From: *Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture*
J. A. Silva and R. Uchida, eds. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, ©2000

Plant Nutrient Management in Hawaii's Soils

Approaches for Tropical and Subtropical Agriculture

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Published by the College of Tropical Agriculture and Human Resources (CTAHR) and issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Andrew G. Hashimoto, Director/Dean, Cooperative Extension Service/CTAHR, University of Hawaii at Manoa, Honolulu, Hawaii 96822. An Equal Opportunity / Affirmative Action Institution providing programs and services to the people of Hawaii without regard to race, sex, age, religion, color, national origin, ancestry, disability, marital status, arrest and court record, sexual orientation, or veteran status. CTAHR publications can be found on the Web site <http://www2.ctahr.hawaii.edu> or ordered by calling 808-956-7046 or sending e-mail to ctahrpub@hawaii.edu.

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CTAHR departments

The College of Tropical Agriculture and Human Resources (CTAHR), University of Hawaii at Manoa, recently reorganized its departmental programs. Most of those who contributed to this book are former faculty of the Department of Agronomy and Soil Science; their current units in CTAHR are

ADSC Agricultural Diagnostic Service Center
NREM Department of Natural Resources and Environmental Management
PEPS Department of Plant and Environmental Protection Sciences
TPSS Department of Tropical Plant and Soil Sciences

About this publication

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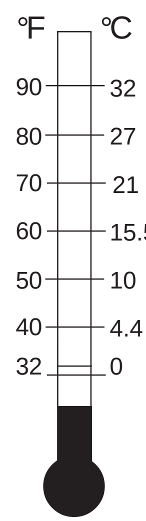
Conversions from U.S. measure to metrics

In most cases, measurements in this book are given in the units most commonly used in the USA. For the convenience of other readers, the following conversions are provided.

1 inch = 25.4 mm = 2.54 cm
1 foot (ft) (12 inches) = 30 cm
1 pound (lb) = 0.454 kg
1 ounce (oz) = 28.4 g
1 acre = 0.4 hectare (ha)
1 lb/acre = 1.12 kg/ha
1 ton/acre = 2.24 tonnes/ha (2240 kg/ha)
1 gallon (gal) = 3.78 liters
1 square foot (sq ft) = 0.093 m^2
1 gal/acre = 9.35 liters/ha
1 pound/square inch (psi) = 6.89 kPa
1 mile/hour = 1.6 km/hr



ISBN 1-929235-08-8

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Preface

Good crop management depends on identifying and correcting nutrient deficiencies and toxicities. This can be done by regularly sampling soils and plants for analysis and taking the corrective measures that are indicated based on knowledge of the crop's nutrient requirements and the soil's characteristics. Such a nutrient management program can increase economic returns and reduce risks of environmental pollution.

This book presents information about how soils provide nutrients to plants and how soils can be managed to improve their nutritional status for plant growth. The chapters are intended to help growers and agricultural extension personnel understand how soil and plant tissue analyses are interpreted to diagnose plant nutrition problems, and how soil management recommendations are developed to prevent or correct those problems. The approach is a scientific one, based on methods and processes used by faculty of the University of Hawaii at Manoa's College of Tropical Agriculture and Human Resources (CTAHR). Although the details discussed are about crops and soils found in the Hawaiian Islands, the general information on soil conditions and nutrient management are applicable in many other regions of the world where the plants, soils, and climate are similar to those of Hawaii.

Hawaii's agriculture has shifted from being dominated by extensive plantings of just two crops, sugarcane and pineapple, to an agriculture characterized by crop diversity and smaller farms, set in a social context in which there is increasing concern for the effects agriculture has on the environment, and on water quality in particular.

New crops and new crop management practices have placed new demands on soil testing and plant analysis. For example, reduced-tillage practices require a reevaluation of soil sampling procedures and soil test calibrations, because cultivations are shallower, or less frequent. The nutritional requirements of new crops must be evaluated under the various conditions in which they will be grown, which in Hawaii can be very diverse in terms of soil type and microclimate. As farming techniques become more sophisticated, farmers need more precise information about the fertility of a particular soil and the nutritional requirements of a particular crop. As the agricultural economy becomes more competitive and subject to effects of globalization, as it has in Hawaii, economic margins become tighter, requiring optimization of inputs and maximization of outputs in both quantity and quality. Also, increasing public concerns about environmental pollution emphasize the need for improved accuracy of results from soil testing and plant analysis.

CTAHR's plant and soil scientists and extension experts have, in fact, made substantial progress in developing improved methodologies for analyzing soils and plant tissues and in interpreting the analytical results. This progress helps growers develop the "best management practices" that make efficient use of fertilizers, resulting in optimum yields while minimizing the potential for polluting water resources.

Growing a successful crop requires the timely integration of numerous complex factors, as well as favorable environmental conditions. This book addresses many of these factors, with the hope that a better general understanding of their interrelationships and effects will assist growers in properly managing them.

Analysis of soil and plant samples is only the first step in the process leading to good nutrient management. Correct interpretations of the analytical values are required to identify the problem and formulate a recommendation for correcting it. An important part of the process of making diagnoses and fertilizer recommendations is feedback from the users. Feedback helps to confirm diagnoses, validate recommendations, and suggest modifications or refinements. Thus, the grower is an essential part of the agricultural science and extension process.

Readers of this book who live in Hawaii and use data and recommendations from the CTAHR Agricultural Diagnostic Service Center are encouraged to provide feedback on their experience through CTAHR Cooperative Extension Service personnel.

J. A. Silva, N. V. Hue

Introduction

Hawaii's Agricultural Setting

Agriculture in the Hawaiian Islands has a history that is somewhat unique, but it also has strong similarities to agriculture elsewhere in the Pacific, and in many other subtropical and tropical locations as well. The islands contain 11 of the 12 soil "orders," from very young soils to highly weathered ones. Elevations extend from sea level to over 13,000 feet, providing variation in temperature from warm subtropical lowlands to temperate conditions at the highest elevations. The position of the archipelago in the path of Pacific northeast trade winds results in significant variation in rainfall between the windward and leeward sides of the islands, producing climates from near-desert to rainforest. Over millions of years, the domed volcanic "shields" that emerged from the ocean floor to rise far above sea level have become sharply disected into ridges and valleys by gradual soil erosion and massive, catastrophic landslides. All of these geologic characteristics combine their effects to result in exteme variation in soil and climatic environments. This variation is also remarkable in that it occurs over relatively short distances.

These conditions complicate methodological approaches to agriculture. Other places in the world where climate is more uniform and soils are not so variable are perhaps more fortunate, in that strategies for managing soil fertility can apply over broader areas. Hawaii's "micro-" variation has meant that many solutions to soil fertility problems have had to be found, and that their applicability beyond their particular situation has had to be tested and scrutinized. This situation has lead to an emphasis on "agrotechnology transfer" in the College of Tropical Agriculture and Human Resources (CTAHR) at the University of Hawaii that has benefited agricultural scientists and practitioners in many parts of the world over the past several decades.

The first human agriculturists in Hawaii that we know about were the Polynesian colonizers who became the Hawaiian people. In these exceptionally remote islands, they found a diverse vegetation, much of which evolved in the islands and is found nowhere else. Their civilization was based on about 32 plants they brought with them in their voyaging canoes, and on their ability to establish a thriving agriculture in their new island home.

The arrival of European explorers in 1778 began an extensive transformation of the islands' agriculture. Thousands of new plant species were introduced, along with hundreds of species of animals, and an exploitation of the islands' natural resources began that decimated some native species. Within 100 years of that arrival, an extensive plantation-scale agriculture had developed based on sugarcane and pineapple, in a situation not unlike that of many other parts of the world subjected by European colonialism.

Hawaii's plantation agriculture benefited from the relatively concurrent development of modern agricultural science. Both sugarcane and pineapple fostered their own research institutes, and the agronomy of both crops achieved marvelous sophistication. Precise use of index tissue analysis and careful "crop logging," field by field, allowed yields that were the envy of the world.

But within a second 100 years after European contact, Hawaii's agriculture began another major transformation. Economic forces ended the viability and dominance of the two plantation crops, and their decline has led to the present-day agricultural economy based on a diverse assortment of crops. In 1978, thousands of acres of the best agricultural land were occupied by sugarcane and pineapple, while other crops utilized pockets of land that were often of only marginal value. Today, much of that former plantation land is being planted to various crops, with different demands for particular soil and climatic conditions. Agricultural operations are generally smaller today than in the plantation days, and this means that more people are making soil and land management decisions that affect the environment.

This book was developed for this new group of growers, anticipating their need for up-to-date information on soil conditions and plant growth. The information this book contains is important for soil and crop management, which has a direct influence on our natural environment. Better knowledge of the various components of crop production allows us to manage them wisely and enables us to protect the environment more effectively. Growers are primary trustees of the land and must act responsibly to keep it productive for future generations. The purpose of this book is to help those who manage soils and plants both to improve agricultural productivity *and* protect the environment.

Soil characteristics—key to plant growth

Soils are the products of weathering—the physical and chemical breakdown of parent materials, which in the case of Hawaii include basaltic and andesitic lavas and volcanic ash and pumice. Through time, soils develop under varied climatic conditions and different vegetative covers. The resulting soils have distinctively different chemical and physical properties that require different management.

The soils of Hawaii are relatively young, geologically speaking. Hawaii's oldest soils are found on the older islands, Kauai and Oahu, while the youngest soils are found on the younger islands, Hawaii and Maui. Some of the soils are over 10 feet deep, while others are less than 1 inch thick. Over the past 100 years, several institutions including CTAHR, the Hawaiian Sugar Planters' Association (now the Hawaii Agriculture Research Center), and the former Pineapple Research Institute conducted research that provided data on the physical and chemical properties of Hawaii's soils. In addition, thousands of experiments on soil fertility, irrigation, and crop management have been conducted, on a variety of crops.

Knowledge about soil characteristics and behavior is essential to successful agricultural production. It has been found, for example, that soils derived from volcanic ash tend to have high phosphate sorption (fixation) capacity, while those derived from basalt fix phosphorus to a lesser degree; this characteristic dramatically affects the soil's ability to supply a major essential plant nutrient. Soils differ in pH and in the amount of lime required to raise pH to a desired level for optimum growth of a particular crop. Chemical reactions with applied fertilizers differ among soils, as does their ability to supply nutrients to crops. This book was developed to provide awareness of factors such as these and to improve the availability of information growers need to manage crop nutrients properly.

Plants have diverse soil and nutrient requirements

The diversity of Hawaii's climate and soils makes it possible to grow a wide variety of crops, ranging from tropical to temperate species. To produce a particular crop profitably in a situation of such diversity, it is necessary to find the correct environmental niche for that plant and then learn to manage the soil of that location. Providing the crop with adequate nutrients requires analyzing the soil before planting the crop, adding the needed fertilizers, and monitoring the nutrient status of the crop during its growth. Much research must still be done to determine how best to sample particular crops for nutrient analysis and how to interpret the nutrient levels found in the sampled tissues. Other than the studies of sugarcane and pineapple done in Hawaii, much of the information on plant nutrient levels is from research on major temperate-zone crops, whereas many of the crops now grown in Hawaii are relatively "minor" ones not found in temperate regions. Therefore, growers in places like Hawaii need to have local information about their crops under the given growth conditions.

Agricultural scientists have done some of the work needed for Hawaii's major "minor" crops, but crop diversification in the state is increasing while support for agricultural research is not. In such a situation, the more knowledge growers have, the better able they are to do their own research and develop appropriate crop management practices for themselves. More knowledgeable growers also make more efficient use of the personnel resources available from agricultural extension agencies.

This book presents information about soils and crops, as well as current information about plant nutrition, soil processes, fertilizers, and crop management. The discussions of soils and plant nutrient requirements provide a basis for understanding crop management. We hope that readers will find this book a valuable tool for learning and a useful reference for questions and problems encountered in managing soils and crops in Hawaii and elsewhere.

Y. N. Tamimi, J. A. Silva

In: Silva JA, Uchida RS (eds) Plant nutrient management in Hawaii soils. College of Tropical Agriculture and Human Resources, University of Hawaii, Honolulu, pp 23â€“30Google Scholar. Kardol P, Dickie IA, St. John MG, Husheer SW, Bonner KI, Bellingham PJ, Wardle DA (2014) Soil-mediated effects of invasive ungulates on native tree seedlings.Â Lincoln NK (2014) Effect of various monotypic forest canopies on earthworm biomass and feral pig rooting in Hawaiian wet forests. For Ecol Manage 331:79â€“84CrossRefGoogle Scholar. Soil texture affects soil fertility and nutrient management: Most sulfur deficiencies occur in sandy soils. Nitrogen is easily leached from sandy soils.Â Seventeen elements are considered essential nutrients for plant growth, and 14 of these elements come from the soil (Table 3). If there is a deficiency of any essential element, plants cannot complete their vegetative or reproductive cycles. Some of these nutrients combine to form compounds that make up cells and enzymes. Other nutrients are necessary for certain chemical processes to occur. Table 3. Seventeen essential plant nutrients derived from air, water and soil. Plant nutrient. Source.