It was approximated in the laboratory by determining the difference between the equilibrium moisture contents at suctions of $^{1}/_{3}$ bar (sieved material <2 mm), and 15 bar (Beckmann *et al.* 1976).

Clay activity ratio: CEC/clay content (m. equiv./g of clay). It is a measure of the activity of the clay fraction (assuming that only clay particles contribute to CEC). From the values obtained, one may infer whether one has 2:1 or 1:1 clays dominant or mixtures of the two. Where organic matter makes a significant contribution to measured CEC, a corrected CEC can be calculated (Coughlan 1969).

Laterite: A term used for accumulations of "ironstone", either nodular or vesicular, often associated with red soil materials, and is usually regarded as being the result of long continued and/or intense leaching in association with ground-water movement in the course of which there has been a concentration of hydrated iron oxides and alumina. It is frequently associated with old surfaces of low relief and commonly occurs in a profile consisting of red highly ferruginous material (the "ferruginous zone") overlying a layer of mottled red and grey material (the "mottled zone"). (Beckmann 1967). Under the mottled zone a layer of grey material (the "pallid zone") may occur.

Soil profile class: A group or class of soil profiles, not necessarily contiguous, grouped on their similarity of morphological characteristics (Beckett 1971; Beckett and Burrough 1971; Beckett and Webster 1971; Burrough *et al.* 1971). As mapped they are representative of bodies of soil with similar parent materials, topography, vegetative structure and generally vegetation composition.

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Drafting section of the Division of Land Utilization drafted the map.

Bill McDonald of Botany Branch identified plant species and checked the vegetation section.

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APPENDIX 1

Vegetation - Common and Scientific Names

Common Name	Scientific Name
Trees	
Black sheoak	*Casuarina littoralis*
Brush box	*Tristania conferta*
Narrow-leaved ironbark	*Eucalyptus crebra*
Narrow-leaved red gum	*E. seeana*
Paper bark tea tree	*Melaleuca quinquinervia*
Paper bark tea tree	*M. sieberi*
Pink bloodwood	*Eucalyptus intermedia*
Red mahogany	*E. resinifera*
Rusty gum	*Angophera costata*
Scribbly gum	*Eucalyptus signata*
Small-fruited bloodwood	*E. trachyphloia*
Smudgee	*Angophera woodsiana*
Swamp mahogany	*Tristania suaveolens*
Tallowwood	*Eucalyptus microcorys*
Shrubs	
Black sheoak	*Casuarina littoralis*
Broad-leaved banksia	*Banksia robur*
Geebung	*Persoonia cornifolia*
Red ash	*Alphitonia excelsa*
Ground Cover	
Blady grass	*Imperata cylindrica*
Bracken fern	*Pteridium esculentum*
Kangaroo grass	*Themeda australis*

Long-leaved mat rush	*Lomandra longifolia*
Native grape	*Cissus opaca*
Queen of the bush	*Pimelea linifolia*
Sedge	*Ptilanthelium deustium*
Sundew	*Drosera sp.*
Wild may	*Leptosperinum flavescens*
Wire grass	*Aristida calycima*
	Acrotriche aggregata
	Desmodium rhytidophyllum
	Entolasia stricta
	Goodenia rotundofolia
	Hibbertia stricta sens. lat.
	Lomandra multiflora
	Lomatia silaifolia
	Tricoryne elatior
	Velleia spathulata

APPENDIX 2

Detailed Morphological Descriptions of Soil Profile Classes

Notes:

General: Soil profile classes are presented in the same order as in the map reference (legend).

Soil Profile Morphology:

(i) The most commonly observed range of profile attributes are 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 (1977). On the left of each profile diagram, each horizon is also given a Unified soil classification (Olson, 1973).

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

(v) Texture : As defined in Northcote (1979).

(vi) Structure : As per Soil Survey Manual (Soil Survey Staff 1951).

(vii) Consistence and horizon boundaries : As per Soil Survey Manual (Soil Survey Staff 1951).

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

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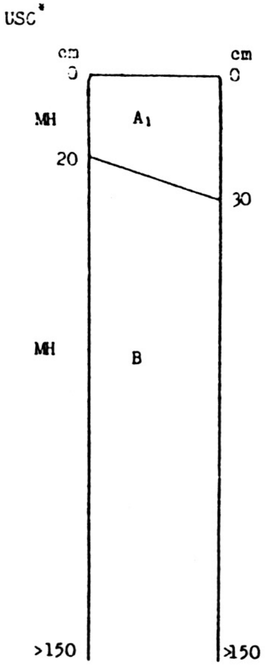
SOIL PROFILE CLASS: REDLANDS

PRINCIPAL PROFILE FORMS: Uf 6.31, Gn 3.11

SOIL PROFILE MORPHOLOGY:



Surface condition: loose in virgin state, becomes periodically hardsetting and cloddy when cultivated.

<u>A₁-horizon:</u> red brown to red (5YR - 2.5YR 3-4/3-4); clay loam (virgin) to medium clay; moderate to strong medium granular; friable to firm; medium to slightly acid (pH 5.7 - 6.2). Clear to -

<u>B-horizon:</u> red (2.5YR 4/4-6 - 10R 4/4) light clay to medium clay; strong fine blocky or polyhedral; firm to very firm; strongly to medium acid (pH 5.5 - 6.0).

Variations outside the above range:

Surface: ferruginous and ferromanganiferous gravel

A_1-horizon: dark (2.5YR 3/2); 0 - 15 cm deep; ferruginous or ferromanganiferous nodules

B_1-horizon: present in undisturbed sites

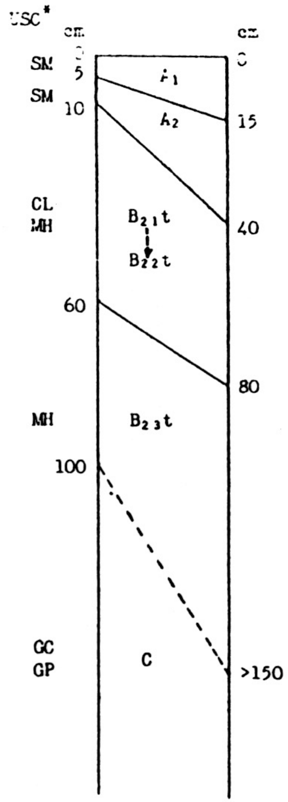
B_2-horizon: faint yellow mottle at depth; red and grey mottle below red yellow mottle; bright brown (2.5YR 5/8) at depth; ferruginous or ferromanganiferous gravel; medium-heavy clay; zones of loam to clay loam texture

* Unified Soil Classification (Olson 1973)

SOIL PROFILE CLASS: WOODRIDGE

PRINCIPAL PROFILE FORMS: Dy 2.41, Dy 3.41, Dy 4.41, Gn 3.04

SOIL PROFILE MORPHOLOGY



Surface condition: hardsetting

<u>A₁-horizon:</u> grey-brown (7.5YR 4-5/1-2, 5/3) to grey (10YR 4/1,2 - 5/1, 2, 3); sandy loam to sandy clay loam; weak fine granular to massive; very friable, small amounts of siliceous gravel; strongly to medium acid (pH 5.5 - 6.0). Clear to -

<u>A₂-horizon:</u> grey (10YR 5/1, 6-7/2) to yellow brown (10YR 7/3-4) (bleached when dry); sandy loam to sandy clay loam; massive; occasionally an earthy pan when dry; friable to very friable; small to medium amounts of siliceous gravel. Strongly to medium acid (pH 5.5 - 5.7). Abrupt to -

<u>B₂₁t-horizon:</u> yellow-grey to yellow (10YR 5/4-6, 6/3, 4) which becomes red mottled at depth ($B_{22}t$-horizon); light-medium to medium clay; blocky; firm to very firm; occasionally small amounts of siliceous and/or ironstone gravel; strongly acid (pH 5.1 - 5.5). Clear or gradual to -

<u>B₂₃t-horizon:</u> red (2.5YR - 10R 4-5/6) and grey (10YR 2.5Y 7/1, 8/1) mottled medium to heavy clay becoming less ret mottled with depth; blocky; very firm to extremely firm; very strongly to strongly acid (pH 4.5 - 5.5). Clear to -

<u>C-horizon:</u> hard ironstone and siliceous gravel.

Variations outside the above range:

Surface: loose

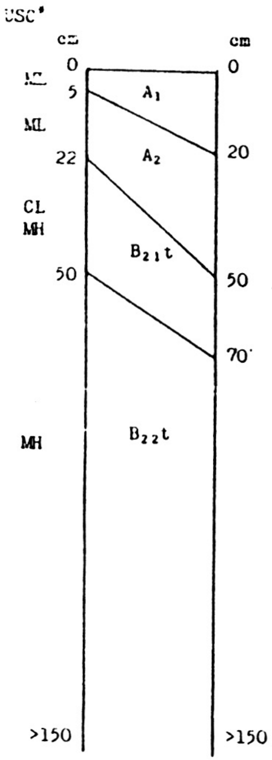
A-horizons: small to medium amounts of ferruginous gravel

$B_{21}t$-horizon: gritty medium clay; brown or yellow mottles at depth

SOIL PROFILE CLASS: QUEEN

PRINCIPAL PROFILE FORMS: Dy 2.41, Dy 3.41, Dy 2.21, Db 1.41

SOIL PROFILE MORPHOLOGY



Surface condition: hardsetting

A_1-horizon: dark (10YR 3/1-2) to grey-brown (7.5YR 4/1-10YR 4/2, 5/2-3); loam to clay loam; weak fine granular to massive; very friable to friable; occasionally small amounts of siliceous or ferruginous gravel; medium acid (pH 5.5 - 6.0). Clear to -

A_2-horizon: grey (10YR 6/2-4, 7/3, 8/2) (bleached when dry); loam to clay loam; massive, often earthy pan; friable; occasionally small amounts of siliceous or ferruginous gravel; strongly acid (pH 5.1 - 5.5). Abrupt to -

$B_{21}t$-horizon: yellow-grey (10YR 5/2-6, 6/4) to yellow (10YR 5-7/6) becoming red or grey mottled at depth; light-medium to medium clay; blocky; firm to very firm; occasionally small amounts of siliceous gravel; strongly acid (pH 5.1 - 5.5). Clear or gradual to -

$B_{22}t$-horizon: grey (10YR 5-7/1-2, 2.5Y 8/1) with red mottle; medium to heavy clay; blocky; very firm to extremely firm; occasionally small amounts of ferruginous or siliceous gravel; very strongly to strongly acid (pH 5.0 - 5.5).

Variations outside the above range:

A_1-horizon:	sandy clay loam; gravelly loam
A_2-horizon:	grey-brown (10YR 4/2) (unbleached when dry) with slight yellow mottle
$B_{21}t$-horizon:	brown (10YR 4/4); red mottle in upper 20 cm of horizon
B_{22}-horizon:	yellow (10YR 5/6) with red mottle; overlies stony material at 90 cm

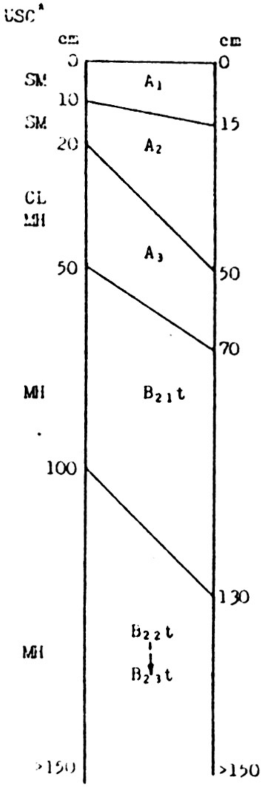
* Unified Soil Classification (Olson 1973)

SOIL PROFILE CLASS: COBURG

PRINCIPAL PROFILE FORMS: Gn 3.14, Gn 3.64, Gn 3.54, Dy 2.21, Dy 2.41

SOIL PROFILE MORPHOLOGY

Surface condition: moderately to weakly hardsetting or loose



A_1-horizon: grey-brown to grey (7.5YR - 10YR 4-6/2); sandy loam; weak fine granular; very friable; occasionally small amounts of ironstone gravel; medium to slightly acid (pH 5.8 - 6.2). Clear to -

A_2-horizon: yellow-brown (10YR 5-7/4, 6/3, 7.5YR 5-6/4-6); sandy loam to sandy clay loam; weak sub-angular blocky to massive; occasionally an earthy pan when dry; friable to very friable; occasionally variable amounts of ironstone gravel; strongly acid (pH 5.3 - 5.5). Gradual to -

A_3-horizon: yellow-brown (7.5YR - 10YR 6/6) to red-brown (5YR 5/8, 6/6-8); loam to clay loam; massive; friable; occasionally ironstone or manganese gravel; medium acid (pH 5.6). Clear to gradual to -

$B_{21}t$-horizon: red (2.5YR 5/8), red-brown (5YR 4/6) or yellow-brown (7.5YR 5/6, 6/8) becoming redder with depth; clay loam to light clay; moderate very fine blocky; firm to very firm; occasionally ironstone gravel; strongly to medium acid (pH 5.5 - 6.0). Gradual to -

$B_{22}t$-horizon: red (2.5YR - 10R 4/6-8, 5/6) with yellow or grey mottle; light clay; strong fine blocky; very firm; occasionally ironstone gravel; strongly to medium acid (pH 5.5 - 5.8).

$B_{23}t$-horizon: has yellow mottle when $B_{22}t$-horizon above does not.

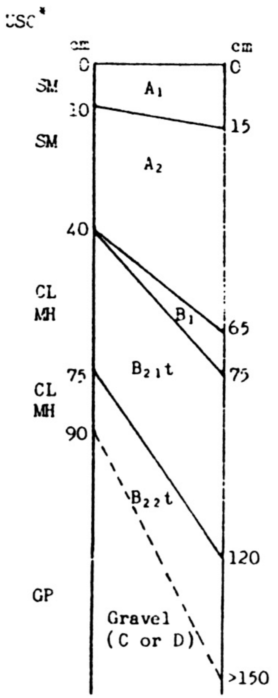
Variations outside the above range:

A_1-horizon:	brown (7.5YR 4/3); light sandy clay loam
A_2-horizon:	trace of manganiferous gravel
A_2-horizon:	bleached when dry
A_3-horizon:	absent
$B_{21}t$-horizon:	yellow-brown (10YR 5/4) becoming yellow and red mottled with depth; medium clay; massive
$B_{22}t$-horizon:	large amounts of ferruginous gravel

SOIL PROFILE CLASS: DELANCEY

PRINCIPAL PROFILE FORMS: Dy 2.41, Dy 3.41, Gn 3.74, Gn 3.84

SOIL PROFILE MORPHOLOGY



Surface condition: hardsetting

A_1-horizon: grey to grey brown (10YR - 7.5YR 4/1, 4/2-6/2), sandy loam; weak fine granular to massive; very friable; medium acid (pH 5.8 - 6.0). Clear to -

A_2-horizon: yellow-brown (10YR 5/4, 6/3, 7/3-4) (bleached when dry) or yellow (10YR 6-7/6); sandy loam to sandy clay loam; massive; friable; occasionally small amounts of ironstone gravel; strongly acid (pH 5.2 - 5.5). Clear or gradual to -

B_1-horizon: yellow (10YR 6/6-8); clay loam to light clay; massive; friable to firm; commonly small amounts of ironstone gravel; strongly acid (pH 5.2 - 5.5). Gradual to -

$B_{21}t$-horizon: yellow-brown (10YR 5-7/4) or yellow (10YR 7/6-8, 7.5YR 6/8), becoming red mottled at depth; light-medium to medium clay; blocky; very firm; commonly small amounts of ironstone gravel; strongly to medium acid (pH 5.2 - 5.7). Gradual to -

$B_{22}t$-horizon: yellow-brown (7.5YR 5/6, 10YR 6/4, 10YR 7/6) or grey-brown (7.5YR 7/1) with red mottle; light to medium clay; blocky; very firm; variable amounts of ironstone and siliceous gravel; strongly to medium acid (pH 5.2 - 5.7).

Variations outside the above range:

Surface: loose

A_1-horizon: light sandy clay loam; small amounts of ironstone gravel

A_2-horizon: yellow mottling at depth; medium amounts of ironstone gravel, earthy pan

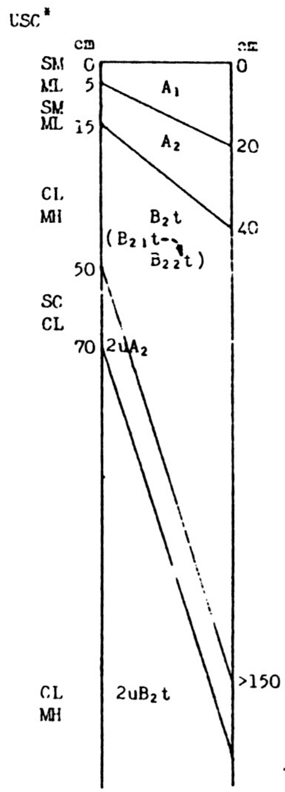
A_3-horizon: yellow (10YR 5-6/6); massive; sandy clay loam to clay loam developed below yellow-brown A_2-horizon at 50 - 90 cm.

* Unified Soil Classification (Olson 1973)

SOIL PROFILE CLASS: HILLIARDS

PRINCIPAL PROFILE FORMS: Dy 2.41, Dy 3.41, Gn 3.04, Dy 4.41, Dy 2.42

SOIL PROFILE MORPHOLOGY



Surface condition: hardsetting

A_1-horizon: grey brown (7.5 - 10YR 4/1-2, 5/2); fine sandy loam to silty clay loam; weak granular to massive; friable; medium acid (pH 5.6 - 6.0). Clear to -

A_2-horizon: grey (10YR 5/2, 6-7-8/1-4), (bleached when dry); fine sandy loam to silty clay loam; massive; often earthy pan; friable; medium acid (pH 5.6 - 6.0). Clear or abrupt to -

B_2t-horizon: grey (10YR 5-7/1-2) or yellow-brown (10YR 6/3-4) becoming increasingly mottled at depth; light to medium-heavy clay; moderate medium blocky; firm to extremely firm; strongly to medium acid (pH 5.4 - 6.0). Clear to -

2_uA_2-horizon: grey (10YR 5-7/1-3) with slight yellow mottle (bleached when dry); sandy clay loam to sandy clay; massive; often earthy pan; friable to firm; strongly acid (pH 5.4 - 5.5). Clear or abrupt to -

2_uB_2t-horizon: grey (10YR 7/1) and yellow brown (10YR 6/3, 7.5YR 5/6) mottled; medium clay; medium blocky; very firm; strongly acid (pH 5.4 - 5.5).

Variations outside the above range:

Surface: loose

A_1-horizon: light sandy clay loam (on first terrace); light clay (disturbed area) 0 - 5 cm depth

B_2t-horizon: silty clay; siliceous gravel at 80 - 120 cm lower boundary 30 cm, neutral (pH 6.8)

2_uB_2t-horizon: upper boundary 50 cm

BD-horizon: present as a mottled grey (10YR 8/2) light clay, high in quartz gravel below a B_{22}-horizon

APPENDIX 3

Morphology and Analysis of Representative Profiles

Notes:

Soil Profile Morphology: As per notes (iii) to (vii) of Appendix 2.

Chemical data: Apart from pH, E.C. and Cl, which are air dry figures, all chemical data are presented on an oven dry basis.

Soil Profile Class: REDLANDS

Great Soil Group: Krasnozem

Parent Material: Tertiary basalt

Topography: 3% upper slope of broadly convex low hills

Map Unit:

Taxonomy Subgroup: Tropeptic Eutrustox

A.M.G. Ref: 525150 mE, 6954625 mN

Air Photo Ref:

Location: Redlands Horticultural Research Station, Ormiston

Site No: R1

P.P.F.: Gn 3.11

Vegetation: Open forest of scribbly gum, pink bloodwood and narrow-leaved ironbark.

Profile Morphology: Surface : loose

A_1	0 - 20 cm	Dark reddish-brown (5YR 3/3); clay loam; strong medium granular; friable. Clear to -
B_1	20 - 40 cm	Reddish-brown (2.5YR 4/6); light clay; strong fine blocky; firm; trace amounts of ironstone nodules. Diffuse to -
B_{21}	40 - 110 cm	Reddish-brown (10R 4/6); light-medium clay; strong very fine blocky; firm; trace amounts of ironstone nodules. Diffuse to -
B_{22}	110 - 130 cm	Red (2.5YR 4/6); light-medium clay; strong very fine blocky; firm; moderate amounts of ferromanganiferous nodules. Diffuse to -
B_{23}	130 - 150 cm	Bright brown (2.5YR 5/8); medium clay; strong very fine blocky; very firm; moderate amounts of ferromanganiferous nodules.

Laboratory Data:

Lab.No.	Depth cm	pH 1:5	E.C.(1:5) $mScm^{-1}$	Cl ppm	Dispersion Ratio (R_1)	C.S. Particle Size % O.D.	F.S.	Si	C	C.E.C. Exch. Cations m. equiv/100 g O.D.	Ca^{++}	Mg^{++}	K^+	Na^+	P % O.D.	K	S	Moisture % A.D.	1/3 bar	15 bar
5761J	0-10	5.9	0.03	21	0.43	22	22	19	33	16	4.1	3.5	.44	.42	.027	0.13	.040	4.2	26	18
5763J	20-30	5.8	0.02	10	0.31	11	19	13	54	11	1.5	3.0	.06	.36	.019	0.10	.025	4.2	29	20
5766J	50-60	6.0	0.03	42		7	10	8	73	5					.014	0.06	.039	5.9	35	26
5769J	80-90	6.1	0.03	42		7	10	10	71	5	1.3	3.1	<.03	.41	.013	0.05	.036	2.4	33	27
5772J	110-120	6.0	0.03	42		7	9	12	69	4	1.3	2.7	<.03	.41	.014	0.04	.038	3.0		
5775J	140-150	6.0	0.03	42		10	9	12	67	3	1.3	2.2	<.03	.36	.015	0.03	.041	2.4		

Lab.No.	Depth cm	Org. C %	Tot. N	Acid Extr. P ppm	Bicarb	Repl. K m.equiv/100g	Fe D.T.P.A. Extr. ppm	Mn	Cu	Zn	B ppm
5760J	0-10	4.0	0.20	8	7	0.42	21	21	0.4	0.5	
5762J	10-20	2.3	0.22	3	5	0.20					

Soil Profile Class: WOODRIDGE

Great Soil Group: Yellow podzolic soil

Parent Material: Weathered Mesozoic sediments (Woogaroo subgroup)

Topography: 6% midslope of low convex hills

Map Unit:

Taxonomy Subgroup: Ultic Paleustalf

A.M.G. Ref: 523725 mE, 6954725 mN

Air Photo Ref:

Location: Redlands Horticultural Research Station, Ormiston

Site No: 52

P.P.F.: Dy 2.41

Vegetation: Woodland of scribbly gum with some smudgee and small-fruited bloodwood.

Profile Morphology: Surface : hardsetting

A_1	0 - 12 cm	Greyish yellow brown (10YR 4/2); sandy loam; weak fine granular; very friable. Clear to -
A_2	12 - 28 cm	Dull yellow orange (10YR 6/3), (bleached when dry); sandy clay loam; massive; friable; moderate amounts of ironstone nodules. Abrupt to -
B_{21}	28 - 50 cm	Dull yellow orange (10YR 6/4); medium clay; moderate medium blocky; firm; traces of quartz gravel. Diffuse to -
B_{22}	50 - 70 cm	Dull yellow orange (10YR 6/4) with red mottle; medium-heavy clay; strong fine blocky; very firm. Gradual to -
B_{23}	70 - 150 cm	Light grey (2.5Y 8/1) with red mottle; heavy clay; strong coarse blocky; extremely firm.

Laboratory Data:

Lab.No.	Depth cm	pH 1:5	E.C.(1:5) mScm^{-1}	Cl ppm	Dispersion Ratio (R_1)	C.S.	F.S.	Si	C	C.E.C.	Ca^{++}	Mg^{++}	K^+	Na^+	P	K	S	Moisture % A.D.	1/3 bar	15 bar
						Particle Size % O.D.				Exch. Cations m. equiv/100 g O.D.					% O.D.					
5777J	0-10	5.5	0.03	10	0.66	25	33	25	15	8	.82	1.2	.10	.30	.006	0.08	.016	1.3	23	7
5779J	20-30	5.5	0.02	10	0.81	21	34	23	22	4	.17	1.4	.03	.25	.005	0.07	.012	1.1	20	8
5782J	50-60	5.4	0.04	41	0.31	9	14	13	59	10	.17	3.8	.03	.56	.008	0.10	.031	2.5	32	23
5785J	80-90	5.3	0.04	41	0.35	5	12	15	64	12	.10	4.0	.06	.62	.009	0.13	.018	2.6	34	22
5788J	110-120	5.4	0.04	41		6	20	18	50	17	.04	4.2	.12	.72	.005	0.57	.009	2.4		
5791J	140-150	5.3	0.05	61		8	17	20	49	10	.06	4.5	.15	.92	.006	0.82	.007	2.3		

Lab.No.	Depth cm	Org. C %	Tot. N %	Acid Extr. P ppm	Bicarb Extr. P ppm	Repl. K m.equiv/100g	Fe D.T.P.A. Extr. ppm	Mn	Cu	Zn	B ppm
5776J	0-10	1.7	0.11	2	8	0.14	192	2	0.1	0.4	
5778J	10-20	0.93	0.05	2	6						

Soil Profile Class: COBURG

Great Soil Group: Red podzolic soil

Parent Material: Weathered Mesozoic sediments (Woogaroo subgroup)

Topography: 9% mid upper slope of low convex hills

Map Unit:

Taxonomy Subgroup: Oxic Paleustalf

Site No: R3

P.P.F.: Gn 3.14

A.M.G. Ref:

Air Photo Ref: 524200 mE, 5954575 mN

Location: Redlands Horticultural Research Station, Ormiston

Vegetation: Tall woodland of tallowwood with small-fruited bloodwood and scribbly gum

Profile Morphology: Surface : weakly hardsetting

A_1	0 - 12 cm	Greyish brown (7.5YR 4/2); sandy loam; weak fine granular; very friable; trace of ironstone nodules. Clear to -
A_2	12 - 25 cm	Dull brown (7.5YR 5/4); sandy clay loam; weak fine subangular blocky; trace of manganese nodules. Gradual to -
B_1	25 - 60 cm	Orange (5YR 6/6); clay loam; weak fine subangular blocky; small amounts of manganese nodules. Gradual to -
B_{21}	60 - 90 cm	Reddish brown (2.5YR 4/6); light clay; moderate very fine blocky; firm; small amounts of ferromanganiferous nodules. Diffuse to -
B_{22}	90 - 130 cm	Reddish brown (2.5YR 4/6); light clay; strong very fine blocky; very firm; small amounts of ferromanganiferous nodules. Gradual to -
B_{23}	130 - 150 cm	Bright brown (2.5YR 5/6) with faint yellow mottle; light clay; strong fine blocky; very firm; moderate amounts of ironstone nodules.

Laboratory Data:

Lab.No.	Depth cm	pH 1:5	E.C.(1:5) $mScm^{-1}$	Cl ppm	Dispersion Ratio (R_1)	C.S.	F.S.	Si	C	C.E.C. Exch.	Ca^{++}	Mg^{++}	K^+	Na^+	P	K	S	Moisture % A.D.	1/3 bar	15 bar
						Particle Size % O.D.				Cations m. equiv/100 g O.D.					% O.D.					
5793J	0-10	5.9	0.02	10	0.75	37	38	19	4	6	1.3	.98	.08	.20	.006	0.05	.013	1.0	16	5
5795J	20-25	5.3	0.02	20	0.73	28	40	19	11						.005	0.06	.009	0.9	14	
5808J	25-30	5.6	0.02	10	0.68	24	40	17	17	4	.38	1.1	<.03	.20	.005	0.03	.011	1.1	15	8
5798J	50-60	5.6	0.02	20		18	30	14	34	3	.51	2.0	<.03	.25	.007	0.04	.028	1.7	20	15
5801J	80-90	5.9	0.03	30		13	20	12	53	4	.37	3.6	<.03	.41	.007	0.06	.033	2.4	28	23
5805J	110-120	5.8	0.03	41		11	17	13	56	4	.29	3.8	<.03	.46	.007	0.05	.035	2.3		

Lab.No.	Depth cm	Org. C %	Tot. N %	Acid Extr. P ppm	Bicarb P ppm	Repl. K m.equiv/100g	Fe D.T.P.A. Extr. ppm	Mn	Cu	Zn	B ppm
5792J	0-10	1.6	0.07	2	4	0.09	26	2	0.1	0.2	
5794J	10-20	0.7	0.04	2	3	0.02					

Soil Profile Class: HILLIARDS

Map Unit:

Site No: 8A

Great Soil Group: Soloth

Taxonomy Subgroup: Natrudalf

P.P.F.: Dy 3.41

Parent Material: Quaternary alluvium

A.M.G. Ref:

Topography: Alluvial creek flat with 0.5% slope

Air Photo Ref: 524450 mE, 6954700 mN

Location: Redlands Horticultural Research Station, Ormiston

Vegetation: Stunted woodland of swamp mahogany, rusty gum and paper-bark tea trees.

Profile Morphology: Surface: strongly hardsetting

A_1	0 - 10 cm	Brownish grey (7.5YR 4/1); loam, fine sandy; weak granular; firm. Clear to -
A_2	10 - 20 cm	Light grey (7.5YR 8/2) (bleached when dry); silty loam; massive; very firm. Abrupt to -
B_{21}	20 - 50 cm	Dull yellowish brown (10YR 5/3) with faint yellow mottle; light clay; moderate medium blocky; very firm. Gradual to -
B_{22}	50 - 80 cm	Dull yellow orange (10YR 7/2) with yellow and red mottle; light clay; moderate coarse blocky; very firm. Gradual to -
BD	80 - 100 cm	Light grey (10YR 8/2) with red and yellow mottle; light clay; weak fine blocky; friable; large amounts of quartz gravel.

Laboratory Data:

Lab.No.	Depth cm	pH 1:5	E.C.(1:5) mScm^{-1}	Cl ppm	Dispersion Ratio (R_1)	C.S. Particle Size % O.D.	F.S.	Si	C	C.E.C. Exch. Cations m. equiv/100 g O.D.	Ca^{++}	Mg^{++}	K^+	Na^+	P % O.D.	K	S	Moisture % A.D.	1/3 bar	15 bar
5810J	0-10	5.6	0.03	20	0.85	3	51	38	8	4	1.1	.98	.06	.25	.008	0.05	.018	0.75	26	5
5812J	20-30	5.7	0.04	20	0.92	2	39	29	28	4	.45	3.7	.03	.65	.006	0.06	.015	1.56	24	14
5815J	50-60	5.5	0.13	132	0.79	3	35	23	36	4	.13	6.0	.04	1.5	.006	0.10	.026	1.97	28	18
5818J	80-90	5.4	0.11	131	0.94	17	44	21	21	4	.09	3.1	<.03	1.1	.004	0.08	.016	1.0	18	9

Lab.No.	Depth cm	Org. C %	Tot. N	Acid Extr. P ppm	Bicarb	Repl. K m.equiv/100g	Fe D.T.P.A. Extr. ppm	Mn	Cu	Zn	B ppm
5809J	0-10	2.0	0.08	5	7	0.09	172	8	0.2	0.4	
5811J	10-20	0.65	0.04	3	3	0.03					