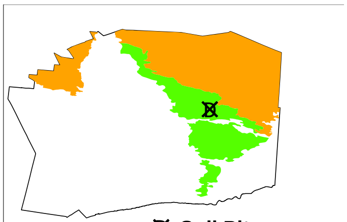
Soil 18 Sandy loam over red clay



<u>Landscape</u> Gently undulating plains of the "mallee" component of the Langhorne Creek Region. Underlying sediments are heavy clays. Surface soil is firm and stone free.

<u>Profile</u> Sandy loam to sandy clay loam over a well structured red calcareous clay, becoming more clayey and calcareous with depth.

Depth (cm)	*Description*
0-13	Dark reddish brown hard massive slightly calcareous light sandy clay loam. Clear to:
13-30	Reddish brown firm highly calcareous light clay with strong fine polyhedral structure. Gradual to:
30-60	Reddish brown firm very highly calcareous light medium clay with strong medium polyhedral structure. Gradual to:
---------------- buried soil -----------------------	
60-90	Reddish brown and dark greyish brown mottled firm calcareous blocky medium clay. Gradual to:
90-140	Brown and dark greyish brown mottled firm blocky medium heavy clay with 20-50% soft carbonate (Blanchetown Clay equivalent).

Key properties

Drainage — Moderately well drained. The soil rarely remains wet for more than a week or so following heavy or prolonged rainfall. However, deep drainage is impeded by the heavy clay substrate.

Potential root zone — 90 cm in sampling pit, but few roots below 60 cm.

Barriers to root growth

Physical: The coarsely structured heavy clay from 90 cm prevents deeper growth.

Chemical: High pH, sodicity and boron concentration from 30 cm restrict root growth.

Water holding capacity : Estimated for the depth of the potential root zone of grapevines

Total available: 75 mm
Readily available: 35 mm

Fertility — Inherent fertility is moderately high. Although nutrient retention capacity is satisfactory, free carbonate to the surface tends to tie up phosphorus, manganese and zinc.

Erosion potential — Low potential for both water and wind erosion.

Laboratory data

Depth Cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	S mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exchangeable cations - cmol(+)/kg Ca	Mg	Na	K	#CEC	#ESP
Target →	< 9.2	>5.0	na	< 2.0	< 350	10	< 3	80	200	> 1.0	% of (Ca+Mg+Na+K) 65-75	10-15	< 6	3-8	> 5	< 6
0-13	8.7	7.9	3.0	1.33	83	10.8	2.4	17	413	0.78	12.1	3.08	1.09	1.15	17.5	6.2
13-30	9.1	8.3	14.2	2.87	321	35.2	4.6	4	223	0.44	12.7	5.45	3.35	0.60	22.1	15.2
30-60	9.5	8.5	22.2	5.13	542	38.6	12.1	2	442	0.17	6.67	6.23	6.19	1.10	20.2	30.7
60-90	9.5	8.6	6.8	2.47	347	28.6	15.7	3	527	0.06	5.06	6.48	8.65	1.36	21.6	40.1
90-140	9.5	8.6	23.4	3.51	322	78.8	10.7	4	342	0.12	5.99	3.94	7.40	0.84	18.2	40.7

CEC estimated from sum (Ca+Mg+Na+K). # ESP is estimated by = Na / (Ca+Mg+Na+K)

Explanation of highlighted data

Grape vines can suffer 10% yield loss when ECe exceeds 2.5 dS/m, or chloride exceeds 350 mg/kg.
Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for grape vines (American literature).
Root growth generally poor where pH in water exceeds 9.2.
Carbonate concentration in clayey matrix generally retards root development.
Free carbonate and high pH in surface layer can cause tie-up of phosphorus and trace elements.

Notes:

Management of Soil 18

Sandy loam over red clay

by John Rasic

Problems

Wine grape growing on this soil is unlikely to be profitable over a period of decades. The laboratory data show that the levels of salinity, sodicity, alkalinity, pH and boron are all high at shallow depth. The mottled colouring in the heavy clay layer below 90cm indicates inadequate deep drainage. These severe limitations are not easily corrected at an affordable cost.

Pre-planting action that can be used to tackle the problems

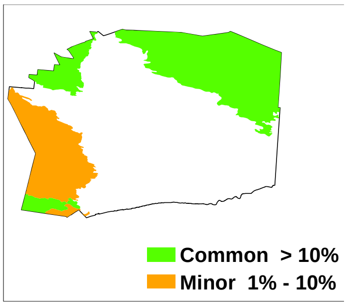
As this soil is not easily leached, it cannot be repaired at acceptable costs.

Soil management after planting

Initial plant growth can be satisfactory but, under irrigation, growth may decline significantly.

The strategy needed to overcome the soil limitations and then to achieve only moderate plant production is very expensive and the soil limitations often continue to affect grapevine yield even after the strategy has been implemented.

Soil 19 Sandy loam over red clay



Landscape: Gentle slopes formed on clayey alluvium. Surface soil is hard setting and stone free.

Profile: Hard setting red brown loamy sand to clay loam overlying a well structured red clay subsoil, highly calcareous with depth.

Depth (cm)	*Description*
0-18	Dark reddish brown hard massive light sandy loam. Clear to:
18-23	Pink hard massive light sandy loam. Sharp to:
23-36	Dark red well structured light medium clay. Clear to:
36-55	Dark reddish brown light clay with more than 50% soft calcareous segregations. Gradual to:
55-90	Very pale brown very highly calcareous massive medium clay. Diffuse to:
90-120	Dark brown and yellowish brown mottled medium clay with strong blocky structure and veins of soft carbonate.

Key properties

Drainage — Moderately well drained. Soil may remain wet for up to one week following heavy or prolonged rainfall. Deep drainage is marginal.

Potential root zone — 55 cm in sampling pit pasture / cereal roots). Most vine root growth would be in this zone, with some roots extending to 75 cm.

Barriers to root growth

Physical: Hard massive surface soil and firm, coarsely structured subsoil clay prevent optimal root distribution.

Chemical: Highly calcareous clay from 55 cm typically restricts root growth. There is no significant salinity, sodicity or boron levels above 90 cm.

Water holding capacity : Estimated for the depth of the potential root zone of grapevines

Total available: 75 mm
Readily available: 35 mm

Fertility — Inherent fertility is moderately low due to relatively sandy surface. However, nutrient retention capacity in the subsoil is very high, providing a reserve of macro nutrients. Maintaining adequate levels of nutrition in these soils is straightforward, provided acidity is controlled.

Erosion potential — Moderately low to low potential for water erosion, depending on slope. Wind erosion is only likely if soil is excessively cultivated.

Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	S mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exchangeable cations - cmol(+)/kg Ca	Mg	Na	K	CEC	ESP
Target →	< 9.2	>5.0	na	< 2.0	< 350	10	< 3	80	200	> 1.0	% of (Ca+Mg+Na+K) 65-75	10-15	< 6	3-8	> 5	< 6
0-18	5.3	5.3	0	*1.4	65	-	0.5	26	540	1.0	3.6	0.6	0.1	0.7	5.2	2
18-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23-36	7.3	7.3	0.3	*1.1	14	-	2.0	4	700	0.6	22.4	5.0	0.5	2.1	33.6	1
36-55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55-90	8.4	7.9	35.0	*1.2	79	-	2.0	<2	370	0.3	13.5	5.4	0.8	1.2	22.2	3
90-120	8.9	8.3	10.5	*2.0	69	-	5.0	<2	590	0.1	7.6	8.9	2.9	1.7	21.8	13

* ECe estimated from $EC_{1:5}$

Explanation of highlighted data

Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for grape vines (American literature).
Carbonate concentration in clayey matrix generally retards root development.

Notes:

Management of Soil 19
Sandy loam over red clay
by John Rasic

Problems
Even with careful management, on this soil it is difficult to grow grapes that will meet the quality specifications and yield quantity will decline over time.
When this soil is wet, the sharp boundary at 23cm between the porous surface layer and the clay can cause the sand to collapse (slake) into a slurry that blocks pores and dries to become an impenetrable cap (capping). Salts and toxins can then accumulate above the cap.

In addition, the carbonate-rich (calcareous) layers below 36cm are likely to contain toxins and be a strong chemical barrier to root penetration.

Soil problems can worsen if this soil is inappropriately managed.

Pre-planting action that can be used to tackle the problems
Remove the sharp boundary and permanently increase the uniformity of the topsoil by incorporating gypsum during mechanical mixing of the layers down to 36cm. This will improve the penetration of roots and of water and prevent waterlogging and compaction.

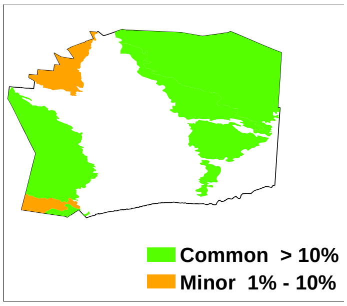
To avoid carbonate contamination of the topsoil, the carbonate-rich layer below 36cm must not be mixed with the soil above it.

Soil management after planting
Management will depend on how effectively the boundaries have been removed and the uniformity improved by the addition of gypsum and mixing.

Increase the organic matter in the soil of the mid-row by establishing a cover crop. After adding gypsum, mixing and increasing the organic matter, move some of the top 36cm of the soil from the mid-row and mound it along the row of grapevines to increase the depth of soil above the carbonate-rich subsoil. Do not expose the white layer of this soil.

Apply irrigation to wet less than the depth of improved soil in order to minimise re-contamination of the improved soil with carbonate in water that can be wicked upwards from the deeper layers.

Soil 20 Calcareous sandy loam



<u>Landscape</u> Gently undulating plains and rises formed on carbonate capped sandy clay. Surface soil is firm with up to 20% calcrete stones.

<u>Profile</u> Calcareous sandy loam grading to a very highly calcareous sandy clay loam with abundant rubble, decreasing with depth.

Depth (cm)	*Description*
0-9	Brown calcareous soft sandy loam. Clear to:
9-27	Yellowish red soft highly calcareous sandy loam. Abrupt to:
27-43	Light brown highly calcareous fine sandy clay loam with 20-50% carbonate nodules. Clear to:
43-75	Yellowish red highly calcareous fine sandy clay loam. Gradual to:
75-121	Yellowish red and reddish yellow highly calcareous fine sandy clay loam. Clear to:
121-160	Yellowish red highly calcareous fine sandy clay loam with more than 50% carbonate nodules. Diffuse to:
160-185	Yellowish red and light grey massive moderately calcareous sandy light clay.

Key properties

Drainage — Well drained. The soil never remains wet for more than a couple of days. Deep drainage is somewhat impeded by clayey substrate.

Potential root zone — Previous cereal crop roots to 75 cm but few below 43 cm in sampling pit.

Barriers to root growth

Physical: There are no physical barriers.

Chemical: High pH, sodicity and boron concentrations, and moderate salinity (as highlighted in table below) restrict root growth.

Water holding capacity : Estimated for the depth of the potential root zone of grapevines

Total available: 75 mm
Readily available: 35 mm

Fertility — Nutrient retention capacity is moderately low. Phosphorus, nitrogen and zinc deficiencies can be expected. Copper and manganese may be required from time to time.

Erosion potential — Low potential for water erosion, moderately low potential for wind erosion.

Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	S mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exchangeable cations - cmol(+)/kg Ca	Mg	Na	K	CEC	ESP
Target $\rightarrow$	< 9.2	>5.0	na	< 2.0	< 350	10	< 3	80	200	> 1.0	% of (Ca+Mg+Na+K) 65-75	10-15	< 6	3-8	> 5	< 6
0-9	8.4	8.0	0.5	0.61	-	-	1.5	7	470	1.33	7.1	0.9	0.16	0.82	7.9	2.0
9-27	8.6	8.1	2.5	0.50	-	-	2.0	<5	350	1.00	9.8	2.0	0.16	0.87	12.1	1.3
27-43	9.4	8.5	12.2	1.52	-	-	3.2	<5	270	0.49	3.6	4.3	1.49	0.62	8.4	17.7
43-75	10.0	8.8	16.0	2.23	-	-	6.9	<5	390	0.19	1.0	2.6	4.79	0.94	7.6	63.0
75-121	10.0	8.9	5.5	2.69	-	-	11.7	<5	450	0.06	0.9	2.5	5.59	1.01	9.8	63.5
121-160	9.8	8.7	10.0	4.57	-	-	13.8	<5	440	0.01	0.7	2.6	5.72	0.99	10.0	57.2
160-185	9.9	8.7	7.0	4.13	-	-	15.6	<5	470	0.23	1.0	2.8	6.29	1.20	9.9	64.0

Explanation of highlighted data

Grape vines can suffer 10% yield loss when ECe exceeds 2.5 dS/m, or chloride exceeds 350 mg/kg.
Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for grape vines (American literature).
Root growth generally poor where pH in water exceeds 9.2

Notes:

Management of Soil 20
Calcareous sandy loam

by John Rasic

Problems

Wine grapes, either irrigated or dry-grown, are unlikely to be profitable on this soils due to low returns and high costs. The high pH causes plants to grow poorly and to display symptoms called “lime-induced chlorosis”. Despite good drainage, good aeration, and good stability when wet, this soil has severe limitations that are not easily corrected at an acceptable cost.

From the laboratory data, the limitations are the excessive quantity of powder-sized particles of carbonate (CO3), the high pH and high alkalinity, high exchangeable sodium percentage (ESP) and high level of boron.

The high pH restricts the availability of essential elements including manganese and iron.

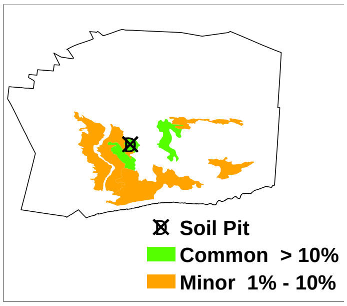
Pre-planting action that can be used to tackle the problems

Acidifying materials can be used to remove carbonate from the top 30 to 40 cm of soil, but this is expensive and impractical.

Soil management after planting

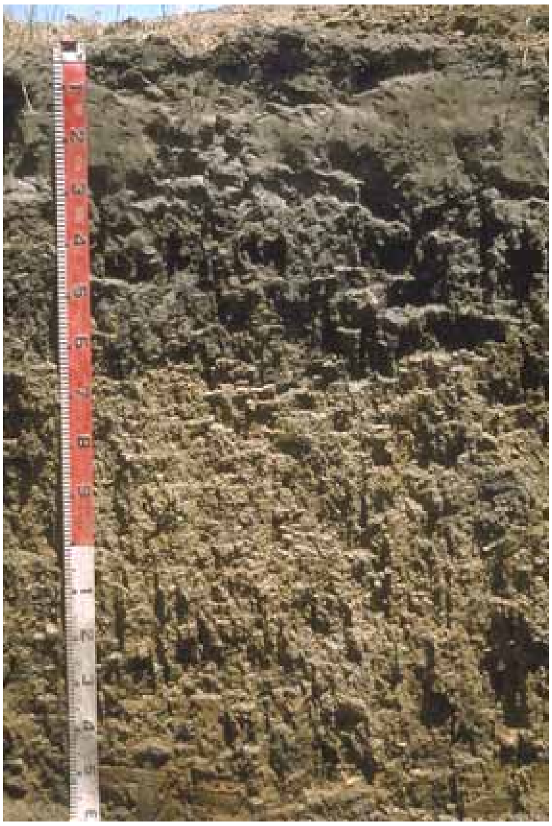
Even if carbonate is removed from the surface soil and after that soil is mounded, contaminated water can wick up from the subsoil to cause re-contamination with carbonate, salts, sodium and boron.

Soil 21 Sandy loam over dark dispersive clay



Landscape: Old alluvial flats of the Angas Bremer flood plains. Surface soil is hard setting and stone free.

Profile: Dark brown sandy loam to clay loam overlying a black silty clay to medium clay with strong blocky structure, becoming yellowish mottled and usually weakly calcareous with depth.



Depth (cm)	*Description*
0-10	Dark brown massive hard setting fine sandy loam. Abrupt to:
10-20	Very dark grey massive hard fine sandy loam. Clear to:
20-40	Very dark grey hard fine sandy clay with weak coarse prismatic structure. Clear to:
40-70	Dark brown and greyish brown mottled hard medium heavy clay with strong medium angular blocky structure. Diffuse to:
70-110	Grey brown, yellow brown and orange mottled firm medium heavy clay with strong angular blocky structure. Gradual to:
110-180	Greyish brown and red mottled firm medium heavy clay with strong coarse prismatic structure.

Key properties

Drainage — Moderately well to imperfectly drained, due to its dispersive, sodic subsoil clay. The upper part of the soil may remain wet for a week to several weeks.

Potential root zone — 70 cm (estimated) in sampling pit, with some roots persisting to 110 cm.

Barriers to root growth

Physical: Roots in the subsoil are largely restricted to the surfaces of the aggregates - few penetrate due to the high density of the clay. The hard, massive surface soil and temporary perched water tables also affect root proliferation to some extent.

Chemical: Mild salinity and moderate sodicity from 40 cm restrict root growth in grape vines to some extent. Salt and sodium accumulation can be expected under irrigation due to imperfect deep drainage.

Water holding capacity : Estimated for the depth of the potential root zone of grapevines

Total available: 100 mm
Readily available: 45 mm

Fertility — Nutrient retention capacity is moderately high. Maintaining adequate levels of nutrition in these soils is straightforward.

Erosion potential — Low potential for both water and wind erosion.

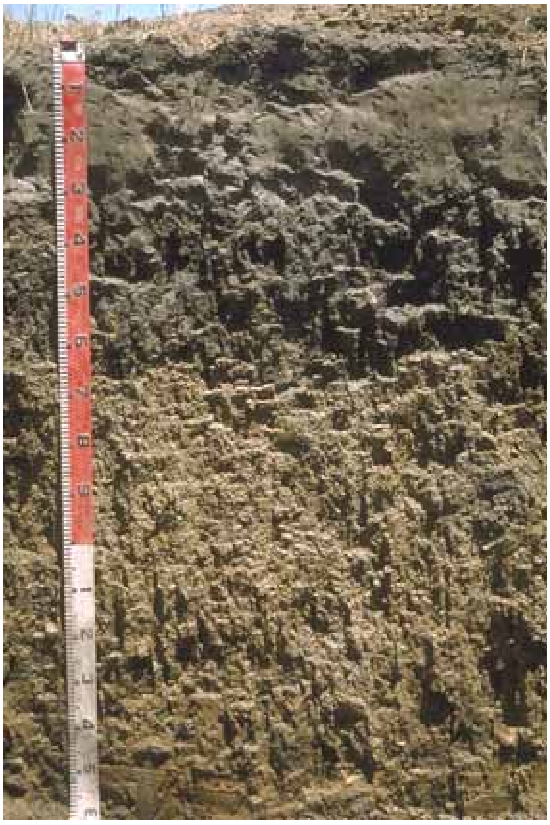
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	S mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exchangeable cations - cmol(+)/kg Ca	Mg	Na	K	CEC	ESP
Target →	< 9.2	>5.0	na	< 2.0	< 350	10	< 3	80	200	> 1.0	% of (Ca+Mg+Na+K) 65-75	10-15	< 6	3-8	> 5	< 6
0-10	7.6	7.2	0	0.90	-	-	2.0	124	409	2.1	6.70	2.58	1.13	0.79	10.4	10.9
10-20	7.6	7.1	0	1.56	-	-	1.2	86	411	0.9	5.24	2.11	0.74	0.75	8.8	8.4
20-40	7.8	7.4	0.1	2.02	-	-	2.3	48	485	0.6	8.15	4.22	1.34	1.05	14.4	9.3
40-70	8.4	7.8	0.1	2.30	-	-	3.3	15	559	0.5	10.4	6.11	4.48	1.42	23.0	19.5
70-110	8.3	7.8	0.1	2.83	-	-	3.6	11	466	0.3	9.02	5.31	5.20	0.91	20.7	25.1
110-180	8.0	7.6	<0.1	5.15	-	-	2.0	10	459	0.3	9.11	5.77	4.95	0.76	19.9	24.9

Explanation of highlighted data

Grape vines may crops suffer yield / quality loss when ECe exceeds 2.5 dS/m.
Exchangeable sodium less than 6% of CEC is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for grape vines (American literature).
Apply gypsum to increase the low ratio of Ca to Mg.

Notes:



Management of Soil 21
Sandy loam over dark dispersive clay
by John Rasic

Problems
The limitations are waterlogging and the accumulation of toxins. These limitations are caused by slaking and capping on top of the clay layer at 20cm. The limitations are severe because, when it is wetted, the dispersive clay below 20cm will form a cloud of minute particles that can move (disperse) and very effectively block the soil pores and prevent deep drainage. Another problem is the absence of a sandy layer to provide drainage at depth.

Pre-planting action that can be used to tackle the problems
Adding gypsum and mechanically mixing the soil layers down to about 40cm will improve the uniformity of this soil profile so that the sandy loam will not collapse (slake) into a slurry and flow down through the profile to block pores and form an impenetrable cap (capping) that causes waterlogging above the clay.

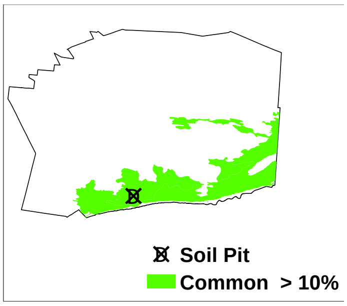
However, in order to avoid contamination of the entire profile, the dispersive material that lies below 40cm should not be mixed with the surface soil.

Soil management after planting
To manage dispersion and to improve the penetration of roots and of water, the laboratory results from annual soil tests are needed in order to determine the dates and the amounts of gypsum to apply on to the soil surface.

The establishment of a cover crop that has roots that will grow deep into the sodic, saline, boron-rich soil below 40cm may, over many years, increase the effective depth of this soil.

Use soil moisture monitoring equipment to ensure that irrigation applications wet only the depth of improved soil (40cm) in order to minimise re-contamination of the improved soil with water wicked upwards from the deeper, dispersive layer.

Soil 22 Loam over brown clay



<u>Landscape</u>

Old alluvial plains of the lower reaches of the Bremer River formed on mixed coarse and fine grained sediments. Surface soil is firm and stone free.

<u>Profile</u>

Medium thickness dark loam over a coarsely structured brown, black and red mottled clay, calcareous with depth, grading to variable alluvium.

Depth (cm)	*Description*
0-15	Very dark grey firm granular loam. Abrupt to:
15-33	Brown hard medium clay with strong coarse prismatic structure. Clear to:
33-70	Reddish brown hard highly calcareous medium clay. Gradual to:
70-105	Yellowish brown and brown mottled firm massive slightly calcareous sandy light clay. Gradual to:
105-130	Light olive brown and brownish yellow mottled massive alluvial clayey sand. Gradual to:
---------buried Tertiary age sediments----------	
130-145	Grey and brown mottled firm coarse blocky medium clay. Gradual to:
145-190	Grey, yellow and brown mottled friable coarse blocky fine sandy light clay.

Key properties

Drainage — Moderately well drained. The upper subsoil may remain wet for up to a week following heavy or prolonged rainfall. Deep drainage is somewhat impeded by the clayey layer at 130 cm and the water table at 190 cm.

Potential root zone — 130 cm in pit, but few roots below 70 cm.

Barriers to root growth

Physical: The clayey subsoil and deep subsoil present a minor barrier to root growth, mainly by restricting even proliferation.

Chemical: High pH, sodicity and boron levels from 33 cm impede root growth. High salinity from 70 cm defines the effective root zone.

Water holding capacity : Estimated for the depth of the potential root zone of grapevines

Total available: 95 mm
Readily available: 40 mm

Fertility — Nutrient retention capacity is moderately high. Apart from a slight susceptibility to high pH induced tie-up of trace elements, maintaining adequate levels of nutrition in these soils is straightforward.

Erosion potential — Low potential for both water and wind erosion.

Laboratory data

Depth Cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	S mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exchangeable cations - cmol(+)/kg Ca	Mg	Na	K	#CEC	#ESP
Target →	< 9.2	>5.0	na	< 2.0	< 350	10	< 3	80	200	> 1.0	% of (Ca+Mg+Na+K) 65-75	10-15	< 6	3-8	> 5	< 6
0-15	8.4	7.6	0	2.15	133	6.2	3.2	28	636	1.55	8.24	6.61	1.39	1.68	17.9	7.8
15-33	9.1	8.2	0	1.30	98	17.9	6.5	5	455	0.60	7.50	10.2	2.92	1.27	21.9	13.3
33-70	9.5	8.5	19.3	1.85	242	34.8	10.1	4	495	0.21	6.59	7.03	5.36	1.24	20.2	26.5
70-105	9.4	8.4	1.2	8.26	1130	140.0	7.4	2	367	0.13	4.57	4.68	8.14	0.93	18.3	44.4
105-130	8.6	8.0	0	11.9	1340	197.0	2.8	2	205	0.07	1.39	2.78	5.90	0.46	10.5	56.0
130-145	8.1	7.7	0	11.8	2190	348.0	3.2	2	379	0.15	2.76	5.35	10.2	0.89	19.2	53.1
145-190	7.9	7.6	0	18.7	2540	413.0	2.6	3	379	0.16	2.95	5.66	10.5	0.89	20.0	52.4

CEC estimated from sum (Ca+Mg+Na+K). # ESP is estimated by = Na / (Ca+Mg+Na+K)

Explanation of highlighted data

Grape vines can suffer 10% yield loss when ECe exceeds 2.5 dS/m, or chloride exceeds 350 mg/kg.
Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for grape vines (American literature).
Root growth generally poor where pH in water exceeds 9.2
Carbonate concentration in clayey matrix generally retards root development.
Low Ca:Mg ratio, but gypsum will increase salt load, already high in subsoil.

Notes:

Management of Soil 22

Loam over brown clay

by John Rasic

Problems

Due to low returns and high costs, growing wine grapes on this soil, with or without irrigation, is unlikely to be profitable.

The water table at 190cm indicates poor deep drainage.

The laboratory data for this soil show high levels of salinity, sodicity, alkalinity, pH and boron. These severe limitations are not easily corrected at an affordable cost.

Pre-planting action that can be used to tackle the problems

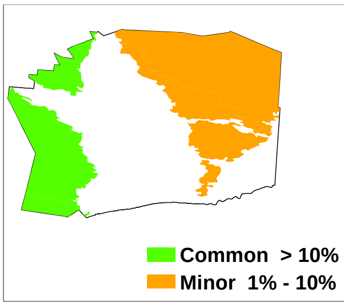
As this soil is not easily leached, it cannot be repaired at acceptable costs.

Soil management after planting

Initial plant growth can be satisfactory, but with irrigation, growth may decline significantly.

The strategy needed to tackle the soil limitations, and then to achieve only moderate plant yield, is very expensive and soil limitations are likely to continue to reduce grapevine yield even after the strategy has been implemented.

Soil 23 Sand over poorly structured brown clay



Landscape

Plains and swales formed on heavy clay sediments (Blanchetown Clay equivalent). Surface soil is soft and stone free.

Profile

Medium thickness sandy surface sharply overlying a brown mottled coarsely columnar sandy clay to clay, calcareous with depth, grading to heavy clay.

Depth (cm)	*Description*
0-17	Soft dark brown loamy sand. Abrupt to:
17-20	Soft bleached light loamy sand. Sharp to:
20-30	Yellowish brown and pale brown mottled firm sandy medium clay with coarse columnar structure. Clear to:
30-43	Yellowish brown, grey and orange mottled medium clay with strong prismatic structure. Clear to:
43-70	Yellowish brown, yellow and orange mottled very highly calcareous light clay. Gradual to:
70-115	Light grey and orange mottled highly calcareous coarsely prismatic light clay. Gradual to:
115-150	Olive, orange and brown mottled medium clay with strong coarse blocky structure.

Key properties

Drainage — Imperfectly drained. Perched water tables can develop for several weeks on the dispersive sodic subsoil clay. Deep drainage is very poor due to the very slowly permeable clay at depth.

Potential root zone — 70 cm in pit, but few pasture roots below 43 cm. Main root zone for grape vines is 43 cm.

Barriers to root growth

Physical: The hard dispersive clay subsoil restricts good root proliferation.

Chemical: High pH, sodicity and boron concentration from 43 effectively limit the root zone.

Water holding capacity : Estimated for the depth of the potential root zone of grapevines

Total available: 50 mm
Readily available: 25 mm

Fertility — Natural fertility is low due to the low clay content of the surface soil. Apart from nitrogen and phosphorus deficiencies, copper and zinc will be required periodically. Sandy surface is prone to acidification.

Erosion potential — Potential for water erosion is low, and for wind erosion, moderately low.

Laboratory data

Depth Cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	S mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exchangeable cations - cmol(+)/kg					ESP
											Ca	Mg	Na	K	CEC	
Target →	< 9.2	>5.0	na	< 2.0	< 350	10	< 3	80	200	> 1.0	% of (Ca+Mg+Na+K)				> 5	< 6
											65-75	10-15	< 6	3-8		
0-17	5.3	4.8	0	1.31	-	65	0.4	35	213	1.2	3.78	0.49	0.09	0.23	4.7	1.9
17-20	7.8	7.4	0	0.67	-	17	0.1	5	50	0.1	0.78	0.24	0.15	0.09	1.6	na
20-30	6.8	5.7	0	0.83	-	32	1.4	10	188	0.3	4.43	4.45	1.70	0.49	11.1	15.3
30-43	8.3	7.3	0	1.36	-	45	4.4	<4	327	0.2	4.54	8.03	3.94	0.77	18.5	21.3
43-70	9.7	8.5	23.7	2.39	-	101	9.6	<4	405	0.3	4.05	8.83	6.47	1.06	18.1	35.7
70-115	9.9	8.6	16.4	1.47	-	24	11.0	<4	424	0.3	2.62	7.85	6.91	1.03	16.1	43.0
115-150	9.7	8.9	1.1	1.73	-	62	21.6	<4	525	0	2.49	10.0	8.97	1.40	23.4	38.3

Explanation of highlighted data

Root growth generally poor where pH in water exceeds 9.2
Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for grape vines (American literature).
pH less than 5.0 requires treatment, especially in subsurface layers.
Sum of exchangeable cations of less than 5 cmol(+)/kg is indicator of low inherent fertility.
High carbonate concentrations in clay restrict root growth.

Notes:

Management of Soil 23
Sand over poorly structured brown clay
by John Rasic

Problems
Growing grape vines is unlikely to be economic on this soils due to low yields and high costs.

The laboratory data show that the levels of salinity, sodicity, alkalinity, pH and boron are all high at all depths below 20cm. These severe limitations are not easily corrected at an affordable cost.

Above the clay layer at 20cm, waterlogging can be caused by the soil collapsing (slaking) into a slurry that blocks pores and becomes an impenetrable cap (capping). Inadequate drainage is indicated by the mottled colours of the clays at all depths below 20cm.

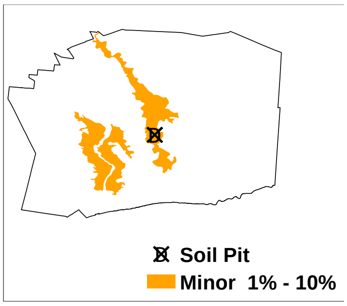
If rain or irrigation applications wet down to below 20cm, water that contains toxins (e.g. salts, sodium) can be wicked upwards from the deeper layers to contaminate the topsoil.

Pre-planting action that can be used to tackle the problems
Some pre-planting actions could be undertaken to improve establishment and early growth, but effects are unlikely to persist in the longer term.

The low leaching capacity of this soil is a problem because large quantities of good quality water must be applied to remove the toxins. Leaching toxins is possible only after increasing the speed at which water can move through the soil (its permeability) and ensuring that the soil remains stable after wetting. This requires the incorporation of gypsum, mechanical mixing and the installation of a drainage system.

Soil management after planting
Unless extreme (expensive) measures are used to overcome its limitations, this soil has properties that make it unsuitable for grapevines.

Soil 24 Black cracking clay (salt affected)



Landscape: Alluvial plains and flats formed on clayey alluvium. Surface soil seasonally cracks and is stone free.

Profile: Black coarsely structured silty clay to medium clay, becoming more clayey and sometimes calcareous with depth.

Depth (cm)	*Description*
0-10	Very dark grey medium clay with strong polyhedral structure. Clear to:
10-20	Very dark grey medium heavy clay with strong polyhedral structure. Clear to:
20-50	Black heavy clay with strong angular blocky structure. Diffuse to:
50-100	Black heavy clay with strong angular blocky structure. Diffuse to:
100-200	Black heavy clay with strong angular blocky structure. Gradual to:
150-200	Very dark brown heavy clay with strong very coarse prismatic structure. Water table at 160 cm.

Key properties

Drainage — The soil is imperfectly drained, due to its clayey texture and shallow (160 cm) water table. The soil may remain wet for several weeks.

Potential root zone — 150 cm in sampling pit, but most growth confined to upper 70 cm.

Barriers to root growth

Physical: High clay strength restricts the development of root systems below about 70 cm.

Chemical: Salinity and sodicity are sufficiently high to kill vines at this site. These salinity and sodicity levels are not typical of this soil, but are caused by the shallow saline water table.

Water holding capacity (Estimates for potential root zone of grape vines - use 70 cm)

Total available: 75 mm
Readily available: 40 mm

Fertility — Nutrient retention capacity is very high. Controlling vegetative growth is a management issue on these naturally fertile soils. Note however, that black clays are prone to zinc deficiency.

Erosion potential — Low.

Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	S mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exchangeable cations - cmol(+)/kg Ca	Mg	Na	K	CEC	ESP
Target →	< 9.2	>5.0	na	< 2.0	< 350	10	< 3	80	200	> 1.0	% of (Ca+Mg+Na+K) 65-75	10-15	< 6	3-8	> 5	< 6
0-10	7.2	7.1	0	11.6	-	-	4.2	100	766	2.8	21.8	10.4	3.71	1.98	29.8	12.4
10-20	7.0	6.8	0	7.82	-	-	4.2	86	681	2.6	18.4	10.1	3.98	1.64	27.9	14.3
20-50	7.3	7.0	<0.1	6.11	-	-	3.1	60	560	1.5	12.1	9.15	5.13	1.24	28.6	17.9
50-100	7.9	7.5	<0.1	4.88	-	-	2.8	27	566	1.4	12.8	9.64	5.88	1.38	29.0	20.3
100-150	7.9	7.4	<0.1	3.55	-	-	2.8	15	556	1.1	12.9	8.68	5.31	1.30	26.4	20.1
150-200	7.8	7.3	<0.1	2.93	-	-	2.6	8	519	0.8	10.1	7.67	4.66	1.13	23.5	19.8

Explanation of highlighted data

Grape vines can suffer 10% yield loss when ECe exceeds 2.5 dS/m, or chloride exceeds 350 mg/kg.
Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for grape vines (American literature).
Low Ca:Mg ratio due to magnesium from water table.

Notes:

Management of Soil 24
Black cracking clay (salt affected)
by John Rasic

Problems
Note that the shallow water table at this site has caused problems that are not typical of a black cracking clay.

This soil can store high levels of both nutrients and toxins and it is not easily leached. Grapevines will produce highly variable growth and yield and some vines may die (see photo).

Plants in this soil quickly become water stressed during hot, dry weather. Between the refill point and the wilting point only a small amount of water is available to the plant. When this soil dries, it becomes hard and cracks deeply, breaking plant roots and increasing the loss of moisture from the deeper soil. The reduced root volume and the loss of soil moisture cause rapid plant water stress.

With irrigation it is easy to apply water, but because the broken roots do not recover quickly, plants in this soil can suffer water stress even very soon after an irrigation.

The soil is soft, plastic, sticky and anaerobic. It is often impassable when wet. When the cracks close, water moves only slowly through this soil.

In depressions (as at this site), this soil may have accumulated high levels of salts (including sodium) and of other toxins that can kill the grapevines.

Pre-planting action that can be used to tackle the problems
Deep ripping and mixing can be very damaging if sodic, saline or boron-rich layers are mixed into the root zone.

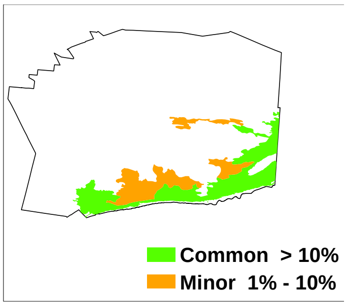
To avoid spreading toxins, do not deep-rip this soil. Ripping is not needed if trellis posts are installed when this soil is moist, soft and friable.

Soil management after planting
Manage this soil to avoid the cracking that causes the loss of moisture from the deeper layers. Use mulches, including clay as a mulch, and irrigate to keep this soil permanently moist but not saturated.

The water holding capacity of this soil is high but only a small fraction of this water can be extracted easily by plants. The plants can be affected by water stress even when the soil appears moist.

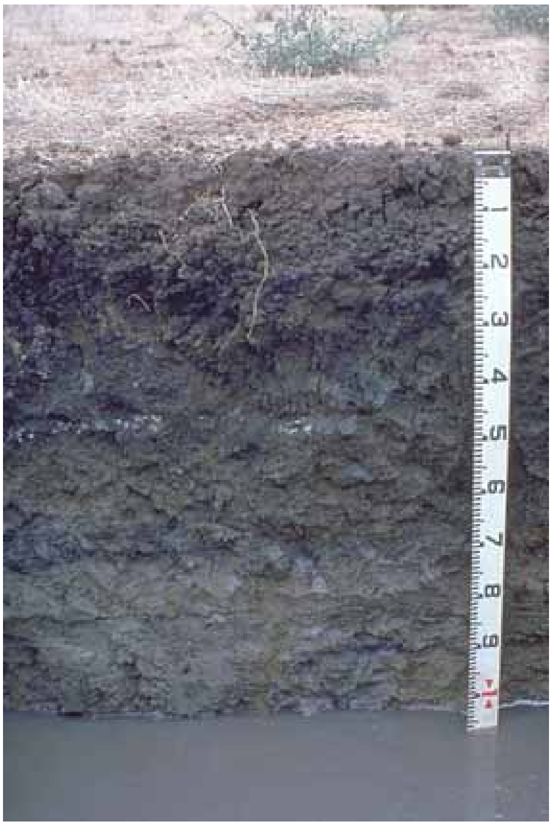
Use soil moisture monitoring equipment to decide the amount of water per irrigation and the time between irrigations. Irrigate with small volumes applied at short intervals and applied slowly using low-discharge drippers at close spacing

Soil 25 Saline black cracking clay



Landscape: Low lying plains adjacent to the lake. Seasonally cracking surface.

Profile: Black cracking clay, becoming greyer with depth and saline throughout, with a saline water table at about a metre.



Depth (cm)	*Description*
0-10	Black hard clay with strong coarse granular structure. Abrupt to:
10-25	Black hard medium heavy clay with coarse angular blocky structure. Clear to:
25-45	Very dark grey moderately calcareous firm medium heavy clay with weak very coarse angular blocky structure. Diffuse to:
45-75	Dark grey medium clay. Diffuse to:
75-105	Olive grey medium clay.
105-	Water table.

Key properties

Drainage — Imperfectly drained. Soil may remain saturated for several weeks following heavy or prolonged rainfall. Deep drainage is severely restricted due to the shallow water table.

Potential root zone — 10 cm in sampling pit.

Barriers to root growth

Physical: Dense clay may impede root growth to some extent, but chemical constraints over-ride any physical limitations.

Chemical: High boron and salt levels, and high sodicity from 10 cm restrict root growth.

Water holding capacity : Estimated for the depth of the potential root zone of grapevines

Total available: 15 mm
Readily available: 5 mm

Fertility — Nutrient retention capacity is high due to clay content, but chemical constraints to root growth over-ride fertility considerations.

Erosion potential — Low potential for both water and wind erosion.

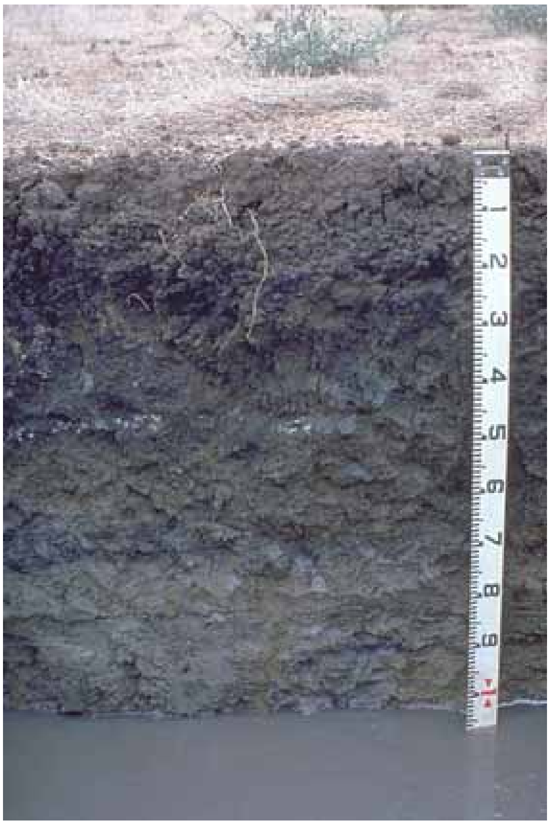
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	S mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exchangeable cations - cmol(+)/kg Ca	Mg	Na	K	CEC	ESP
Target →	< 9.2	>5.0	na	< 2.0	< 350	10	< 3	80	200	> 1.0	% of (Ca+Mg+Na+K) 65-75	10-15	< 6	3-8	> 5	< 6
0-10	6.0	5.3	1	2.71	-	-	7.3	78	1100	2.9	12.5	9.51	4.12	3.74	31.4	13.1
10-25	7.6	7.3	3	8.72	-	-	6.3	22	1500	1.0	13.7	13.7	12.5	4.62	49.0	25.6
25-45	8.5	8.1	5	14.0	-	-	24	29	1500	0.6	13.4	13.9	19.1	4.05	49.6	38.4
45-75	8.1	7.9	2	18.2	-	-	29	54	1400	0.2	12.6	13.7	22.2	3.80	52.2	42.5
75-105	7.8	7.8	2	28.6	-	-	26	25	1200	0.2	10.5	10.4	18.5	3.09	35.1	52.7

Explanation of highlighted data

Grape vines can suffer 10% yield loss when ECe exceeds 2.5 dS/m, or chloride exceeds 350 mg/kg.
Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for grape vines (American literature).
Cation imbalance due to high amounts of magnesium and sodium relative to calcium in groundwater.

Notes:



Management of Soil 25
Saline black cracking clay
by John Rasic

Problems
Because there is a saline water table at 1.0 metre, it is not possible, economically, to overcome the limitations of this soil. Expect high costs to grow only low tonnages of lower quality grapes.

This soil is typically located close to the lake and drainage is controlled by the permanent, shallow water table. The soil has high salinity, high sodicity, high alkalinity, and a high level of boron. These severe limitations cannot be corrected easily at an acceptable cost.

Glossary

Abrupt: Boundary between soil layers is 5-20 mm

Alkaline soil: *Specifically a soil with pH value > 7.0 caused by the presence of carbonates of calcium, magnesium, potassium and more especially sodium. Usually refers to soils with values for pH in water > 8.5.*

Amelioration *A subspecialisation of agricultural soil engineering concerned with the physical, chemical, biological, hydrological and thermal improvement of soils*

Bearing capacity: *The ability of a soil to sustain external loading without collapse*

Biological improvement: *Improvement of a soil by biological means such as activity of soil animals, plants and addition of organic manures*

***Calcareous soil**: A soil that contains enough calcium carbonate so that it fizzes when treated with hydrochloric acid.*

Capping: *The crust produced on drying by a slurry of soil and water.*

Chlorosis *A condition in plants relating to the failure of chlorophyll (the green colouring matter) to develop. Lime chlorosis is caused by excessive amount of free lime or active carbonates that prevent extraction of other elements that are essential for the normal growth of plants*

Clear: Boundary between soil layers is 20-50 mm

Coarse texture *The texture exhibited by sands, loamy sands, and sandy loams (except very fine sandy loam)*

***Compaction**: Increase in bulk density due to mechanical forces such as tractor wheels.*

Contrasting: *different, opposite*

Diffuse: Boundary between soil *layers is more than 100 mm*

Disperse *(1) To break up compound particles, such as aggregates, into the individual component particles. (2) To distribute or suspend fine particles, such as clay, in water.*

Dispersion: *The process whereby the structure or aggregation of the soil is destroyed so that each particle is separate and behaves as a unit.*

Drought stress: *Inability of a plant to extract moisture from a soil.*

***Free lime**: Usually refers to soluble or active carbonates that may cause the insolubility of various necessary mineral elements such as manganese, iron and some trace elements. Free lime causes lime chlorosis.*

Gradual: Boundary between soil layers is 50-100 mm

Mottling: *Spots or blotches of different colour or shades of colour interspersed with the dominant colour.*

Permeability: *The ease with which air and water penetrate into or pass through a specific soil layer.*

Polyhedral structure: *Soil particles arranged around a point and bounded by more than six relatively flat, un-equal, dissimilar faces. The aggregates separate easily to allow good root growth and permeability.*

Ponding: *Standing water in a depression that is removed only by percolation, evaporation, and/or transpiration.*

Prismatic *soil structure: A soil structure type with prism-shaped aggregates that have a vertical axis much longer than the horizontal axes. Soils have high bulk density, low permeability and high resistance to root growth.*

Puddled soil *Dense, massive soil artificially compacted when wet and having no aggregated structure. The condition commonly results from the tillage of a clayey soil when it is wet.*

Rebound effect: *The ability of a soil to bounce back after compression*

Self-repair mechanism: *Soils that shrink-swell have self-repair mechanism*

Sharp: Boundary between soil layers is less than 5 mm

Slaking: *The partial breakdown of soil aggregates in water due to swelling and the expulsion of air from pore space.*

Sodicity: *A sodic soil contains sufficient sodium to interfere with the growth of most plants. Soil is considered sodic when it has an exchangeable sodium percentage (ESP) of more than 6, and strongly sodic when the ESP exceeds 13.*

Soil Stability: *Soil characteristic that enables soil to sustain tillage, rainfall, trampling, compaction etc. without reduction in permeability or ease of root growth.*

Soil Structure: The combination or arrangement of primary soil particles (e.g. sand grains and clay minerals) into secondary units, or peds. In a soil layer, the way in which particles are arranged and the size of the peds affects the permeability and the ease of root growth. Characteristic ped shapes include polyhedral, prismatic, blocky, granular and columnar.

Soil texture *Proportion of silt, sand, clay and gravel in soil*

Tilth: *The physical condition of soil as related to its ease of tillage, fitness as a seedbed, and its impedance to seedling emergence and root penetration.*

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