Soils of Molokai

Fertility and Crop Nutrition

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Outline

• Importance of Soils
• Soils of Molokai
• Fertility Status
• Management Strategies
Medium for Plant growth

Water supply and purification

5 Functions of Soil

Recycling system

Habitat for Soil organisms

Engineering Medium
Soil Plant Relationships

Havlin et al., 2005. Soil Fertility and Fertilizers
Idealized Soil Composition

- 45% Mineral
- 25% H₂O
- 25% Air
- 5% Organic Matter
- 50% Solids
- 50% Pores
Negatively charged sites that adsorb cations: \( \text{Ca}^{2+}, \text{Mg}^{2+}, \text{K}^{+}, \text{NH}_4^{+} \)
Soil pH and Nutrient Availability

- Soil pH controls nutrient solubility
- Ideal range 6.0-6.5
- As pH drops below 5.0 Al$^{3+}$ can become toxic
- Manganese toxicity common in soils with pH <5.5

Solid Component

Clays

Properties:

- Non-expanding
- pH dependent charge
- Low Cation Exchange Capacity
- Exists in weathered environments
- Most common clay mineral in Molokai soils

Kaolinite
Nutrient poor clay

http://soil.gsfc.nasa.gov/forengeo/thnsec.htm
Clays

Properties:
- Expanding
- High CEC
- Sticky
- Exists in less weathered environments

Montmorillonite
Nutrient rich clay

Solid Component
Organic Matter

Importance of Organic Matter in Soils

- **Physical**
  - Improves aggregation (glue)
  - Improves water holding capacity (surface area)

- **Chemical**
  - Increases nutrient availability (N cycling, micronutrient solubility)
  - Increases CEC (200 cmol$_c$ kg$^{-1}$)
  - Buffers the soil against pH changes

- **Biological**
  - Increases microbial diversity
  - Assists in pathogen suppression
Know Your Soil!

Soil Controls:

• Water storage and movement
• Nutrient availability
• Trafficability
Hawaii's Diverse Soils

1. Processes:
   - Physical weathering
   - Chemical weathering

2. Factors
Soil Forming Factors

- Parent rock
- Age
- Climate (rainfall, temperature)
- Biota (vegetation, micro-organisms)
- Topography (drainage)
Geography of Molokai

1,200 ft

4,500 ft

15” 30” 80” >100”

Soil Orders:
- Andisols
- Aridisols
- Entisols
- Inceptisols
- Mollisols
- Oxisols
- Sodosols
- Ultisols
- Vertisols
Soils of Molokai
Important Soils of Molokai

**Lahaina Series:**
- Acid pH ≈ 5.5
- Sum of bases = 7.1 cmol$_c$ kg$^{-1}$
- Low organic matter
- If pH < 5.0 Mn toxicity likely

**Molokai Series:**
- Slightly acid to neutral
- Sum of bases = 16.4 cmol$_c$ kg$^{-1}$
- Low organic matter
- Good physical properties
Important Soils of Molokai

Legend
- Holomua
- Lahaina
- Molokai
Important Soils of Molokai

**Hoolehua Series:**
- Extremely acid pH 3.9
- Sum of bases = 2.6 cmol$_c$ kg$^{-1}$
- Low organic matter
- Al and Mn toxicity likely
Important Soils of Molokai
Important Soils of Molokai

Kalae Series:
- Strongly acid pH ≈ 5.0
- Sum of bases = $1.3 \text{ cmol}_c \text{ kg}^{-1}$
- Moderate organic matter
- Al toxicity likely

Similar soils:
Alaeloa
Halawa
Olelo
Important Soils of Molokai

Legend
- Alaeloa
- Halawa
- Kalae
- Olelo
Important Soils of Molokai

Pamoa Series:
• Neutral pH ≈ 7.0
• Sum of bases = 18.5 cmol$_c$ kg$^{-1}$
• Moderate organic matter
• Fertile soil

Similar soils:
Haleiwa
Pulehu
Waikapu
Important Soils of Molokai
Important Soils of Molokai

**Oli Series:**
- Acid pH ≈ 5.5
- Sum of bases = 27.1 cmol$_c$ kg$^{-1}$
- High organic matter
- Fertile soil

**Similar soils:**
*Kalaupapa*
Important Soils of Molokai

Legend
- Pink: Kalaupapa
- Purple: Oli
Important Soils of Molokai

• Sandy
• Neutral pH
• Low organic matter
• Rapid drainage
• Infertile soil

Similar soils:
Mala
Soil Acidity

Natural Sources of Acidity:
- Precipitation and cation leaching
- Carbonic acid and organic acids
- Organic matter
- Cation uptake
- Deprotonation of pH-dependent charge

Human Induced Acidity:
- Acid rain
- Urea
- Ammonium fertilizers
- Mono and diammonium phosphate
- Elemental S
Adverse Effects of Soil Acidity

- Aluminum toxicity
- Manganese toxicity
- Nutrient deficiencies
- Decreased microbial activity
Manganese

- A mineral in basalt - MnO$_2$, Mn$_2$O$_3$, Mn$_3$O$_4$
  Exists as Mn$^{2+}$, Mn$^{3+}$, Mn$^{4+}$
- Mn$^{2+}$ is an essential plant nutrient, but at high concentrations it becomes toxic
- Mn$^{2+}$ concentration depends on:
  - Soil pH - high Mn in acid soils
  - O$_2$ availability - Mn solubility increases in flooded soils
  - organic matter - Mn solubility increases with OM
Mn solubility and soil pH

Source: Hue et al., 1998
Mn Toxicity Increases with Organic Inputs

Source: Hue et al., 2001
Molokai Soils with Potential for Mn Toxicity

Legend

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>% MnO₂</th>
</tr>
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<tbody>
<tr>
<td>Halomua</td>
<td>0.3</td>
</tr>
<tr>
<td>Hoolehua</td>
<td>1.49</td>
</tr>
<tr>
<td>Lahaina</td>
<td></td>
</tr>
<tr>
<td>Molokai</td>
<td></td>
</tr>
<tr>
<td>Parnoa</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Legend:
- Blue: Halomua
- Green: Hoolehua
- Red: Lahaina
- Purple: Molokai
- Green: Parnoa

Miles: 0 1.25 2.5 5 7.5 10
Phosphorus Deficient in Acid Soils

The diagram illustrates the amount of phosphorus fixation in soil across different pH levels from pH 3 to pH 9. The pH levels are categorized into five ranges: Acid soils (pH 3-4), Neutral (pH 5-6), and Alkaline soils (pH 7-9).

- **Phosphorus fixation by iron** increases from Low to Medium and then decreases to Very Low at pH 3.
- **Phosphorus fixation due to aluminum** peaks at pH 5 and then decreases to Low at pH 9.
- **Phosphorus fixation by calcium** increases from Low to Medium at pH 9.

The range for the highest phosphorus availability is indicated between pH 5 and pH 6, where both iron and aluminum fixation are low, and calcium fixation is moderate.
Factors Affecting P Fixation

- **Soil type**
  
  Andisol > Ultisol ≈ Oxisol > Inceptisol > Mollisol > Entisol

  Oli  Kalae  Hoolehua  Pamoa  Jaucus
  Kalaupapa  Alaeloa  Pulehu  Mala
  Halawa  Lahaina
  Molokai

- **Organic matter**
  
  - OM imparts negative charge to surfaces inhibiting reaction between phosphate and oxide surface
Correcting Soil Acidity with Lime

1. To raise pH
   - Reduces P fixation
   - Reduces Al & Mn solubility
   - Increases N, S, B, Cu and Mo availability

2. To supply Ca
Liming

4 T/a

1.5 T/a
Summary

- Soils give us life
- Soils vary on the landscape
- Some soils are inherently more fertile than others
- Some Molokai soils have high reserves on Mn
- If we know our soils we can manage them well
Resources

Books

Resources

Web

- http://ortho.ftw.nrcs.usda.gov/cgi-bin/osd/osdnamequery.cgi
Resources

HOOLEHUA SERIES

The Hoolehua series consists of deep, well drained soils that formed in alluvial weathered from basic igneous rock. Hoolehua soils are on uplands and have slopes of 0 to 35 percent. The mean annual rainfall is about 30 inches and the mean annual temperature is about 72 degrees F.

TAXONOMIC CLASS: Fines, paraglices, solodystroths, Ost. Halophytosols

TYPICAL PEDON: Hoolehua silty clay - cultivated. (Colors are for composted material unless otherwise noted. All textures are "apparent field textures".)

Ap1—0 to 9 inches, dark reddish brown (5YR 3/3) silty clay, dark reddish gray (5YR 4/2) dry, cloyly due to tillage; hard, firm, sticky and plastic, compacted by agricultural machinery, common roots; few medium and coarse tubular pores, violent effervescence with hydrochloric acid, extremely acid (pH 3.9); clear smooth boundary (0 to 9 inches thick)

Ap2—9 to 15 inches, dark reddish brown (5YR 3/3) moist and dry silty clay, cloyly, hard, fissile, sticky and plastic; few roots; few very fine tubular pores, violent effervescence with hydrochloric acid, extremely acid (pH 4.4); clear very wavy boundary (9 to 15 inches thick)

Bh1—15 to 21 inches, dark reddish brown (5YR 3/3) moist and dry silty clay loam, weak fine and medium subangular blocky structure, slightly hard, very friable, sticky and plastic; few roots; many very fine and fine pores, common medium tubular pores, many very fine black concentric; violent effervescence with hydrochloric acid, slightly acid (pH 5.3); clear wavy boundary (15 to 21 inches thick)

Bh2—21 to 27 inches, dark reddish brown (5YR 3/3) moist and dry silty clay, weak fine and medium subangular blocky structure slightly stronger than B12 horizon, hard, friable, sticky and plastic; many very fine and fine pores, common medium tubular pores; common black stains in pores, many very fine black concentric; violent effervescence with hydrochloric acid, slightly acid (pH 5.3); clear wavy boundary (21 to 27 inches thick)

B2—27 to 49 inches, dark reddish brown (5YR 3/3, 3/4) moist and dry silty clay, strong very fine subangular blocky structure, few pockets of weak and medium very fine subangular blocky structure, very hard, friable, sticky and plastic; compact in place, common very fine tubular pores, common black stains on faces of peds, almost continuous coatings on peds; many very fine black concentric; common hard earthy lumps break down after prolonged soaking, strong effervescence with hydrochloric acid, slightly acid (pH 5.0); gradual wavy boundary (27 to 49 inches thick)

B2—49 to 64 inches, dark reddish brown (5YR 3/4) moist and dry silty clay, moderate and strong fine subangular blocky structure, very hard, firm, sticky and plastic; slightly firm in place, common very fine tubular pores; few black stains on faces of peds, common thin film on faces of peds; common very fine black concentric; many hard earthy lumps break down after prolonged soaking, moderate effervescence with hydrochloric acid, slightly acid (pH 5.2)

TYPE LOCATION: Island of Molokai, Maui County, Hawaii, Kupukulu Quadrangle 21 degrees 9 feet 34 inches N latitude and 157 degrees 3 feet 8 inches W longitude, approximately 3 vehicle west of Hualapai Post Office

RANGE IN CHARACTERISTICS: Stratification of the soil ranges from moderate to severe. Few to many pebbles and cobbles are at varying depths in some profiles. The mean annual soil temperature is about 72 degrees F. Microl is throughout the soil. The soil is dry in some horizon below 10 inches for more than 50 cumulative days in most years. Else of the soil is 5YR, 4.5YR, and chroma ranges from 2 through 4.

COMPETING SERIES: These are the Honaldik Koa, Lahana Waiaka, Wahana, Waiaka, and Waiakai series. Honaldik soils are clay and are very sticky and very plastic. Koa soils have 2.5YR, or redder hues in the B horizons and dark black stains in the B horizon. Waiaka soils have mean annual soil temperature of less than 71.6 degrees F., clay texture, and they are very sticky and very plastic throughout. Wahana soils are clay loam in the B horizon and have a lower content of organic matter in the B horizon. Waiakai soils have 5YR or redder colors and precipitous structure and dark mottles in the B horizon.

GEOGRAPHIC SETTING: Hoolehua soils are in basins and on alluvial fans and have slopes of 0 to 35 percent. Elevation ranges from 400 to 1,300 feet. The soils formed in alluvial material weathered from basic igneous rock. The mean annual precipitation is from 20 to 35 inches. The mean annual temperature is about 72 degrees F., the average January temperature is about 69 degrees F., and the average July temperature is about 76 degrees F.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Koa and Molokai soils and the competing Lahana and Waiaka soils. Koa soils have an angular horizon that has continuous clay film. Molokai soils have 2.5YR or redder hues in the B horizon, and weak prismatic structure in the upper part.

DRAINAGE AND PERMEABILITY: Well drained, medium runoff, moderate permeability.

USE AND VEGETATION: Used mainly for grazing cattle and barley. Natural vegetation is banana, cattails, and ferns.
Resources

Web

- [http://ssldata.nrcs.usda.gov/querypage.asp?chksa=1&ac=244&as=3962#sitevar](http://ssldata.nrcs.usda.gov/querypage.asp?chksa=1&ac=244&as=3962#sitevar)