SOILS OF THE MALLEE RESEARCH STATION, WALPEUP, VICTORIA

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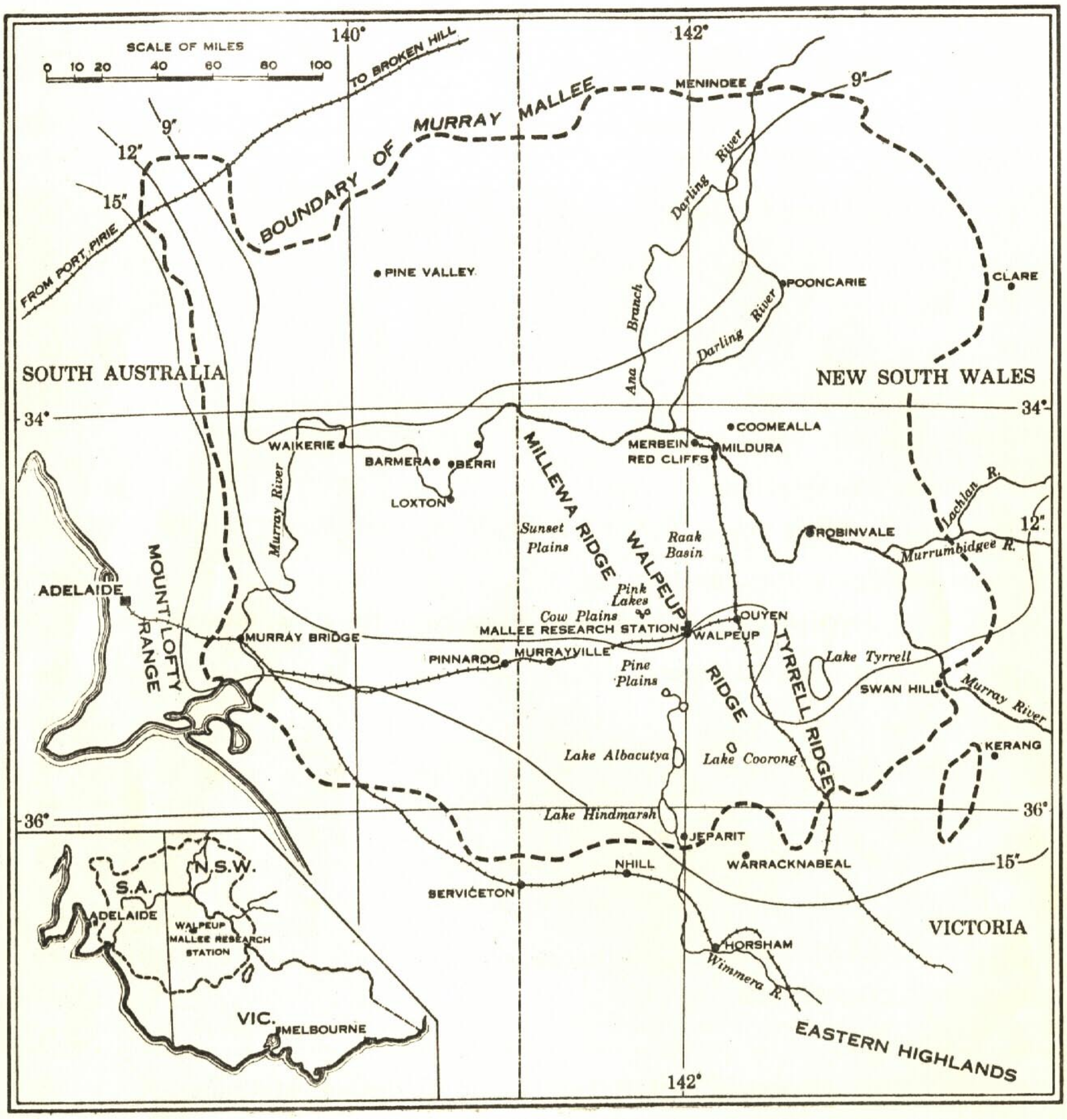
Fig 1. Locality Plan Showing the Murray And Rainfall Ishoyets.



INTRODUCTION

The Mallee Research Station includes parts of the Parishes of Walpeup and Paignie, County of Karkarooc, and of Kattyoong, County of Weeah.

It was established in 1932 on 1,928 acres. In 1946, a western section of 628 acres was added in order to include an area of marked dune and swale formation more typical of much of the central Victorian Mallee.

The Station is one mile from the railway township of Walpeup, 20 miles from Ouyen, 230 by road from Adelaide and 300 from Melbourne.

As the locality map (Fig. 1) shows, it is centrally placed in the Victorian Mallee and is within the larger physiographic unit of the Murray Mallee.

Agricultural practices have been a marked impact on the soils of the Mallee. Clearing of the more favoured parts for wheat-growing commenced about 1890 and, by the turn of the century this was the main agricultural pursuit. The then current practices of bare fallowing and stubble-burning, assisted by the activities of rabbits, were conductive to blowing of the light surface soils. This was accelerated as settlement immediately following the 1914-18 war pushed cultivation into marginal areas. Soil erosion reached disastrous proportions by 1930. Its effects are evident on the Research Station. The narrow shelter belt in paddock No. 6 has given rise to a north-south sand dune about 15 ft. high. Subsoil is exposed in many places as in paddock No. 3 while surfaces have been altered elsewhere. Sand sheets in paddocks Nos. 1, 2, 3, 7, and 9 appear to date from this erosive period.

Soil erosion now has been largely arrested, although this position is still precarious in some situations. The great improvement is due to the amalgamation of properties into larger farming units with greater emphasis on grazing sheep, assisted by a succession of favourable seasons, and in part to changes in farming methods developed on the Research Station since 1939. Principally, these are the use of barrel medic pasture in rotation with cereals, and trash fallowing in place of stubble burning.

Research is continuing on the Station into the above and other problems of Mallee agriculture. The soil survey should help in planning these investigations and in applying the findings systematically.

GENERAL ENVIRONMENT

Physiography and Geology

The surveyed area includes part of the Walpeup Ridge, and part of the basin of Cow Plains and Pine Plains lying to the west. Basin and ridge are two of the main physiographic features of a natural region, the Murray Mallee. This may be delineated on the basis of Mallee eucalypt trees and a marked dune landscape. It extends from the flood plain of the Loddon River near Kerang in Victoria, westwards for 270 miles to the foot-hills of the Mount Lofty Ranges near Murray Bridge in South Australia. The south to north extent is roughly 240 miles from Jeparit in Victoria almost to

Menindie in New South Wales (Hills 1959, Beadle 1948). Similar soils recur throughout most of this region.

Overall the Murray Mallee is an area of low relief and elevation, but local relief is most marked. For example, from the undulating crest of the Walpeup Ridge, at 380 ft. on the research Station, the land falls away approximately 160 ft. within $2^1/_2$miles into the Raak Basin to the east and into the Cow Plains and Pine Plains to the west and south-west.

A series of east-west dunes and swales covers much of the floor of the basins and occurs in less marked form on the ridges. The dunes may be as closely spaced as 200 yards between crests and have a difference in elevation of up to 40 ft. from trough to crest, although 20 to 25 ft. is more common. Major swamps and drainage lines also occur within the basins, carrying sumps receive surface water from outside the region, as do the salt lakes Tyrell and Albacutya. Others do not, for example the Pink Lakes, and the un-named salt swamp between Walpeup and Ouyen.

Unconsolidated deposits of great thickness underlie the Mallee area. These are Miocene marine sands, clays and coralline limestone overlain by later fresh water deposits (Hills 1959). However, it is probable that most of the material comprising the present land surface of the Mallee was blown inland during the Pleistocene form calcareous coastal dunes lying to the south and west. This has since been further leached, winnowed and piled into fresh dunes. The successive layers of travertine limestone in the more stable dunes suggest alternating deposition and soil formation in a fluctuating climate. The fashioning if the highly calcareous east-west dune system may have ended as recently as 4,000 years ago (Crocker 1946, Crocker and Wood 1947), whereas the lighter and less calcareous dunes are still unstable. Lime resting on the surface of deep, non-calcareous sand at the crest of a high dune at Walpeup is evidence that soil movement and soil formation have continued intermittently until now.

Climate

The climate changes only gradually over the whole of the Murray Mallee. Most of the region is classed as warm temperate semi-arid, with Walpeup near the southern and more humid limit of the range. Walpeup records may be compared with those of Mildura and Merbein, towns which are central to the whole Murray Mallee. Rainfall, temperature and evaporation data are given in Table 1.

Table 1 :- Climatic Data *

	No. of years	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	YEAR
Walpeup (350 ft)														
Temperature °F														
Av. max.		81	85	81	72	64	58	57	61	67	72	79	85	72
Av. min.		59	59	55	49	45	41	41	41	44	48	52	57	49
Av. mean	12	74	72	68	60	55	50	44	57	54	60	66	71	61
Rainfall, in.	48	0.8	1.0	0.9	0.7	1.3	1.3	1.2	1.3	1.3	1.5	1.0	0.9	13.2
Days, 0.4 in. or more **	30	0.6	0.8	0.6	0.6	0.9	0.9	0.7	0.7	0.6	1.2	0.7	0.6	8.9
Mildura (177 ft)														
Temperature °F														
Av. max.		90	90	84	75	67	60	60	64	70	77	83	88	76
Av. min.		61	62	57	51	46	41	41	43	46	51	55	60	51
Av. mean	30	75	76	71	63	56	51	50	53	58	59	69	74	63
Rainfall, in.		0.7	0.8	0.7	0.6	1.0	1.2	0.9	1.0	0.9	1.1	0.8	0.7	10.5
Evaporation, in. $^{\phi}$	32	9.5	7.4	6.4	4.0	2.5	1.8	1.7	2.4	3.8	5.5	7.2	8.9	61.0

** Average number of days on which 0.4 in. or more is recorded

$^{\phi}$ Recorded at Commonwealth Research Station, Merbein.

* The climatic data were supplied by Hounam of Commonwealth Bureau of Meteorology, Melbourne. More complete information can be found in the Resources Survey of the Mallee Region (Anon. 1952).

At Walpeup summers are normally hot and dry, temperatures above 100°F being expected on 10 to 14 days a year. Winters are mild, although about 35 frosts a year can be expected, with considerable local variation owing to topography and aspect.

The rainfall averages 13 in. annually with a slight winter maximum and marked unreliability in summer. For example the variability (standard deviation as percentage of the mean monthly rainfall) of the January rainfall is 110 per cent compared with 60 per cent in July. The average rainfall per day of recorded rain is fairly low in common with most of southern Australia, the 30 year average being 19 points (17 points at Merbein). However, the amount of rain received in heavier falls is considerable. For instance, on an average of 9 days each year, the rainfall is 40 points or more, yielding 638 points per year 49% of the annual rainfall. The corresponding figure for Merbein is 47% (Baldwin personal communication).

Evaporation is undoubtedly high throughout the region and is less variable from year to year than is rainfall. At Merbein, evaporation (from an Australian standard tank) is 61 in. per year or six times the average rainfall. It exceeds rainfall for every month and exceeds 6 in. for each of the months November to March. Evaporation at Walpeup is likely to be slightly lower.

In this connection, observations at Walpeup suggest that run-off may be more important than is generally thought. Three definite scour courses were present in paddock No. 3 before final clearing. One of these is still active. Silty textures in the depression soil, Type D, point to local run-off as a factor in soil formation. At least three falls of rain in November 1960 were of sufficient intensity to cause visible run-off from the steeper surfaces of Winkie sand. Extremely wide variations were noted in the moisture profiles of this type.

That moisture penetrates deeply into the subsoils is shown by the drought-resistance of the Mallee eucalyptus and belar and, to a lesser extent, Murray pine. The very deep rooting habit of these species is well known.

Vegetation [*]

Plants and soils. – The overall conclusion of the survey is the familiar one, that native vegetation and soil associations are closely related, but that soil types and vegetation types, as defined, show little correlation. For instance, belar woodland often gives place to Mallee woodland, with practically no mixing where the subsoil changes from sandy clay loam or clay; yet elsewhere the lighter textured soil may carry mallee or pine.

It is recognised that mallee and belar may persist in some sites by virtue of first possession. On the other hand, in a semi-arid environment, small local differences in moisture may be expected to make large differences in native vegetation, and yet be too small to show any effect on the soil profile. These variations in effective moisture could be dependent on exposure and aspect, or equally on small changes in drainage. Either might be unimportant in a wetter or a drier climate.

Whatever its cause, the clear-cut pattern of native vegetation suggests itself as one clue to the understanding of the soils in the area. In the present survey, no more could be attempted than a tentative reconstruction of the former vegetation. Hence any correlation with soils must also be a very general nature. These are mentioned in the section on Soils and Landscape.

Native Plant communities. – For the eastern section of the Station, vegetation maps were made of each paddock before it was cleared. No descriptions of the mapping units have been preserved, but from the several maps made at different times, and from the remaining uncleared paddocks and shelter belts, a rough picture of the original plant cover has been reconstructed.

For the western section, remnants of original vegetation on the central higher dune and outside the Station indicated that the original vegetation was of the Stunted Mallee type with the Small Mallee type in the swales. These and other vegetation units are described later.

The whole Station has been grazed heavily by sheep and rabbits at various times, and most of the Murray pine cut for building and fencing material. However, the stumps can be counted at least 15 years after felling, and standing spars probably more than

[*] The principal plants recorded are listed in Appendix II.

30 years after the death of the tree. In the descriptions which follow, the tree cover is probably close to the original, but the under storeys are certainly influenced by grazing and partial clearing of the trees. This is particularly so in the case of the Pine-Hopbush and Stunted Mallee communities.

The form of the vegetation communities was chiefly low or tall sclerophyll shrub woodland (Wood and Williams 1960), with trees of pine and belar approaching forest form in some types. The eucalypts were all of mallee form. On the lighter, more arid sand dunes they were very stunted, and a range of other shrubs became almost co-dominant. There were also grassy communities.

The soil survey was made in the late spring of 1960, a season particularly favourable for growth, which may account for the richness of ephemeral ground flora. However one most striking feature is probably more permanent, and apparently has not been recorded elsewhere. This is the ground coating of mosses, lichens, fungi, etc. it was especially noticeable in the more open parts of the Pine-Hopbush and Belar-Buloke-Pine units, but was present in all except the Stunted Mallee unit. It could well be a major factor in the ecology of partly cleared and lightly grazed country.

The earlier surveys of the eastern section of the Station used a rather large number of units. These have been grouped into the six main vegetation types described below, with a seventh added for the more arid dunes in the western part.

Pine-Hopbush. Low or tall sclerophyll shrub woodland. Pine of woodland form to 30 ft. Tree spacing probably about twice the diameter of the canopies, i.e., dense to mid-dense, and about 150 per acre, with some belar, sugar wood, and big mallee amongst the pines. Where the pines are thinned out, there is a dense understorey to 8 ft. of hopbush, turpentine bush and Mallee daisy. A rich ephemeral ground cover with some permanent grasses.

Belar-Buloke-Pine. Probably tall sclerophyll shrub woodland. Trees of woodland form to 40 ft, dense to mid-dense. Belar plus Buloke greater than 70 per cent of the trees, with pine and some sugarwood and scattered clumps of big mallee. Mid-dense shrub layer rich in species including cattle-bush, hopbush, emu-bush, various acacias, Mallee daisy and weeping pittosporum. Probably quandong, cassias, hakeas and grevilleas.

Belar-Buloke. Tall sclerophyll shrub woodland. A dense, approaching very dense, tree storey, 40 ft or more. Belar-Buloke approach 100 per cent of the tree storey with some sugarwood. Shrub layer open, with little ground cover.

Big Mallee. A form of sclerophyll shrub low woodland. Mid-dense tree storey of various eucalypt species of mallee form to 30 ft. with some Murray pine and Buloke and an open shrub layer rich in species including acacias, cassias, pittosporum leafless ballart, hakeas and small chenopods. Ground cover includes twin leaf and poached eggs daisy.

Small Mallee. This differs from the Big Mallee unit in that the trees are about 15 ft. high, and there is a mid-dense shrub layer and little ground cover.

Stunted Mallee. Mallee form of sclerophyll shrub low woodland. Eucalypts are reduced to below 10 ft (whipstick), mid-dense to open, with a dense sclerophyll shrub layer of characteristic species. These often have "broom bush" form i.e., with long, thin, parallel twigs. This unit grades into areas with an open shrub layer and a rich ephemeral ground cover with porcupine grass dominant amongst the perennial herbs. Scrub pine, absent from all the other units, occurs occasionally. Melaleuca uncinata, Leptospermum coriaceum and Dampiera lanceolata are frequent and confined to this unit.

Grassy Communities. These have open to scattered shrubs and small trees, and many herbs other than grasses. No estimate could be made of the original flora, nor of the number of vegetation types. It seems probable that the smaller areas on the heavier soils are permanent associates of the Big, Small and Stunted Mallee units. This agrees with White's observations in 1852 (Kenyon 1914), and with Zimmer (1937) who describe communities of spear and wallaby grasses, sometimes with blue bush and other species, and Skene (1951) and Northcote (1951) who record spear grass communities.

Larger areas of grassy plain marked on the earlier survey of the Station have no apparent regard for topography or soils and are the result of early clearing and possibly are related to stock routes and aboriginal tracks.

Crops and weeds. – Introduced plants which are grown profitably on the Station are the cereals wheat, oats and barley, and in the pastures, hairy burr medic and barrel medic and barley and rye grasses. On the lighter soils other species are lucerne, cereal rye, blue lupins and sterile brome grass. Medicago littoralis is becoming important.

Many species have become well established, both as weeds in cereal crops, and as components of volunteer pastures following cultivation. Some are prominent in the shelter belts. No survey was made but it was noted that by far the most widespread and prominent species in self sown and in older sown pastures, including lucerne, are barley grass and hairy burr medic. The barley grass is often displaced by sterile brome grass on deep sands, including recent sand sheets in shelter belts, and by Wimmera rye grass in fallows and crops. Barrel medic is well established on all soils except Winkie sand and Kattyoong sand and some of the minor soil types.

There is a wide range of smaller medics and some clovers, widely spread but seldom dominant.

Wild mustard and wild turnip are wide spread, dominating many ungrazed sands and some pastures and crops.

Skeleton weed was noticed only on Kattyoong sand. Saffron thistle is ubiquitous but rare, although many nearby areas of similar soils outside the Station are badly infested.

THE SOILS

The soils of the Station have certain general features which recur throughout the Murray Mallee. There are no heavy clays; there is very little silt in any horizon except in one soil type; coarse sand and fine sand are mixed in roughly equal amounts; and there is much free calcium carbonate (lime) and appreciable sodium chloride in all but eh very sandiest types. On the other hand, textural boundaries are not as diffuse as in the soils of the Mallee further north.

Soils and Landscape

There are two clearly defined groups of soils, each group being associated with a characteristic landscape and pattern of native vegetation. These two land units are described below.

WALPEUP RIDGE LAND UNIT
This comprises the soils of the hummocks and hollows of the high north to south Walpeup Ridge. They are for the most part brown and red-brown soils with a narrow range of textural profiles. The overall impression is one of soils developed from a reddish brown, calcareous sandy clay loam containing very little silt. The only clay horizons occur in Type D and Midmallee sandy loam which occupy some of the depressions.

This land unit originally carried five of the vegetation types described earlier. The Pine-Hopbush type was mainly on the deeper sandier surfaces in the east, south and west, while Belar-Buloke-Pine and Big Mallee types occupied the main ridge on Ridge sand and Walpeup sandy loam. The last two also shared the lower ground with the Small Mallee and Belar-Buloke types.

For the most part, trees were tall for the district (20 to 40 ft) with a fairly high proportion of Murray pine and belar amongst the mallee. Shrubs were vigorous and varied.

Soil types. – The principal soil types are Ridge sand and Walpeup sandy loam, with Type D locally important. Type E and Midmallee sandy loam are of minor extent.

General features of the Soils. – Surfaces very erratically in texture, depth, colour and lime content, apparently due to recent movement in the wind, and to the former activities of rabbits. Frequently textures ranging from sand to sandy clay loam are layered in the top 6 to 12 inches. The common feature distinguishing surface and subsurface from subsoils is their porous and apparently structureless nature, though some of the sandy clay loams are subplastic.

There is usually a well defined zone of organic darkening 4 to 8 in. deep, in both virgin and cropped areas, though this may be blown away in some cases, or in others covered by recently drifted sand. Sand sheets in extensive, uncleared areas have apparently originated from wind action on neighbouring fallows. These sheets are shown on the soil map by the inscription “light surface”, but exceptional drifts, up to 15 ft deep, are mapped as a soil type where of sufficient extent.

Sandy clay loam and sandy clay subsoils exposed by recent wind erosion (shallow surface variants) may puddle strongly in heavy rain leaving a crust up to 1 in. thick. This is dense on the upper surface and markedly vesicular underneath.

Dull brown to reddish brown colours* predominate on the higher ground, with only the very sandiest ridges approaching the pale yellowish brown colours found in the East-West Dune Land Unit. Lower slopes are redder and darker, with dark red-brown in the depression soils. In the lime-rich zone of any profile, various pale and very pale brownish colours predominate, with darker and redder colours below the lime.

All the subsoils are visibly calcareous, but, in most cases, the surface is without detectable free lime. This appears from 1 to 3 in. below the top of the first compact horizon (sandy clay loam, sandy clay or clay). In depressions and in the sandier profiles it may be slightly deeper. The lime content then increases sharply to light or moderate amounts, but falls off again to negligible amounts somewhere between 3 ft and 8 ft. There may be two or three weak maxima before this depth. The lime-enriched materials are not very hard nor pan-like, except occasionally where hard rubble occurs in depressions.

Lime detectable by effervescence with dilute acid occurs in some surface soils. These are evident as dull brown to brownish grey areas and occur over all the soil types of the unit. After cultivation these dull surfaces show scattered small lime concretions. The profiles of the dull areas are varied, but are always more highly calcareous than the immediately surrounding soils, at least in the upper 3 ft. The larger areas are usually on northern and western slopes. Smaller areas (a few yards across) are very numerous. These are indicated by an inscription on the soil map only when amounting to more than 25 per cent.

Subsoils generally show weak subangular blocky structure with brittle 1 to 2 in. peds. Evidence of organisation increases with clay and silt content, so that the B horizons of Type D and Midmallee sandy loam, and sometimes of Walpeup sandy loam under mallee timber, show a moderate to strong structural development, crumbling readily when moist or moderately moist into subangular blocky $^1/_2$ in. peds with secondary peds about $^1/_5$ in.

Deep subsoils are usually very weakly organised into large subangular blocky to massive units, very hard and brittle when dry and soft when moist. The lime-rich zone if sandy clay or sandy clay loam, may be weakly subangular blocky in an amorphous matrix.

Deep Layers. – There is some evidence of discontinuities in the underlying layers. Strongly organised layers occur at Type D sample site and in Midmallee sandy loam in the north-western corner of the Station, while at the Walpeup sandy loam sample site below 4 ft there are changes in pH (strongly alkaline to strongly acid), in colour and in the ratio of coarse to fine sand.

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* * Colours throughout this report refer to the dry soil. Munsell notations for the soil colours are given in the section, Soil Type Descriptions.

EAST-WEST DUNE LAND UNIT

This unit includes more soil types that the Walpeup Ridge unit, an extreme range of texture profiles matching the pattern of sharply contrasting dunes and swales, with their corresponding plant communities.

The original vegetation types were probably the Small Mallee and Grassy Communities, with the Stunted Mallee type on the more arid dunes. The Pine-Hopbush vegetation type probably occurred where this land unit bordered the Walpeup Ridge unit.

Soil types. – The principal soil types are Winkie sand and Kattyoong sand on the dunes, with Midmallee sandy loam in the swales. Minor soils found on the dunes are Type A and Type C, with small areas of Ridge sand and Walpeup sandy loam. In the swales, the minor soils are Type B, Type D and Midmallee sand.

General features of the soils. – The dune soils in this unit are characteristically deep, pale yellowish brown sands which are low in organic matter, loose, porous and strongly leached. The soils are very prone to move in the wind. Steep slopes are common and are often steep enough to shed the rain.

An horizon or layer of sandy loam or sandy clay loam with slight lime and reddish mottling occurs at depths ranging from 1 ft to deeper tan 10 ft. Alternatively, the sand may pass abruptly into a red-brown sandy clay or clay of an older swale soil.

A curious feature of these dune sands is the irregular occurrence of hard-drying pans of various sandy textures, without free lime or visible cementing agent. Where locally important, the micro-complex of normal and hard-setting soils has been mapped as a variant of the type.

The soils of the swales mostly have dark red-brown surfaces shallower than 6 in., over red-brown clay, dense, moderately well structured, and highly calcareous. The lime in the first 4 ft is commonly in two layers distinguished by differences in form and hardness. Hard rubble is common.

Low rises within the swales may be either sand sheets, or very highly calcareous dune-remnants.

Calcareous surfaces occur. On the dunes these are usually on north-western and western shoulders, and are greyish, pale sands to sandy clay loams with “pan” lime near the surface. In the swales, the calcareous surfaces are usually dull red-brown to grey-brown with scattered surface rubble.

Key to the Soil Types

The key will help in the identification of the soil types in the field, but it does not replace the soil type descriptions which follow.

I Surface non-calcareous, brown to red-brown, sometimes with a veneer of paler sand

Subsoil,

(a) Sandy clay loam	
(i) lightens before 4 ft	RIDGE SAND light phase
(ii) continues beyond 4 ft	RIDGE SAND
(iii) passes to sandy clay	WALPEUP SANDY LOAM
(b) Sandy clay	
(i) lightens to sandy clay loam before 4 ft	WALPEUP SANDY LOAM heavy phase
(c) Clay before 4 ft	
(i) Surface – sand deeper than 6 in.	MIDMALLEE SAND
(ii) Surface – sand less than 6 in., sandy loam or sandy clay loam	
1. Sharp transition (less than 4 in.) from surface to clay	MIDMALLEE SANDY LOAM
2. Gradual transition (more than 4 in.)	TYPE D

II Surface non-calcareous, pale yellowish brown sand

Subsoil,

(a) Loamy sand deeper than 4 ft	WINKIE SAND
(b) Sandy loam before 4 ft continuing deeper	WINKIE SAND shallow phase
(c) Sandy clay loam	
(i) continues beyond 6 ft	TYPE A*
(ii) passes to sandy loam	KATTYOONG SAND
(d) Sandy clay or clay before 4 ft	TYPE A*

III Surface calcareous, grey-brown or dull coloured

(a) Dull yellowish brown; lime pan within 12 in. (on east-west dunes)	TYPE C
(b) Grey-brown sandy clay loam or clay loam, soft lime nodules, no hard pan (on Walpeup Ridge)	TYPE E
(c) Grey-brown sandy loam, moderate lime, heavy rubble within 12 in.	TYPE B
(d) Scattered rubble on surface in areas of Midmallee sandy loam	MIDMALLEE SANDY LOAM calcareous phase

* The surface may be brown or red-brown at the bottom of slopes.

Soil Type Descriptions

The detailed descriptions which follow should be read in conjunction with the general notes given previously under the appropriate land unit. Chemical and physical data are given later while the relationship to soils elsewhere is discussed under Classification and Relationships.

KATTYOONG SAND

This is a soil of major extent occurring below Winkie sand on the slopes of the East-West Dune Land Unit. It is intermediate in texture between Winkie sand, shallow phase, and Type A, and approaches very closely to the light phase of Ridge sand.

Profile

0-4 in.	Yellowish grey-brown (10YR5/3) sand; abrupt boundary with
4-18 in.	Pale yellowish brown (10YR6/8) sand; clear boundary with
18-36 in.	Dull yellowish brown and reddish brown (10YR5/4, 5YR5/6) sandy clay loam; slight lime; grading into
36-60 in.	Red-brown (2.5YR4/6) and yellowish brown finely mottled sandy loam; clear boundary with
60-72+ in.	Dominantly red-brown sandy clay loam passing to sandy clay with lime pan or hard rubble.

The lower 2 to 6 in. of the sand surface may be strongly "bleached" (10YR6/2 to 7/3). The sandy clay loam subsoil may come in at depths of from 14 in. to 48 in., and be overlain by as much as 10 in. of sandy loam.

Variant. – A "hard pan variant" is characterised by an extremely hard-drying sand or sandy loam horizon within 12 in. of the surface. Sometimes the hard-pan occurs deeper than 12 in. but these occurrences have not been delineated. The pan is 2 to 6 in. thick, soft when moist. Lower parts of the profile may be slightly heavier than normal for the type. This variant usually occurs with the normal profile in a micro-complex.

MID-MALLEE SAND

This is a minor soil, occurring as a sand sheet or low dune in the interdune corridors of the East-West Dune Land Unit. It differs from Type A primarily in the latter's topographical position below Winkie sand, but also in having a uniform surface colour, more gradual texture boundaries, and generally heavier concentration of rubble in the deep subsoil.

Profile

0-15 in.	Reddish brown (5YR4/8) loamy sand; diffuse boundary with
15-22 in.	Red-brown (2.5YR4/8) sandy loam; trace of lime; grading into
22-36 in.	Red-brown and dull yellowish brown moderately mottled light clay; trace of lime, some hard rubble; weakly structured, some black flecks on the ped surface; diffuse boundary with
36-44 in.	Red-brown medium clay; slight lime with some hard rubble; moderate structure, with black flecks on the shiny ped faces; clear boundary with

44-50+ in.	Pale brown with some red-brown mottling light clay; heavy concentration of hard rubble.

The depth of surface ranges from 6 in. of sand to a total depth of 36 in. of sand plus sandy loam.

MID-MALLEE SANDY LOAM

This is a soil of major extent, occurring in the swales of the East-West Dune Land Unit, and with Type D in the major depressions of the Walpeup Ridge. It is the heaviest soil on the Station, characterised by a thin, dark red-brown surface, a red-brown subsoil clay, and light to heavy concentrations of lime with hard rubble.

Normal phase profile

0-4 in.	Reddish brown (5YR5/6) sandy loam or light sandy clay loam; structureless, porous and brittle; sharp wavy boundary with
4-10 in.	Dark red-brown (2.5YR3/6) light or medium clay; moderate structure, $1^1/_2$ to 2 in. peds, plant roots mostly on the structural faces; grading into
10-36 in.	Dull brown to reddish brown light or medium clay; trace of soft lime increasing to light; weak to moderate structure, $^3/_4$ in. peds; a few plant roots evenly distributed; grading into
36-56+ in.	Reddish brown light clay; slight to light lime; weak to moderate structure, $^1/_2$ in. peds; evident clay skins and black flecks;

The structure varies from 3 in. of sandy clay loam to 6 in. of sand or up to 10 in. of sandy loam plus sandy clay loam. Hard rubble may occur below 15 in., sometimes increasing to moderate amounts at about 30 in. Small areas of clay surface also occur.

Calcareous phase profile

0-3 in.	Dark reddish brown to dull brown (5YR3/4-7. 5YR5/4) sandy loam or sandy clay loam; fine soft lime with scattered small rubble; apparently structureless; soft and brittle; many fine plant roots; sharp boundary with
3-11 in.	Dark red-brown (2.5YR3/4-4/6) light clay; soft lime increasing; weak structure, few roots; clear boundary with
11-24 in.	Pale brown (5YR to 7.5YR7/6) light clay; heavy soft lime, moderate hard-pan in slabs up to 18 by 8 in.;
24-36+ in.	Red-brown with very pale brown sandy clay; moderate soft lime moderate rubble, very hard, rounded with dark surfaces.

RIDGE SAND

Ridge sand is a soil of major extent, occurring on some of the crests and upper slopes of the Walpeup Ridge. It has the lightest profile of all soils in the Walpeup Ridge Land Unit, its light phase approaching very closely to Kattyoong sand of the East-West Dune Land Unit.

Normal phase profile

0-9 in.	Brown (7.5YR4/6) to reddish brown (5YR5/8) loamy sand; slight organic darkening to 6 in.; clear boundary with

9-12 in.	Reddish brown (5YR5/8) sandy clay loam; compact; clear boundary with
12-45 in.	Dull brown diffusely mottled sandy clay loam; trace of lime increasing to light or moderate sandy clay loam; trace of lime increasing to light or moderate amounts at about 18 in., with greyer and very pale brown colours; clear boundary with
45-66 in.	Dull reddish and yellowish brown diffusely mottled sandy clay loam; lime decreasing irregularly, slight small rubble; clear boundary with
66-84+ in.	Reddish brown or yellowish brown sandy clay.

The surface may be reduced or removed by wind action or overlain by as much as 6 in. of sand as distinct from loamy sand. This is often dull pale brown or yellowish brown. The total depth of surface ranges from 4 to 12 in.

The lower limit of the lime-rich zone varies from about 40 in. to deeper than 84 in.

Bands of sandy clay or sandy loam may occur below 4 ft.

Variants. – A "shallow surface variant" has less than 4 in. of surface material over a compact sandy clay loam.

– A "deep surface variant" has either a sand layer (not loamy sand) thicker than 6 in., or a total surface depth of more than 12 in.

Light phase - This phase is of minor extent on the Research Station. It differs from the normal phase in that the sandy clay loam subsoil lightens to sandy loam before 4 ft. Also, the surface is duller brown and deeper and is sand instead of the normal loamy sand.

WALPEUP SANDY LOAM

This is an extensive soil type, occurring on the slopes, and on some of the crests and depressions of the Walpeup Ridge Land Unit. It is distinguished from Ridge sand by a generally slightly heavier surface, and the presence of sandy clay before 4 ft.

Normal phase profile

0-5 in.	Dull brown to reddish brown (7.5YR4/4-5YR4/6) sandy loam or loamy sand; clear wavy boundary with
5-8 in.	Brown to red brown sandy loam, sometimes loamy sand; clear boundary with
8-14 in.	Reddish brown sandy clay loam; trace of soft lime at about 12 in.; clear boundary with
14-18 in.	Pale brown variously mottled sandy clay loam; light soft lime; clear or gradual boundary with
18-40 in.	Pale brown or very pale yellowish brown, variously mottled in very pale colours, sandy clay; light increasing to moderate soft lime at about 22 in.; grading into
40-50 in.	Reddish brown sandy clay; slight lime, grading into
50-84+ in.	Reddish brown, or red-brown finely mottled sandy clay loam.

The organic-darkened horizon may be reduced by wind action, or be absent, or be overlain with up to 6 in. of pale dull brown sand. The total surface depth ranges from 3 to 12 in.

In the subsoil, there is always at least 2 in. of sandy clay loam between the surface soil and the underlying sandy clay. The last is commonly found at about 18 in., but may occur at any depth down to 48 in. The lime maximum may extend to below 50in.

Variants. – A "shallow surface variant" has less than 3 in. of surface.
– A "light surface variant" has either more than 6 in. of sand or a surface depth of more than 12 in.

Heavy phase - This is of major extent, occurring on the slopes, particularly the western slopes of the Walpeup Ridge. It differs from the normal profile in having less than 2 in. of sandy clay loam subsoil before the sandy clay.

0-4 in.	Dark dull brown to dark reddish brown sandy loam; clear boundary with
4-8 in.	Reddish brown sandy loam or light sandy clay loam; porous and structureless; clear wavy boundary with
8-12 in.	Reddish brown sandy clay; compact; moderate structure; clear boundary with
12-36 in.	Dull brown passing to pale brown, mottled sandy clay; trace of lime increasing to moderate at 20 in.; grading into
36-48+ in.	Variously mottled in pale dull brownish colours, sandy clay loam; moderate or light lime.

The sandy clay horizon may contain up to 8 in. of clay.

Variants. – A "shallow surface" and a "light surface" variant are defined as for the normal phase.

WINKIE SAND

This is the lightest soil and a major component of the higher ridges of the East-West Dune Land Unit.

Normal phase profile

0-60 in.	Pale brown or pale yellowish brown (8.5YR6/8) loamy sand; clear boundary with
60-90 in.	Pale yellowish brown with reddish brown (5YR5/8) mottle loamy sand; trace to slight lime in lower part; clear boundary with
90-110 in.	Red-brown and yellow-brown mottled sandy loam pockets of soft lime.

The sand varies from 4 ft to more than 11 ft deep, and may contain pale grey-brown, or very pale yellowish brown layers, and some variation in proportions of fine and coarse sand.

Shallow phase - The shallow phase is associated with the normal phase, usually on western or northern slopes, and on crests and slopes of the smaller dunes.

0-4 in.	Pale dull yellowish brown sand; clear boundary with
4-24 in.	Pale yellowish brown sand passing to loamy sand; clear boundary with
24-60 in.	Pale yellow-brown and red-brown (10YR + 2.5YR4/6) sandy loam; trace of lime;
60-72 in.	Brownish red and yellow brown mottled sandy clay loam; slight lime.

The sand varies from 12 to 48 in. deep, and may be distinctly bleached in the lower part.

TYPE A

This is a variable soil of minor extent occupying the lower slopes of the east-west dunes below Winkie sand or Kattyoong sand.

Profile

0-4 in.	Dull reddish brown or dull yellowish brown loamy sand; clear boundary with
4-18 in.	Reddish brown or yellowish brown loamy sand; sharp boundary with
18-27 in.	Red-brown sandy clay loam; slight lime in the lower part; clear boundary with
27-48+ in.	Red-brown or reddish brown mottled sandy clay; slight to light lime.

The sand surface varies from 6 to 48 in. deep depths of more than 30 in. being indicated on the map by an inscription. Reddish brown surfaces are mostly less than 15 in. deep and show the most organic darkening (lower topographical position). Some soils with a subsoil of dull or yellow-brown sandy clay loam and sandy clay with moderate lime have been included in the type.

TYPE B

This is a minor soil type occupying slight rises within the swales of the East-West Dune Land Unit. There is light to moderate surface rubble.

Profile

0-4 in.	Dull brown (7.5YR4/4 moist) sandy loam; slight fine soft lime and slight small rubble; clear irregular boundary with
4-10 in.	Grey-brown sandy loam; heavy soft lime and moderate rubble;
10-22 in.	Pale dull brown sandy loam or sandy clay loam; light soft lime and heavy rubble ("pavement" blocks to 18 in. x 8 in. thick); marked proliferation of plant roots in these 3 horizons;
22-30 in.	Pale reddish brown (5 to 7.5YR7/6) sandy clay loam; light soft lime and moderate rubble, rounded and very hard;
30-48+ in.	Reddish brown mottled light clay with sand; slight lime and rubble; moderate structure, $^1/_2$ in. peds

TYPE C

This minor soil occurs on western shoulders and northern slopes of east-west dunes, associated with Kattyoong sand. There is usually scattered to light surface rubble. Lower occurrences are difficult to separate from Type E which, however, has slightly less yellowish colours and slightly more crumbly horizons.

Profile

0-5 in.	Dull yellowish brown sand or sandy loam; trace soft lime with trace of rubble; very light grey in lower part; sharp very irregular boundary with
5-24 in.	Dull yellowish brown and dull brown diffusely mottled sandy clay loam; trace of lime increasing to light or moderate pan or soft rubble at 10 to 16 in.; sharp boundary with
24-48+ in.	Brown and yellowish brown moderately mottled sandy loam; slight lime.

Textures below 24 in. may include sandy clay loam continuously, or in bands with sandy loam. Light or moderate lime concentrations may recur below 24 in. down to 78 in. or deeper.

TYPE D

This is a soil of the flats and major depressions of the Walpeup Ridge Land Unit where it occurs mixed with Midmallee sandy loam. It assumes major importance in the north-western corner of the Station on extensive, very gently sloping areas at intermediate levels, and in the interdune corridors of the East-West Dune Land Unit.

Profile

0-5 in.	Dark dull reddish brown (5YR3/4) ranging to greyish brown loamy sand or sandy loam; frequently stratified; clear or gradual boundary with
5-18 in.	Dark brown to dark reddish brown sandy clay loam or fine sandy clay loam, increasing in texture with depth; trace of lime from about 10 in.; gradual or diffuse boundary with
18-35 in.	Red-brown to dull reddish brown (2.5YR4/6 – 5YR4/4) passing into mottled pale brown light clay (or clay loam); light or sometimes moderate lime; clear boundary with
35-48+ in.	Pale brown variously mottled sandy clay; light lime.

The degree of stratification and profile development varies considerably, apparently due to both wind action and local run-off.

The soil type is distinguished from Midmallee sandy loam in having more than 4 in. (usually more than 10 in.) of transition between the surface and the red-brown light clay horizon. Clay loam subsoil textures commonly replace the light clay at 18 in. The texture below 30 in. occasionally lightens to sandy clay loam or increases to a denser, strongly structured, medium clay.

TYPE E

This is a minor and variable soil of the Walpeup Ridge Land Unit. It also occurs in lower situations on some of the East-West dunes where it approaches Type C in profile features. It is characterised by a dull or greyish calcareous surface horizon and sandy textures throughout the first 4 ft.

Profile

0-4 in.	Greyish brown to brownish grey sandy loam; soft lime, usually with scattered soft rubble; clear to gradual boundary with
4-10 in.	Similarly coloured sandy clay loam or fine sandy clay loam with lime increasing, diffuse boundary with
10-20 in.	Light to heavy soft lime with light to moderate rubble; clear boundary with
20-36 in.	Pale brown and brownish grey mottled sandy clay; moderate lime; clear or gradual boundary with
36+ in.	Reddish brown or red-brown mottled sandy clay loam continuing to variable depths.

This soil type is very variable in regard to the sharpness of horizons and the texture of the deep subsoil. The lime-free horizon may occur at any depth from 36 to 72 in.

Extent of the Soil Types

The area of each soil type recorded on the Station is given in Table 2.

Table 2:-   Areas of the Soil Types

Soil Type	Area (acres)	
Walpeup sandy loam (including sandy surface variants)	732	
Walpeup sandy loam, shallow surface variant	30	953
Walpeup sandy loam, heavy phase	191	
Ridge sand (including deep surface variants)	549	
Ridge sand, light phase	28	577
Midmallee sandy loam	314	
Midmallee sandy loam, calcareous phase	48	362
Type D		
Kattyoong sand	135	
Kattyoong sand, hardpan variant	59	194
Winkie sand	64	
Winkie sand, shallow phase	104	168
Type A		73
Type B		25

Soil Type	Area (acres)
Type C	13
Type E	12
Midmallee sand	12
Total (including 70 acres of roads)	2626

Relationships and Classification

Relationships. – Two factors make it unlikely that the soil types at Walpeup will be identifiable with those described in the earlier surveys of Mallee soils in the horticultural settlements along the Murray River. Firstly, the climate is probably significantly different in its leaching effect and, secondly, the physiography suggests a possible difference in the grading of the aeolian parent materials. Actually, on the basis of published descriptions, only one soil on the Station can be identified with an established soil type, namely Winkie sand first described at Berri and Cobdogla in South Australia (Marshall and Hooper 1935) and afterwards at Redcliffs (Hubble and Crocker 1941), Waikerie (Herriott and Johnston 1941) and Boundary Bend (Skene 1949).

In the early soil surveys, the descriptions of some soil types that recur in a number of districts show considerable divergence from their originally described profiles. This makes it difficult to compare the Walpeup soil types with those of the earlier surveys. However, more recently the specific textural and colour requirements for the commoner Mallee soil types were placed on an orderly basis for purposes of soil mapping at Robinvale (Skene 1951), and it is possible to record some similarities between the Walpeup and Robinvale soil types. These are as follows:

Ridge sand has affinities with Barmera sand in situation, colour and texture, but the latter has a much deeper surface. Also, in Ridge sand, the lime is typically leached a few inches below the top of the B horizon, not noted elsewhere.

Walpeup sandy loam has no equivalent elsewhere. The normal phase is intermediate between the Barmera series and the swale soils of the Nookamka series. Most commonly it is closest to Nookamka sandy loam, but, where its sandy clay horizon is deeper than 3 ft, it resembles Barmera sandy loam, shallow phase.

Generally, the reddish brown soil types found on the lower parts of the Station landscape occupy similar positions and have affinities with the Nookamka series.

Midmallee sandy loam, Midmallee sand and Type A may be compared with Nookamka clay loam, light surface variant. However, the last has 8 in. of sandy loam surface, whereas Midmallee sandy loam has only 4 in. Midmallee sand and Type A differ even more in having deep sand surfaces. Type D is nearest to Nookamka loam.

The dull surface, calcareous soils, Type B, C and E can be considered as related to either Coomealla sandy loam or Moorook sandy loam.

Kattyoong sand has no equivalent at Robinvale.

Classification. – Most generalised soil maps of Victoria and Australia show the station within the Great Soil Group zone of Solonised Brown Soils. A recent example of these maps is that compiled by Stephens (1961).

In view of the absence of specific classificational criteria for the Great Soil Groups, it is not particularly profitable to attempt to classify the individual soil types at the Great Soil Group level. All that need be said is that the characteristics of the main soil types, Ridge sand and Walpeup sandy loam closely approximate to broad descriptions of the Solonised Brown Soils as published by Stephens (1956).

Northcote (1960a) describes the soils in the Murray Mallee region as dominantly brown calcareous earths, and on Sheet No. 1 of his Atlas of Australian Soils shows these soils at Walpeup to occupy a landscape unit of dunes with relatively small plains between. He identifies various profile forms of the brown calcareous earths both on the dunes and on the plains. Other soils described in the unit by Northcote are brown sands on the dunes and crusty loamy soils on the lower-lying parts of the plain.

Northcote (1960b) has developed a classification of soil groups based on recognition of specific properties of the soil profile, and has used this to classify the soils found within the mapping units shown on his soil map. As this classification is still in the developmental stage, no attempt has been made to classify the Walpeup soil types into Northcote's soil groups.

CHEMICAL AND PHYSICAL PROPERTIES OF THE SOIL TYPES

Texture and Particle Size

The soils consist of a matrix of coarse and fine sand, with clay and lime added, but with very little silt. There are no heavy clays, the maximum clay content calculated on a lime free basis being 47% and 49% for parts of the B horizon in the Midmallee series and in Type D.

The coarse nature of the soils is illustrated by the amount and distribution of the particles in the non-clay fraction. Silt is less than 7% in almost every horizon samples except in Type D, while the ratio of sand to silt is high, ranging from 40 to 100 in the majority of horizons. The ratio is higher (100 to 500) in the lightest soil types, viz., Winkie sand and Kattyoong sand, and lower (8 to 35) in Midmallee sandy loam and Type D.

Coarse sand is characteristically high in the sand fraction of all horizons, coarse to fine sand ratios ranging from 0.7 to 2.0. Surface horizons show values below 1 in the Walpeup Ridge Land Unit, and above 1 in the East-West Dune Unit. The deep subsoils have ratios very close to 1.1, except that of Walpeup sandy loam which approaches 2.0.

Many soils were found to be subplastic, but after thorough manipulation their field texture assessments were found to accord very closely with the "texture diagram" classes on the basis of sand + silt + clay = 100% (Marshall 1947). This is another way of saying that with thorough working the lime, other than gravel, behaves if it had the same particle size distributions as the rest of the soil material. Soils with above 35% clay (after acid treatment) were found to have the field texture of medium clay.

The field texture class "loamy sand" was used for slightly coherent sands. This departs slightly from the texture diagram. It was found possible, in this limited environment, to separate "loamy sands" with clay content from 6% to 10%, from "sands" (less than 6% clay) and "sandy loams" (10% to 18% clay).

Lime

The term lime covers all accumulations of carbonates detectable in the field, either visibly or by effervescence with dilute hydrochloric acid.

Visible lime may be in the form of soft lime, lime pan or rubble. Soft lime is inferred from the colour of the material; it does not noticeably harden the earth fabric. Rubble consists of clearly defined, hardened units of any shape or size, greater than 2 mm, usually rounded. However, it includes rather flat units 1 ft or more across and quite closely placed in the soil ("pavement blocks"). Pan lime is a layer of lime-cemented earth not consisting of clearly defined units, although it may be fragmented. Pan and rubble may be relatively soft and easily crushed with a wooden pestle, or they may be hard or very hard. The last is difficult to break with a steel pestle.

In field estimates of lime content, the terms "trace" and "slight" refer to calcium contents from 0.1% to about 5% "light" and "moderate", from 5% to 50%, and "heavy" above 50%.

Details of the actual lime contents are given by the calcium carbonate figures in Appendix III. Where calcium carbonate has not been determined, the loss on acid treatment provides an approximation, except where this figure is less than about 1%.

It is seen that most of the surface soils have about 0.02% calcium carbonate, but that figure is between 0.5% and 2.5% in Midmallee sand, in the calcareous phase of Midmallee sandy loam, and in Types B, C and E. Type B has 6% rubble in addition. The figure for Type D is not presented as the surface may not be representative of the type.

Table 3:- Summarised Lime Content of the Soil Type Profiles

Soil Type	Average lime 0 to 4 ft *	Horizon of maximum lime		
		Depth to horizon	$CaCO_3$ ϕ	Rubble
	%	in.	%	%
<u>Non-calcareous</u>				
Winkie sand	0.03	no accumulation to 7 ft.		
Kattyoong sand	0.03	27	0.1	Nil
<u>Moderately calcareous</u>				
Most soil types		10-25	10-20	1-10
Walpeup sandy loam	9	9	14	1
Midmallee sandy loam	12	9	15	Nil
<u>Highly calcareous</u>				
Midmallee sandy loam calcareous phase	50	11	40	50
Type B	57	4	30	60
Type E	27	9	25	7

* Total rubble plus lime in the fine earth as a percentage of the whole soil to 4 ft.
ϕ in the fine earth.

Lime contents are summarised in Table 3, and the range occurring on the Station is further emphasised. The profiles are selected to illustrate three groups of soils. The central group, i.e. the commonest soil types show in contrast to the deep, non-calcareous sands, and to the highly calcareous group.

Soluble Salts

Various estimates of the soluble salt content of these soils are summarised in Tables 4 and 5, and in the total soluble salt column of Appendix III.

Figures for total soluble salts are very low in all the surface soils analysed, vix., 0.01-0.03% except in Type D which has 0.09%. (Appendix III)

The salt content rises with increasing clay content and depth, being from 0.2% to 0.5% in the lime-rich horizons, where the clay content is from 25% to 40%. However, the Kattyoong sand and Midmallee sand profiles are exceptional, with total soluble salt contents of only 0.05% and 0.06% where the clay is 26% and 40% respectively.

The Walpeup sandy loam profile differs from the other type profiles in that chloride and total salts drop off appreciably in the deeper horizons after reaching a maximum just below the lime.

Table 4 lists the individual ions in the soluble salts in six subsoil horizons. The first three soils all come from below horizons of maximum lime while the other three correspond to lime maxima.

Table 4:- Water Soluble Salts in Subsoil Horizons

Soil Type	Depth in.	Cations m.e. %				Anions m.e. %				Total Salts %	Soil pH
		Ca	Mg	K	Na	Cl	SO_4	HCO_3	CO_3		
Ridge sand	66-84	0.05	0.12	0.07	6.96	3.86	1.89	1.09	0.18	0.466	9.6
Walpeup sandy loam	32-46	0.05	0.12	0.05	5.17	2.37	1.24	1.27	0.13	0.350	8.9
Type D	46-60	0.12	0.32	0.11	7.72	4.85	2.30	0.80	0.08	0.523	9.2
Type A	31-53	0.05	0.04	0.04	2.04	0.04	tr	1.75	0.24	0.167	10.0
Midmallee sandy loam	9-36	0.05	0.08	0.05	4.02	1.52	0.76	1.34	0.38	0.248	9.7
Type B	22-30	0.06	0.04	0.04	2.70	0.26	0.13	1.33	0.83	0.187	10.1

The horizons from below the lime maxima show higher figures for total salts, sodium, magnesium, chloride and sulphate than the calcareous horizons. In contrast, potassium, calcium carbonate and bicarbonate show a much smaller range of values, and are therefore relatively more concentrated in the lime-rich horizons.

The Robinvale survey showed that calcareous horizons of soils there had total salt concentrations similar to the Walpeup soils.

Table 5 shows the distribution of sodium chloride at two selected depths in the various soil types. The significance of the medium and of the 90% limit values is that, in a large number of samples from any one soil type and depth, 50% of the samples would be expected to have salt contents above the median, and 50% below, whereas 90% would have contents below the 90% limit. The mean figure is not quoted, but in most cases is rather higher that the median.

Table 5:- Sodium Chloride Content of the Soils

Soil Type	Depth ft.	% Sodium chloride		No. of samples
		Median	90% Limit	
Winkie sand	1-2	.006	.008	15
Normal phase	3-4	.007	.018	17
Winkie sand	1-2	.008	.016	32
Shallow phase	3-4	.009	.025	32
Kattyoong sand	1-2	.008	.021	32
	3-4	.010	.055	30
Type A	1-2	.009	.035	17
	3-4	.016	.095	14
Midmallee sandy loam	1-2	.030	.150	30
	3-4	.070	.202	23
Walpeup sandy loam	1-2	.030	.140	118
	3-4	.100	.200	96
Ridge sand	1-2	.048	.142	57
	3-4	.112	.180	56
Type D	1-2	.040	.175	32
	3-4	.133	.210	21
Type E	1-2	.015	.136	14
	3-4	.067	.235	11

The figures show the usual trend to higher concentrations with increasing depth to 4 ft. A few samples taken at 5 to 6 ft show that the trend continues to this depth in most cases. There is also the usual marked trend to higher sodium chloride concentration in the heavier profiles. These trends as well as the levels of sodium chloride are similar to those found at Robinvale.

The 90% limit is from 2 to 6 times the median value (2 to 4 times the mean). It is therefore the better figure to use when considering the suitability of salt-sensitive plants for the soil types. For example, in the second foot on Midmallee sandy loam, a 90% limit of 0.15% contrasts with a median of 0.03% sodium chloride.

The table brings out the fact that the last five soil types listed are similar in one respect, namely that they each have 90% limits of about 0.15% in the second, and 0.20% in the fourth foot. Individual sites confirm this, except that in some cases the figure for the second foot is higher, the maximum found being 0.31% at one site in Type D.

Under dry land farming conditions salinity such as this is probably insignificant, even allowing for the fact that the sodium chloride is only about half of the total soluble salts. The occasional higher figure around 0.20% in the second foot of the heavier soils might retard seedling growth over small areas if these subsoils were exposed by erosion, but there are no surface salt data from wind scalded areas to test this. However, even here salt would not be the main problem, but rather physical problems of water penetration and perhaps shoot emergence.

Irrigation of small areas, e.g. farm gardens, would be expected to cause salts to move through the profile and down slope if overwatered, as in comparable Mallee soils in established irrigation areas.

Organic Matter, Potassium and Phosphorus

An overall impression of the nutrient status and organic matter content of these soils can be obtained from the data in Table 6. Some of these are from spot samples, namely horizons at the type sample sites, others are from composite samples taken from standard depths at a number of sites scattered over large areas.

Organic Matter. – In the case of organic carbon and total nitrogen, the composites for five surface soils lend general support to the type sample analyses. The figures for the composites are lower, but no significance can be attached to this.

Table 6:- Organic Matter, Potassium and Phosphorus

Soil Type	Details of Sample*	Depth	Clay	Organic Matter		Avail. K	Inorganic P+	
				Org. C	Total. N		A	B
		in.	%	%	%	ppm	ppm	ppm
Ridge sand	Profile No.2	0-7	7	0.65	0.061			
		7-10	7		0.041			
	Virgin (21)	0-6		0.62	0.056	285	11	20
	Virgin (12)	12-24					3	13
Walpeup sandy loam	Profile No. 3	0-4	13	0.64	0.060			
		6-9	25		0.050			
	Virgin (35)	0-6		0.48	0.049	225	10	20
	Virgin (12)	12-24					3	14
Type D	Profile No. 5	0-3	21		0.102			
		3-8	30		0.074			
	Various (12)	12-24					5	21
Winkie sand	Profile No. 8	0-7	5	0.09	0.014			
	Long cult. (28)	0-6			0.007	73	3	9
	Long cult. (13)	12-24				64	0.3	4
Winkie sand shallow phase	Profile No. 14	0-4	3		0.032			
		4-12	5		0.025			
	Long cult. (28)	0-6		0.18	0.014	95	4	7
Kattyoong sand	Profile No. 15	0-4	4	0.21	0.020			
		4-13	3		0.017			
	Long cult (13)	12-24				80	1	5
Midmallee sandy loam	Profile No. 10	0-3	14	0.73	0.056			
		3-9	38		0.046			
	Long cult. (42)	0-6		0.67	0.040	330	5	18
	Long cult. (13)	12-24					1	13

Total nitrogen in other soil types	Profile No.	Surface %	Subsurface %
Ridge sand, light phase	6	0.039	0.036
Midmallee sand	13	0.028	
Midmallee sandy loam, calcareous phase	11	0.081	0.066
Walpeup sandy loam, heavy phase	4	0.050	0.054
Type A	9	0.036	0.027
Type B	12	0.068	0.094
Type E	7	0.068	0.055

* Profile Nos. refer to sites, Appendix III. Figures in brackets are the number of sites in composite samples. + A = acid, B = alkali soluble P

Either organic carbon or total nitrogen can be used as an indirect measure of organic matter. The data for total nitrogen show that the soils as a whole are low in organic matter content (less that 0.1% total nitrogen). The surface sands of the East West Dune Land Unit and of Ridge sand light phase have the lowest amounts, viz., less than 0.04% of total nitrogen. Midmallee sand is in this group.

In most instances, organic matter is lower in the subsurface or subsoil than in the surface, but not markedly so.

Potassium. – Data not presented show that the available potassium is a measure of exchangeable potassium in the non-calcareous soils. Some data for exchangeable potassium are given in Table 7 and these may be converted to parts per million for comparison with available potassium by multiplying potassium in me% by 390.

The few figures for available potassium further illustrate the lower fertility of Winkie sand and Kattyoong sand compared with Ridge sand, Walpeup sandy loam, Midmallee sandy loam and Type D.

Actually available potassium in the surface of the first two soils is in the range which would be slightly deficient for pastures in Southern Victoria. This suggests the possibility that potassium may limit growth of some plants in wet years on these light soils of the East-West dunes. Elsewhere, the soils have adequate available potassium.

Phosphorus. – All the soils, both surface and subsoil, are seen to have low contents of acid and alkali soluble inorganic phosphorus and a marked accumulation in the surface 6 in. Winkie and Kattyoong sands are particularly poor, with about 12 p.p.m. (acid + alkali soluble P) in the surface and 5 p.p.m. in the subsoil (12-24 in.), even though superphosphate has been applied over the years. By contrast, uncleared areas of Ridge sand and Walpeup sandy loam have about 30 p.p.m. in the surface and 16 p.p.m. in the subsoil. These last two figures provide a good estimate of the likely original phosphorus status of most of the soils on the Station.

Alkali soluble phosphorus which is regarded as having appreciable availability in alkaline soils such as these, is from 2 to $3^1/_2$ times the acid soluble phosphorus in the surface soils, but is 4 or more times as much in the subsoils.

Exchangeable Cations

The exchangeable cations in the profiles of the five most important soil types are summarised in Table 7.

Table 7:- Exchangeable Cations in the Profiles of the Main Soil Types

Soil Type	Horiz	Depth in.	pH	Clay %	Total Cations		Cations - % of total			
					Soil me %	Clay* me%	Ca	Mg	K	Na
Ridge sand	A_1	0-7	7.8	6.5	7.7		67	25	5	3
	B_{L1}	13-33	9.5	21	16.0	78	29	39	5	27
	B_{L2}	33-43	9.6	23	16.1	71	20	43	6	31
Walpeup sandy loam	A_1	0-4	7.8	13	10.4		59	33	5	3
	B_{L1}	9-11	9.4	29	27.2	94	35	39	4	22
	B_{L2}	11-32	9.5	28	20.7	74	21	45	4	30
	C?	32-46	8.9	29	17.8	61	10	48	5	37

Soil Type	Horiz	Depth in.	pH	Clay %	Total Cations		Cations - % of total			
					Soil me %	Clay* me%	Ca	Mg	K	Na
Midmallee sandy loam	A	0-3	7.6	14	10.0		64	27	7	2
	B_1	3-9	9.0	38	24.3	66	41	40	6	13
	B_{L1}	9-36	9.7	39	26.2	68	21	42	6	31
Kattyoong sand	A_1	0-4	7.9	3.5	2.2		78	17	4	1
	B	19-27	8.7	26	14.1	58	46	46	2	6
	C	27-56	9.3	16	8.7	55	38	48	3	11
Winkie sand	A_1	0-7	8.2	4.9	3.1		73	19	7	1
	A?	32-50	9.1	4.9	3.5	73	75	20	4	1
	B	50-68	9.2	7.1	4.8	67	61	33	5	1

* Total cations per 100 g of clay. Surface horizons omitted because of presence of organic matter.

It is seen that these soils are in general accord with Mallee soils elsewhere, in that the sum of the exchangeable cations per 100 g of clay is fairly high; that calcium strongly dominates the exchange complex of the surface soils; and that with increasing depth the calcium is gradually displaced by magnesium and sodium. However, in the very sandy type Winkie sand, there is less displacement by magnesium and none by sodium at the depths investigated (about 60 in.).

The data illustrate the place of sodium in the genesis of these soils. Well developed horizons of clay accumulation in the first three profiles show a high percentage of sodium; this ranges from 13 to 31% of the total exchangeable cations. Winkie sand has no clay accumulation and 1% of exchangeable sodium; Kattyoong sand shows a weak B horizon at 19 to 27 in. with 6%, rising below this depth to 11% of sodium in the exchange complex.

Exchangeable potassium is moderate in most of the surface soils but increases in the subsoils and deep subsoils. It should be adequate for plants over most of the Station. However in Kattyoong sand and Winkie sand exchangeable potassium is low, and could be a factor limiting plant growth, at least in the wetter seasons.

The total of the exchangeable cations in the clay is high, ranging from 55 to 78 m.e. with one exception and averaging 67 m.e. per 100 g of clay. This is consistent with a dominantly illite type of clay mineral, as has been found in Mallee soils elsewhere.

pH

The pH values of the soil type samples, given in Appendix III show that there is not a great variation between the types. They are broadly similar to Mallee soils elsewhere.

The surface soils are mostly slightly or moderately alkaline (pH 7.3-8.5) but a few are strongly alkaline (pH 8.7-9.1). Alkalinity then increases with depth to strongly or very strongly alkaline (pH values above 9.5 are common below 2 ft).

The pH values of the surfaces, with one exception, range from 7.3 to 8.5 where there is no visible lime, and are 8.7 or 8.8 in the four visibly calcareous surfaces (Types B, C and E, and the calcareous phase of Midmallee sandy loam). The Midmallee sand profile is exceptional in this as in other ways, with a surface pH of 9.1, and no visible lime nor effervescence with acid before 16 in.

Except in the calcareous surface types, there is a rise of about1 pH unit between the surface and the B_1 horizon, where the value is 8.6 to 9.2.

The maximum pH (9.3 to 10.1) occurs at or below the horizon of maximum visible lime.

The Walpeup sandy loam profile illustrated is unusual in that the pH drops from 9.5 at 11-32 in. (lime maximum) to 6.1 at 46-66 in. and 5.3 at 66-84 in. This probably is not representative of the type.

SOILS AND LAND USE

Profitable cropping is normally precarious in much of the Mallee country, and indeed any utilisation at all of some soils is hazardous in dry years. Despite great advances, it is by no means certain that serious drifting can be prevented in the second and third years of a long dry spell, or that maximum use is made of the available moisture in the wetter years.

Farming methods have changed quite radically several times in the past, and changes can be expected in the future. The basic aims and problems remain: high average yields, prevention of wind erosion, prevention or utilisation or run-off, utilisation of soil moisture. These all involve crop varieties, sowing techniques, fertilisers, fallowing, pastures and stock management. Of recent years soil organic matter and quality of grain have received increased attention.

The values of different varieties and treatments are usually averaged over several seasons and several soil types. His has lead to steady advances in the past. It leads to the most widely adaptable varieties and to uniformity of treatment, and is therefore in keeping with the tendency towards bigger farms and more powerful machinery. It does not always tell in what respect one plant or treatment is or is not better than another.

It is possible that investigations into the potential of each different soil type, and into the response of plants in each different season, might increase yields and quality still further, and still be profitable.

Winkie sand presents the greatest problems, combining as it does low chemical fertility, high permeability, and low water holding capacity. Slopes are often steep enough to shed the rain to lower levels. Management should regard prevention of run-off as being of an importance second only to holding the top soil from blowing away.

The plants grown should be able to use the large proportion of the rain which falls in showers that wet no more that the surface foot or so of the soil, and also to recover the moisture from heavier falls which penetrates to 10 ft or more. The required extent of roots can be provided efficiently only by perennial plants, or by a mixture of perennials and annuals.

It was noticed during the survey that plants in the annual pastures had little root development below 12 in. in these soils, despite a much deeper moisture profile. They are adapted to mature quickly in dry conditions. Zimmer (1940) notes the ratio or root to shoot length for seedlings of various plants. This suggests one factor which could be used in evaluating plants for use on Winkie sand. Perhaps the use of fertilisers, including potash, could be reviewed with these special points in mind. It also seems necessary to consider perennial plants which could be established with a minimum of rains in a long dry spell, after lucerne, for instance, had exhausted the deep subsoil moisture reserves.

Kattyoong sand should be regarded as a very different soil from Winkie sand, despite similarities in surface and situation. Just how different depends on the depth of sand and the properties of the subsoil, particularly its permeability, water holding capacity and chemical fertility. Assessment of Kattyoong sand will be complicated by the numerous small areas of hard-setting soils scattered throughout the type.

Midmallee sandy loam is the soil with the highest chemical fertility in the East-West Land Unit and appears equal to any on the Station. Its problems include lack of water penetration in dry years, a shorter workable period, and some danger of waterlogging in wet seasons. On the scanty evidence available, the calcareous phase may be somewhat better than the normal phase, in both water penetration and chemical fertility.

Type D appears to be similar to Midmallee sandy loam with a rather more permeable profile.

Type B has the mechanical disadvantage of much hard rubble on or near the surface, but has good water penetration, and the cereal roots proliferate markedly amongst the rubble.

The three main soils in the eastern portion of the farm are ***Walpeup sandy loam and its heavy phase***, and ***Ridge sand***. They will be discussed together. Their chemical fertilities are apparently similar, while each has a reasonably deep, permeable surface and fairly permeable subsoil.

Ridge sand, and particularly the deep surface variant, might be expected to dry out quickly and to "blow" badly in dry periods. On the other hand in wet periods, water and roots of annual plants appear to penetrate the B horizon rather better than into Walpeup sandy loam. Some areas of Ridge sand, particularly in paddock No. 10, probably have surfaces of much lower fertility than at the type sample site.

The heavy phase of Walpeup sandy loam probably has a sharper increase in texture at the top of the B horizon than appears from the type samples (Profile No. 4). This, when combined with a high and moderately sloping position, causes run-off and scouring during heavy rain, and so may contribute to quicker drying, and wind erosion later. Shallow "blown" surfaces of this phase form a very unattractive crust which puddles badly in the rain. They might warrant special treatment designed to incorporate more organic matter into the surface and to catch any passing sand, in order to make the surface more permeable.

Much of the heavy phase of Walpeup sandy loam is situated high on the slopes, and does not waterlog there. Type D is normally in the bottom of depressions. However both soil types do occur in lower slope positions, and here surface wetness can cause damage to crops in wet seasons. In paddock No. 3 the old track appears to accentuate this, north-west of the rifle butts.

Areas of ***Type E*** are usually, but not always, more powdery than the surrounding soils. Fibrous root systems appear to be more evenly distributed and of greater depth than in the less calcareous soils. Cereals are reputed to make good early growth with the risk of premature wilting. It has been suggested that this is due to high nitrogen content. However at the type sample site, the total nitrogen of the surface horizon is similar to that of Walpeup sandy loam. The conditions are complex, for salts are low, and pH is high throughout the profile. Differential fertiliser treatment might be worth investigation.

The area of ***Midmallee sand*** at the type sample site appears lethal to cereals, although the areas mapped in paddock Nos. 11 and 12 grew good medic pastures in 1960. These morphologically similar soils may be significantly different chemically and warrant investigation from this aspect.

Type A receives some seepage and run-off from the higher dunes, but requires a moderately deeply rooting plant to exploit this moisture. The surface material is typically sand blown off the higher areas of Winkie sand or Kattyoong sand and may be chemically similar. However some areas have an admixture of other materials.

The place of phosphorus and nitrogen in Mallee agriculture is recognised – that of potassium is not so well understood. Most of the soils are well supplied with potassium, but not so soils such as Winkie sand and Kattyoong sand. Trials with potash, particularly in the pasture phase of rotations, are warranted on these soil types.

Walpeup is likely to remain a dry farming area, but the economics of irrigation in parts of the Mallee should be received from time to time, as an adjunct to dry-farming. Deep bore pumping is feasible in the west. There is probably scope for a small amount of water harvesting from the higher land such as the Walpeup Ridge, while improved methods of distribution and storage might release greater amounts of water for use in the Wimmera-Mallee. Increased fodder reserves, or an acre or two of vegetables, or of green feed for poultry, would provide a welcome diversity on many district farms.

Any general increase in soil organic matter due to medic ley and short fallow will effect many phases of farm which will need to be reviewed in the light of the changing soil conditions.

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Plant specimens were identified at the National Herbarium.

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APPENDIX I - Glossary of Soil Terms and Analytical Methods Soil Terms

Clay skin or cutan. – A descriptive term for any apparent film, usually smooth and shiny, on the surface of the peds or within the soil pores.

Colour. – Soil colours, besides being described in common terms such as brown, red-brown etc. may be defined in terms of the Munsell notation by matching the soil against colour charts, e.g., 2.5YR5/8 denoting in order hue, value, and chroma, defines one particular soil colour in the red-brown range.

Concretion. – A hard aggregate caused by local concretions of compounds that irreversibly cement the soil grains together. Calcium carbonate concretions in the Mallee soils are commonly referred to as rubble.

Consistence. – Describes the behaviour of a soil when manipulated. It indicates its resistance to deformation and is a measure of the degree of cohesion of a soil, or of a soil aggregate. Terms used such as incoherent, soft, hard, brittle, crumbly and plastic are self explanatory.

Depositional layer. – All material of one depositional phase constitutes a layer, whether or not horizons have developed in it.

Gravel. – Particles larger than 2 mm diameter (as distinct from the fine earth which is comprised of particles smaller than 2 mm). In the Walpeup soils gravel consists entirely of calcium carbonate concretions.

Horizon. – A layer of soil, more or less parallel to the land surface, similar throughout and recognisably different from the material above and below. The following horizons in the soil profile may be recognised:

> ***A horizon.*** The uppermost layer where accumulation of organic matter and evaluation or removal of materials commonly occur. It may be divided into two or more subhorizons as follow:
>
> > ***A_1 horizon.*** The surface soil more or less darkened by organic matter – a zone of maximum biological activity.
> >
> > ***A_2 horizon.*** A subsurface layer lower in organic matter than the A_1, and in consequence, usually lighter in colour.
>
> ***B horizon.*** A zone of accumulation of soil materials from the A horizon above. It may be subdivided from the top down into B_1, B_2, etc. on differences in colour, texture, structure, etc., except that in this report B_L is used to denote the main zone of lime accumulation. The B_1 horizon is commonly the first zone of clay accumulation.
>
> ***C horizon.*** A zone less enriched from above than the B horizon and though to be little effected by biological soil forming processes.

Any of the above subhorizons may be further divided on the basis of slight changes in a property, for example, the A_1 into A_{11} and A_{12}, the B_L into B_{L1} and B_{L2}.

Organisation. – A term used to express the degree to which a presumed uniform material has been differentiated by soil forming processes. A "well organised clay" is one arranged into very distinct, dense peds with clay skins evident.

Ped. – An individual natural soil aggregate.

Soil profile. – Vertical section of soil showing the sequence of horizons from the surface to the parent material or substrata.

Soil type. – The basic unit for classifying and mapping soils. It groups soils with profiles varying only within defined, narrow limits, developed from a common parent material and, following U.S. definition, has area as well as depth.

Soil phase. – A subdivision of a soil type wherein one feature is emphasised, such as the depth of the A horizon.

Structure.- The manner and degree of natural aggregation of the primary soil particles. Most of the subsoils on the Station have either weakly or moderately developed subangular blocky structure. This means that each ped is roughly cubic, but with rounded corners and curved as well as plane faces.

Subplastic. – Describes soils which become tougher when manipulated for some time, even when kept uniformly moist, i.e., there is an apparent increase in clay content.

Subsoil. – The B_1 and B_{L1} horizons. The *deep subsoil* refers to horizons below the B_{L1} horizon, including those of possible buried soils.

Analytical Methods

The methods used for the analyses shown in Tables 4 to 7 and in Appendix III are given below and, except where indicated otherwise, are essentially as described by Piper (1950). All estimations were carried out on the air-dried fine earth, i.e., material passing a 2 mm round hole sieve. For calcium carbonate, phosphorus, nitrogen and organic carbon, the fine earth was further reduced to pass through a 0.5 mm sieve.

Particle Size Distribution:- International "Method A." Results expressed as percentage of oven dry soil.

Total Nitrogen:- Kjeldahl digestion. Results given on oven dry basis.

Organic Carbon:- Walkley and Black's Method using a recovery factor of 1.25. Results given on oven dry basis.

Calcium Carbonate:- Hutchinson and Maclennan's Method. Carbon dioxide estimated and expressed as per cent calcium carbonate in the air-dry soil.

Available Potassium:- Potassium determined in a 1:20 soil to $^{N}/_{20}$ hydrochloric acid equilibrium extract and expressed as parts per million of air-dry soil.

Inorganic Phosphorus:- Williams Method (1950). A: Phosphorus determined in a 1:40 soil acid (2.5% acetic acid – 1% 8-hydroxy-quinoline) equilibrium extract). B: After acid extraction, phosphorus determined in a 1:40 soil to alkali (0.1 N sodium hydroxide) equilibrium extract. Results expressed as parts per million of air-dry soil.

Exchangeable Cations:- Tucker's Method (1954). Soluble salts first removed with 60% ethanol, then calcium, magnesium, sodium and potassium determined in leachate of N ammonium chloride in 60% ethanol adjusted with ammonia to pH 8.5. The sum of the four cations expressed as milligram equivalents per 100 g of oven dry soil, the individual cations expressed as percentages of the total.

Chlorides:- Determined by the electrometric titration method of Best and reported as chloride ion (Appendix III) or sodium chloride equivalent
(Table 5).

Soluble Salts:- Cations and anions determined in a 1:5 soil to water extract and expressed as milliequivalents per 100 g of air dry soil. Total salts determined gravimetrically (Table 4) or estimated (Appendix III) from the electrical conductivity of a 1:5 suspension at 20^{o}C. For Walpeup soils, %T.S. = E.C. in mho/cm x 330.

pH:- Determined on a 1:5 soil to water suspension by the glass electrode.

APPENDIX II - Recorded Plant Species

(* Plants introduced to Victoria)

Acacia Wattles including
A. pycnantha Golden Wattle
A. microcarpa
Ballarat, leafless *Exocarpus aphylla*
Belar *Casuarina lepidophloia*
Blue bush *Kochia* species
Broombush *Melaleuca uncinata*
Buloke *Casuarina Luehmannii*
Cassia *Cassia eremophila*
C. Sturtii
Cattle bush *Heterodendron oleifolia*
Chenopods, in this context salt bush, blue bush etc.
Daisy, Mallee *Olearia pimeleoides*
Daisy, poached egg *Myriocephalus Stuartii*
Dampiera lanceolata
Emu bush *Eremophila crassifolia* and others
* Grass, Barley *Hordeum leptorinum*
*Sterile brome *Bromus sterilis*
Quandong *Santalum acuminatum*
Quandong, bitter ("Ming") *S. Murrayanum*
Salt bush *Atriplex* and *Bassia* spp.
Skeleton weed *Chrondrilla juncea*
Sugar wood (false sandal wood) *Myoporum platycarpum*

Grass, Porcupine *Triodia irritans*
*Wimmera rye *Lolium rigidum*
Spear *Stipa nitida*
S. acrociliata et al.
Wallaby *Danthonia* spp.
Grevillea *G. Huegelii et al.*
Hakea needlewood
Hop bush *Dodonea attenuata*
D. bursariifolia
D. cuniata
* Lucerne *Medicago sativa*
* Lupin, Common blue *Lupinus pilosus*
Mallee Eucalyptus calcogona, *dumosa incrassata*, *oleosa*, *viridis*
* Medic, Barrel *Medicago tribuloides*
* Wooly burr *M. Minima*
* Harbinger *M. littoralis*
*Mustard *Sisymbrium orientale et al.*
Pine, Murray *Callitris Preissii*
Scrub *C. verrucosa*
Pittosporum, weeping *P. phyllyreoides*
Tea tree *Leptospermum coriaceum*
Thistle, saffron *Carthamus lanatus*
Turnip, wild Raphanus, *Brassica* spp.
Twin leaf (gall weed) *Zygophyllum apiculatum*
Terpentine bush *Beyeria Leschenaultii*

APPENDIX III - Field and Laboratory Data for Representative Soil Profiles

Chemical and physical data and summarised morphological descriptions are given for sixteen profiles representing all the soil types. The location of each profile can be identified on the soil map by its profile number. Analytical methods are given in Appendix I.

The abbreviations used in the tables have the following meanings:-

Hor.	Horizon. In general the designations accord with the definitions given in Appendix I. However there is evidence that some of the so-called B and C horizons are relics of earlier soils, variously eroded and then buried by the materials above.
Bdy	Nature of boundary with the underlying horizon: a = abrupt; c = clear; d = diffuse; g = gradual; I = irregular; w = wavy.
Text.	Field texture assessment (fld); S = sand; LS = loamy sand; SL = sandy loam; CL = clay loam; SCL = sandy clay loam; SC = sandy clay; LC = light clay; MC = medium clay; C = clay (unspecified).
Colour	Main colours: RB = red-brown, B = brown; GB = grey-brown; YB = yellow-brown. Modifications: r = reddish; y = yellowish; g = greyish; vp = very pale; d = dull; dk = dark; b = brownish.
LAT	Loss on acid treatment.
Particle size	CS = coarse sand (2.00 – 0.2 mm); FS = fine sand (0.2 – 0.02 mm); Si = silt (0.02 – 0.002 mm); C = clay (< 0.002 mm) as :- (i) % of fine earth. (ii) % of "lime free" fine earth (i.e. CS + FS + Si + C = 100%)
Sol. salts	Water soluble salts calculated from electrical conductivity (see Methods: Appendix I).
-	Indicates that the analysis has not been made.
?	Doubtful, or unknown horizon designation.
tr	Trace.

WINKIE SAND Profile No. 8 Nos. 29734-38/60

Gentle slope; crest of major E-W dune. Surface even.

Original vegetation before 1918 probably Stunted Mallee. Volunteer pasture following wheat in 1959; open ground cover of annual herbs and grasses, mainly wild turnip, poached egg daisy and Bromus species.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS	FS	Si	C i	C ii	LAT	$CaCO_3$	Sol. Salts	Cl	pH
					%	%	%	%		%	%	%	%	
0-7	A_1	ai	pyB	S	49	44	tr	5		.8	0.03	.01	.001	8.2
7-32	A_{21}	c	pyB	S*	49	45	tr	5		.5	-	.02	.002	9.2
32-50	A_{22}	a	pyB	S	41	52	tr	5		.6	0.03	.02	.001	9.1
50-68	B	d	yB, rB	LS	40	51	tr	7		.7	-	.02	.002	9.2
68-84	C		pB	S	42	52	tr	6		.7	-	.03	.002	9.1

* Slightly more compact than 0-7 in.

WINKIE SAND shallow phase Profile No. 14 Nos. 29765-70/60

Middle N-slope major E-W dune.

Cropped to cereals from 1919; now under 4 course rotation; sparse ground cover of Wimmera rye grass on fallow.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS	FS	Si	C i	C ii	LAT	$CaCO_3$	Sol. Salts	Cl	pH
					%	%	%	%		%	%	%	%	
0-4	A_1	c	yGB	S	59	36	1	3		0.3	0.0	.02	.001	7.8
4-12	A_{21}		dyB	S	55	39	1	5		0.1	-	.02	.002	7.8
12-24	A_{21}	c	yB	S	52	40	1	6		0.3	-	.02	.002	8.2
24-30	B_1	cw	yB	SL	48	39	1	11		1.0	-	.04	.002	8.9
30-48	B_2	cw	yB,bR	SL	44	39	1	14		2.3	1.4	.05	.004	9.2
48-72	?		bR	SL	-	-	-	-		-	tr	-	-	-

KATTYOONG SAND Profile No. 15 Nos. 29771-76/60

Extensive lower gentle N-facing slope of major E-W dune. Even surface. Sparse ground cover of Wimmera rye grass, as volunteer pasture in fallow in 4 course rotation. Intensively cropped to cereals from 1919 to 1946.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS	FS	Si	C i ii	LAT	$CaCO_3$	Sol. Salts	Cl	pH
					%	%	%	%	%	%	%	%	
0-4	A_1	a	GB	S	61	33	1	4	0.2	0.02	.02	.001	7.9
4-13	A_2	c	pyB	S	55	40	2	3	0.3	-	.02	.001	8.2
13-19*	A_2B_1	ai	pgyB	S	53	43	1	3	0.3	-	.02	.002	8.2
19-27	B_1	g	B	SCL	44	29	1	26	1.0	0.04	.05	.004	8.7
27-56	B_2	c	bR,yB	SL	46	37	1	16	0.8	0.1	.07	.002	9.3
60-64	?		bR,yB	SCL	-	-	-	-	-	-	-	-	-
64-67	?		RB	SC	-	-	-	-	-	- **	-	-	-

* Pale sand fills irregularities 6 in. deep in top of 19-27 in. horizon;
** Heavy concentrations of hard rubble below 67 in.

KATTYOONG SAND hard pan variant Profile No. 17 Nos. 29784-88/60

Upper Middle W-facing slope of E-W dune. Even surface.

Barrel and hairy burr medics, sterile brome and barley grasses; grazed in 4 course rotation, following intense cropping to wheat for many years. Pasture dried off 15 days earlier than that on nearby less-hard soils.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS	FS	Si	C i ii	LAT	$CaCO_3$	Sol. Salts	Cl	pH
					%	%	%	%	%	%	%	%	
0-3	A	a	dB	LS	51	40	tr	7	0.5	-	.04	.002	8.1
3-5	AB_1	a	B	SL	45	39	1	15	0.7	-	.03	.005	8.8
5-10	B_1	c	B,yB	SCL	41	39	tr	18	0.9	-	.09	.007	9.9
10-21	B_2	c	yB,yG	SCL	40	40	1	18	2.3	-	.18	.030	10.0
21-28	?	a	rB,yB	SL	-	-	-	-	-	-	-	-	-
28+	?		vpB	SCL	contains moderate soft lime.								

AB_1 is very hard-drying. B1 has weak prismatic structure $1^1/_2$ in x 6 in.

RIDGE SAND Profile No. 2 Nos. 29705-11/60

Near crest on N-slope of high, gently undulating N-S ridge.

Belar-Buloke-Pine vegetation type; shrubs cleared, grazed by sheep.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-7	A_1	c	drB	LS	36	52	4	7		0.7	0.1	.04	.00	7.8
7-10	A_2	ai	prB	LS	37	53	1	7		0.7	-	.06	.02	7.4
10-13	B_1	ci	rB	SCL	32	37	1	28		1.6	-	.19	.09	8.6
13-33	B_{L1}	d	gB	SCL	24	32	1	21	27	23	20.8*	.27	.07	9.5
33-43	B_{L2}	g	pgB	SCL	29	31	2	23	26	14	-**	.32	.09	9.6
43-58	C	d	yB,rB	SCL	32	38	1	20	22	10	-	.32	.10	9.8
66-84	?		dB	SC	29	31	2	34	35	3.8	-	.47	.14	9.6

In addition in field samples; * 7% rubble ** 5% rubble.

RIDGE SAND light phase Profile No. 6 Nos. 29698-704/60

On subdued E-W dune on crest of gently undulating N-S ridge.

Pine-Hopbush vegetation type, partly cleared of timber; dense shrub layer.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-4	A_1	c	GB	LS	43	48	2	6		0.6	0.0	.03	.00	7.3
4-9	A_{21}	c	dB	S	42	51	1	5		0.5	-	.05	.01	7.8
9-12	A_{22}	c	pGB	S	45	49	1	5		0.8	-	.05	.06	9.2
12-18	B_1	g	B	SCL	40	38	1	21		1.4	-	.19	.04	9.7
18-25	B_2	a	vpgB	SCL	36	37	1	22	33	4.4	2.3	.30	.06	9.7
25-54	B_{L1}		vpB	SCL	33	34	1	20	23	13	11.9*	.29	.06	9.9
54-65	B_{L2}		pGB	SCL	40	33	1	20	21	6.2	-	.28	.06	9.9

* In addition 4% rubble in field sample.

MIDMALLEE SAND Profile No. 13 Nos. 29760-64/60

Very gentle slope on a slight rise in almost level broad swales between moderate dunes.

Cleared and cropped from 1918. Sown with annual pasture in 4 course rotation in 1948. Oats had failed almost completely at time of sampling.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-16	A	g	rB	LS	52	39	1	6		1.1	0.6	.03	.003	9.1
16-22	AB_1	g	rB	SL	48	37	1	13		1.1	-	.04	.004	9.1
22-37	A_L	d	rB	LC	29	22	1	39	42	7.7	5.4*	.06	.002	8.7
37-44	?	c	rB	LC	28	22	1	45	47	4.0	1.6**	.06	.003	9.9
44-50	?		pB	C	24	19	2	37	45	18	- #	.07	.003	9.0

* 3% soft rubble, ** 3% very hard rubble, # 62% very hard rubble.

TYPE A Profile No. 9 Nos. 29739-44/60

On lower, S-slope of major E-W dune.

Cropped intensively; now under pasture phase (dense barrel medic and Wimmera rye) of 4 course rotation.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-3	A_{11}	c	drB	LS	48	44	1	7		0.8	0.02	.03	.002	8.4
3-11	A_{12}	g	rB	LS	44	47	1	7		0.6	-	.05	.005	8.6
11-14	A_2	a	dpB	S	44	49	1	5		0.4	-	.03	.003	9.2
14-20	B_1	c	B	SCL	40	35	2	23	23	1.5	0.4	.06	.003	9.2
20-31	B_{L1}	g	drB	SC	31	23	tr	37	41	9.6	7.3	.10	.006	9.6
31-53	B_{L2}		rB	SC	32	27	2	30	33	10	-	.17	.006	10.0

MIDMALLEE SANDY LOAM Profile No. 10 Nos. 29745-48/60

Very gently sloping swale between moderately steep dunes.

Intensively cropped to cereals from 1919; now under barrel medic and Wimmera rye grass pasture introduces into 4 course rotation in 1955.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-3	A	aw	rB	SL	35	48	2	14		1.0	0.0	.04	.01	7.6
3-9	B	g	dkRB	C	28	27	7	38	38	2.4	-	.09	.01	9.0
9-36	B_{L1}	g	dB	C	19	21	3	39	47	17	14.7	.28	.07	9.7
36-48	B_{L2}		rB	C	18	22	4	42	49	15	11.6	.40	.11	9.4

MIDMALLEE SANDY LOAM Profile No. 11 Nos. 29749-52/60

Calcareous phase

Gentle lower slope of slight rise in extensive almost level swale.

Under heavy wheat crop. Intensively cropped to cereals from 1918 to 1948; latterly in 4 course rotation with sown annual pasture.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-3	A	a	rB	SCL	48	26	5	18		3	1.1	.05	.005	8.7
3-11	B_{L1}	c	rB	LC	31	23	6	32	35	9	-	.06	.006	8.8
11-24	B_{L2}	c	vpB	LC	13	13	2	21	41	50	45*	.09	.007	9.5
24-36	B_{L3}		rB	SC	16	17	1	21	34	41	37**	.12	.006	9.9

In addition in the field samples; * 54% rubble, ** 48% hard rubble.

WALPEUP SANDY LOAM Profile No. 3 Nos. 29712-19/60

Upper W-slope of gently undulating high N-S ridge.

Big Mallee type, pines removed; open shrub layer; some perennial grasses and good ground cover.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-4	A_{11}	cw	drB	SL	34	47	5	13		1.0	-	.03	.00	7.8
4-6	A_{12}	a	drB	SL	36	46	3	14		0.9	-	.03	.01	8.1
6-9	B_1	c	rB	SCL	33	37	3	25		1.6	0.1	.10	.02	8.8
9-11	B_{L1}	c	dB	CL	25	27	7	29	34	12	-	.18	.05	9.4
11-32	B_{L2}	g	rB	SC	28	27	2	28	34	16	14.3	.34	.08	9.5
32-46	C?	g	rB	SCL	39	26	4	29	30	1.5	-	.35	.09	8.9
46-66	?	g	rB	SCL	46	25	2	26		0.9	-	.24	.07	6.1
66-84	?		rB	SCL	50	26	1	21		0.5	-	.20	.05	5.3

WALPEUP SANDY LOAM Profile No. 4 Nos. 29720-24/60
heavy phase

On western middle slope of gently undulating N-S ridge. Site between mounds of slightly hummocked surface.

Small Mallee vegetation type; scattered shrub layer and poor ground cover.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-6	A_1	aw	rB	LS	39	49	3	8		0.8	0.01	.04	.01	8.4
6-11	AB_1	cw	rB	SCL	38	36	3	23		1.2	-	.23	.07	8.9
11-16	B_1	c	drB	SC	33	30	2	29	31	5.0	2.7	.37	.12	9.2
16-20	B_{L1}	g	drB	SC	28	28	2	31	34	9.9	-	.46	.15	9.3
20-44	B_{L2}		pGB	SCL	31	26	1	27	31	14	11.2	.46	.14	9.6

TYPE B Profile No. 12 Nos. 29753-57/60

Upper gently slope of slight rise in extensive swale between moderately sloping dunes.

Intensively cropped from 1918. Under heavy wheat crop in 4 course rotation with sown pastures first introduced in 1948.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-4	A?	ci	gB	SL	44	36	2	14		4	2.6	.05	.00	8.8
4-10	B_{L1}?	gw	gB	SL	32	37	2	17	19	11	8.1	.06	.01	9.0
10-22	B_{L2}	g	pgB	SL	18	23	2	17	27	38	36	.13	.01	9.7
22-30	B_{L3}	g	pB	SCL	18	20	6	20	31	35	33	.19	.01	10.1
30-47	B_{L4}		rB	SC	17	21	3	40	49	19	18	.24	.03	10.0

Rubble in field samples of above horizons (%); 6, 63, 61, 53, 36 (last 2 very hard).

TYPE C Profile No. 16 Nos. 29777-83/60

Upper N-slope of moderate E-W dune. Surface even. Wind-scoured crust.

Intensively cropped to cereals from 1918; now fair lucerne sown in 1957.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-5	A	ai	dyB	LS	53	36	1	10		1	-	.04	.003	8.8
5-14	B_1	ai	dB	SCL	42	40	1	16		1	-	.05	.004	8.9
14-22	B_L	a	pB,yB	SCL	41	33	tr	14	15	11	-	.05	.004	9.4
22-32	?	g	pB	SL	44	41	1	13	13	2	-	.05	.003	9.4
40-46	?	g	pB	SCL	40	37	1	14	15	8	-	.07	.004	9.9
46-68	?	g	prB	SL	41	31	tr	12	14	17	-	.08	.004	9.9

TYPE D Profile No. 5 Nos. 29725-29/60

Bottom of major high level depression in high N-S ridge.

Cleared and burnt in 1956; now in 4 course rotation; third and very heavy oat crop harvested just before sampling.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-3	A_1	c	dkGB	SCL	28	40	9	21		2.7	0.7	.09	.09	8.5
3-8	AB_1	a	dkrB	SCL	24	37	8	30		1.8	-	.10	.02	8.6
8-19	B_1	d	rB	CL	15	25	19	34	36	7.2	3.0	.27	.06	9.2
19-46*	B_L	d	B	LC	16	23	4	39	48	19	16.9	.37	.08	9.5
46-60	?	d	dB	MC	24	26	2	35	40	13	-	.52	.18	9.2

* Sampled 19-36 in. only.

TYPE E Profile No. 7 Nos. 29730-33/60

Gentle lower northern slope of subdued E-W dune, being part of the gently undulating crest of the N-S ridge.

Pine-Hopbush transitional to Small Mallee vegetation type; part cleared and re-grown. Shrubs mid dense with good ground cover of perennial grasses.

Depth in.	Hor	Bdy	Main colour	Text (fld)	CS %	FS %	Si %	C i %	C ii %	LAT %	$CaCO_3$ %	Sol. Salts %	Cl %	pH
0-3	A	a	GB	SL	37	37	5	20		1.5	-	.04	.008	8.7
3-9	AB_1	c	gB	SCL	32	36	3	22	24	7.5	-	.05	.006	8.8
9-20	B_{L1}	d	pGB	SC	24	26	3	22	30	25	-	.06	.006	9.1
20-40	B_{L2}		pGB	SC	24	21	2	22	33	32	-*	.15	.009	10.0

* 7.2% soft limestone rubble in the field sample.