PRL-23

ALAN M. ARAKAWA
Mayor

KA'ALA BUENCONSEJO
Director

BRIANNE L. SAVAGE
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DEPARTMENT OF PARKS AND RECREATION

700 Hali'a Nakoa Street Unit 2, Wailuku, Hawaii 96793

October 18, 2017

Honorable Alan M. Arakawa
Mayor, County of Maui
200 South High Street
Wailuku, Hawaii 96793

For Transmittal to:

Honorable Don S. Guzman, Chair
Parks, Recreation, Energy and
Legal Affairs Committee
Maui County Council
200 South High Street
Wailuku, Hawaii 96793

APPROVED FOR TRANSMITTAL

Acting Mayor 10/23/17
Date

Dear Chair Guzman:

SUBJECT: DONATION TO THE COUNTY OF MAUI, DEPARTMENT OF PARKS AND RECREATION, MAINTENANCE DIVISION, FROM BEYOND PESTICIDES FOR SOIL ANALYSIS AND REVIEW OF CURRENT TURF MAINTENANCE PRACTICES (PRL – 23)

As requested in your correspondence dated October 5, 2017, attached is the status update on the work being done with Beyond Pesticides.

If you have any questions or require additional information, please feel free to contact me at Ext. 7230.

Sincerely,

KA'ALA BUENCONSEJO
Director of Parks and Recreation

Attachment

c: Brianne Savage, Deputy Director
Karla Peters, Parks Maintenance Superintendent
Elmo Kahalekai, Beautification Manager

KB:KP:lm

DONATION TO THE COUNTY OF MAUI, DEPARTMENT OF PARKS AND RECREATION, MAINTENANCE DIVISION, FROM BEYOND PESTICIDES FOR SOIL ANALYSIS AND REVIEW OF CURRENT TURF MAINTENANCE PRACTICES
(PRL – 23)

STATUS UPDATE

Soil samples were sent to laboratory in March 2017 and results were reviewed by Beyond Pesticides. Attachment #1 contains the soil test results for the four selected fields.

On May 17 and 18, 2017, the Beyond Pesticides staff conducted site inspections of the four fields and worked with DPR staff to provide education regarding the pilot program.

Turf management reports were completed by Beyond Pesticides and were transmitted to the Department in late August 2017. The reports provided both a site specific and general discussion on natural organic turf management. This report is referenced on Attachment #2.

After reviewing the reports, it was discovered that many of the recommended products were not readily available in Hawaii. Beyond Pesticides then contracted Duane Sparkman of Edaphic Perspective to assist the Department in identifying products that could be purchased locally as well as assist with a new implementation plan.

On Monday, September 11, 2017, the Department's Beautification staff met with Mr. Sparkman to discuss the implementation plan. Attachment #3 is the plan that was implemented on September 13, 2017 starting with the War Memorial Little League Field #1. This field is currently being monitored and the soil enrichment program has been completed. The issue that we are currently being faced with is the weed population. We will be starting with the same plan at the South Maui Regional Park Soccer Field in November.

War Memorial Little League Field #1

Soil test results

Particle size analysis
71.14% sand, 24.47% silt, 4.39% clay

Soil chemistry

Organic Matter	11.24%
CEC	46.55 meq/100g
pH	7.9
Phosphorus	154 ppm
Potassium	639 ppm
Calcium	6502 ppm
Magnesium	1353 ppm
Iron	41 ppm

Soil biology

Active bacterial fraction is low	Total bacterial fraction is good
Active fungal fraction is low	Total fungal fraction is good

Flagellates are low
Amoeba are good
Ciliates are low
Beneficial nematodes are low
Endo mycorrhizal colonization is low
Potential plant available nitrogen supply through the biomass is 100-150 lbs/acre
The F:B ratio is 1.10:1 Desired range is .75:1 to 1.25:1

Attachment #1

Luana Gardens

Soil test results

Particle size analysis
83.35% sand, 13.60% silt, 3.05% clay

Soil chemistry

Organic Matter	5.72%
CEC	47.50 meq/100g
pH	8.3
Phosphorus	26 ppm
Potassium	529 ppm
Calcium	7472 ppm
Magnesium	967 ppm
Iron	12 ppm

Soil biology

Active bacterial fraction is low
Active fungal fraction is low
Total bacterial fraction is good
Total fungal fraction is good
Flagellates are low
Amoeba are good
Ciliates are low
Beneficial nematodes are low
Endo mycorrhizal colonization is low
Potential plant available nitrogen supply through the biomass is 100-150 lbs/acre
The F:B ratio is 1.25:1 Desired range is .75:1 to 1.25:1

Makana Park

Soil test results

Particle size analysis

14.19% sand, 60.73% silt, 25.08% clay

Soil chemistry

Organic Matter	10.3%
CEC	19.46 meq/100g
pH	7.3
Phosphorus	41 ppm
Potassium	679 ppm
Calcium	2168 ppm
Magnesium	660 ppm
Iron	23 ppm

Soil biology

Active bacterial fraction is low — Total bacterial fraction is good

Active fungal fraction is low — Total fungal fraction is good

Flagellates are low

Amoeba are good

Ciliates are low

Beneficial nematodes are low

Endo mycorrhizal colonization is low

Potential plant available nitrogen supply through the biomass is 100-150 lbs/acre

The F:B ratio is 1.17:1 Desired range is .75:1 to 1.25:1

South Maui Regional Park Soccer

Soil test results

Particle size analysis
51.0% sand, 39.9% silt, 9.1% clay

Soil chemistry

Organic Matter	13.26%
CEC	49.25 meq/100g
pH	7.6
Phosphorus	149 ppm
Potassium	1553 ppm
Calcium	6335 ppm
Magnesium	1082 ppm
Iron	223 ppm

Soil biology

Active bacterial fraction is low
Active fungal fraction is low
Total bacterial fraction is very good
Total fungal fraction is good
Flagellates are low
Amoeba are excellent
Ciliates are low
Beneficial nematodes are low
Endo mycorrhizal colonization is low
Potential plant available nitrogen supply through the biomass is 200+ lbs/acre
The F:B ratio is .48:1 Desired range is .75:1 to 1.25:1

Natural Turf Management Technical Review

County of Maui
Department of Parks and Recreation
Turf Pilot Project

Prepared by:
Beyond Pesticides

Chip Osborne
Jay Feldman

August 2017

Attachment #2

Table of Contents

Introduction

Report Organization

This report is divided into a number of sections that include a framework for evaluating and managing soil chemistry and microbial activity, elements of and transition to natural-based practices, site analysis, and recommendations for the pilot sites. More specifically, the report provides site analyseis to document the strengths and weaknesses of the turf areas, photographs of the sites, and soil test results that include nutrient, textural, and biological analyses. In doing so, the report documents the existing physical condition of the turf areas and establishes a baseline soil analysis for chemistry, texture, biology, and nutrient availability. Staff at the sites provided some informal information on current and past management and practices, as well as the history of the sites. Goals for the turf areas were discussed and will be further refined during a future site visit.

Turf Management Orientation

Lawn and turf management programs raise a variety of issues related to health, the environment, and best and most effective, sustainable management practices. It is understood that for many people there is a growing awareness about the hazards of chemical products used to maintain lawns and turf, including playing fields. Many also realize the impact of some of these products on the environment. They are aware that some chemicals, even at low-dose exposures, may be harmful to public and children's health.

Included here is an explanation of the principles and protocols of natural organic turf management based on detailed soil test data, site assessments and then recommendations for beginning a natural approach to turf management.

It is important, first, to document the existing physical condition of the turf areas and to establish a baseline soil analysis for chemistry, texture, and nutrient availability. A review is prepared to facilitate the adoption of a natural, organic management program, and all recommendations are made with that in mind. One important difference between an organic program and a conventional, chemical-intensive one is that organic programs are much more site-specific, as distinguished from a generalized approach to fertility and weed control. We are addressing management practices tailored to site conditions, state expectations, and budget. Because inputs for fertility management and building the soil biomass are important to a successful result, our approach addresses the soil biology needs of the individual properties in the program that are under review. That is not to say that we are going to have many different programs on multiple areas or playing fields, but rather that we are addressing any deficiencies and allowing for the inclusion of strategies that will help move a property through the transition process as quickly and efficiently as possible.

When we discuss different management levels, we are referring to the cultural intensity required to maintain an individual turf area, to the degree that meets expectations. There is not just one organic program, but rather different programs with different levels of intensity that can be created to meet the needs and expectations for an individual site. Clearly, recommendations are made based on communicated expectations.

Cultural intensity is the amount of labor and material inputs required to meet those expectations. One fact is a given in either a conventional or natural turf management program; minimal product and labor inputs meet low expectations, while higher levels of inputs meet higher expectations. This is true in any type of program, conventional or natural. Programs are created to address the soil and turfgrass that will meet the expectations for the site.

Transitioning

When a natural management program is being put in place after conventional management, a window of time, referred to as the transition period, is typically required to make practice and input changes. It is during this time frame when new products are put in place and specific cultural practices are adopted. The most important element of the transition is the attention to the soil, not just texture and chemistry, but the biomass as well. Success is achieved by focusing on the living portion of the soil from the beginning of the natural program. The length of time required for this process is directly related to the intensity of conventional management practices that are currently employed.

The goal of a natural organic turf management program is to create turf that meets aesthetic site objectives, while eliminating toxic and synthetic chemical inputs that may have adverse impacts on health, the environment, and the soil biology. Additionally, the products and programs are designed to utilize materials and adopt cultural practices that will avoid problems associated with runoff or leaching of nutrients and pest control products into water bodies and groundwater.

This approach will build a soil environment rich in microbiology that produces strong, healthy turf that is more resilient and better able to withstand many of the stresses that affect turfgrass. If good cultural practices are adopted and products are chosen to enhance and continually address the soil biology, the natural turf system is better able to withstand pressures from heavy usage, insects, weeds, and disease, as well as drought and heat stress,. While problems can arise in any turf system, they will be easier to alleviate as long as the soil is healthy with the proper microbiology in place.

Turf Program Comparison

Conventional turf management programs are generally centered on a synthetic product approach that uses highly water soluble fertilizers and pesticide control products that continually treat symptoms on an annual basis. It is important to acknowledge that in addition to having adverse effects on human health and the environment, pesticides by definition kill, repel, or mitigate a pest. They do not grow grass. Our approach implements a strategy that proactively solves problems by creating a healthy soil and turfgrass system. Healthy, vigorously growing grass will outcompete most weed pressures, and a healthy soil biomass will assist in the prevention of many insect and disease issues.

We are following a Systems Approach to Natural Turf Management, which is designed to put a series of preventive steps in place that will solve problems. This approach forms the basis for our recommendations. This Systems Approach is based on three concepts:

1) Natural product where use is governed by soil testing or site considerations.
2) The acknowledgment that the soil biomass plays a critical role in fertility.
3) Specific and sound horticultural practices.

The Systems Approach is a "feed-the-soil" approach that centers on natural, organic fertilization, soil amendments, microbial inoculants, compost teas, microbial food sources, and topdressing as needed, or indicated, with high quality, finished compost. It is a program that supports the natural processes that nature has already put in motion. These inputs, along with very specific cultural practices that include mowing, aeration, irrigation, and overseeding, are the basis of the program.

There is a lot that goes into a natural organic program. It is much more than just a product substitution program. When we see situations where an "organic" program has been simply a product swap, they usually do not result in satisfying a higher level of expectations.

In a situation where a municipality or other entity subcontracts applications of product or cultural practices, it requires someone internally that possesses the knowledge about organic turf management to perform the initial soils testing and outline a program. That program then is incorporated into a request for a proposal (RFP) and goes out to bid. What should not happen is letting an individual service provider come in and create a program that seems to make sense to them based on their product choice.

Osborne Organics

As a company, Osborne Organics (Chip Osborne, President) is neither a service provider nor a product company. Osborne Organics has been part of the process of moving turf and landscapes from conventional management practices to a natural approach in a variety of situations and at different levels for the past 15 years. Osborne Organics has the technical expertise to apply the principles and practices mentioned above in the field. Th company's approach is backed by sound science that responds to the need for a safer and healthier landscape from both the environmental and human health perspective. Educational opportunities are provided in the form of in-depth trainings to both landscape contractors and municipal employees in natural turf methods.

Section 1 red = out of range

Soil analysis

War Memorial Little League Field #1

Soil test results

Particle size analysis

71.14% sand, 24.47% silt, 4.39% clay

Soil chemistry

Organic Matter	11.24%
CEC	46.55 meq/100g
pH	7.9
Phosphorus	154 ppm
Potassium	639 ppm
Calcium	6502 ppm
Magnesium	1353 ppm
Iron	41 ppm

Base Saturation

Calcium	%	50% to 80% optimum
Magnesium	%	10% to 30% optimum
Potassium	%	2% to 7% optimum

Soil biology

Active bacterial fraction is low
Total bacterial fraction is good
Active fungal fraction is low
Total fungal fraction is good
Flagellates are low
Amoeba are good
Ciliates are low
Beneficial nematodes are low
Endo mycorrhizal colonization is low
Potential plant available nitrogen supply through the biomass is 100-150 lbs./acre
The F:B ratio is 1.10:1 Desired range is .75:1 to 1.25:1

Luana Gardens
Soil test results

Particle size analysis
83.35% sand, 13.60% silt, 3.05% clay

Soil chemistry

Organic Matter	5.72%
CEC	47.50 meq/100g
pH	8.3
Phosphorus	26 ppm
Potassium	529 ppm
Calcium	7472 ppm
Magnesium	967 ppm
Iron	12 ppm

Base Saturation

Calcium	%	50% to 80% optimum
Magnesium	%	10% to 30% optimum
Potassium	%	2% to 7% optimum

Soil biology
Active bacterial fraction is low
Total bacterial fraction is good
Active fungal fraction is low
Total fungal fraction is good
Flagellates are low
Amoeba are good
Ciliates are low
Beneficial nematodes are low
Endo mycorrhizal colonization is low
Potential plant available nitrogen supply through the biomass is 100-150 lbs/acre
The F:B ratio is 1.25:1 Desired range is .75:1 to 1.25:1

Makana Park
Soil test results

Particle size analysis
14.19% sand, 60.73% silt, 25.08% clay

Soil chemistry

Organic Matter	10.3%
CEC	19.46 meq/100g
pH	7.3
Phosphorus	41 ppm
Potassium	679 ppm
Calcium	2168 ppm
Magnesium	660 ppm
Iron	23 ppm

Base Saturation

Calcium	%	50% to 80% optimum
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Soil biology

Active bacterial fraction is low
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Endo mycorrhizal colonization is low
Potential plant available nitrogen supply through the biomass is 100-150 lbs/acre
The F:B ratio is 1.17:1 Desired range is .75:1 to 1.25:1

South Maui Regional Park Soccer
Soil test results

Particle size analysis
51.0% sand, 39.9% silt, 9.1% clay

Soil chemistry

Organic Matter	13.26%
CEC	49.25 meq/100g
pH	7.6
Phosphorus	149 ppm
Potassium	1553 ppm
Calcium	6335 ppm
Magnesium	1082 ppm
Iron	223 ppm

Base Saturation

Calcium	%	50% to 80% optimum
Magnesium	%	10% to 30% optimum
Potassium	%	2% to 7% optimum

Soil biology
Active bacterial fraction is low
Active fungal fraction is low
Total bacterial fraction is very good
Total fungal fraction is good
Flagellates are low
Amoeba are excellent
Ciliates are low
Beneficial nematodes are low
Endo mycorrhizal colonization is low
Potential plant available nitrogen supply through the biomass is 200+ lbs/acre
The F:B ratio is .48:1 Desired range is .75:1 to 1.25:1

Summary

War Memorial Little League Field #1

The soil is a sandy loam at 71% sand. There is a moderately low clay percentage of 4.3%. It should be expected that the soil drains reasonably well and should respond to aeration satisfactorily provided it is done on a regular basis. Organic matter is high at 11.2%. The organic matter fraction here should give good water retention in the root zone. The organic matter percentage should be considered when setting irrigation schedules.

There are potentially good resources to support biological life, but the microbial fraction itself needs improvement. The CEC is 46.55 meq/100g. There is a high degree of nutrient retention available in this soil. Ammonium nitrogen, potassium, calcium, and magnesium will be strongly held in the soil. The pH is 7.9 which is at the high end of alkalinity for Hybrid Bermuda grass. Bermuda will tolerate this pH, but it would prefer it to be between 6 and 7.

Phosphorus, potassium, calcium, and magnesium are all on the high side. Calcium and magnesium are to be expected with island soil, but phosphorus and potassium is most likely a result of a combination of native soils and past fertility programs.

The total fraction of bacterial life and fungal life is moderately good. There is room for improvement to grow the total fractions. The active bacterial and fungal fractions are both low. It is the active bacterial fraction that breaks down organic materials during the process of mineralization. The nitrogen that is produced in this process finds its way to the grass in a non-leachable way. The active fungal fraction is low, which indicates potentially diminished natural disease suppression. The more we can elevate the active fraction the better we can compete with, and outcompete potential fungal pathogens.

Flagellates and amoeba represent the higher-level predators that consume bacteria. After consuming the bacteria, these organisms release nitrogen and carbon into the soil system. The carbon becomes an energy resource for other organisms and the nitrogen is now plant available. It is our goal to cycle 2 pounds of nitrogen every 1000 $ft.^2$ monthly to the root of the grass plant. Ciliates are low, which is a good indicator of available oxygen in the soil. Mycorrhizal colonization is low and should be improved over time.

Currently, the potential plant available nitrogen supply within the biomass is between 100 and 150 pounds per acre. The fungal to bacterial ratio is almost exactly where it should be.

We do not have to change any ratio, but rather we just need to awaken and improve certain aspects of the biological fraction. This will be done with soil amendment materials and biological foods.

Luana Gardens

The soil here is 83% sand and only 3% clay. The same general soil characteristics are here as at the Little League field. Organic matter is average at 5.7% providing a satisfactory home for microbial life. There will be less moisture retention in the root zone here due to the lower organic matter percentage. CEC is very high at 47.50 meq/100g and will provide very good nutrient retention. Phosphorus is much lower here at 26 ppm. The rest of the macronutrients are generally in range. The same conditions exist here with the bacterial and fungal biomass. The total fractions are both good and the active fractions are both lower. The protozoan community is essentially the same as the Little League field so we have the same general things happening. The fungal to bacterial ratio is perfect for turf. Refer above for specific details.

Makana Park

The soil here is exactly the opposite of the previous two samples. It is only 14% sand and the balance is silt and clay, which are the finer textured particles. Silt is 60% and clay is 25%. This soil has a significant ability to compact relatively easily and to impede water movement through the soil profile.

Organic matter is high at 10%. There should be good moisture retention in the root zone. CEC is somewhat high at 19.4 meq/100g. There is good nutrient retention and the organic matter provides a good home for biological life. Potentially, this soil has limitations, but also resources. Macronutrients are all in balance. The pH is just above the ideal range.

Even though this soil is significantly different than the previous two samples, the same biological situation exists. There is good potential in both fungal and bacterial organisms, but there is a small number that is active in working for us. Like the other two properties, the goal is to improve the total fraction and make more of the dormant fraction. The fungal to bacterial ratio again is in the ideal range for turf.

South Maui Regional Park Soccer

The soil is the most balanced soil of the four properties. It is 51% sand and 9% clay with the balance being silt. The soil should experience reasonably good drainage. Organic matter is high at 13.2%. In addition to an excellent home for the microbial fraction, there should be very good moisture retention in the root zone. CEC is high at 49.25 meq/100g which will provide very good nutrient retention.

The pH is somewhat high at 7.6, but should not be a problem. Phosphorus is very high as is calcium and magnesium. Potassium is exceptionally high at 1553 ppm. This is a combination of soils and current fertilizer practices.

The same situation within the biomass exists here. Refer to the above description. The fungal to bacterial ratio is a little too bacterial and fungal growth should be encouraged at a greater rate than bacterial growth.

There were two soil tests run. One was in March and the other was in May. They are essentially the same with some minor differences, which can be attributed to testing.

Based on the recommendations on both tests, all four grass areas should be receiving only nitrogen from fertilizer. Currently phosphorus or potassium is not recommended. If the fertilizer was chosen to deliver some of either of those nutrients, they should be in relatively small quantities. The soil tests do not call for the application of a balanced fertilizer.

We may need to use a balanced fertilizer at this point because of availability on the island and the cost to bring over more specific organic fertilizers that contain high percentages of organic nitrogen and either zero or minimal phosphorus and potassium. We will be having an ongoing discussion how best to work with a limited range of materials.

Section 2
Questionnaire

BEYOND PESTICIDES
701 E Street, SE ▪ Washington DC 20003
202-543-5450 phone ▪ 202-543-4791 fax
info@beyondpesticides.org ▪ www.beyondpesticides.org

Questionnaire on Prior Turf Management Practices

In order to move forward with the natural land care pilot project, we are requesting background information on previous management practices. Compiling this information will give us the ability to advance the project and create specific to the community's need and budget. Please provide answers to the following questions and return your responses to Beyond Pesticides at info@beyondpesticides.org:

1. A communicated expectation for each property or properties-visual appeal, turf density, playability or functionality of the system, and tolerance for weed pressures.
2. A description of each property's use, ie: public park, either passive or heavily used, athletic field, or lawn area.
3. An understanding of both current and past nutrition (fertilizer programs) for each site, including products used, brand names, analysis, frequency of application, and rates. It is important to understand how fertility was delivered in the past and specifically the amount of nitrogen that has been delivered on an annual basis. This gives us information on how best to move nutritional programs from conventional to natural.
4. An understanding of control products (pesticides) used to mitigate insects, weeds, or disease at each site, including products used, brand names, active ingredients, and rates. This includes both pre and post emergence herbicides, insecticides for grub control or other insect problems, and any fungal disease issues.
5. Documentation of cultural practices: aeration, overseeding, and topdressing.
6. An accurate area of each property. This can be given in either square footage or acreage depending upon the size of the property.
7. Information on whether turf management programs are implemented in-house or outsourced. If management is outsourced, whether IFB or RFP are created.
8. Information on internal (staff) labor resources able to be committed to management.
9. Are liquid applications a possibility?
10. Budget allocated to turfgrass management either by property or acreage.
11. Is there any other background information or property-specific issues regarding the pilot sites that you'd like to convey?

ALAN M. ARAKAWA
Mayor

KA'ALA BUENCONSEJO
Director

BRIANNE L. SAVAGE
Deputy Director

(808) 270-7230
Fax (808) 270-7934

DEPARTMENT OF PARKS AND RECREATION

700 Hali'a Nakoa Street Unit 2, Wailuku, Hawaii 96793

May 9, 2017

Mr. Jay Feldman
Beyond Pesticides
701 E. Street, SE
Washington, DC 20003

Dear Mr. Feldman:

SUBJECT: QUESTIONNAIRE ON PRIOR TURF MANAGEMENT PRACTICES

Listed below are our responses to your Questionnaire on Prior Turf Management Practices.

Response to Questions 1 & 2:

1) Makana Park:
Baseball and multi-purpose fields.
Turf: Bermuda. Fair condition, not a heavily used facility.

2) Luana Gardens:
High traffic soccer, baseball and little league fields.
Turf: Dense Bermuda. Well aeravated sand-based fields with good success of the removal of Love Grass and Sand Burr that once infested these fields. Successful herbicide and pre-emergent program on practice and game fields.

3) War Memorial Little League Field 1:
High traffic, Little League and Senior Softball practices and games.
Turf: Dense Bermuda 419. Good aeravation and herbicide program, mostly Goose Grass, Crab Grass and Spurges which are under control.

4) South Maui Regional Park Soccer Field:
High traffic soccer field.
Turf: Mixture of Bermuda 419 and Seashore Paspalum. On an aeravation program with screened dune sand topdressing program. This field was built on a blue rock bed and we are currently working on turf management. Weeds on field are mostly Goose Grass and Crab Grass. Weed control program in place with average success.

Response to Question No. 3

All fertilizer applications are at 1-5 pounds of nitrogen per 1000 square feet of turf area. We may adjust this if we do soil samples and nutrient recommendations require something different.

YaraMila Turf Royale 21-7-14 is a product we were using often but have stopped using it. We have better results with Best 16-15-16 with iron applied every 60 days. We will occasionally use Urea 45-0-0.

We have a variety of liquid fertilizers that we use depending on the condition of the field. We use Essential Plus, Riser for rooting, Accomplish LM for rooting, salt stress, nutrient update and better water uptake. Additionally, Silstar 0-0-26 is used for strengthening of cell walls of grass blades, Prospect to help plants absorb phosphorus and Feature if we need quick color.

Response to Question No. 4

We do not use insecticides except for ant bait (Amdro and Siesta) and occasional fungicide (Dacanil) during extreme wet and dark seasons. Our herbicide program consists of Revolver, Dismiss, Tenacity, Speedzone, Surflan, Ronstar Flowable, and LI-700. All chemicals are mixed according to the rates that the manufacturer's labeling recommend.

Response to Question No. 5

1) Makana Park:
   Occasional once a year aeravation, with either 3" solid tine, Rotoknife slicer or Shockwave, no topdressing.

2) Luana Gardens:
   Two times a year, aeravation with Shockwave and Rotoknife, no topdressing.

3) War Memorial Little League Field 1:
   Aeravated with Shockwave, Rotoknife and Aeravator at least three times a year and topdressed with screened dune sand at least two times a year.

4) South Maui Regional Park Soccer Field:
   Aeravation with Shockwave, Rotoknife at least two times a year and topdressed with screened dune sand at least once a year.

Response to Question No. 6

Makana Park – 11.062 park acres
Luana Gardens – 13.0 park acres
War Memorial Little League Field 1 – 2 acres
South Maui Regional Park Soccer Field – 3 acres

Response to Question No. 7

Turf Management programs are implemented in-house with training and consultation provided as needed.

Response to Question No. 8

Each district within the department has park caretakers who provide the daily park maintenance.

Response to Question No. 9

Yes.

Response to Question No. 10

The Department's budget is utilized for all 2,212 acres of the 148 parks within Maui County. Through a strategic planning process, we are currently working on system plans and maintenance management to be able to identify the costs associated with each park's turf management.

Please feel free to contact me or Karla Peters, Parks Maintenance Superintendent, at 270-7327 or karla.peters@co.maui.hi.us if you have any questions.

Sincerely,

KA'ALA BUENCONSEJO
Director of Parks & Recreation

Attachment

c: Karla Peters, Parks Maintenance Superintendent

KB:KP:lm

Section 3
Current Program
Current Site Conditions

Fertilizers

YaraMila Turf Royale 21-7-14 Discontinued
1.5 lbs. N/1000 ft.^{2} per application applied every 60 days
100% water-soluble 11.1% Ammonium nitrogen 9.9% Nitrate nitrogen

Simplott Best 16-15-16 w/Fe
1.5 lbs. N/1000 ft.^{2} per application applied every 60 days
100% water-soluble Ammonium sulfate and Urea

Urea 46-0-0 occasional

The above materials are all water-soluble. The general recommendation for Bermuda grass fertilization for high expectation and performance turf, according to The University of Hawaii Cooperative Extension, is to deliver 1 lb. to 1.5 lb. N/1000 ft.^{2} monthly throughout the active growing season. When using water-soluble, synthetic fertilizers it is recommended to deliver no more than 1 lb. N/1000 ft.^{2}. When using either organic or synthetic slow-release fertilizers, it can be appropriate to deliver up to 1.5 lbs. N/1000 ft.^{2}. These recommendations are for applications during the active growing months, generally March through November.

The rate and delivery of nitrogen is directly related to communicated expectations for the site. As nitrogen levels increase, so does quality, which then meets communicated expectations. A water-soluble fertilizer with no slow-release capability is generally gone 4 to 6 weeks after the application. Increasing the rate of application does not extend the release rate, but rather contributes to excessive nitrogen being released in the beginning of the cycle. It is a slow release fertilizer that extends to an 8 to 10-week cycle or longer. By using water-soluble N at the rates indicated above, too much N is being delivered in the short-term, potentially causing issues for the grass and the environment.

There have been a variety of liquid products used at various times-Essential Plus, Riser, Accomplish LM, Silstar 0-0-26, and Feature.

Accomplish LM is marketed as a fertilizer catalyst. It is actually three different species of Bacillus (bacterial organisms) that improve the biological fraction of the soil. A product of this type is used often in organic management programs, but it should be used after synthetic, water-soluble, salt-based fertilizers have been eliminated. The salts from synthetic fertilizers diminish the efficacy of a product like this.

Essential plus has a 1-0-1 analysis and the active ingredients are kelp, fish hydrolysate, plant extracts, and yucca extract. It is marketed as a root and plant stimulator.

Riser is a liquid fertilizer with a 7-17-3 analysis. It also contains Mn, Fe, Cu. It is marketed as a liquid starter fertilizer.

Feature is a liquid marketed as a foliar nutrient. It is used for fast green-up. It contains Mn, Fe, and Mg.

Silstar 0-0-26 is phosphite and potash. Potassium thickens cell walls and imparts stress resistance to the grass plant.

Pesticides

There are no insecticides currently being used on the four properties. Occasionally, Daconil is used as a turf fungicide during wet and dark periods. Herbicides that have been used overall as part of a program or programs include Revolver, Dismiss, Tenacity, Speedzone, Surflan, Ronstar Flowable, and LI-700. It is our understanding that none of these control products have been used on the trial sites since November 2016.

Cultural practices
Aeration and topdress

War Memorial Little League Field #1
Shockwave, Rotoknife, Aeravator 3x annually topdressed with dune sand 2x annually

Makana Park
3" solid tine*, Shockwave, Rotoknife occasional 1x annual aeration no topdress

Luana Gardens
Shockwave, Rotoknife 2x annually no topdress

South Maui Regional Park Soccer
Shockwave, Rotoknife 2x annually topdressed with dune sand 1x annually

*Solid tine is not generally beneficial in clay soils. See Cultural practice section.

Sites

War Memorial Little League Field #1
This field is Bermuda grass Tifway 419 of varying density. There is weed involvement as

evidenced in the accompanying photographs. Weed identification was not provided, but there are some of the weeds listed below in different areas of the field. At the time of our site visit, the field presented chlorotic. There was no immediate explanation, but it was communicated that the field met current expectations.

Makana Park
There is significant weed pressure and compaction at this property. It is not heavily used and has not received management at the same level as other properties.

Luana Gardens
This is a large open Bermuda grass recreation field. There is generally good turfgrass density. There are some weed pressures scattered throughout. There are also some areas that were off-color. See pictures.

South Maui Regional Park Soccer
This field is Bermuda grass Tifway 419 and Seashore paspalum. Visually it presents very nicely. There are some heavy wear areas. There is goosegrass and crabgrass present. There has been a weed control program in place with average success. At the time of the site visit it was recommended to hand pull the heaviest goosegrass infestation.

Grasses

Tifway 419 Bermuda

- Reproduces by stolons and rhizomes
- Survives droughts with minimal water availability
- 1 to 2 inches of available water weekly provides acceptable turf surface
- It will survive at ½ inch water, but quality will decline
- Very good recuperative capacity
- When dense growth is properly maintained, it will efficiently compete with many turf weeds
- Demonstrates a tolerance to and fast recovery from damage after pest problems
- Grows best when soil pH is between 5.5 and 7.0 will tolerate to 8.0
- Soil levels should be, but not exceed 100 lbs. phosphorus/acre
- Soil levels should be, but not exceed 150 to 200 lbs. potassium/acre
- Nitrogen is applied at 1 lb./1000 ft.^{2}per growing month for highest quality
- As nitrogen levels increase, higher levels of expectation, performance, aesthetics, and weed control are realized
- Soluble nitrogen should not exceed 1lb. per application. 1 ½ lbs. is acceptable if using slow-release or organic fertilizer
- Reproduces by rhizomes, stolons or stems, or as sod

Seashore paspalum

- Reproduces by stolons and rhizomes
- Unlike Bermuda grass it can reproduce by seed ¾ to 1 ¼ lb. seed/1000 $ft.^2$
- Sow only when soil temperatures are 60° or above
- Highly tolerant of various environmental stresses including salt
- Similar to Bermuda grass Both species spread rapidly and form fine textured, dense turf
- Both exhibit deep root systems and are tolerant of low mowing heights < ½ inch
- 5-8 lbs N/1000 $ft.^2$ annually
- As nitrogen levels increase, higher levels of expectation, performance, aesthetics, and weed control are realized
- 3% to 8% of exchange sites should be potassium 1:1 N:K ratio for fertilizer

Technical sheets included in glossary

Weed problems

Carpetgrass
Crabgrass
Goosegrass
Lovegrass
Hilograss

See glossary.

Section 4
Recommendations and Proposed Program

Aeration
Increase aeration to 4x annually on heaviest wear areas.

Topdressing
Instead of repeated top dressings with dune sand, it would be a sound strategy to begin to look at a compost source for top dressing. Refer to the compost section of this report for the science and justification for the use of this material. We are in the process of looking at recycled brewer's waste. The raw waste can be turned into a high-grade compost that could provide significant benefits when top dressed on an athletic field. It is my understanding that this material is readily available and at a reasonably low cost. The rate for an application of any composted product is roughly ½ cubic yard per 1000 $ft.^2$.

Seed
Seashore paspalum
When soil temperatures exceed 60°F, over seeding with Seashore paspalum can happen. Makana Park would benefit from this. Because we can only get vegetative reproduction from Hybrid Bermuda grass it might make the most sense to try and establish some other cover here. If additional grass cover is not established, it will be difficult to keep up with weed pressures in either a chemical or organic program.

Irrigation
It is important to make sure that irrigation does not exceed the above recommended amounts for either of these grass species. Having grass too wet for too long a period, even in hot dry weather, can oftentimes be problematic. There is accompanying technical information on Hybrid Bermuda grass regarding water requirements in Hawaii. There is one protocol for residential care and another one for athletic fields.

Fertility
Again, refer to the technical sheets included in this report for Bermuda grass fertility. There is a completely different requirement for athletic surfaces as opposed to residential or passive areas. There are also specific recommendations for the delivery of nitrogen to Hybrid Bermuda grass in Hawaii depending upon whether that material is water-soluble or water-insoluble nitrogen.
A conventional recommendation for water-soluble nitrogen to Hybrid Bermuda grass athletic fields is to deliver 1 lb. N/1000 $ft.^2$ monthly during the growing season. This is March or April through October or November.

If we want to fertilize every 60 days, we could deliver 1.5 lbs. N/1000 $ft.^2$ with water-insoluble nitrogen. In either case, we would be delivering between 7 and 8 pounds of nitrogen annually to maintain high expectations and high quality sports turf. Lower rates of nitrogen can be applied, but quality and density will decline and weeds will probably increase.

There is no recommendation to deliver 1.5 lbs./1000 $ft.^2$ water-soluble nitrogen every 60 days. We understand that this is the least expensive way to do it from the labor perspective. We also understand that 100% water-soluble nitrogen for turf is the least expensive product. When we are trying to manage to the higher expectations, we try to get things all within optimum situations.

With water-soluble nitrogen being delivered at 1.5 lbs./1000 $ft.^2$ fertility is being delivered in a relatively harsh way. The release mechanism of that nitrogen is described in detail in the fertilizer section of this report. With water-soluble nitrogen, release begins in 48 hours, maximum release is 7 to 10 days after application, and the nitrogen is essentially gone 4 to 6 weeks after application. This is true no matter what the rate of delivery-1.5 lbs. will not last any longer than 1 lb. It is simply that more total N will be released within the four to six-week period.

Nitrogen and soil amendment delivery

We will be using natural, organic nitrogen sources for most of the program. A detailed explanation on the mechanism of nitrogen release with both organic and synthetic fertilizers is addressed in this report.

Organic fertilizers require active microbial life, particularly the bacterial fraction, to work efficiently. I refer to the soil test analysis that indicates on all four properties the active bacterial life is low. This fraction needs to be built up before organic fertilizers can be expected to perform adequately. Our initial approach will focus on addressing the immediate needs of the grass and simultaneously improving soil biological life. Organic fertilizers build biological life and synthetic fertilizers generally do not. We will address the low active bacterial fraction with molasses and other microbial foods in the liquid portion of the program.
We are going to recommend that we might begin the program using a granular bridge fertilizer over the next 3 months. This is a material that will contain both synthetic water-soluble nitrogen and water insoluble organic nitrogen.

We would like two applications of this same material next spring and then switch to 100% organic fertilizer. The water-soluble portion will become available and while using that we will build the bacterial fraction with the liquid soil amendments. I am going to present two fertility programs and either one would work. They are based on the above recommendations and how best to deliver N for hybrid Bermuda. We can deliver 1 lb. more frequently or 1.5 lbs.at 60 day intervals.

Property area	managed turf	estimated
War Memorial Little League Field #1		1¾ acres
Makana Park		4 acres
Luana Gardens		7 acres
South Maui Regional Park Soccer		3 acres

Proposed programs

Program 1 2018
Granular N, P, K
Liquid soil building applications

March	1 lb. N/1000 ft.^{2}	granular bridge fertilizer
April	1 lb. N/1000 ft.^{2}	granular bridge fertilizer
May	liquid	
June	1 lb. N/1000 ft.^{2}	granular organic fertilizer
July	1 lb. N/1000 ft.^{2}	granular organic fertilizer
August	1 lb. N/1000 ft.^{2}	granular organic fertilizer
August	liquid	
September	liquid	
October	1 lb. N/1000 ft.^{2}	granular organic fertilizer

6 lbs. N granular + 1.5 lbs. N liquid equivalent from liquid = 7.5 lbs. N total

Program 2 2018
Granular N, P, K
Liquid soil building applications

March	1 lb. N/1000 ft.^{2}	granular bridge fertilizer
April	liquid	
May	1 lb. N/1000 ft.^{2}	granular bridge fertilizer
June	liquid	
July	1.5 lb. N/1000 ft.^{2}	granular organic fertilizer
September	1.5 lb. N/1000 ft.^{2}	granular organic fertilizer
October	liquid	
November	1 lb. N/1000 ft.^{2}	granular organic fertilizer

6 lbs. N granular + 1.5 lbs. N equivalent from liquid = 7.5 lbs. N total

Specific fertilize recommendations will be made based on availability on the island. We are currently working to get that information in place.

Liquid recipe for Program 1 or 2
3 applications annually

	Rate/1000 ft.^{2}	rate/acre
Fish hydrolysate	6 oz.	2 gal.
Accomplish LM	1.5 oz.	.5 gal.
Essential Plus	3 oz.	1 gal.
Humic acid	2 oz.	.75 gal.
KeyPlex	3 oz.	1 gal.
Molasses	.25 oz.	11 oz.
Yucca extract	.25 oz.	11 oz.

Actual N delivered = .12 lb/1000 ft.,^{2} but because of the synergistic action of all materials we realize a response closer to .5 lb. N/1000 ft.^{2}.
The final solution should be delivered at a rate of/100 gallon/acre.

Gallons concentrate required per application

	rate/acre	LL	Luana	Makana	S Maui soccer
Fish hydrolysate	2 gal.	3.5	14	8	6
Accomplish LM	.5 gal.	1	3.5	2	1.5
Essential Plus	1 gal.	2	7	4	3
Humic acid	.75 gal.	1.5	5.25	3	2.25
KeyPlex	1 gal.	2	7	4	3
Molasses	11 oz.	20oz	75oz	44oz	33oz
Yucca extract	11 oz.	20oz	75oz	44oz	33oz

Gallons required per season 3 applications

	LL	Luana	Makana	S Maui Soccer	Total
Fish hydrolysate	11	42	24	18	95
Accomplish LM	3	10.5	6	4.5	24
Essential Plus	6	21	12	9	48
Humic acid	4.5	15.75	9	6.75	36
KeyPlex	6	21	12	9	48
Molasses	.5	1.75	1	.75	4
Yucca extract	.5	1.75	1	.75	4

Amount of final solution needed by property.

	area/acre	volume
War Memorial LL #1	1¾	175 gal
Luana Gardens	7	700 gal
Makana	4	400 gal
S Maui soccer	3	300 gal

Cost and Availability

We are communicating with Hawaii Grower Products/J. R. Simplott Co. on the availability of granular and liquid materials suitable for our program. It appears that material can be sourced in the short term from them. We can choose to continue to move forward with them or move in a different direction. The prices quoted here are current prices for granular fertilizer. We do not have an exact price for the liquid materials, but it is expected that a cost per acre would be between $200.00 and $250.00.

Granular fertilizer

		bag	ton
Possible bridge	EcoGreen 12-4-6	$24.50	$ 980.00
Possible organic	EcoGreen 5-3-2	$15.00	$ 600.00
Possible organic	EcoGreen 9-1-3	$42.00	$1,680.00

Product required to deliver 1 lb N /1000 ft.^{2}

EcoGreen 12-4-6

12 lbs. fertilizer = 1 lb. N

$24.50 bag = $.50/lb.

1000 ft.^{2}	12 lbs.	$6.00
1 acre	522 lbs.	$261.00

	acres	fert needed	cost
War Memorial LL #1	1¾	915 lbs.	$ 460.00
Luana Gardens	7	3,654 lbs.	$1,627.00
Makana	4	2,088 lbs.	$1044.00
S Maui soccer	3	1,566 lbs	$ 783.00

Product required to deliver 1 lb N /1000 ft.^{2}

EcoGreen 5-3-2

20 lbs. fertilizer = 1 lb. N

$15.00 bag = $.30/lb.

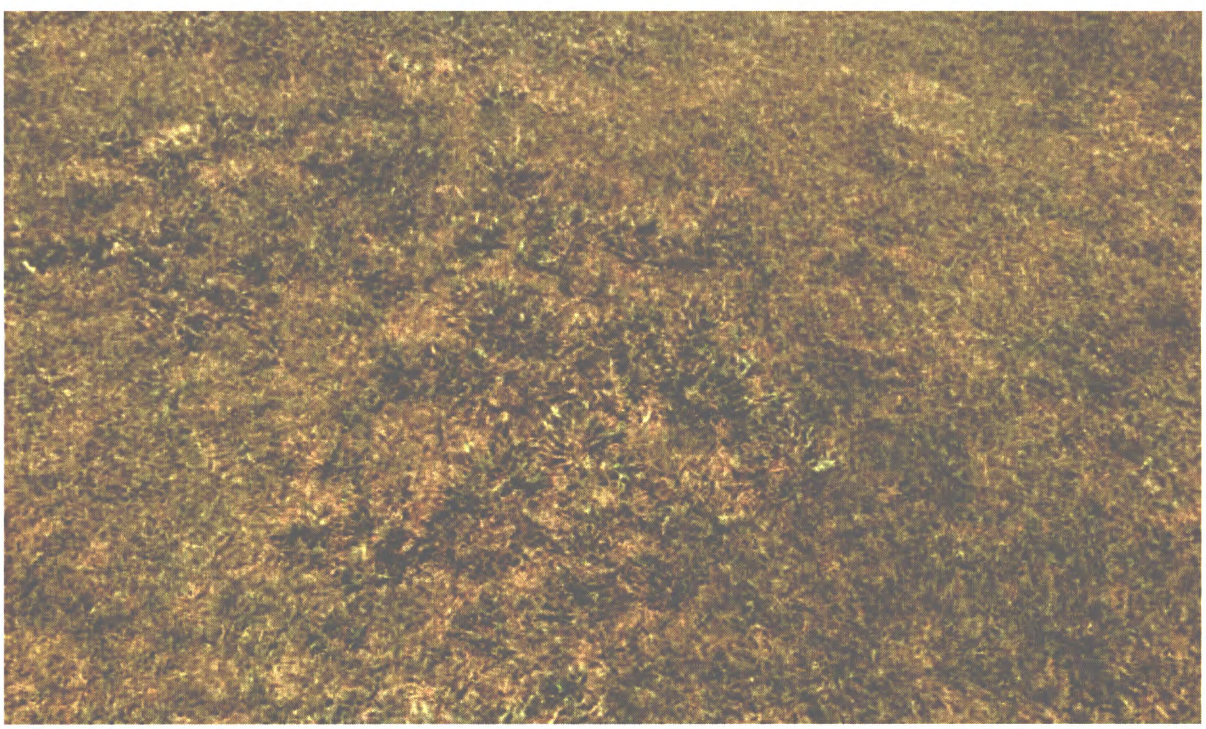
1000 ft.^{2}	20 lbs.	$6.00
1 acre	870 lbs.	$261.00

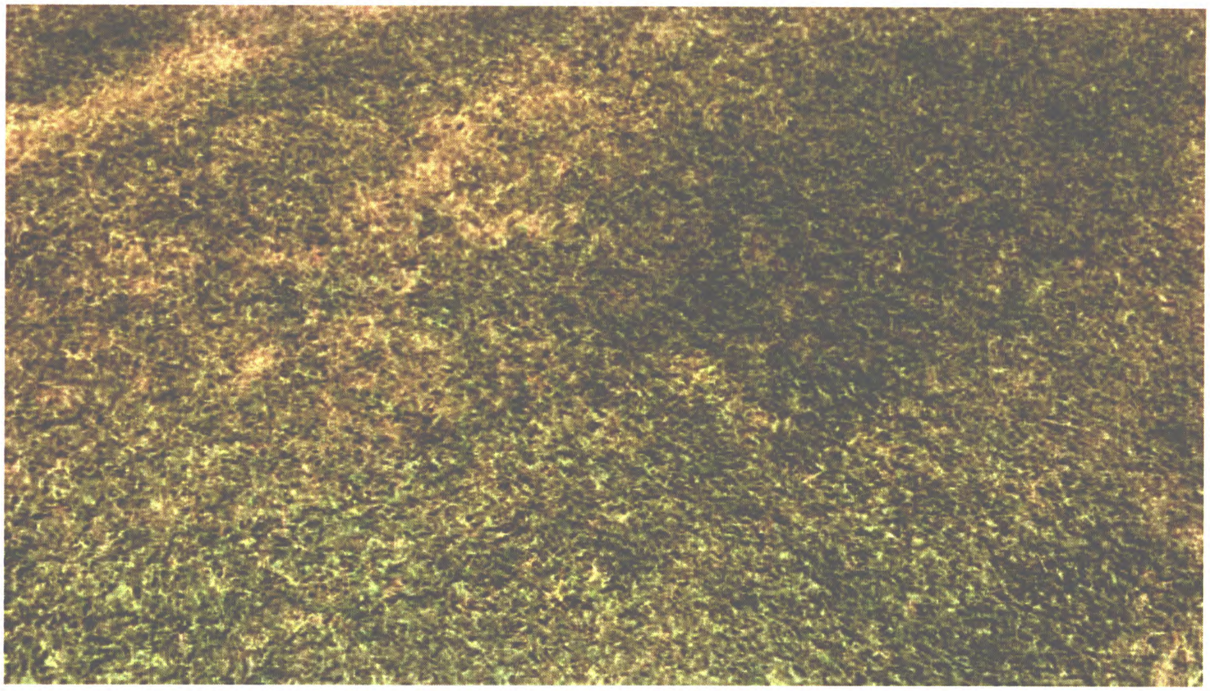
	acres	fert needed	cost
War Memorial LL #1	1¾	1,522 lbs.	$ 460.00
Luana Gardens	7	6,090 lbs.	$1,627.00
Makana	4	3,480 lbs.	$1,044.00
S Maui soccer	3	2,610 lbs	$ 783.00

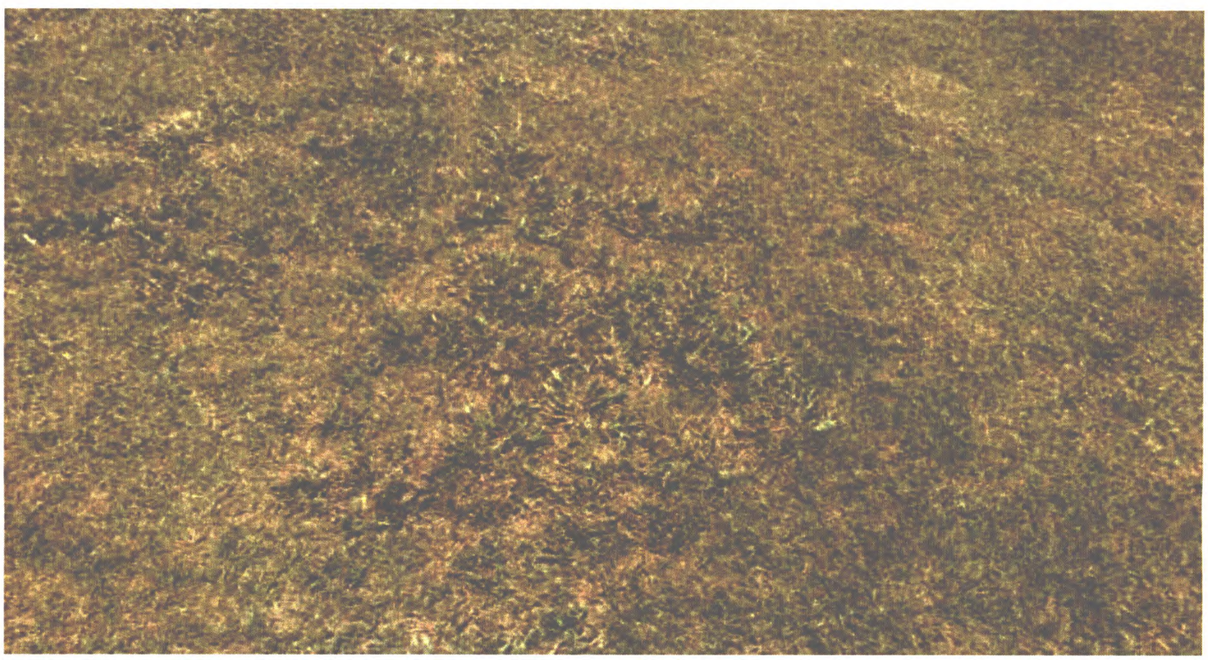
The above programs and costs represent sample programs that could be implemented. Further discussion will fine-tune the program from the implementation and cost perspective. After year one, it should be expected that each application of organic nitrogen would be reduced by .25%.

This will reduce both the volume of material and the cost. As we move into year three and beyond, granular applications can be eliminated in favor of liquid applications. Liquid applications are significantly lower in cost.

Section 5
Site Photographs   War Memorial Little League Field #1



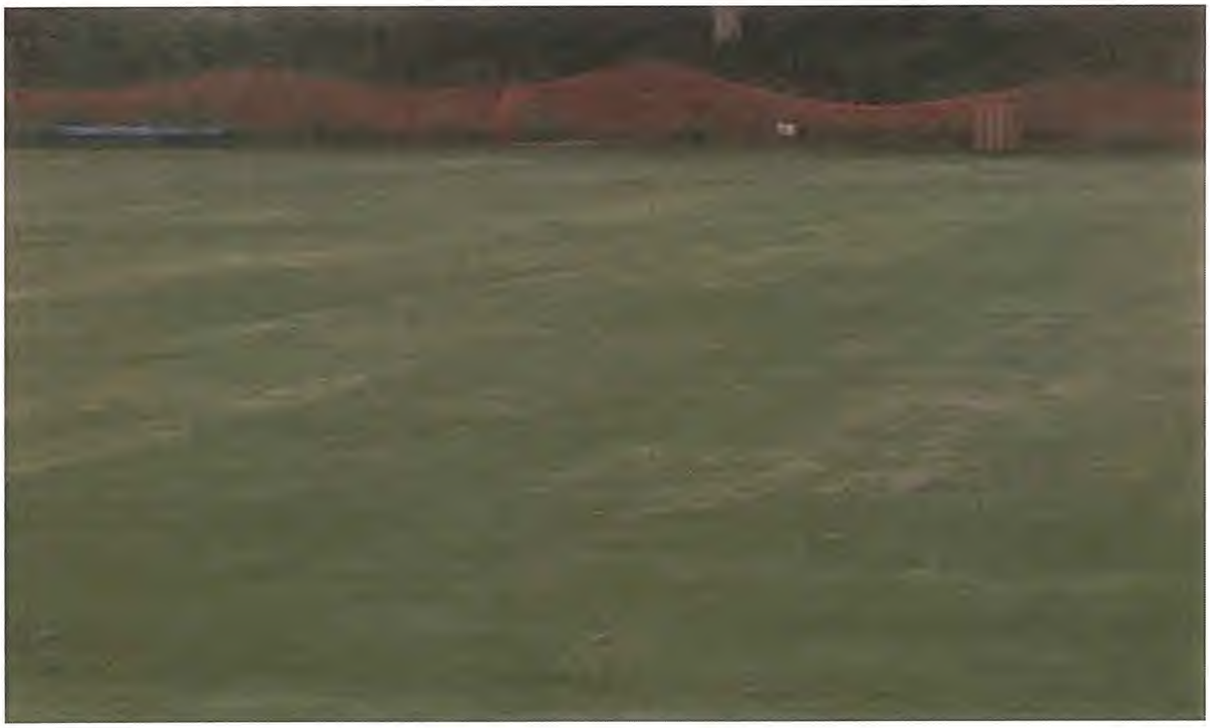




Makana Park

Luana Gardens

South Maui Regional Park Soccer Field



Section 6
Soil Test Reports

CTAHR

College of Tropical Agriculture & Human Resources
University of Hawaii at Manoa

Soil/Plant Analysis Report

Agricultural Diagnostic Service Center

Department of Agronomy and Soil Science
1910 East-West Road, Honolulu, HI 96822
Ph: (808) 956-6706/[redacted] FAX: (808) 956-2592
Email: adsc@ctahr.hawaii.edu

Client:	BEYOND PESTICIDES 701 E. STREET; SE; SUITE 200 WASHINGTON, DC 20003	Date Reported:	03/13/2017
		Agent:	NO AGENT, Office: NONE NONE NONE, NONE NONE , Fax:

Sample Information

Job Control No:	17-054286-003	Map Unit:		Plant Grown:	TURFGRASS
Sample Label:	FIELD 1	Soil Series:		Plant to be grown:	TURFGRASS
Date Received:	3/10/2017	Soil Category:	HEAVY SOIL	Can you till 4-6 in.?	Yes
Send Copy To		Soil Depth (in):		Test Results Only?	No
Elevation (ft.):		Latitude:		Longitude:	

Test Results and Interpretation

HEAVY SOIL — INTERPRETATION

Soil Analysis	Results	Expected	Very Low	Low	Sufficient	High	Very High
_pH	7.5	6					
P_ppm	172	37.5					
K_ppm	1922	250					
Ca_ppm	5866	1750					
Mg_ppm	1459	350					
OC_%		No criteria found					
Total_N_%		No criteria found					
Salinity_EC		1.25					
S_ppm		No criteria found					
Fe_ppm	123	No criteria found					
Mn_ppm	14.1	No criteria found					
Zn_ppm	22.9	No criteria found					
Cu_ppm	4	No criteria found					
B_ppm		No criteria found					
Mo_ppm		No criteria found					
Al_ppm		No criteria found					

TURFGRASS — INTERPRETATION

Plant Analysis	Results	Expected	Very Low	Low	Sufficient	High	Very High
N_%		No criteria found					
P_%		No criteria found					
K_%		No criteria found					
Ca_%		No criteria found					
Mg_%		No criteria found					
S_%		No criteria found					
Fe_ppm		No criteria found					
Mn_ppm		No criteria found					
Zn_ppm		No criteria found					
Cu_ppm		No criteria found					
B_ppm		No criteria found					
Mo_ppm		No criteria found					
Al_ppm		No criteria found					
NO3_ppm		No criteria found					

Page 1 of 2

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1910 East-West Road, Honolulu, HI 96822
Ph: (808) 956-6706/[redacted] FAX: (808) 956-2592
Email: adsc@ctahr.hawaii.edu

Date Reported: 03/13/2017

Client:	BEYOND PESTICIDES ATTN: J. Feldman 701 E Street; SE Suite 200 Washington, DC 20003	Agent	NO AGENT, Office: NONE NONE NONE, NONE NONE , Fax:

Sample Information

Job Control No:	17-054286-001	Map Unit:		Plant Grown:	TURFGRASS
Sample Label:	MAKANA PARK	Soil Series:		Plant to be grown:	TURFGRASS
Date Received:	3/10/2017	Soil Category:	HEAVY SOIL	Can you till 4~6 in.?	Yes
Send Copy To		Soil Depth (in):		Test Results Only?	No
Elevation (ft.):		Latitude:		Longitude:	

Test Results and Interpretation

HEAVY SOIL — **INTERPRETATION**

Soil Analysis	Results	Expected	Very Low	Low	Sufficient	High	Very High
_pH	6.9	6					
P_ppm	41	37.5					
K_ppm	641	250					
Ca_ppm	1935	1750					
Mg_ppm	680	350					
OC_%		No criteria found					
Total_N_%		No criteria found					
Salinity_EC		1.25					
S_ppm		No criteria found					
Fe_ppm	28	No criteria found					
Mn_ppm	45.4	No criteria found					
Zn_ppm	3.9	No criteria found					
Cu_ppm	1.9	No criteria found					
B_ppm		No criteria found					
Mo_ppm		No criteria found					
Al_ppm		No criteria found					

TURFGRASS — **INTERPRETATION**

Plant Analysis	Results	Expected	Very Low	Low	Sufficient	High	Very High
N_%		No criteria found					
P_%		No criteria found					
K_%		No criteria found					
Ca_%		No criteria found					
Mg_%		No criteria found					
S_%		No criteria found					
Fe_ppm		No criteria found					
Mn_ppm		No criteria found					
Zn_ppm		No criteria found					
Cu_ppm		No criteria found					
B_ppm		No criteria found					
Mo_ppm		No criteria found					
Al_ppm		No criteria found					
NO3_ppm		No criteria found					

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Agricultural Diagnostic Service Center
Department of Agronomy and Soil Science
1910 East-West Road, Honolulu, HI 96822
Ph: (808) 956-6706/[redacted] FAX: (808) 956-2592
Email: adsc@ctahr.hawaii.edu

Client	BEYOND PESTICIDES 701 E. STREET; SE; SUITE 200 WASHINGTON, DC 20003	Date Reported:	03/13/2017
		Agent:	NO AGENT, Office: NONE NONE NONE, NONE NONE , Fax:

Sample Information

Job Control No:	17-054286-002	Map Unit:		Plant Grown:	TURFGRASS
Sample Label:	LUANA	Soil Series:		Plant to be grown:	TURFGRASS
Date Received:	3/10/2017	Soil Category:	HEAVY SOIL	Can you till 4-6 in.?	Yes
Send Copy To		Soil Depth (in):		Test Results Only?	No
Elevation (ft.):		Latitude:		Longitude:	

Test Results and Interpretation

HEAVY SOIL — **INTERPRETATION**

Soil Analysis	Results	Expected	Very Low	Low	Sufficient	High	Very High
_pH	8.1	6					
P_ppm	47	37.5					
K_ppm	560	250					
Ca_ppm	6342	1750					
Mg_ppm	970	350					
OC_%		No criteria found					
Total_N_%		No criteria found					
Salinity_EC		1.25					
S_ppm		No criteria found					
Fe_ppm	16	No criteria found					
Mn_ppm	6.2	No criteria found					
Zn_ppm	8.9	No criteria found					
Cu_ppm	1	No criteria found					
B_ppm		No criteria found					
Mo_ppm		No criteria found					
Al_ppm		No criteria found					

TURFGRASS — **INTERPRETATION**

Plant Analysis	Results	Expected	Very Low	Low	Sufficient	High	Very High
N_%		No criteria found					
P_%		No criteria found					
K_%		No criteria found					
Ca_%		No criteria found					
Mg_%		No criteria found					
S_%		No criteria found					
Fe_ppm		No criteria found					
Mn_ppm		No criteria found					
Zn_ppm		No criteria found					
Cu_ppm		No criteria found					
B_ppm		No criteria found					
Mo_ppm		No criteria found					
Al_ppm		No criteria found					
NO3_ppm		No criteria found					

CTAHR

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University of Hawaii at Manoa

Soil/Plant Analysis Report

Agricultural Diagnostic Service Center
Department of Agronomy and Soil Science
1910 East-West Road, Honolulu, HI 96822
Ph: (808) 956-6706/[redacted] FAX: (808) 956-2592
Email: adsc@ctahr.hawaii.edu

Date Reported: 03/13/2017

Client: BEYOND PESTICIDES
701 E. STREET, SE; SUITE 200
WASHINGTON, DC 20003

Agent: NO AGENT, Office: NONE
NONE
NONE, NONE NONE
, Fax

Sample Information

Job Control No:	17-054286-004	Map Unit:		Plant Grown:	TURFGRASS
Sample Label:	KIHEI SOCCER	Soil Series:		Plant to be grown:	TURFGRASS
Date Received:	3/10/2017	Soil Category:	HEAVY SOIL	Can you till 4-6 in.?	Yes
Send Copy To		Soil Depth (in):		Test Results Only?	No
Elevation (ft.):		Latitude:		Longitude:	

Test Results and Interpretation

HEAVY SOIL — **INTERPRETATION**

Soil Analysis	Results	Expected	Very Low	Low	Sufficient	High	Very High
_pH	8	6					
P_ppm	158	37.5					
K_ppm	594	250					
Ca_ppm	5930	1750					
Mg_ppm	1160	350					
OC_%		No criteria found					
Total_N_%		No criteria found					
Salinity_EC		1.25					
S_ppm		No criteria found					
Fe_ppm	31	No criteria found					
Mn_ppm	7.5	No criteria found					
Zn_ppm	17.2	No criteria found					
Cu_ppm	2.3	No criteria found					
B_ppm		No criteria found					
Mo_ppm		No criteria found					
Al_ppm		No criteria found					

TURFGRASS — **INTERPRETATION**

Plant Analysis	Results	Expected	Very Low	Low	Sufficient	High	Very High
N_%		No criteria found					
P_%		No criteria found					
K_%		No criteria found					
Ca_%		No criteria found					
Mg_%		No criteria found					
S_%		No criteria found					
Fe_ppm		No criteria found					
Mn_ppm		No criteria found					
Zn_ppm		No criteria found					
Cu_ppm		No criteria found					
B_ppm		No criteria found					
Mo_ppm		No criteria found					
Al_ppm		No criteria found					
NO3_ppm		No criteria found					

Soil Detail

Report prepared for:
Beyond Pesticides
Jay Feldman
701 E St SE
Washington, DC 20003 USA
jfeldman@beyondpesticides.org

For interpretation of this report please contact your local Soil Steward or the lab.

Report Sent: 04 May 2017
Sample #: 01-125105
Unique ID: War Memorial LL Field 1
Plant: Turf
Season: spring
Invoice Number: 14807
Sample Recieved: 27 Apr 2017

earthfort

Earthfort, LLC
635 SW Western Blvd
Corvallis, OR 97333
+1 (541) 257-2612
info@earthfort.com
http://earthfort.com

Assay Name	Result	Units	Desired Level	Commentary
			Organism Biomass Data	
Dry Weight	0.72	N/A	0.45 to 0.85	Within normal moisture levels.
Active Fungi	**4.04**	**µg/g**	**> 75.00**	**Fungal activity low, foods may be required. -**
Total Fungi	685.40	µg/g	> 300.00	Good fungal biomass. - Good fungal diversity, hyphal diameter: 1.5 to 7um
Hyphal Diameter	**2.90**	**µm**	**> 2.50**	**Good balance of fungi. -**
Active Bacteria	80.59	µg/g	> 75.00	Bacterial activity within normal levels.
Total Bacteria	**621.77**	**µg/g**	**> 300.00**	**Good bacterial biomass. -**
Actinobacteria	10.61	µg/g	< 20.00	
			Organism Biomass Ratios	
TF:TB	1.10		1.00 to 2.00	Correctly balanced fungal and bacterial biomass for indicated plant.
AF:TF	**0.01**		**> 0.25**	**Low fungal activity relative to total biomass, foods may be required.**
AB:TB	**0.13**		> 0.25	Low bacterial activity relative to total biomass, foods may be required.
AF:AB	**0.05**		**1.00 to 2.00**	**Fungal dominated, becoming more bacterial**
			Protozoa (Protists)	
Flagellates	**1,923.77**	**number/g**	**> 10,000.00**	**Lacking species diversity.**
Amoebae	38,483.75	number/g	> 10,000.00	
Ciliates	**384.48**	**number/g**	**< 404.00**	
Nitrogen Cycling Potential	100-150	lbs/acre		Nitrogen levels dependent on plant needs. Estimated availability over a 3 month period
			Nematodes	
Nematodes	**7.01**	number/g	> 10.00	Low numbers, but good diversity.
Bacterial	**4.67**	**number/g**	**> 4.00**	
Fungal	**0.12**	number/g	> 4.00	
Fungal/Root	**1.64**	**number/g**	**< 1.00**	
Predatory	**0.00**	number/g	> 2.00	
Root	**0.58**	**number/g**	**< 1.00**	
			Mycorrhizal Fungi	
ENDO	**Not Ordered**	**%**	**> 0.10**	**-**
ECTO	Not Ordered	%	> 0.10	
Ericoid	**Not Ordered**	**%**	**> 0.10**	
			Miscellaneous Testing	
E.coli	**Not Ordered**	**CFU/g**	**< 800.00**	**For most areas, the maximum E.coli CFU/g is 800 - 1000. Please check your local regulations for more information. -**
pH	Not Ordered			
Electrical Conductivity	**Not Ordered**	**µS/cm**	**< 1000.00**	

Soil Notes:

Nematode Detail

Report prepared for:
Beyond Pesticides
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For interpretation of this report please contact your local Soil Steward or the lab.

Report Sent: 04 May 2017
Sample #: 01-125105
Unique ID: War Memorial LL Field 1
Plant: Turf
Season: spring
Invoice Number: 14807
Sample Recieved: 27 Apr 2017

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 # per gram or # per mL
Classified by type and identified to genus.
If section is blank, no nematodes identified.

Nematode Genus	#/gram	Units	Group	Common Name
Acrobeles	**0.12**	**number/g**	**Bacterial Feeders**	
Cephalobus	0.70	number/g	Bacterial Feeders	
Eucephalobus	**0.12**	**number/g**	**Bacterial Feeders**	
Geomonhystera	0.93	number/g	Bacterial Feeders	
Panagrolaimus	**1.29**	**number/g**	**Bacterial Feeders**	
Prismatolaimus	0.12	number/g	Bacterial Feeders	
Rhabditidae	**1.29**	**number/g**	**Bacterial Feeders**	
Zeldia	0.12	number/g	Bacterial Feeders	
Aporcelaimellus	**0.12**	**number/g**	**Fungal Feeders**	
Aphelenchoides	0.70	number/g	Fungal/Root Feeders	Foliar nematode
Aphelenchus	**0.12**	**number/g**	**Fungal/Root Feeders**	
Ditylenchus	0.70	number/g	Fungal/Root Feeders	Stem & Bulb nematode
Filenchus	**0.12**	**number/g**	**Fungal/Root Feeders**	
Helicotylenchus	0.23	number/g	Root Feeders	Spiral nematode
Pratylenchus	0.35	number/g	Root Feeders	Lesion nematode

Soil Detail

Report prepared for:
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For interpretation of this report please contact your local Soil Steward or the lab.

Report Sent: 04 May 2017
Sample #: 01-125107
Unique ID: Makana Park
Plant: Turf
Season: spring
Invoice Number: 14807
Sample Recieved: 27 Apr 2017

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Assay Name	Result	Units	Desired Level	Commentary
			Organism Biomass Data	
Dry Weight	0.75	N/A	0.45 to 0.85	Within normal moisture levels.
Active Fungi	**9.97**	**µg/g**	**> 75.00**	**Fungal activity low, foods may be required. -**
Total Fungi	824.24	µg/g	> 300.00	Good fungal biomass. - Good fungal diversity, hyphal diameter: 1.5 to 6.5um
Hyphal Diameter	**2.80**	**µm**	**> 2.50**	**Good balance of fungi. -**
Active Bacteria	64.63	µg/g	> 75.00	Bacterial activity low, foods may be required.
Total Bacteria	**706.86**	**µg/g**	**> 300.00**	**Good bacterial biomass. -**
Actinobacteria	51.57	µg/g	< 20.00	
			Organism Biomass Ratios	
TF:TB	1.17		1.00 to 2.00	Correctly balanced fungal and bacterial biomass for indicated plant.
AF:TF	**0.01**		**> 0.25**	**Low fungal activity relative to total biomass, foods may be required.**
AB:TB	0.09		> 0.25	Low bacterial activity relative to total biomass, foods may be required.
AF:AB	**0.15**		**1.00 to 2.00**	**Fungal dominated, becoming more bacterial**
			Protozoa (Protists)	
Flagellates	**769.56**	**number/g**	**> 10,000.00**	**Lacking species diversity.**
Amoebae	37,107.44	number/g	> 10,000.00	
Ciliates	**18.74**	**number/g**	**< 379.00**	
Nitrogen Cycling Potential	100-150	lbs/acre		Nitrogen levels dependent on plant needs. Estimated availability over a 3 month period
			Nematodes	
Nematodes	3.29	number/g	> 10.00	Low numbers, but good diversity.
Bacteral	**0.90**	**number/g**	**> 4.00**	
Fungal	0.77	number/g	> 4.00	
Fungal/Root	**1.48**	**number/g**	**< 1.00**	
Predatory	0.00	number/g	> 2.00	
Root	**0.13**	**number/g**	**< 1.00**	
			Mycorrhizal Fungi	
ENDO	**Not Ordered**	**%**	**> 0.10**	**-**
ECTO	Not Ordered	%	> 0.10	
Ericoid	**Not Ordered**	**%**	**> 0.10**	
			Miscellaneous Testing	
E.coli	**Not Ordered**	**CFU/g**	**< 800.00**	**For most areas, the maximum E.coli CFU/g is 800 - 1000. Please check your local regulations for more information. -**
pH	Not Ordered			
Electrical Conductivity	**Not Ordered**	**µS/cm**	**< 1000.00**	

Soil Notes:

Nematode Detail

Report prepared for:
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Jay Feldman
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For interpretation of this report please contact your local Soil Steward or the lab.

Report Sent: 04 May 2017
Sample #: 01-125107
Unique ID: Makana Park
Plant: Turf
Season: spring
Invoice Number: 14807
Sample Recieved: 27 Apr 2017

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 # per gram or # per mL
Classified by type and identified to genus.
If section is blank, no nematodes identified.

Nematode Genus	#/gram	Units	Group	Common Name
Cephalobus	**0.26**	**number/g**	**Bacterial Feeders**	
Diploscapter	0.13	number/g	Bacterial Feeders	
Plectus	**0.06**	**number/g**	**Bacterial Feeders**	
Rhabditidae	0.45	number/g	Bacterial Feeders	
Aporcelaimellus	**0.19**	**number/g**	**Fungal Feeders**	
Epidorylaimus	0.13	number/g	Fungal Feeders	
Eudorylaimus	**0.32**	**number/g**	**Fungal Feeders**	
Tylencholaimus	0.13	number/g	Fungal Feeders	
Aphelenchoides	**0.58**	**number/g**	**Fungal/Root Feeders**	**Foliar nematode**
Ditylenchus	0.45	number/g	Fungal/Root Feeders	Stem & Bulb nematode
Filenchus	**0.45**	**number/g**	**Fungal/Root Feeders**	
Pratylenchus	0.06	number/g	Root Feeders	Lesion nematode
Xiphinema	**0.06**	**number/g**	**Root Feeders**	**Dagger nematode**

Soil Detail

Report prepared for:
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Jay Feldman
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For interpretation of this report please contact your local Soil Steward or the lab.

Report Sent: 04 May 2017
Sample #: 01-125106
Unique ID: Luana Gardens
Plant: Turf
Season: spring
Invoice Number: 14807
Sample Recieved: 27 Apr 2017

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Assay Name	Result	Units	Desired Level	Commentary
			Organism Biomass Data	
Dry Weight	0.80	N/A	0.45 to 0.85	Within normal moisture levels.
Active Fungi	**7.27**	**µg/g**	**> 75.00**	**Fungal activity low, foods may be required. -**
Total Fungi	726.09	µg/g	> 300.00	Good fungal biomass. - GOod fungal diversity, hyphal diameter: 1.5 to 5um
Hyphal Diameter	**2.85**	**µm**	**> 2.50**	**Good balance of fungi. -**
Active Bacteria	83.63	µg/g	> 75.00	Bacterial activity within normal levels.
Total Bacteria	**579.23**	**µg/g**	**> 300.00**	**Good bacterial biomass. -**
Actinobacteria	10.74	µg/g	< 20.00	
			Organism Biomass Ratios	
TF:TB	1.25		1.00 to 2.00	Correctly balanced fungal and bacterial biomass for indicated plant.
AF:TF	**0.01**		**> 0.25**	**Low fungal activity relative to total biomass, foods may be required.**
AB:TB	0.14		> 0.25	Low bacterial activity relative to total biomass, foods may be required.
AF:AB	**0.09**		**1.00 to 2.00**	**Fungal dominated, becoming more bacterial**
			Protozoa (Protists)	
Flagellates	**1,736.75**	**number/g**	**> 10,000.00**	**Lacking species diversity.**
Amoebae	34,742.58	number/g	> 10,000.00	
Ciliates	**57.64**	**number/g**	**< 365.00**	
Nitrogen Cycling Potential	100-150	lbs/acre		Nitrogen levels dependent on plant needs. Estimated availability over a 3 month period
			Nematodes	
Nematodes	2.91	number/g	> 10.00	Low numbers, but good diversity.
Bacterial	**1.12**	**number/g**	**> 4.00**	
Fungal	0.52	number/g	> 4.00	
Fungal/Root	**0.89**	**number/g**	**< 1.00**	
Predatory	0.00	number/g	> 2.00	
Root	**0.37**	**number/g**	**< 1.00**	
			Mycorrhizal Fungi	
ENDO	**Not Ordered**	**%**	**> 0.10**	**-**
ECTO	Not Ordered	%	> 0.10	
Ericoid	**Not Ordered**	**%**	**> 0.10**	
			Miscellaneous Testing	
E.coli	**Not Ordered**	**CFU/g**	**< 800.00**	**For most areas, the maximum E.coli CFU/g is 800 - 1000. Please check your local regulations for more information. -**
pH	Not Ordered			
Electrical Conductivity	**Not Ordered**	**µS/cm**	**< 1000.00**	

Soil Notes:

Nematode Detail

Report prepared for:
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For interpretation of this report please contact your local Soil Steward or the lab.

Report Sent: 04 May 2017
Sample #: 01-125106
Unique ID: Luana Gardens
Plant: Turf
Season: spring
Invoice Number: 14807
Sample Recieved: 27 Apr 2017

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 # per gram or # per mL
Classified by type and identified to genus.
If section is blank, no nematodes identified.

Nematode Genus	#/gram	Units	Group	Common Name
Cephalobus	**0.22**	**number/g**	**Bacterial Feeders**	
Diploscapter	0.07	number/g	Bacterial Feeders	
Monhystrella	**0.30**	**number/g**	**Bacterial Feeders**	
Panagrolaimus	0.22	number/g	Bacterial Feeders	
Prismatolaimus	**0.07**	**number/g**	**Bacterial Feeders**	
Rhabditidae	0.22	number/g	Bacterial Feeders	
Aporcelaimellus	**0.07**	**number/g**	**Fungal Feeders**	
Epidorylaimus	0.07	number/g	Fungal Feeders	
Eudorylaimus	**0.30**	**number/g**	**Fungal Feeders**	
Microdorylaimus	0.07	number/g	Fungal Feeders	
Aphelenchoides	**0.60**	**number/g**	**Fungal/Root Feeders**	**Foliar nematode**
Ditylenchus	0.30	number/g	Fungal/Root Feeders	Stem & Bulb nematode
Paratrichodorus	**0.07**	**number/g**	**Root Feeders**	**Stubby Root nematode**
Pratylenchus	0.30	number/g	Root Feeders	Lesion nematode

Soil Detail

Report prepared for:
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For interpretation of this report please contact your local Soil Steward or the lab.

Report Sent: 04 May 2017
Sample #: 01-125108
Unique ID: South Maui Regional Park Soccer
Plant: Turf
Season: spring
Invoice Number: 14807
Sample Recieved: 27 Apr 2017

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Assay Name	Result	Units	Desired Level	Commentary
			Organism Biomass Data	
Dry Weight	0.70	N/A	0.45 to 0.85	Within normal moisture levels.
Active Fungi	**3.87**	**µg/g**	**> 75.00**	**Fungal activity low, foods may be required. -**
Total Fungi	541.49	µg/g	> 300.00	Good fungal biomass. - Fairly good fungal diversity, hyphal diameter: 1.5 to 6um
Hyphal Diameter	**2.75**	**µm**	**> 2.50**	**Good balance of fungi. -**
Active Bacteria	81.92	µg/g	> 75.00	Bacterial activity within normal levels.
Total Bacteria	**1,122.00**	**µg/g**	**> 300.00**	**Good bacterial biomass. -**
Actinobacteria	62.76	µg/g	< 20.00	
			Organism Biomass Ratios	
TF:TB	0.48		1.00 to 2.00	Too bacterial for indicated plant.
AF:TF	**0.01**		**> 0.25**	**Low fungal activity relative to total biomass, foods may be required.**
AB:TB	0.07		> 0.25	Low bacterial activity relative to total biomass, foods may be required.
AF:AB	**0.05**		**1.00 to 2.00**	**Bacterial dominated, becoming more bacterial.**
			Protozoa (Protists)	
Flagellates	**822.75**	**number/g**	**> 10,000.00**	**Lacking species diversity.**
Amoebae	198,360.29	number/g	> 10,000.00	
Ciliates	**198.89**	**number/g**	**< 1992.00**	
Nitrogen Cycling Potential	200+	lbs/acre		Nitrogen levels dependent on plant needs. Estimated availability over a 3 month period
			Nematodes	
Nematodes	4.71	number/g	> 10.00	Low numbers, but good diversity.
Bacterial	**3.69**	**number/g**	**> 4.00**	
Fungal	0.13	number/g	> 4.00	
Fungal/Root	**0.76**	**number/g**	**< 1.00**	
Predatory	0.00	number/g	> 2.00	
Root	**0.13**	**number/g**	**< 1.00**	
			Mycorrhizal Fungi	
ENDO	**Not Ordered**	**%**	**> 0.10**	**-**
ECTO	Not Ordered	%	> 0.10	
Ericoid	**Not Ordered**	**%**	**> 0.10**	
			Miscellaneous Testing	
E.coli	**Not Ordered**	**CFU/g**	**< 800.00**	**For most areas, the maximum E.coli CFU/g is 800 - 1000. Please check your local regulations for more information. -**
pH	Not Ordered			
Electrical Conductivity	**Not Ordered**	**µS/cm**	**< 1000.00**	

Soil Notes:

Nematode Detail

Report prepared for:
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Jay Feldman
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For interpretation of this report please contact your local Soil Steward or the lab.

Report Sent: 04 May 2017
Sample #: 01-125108
Unique ID: South Maui Regional Park Soccer
Plant: Turf
Season: spring
Invoice Number: 14807
Sample Recieved: 27 Apr 2017

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 # per gram or # per mL
Classified by type and identified to genus.
If section is blank, no nematodes identified.

Nematode Genus	#/gram	Units	Group	Common Name
Acrobeles	**0.25**	**number/g**	**Bacterial Feeders**	
Alaimus	0.51	number/g	Bacterial Feeders	
Butlerius	**0.13**	**number/g**	**Bacterial Feeders**	
Cephalobus	0.51	number/g	Bacterial Feeders	
Diploscapter	**0.13**	**number/g**	**Bacterial Feeders**	
Monhystrella	0.76	number/g	Bacterial Feeders	
Plectus	**0.13**	**number/g**	**Bacterial Feeders**	
Prismatolaimus	0.38	number/g	Bacterial Feeders	
Rhabditidae	**0.51**	**number/g**	**Bacterial Feeders**	
Rhabdolaimus	0.38	number/g	Bacterial Feeders	
Eudorylaimus	**0.13**	**number/g**	**Fungal Feeders**	
Ditylenchus	0.25	number/g	Fungal/Root Feeders	Stem & Bulb nematode
Filenchus	**0.51**	**number/g**	**Fungal/Root Feeders**	
Helicotylenchus	0.13	number/g	Root Feeders	Spiral nematode

Section 7
Soil Texture

Soil is the foundation of our landscape. It is much more than just a functional medium to hold turfgrass and other plants upright. In many cases, conventional programs that are focused on water-soluble fertility and a series of chemical control products can reduce the impact of the soil to that medium, doing little more than physically support the plant. The mineral portion of the soil is comprised of sand, silt, and clay, mixed with varying amounts of organic matter, water, and air. The soil is very much alive. It is home to a microbial community that is made up of organisms both large and small. These microbes give the soil its life. With organic matter on average at 5%, it is a very small portion of the soil. The microbes are supported within this small fraction. Ideal soils are typically described as having the following characteristics: 45% mineral, 25% air, 25% water, and 5% organic matter.

All soil particles, from the microscopic sheets of clay to the largest grains of sand, should be surrounded on all sides by air. When soils have varying degrees of moisture, some amount of water occupies the air space. This air and water portion is referred to as pore space. It is this pore space that allows the soil to function in a healthy way to support both microbial organisms and the roots of turfgrass by ensuring good gas exchange with the atmosphere. It is this gas exchange that releases carbon dioxide from the biomass, and in turn allows oxygen to be incorporated into the soil environment. When we think of soil within this framework, we realize that when we pick up a handful of soil, only one half of it is solid matter, while the other half is some combination of air and water.

The mineral particles in the soil are of varying sizes. They are derived from parent rock material. That material varies in different regions of the country, therefore mineral nutrients and composition vary as well.

At the most basic level, clay is the smallest particle, being microscopic. It has a sticky feel to it when moist, and is largely responsible for influencing the bulk density of the soil. It has a tendency to compact and impede water movement down through the soil profile. In regions of the United States where clay percentages are high, we face particular challenges in growing grass.

The next largest particles are silt. Silt feels much like flour. It is considered to be fine-textured and has a very smooth feel to it. Although silt is not as fine as clay, silt can combine with clay and the end result is a soil that is relatively tight.

Grains of sand are the largest mineral particles in the soil. Sands are subdivided into five individual textural classifications –very fine, fine, medium, course, and very course. Although sands are not considered to be a primary source of compaction, there is no question that the finer particles can combine with other fine particles in the soil and create a compacted situation.

Topsoil, as the name implies, is the uppermost layer of soil. This surface layer of soil is usually darker than subsoil because of the accumulation of organic matter. In different parts of the United States, we see very different depths of topsoil. It can range from six to eight inches in the Northeast to two feet or more in the Midwest, and variable depths in the West.

Loam, on the other hand, is a textural classification. Loam is a word that is very often misused in the industry. We do not buy loam to work on a project, but rather we purchase topsoil. That topsoil may in fact be a loam, but that depends entirely on the relative percentages of sand, silt, and clay. A loam is technically a soil with between 7% and 27% clay, 28% and 50% silt, and less than 52% sand. The term loam can then be modified to sandy loam, sandy clay loam, clay loam, silty clay loam, or silt loam as the individual soil fractions change. The textural classification for the soils on the pilot sites appears on the following reports.

Sands

Sands are loose and singled grained (that is, not aggregated together). They feel gritty to the touch and are not sticky. Each individual sand grain is of sufficient size that it can be easily seen and felt. Sands cannot be formed into a cast by squeezing when dry. When moist, sands will form a very weak cast that crumbles when touched. Soil materials that are classified as sands must contain 85% to 100% sand sized particles, 0 to 15% silt sized particles, and 0 to 10% clay sized particles. The reason that sands are referred to in the plural is that there are several USDA textures within this group. All of these textures fit in the sand portion of the textural triangle, but they differ from each other in their relative portions of the various sizes of sand grains.

Silt

Silt is similar to silt loam but contains even less sand and clay. Sand sized particles, if present, are generally so small (either fine or very fine) that they are non-detectable to the fingers. Clay particles are present in such low percentages that little or no stickiness is imparted to the soil when moistened. Instead it feels smooth and rather silky. Silt sized particles are somewhat plastic, and can be formed into casts that will bear careful handling.

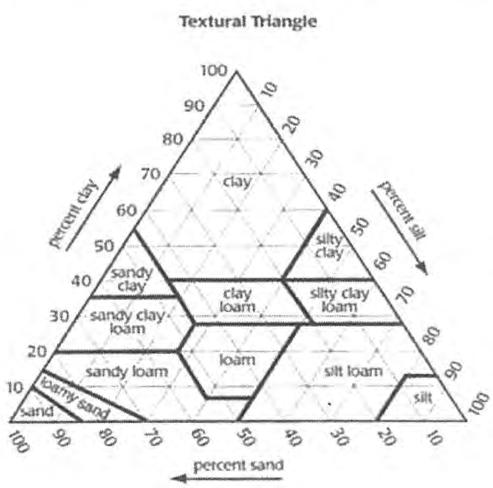
Clay

Clay is the finest textured of all of the soil classes. Clay usually forms extremely hard clods or lumps when dry and is extremely sticky and plastic when wet. When containing the proper amount of moisture, it can be "ribboned out" to a remarkable degree by squeezing between the thumb and forefinger, and may be rolled into a long, very thin wire.

As part of the data collection process, one of the soil tests that we have performed is the Textural Analysis or Particle Size Analysis. Those test results appear on the following pages.

In some cases, a field or a park may be native soil, while at other times the soil that is used for construction is imported to the site or engineered. It is these soils that we try to identify, as they may be significantly different than existing soils. It is in this testing process that the above referenced particle size is determined. The results of that test are then applied to the textural triangle and we get the soil classification. The USDA textural triangle is the tool that we use to determine soil textural classifications. After soil testing determines the relative percentages of sand, silt, and clay, we refer to the triangle and find the percentages on each side and follow the lines to the intersecting point.

It should be noted here that soil texture is a given, and we will have very little ability to influence it one way or another. We will be working with soils on-site, as is, and develop a program that best addresses the needs of the grass given the soil conditions.



If we are constructing a turfgrass area from scratch, we have the ability to create an engineered soil by blending sands with native topsoil and an organic amendment to create an ideal soil to support a turfgrass system. In any new construction project, we should always be aware that the establishment of a good soil is critically important.

Section 8
Soil Chemistry

The second test of the soil is the Nutrient Analysis. It is this soil test that gives us critical information relating to soil chemistry. Soil chemistry involves pH, micro and macro mineral nutrients, organic matter percentage, cation exchange capacity, and nitrate and ammonium nitrogen.

The first and probably most important area of attention is the relative acidity (or alkalinity) of the soil. It is measured as pH. The pH scale runs from 1.0 to 14.0 with 7.0 being neutral. The lower end of the scale is acidic and the higher-end is alkaline. A soil becomes acid when there is a substantial amount of hydrogen ions occupying cation exchange sites. As more hydrogen is attracted and retained on those sites, the soil becomes more acidic. When we use a liming material, we replace the hydrogen with calcium or magnesium and the pH rises. As the hydrogen ions are knocked off the exchange sites, two hydrogen ions combine with one oxygen ion to form water.

Establishing the pH within a desired range for any individual plant species is critically important. Cool season turfgrasses prefer the pH to be slightly acidic, generally between 6.2 and 7.0. Establishment of the pH within this range is important to the success of a natural management program. The nutrients that the grass plant uses in the largest amounts are most readily available when the pH is established within this range. The grass plant uses nitrogen in the largest amount, followed by potassium, and then phosphorus. The most important and critical step in a natural program is to adjust the pH within the desired range. Unless pH is close to this range, the grass plant does not get the nutrients it needs with any degree of efficiency. Fertilizer can be repeatedly applied, but will have less than the maximum desired effect.

Lime is used as the preferred input for raising the pH in those regions of the country with acidic soils. The calcium to magnesium ratio, as determined by the nutrient analysis, is considered when determining the type of lime to be used. We have two choices, calcitic or dolomitic lime. The guidelines we follow call for roughly an 8:1 calcium to magnesium ratio. Calcitic lime is higher in calcium and dolomitic lime is higher in magnesium. These materials can be purchased as regular lime or high cal or high mag lime. With the more concentrated products, substantially less material is used. When calcium to magnesium ratios are optimum, dolomitic lime is preferred. If we have less than the optimum ratio, calcitic lime is chosen.

The generally accepted practice of lime applications would be to not exceed 50 pounds per 1000 $ft.^2$ in any one application. If recommendations call for applications greater than that amount, we apply over two growing seasons. Elevation of the pH is not a rapid process, but rather can take up to 100 days for the material to break down and begin to elevate the pH. Soluble calcium products marketed for their ability to make rapid changes in the pH have a place but should not generally replace traditional lime.

The establishment of the proper pH by liming is usually an expense occurred in the first years of a natural program. Natural fertilizers do not tend to acidify the soil in the way conventional products do after repeated applications. One of the benefits of natural fertilizers and composts that are used to feed the soil is a natural buffering of the soil and pH becomes stabilized within the desired range.

In some cases, it may be desirable to lower the pH by adding an acidifying agent such as elemental sulfur (flowers of sulfur). This can be done successfully on soils that do not contain large amounts of free lime. Amounts of sulfur needed to lower the pH of a silt loam soil to a 6-inch depth are easily calculated. Sandy soils would require less and clayey soils would require more. Elemental sulfur is converted to sulfuric acid by soil bacteria. Therefore, in order for sulfur to work, the following must be satisfied:

- Sulfur must be mixed with the soil to provide contact.
- The soil must be moist.
- The soil must be aerated (bacteria need oxygen).
- The soil must be warm for rapid bacterial growth.
- Time is required for the reaction to go to completion.

Do not confuse sulfur as a soil-acidifying agent with sulfur as a plant nutrient. Soil test reports generally recommend 10 pounds of sulfur per acre as a plant nutrient. Most fertilizer sources of sulfur are in the sulfate form (SO_4^{-2}), which is readily available to plants, e.g., ammonium sulfate, calcium sulfate (gypsum), potassium sulfate, sul-po-mag, magnesium sulfate (epsom salts), etc. Sulfate sulfur is usually contained in mixed fertilizers. This form will not acidify soils. Elemental sulfur is a yellow powder. This is the form used for soil acidification. It is not plant available. Soil bacteria must oxidize it to the sulfate form. This process takes time, usually several weeks.

Nutrient Management

An approach using primarily synthetic, water-soluble fertilizers is directly feeding the grass plant. These products are broken down by soil moisture and almost immediately available. Natural, organic fertilizers work in a different way. It is the soil microbiology that breaks down the fertilizer and uses it as a food source. The microbes then make the nutrients available to the grass plant in plant available forms. It is this feed-the-soil approach that will be the basis of our recommendations for a nutrient program. In a natural program, we do not focus on pounds of nitrogen per 1000 $ft.^2$ in quite the same way that we do in a conventional program. A healthy soil where the microbes are nourished with natural fertilizers has the ability to cycle up to two pounds of nitrogen per 1000 $ft.^2$ to the grass plant on a monthly basis. This plateau is reached when sustainability is approached, generally three to four years into a complete natural turf management program. This is what we refer to as fertilizing through the biomass. Our focus begins to center on the microbial community as opposed to the fertilizer bag. It is through the optimization of the biomass that we can effectively manage turfgrass nutrition with natural materials.

All nutrient and cultural recommendations that are made will ultimately affect the microbes. They are a big part of creating and achieving good soil health and quality. This is really the starting point. Once we have addressed the pH of the soil, we then move to addressing the other aspects of soil chemistry. The following aspects are some key considerations of which we need to be aware and are all found in the soil test report.

Organic Matter

Organic matter makes up a relatively small fraction of the soil. A typical agricultural soil has between 1% and 6% organic matter. This percentage varies in all regions of the United States. As previously noted, we work with a number of 5% as an average.
A soil that supports turfgrass should have between 3% and 6% organic matter. Organic matter has a tremendous effect on most soil properties. Think of organic matter as the home for the microbial community. It is the complex interactions within the organic matter portion of the soil that makes the system function.

Organic matter is made up of living organisms, fresh residues, and well-decomposed residues. These three components of organic matter have been referred to as the living, the dead, and the very dead (Magdoff, University of Vermont). The living portion is comprised of a wide variety of microorganisms, including bacteria, fungi, protozoa, and nematodes among others. Also included are plant roots, earthworms, insects, and larger animals that spend time in the soil. This living portion represents about 15% of total organic matter.

The fresh residues, or the dead portion, are comprised of recently deceased microorganisms, insects, earthworms, and compost if applied as a topdress.
The dead portion also includes crop or plant residues. In the case of a turfgrass system, it is grass clippings that are left on the turf to be decomposed by saphrophytic organisms. Nutrient cycling happens here in the dead portion of organic matter.

The very dead part of organic matter is humus. Humus is the end product of decomposition. When the living and the dead portions of organic matter can decompose no further, the final and stable byproduct of that decomposition is referred to as humus. Humus is fully stable and is considered to be a long-term soil resource lasting many hundreds of years. You will notice as we begin to design programs of inputs to support the turfgrass and the biomass, we frequently use extracts of humus to enhance soil function.

Humus is one of the central components that tie together the inter-related functions of soil chemistry, texture, and biology. As we begin to address and enrich soil organic matter, we are improving the humus content of the soil and all of the interactions that take place. When we get all of these aspects working in harmony, we begin to achieve what is referred to as soil health.

Conventional soil science has looked at soil chemistry, texture, and biology separately. The emerging way of looking at the soil is to try to achieve optimum levels in each of these three areas, resulting in good soil quality or soil health. Many natural fertilizers are now including humates as part of the blend for the specific purpose of working to create a healthy soil. If not included in a fertilizer blend, humates can be applied separately in granular or liquid form. The liquid programs that we put forth for managing a turfgrass system will generally include humates.

Cation Exchange Capacity (CEC)

CEC is a measure of the nutrient holding capacity of the soil. Some of the clays and the well-aged humus portion of organic matter contain negatively charged ions that attract and hold on to plus charged cations (nutrients). Older, well-aged organic matter (humus) contains the largest percentage of exchange sites. As we improve organic matter and its humus content, we increase the exchange sites in the soil.

There are different clays that make up this fine, mineral portion of the soil. They are montmorillonite and koalinite clays. They each have different characteristics with regard to possessing the ions to attract nutrients. We can look at different soil samples and see results that seem to contradict other results from the same general property, but most often the variable is that some soils are not native to the site, but rather brought in as a topsoil to supplement existing soil on site.

As we improve the nutrient holding capacity of the soil, whatever we apply tends to be held more strongly in the soil. The primary macronutrients that are held on the exchange sites are calcium, magnesium, potassium, aluminum, ammoniacal nitrogen ($NH4+$), and hydrogen. An abundance of hydrogen creates an acidic condition in the soil, whereas an abundance of calcium and/or magnesium creates an alkaline soil. We look at ammonium nitrogen as being reserve nitrogen. It can be converted to nitrate little by little by specific bacteria that are present in the soil. A more detailed explanation of nitrogen and its function is provided later.

Section 9
The Soil Biomass

Any discussion of nutrient management in a natural turf program would be incomplete if the role of the biomass was not addressed. It is really the foundation upon which our nutrient management program is based. In taking a "feed-the-soil" approach, soil microbes are at the heart of our management strategy. It is the natural, organic fertilizer that is broken down by the microbial life and nutrients are made plant available. Synthetic fertilizers by their nature, and with their high salt content, may compromise the activity of much of this life in the soil under certain conditions. The microbes do not reproduce and function at healthy levels in soils that exhibit high salinity.

One of the soil tests performed on the trial properties is the assay of microbial life. It is a test that gives us a picture of the living portion of the soil. This test gives us information on both the bacterial and fungal communities and how much of each is actively working. We also get information on protozoa and nematodes, which are higher-level predators. At the most basic level, these organisms interact in a predatory relationship. It is a situation where organisms compete for a chance for survival. One organism consumes another and the byproduct is carbon, nitrogen, and other nutrients made available to either the biomass or the grass plant. For example, a single cell bacterium is comprised of individual units of carbon and nitrogen. If that bacterium is consumed by a protozoa, a higher level predator, that protozoa assumes the carbon and nitrogen. It possesses its own carbon and nitrogen, therefore, it does not need that which has been processed from the bacteria. The excess carbon and nitrogen is exuded into the soil environment. The nitrogen is in an inorganic form and readily available to be taken up by the grass plant. The carbon is sequestered in the soil environment as an energy resource for other organisms.

During the transition from a conventional fertility management program to a natural one, it is important to address the role of the microbial community and choose products that science has shown enhance their development and function. The soil environment, specifically the organic matter, is the home for soil microbial life. When we have soils with a given organic matter percentage, we can use strategies to elevate that organic matter percentage to some degree, if need be. As acknowledged, with native soils, it is not likely that we will raise that percentage any great amount. The enhancement of the organic matter percentage improves the function of the microbial community, but increase is limited to what we can do with a sustainable approach. At some point we become content with the percentage that we have and learn to best manage the soil and the biomass to produce the best turf system that we can.

We now look at soil as being an interactive part of building this system. Our management strategies that deal with the growth of the turfgrass ultimately will affect the microbes. For example, a healthy vigorously growing stand of grass will produce carbohydrate exudates that will be introduced to the soil environment by way of the root system and ultimately become a food source for the microbial community.

The existence and survival of a healthy microbial community depends on an aerobic soil of good texture, chemistry, and fertility. This is the reason that we focus on all three components of our soils and work to establish desired ranges. Soil texture will not be altered with inputs from us. It is what it is in each individual region of the country and we learn how to work with it and adapt those soils to best grow our system. We do have the ability to influence soil chemistry and the biomass. It is in these two areas where we focus our attention.

It is the ability of the microbes to make the conversion from natural, organic sources of nitrogen to inorganic nitrogen that allows the natural process of fertility to work. The organic nitrogen from natural fertilization or from the decomposition of organic matter in the soil is converted to inorganic ammonium nitrogen (NH_4^+) by bacteria in the process of mineralization. It is also converted to nitrate nitrogen (NO_3^-) during the process of nitrification. As higher-level predators consume the bacteria, the nitrogen is then released in plant available forms. Higher-level successional plants, like high production turfgrasses, prefer equal amounts of nitrate and ammonium. This concept will be further clarified in the section on fertility.

Nitrate nitrogen has a negative electrical charge and is therefore soluble. It relatively quickly moves to the root zone of the grass plants after it has been released from the bodies of the predator organisms. Ammonium nitrogen, on the other hand, has a positive charge and is therefore held on the cation exchange sites and is referred to as reserve nitrogen.

When we design a fertility program that is based on natural, organic fertilizer inputs, we also include materials that support and maintain a healthy soil and microbial community. We have a wide range of inputs from which to choose, depending upon our transitional program that we have put in place.

The soil bioassay tests outline for us the living portion of the soil. By determining the organisms that are in the soil, both active and dormant, we begin to understand what we have working for us, and what we can expect in the way of nutrient availability through the biomass. These tests also guide us in our recommendations for inputs to stimulate or improve the biological function of the soil.

Section 10
Transition Period

When turf management programs change, there is a period of time we refer to as the transition period. When we move from a conventional, chemical-intensive program to a natural one, the length of time involved in transition is directly related to the intensity of current and past management practices and the overall turf quality.

During transition, it is important to address the soil and the biomass, as well as the cultural practices that support it and the turf itself. The biggest issue is moving the management of fertility from the conventional program to a natural one. After many years of conventional fertility management that has used synthetic, water-soluble fertilizers with high salt levels, the soil microbiology has been bypassed and possibly compromised. We strive to support and restore the soil to good health during this transition period so that the natural processes of fertility will take over and produce healthy turf. During this transition, we do not expect to see a collapse or failure of the turfgrass system. As long as the transition process addresses the whole system, including the soil biomass, natural product, and cultural practices, we expect to see steady improvement.

Any inputs to the system should remain constant for two or three years, until we feel comfortable that we are beginning to see the establishment of a healthy, organic system. Once we begin to approach some level of sustainability, we then can revisit the product input and determine exactly where we need to be to maintain the functionality of this system.

It is important during transition that we establish a sound management plan that enables us to successfully move forward. The reality in the municipal sector is that there is not always budget money available in the amount desired or needed to implement some turf management programs. In this approach, it is important to address the 4P's – protocol, procedure, product, and prioritization. The concept of prioritization enables us to create levels of management and then to allocate often scarce financial resources to those areas of properties where the greatest impact will be made. This is critical, especially during the transition, when we need to be the most aggressive with input and cultural practices.

Section 11
Fertility and Turfgrass Nutrition, An Organic Perspective

When we address fertility issues, it is important to look at the needs of the grass itself. Of the three major nutrients used by turfgrass, nitrogen is used in the largest amount. It is followed by potassium and then phosphorus. There are other nutrients, of course, but our primary focus is with these three. When we set nutrient budgets, we are basing them on nitrogen to be delivered in one form or another to the turfgrass system. Our nutrient analysis soil tests point out any deficiencies in the other macro nutrients or micronutrients. We then take the opportunity during the initial years of transition to balance soil chemistry with the appropriate amendments.

When a turf area is used, as opposed to just "viewed," the turf is generally under some stress. Grass plants get damaged and often cannot reproduce at a rapid enough rate to maintain maximum turf density. The recuperative capacity of the grass plant is governed by the genetic capabilities of individual species as well as nutrient availability.

We need more available nutrient, specifically nitrogen, to sustain this type of turf system, as opposed to what we might need for a homeowner's lawn. It is available nitrogen that directly stimulates growth. That is not to say that we need excessive amounts of nitrogen, but rather nitrogen delivered in an appropriate form and in a manner that will allow the capabilities of the grasses to do what we need them to do. We now begin to think in terms of the concept "less is more." Introduction of nitrogen to a turfgrass system in an organic program can be done at rates as low as .1 lb of actual nitrogen.

We establish nutrient budgets based on nitrogen for individual turf systems. The nutrient budget has a direct relationship to the expectations that we have for that grass. If our expectations are on the lower side, then we can satisfy that system with a lower total annual nitrogen input. If we have high use or high profile playing fields, our expectations are high, and therefore the nutrient budget needs to be set at a higher level so that the system can reproduce and maintain itself under high stress.

One of the basic differences between a natural program and a conventional one is that we do not expect to get all of the nitrogen from natural, organic, granular fertilizer product alone. Nitrogen from that product is certainly important, but it is only a part of a balanced approach. We acknowledge contributory nitrogen from compost topdressing, liquid fertilizers, compost tea, humic substances, and clippings returned to the system. Some of these products contain actual nitrogen, while others contain stimulants to the soil system to the point that nitrogen availability is increased through the biomass. When we use product to initially improve soil health, we are building a system that will make nitrogen readily available naturally to the grass plant in the future. It is this concept that allows us to have a healthy turf at a lower cost three or four years down the road.

In a conventional, chemical-intensive program, when primarily water-soluble nitrogen is delivered at the customary rate of one pound of nitrogen to 1000 $ft.^2$, much of that material might not make a beneficial impact on the grass, depending on several factors. This type of fertility product works in such a way that it is readily available upon contact with moisture. The nitrogen begins to become available within 48 hours of application. Maximum nitrogen release occurs in the 7 to 10 day range. By the end of a 4 to 5 week period, the nitrogen is no longer available. Either the grass used the nitrogen or it has moved through the soil profile. There is little or no residual.

This type of fertility can potentially pose negative issues for bodies of water in close proximity to the grass area or to groundwater. Depending upon a variety of factors, much of this nitrogen can have the ability to move below the root zone and potentially become a problem. University research has produced trials that indicate that almost all of the nitrogen applied in this manner is used by the grass and poses no adverse threat. It is important to remember that in this work we are generally looking at a relatively perfect turf system that exhibits maximum turf density with little or no voids in the surface area. The fact is that in the real world those perfect conditions do not always exist and a turf system with less than maximum turf density will not process all of the nitrogen in the same way that the research plots did. This is especially true when we have regular irrigation or heavy rains after an application. Because all the nitrogen from this conventional material may not be used by the grass plant, we can have problems. There are different ways that the nitrogen can leave this system, including leaching below the root zone, runoff, and volatilization. As this material leaches, it can become a groundwater contaminant as well as runoff into fresh or salt water bodies. In many regions of the country, there are restrictions being placed on this type of fertility for the reasons mentioned above.

Natural, organic fertilizers can be either granular or liquid. Granular fertility product is generally a source of nitrogen that is water insoluble. The liquid fertilizers can be water-soluble, but not in the same sense as synthetic fertilizers. The nitrogen is from protein. Nitrogen is a building block of proteins and amino acids. Along with nitrogen, these fertilizers can deliver enzymes, amino acids, and proteins to the grass plant. With organic fertilizers, the nitrogen reaches its target goal, the grass plant. They are not soluble in the same way as their synthetic counterparts because moisture has very little to do with the actual release of nitrogen to the plant. It is the natural process of mineralization that makes nitrogen available.

The difference between natural, organic fertilizers and conventional or synthetic fertilizers is simple. Synthetic fertilizer is inorganic. It is manufactured with a chemical process that produces a highly water soluble fertilizer. Anhydrous ammonia is reacted under great pressure and high temperatures. Urea is formed. It takes five ton of petroleum to produce one ton of urea. It breaks down on contact with soil moisture and is taken up by the grass plant very rapidly. This is why you see a quick green up or burst of growth with these products. There is a way to coat or encapsulate the fertilizer to delay the breakdown. Urea can also be secondarily reacted with formaldehyde to produce a urea formaldehyde or methylene urea product. This material is synthetic slow release and needs microbial action to break it down. Generally speaking, with urea, it is taken up rapidly, works quickly, and then leaves the root zone. This process is directly feeding the grass plant. Most synthetic fertilizer programs call for numerous applications annually.

Natural, organic fertilizer products work in a completely different way. Nature has put in place a system that makes nutrients available to the grass plant. A good example of this is a mature forest. No one fertilizes a forest, yet plant material grows and is healthy and adequately nourished. Other plant material functions in basically the same way, but because in a turfgrass area it is a closed system, we add fertilizer or other nutrients to meet the needs of the grass in the same way that the fallen leaves meet the needs of the tree. Grass, as a horticultural crop, needs more nitrogen than nature can provide if we are seeking to achieve higher expectations. Grass can obtain nutrients it needs from soil organic matter, the biomass, and minerals in the soil, but not enough nitrogen can be made available initially to produce a high quality turf system much of the time. If our expectations are on the lower side, then we can be satisfied with nitrogen made available by nature only. Given that we are managing sports fields and public parks with a high set of expectations, it is necessary for us to provide supplemental nitrogen to drive this process.

The nitrogen in natural, organic fertilizer is in the organic form. It is important to remember that plants cannot use organic forms of nitrogen. They can only use it in the inorganic form. The two inorganic forms of nitrogen that are plant available within the soil are ammonium and nitrate. Water-soluble synthetics work rapidly because laboratory derived nitrogen, in a synthetic form, is designed to mimic what the plant can actually use. Natural fertilizers supply organic nitrogen to the microbes as a food source, and then the bacteria break it down and, in turn, release it to the plant in the inorganic form. It is in the process of mineralization where that organic nitrogen is converted to ammonium nitrogen. It can be found in soil solution as well as held on to on the cation exchange sites. Other bacteria in the soil then further convert the ammonium to nitrate. The nitrate is soluble, not attracted to exchange sites, and immediately in the soil solution. Nitrogen fixing bacteria further convert ammonium from the exchange sites to nitrate to meet the needs of the plant. Successional grasses, including turfgrass, prefer nitrogen in equal parts, nitrate and ammonium.

It is the microbial life in the soil that makes nutrients available to the grass plants in a natural program. If we think back to a basic biology course, we learned that a handful of soil contains billions of mostly beneficial living organisms that nature put in place for the sole purpose of growing plants. It is these organisms that, in fact, make the nutrients available. This is the foundation for our "feed-the-soil" approach, as outlined in the biomass section.

Nutrients in organic fertilizers can be derived from plant, animal, or mineral sources. Nitrogen is derived from plants (grains like corn, soy, alfalfa) or animal byproducts (manure, feathers, bones, blood). It is important to note that the nutrients, specifically nitrogen, that make up fertilizer products, either synthetic or natural, are not plant food.

These materials are simply catalysts in the process of photosynthesis. When nitrogen is introduced to a turfgrass system, the plant responds in multiple ways. One of the responses is a greening of the plant. This greening is the intensification of chlorophyll in the blades. As the grass gets greener, chlorophyll is increasing in density. During the process of photosynthesis, chlorophyll reacts with energy from the sun in the presence of carbon dioxide and moisture.

There are microscopic openings on the underside of the leaf blades called stomates. These stomates open and close at the times of the day when the air is generally the calmest; dawn and dusk. Carbon dioxide, in the presence of moisture, enters the grass plant through these openings and a reaction takes place between the carbon dioxide, the sun's energy, and the chlorophyll. The end result is the production of carbohydrates, amino acids, and sugars, among others. It is these carbohydrates and sugars that are plant food. These materials provide energy for the plant to grow and reproduce. Respiration is the opposite of photosynthesis, or the function that releases this stored energy that facilitates the actual growth of the plant. Our job as turf managers is to maximize the growing conditions of the grass plant that will enable it to photosynthesize at its maximum rate. As photosynthesis improves, more carbohydrate is produced for the plant.

The grass plant uses these carbohydrates for its immediate growth, stores a portion of the carbohydrates in the crown for future growth, and then the balance of the carbohydrates are exuded through the root system into the rhizosphere. These exudates provide nourishment for microbes that colonize and live in this region and help support the turfgrass plant in the soil.

Fertilizer Summary

- Synthetic and natural fertilizers work in completely different ways, but can produce similar results.
- Synthetic can be harsh to the biomass and can be counterproductive to building a healthy microbial soil population.
- Because synthetics work rapidly and organics work more slowly, we must set our expectations appropriately.
- We do have organic liquids that will produce more results in the short-term and sustain it for the long-term.
- The timing of the applications becomes critical.
- With a granular urea, we get reaction in 48 hours and then it is done in a month or so.
- With a granular organic, that reaction will take 10 or 12 days and it lasts for 8 to 10 weeks.
- The organic liquid will give us the results in about four or five days and then sustain it for several weeks.
- Because the liquids are in a soluble form, the organic nitrogen is more rapidly processed by the biomass.

With so many different fertilizers and formulations on the market, it can be confusing to determine the difference between the products. As a rule, we can get an idea about the type of fertilizer in the bag from the percentage of nitrogen in the product. The three numbers on the bag represents nitrogen, phosphorus, and potassium, in that order. These numbers are referred to as the analysis. It is stated as a percentage of each nutrient in 100 pounds of fertilizer. There is generally a relationship between the numbers. This is referred to as the ratio.

The reason that nitrogen is our benchmark is because nitrogen is used in the largest amount by the turfgrass. If the nitrogen number is less than 10, the product is most likely a natural, organic product. If the number is between 11 and 18, it can be a bridge product. Bridge products are those that contain both synthetic and natural sources of nitrogen. Bridge products often contain biosolids (sewerage sludge) because it is a relatively inexpensive source of nitrogen. One must be aware that there are potential problems with this material. When the nitrogen percentage is greater than 18 to 20 (there are synthetics in the 13-16 range), the product is probably synthetic. There are certainly exceptions to these guidelines. We now have an organic fertilizer that is a powder reconstituted with water, which has a nitrogen analysis of 16%. This is new technology that has broken the protein bond and allows the organic nitrogen to be more readily mineralized.

Section 12
Cultural Practices

Irrigation

- Field capacity is a measure of the amount of moisture that any soil can hold.
- As previously discussed, the generally accepted composition of the soil is
  45% mineral content,
  5% organic matter content on average,
  5% air and 25% moisture.
- A handful of healthy, aerobic soil contains 50% solid matter and 50% air.
- One half of the airspace is generally occupied by soil moisture.
- This airspace is referred to as pore space.

Every soil particle, from the microscopic sheets of clay to the largest grains of sand, should be surrounded on all sides by pockets of air. This is a function of good soil aggregation as well as our management practices. Not only does the pore space create a loose friable soil environment that allows for good root growth and penetration, it also contributes to the creation of an aerobic soil profile. An aerobic environment is one that contains oxygen. Oxygen is critically important to the growth of the turfgrass as well as to the survival and proliferation of the microbial community. If a soil becomes over-watered or waterlogged, or extremely compacted, the manager begins to have problems. Airspace is lost, oxygen decreases, and the biomass and turfgrass plants begin to suffer. If either waterlogged soils or compacted soils persist for any amount of time, the grass plant can decline to the point from which it is difficult to recover.

Field capacity is determined in the following way. We will make the assumption that a dry soil is 50% airspace. After an irrigation or heavy rain event, all of the pore space fills with water. Over a period of time, which is a reflection of an individual soil's permeability, bulk density, and infiltration rate, the water drains from the soil and the root zone. When freestanding water is gone, what remains is a combination of air and moisture. With a soil textural classification of a loam, field capacity is generally at 25%. This means we have one-half of the pore space occupied by water. As clay percentages in the soil increase, field capacity increases. As clay percentages decrease and sand increases, field capacity decreases. This is one of the reasons that we have performed the soil textural analysis. Those individual percentages of sand, silt, and clay can guide us to a better understanding of the potential of any individual soil to hold moisture.

- The best way to irrigate turfgrass is to provide enough water so that moisture penetrates and does not remain near the surface.
- Deep thorough irrigations are far more preferable than shallow irrigations.
- Irrigation schedules are generally changed at different times of the season.

- During the spring and fall, we generally need less moisture than we do during the middle of the summer.
- During hot summer months, frequency can be increased so that the system remains moist and as cool as possible on hot days.

There is also an irrigation method referred to as syringing. This is a process where short duration, shallow irrigation is provided during the high heat times on a summer day for the purpose of cooling the top two inches of soil and keeping some moisture readily available. This practice is generally reserved for extreme conditions during the summer when we are trying to maintain steady growth on an athletic field. We are not trying to keep the system overly stimulated with moisture, but rather to keep it actively growing.

Cultivation

In turfgrass management, the cultural practice of cultivation is referred to as aerification or aeration. In many cases, this can be a practice that takes a backseat to the product side inputs in a conventional program.

The absence of aggressive aeration may, in some cases, try to be offset by increased synthetic product use. Weeds that emerge as a result of compacted soils can be mitigated with the use of herbicides, and fast acting soluble fertilizers can provide a short-term stimulus to the grass plant. Neither the fertilizer application nor the herbicide treatment will have any lasting effect as long as the soil remains compacted. It is this shortcut in turfgrass management that ultimately can cause bigger problems.

Compaction is the biggest enemy of turfgrass. As mentioned previously, all soil particles, both mineral and organic, should be surrounded on all sides by airspace. This pore space is critical in order to keep the soil environment aerobic and to provide a loose, friable medium for the root system of the grass plant to penetrate. Compaction is the result of continued or prolonged downward pressure on the surface of the soil. This can be the result of athletic play, heavy pedestrian pressure, heavy rain, regular irrigation, or mowing and other turf management equipment. As a result of this pressure, particle touches particle as pore space becomes eliminated. With the loss of pore space, we no longer have a situation where each particle has air around it and the soil becomes dense and anaerobic.

There are multiple pieces of equipment with which to aerate. For soils that have high percentages of clay and silt should not be aerated with solid time equipment. This practice produces an extremely compacted layer below the depth that the tine penetrates.

- Compaction favors weeds and discourages the growth of healthy grass.
- Turfgrass roots, as well as soil microbiology, are entirely dependent upon an aerobic soil environment.
- Aerobic soils are those soils with a reasonable amount of oxygen available.

- When soils become overly compacted, gas exchange with the atmosphere is severely reduced.
- Carbon dioxide cannot leave the soil environment and oxygen cannot penetrate the surface of the soil.

Based on regional considerations, weeds that might be considered indicator weeds of compaction vary. Some weeds possess genetics and root systems that allow them to adapt and thrive in compacted soils. Generally speaking, the root systems are short, thick, and/or clubby. They only need to penetrate an inch or two (generally less than 3 inches) into the soil. They do not need to have the same aerobic soil environment that grass plants do. They survive very well in anaerobic conditions. There are also weeds that have an extremely aggressive root system that can physically push their way through clays and finer textured soil particles that have become compacted. Grass plants, on the other hand, possess very different genetics. They have long, fibrous root systems that should penetrate deep into the soil. They will not survive for any length of time in compacted, anaerobic soil conditions.

The textural analysis that we performed as part of our diagnosis gives us some insight into the tendency of the soil to become compacted. Bulk density is a term used as an indicator of soil compaction.

- It is calculated as the dry weight of the soil divided by its volume.
- This volume includes the volume of soil particles and the volume of pores among the soil particles.
- Bulk density is typically expressed as grams per cubic centimeters.
- Bulk density is dependent on soil texture and the densities of the mineral portion of the soil (sands, silt, and clay) and organic matter particles, as well as their packing arrangement.

Generally speaking, a medium textured soil with roughly 50% pore space should have a bulk density of about one half of the density of rock. Loose, porous soils and those that are high in organic matter content have lower bulk density.

Sandy soils have relatively high bulk density because total pore space in sands is less than that of silt or clay soils.

The finer textured soils, such as silt and clay loams, that have good structure have higher pore space and lower bulk density compared to sandy soils.

As aggregation and organic matter content decrease, bulk density will increase.

Any practice that improves soil structure decreases bulk density.

The result can be either permanent or temporary.

With an athletic field, we need to understand that aeration is temporary and needs to be done on a regular basis.

Section 13
Non-fertilizer Inputs

Conventional vs. Organic from a Regulatory Perspective
Conventional materials used in turfgrass management may or may not be approved or tested by a regulating body. Pesticides, the umbrella term for those control products used in turfgrass management, are regulated by the U.S. Environmental Protection Agency (EPA). EPA registers active ingredients as opposed to products, or formulations. Any testing that is done on pesticide active ingredients as part of the process that brings them to market is done by the chemical manufacturer or laboratories it contracts, in compliance with EPA testing protocol. EPA is not involved in the actual testing process. EPA evaluates the manufacturer's data within the framework of risk assessment.

The basic premise is that pesticides are poisons and have some degree of harm or danger associated with them. Risk assessment is the framework within which these pesticides are classified and characterized. Risk assessment looks at levels of exposure and acceptable hazard, as defined by EPA. Except for public health uses, the benefit, which can be economic or aesthetic, is determined by the market or you, the user of the pesticide. The risk is the exposure to the human population or the environment.

Pesticides, under the model of risk assessment, are looked at for both acute oral or dermal toxicity. This is a basis that looks at the negative effects that increasingly higher doses of these materials will have on laboratory animals, and then those values are extrapolated to the human population. There is no framework within risk assessment that looks at repeated low dose exposures at this time.

Current science and medical research strongly indicates that many of the products that EPA has found to be of minimal risk at high doses have now been found to be high risk at low doses, especially for children. Because a product carries an EPA registration number, there can be no assumption of safety across the board within the human population. In fact, it is a violation of federal pesticide law, the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA), for manufacturers to characterize their EPA registered pesticide as safe when used as directed.

Synthetic fertilizers are not subject to these same regulations. EPA does not register these products. There is no governing body that looks at and regulates synthetic fertilizers for their potential negative effects to human health or the environment. The information that we have for synthetic fertilizers comes from the manufacturer or from research at universities around the country. It is important to note that this research is funded by this fertilizer industry. This work is primarily devoted to the efficacy of these products.

Within the organic community, we have products and suppliers that produce material for organic programs. Many of these materials have a certification from OMRI (Organic Materials Review Institute). This certification means that these materials have been scrutinized to determine that they are natural or organic in origin with only a select, relatively small list of allowed synthetic materials, which are evaluated under the Organic Foods Production Act (OFPA) and placed on the National List of Allowed and Prohibited Substances by the U.S. Department of Agriculture (USDA).

OMRI was founded in 1997 as a material review organization (MRO). There are other MROs, including the Washington State Department of Agriculture. OMRI provides organic certifiers, growers, manufacturers, and suppliers an independent review of products intended for use in certified organic production, handling, and processing. OMRI is a 501(c)3 nonprofit organization. When companies apply, OMRI reviews their products against the National List and those in compliance with the law appear on the OMRI products list. OMRI also provides subscribers and certifiers guidance on the acceptability of various material inputs in general under the National Organic Program (NOP), an office at USDA. A company that produces or manufacturers an organic product pays a fee to have OMRI assess and analyze their product and certify it for use in organic food production. Although OMRI certification is not required for product use in land management, many choose to use OMRI-listed products whenever applicable or available.

There is certainly a large amount of legitimate organic product that is used in organic land management that has not yet received OMRI certification. OMRI certification is not necessarily a limitation to product use. As much as possible, product choice on this project will be OMRI approved material.

Any material inputs chosen to meet the needs of turfgrass fertility or the building of healthy soils will be carefully chosen with an overriding concern for public health and safety. As much is possible, all materials will be approved by OMRI or another MRO. OMRI certification is nationally recognized as the benchmark for organic materials. NOP accepts OMRI certification for inclusion of materials into certified organic agriculture. Again, it should be noted that there may be some products that have not gone through this product certification, but possess all of the qualities of certified material.

Compost

Compost and composting is a complex subject. It is far more than just creating a pile of organic matter and watching it turn into a soil like material. Composting is an exacting science when we want to produce a finished product of high quality. The discussion here is intended to give an overview of product and process, and in no way should be thought of as a totally comprehensive overview necessary to fully understand the subject.

Compost is the product of an aerobic process, whereby microorganisms break down and decompose various forms of organic matter. The organic matter is referred to as a feedstock or substrate, and this can be made up from a wide range of materials. The feedstock can be random materials or they can be chosen to meet a particular recipe. When composting is done by recipe, the starting point in choosing material inputs is generally to follow a 20:1 to 30:1 carbon to nitrogen ratio. The end result of the composting process should ideally give us a material that has a carbon to nitrogen ratio of 12:1 to 20:1.

Microorganisms use the feedstock material as a food source throughout the decomposition process. Composting is a four phased process –mesophyllic, thermophyllic, second mesophyllic, and maturity. During this process, heat rises and then declines. Different organisms populate the compost windrow at each of these four phases. They produce heat, carbon dioxide, water vapor, and humus as a result of their activity. Humus is the highly stable byproduct of the decomposition process. It can make up to 60% of a finished compost. The process also stabilizes nutrients and pH, giving us a finished material rich in nutrients and microbial life, a high percentage of humus and organic matter, and close to neutral pH. This becomes an ideal soil amendment and topdress material for established turfgrass.

Composting is done at the municipal level in many areas, as well as in the private sector. Composters are generally required in most states to conform to guidelines that deal with health issues, as in the case of E. coli bacteria. Neither EPA nor the U.S. Composting Council currently regulate compost, but they do have programs in place that suggest compost testing as part of the process. At the present time, there are no national standards that deal with compost quality. One must have a good understanding of the criteria that define compost quality and rely on one's own assessment. That assessment should include testing whenever possible. Information should be obtained from the supplier to support the quality of the compost. If no testing data can be provided by the supplier, we then take it upon ourselves to perform the necessary testing to determine the quality and safety of the material.

Compost quality can be determined by several criteria. The finished material should have no offensive odor, there should be no recognizable remnants of the original feedstocks, and it should be finished or mature. There should be no heat escaping from the pile when turned. An offensive odor would be one that has a strong smell of ammonia, turpentine, or bark mulch. Fully mature compost, ready to use, should look, smell, and feel like a high quality topsoil. It should be:

- Between 30% and 45% organic matter,
- pH of 7.0,
- Moisture content between 30% and 50%,
- Exhibit retained nutrients on a compost chemistry test,
- Have minimal ash content, and
- Secure a biological assay to determine maturity.

Immature compost would be considered to be a product of inferior quality. It can, in fact, be very detrimental to a turf system and can cause turf damage. Once the composting process has begun, it naturally wants to complete itself. Immature compost will pull nitrogen from the soil to try and complete the composting process. This nitrogen depletion in the soil will have an end result of causing a chlorosis, or yellowing, of the turf. As the nitrogen levels drop, chlorophyll production in the grass plant decreases, resulting in a plant that no longer has the resources necessary to undergo photosynthesis at a satisfactory level. As photosynthesis decreases, carbohydrate production drops off, and the turf weakens.

Application rates are generally in the range of one-half to three-quarters of a cubic yard to 1000 $ft.^2$ of turf area. Older texts talk about rates as high as 1 $yd.^3$ per 1000, but that is on the heavy side and generally not used at the current time. The depth of the topdressed material should be between 1/4 inch and 3/8 inch. If the depth approaches 1/2 inch, it is too heavy for an individual application.

Compost does have a nutrient analysis. It has definite fertility properties. Compost can be mistakenly thought of as being an organic matter supplement and an infusion of soil microorganisms only, but nutrients are definitely introduced into the system. An average nutrient analysis of compost is 1% to 1.5% nitrogen, .5% to 2% phosphorus, and 1% potassium. These nutrients vary in concentration depending upon the source of the feedstocks in the initial compost process. Manures tend to have higher levels than leaves or grass.

Compost as a topdress in a turf system does five things for us.

1. It helps to increase soil organic matter. When we are dealing with low organic matter percentages, topdressing is the preferred practice for addressing the deficiency. This practice in itself gives good results, but when we can combine topdressing with cultivation, the benefit is magnified as the compost is able to fall into the core holes and reach the root zone.

2. When a compost application is combined with overseeding, it enhances germination and establishment. Think of it as creating a seedbed to receive the grass seed, not unlike a seed starting mix one might use to grow a tray of tomato seedlings for transplant.

3. Compost by virtue of its neutral pH has the ability to help buffer the soil and counteract acidic soils without the use of lime.

4. As compost continues to decompose, we experience nutrient release and get good greening of the turf in much the same way we do with a fertilizer application. When compost is used as a topdress, it is important that we adjust fertilizer applications accordingly. We can get a substantial nitrogen and phosphorus influx to the system with a compost, particularly one that is manure-based. Up to 60% of the nutrients in compost can be readily available with the balance mineralized at a future time.

5. A compost application infuses a substantial amount of both active and passive biology. The bacteria are decomposers, mineralizers, and nitrifiers. There are particular fungal organisms in compost that will give the grass what is often referred to as acquired immune resistance. They are beneficial fungal organisms that have the ability to fight and suppress some fungal pathogens. Ultimately, disease issues in turf become much easier to deal with as the fungal community is improved.

Topdressing with sand, or a blend of primarily sand, will not give the same benefits as a high quality compost. The conventional industry uses sand-based materials, but natural programs are based on compost applications. Sand is used at times in our program for very specific purposes, but not as a general topdress. Many times we will create a material that is 50% compost and 50% sand and use it as a topdress. The introduction of the sand helps to loosen the compost and make it spread more easily. It also helps to break up heavy clay soils.

Topdressing with compost can be done at any time during the growing season. The most opportune times are mid-June, late August, and mid to late November at the end of the season. The two early applications can coincide with overseeding applications. We do not always dormant seed late in the season because success rates are generally not as high as seeding during the active growing season. After application, the material breaks down as and is assimilated into the turf within a matter of days. We do need a window of opportunity when the field is not being used. We would generally not topdress when the field is actively in play because the compost might be somewhat sloppy after a rain event or an irrigation.

Compost Tea

Compost tea is a relatively new concept. It should not be looked at as the silver bullet that makes organic programs work. Most of the testing of compost tea and its efficacy has been done in the private sector because there has been no funding at the university level at this point. The conventional industry that typically funds land-grant universities and their turf research has no interest in working with compost tea at this time. It is often criticized because of its variability from batch to batch and the unknowns that some think are associated with it. The fact is that it is a scientific process. The end result is only as good as the compost that is used in the beginning of the process.

It is one tool among many that we have to improve the biological life in the soil. It should not be looked at as a material that supplies fertility, particularly nitrogen. It has been unfairly judged in that context. Typically when fertilizer materials are applied, the industry looks at how well the results can be seen in the short-term. Looking at compost tea within this framework is problematic. Instead, it must be understood as a tool to support and improve the soil biology, as a keep part of a sustainable, natural system. The following is a general description of the material and the process.

Compost tea is an application that directly addresses the introduction of large numbers of microbes to the soil environment. The benefits are many, especially during transition. At the present time, there are some contractors that can provide this service, but there are not many. We are working within the industry to begin to change that. The most cost-efficient approach to compost tea production is an in-house operation.

Compost tea is one of the inputs on the horizon that will change the way we deal with several of the management aspects of growing high-quality turfgrass in an organic program. This is applicable to backyards, parks, athletic fields, and commercial and institutional properties. It is already being used to some extent, but over the next few years will become one of the foundations of a complete natural program. We now use the application of a compost topdress to address the organic matter content of the soil as well as to introduce beneficial soil biology and a plant available nutrient source. The application of a topdress can be expensive, depending on the compost supplier and freight costs. When we have reached our target goal of organic matter percentage, the topdress applications can be reduced or eliminated and compost tea can take their place.

In a turf system, we generally do not see the rapid depletion of organic matter in the same way we might expect in other areas of agricultural production. Compost tea, although valuable from the beginning of a natural management program, has greater weight when compost applications are reduced or eliminated. We rely on the compost tea to supply the microorganisms and all of the benefits that come with them. Compost tea does not directly add organic matter to the soil in the way that compost does, but when our organic matter has reached its target level, we meet the needs with increased biology only.

Compost tea is a liquid extract of high-grade compost. More specifically, compost tea is a concentrated solution of microbial life produced by extracting beneficial microbes from either a vermi-compost (worm castings) or a windrowed compost. When we use a compost from outside our immediate geographic region, it is good practice to take a handful of local soil or compost to add indigenous organisms to the stock. The compost is placed in a finely woven mesh bag and that bag is suspended in a tank of water. The compost tea brewing machine consists of a tank, which can be anywhere from 25 gallons to 1000 gallons and an infused oxygen source. The air containing oxygen is moved through the water causing a gentle agitation. The exact mechanism for agitating the water can be a series of circulating pumps, air pumps and other proprietary technology developed by individual manufacturers. The process is such that this agitation of the water separates the microbes from the physical compost. The compost remains in the bag and the microbes are extracted into the water solution.

The newest technology involves equipment that has the ability to extract the microbes very quickly, usually within a two hour window. We could use the material at this point as an extraction. The same number of organisms that were in the compost are now in the water solution.

The secondary step in the process is actually brewing a compost tea. Once the organisms are extracted into the water solution, we can grow them over a 24 to 48 hour period into extremely large numbers. If that is our goal, we add food sources for these organisms to the water during the initial part of the process. We might add materials like kelp, seaweed, humates, fish hydrolysates, wheat and rice flowers, or straw. These inputs act as foods for the organisms and allow them to grow to very large numbers. There are some guidelines that we must follow. If we are using city water, it must be de-chlorinated. The temperature of the water should be in the 65° to 75° range. If water is too hot, it cannot hold enough dissolved oxygen to support the microbes. If the water is too cold, the microbes will not grow to any great numbers in a reasonable amount of time. The end product is a direct result of the quality of the compost that begins the process. It is critical that all of this is done in an aerobic environment. Oxygen is critical to sustaining the microbial population. The difference between this material, which is known as actively aerated compost tea (AACT), and some of the products that one can buy off the shelf is the diversity of the microbial population in the finished product.

Aside from simply delivering large quantities of active biology to the soil profile, compost tea does considerably more for us.

- It is a source of soil and foliar nutrients delivered in a biologically available form for both plant and microbial update.
- The beneficial microbiology can compete with disease causing organisms and in most times outcompete them, thereby suppressing a pathogen or disease problem before it gets to a point when turf damage occurs.
- The microbes have the ability to degrade and breakdown toxic materials and pesticides.
- They produce essential plant growth hormones.
- They can fix nitrogen and mineralized plant available nutrients.
- As we introduce compost tea to a turf system, we begin to create a biologically active soil environment. As the soil continually becomes more alive, we see direct and lasting benefits to the turfgrass.
- When a healthy balanced soil environment, with the proper biology to sustain turfgrass is in place, we see benefits in the nutritional area, whereby the nutritional health and quality of the plant is improved, as well as the soil's ability to retain nitrogen and other nutrients like calcium, potassium, and phosphorus.
- It helps improves and create good soil structure that increases water infiltration, oxygen diffusion, and the water holding capacity of the soil.

As is evident, the benefits are many and, when the availability of compost tea becomes more prevalent, it will become one of the tools that can assist a natural turf manager at a relatively low cost. At a rate of roughly 1 gallon per 1000 $ft.^2$ or 50 gallons to the acre, it is a very economical way to take natural turf management to the next level.

When compost tea is applied, we generally add other materials to the spray tank immediately prior to application. Those additional materials can be supplemental minerals, such as, nitrogen, humic substances, kelp, seaweeds, and fish fertilizers. All of these materials will provide stimulus to both the soil environment and the grass plant.

Humates

Humates are metal (mineral) salts of humic or fulvic acids. Humus is a highly stable byproduct of organic matter decomposition. Humic acid is the most biologically active component of soil humus. The humus portion of the soil is relatively small. The organic matter percentage generally ranges from 3% to 8% with an optimum level in a turf system in the 5% to 6% range. Humus makes up 65% of the total organic matter component. Humus plays an important role as a component of soil fertility. Its impact is far greater proportionally than the percentage of the soil mass that it makes up. The molecules of humus are not rapidly degraded by microorganisms as many non-humus substances are. Humus is, in fact, slow to decompose, and when in combination with soil minerals can persist for several hundred years.

With the emergence of conventional, synthetic nitrogen, phosphorus, potassium fertilizers, we (and agriculture in general) have lost sight of the natural order of soil management. When it was discovered that the synthetics had the ability to rapidly stimulate plant growth, the turf industry was born and jumped on the bandwagon. The prolonged use of these products, in the absence of properly addressing soil health, can, and has, led to many problems in the area of soil quality.

Humic substances that would be considered to be "fertilizer grade" are obtained from carbon containing mineral deposits in many parts of the world. Here in the United States, there are several mines and deposits that contain good agricultural grade humic substances.

Naturally occurring humic substances from low-grade lignites and leonardites ("nature's soil conditioners") are superior fertilizer ingredients. A major source of humic substances for fertilizer use is from leonardites. Leonardite is defined as a highly oxidized, low-grade lignite that contains a relatively high concentration of fulvic acids. Humates, suitable for both granular and liquid applications, are readily available and can be purchased from a variety of sources. They can be purchased by themselves or as part of a proprietary blend of materials. The application of these products to a turf system is addressing soil health and quality at its most basic level. Some benefits of humic applications include:

- Builds healthy soil.
- Increases organic matter which helps to reduce nitrogen loss through leaching.
- Contains carbon as an energy source for microbes.
- Improves soil structure, aggregation, water infiltration, aeration, and water holding capacity.
- Increases nutrient availability to the grass plant.
- Facilitates mineral breakdown.
- Increases microbial activity.
- Helps with root growth and penetration and maintaining chlorophyll density.

Molasses

Molasses has long been known as a bacterial food. It is incorporated in compost teas and liquid fertilizer programs as a means of providing nutrition and stimulation to the bacterial biomass.

In cases where we have soils that exhibit high numbers of total bacteria, mostly dormant, the introduction of molasses to the system will wake up these organisms and move them into the active population. It is the active population that is doing the work for us. When we introduce active biology to the soil with an input, we incorporate molasses at the same time, so that those organisms have a food source when they are initially introduced to the soil environment.

Kelp

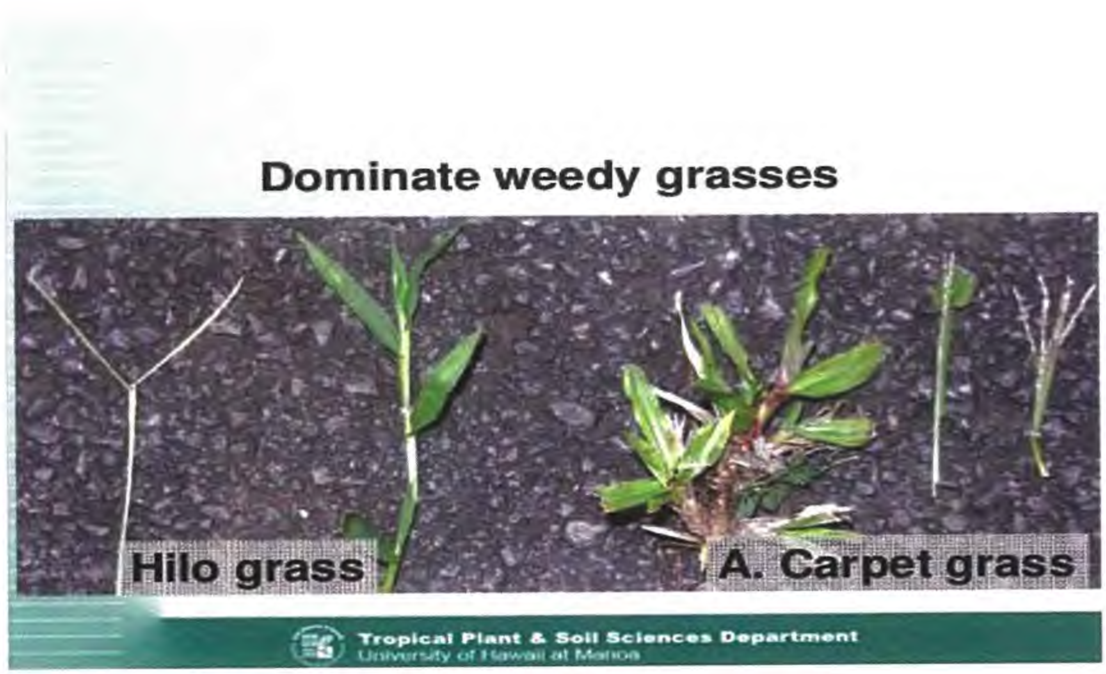
Kelp contains over 70 vitamins and minerals, chelating agents and amino acids. Perhaps more important, it is used as an organic fertilizer supplement for its cytokinins and auxins, both natural plant growth hormones. In sea plants, it is the naturally occurring carbohydrates, polysaccharides, organic acids, amino acids, growth hormones, and macro and micro nutrients that play key roles in boosting stress tolerance and survival. These same components contribute to the stress management and survival potential of plants treated with these extracts. Two of the primary benefits of these extracts are to enhance plant growth and improve stress tolerance. They can significantly increase stress tolerance and survival potential of plants under intense or seasonal stress.

Kelp extracts have been shown by independent research to improve plant health in physiological fitness, photosynthesis, chlorophyll content, plant anti-oxidant levels, cell wall strength, stress tolerance, resistance to disease, and drought tolerance. Kelp is most effectively used when combined with other inputs, including an organic nitrogen source.

Supplemental information

Grasses

Weeds



Goose grass

Carpet grass

Love grass

Crabgrass

Tifway 419 Bermuda

Combining toughness with beauty, Tifway 419 has been the most popular sports turf for the last 40 years. Its dense, rapidly spreading growth habit means quick recovery from injury, making it one of the most durable hybrid Bermudas. Tifway 419 tolerates close mowing and is highly disease resistant. For use on fairways, roughs, sports fields, and commercial and residential lawns.

Tifway is a hybrid bermudagrass cross of *Cynodon dactylon x C. transvaalensis germplasma*. It is characterized as having a dark green color with medium fine textured leaves. Tifway hybrid bermudagrass is dense with a medium to low growth habit. This variety is a vigorous grower and thus establishes quickly at planting.

The 2001 NTEP trial conducted in Griffin, GA showed that Tifway 419 was shown to have better quality ratings than Tifsport.

Characteristics
Temperature Range of Adaptation - Tifway grows best in warm climates within 45 degrees latitude to the equator. Temperatures in excess of 100 degrees F. (38 degrees C.) are readily tolerated by healthy Tifway. May become dormant after repeated winter frosts but recovers quickly when temperatures warm.

Water Quality Tolerance
On a suitably drained profile Tifway can tolerate soil concentration of 2500 ppm total salts. It is well adapted to "brown" water sources and is commonly used in municipal and food industry effluent land application systems.

Drought Tolerance
Tifway will survive droughts with minimal water availability. One to two inches (25 to 50 mm) of actual available water weekly to the plant will provide an acceptable turf surface. Tifway will survive at 1/2 inch (12 mm) irrigation per week, dependent on soil physics.

Traffic and Wear Tolerance
Tifway provides the best recuperative rates of all warm season turfgrasses. A vigorous regenerator.

Weed Tolerance
Tifway's dense growth, when properly maintained, efficiently competes with the presence of many turf weeds. Tifway easily tolerates broadcast application of selective herbicides.

Insect/Pest Tolerance
With the exception of certain leaf feeding insects, Tifway demonstrates tolerance or quick recovery from damage after pest control treatments.

Soil Fertility
Tifway grows best when soil pH is between 5.5 to 7.0. Soil levels of 100 pounds/acre (112 kg/hectare) of phosphorous and 150 to 200 pounds/acre to 224 kg/hectare) potassium will provide sufficient plant growth. Nitrogen applied at 1 pound/1000 sq. ft. per month will provide a healthy plant when combined with the recommended phosphorous and potassium.

Establishment
Tifway is a sterile (no viable seed) Triploid plant species and is successfully propagated as sprigs (rhizomes, stolons and Stems) or as sod.

Hybrid Bermuda grass

The following are fact sheets from CTAHR University of Hawaii at Manoa Cooperative Extension on turf management and fertilizers in Hawaii. Much of the information is relevant to this report. There are recommendations for synthetic product that are not contained in the protocol that we are presenting. These two papers were included to show broadly that our program fits with the science of Bermuda grass management.

Cooperative Extension Service
College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa

Turf Management
Dec. 2007
TM-6*

Managing Bermudagrass Athletic Fields

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Department of Tropical Plant and Soil Sciences

Bermudagrass (*Cynodon* species) is the most commonly used turfgrass on athletic fields in Hawai'i. This grass, which propagates via stolons and rhizomes, is an aggressively growing species that provides a dense, resilient athletic field playing surface. Bermudagrasses grow best in full-sun conditions at air temperatures between 80 and 95°F. Both common and hybrid bermudagrasses can be used on athletic fields in Hawai'i.

This publication outlines strategies for managing bermudagrass athletic fields in Hawai'i.

Common bermudagrass (*Cynodon dactylon*)

Improved common bermudagrass cultivars such as 'Yukon', 'Mirage', 'Pyramid', and 'Riveria' have become available in recent years. These can be established from seed and offer greater aesthetic and functional quality over older common bermudagrass cultivars. The cultivar of common bermudagrass best suited for use on athletic fields is 'Riveria', as it has been found to be highly tolerant of foot traffic.

Hybrid bermudagrass (*Cynodon dactylon* x *Cynodon transvaalensis*)

Hybrid bermudgrasses are interspecific crosses of common bermudagrass and African bermudagrass (Cynodon transvaalensis). These hybrids do not produce viable seed and must be established using sprigs, plugs, or sod. Various hybrid cultivars can be used on athletic fields, including 'Patriot', 'MS-Choice', 'GN-1', and 'Tifsport', but 'Tifway' (also known as 'Tifton 419') has become the industry standard. 'Tifway' is highly tolerant of athletic field traffic and possesses a high recuperative potential. 'Tifway' bermudagrass is commonly used in stadiums throughout the National Football League and Major League Baseball.

Mowing

Proper mowing promotes rooting, tiller density, and uniform growth. The best maintenance practice for bermudagrass athletic fields is to mow frequently at a low height of cut. This practice stimulates new growth and increases the density of the turfgrass stand. Mowing at heights lower than recommended encourages thin, weak turf that is less tolerant of athletic field foot traffic. Suggested heights of cut for both common and hybrid bermudagrass are listed in Table 1.

Mowing frequency is based on the general rule of removing no more than one third of the leaf blade at any one time. A greater percentage of leaf tissue is removed with infrequent mowing. This practice results in scalping, which reduces the traffic tolerance and recuperative potential of the field. When mowing frequently, it is not necessary to collect clippings; however, if mowing is delayed and clippings become excessive, they should be removed.

Reel-type mowers (Figure 1) provide the highest quality cut on athletic fields. Hybrid bermudagrasses require a reel mower, while rotary mowers can be used on common bermudagrass selections maintained at heights of cut greater than 1 inch.

*This revises *Maintaining bermudagrass athletic fields* by D. Hensley, J. Deputy, and J. Tavares, March, 1999.

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Table 1. Mowing heights for bermudagrass sports fields.

Grass	Maintenance level	Mowing height (inches)	Mow when grass reaches this height
Common bermudagrass ('Riviera,' 'Yukon,' 'Sundevil II,' etc.)	Low	1–1½	1½–2
	High	¾	1
Hybrid bermudagrasses ('Tifway', 'Tifway II', 'MS-Choice')	Low	½–¾	¾–1

Fertilizer applications

A proper fertilization program is required to provide good bermudagrass color, quality, traffic tolerance, and recuperative potential. A routine maintenance fertilizer for bermudagrass should have an N-P_2O_5-K_2O ratio of approximately 4:1:2 or 3:1:2. Nitrogen is the nutrient that has the largest effect on bermudagrass quality. Bermudagrass athletic fields require 1–1½ pounds of nitrogen per 1000 square feet, per growing month. It is important that soluble nitrogen sources (i.e., urea, ammonium nitrate, ammonium sulfate) are used to quickly provide the plant with nutrients needed to recuperate from traffic stress. However, do not apply more than 1 pound of soluble ("quick-release") nitrogen per 1000 square feet per application. Apply approximately ½ inch of irrigation following applications of soluble nitrogen fertilizers. This will reduce loses from volatilization and prevent "burning" of the bermudagrass foliage.

Slow-release nitrogen sources such as isobutylidene diurea, milorganite, and sulfur-coated urea can be used on bermudagrass athletic fields. These materials can be applied less often, and at higher rates, than soluble sources. While applying these materials can minimize the potential for foliar burn and promote more consistent bermudagrass growth throughout the entire season, nitrogen release rates in these fertilizers can vary with soil temperature, soil moisture, and microbial activity. To promote turf recovery, it is important that nitrogen be immediately available to the plant following traffic stress. A program incorporating both quick and slow-release fertilizers is recommended.

Each fertilizer application should deliver ½ pound of potash (K_2O) per 1000 square feet. Phosphorus (P) needs should be determined based on a soil test. The tests should be done every 2–4 years to assess nutrient status as well as pH.

1. Reel-type mower

Periodic applications of iron (Fe) can improve turf color without causing additional leaf growth. Granular and liquid sources of iron are commercially available.

Soil pH

The optimum soil pH for bermudagrass is between 6.0 and 7.0. The species can tolerate a pH range from 5.5 to 8.0. Most Hawai'i soils have pH within the acceptable range. Soil tests should be conducted every 2–4 years to assess soil pH and nutrient status. Should soil pH move out of the acceptable range, most soil testing laboratories will provide recommendations to correct the problem.

Irrigation

Irrigation is required to provide a strong bermudagrass turf tolerant of athletic field traffic. Actively growing

2. Underground, automatic irrigation system (photo: T.J. Smereka)

3. Aboveground irrigation gun used for athletic field irrigation

plants contain more than 75 percent water by weight. An underground, automatic sprinkler system is most often preferred when irrigating a frequently used bermudagrass athletic field (Figure 2); however, aboveground systems can be suitable in some situations.

Irrigation is needed to supplement rainfall. Actively growing bermudagrasses require (on average) 1–1½ inches of water per week. This amounts to 635–940 gallons of water per 1000 square feet each week, depending on the size of the field. Try to irrigate no more than twice a week, applying about ¾ inch of water each time. Do not irrigate daily with light amounts of water, because this encourages shallow rooting and increased pest problems. Try to moisten the soil to a 6-inch depth with each irrigation event. Watering during the early morning hours will limit the amount of time leaf tissue remains moist and reduce the amount of water lost due to evaporation. Coordinate irrigation with scheduled activities, applying water at least 24 hours before the field is to be used.

While underground, automatic irrigation systems are the best tool for irrigating bermudagrass athletic fields, certain professional-grade gun-sprinklers can be used in some cases (Figure 3). However, irrigation coverage uniformity is comprised with these systems, as applications are highly subject to wind distortion. Home lawn sprinklers, even traveling models, are not adequate for athletic fields.

4. Vertical mower blades (photo: J.A. Borgel)

Dethatching

Thatch is a layer of undecomposed organic matter intermingled with live plant stems at the soil surface. Periodic removal of thatch with a "vertical mower" (Figure 4) is necessary to properly maintain bermudagrass athletic fields. Visually examine thatch buildup by pulling cores from different areas of the field (Figure 5). Action is required if the layer of thatch is between ½ and ¾ inch thick. Vertical mower blades penetrate into the playing surface, removing thatch buildup at the soil-turfgrass interface. Blades should be spaced approximately 1 inch apart for bermudagrass. Mow in two directions at right angles (Figure 6). Debris (thatch) brought to the surface

5. Core pulled from an athletic field to examine thatch buildup

6. Bermudagrass athletic field after vertical mowing (photo, L. Yoder)

after vertical mowing can be raked, vacuumed, or blown off by hand or with one of the many commercially available units (Figure 7).

Note that the process of vertical mowing places a considerable stress on the existing turf canopy. To promote recovery, vertical mowing should be done in early spring and again in midsummer when conditions favor bermudagrass growth. Irrigate deeply after vertical mowing. Fertilize with 1 pound of ammonium sulfate per 1000 square feet no later than one week after vertical mowing to stimulate growth. Irrigate immediately after fertilizing. The rate of recovery time varies with climatic conditions and soil fertility levels. Note that vertical mowing can expose weed seeds, and application of a preemergence herbicide, such as oxadiazon (Ronstar® G), within a week of vertical mowing should be considered.

Soil compaction

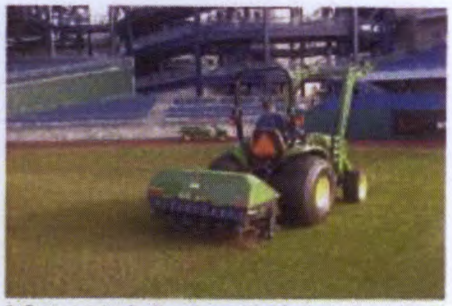
Soil compaction reduces athletic field playing quality. The development of compacted soil conditions on an athletic field is directly proportional to the amount of use the field receives. Compaction reduces pore space in the soil, which in turn reduces the amount of oxygen and water available for root growth. Consequently, turf vigor gradually declines and the field will not recover from the stress imposed by foot traffic. Voids (bare spots) in the turf canopy are also subject to weed invasion. Compaction is usually most severe on areas of the field where foot traffic is the most concentrated, such as between hash marks (football), in front of goals (soccer and football), and along sideline and bench areas (Figure 8).

7. Commercially available vacuum unit to collect debris after vertical mowing (photo, L. Yoder)

Core aeration, sometimes referred to as hollow-tine cultivation, is the practice of removing small soil cores from the root zone. This is one of the most important management practices for bermudagrass athletic fields. Core aeration relieves compaction, allows better penetration of oxygen into the soil, encourages deeper rooting, and increases water infiltration, and reduces thatch buildup.

Core aeration equipment uses special coring tines to remove soil cores from the field (Figure 9). These coring tines can be configured to remove cores ranging in size

8. Effects of soil compaction on areas receiving high foot traffic (photo: T.J. [illegible])



9. Core aerator (hollow tine cultivation) used on athletic fields (photo: L. [illegible])

from ¼ to 1 inch in diameter and 3–8 inches in length (Figure 9). To select the appropriate tine size and spacing configuration, determine the percentage of the field to be affected by the coring procedure. For example, aeration with ¾-inch tines more than doubles the percentage of the field impacted compared to a ½-inch tine. The effects of different tine size and spacing configurations are outlined in Table 2.

Intensively used fields should be core aerated three or four times a year, and fields for seasonal play should be aerated at least twice a year (after the last game, and in the spring). Core-aerate the field in at least two directions. On sand-based fields, allow the plugs to dry and collect them with a core harvester or commercially available vacuum unit such as the one pictured in Figure 7. Removing these cores, which contain both tillers and thatch, will prevent buildup of organic material in the sand profile. On soil-based fields, allow the plugs to dry and pulverize with a steel drag mat to reincorporate them into the holes created by the aerator. Often, sand topdressing is applied following coring on soil-based fields to improve physical properties and mineralize thatch. In these instances, let the cores dry and remove them from the playing surface with a core harvester or vacuum unit. Research has also found that application of compost following aerification on soil-based fields improves playing quality as well.

Core aeration should be done when soil moisture allows for the hollow coring tines to easily penetrate into the soil profile. However, coring in excessively moist soils can damage soil structure. If the hollow coring tines continually clog during operation, soil moisture is likely excessive.

Following aerification (and subsequent topdressing or reincorporation), irrigate and apply 1 pound of soluble ("quick-release") nitrogen fertilizer per 1000 square feet to encourage rapid recovery. If the entire field cannot be aerated, concentrate on the most heavily used areas.

Do not confuse core aeration with solid-tine aeration or spiking. The practices involve poking small holes in the uppermost layers of the soil surface to promote gas exchange and infiltration of water. Solid-tine aeration and spiking are not substitutes for core aeration. Many commercially distributed hollow-tine aerators can easily be reconfigured for solid-tine aeration. Also, many reel mowers have spiking attachments that are relatively easy to use (Figure 10).

10. Spiking attachment for a power-driven reel mower (photo: A.S. [illegible])

Gypsum is sometimes recommended to improve soil structure. Gypsum is effective only on soils high in sodium (Na) content; it has no effect on soils with low or normal sodium levels. When gypsum is used to solve a problem of excess sodium, it is most effective when tilled into the soil. Surface applications of gypsum have limited value.

Wetting agents in liquid or granular form are sold under a variety of trade names. Their main use is to improve water infiltration into the soil surface. They do

11. Topdressing with sand following aeration

12. Layering in an athletic field rootzone

not reduce soil compaction or increase pore space, but they may occasionally aid in alleviating localized dry spots.

Topdressing

Topdressing is the addition of a thin layer of material to the turf surface. In most instances, this material is sand. Topdressing with sand controls thatch, levels low spots, fills holes, and can be used following coring to improve soil physical properties (Figure 11). On sand-based fields, select a sand that is similar in size to that which predominates the rootzone mix in order to prevent layering (Figure 12). On soil-based fields, select a uniform coarse sand (80% of particles between 1.0 and 0.5 mm and 90% between 2.0 and 0.5 mm) to maximize the amount of large pore space in the rootzone. Following aerification, it is recommended that enough sand be applied to fill the holes created by the aerator and leave a thin layer on the soil surface. Table 2 lists volumes required to obtain specific levels of sand topdressing.

When topdressing as part of a general maintenance program (i.e., not after aeration), light, frequent topdressing applications to build up low areas are preferred over less frequent, heavier applications (> ¼ inch).

Composts can be applied as a topdressing as well. Research has found topdressing soil-based fields with ⅛ inch of compost following aeration to improve athletic field playing quality.

Pest management

Weeds

Weeds are commonly found on poorly managed athletic fields. Reductions in turfgrass density and vigor following foot traffic can open voids (bare spots) in the turfgrass canopy for weeds to germinate. Maximizing turfgrass density will reduce the susceptibility for weed invasion.

Weeds are classified either as grasses (e.g., goosegrass, crabgrass), broadleaves (e.g., spurge, pennywort), or sedges (e.g., purple nutsedge, kyllinga). Herbicides to control these weeds can be either preemergent (applied before weed seed germination) or postemergent (applied to growing weeds).

In Hawai'i, weeds are present year-round and are not as seasonal as on the U.S. mainland. Many turf managers in Hawai'i rely heavily on a program of postemergence weed control for bermudagrass athletic fields. Preemergence herbicides such as Ronstar® are used to prevent weed seed germination following aggressive vertical mowing or aeration, as these practices create voids for invasion in the turf canopy. Ronstar does not adversely affect bermudagrass rooting like other preemergence herbicides.

Coarse-textured (wide-bladed) grassy weeds commonly found on athletic fields in Hawai'i include crabgrass (*Digitaria* spp), goosegrass (*Eleusine indica*),

13. Purple nutsedge (*Cyperus rotundus*)

14. White kyllinga (*Kyllinga nemoralis*)

dallisgrass (*Paspalum dilatatum*), hilograss (*Paspalum conjugatum*), and St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze). While these weeds can be controlled in bermudagrass using postemergence herbicides containing methyl arsenate (MSMA, DSMA, and CMA), it should be noted that the Environmental Protection Agency preliminarily decided, in 2006, to deny these active ingredients re-registration. The official ruling on the fate of methyl arsenate herbicides has not been rendered, but it is likely that they will go off the market in the near future.

Alternative chemicals can be used to control certain weeds on bermudagrass athletic fields. For example, applications of Revolver® (foramsulfuron) provide postemergent control of goosegrass in bermudagrass turf. Including a nonionic surfactant in the spray mixture has been reported to improve the efficacy of Revolver applications; note that two applications of Revolver are needed to provide adequate control of goosegrass in bermudagrass turf in Hawai'i.

Purple nutsedge (*Cyperus rotundus*) (Figure 13), green and white kyllinga (*Kyllinga brevifolia*, *Kyllinga nemoralis*) (Figure 14), and sandbur (*Cenchrus longispinus* [Hack.] Fern) in bermudagrass may be controlled with Image® (imazaquin) alone or in combination with MSMA. A nonionic surfactant is required for Image applications. SedgeHammer® (halosulfuron) also provides good control of purple nutsedge. Other products such as Certainty® (sulfusulfuron) and Monument® (trifloxysulfuron-sodium) may be used to control sedges and kyllinga on bermudagrass athletic fields. Reapplications approximately every three months may be necessary. (See CTAHR publication L-9, *Nutgrass control in the lawn, landscape, and garden*.)

Broadleaf weeds can be controlled using herbicide products containing combinations of 2,4-D, MCPP, MCPA, or dicamba. These products are marketed under several trade names. Confront® (triclopyr + clopyralid) and a newer product, SpeedZone® Southern (carfentrazone, 2,4-D, MCPP, and dicamba) can be used to control broadleaf weeds, wide-bladed grasses, and sedges in bermudagrass as well.

Herbicides should be applied to actively growing bermudagrass that is not under heat or drought stress; otherwise, phytotoxic injury may be observed following application. To effectively control certain weed species, multiple herbicide applications may be required.

Insects and mites

Monitoring

It is important to accurately identify insects found on athletic fields. Insects harmful to bermudagrass are classified as root-feeding, shoot-feeding, or burrowing. Ex-

Table 2. Amount of sand required and area impacted for various coring and topdressing programs*

Core spacing (inches)	Holes per ft²	Tine diameter (inches)	Tine depth (inches)	Area removed by each pass (%)	Number of passes with aerifier to impact a given area of the field (% impacted)			Sand needed to fill holes and leave a layer on surface, tons per 1000 ft² per layer of:		
					50	25	10	1/8 inch	1/4 inch	1/2 inch
2	36	1/2	3	5.0	10	5	2	1.22	1.78	2.89
			8					1.76	2.87	4.00
		3/4	3	11	5	2	1	2.04	2.60	3.72
			8					4.51	5.08	6.19
3	16	1/2	3	2.2	22	11	5	0.85	1.41	2.53
			8					1.34	1.90	2.93
		3/4	3	5	10	5	2	1.22	1.78	2.89
			8					2.32	2.87	4.00
4	9	1/2	3	1.3	40	20	8	0.72	1.28	2.40
			8					0.99	1.55	2.68
		3/4	3	3	18	9	4	0.93	1.49	2.61
			8					1.55	2.10	3.22
6	4	1/2	3	0.5	90	45	18	0.63	1.19	2.31
			8					0.75	1.31	2.42
		3/4	3	1.3	40	20	8	0.72	1.28	2.40
			8					0.99	1.55	2.68
8	2 1/4	1/2	3	0.31	161	81	32	0.60	1.16	2.28
			8					0.68	1.22	2.35
		3/4	3	0.69	72	36	15	0.65	1.21	2.33
			8					0.81	1.36	2.48

*Assumes that sand weighs 1.45 ton per cubic yard and there is 100% efficiency on subsequent passes with the aerifier.
Table created by Dr. D. Minner, Iowa State University, http://turfgrass.hort.iastate.edu/extension/core.pdf

amples include sod webworms, armyworms, cutworms, and chinch bugs. Insect samples can be identified by the CTAHR Agricultural Diagnostic Service Center via your nearest CTAHR Cooperative Extension Service office.

To detect cutworms, sod webworms, southern chinch bugs, fiery skipper larvae, and billbug adults, use the pyrethrum test. Mix 1 tablespoon of a commercial garden insecticide containing 1–2% pyrethrins in 1 gallon of water. If the insecticide has only 0.5% pyrethrins, use 2 tablespoons. Using a sprinkling can, apply the solution as evenly as possible to 1 square yard of recently mown turf. The insects will be irritated and move to the surface within 10 minutes. Collect and count the number of insect larvae to assess the seriousness of the infestation. Sample several locations across the playing field. If the problem is localized, spot treatment may be suitable.

Treatments

Insecticide registrations and labels change often. Check with the nearest office of the CTAHR Cooperative Extension Service or your agri-chemical supplier for the latest recommendations.

Before applying an insecticide against foliar or thatch-dwelling pests, irrigate the turf well, and treat as soon as the foliage is dry. Apply the insecticide as specified on the product label, and apply enough to thoroughly wet the canopy down to the soil surface. In general, applications vary from about 2–25 gallons of spray per 1000 square feet for most pests except mites, which may require a greater volume because they hide within the folds of leaf blades. Do not irrigate following insecticide applications, unless or until it is necessary to prevent wilting. This allows the insecticide to remain on the plants for the longest possible time. Do not apply insecticides when temperatures exceed 90°F.

In general, liquid sprays work best for treating foliar turfgrass pests, but granular formulations are acceptable for controlling billbugs, cutworms, skipper larvae, and sod webworms. Granules are good for controlling pests residing in or below a thatch layer, because they move past leaf blades and partially penetrate the thatch layer.

Armyworms and sod webworms are the most serious problems on bermudagrass athletic fields in Hawai'i. Insect problems are encouraged by lush growth, mowing at irregular intervals, and allowing thatch build-up. Watch for browning areas and grass blades with a chewed appearance.

Rhodesgrass scale has been the most troublesome scale insect on bermudagrass in Hawai'i. It is usually found near the base of the plant. This spherical insect is up to 1/8 inch in diameter, has piercing-sucking mouthparts, and is covered with a white, cottony secretion. This white secretion is often visible on the turfgrass foliage in damaged areas. The adult scale lays eggs within its secreted covering. After hatching, the crawlers spread throughout the grass before settling down to feed. The life cycle is about 6–8 weeks. Infested grass turns yellow, and the turf thins and may be killed if the pest is not controlled (Figure 15). Applications of insecticides containing imidacloprid and bifenthrin have been observed to provide control in Hawai'i.

Bermudagrass mite is sometimes a serious pest. Its damage is most severe on common bermudagrass. These yellowish-white, somewhat worm-like mites are extremely small, only about 1/50 inch long. A microscope or strong hand-lens is needed to find them on infested grass. Mites multiply rapidly and require only about seven days to complete their life cycle. Because this pest is so small and hides beneath the leaf sheath, it is identified primarily by damage symptoms. Leaf blades turn light green and cut abnormally. The internodes shorten, the tissues swell, and the grass becomes tufted so that small clumps are noticeable. The turf loses vigor, thins, and may be killed. Injury is more pronounced during dry weather, especially when the grass is stressed due to poor maintenance.

15. Turf infested with rhodesgrass scale.

For more information on controlling insects in bermudagrass, see CTAHR publication IP-5, Destructive turf caterpillars in Hawaii.

Diseases

Plant diseases are rarely a problem on bermudagrass athletic fields in Hawai'i. If disease symptoms are suspected, contact the CTAHR Agricultural Diagnostic Service Center via your nearest CTAHR Cooperative Extension Service office.

Limiting playing field use

A well established and maintained turfgrass athletic field can withstand significant use without serious damage. However, no athletic field can withstand unlimited use. Over-use will result in damage that cannot be overcome by even the best maintenance program. For example, if a single field is subjected to football practice, soccer practice, band practice, official games, practices for other sports, intramural games, physical education classes, and other activities, the extensive foot traffic will render the task of maintaining quality turf impossible. Furthermore, use of fields during inclement weather can result in damage that requires substantial renovations. Coaches and administrators must take an active interest in scheduling activities to prevent over-use.

Ideally, two or more practice fields should be provided for each main game field. Practice fields should be marked according to official regulations, reducing the need to practice on the game field. Many athletic programs lack the resources to provide these additional practice areas. Priorities for use of the field must be established and adhered to. Activities during the off-season should be limited, especially during the summer and wet seasons.

Maintenance of skinned (non-grass) areas

Skinned (non-grass) areas are common on baseball and softball fields. These specialized areas require very specific maintenance. A CTAHR publication titled "Managing skinned areas on baseball and softball fields" will be released in 2008. Until then, refer to ASTM specification F-2107, *Standard Guide for Construction and Maintenance of Skinned Areas on Baseball and Softball Fields* for information on skinned surface maintenance.

Resources available to sports turf managers

CTAHR publications

Adaptation of turfgrasses in Hawaii. Turf Management, TM-4.

Bermudagrass. TM-5.

Nutgrass control in the lawn, landscape, and garden. Landscape, L-9

CTAHR publications can be obtained from the website www.ctahr.hawaii.edu/freepubs.

Magazines and websites

Trade magazines are an excellent way to learn about the latest technology in the field and to learn about products. Several magazines provide free subscriptions to qualified athletic field managers. Most are available online. Some examples are

SportsTurf. M2MEDIA360, Green Media, 760 Market St. #432, San Fransisco, CA 94102. www.greenmediaonline.com/verticalhome/sportsturf.asp

Athletic turf news. www.athleticturf.net/athleticturf

Sport Notes. http://buckeyeturf.osu.edu

Sports Turf Managers Association. www.stma.org

Professional associations for sports-turf managers

Sports Turf Managers Association, 805 New Hampshire, St. E, Lawrence, KS 66044, STMAinfo@stma.org

Books of potential interest

ASTM International. 2007. Annual book of ASTM standards. Vol. 15.07. End use products. Standard guide for maintaining warm season turfgrasses on athletic fields. ASTM F-2269. ASTM, West Conshohocken, PA.

McCarty, L.B, and G. Miller. 2002. Managing bermudagrass turf. Sleeping Bear Press, Chelsea, MI.

Puhalla, J., J. Krans, and M. Goatley. 1999. Sports fields: A manual for design, construction, and maintenance. Wiley & Sons, Inc. Hoboken, NJ.

Puhalla, J, J. Krans, and M. Goatley. 2003. Baseball and softball fields: Design, construction, renovation, and maintenance. Wiley & Sons, Inc. Hoboken, NJ.

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Turf Fertilizers for Hawaii's Landscapes

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Fertilizer requirements of the various turfgrasses common in Hawaii differ greatly. Hybrid bermudagrasses have the highest fertilizer requirements; zoysiagrasses, St. Augustinegrass, and seashore paspalum are intermediate; centipedegrass needs the least amount of fertilizer. Fertilizer requirements for any given turf also vary greatly depending upon its intended use, the desired level of appearance, soil conditions, the amount of rainfall or irrigation, and other environmental conditions. Poor fertilizer practices including excess or insufficient application and poor fertilizer distribution are responsible for many of the common problems associated with turfgrass maintenance.

In Hawaii, where the growing season is year-long, it is necessary to apply fertilizers throughout the year. Failure to follow a regular schedule, especially with the high-demand turfgrasses, will result in uneven appearance and may increase weed, insect, and disease problems.

An important factor in developing a fertilizer application schedule is a good knowledge of the type of turfgrass you are working with. Bermudagrass requires and responds to a monthly feeding of 1 pound of nitrogen (N) per 1000 square feet (sq ft, or ft^2). Applying the same amount to a centipedegrass turf would be a waste of time and money. The main objective of a good turf fertilizer program is to promote good color and vigor of the grass without producing excessive growth. Overfertilizing with N promotes lush growth, which can lead to a number of problems including rapid thatch buildup, higher susceptibility to disease and insect infestation, and higher water requirements. Overfertilized lawns are always the first to show wilting during dry periods in many species of turf, because excess N promotes top growth at the expense of the root system and can eventually lead to a deterioration of the root system. Of course, lush growth also means that the turf will require more frequent mowing. (See also the other CTAHR publications on specific turfgrasses and general lawn care listed at the end of this publication.)

The soil type is another important consideration in developing a fertilizer schedule. Many of Hawaii's soils are heavy clay soils. Clay soils have a high capacity for holding most plant nutrients (referred to as the soil's "exchange capacity"), and they do not require applications of fertilizer as frequently as sandy soils, which generally have low exchange capacity. Sandy soils are also much more susceptible to leaching of nutrients. Neither type of soil is able to hold soluble forms of nitrogen for very long. As a general rule, sandy soils require more frequent applications with lesser amounts of fertilizer at a time, and scheduling should be adjusted accordingly.

Before starting a turf fertilizer program, a soil test should be done to determine the existing fertility level and pH of the soil. The soil test will show the pH of the soil and the level of available phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). These major elements are essential to normal plant growth and should always be present in adequate amounts. Nitrogen (N) is usually not determined in a soil test because most soils are inherently low in nitrogen because it is readily leached through the soil profile. However, N is the most important nutrient for plant growth and therefore must be continually supplied in a turf fertilizer program.

The first step in beginning a fertilizer program is to correct deficiencies of any element identified in the soil test results. Soil testing is available from commercial laboratories or the CTAHR Agriculture Diagnostic Service Center at UH-Manoa (beyond Oahu, contact the nearest CTAHR Cooperative Extension Service office). Fertilizer recommendations are given as a part of the soil test report.

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Correction of soil pH

The pH is a measure of the acidity or alkalinity of the soil. Alkaline soils are sometimes referred to as being "sweet," while acid soils are called "sour." It is important to maintain the pH within fairly narrow limits, because the availability of many of the soil nutrients is dependent upon the pH level. Deficiencies in many of the soil nutrients are often due to the ions becoming insoluble and unavailable to the turf roots at high or low pH, even though these nutrients are present in sufficient amounts.

Agricultural lime or finely ground coral may be used to raise soil pH to the desired level. Potassium bicarbonate can be used if a rapid change is required. Till the material into the soil to a depth of 6 inches if possible. Add only the amount recommended to correct the acid condition. An overapplication of lime will result in alkaline conditions that are as detrimental as the acid condition. Do not apply more than 50 lb per 1000 ft^2 of ground coral at one time. If more than this is required, split the application into two spaced six months apart.

Acid-forming fertilizers, such as ammonium sulfate, used regularly are effective in lowering the pH of alkaline soils. Care should be taken not to over-use these fertilizers on soils that are already acidic (see Table 1). Elemental sulfur (95% wettable) may also be used, but care must be taken not to apply excessive amounts because of the danger of foliar burn. No more than 10 lb per 1000 ft^2 should be applied at one time. If multiple applications of sulfur are required, they should be spaced at least 60 days apart.

Table 1. Acidifying effect of common fertilizers.

Ammonium sulfate	110
Diammonium phosphate	75
Urea	71
Ammonium nitrate	62
Monoammonium phosphate	58
Potash	0
Superphosphate	0
Treble superphosphate	0
Potassium nitrate	–23

Acidifying effect measures a fertilizer's ability to raise or lower pH. These values refer to the number of pounds of calcium carbonate necessary to neutralize the acidity in 100 pounds of the fertilizer. The negative value for potassium nitrate indicates a "sweetening" or alkalinizing effect.

Once the turf is established, any lime or sulfur applied must be washed off of the leaves to reduce danger of foliar burn. Applications in this manner are not very effective in modifying soil pH beyond the soil surface. The best way to apply lime or sulfur to modify soil pH in the root zone of established turf is to use a plug-type aerator to make holes in the soil before applying the material. This will increase the zone of pH change to the depth of these holes, reaching a greater part of the root zone.

Correction of soil nutrient levels

Phosphorus (P) is very important for root development, especially in new seedlings. Therefore, a fertilizer high in P and balanced with nitrogen and potassium should be used when establishing a new turf. These types of fertilizers are called "starter" fertilizers. Phosphorus deficiency in new seedlings results in slow development, and in established turf P deficiency results in blades that appear dull and tend to turn purple.

Low P levels can be corrected by applications of treble superphosphate. P applied to many of Hawaii's acidic soils tends to be retained tightly and released only gradually to plants. The most effective application of P is during soil preparation, when it can be incorporated by tilling.

Potassium (K) contributes to the vitality and hardiness of the plant and is considered a key to the prevention of disease and environmental stress, including improved tolerance of wear from traffic. K deficiency appears on older leaves that become streaked with yellow, turn brown at the tips, and eventually die. The turf also becomes more susceptible to disease and decreases in wear tolerance.

Low K is corrected by addition of potash (K_2O in various forms), muriate of potash (KCl), or potassium sulfate (K_2SO_4). P and K may also be added in a "complete fertilizer" (one which contains N, P, and K) such as a 10-30-10 (10% N, 30% P_2O_5, 10% K_2O) formulation. The amount to apply depends on results of the soil test and the type of fertilizer used.

Magnesium (Mg) deficiency, which appears in older leaves as light green or yellow stripes that turn to bright red, may be corrected by application of magnesium sulfate or magnesium ammonium phosphate.

Calcium (Ca) is normally present in sufficient quantities in Hawaii's soils, and deficiencies are rare. This is also true of sulfur, where deficiencies are almost always associated with soils low in organic matter.

Nutrient elements that are needed by the plant in very small quantities are called minor elements or micronutrients. These include iron, copper, manganese, zinc, boron, molybdenum, and chlorine (Fe, Cu, Mn, Zn, B, Mo, and Cl). Iron and manganese are the only micronutrients that are commonly deficient in Hawaiian soils, and this is usually the result of improper pH. Deficiencies in either of these elements results in yellowed (chlorotic) leaves with green stripes, and they often are difficult to tell apart. Minor elements are often added to turf fertilizers, or they can be applied individually as a foliar spray.

Nitrogen sources

Nitrogen, the nutrient required in the greatest amount by turfgrass, promotes growth and density as well as the turf's deep green color. To a greater degree than the other elements, it is subject to loss through volatilization, microbial activity, and leaching. This necessitates greater amounts and more frequent additions of N to meet the turfgrass' needs. N is therefore the most abundant nutrient in most turf fertilizers, and fertilizer recommendations are normally given in terms of pounds of N required per 1000 ft^2. N may be supplied in immediately available, water-soluble form or as a slow-release formulation, or as a mixture of both. The fertilizer analysis is given as a percentage of nitrogen, phosphorus, and potassium in that order. Fertilizers that contain these three nutrients are known as complete fertilizers. Products that contain equal amounts of each are considered balanced, such as 15-15-15. A typical turf fertilizer is high in N and might have an analysis such as 33-3-10. It may also contain added nutrients such as iron or sulfur or certain insecticides or preemergence herbicides.

Professionals also refer to a fertilizer's "ratio." A fertilizer with an analysis of 12-4-8 has a ratio of 3-1-2, or three parts N, one part P_2O_5, and two parts K_2O. Fertilizer application recommendations may be given in terms of the analysis or the ratio.

Fertilizers for turf use include an ever-growing and widely varied selection of products. As a homeowner or turf manager, one can quickly become overwhelmed with information about the many different formulations, analyses, and grades of products available for purchase. However, among the many choices to consider, *formulation* (fluid or granular) is one of the more important factors to consider in deciding which is the right product for your needs.

Fluid fertilizers

Fluid fertilizers are formulated and packaged as a liquid. This includes fertilizers that are clear liquids (solutions) or liquids that contain suspended solids (suspension fertilizers). Turf managers normally use fertilizers packaged and sold as fluids less frequently than solids (granules). Examples of fluid fertilizers include anhydrous ammonia (which is actually transported as a fluid and injected into soil in gaseous form), nitrogen solutions (usually made from a mixture of urea and ammonium nitrate), ammonium polyphosphate, and triazones. These formulations are usually used only on golf courses and resorts.

A more common source for fluid fertilizer applications on turf is the use of solid water-soluble fertilizers dissolved in water and applied as a liquid to the turf (called "foliar feeding"). MiracleGrow® or any readily soluble salt is applied this way. Liquid application of fertilizer uses a high spray volume (3–6 gallons per 1000 ft^2) to move nutrients to the soil and is a common application method for many commercial lawn-care companies. Foliar feeding uses a lower spray volume to apply a small amount of fertilizer (for example, iron is commonly applied this way) directly to the foliage, providing rapid uptake of nutrients and quick correction of a nutrient deficiency. Typically, applicators use foliar feeding to supply a small amount of a deficient nutrient (usually a micronutrient such as iron), or as part of a pesticide application, rather than to supply all the needed fertilizer for turf growth.

Benefits from using fluid fertilizer or soluble solids as liquid fertilizers include the ability to apply nutrients through irrigation ("fertigation"), possible use as a carrier for selective postemergence or preemergence herbicides, and flexibility of application as a foliar feed. Liquid application can reduce the risk of foliar burn, provide even coverage, and allow simultaneous application of fertilizers and pesticides. Liquid fertilizers can be applied at low rates on a frequent basis to spoon-feed turf, promoting even greening and consistent growth.

Application of small amounts of fertilizer at regular intervals can also prevent overapplication, lessening the risk of nutrient pollution in the environment.

Negatives to the use of fluid fertilizers may include the cost of new or specialized application equipment and the issues of handling a heavy, bulky, liquid material. Plus, it can be difficult to apply higher rates of nutrients in a spray volume appropriate to avoid burning the turf, in which case frequent application becomes the key. However, the need for frequent application can be a problem, especially if labor is in short supply.

Solid fertilizers

Solid fertilizers are dry, inorganic mineral salts that manufacturers size between an upper and lower limit of screen sizes. They may be finely crushed, granular, crystalline, powder, or processed into uniform "prills." These fertilizers, by themselves, are usually water-soluble for quick release. Although easy to apply, care is necessary to ensure even distribution of inorganic granular fertilizers. The effects of an incorrectly calibrated spreader or incorrect application of solid fertilizers are all too visible.

Solid fertilizers can be coated to become controlled-release products, which are also called slow-release, slow-acting, metered-release, or controlled-availability fertilizers.

Soluble materials

Water-soluble fertilizers are rapidly available for turf growth. Examples of common water-soluble turf products include ammonium nitrate (34-0-0), potassium nitrate (13-0-44), ammonium sulfate (21-0-0), potassium sulfate (0-0-50), and urea (45-0-0). Some water-soluble fertilizers are homogeneous products (every particle has the same composition). These have a uniform appearance and are made from blends of raw fertilizer materials such as superphosphate, ammonium solutions, monoammonium phosphate (MAP), diammonium phosphate (DAP), urea, potassium chloride, or potassium sulfate (not all phosphate fertilizers are completely water-soluble). Fertilizer bags always list the raw materials the manufacturer used and the specific fertilizer grade contained in the bag.

Other solid fertilizers are non-homogeneous blends (you can see the individual granules of different fertilizer materials), where the manufacturer simply has mixed particles together to produce a desired overall composition. Non-homogeneous products may not spread as uniformly as homogeneous products, especially if the particles are different sizes. Some products are a mix of soluble and slow-release fertilizers; the bag should list the percentage of each in the product.

Water-soluble fertilizers produce rapid greening, have a low cost per unit of nutrient, are easy to apply, and are readily available from a wide range of dealers. The rapid greening from these fertilizers is due to readily available nitrogen, and perhaps sulfur or iron in the fertilizer as well. These products are usually easy to handle and do not take expensive equipment or intensive training to ensure correct application. Regular application of these products may also offer a business bonus—your clients see you at their site frequently.

A soluble N source provides a readily available supply of N to the turf. The growth rate increases sharply about two days after application, reaches a peak in seven to ten days after application, and, depending on the rate of application, tapers off to the original growth rate in four to six weeks. A uniform growth rate could be produced if very small amounts of soluble N are applied on a daily schedule. However, the only practical method of applying N on a daily schedule would require fertigation, applying fertilizer through the irrigation system. Fertigation may prove economical for high-maintenance golf courses and parks.

The "peaks and valleys" in growth rate observed between applications of soluble N fertilizers may not be obvious on frequently mowed turf areas, but they can have a detrimental effect on the grass. Short bursts of growth after fertilizer application followed by a period of slow growth can deplete carbohydrate reserves in the grass, reduce root development, and eventually thin a turf, leading to a higher susceptibility of the grass to insects and diseases. These effects are not readily apparent by observing growth rate and color response to fertilizer. Long-term observations and responses to stress will more accurately establish the effect of soluble N sources on turf.

At rates of application above ½ pound of N per 1000 ft^2, soluble sources may desiccate or burn the foliage if not watered into the turf shortly after application (see Table 2). A commercial lawn service cannot depend on the homeowner to water the lawn as needed and may find that lower rates with more frequent applications are best suited to their needs. Also, at rates above ½ pound of N per 1000 ft^2, soluble N fertilizers produce the burst of growth for a short period after application that is undesirable from the standpoint of mowing, watering, and other maintenance requirements.

In their favor, soluble N sources have the lowest cost per pound of N, produce an immediate greening response, are effective at the range of temperatures encountered in Hawaii, and are suited to either liquid or dry programs. Where N can be applied at ½ pound per 1000 ft^2 at monthly intervals, the soluble products are the choice of most applicators. However, the need for frequent applications may limit their use in most lawn-service operations.

Slow-release nitrogen sources

Synthetic fertilizers are relatively new products that overcome several of the shortcomings of the soluble N sources. Many of these synthetics have a much longer residual N release pattern and a greatly reduced burn potential. Also, these products do not produce the rapid burst of growth produced by soluble N fertilizers.

A low, uniform supply of available N and other essential minerals during the growing season is the objective of most turfgrass fertilizer programs. Such a program is difficult to accomplish without the use of slow-release sources of N. Residual soil N, that which becomes available to the grass over a relatively long period of time, cannot be built up and maintained with soluble materials alone. Slow-release N sources build up residual soil N that is made available to the grass at various rates. This results in slow, even growth and avoids the damaging growth spurts produced by soluble sources. The rate at which residual N is made available (released) may vary with the N source, temperature, moisture, pH, particle size, microbial activity, and time of application. A single heavy application of slow-release fertilizer is insufficient to provide an adequate level of reserve N to meet the needs of turf. Supplemental applications of water-soluble N sources will be necessary during the first six months to one year that the slow-release fertilizer is used. After this, quarterly applications of slow-release sources will provide adequate N to maintain the turf. More frequent applications may be necessary to maintain bermudagrass turf at high maintenance levels. Knowledge of a particular N source and of conditions favorable for N release, as well as the requirements of the particular turf, is necessary for a turf manager to determine the timing and rates of application of slow-release fertilizers.

Table 2. Salt index of common fertilizers.

Ammonium nitrate	105
Sodium nitrate	100
Urea	75
Potassium nitrate	74
Ammonium sulfate	69
Calcium nitrate	53
Ammonia	47
Diammonium phosphate	34
Monoammonium phosphate	30
Treble ammonium phosphate	10
Superphosphate	8
Gypsum	8

Salt index is a relative measure of the salinity of fertilizers. A high salt index indicates high potential to burn turf as well as increase salinity. Sodium nitrate is the benchmark, given a value of 100.

Urea-formaldehydes (UFs)

These are synthetic products made by reacting urea with formaldehyde under carefully controlled temperature, pH, and reaction time. They contain about 40 percent N in the form of long-chain urea molecules. The N release characteristics of the materials produced are determined by the size of the molecule and the ratio of urea to formaldehyde in the product. Methylene urea (MU) has a ratio of 1.9 to 1 and is ⅔ water-soluble and ⅓ water-insoluble. Other UF products such as Nitroform® and Fluf® have a ratio of urea to formaldehyde of 1.3 to 1 and are ⅓ water-soluble and ⅔ water-insoluble. The rate of N release of these products is closely related to the solubility of the UF. Methylene urea has a faster N release and greening response than Nitroform, but the "residual" N is much greater for Nitroform. One form of MU is methylol urea, which can be applied at 1–1½ pounds of N per 1000 ft^2 in a single application without burning the foliage. However, the residual nitrogen effect for this product is only slightly greater than soluble N fertilizers. A further disadvantage is that the product is tightly bound to the foliage, and clipping removal after application can remove significant amounts of N. Methylol urea is a liquid concentration with 25–30 percent N. It mixes readily with other fertilizer nutrients and pesticides and is well suited to liquid applications. The user should be advised not to remove the grass clippings for at least two mowings after application.

The removal of grass clippings is generally not recommended for at least several weeks after any fertilizer application. This is particularly important with many of the synthetic products that have a much longer residual release of N. Removal of clippings during this time can result in the loss of up to 50 percent of the N supplied.

Mowing, which is likely to destroy the integrity of the fertilizer particles, is also not advisable for at least several days after application, especially on turf that is cut lower than 1 inch. The long-term residual N release of most of these synthetic fertilizers depends on the size of the particle or the intactness of the coating. These types of fertilizers are best allowed to settle into the turf in order to protect the particles from physical damage caused by mowing. Watering them in often helps the particles to settle.

All of the N in UF is dependent on soil microorganisms to break down the methylene urea chains to urea before N can be released. But the short-chain (water-soluble) methylene urea polymers are broken down much faster than the long-chain (water-insoluble) polymers. The water-insoluble fraction of UF may not be completely broken down in the first year, and some carryover (residual) can be expected into the second and third seasons. Where normal rates of UF are applied, two or three years may be required to build up residual N to a level such that annual applications of UF release an adequate amount of N. To overcome this lag in N availability, higher initial rates of UF can be applied, or supplemental soluble N can be used. Higher rates and supplemental sources are commonly applied to Hawaii's turf to compensate for our longer growing season.

Because microorganisms are required to break down UF, environmental conditions that favor microbial activity (high temperatures, neutral soils, and an adequate supply of moisture and oxygen) promote N release from UF. Conversely, low temperatures, nutrient deficiencies, and acid soils inhibit the release of N from UF. Depending upon these environmental conditions and the amount applied, UF products may continue to release adequate levels of N for up to five or six months. The faster acting MU products have a residual period of about 18 weeks.

Losses of N due to leaching and volatilization are less from UF than from soluble N sources. Therefore, over a period of several years, UF sources are at least equal to soluble sources in terms of N use efficiency. In addition, UF sources are more efficient under conditions that favor leaching and volatilization.

Nitrogen losses due to removal of fertilizer granules with grass clippings can be significant on closely mowed turf. Losses may be as high as 20 percent on golf greens. For the first several days after application, the grass should be allowed to dry before mowing. Urea-formaldehyde has little effect on soil pH and salinity. Thus, even at high rates of application, UF does not bum the grass.

Isobutylidene diurea (IBDU)

This condensation product of urea and isobutyaldehyde is an N fertilizer with slow-release characteristics that contains a minimum of 30 percent total N. Unlike UF, IBDU does not depend on soil microorganisms for the release of N. In the presence of water, IBDU is hydrolyzed to urea. The rate of hydrolysis varies with soil pH, temperature, particle size, and moisture. IBDU is effective as a controlled-release N source for turfgrasses in soils with pH between 5 and 8. Below pH 5, the rate of hydrolysis is very rapid, and above pH 8 the rate of hydrolysis is quite slow. IBDU products are commonly used on commercial turf in Hawaii.

Temperature does not influence the release of N from IBDU to the degree that it does for UF and organic N sources. But, high temperatures favor the hydrolysis of IBDU and significantly increase N release. The rate of N release from IBDU is two to three times faster at 75°F than at 50°F, whereas for UF and organic sources the same temperature difference may result in a tenfold increase in N release rates. The particle size of IBDU granules has a significant influence on hydrolysis rate and N release. The finer the particle, the greater the surface area and the faster the rate of hydrolysis. By varying the size of the IBDU granules, N release can be distributed over a longer period of time. A material with a range of particle sizes between 8 and 24 mesh is recommended for turfgrasses. The effective release time is therefore shortened if the particles are broken up by mower activity. It is best to allow the particles to settle into the turf for as long as possible before mowing. Particle size does not influence the rate of N release from UF.

Soil moisture levels also influence the release of N from IBDU. Wet soil conditions favor the release of N from IBDU. Soil moisture levels of 40–70 percent of field capacity are favorable for a controlled-release rate of N from IBDU. Above these levels N release is very rapid, and below these levels N release is very slow. IBDU would not provide a uniform level of available N where turf is exposed to prolonged wet or dry cycles. N losses due to leaching and volatilization are quite low from IBDU. And efficiency, in terms of N recovery, is similar to other slow-release N sources. N losses due to mower pick-up of the IBDU granules are similar to those that occur with UF sources.

Unlike UF sources, IBDU does not require a build-up of residual N to provide adequate levels of available N. Unless particle sizes of IBDU granules are quite large, greater than 2 mm in diameter, most of the N is hydrolyzed within 60 days after application. However, where particles are much over 2 mm in diameter, mowers will pick up significant quantities of IBDU granules on closely mowed turf.

IBDU has little effect on soil pH, although a temporary increase in pH may occur following a high rate of application. Also, IBDU does not damage turfgrasses at normal rates of application. However, temporary chlorosis has developed three to four weeks after the application of very high rates of IBDU (above 6 lb N per 1000 ft^2). This chlorosis has been attributed to excessive absorption of ammonia by the grass.

Sulfur-coated urea (SCU)

SCU is produced by spraying pre-heated urea with molten sulfur in a rotating drum. A wax coating may be applied on top of the sulfur coating to seal pinholes and cracks. Finally, the product is cooled, and a clay conditioner is applied to reduce cracking. The product is screened to remove oversize granules.

SCU granules have been shown to provide a slow-release N source. The rate of release of N from SCU depends on the time required for microorganisms to break down the sulfur coating. Thus, the N release rate can be decreased by heavier sulfur coating and by inclusion of a microbial inhibitor in the coating. However, a problem occurs with heavy sulfur coatings for turfgrass fertilizers because the mower crushes or picks up the larger fertilizer granules.

Factors that influence the release of N from UF (temperature, pH, and moisture) also affect N release from SCU. High temperatures, neutral pH, and moist soils favor the release of nitrogen from SCU.

Sulfur-coated urea is the least uniform of the slow-release N sources discussed. Imperfections exist in the coatings of SCU because of irregularities on the surface of urea. Also, the sulfur coating may not be uniformly applied to the urea granule. These defects, together with incompletely covered granules and cracks in the coatings, provide sites from urea can be released when SCU is exposed to water. Thus, each SCU granule will have a slightly different rate of N release, depending on the extent of the "imperfections," whereas UF and IBDU granules are homogenous and are not affected by "imperfections" in the coating. Sulfur-coated urea granules are also subject to being crushed by the fertilizer distributor during application.

Solubility rates for SCU are expressed as the percent urea released when the product is placed in water at 100°F for seven days. Commercial products usually have a dissolution rate between 20 and 30 percent. Below 20 percent the product is considered too slowly available, while above 30 percent the product would not be considered a slow-release N source.

Nitrogen losses from SCU due to leaching and volatilization are intermediate between those from urea and UF or IBDU. Perhaps the greatest losses of N from SCU occur when the sulfur coating is broken and urea is readily released or when the SCU granules are picked-up with the grass clippings by the mower. SCU has little effect on salinity, but it may reduce soil pH when sulfur is released after the coating is broken down. Where sulfur is deficient in the soil, SCU provides an additional benefit with this release of sulfur, which eventually becomes available to the grass.

Nitrogen recovery for SCU is greater than for urea and other soluble N sources. However, recovery would need to be measured over a longer period of time for SCU than for soluble sources.

Polymer-coated nitrogen
Polymer-coated fertilizers date back to the introduction of Osmocote® in the 1960s. More recent formulations are Scott's Poly-S'R'® and Pursell Industries' Polyon®. These products provide controlled release of N by diffusion through a polymer membrane (coating). They usually consist of coated potassium nitrate, urea, or potassium sulfate. Release rates are dependent on moisture, temperature, and the composition and thickness of the coating. Polymer-coated products are very uniform and provide predictable N release rates. However, like many of the coated fertilizers, these products are susceptible to destruction by mower pickup.

Liquid slow-release products
The triazones are examples of liquid slow-release N sources. They combine the advantages of using a liquid (such as low burn potential and tank mixing) with the benefits of controlled N release. However, like all liquid formulations, they require the appropriate application equipment and the capability to store and handle liquids.

Organic N sources

The oldest sources of N used for turfgrass fertilizer are the natural, organic materials: manure, composted crop residues, sludges, and humus. These materials are low in N content, difficult to store and apply, expensive, and, in some cases, contain undesirable substances such as salts, heavy metals, and weed seeds. Nevertheless, organic N sources can be effectively used in most turf maintenance programs. N release from organic sources is dependent on microorganisms; thus, factors that favor microbial activity increase the rate of N release from these materials. Organic materials are not considered good N sources during the cooler months because of the low activity of microbes. During most of the year in Hawaii, organic sources can be effective.

Organic sources should not be considered slow-release sources. When conditions favor N release from organic sources, the N usually becomes available to the grass within four to six weeks. A significant amount of the N from organic sources may remain tied up in the organic form for years.

Organic sources have the advantage that they will not "burn" the grass, have little effect on pH, contain nutrients other than N, and may moderate soil temperature during cool periods. Also, some of these materials such as manure, sludge, and compost may improve the physical condition of soils.

Milorganite®
This product of the Milwaukee Sewage Commission is a widely used organic N source on fine turf. Milorganite is a processed sewage sludge that contains 6 percent N. The product is granulated, screened, and packaged for application to fine turf. It is perhaps the most widely recognized N source for golf-green turf on the Mainland and is commonly used on Hawaii's golf courses for that purpose.

Advantages of Milorganite and similar products for putting green turf include a uniform N release rate over a period of three to four weeks, a very low burning potential, the addition of phosphorus and iron, and a minimum effect on soil pH and salinity. Leaching and volatilization losses of N from Milorganite are also very small.

Disadvantages of sewage-sludge products include low N content, a short period of residual N availability, a relatively high cost per pound of N, and poor cool-weather response. The limited availability of the products might also be considered a disadvantage.

Turf response to Milorganite in terms of growth rate and color are excellent throughout the year in Hawaii. Additionally, turf researchers have reported less thatch accumulation where Milorganite was used in place of soluble N sources.

Recent changes in Hawaii's landfill regulations have forced city sewage treatment plants on Oahu and Maui to seek alternative disposal methods for treated sewage sludge. Current pilot projects using sewage sludge composted with shredded green waste are currently under way and may lead to an available and inexpensive source of organic N in Hawaii.

Combinations of N sources for turfgrass

In low-maintenance turf areas a single source of N may meet the needs of the turf. But where demands are greater, as in golf courses, athletic fields, and some lawns, combinations of N sources may provide the most uniform level of N to the turf.

The objectives of a fertilizer program have a significant influence on the sources of N needed. If the objective is simply to maintain a grass cover, a single annual application of a slow-release fertilizer, or perhaps two applications of a soluble fertilizer, will meet the requirement of the grass. But where a continuous supply of N is needed to maintain growth, to recover from wear, or to maintain good color, more frequent applications of a combination of N sources will best meet the needs.

For lawns, fairways, athletic fields, and other intensively maintained turf areas mowed at a 1-inch height or greater, coated products, UF, SCU, or IBDU, can provide the "residual" N, while soluble sources can be used to produce rapid green-up. For closely mowed turf areas such as golf greens, tennis courts, and bowling greens, UF and IBDU should be used for residual N, and Milorganite or a similar organic source should be used for rapid green-up. During cooler periods, IBDU or soluble sources must be used to produce a fast greening response.

Other factors to consider include the acidifying potential of SCU and ammonium sulfate; the salinity hazard of ammonium nitrate, ammonium sulfate, and other inorganic salts; and the cost of the slow-release and organic nitrogen sources.

On a cost-per-pound-of-N basis relative to urea, SCU is about 2 times greater, UF and IBDU are 3–4 times greater, and organic sources are 5–6 times greater. Water-soluble inorganic salts are usually even less expensive than urea. Thus, for larger turf areas where soluble sources can safely be used, they may be the logical choice for N fertilizer.

The most important factors when using soluble sources include the rate and timing of applications. Single applications should not exceed 1 pound of N per 1000 ft^2 and should be made prior to—not during—a period of rapid growth. In Hawaii, a single yearly application of fertilizer on most types of turf is best applied in late April, just before the summer growth spurt.

Related CTAHR publications

AS-1 Liming acid soils in Hawaii
AS-2 Predicting soil phosphorus requirements
AS-4 Testing your soil—why and how to take a soil-test sample
TM-1 Seashore paspalum
TM-2 'Sunturf' bermudagrass
TM-3 St. Augustinegrass
TM-5 Bermudagrasses
TM-6 Maintaining bermudagrass athletic fields
TM-7 Watering lawns
TM-8 Zoysiagrasses
TM-9 Calculating the amount of fertilizer needed for your lawn
TM-12 Common lawn grasses for Hawaii
TMS-5 Centipedegrass

Summary of characteristics of nitrogen fertilizers

Fertilizer type and name	NPK analysis	Moisture dependence	Need for microbial activity	Residual N availability
Quickly available				
Ammonium nitrate	33-0-0	Minimal	None	4–6
Ammonium sulfate	21-0-0	Minimal	None	4–6
Urea	46-0-0	Minimal	None	4–6
Slow-release				
Sulfur-coated urea	22–38% N	Moderate	High	10–15
Polymer-coated (urea, nitrate)	24–25% N	Moderate	Low	15–38
Slowly soluble				
IBDU	31-0-0	High	Low	14–18
Ureaform reaction				
Nitroform®	38-0-0	High	Low	10–30
Fluf®	18-0-0	Moderate	Medium	6–10
Nutralene®	40-0-0	Moderate	Medium	6–10
Methylene urea	39-0-0	Moderate	Medium	12–16
Coron®	28-0-0	Mimimal	Moderately high	7–9 weeks
N-Sure® (triazone/urea)	28-0-0	Minimal	Moderately high	6–9 weeks
Natural organic				
Ringers® (blood and bone meal)	6-1-3	High	Medium	10–12 weeks
Sustaine® (composted turkey waste)	5-2-4	High	Medium	10–12 weeks
Milorganite® (activated sewage sludge)	6-2-0	High	Low	10–12 weeks

Notes:
Moisture dependence indicates degree of insolubility. Fertilizers that solubilize slowly need more water to get them into solution than highly soluble fertilizers. If water availability is a problem, use of a more soluble fertilizer would be advised.
Need for microbial activity refers to the degree upon which a fertilizer is dependent on microbial activity for decomposition and nutrient release. The optimum temperature for this microbial process to take place is around 67–74°F (30–35°C).
Residual N availability is a measure of how long an application of fertilizer will provide the plant the needed nutrient(s). In general, the quickly available (water-soluble) materials will have short residual activity, while the less-soluble and/or temperature-dependent materials provide a longer residual activity. This is highly dependent upon environmental conditions.

EDAPHIC PERSPECTIVE
P.O. BOX 2059 Wailuku, Hawaii 96793 T 808-269-0885 E duane.ep808@gmail.com

Date: 9-11-2017

Client Name: County Of Maui Parks Department

Project Locations: War Memorial Little League Field #1, Wailuku

Aloha County of Maui Parks Department,

The following are recommendations to begin the steps toward getting War Memorial Little League Baseball Field #1 off chemical inputs. This information is based upon the meeting on September 11, 2017 at the War Memorial complex meeting spaces. In this meeting we discussed what was currently available to the County of Maui Parks Department and what is needed to be procured that fits this simplified program. The cost offset of procured items will be listed below.

War Memorial Field #1

- **Active grub larvae need to ID, White / brown head / 1" long 1/16"wide. Possible Webworm.** *Once the process begins these will go away.*

- Needs verticut asap. Fungus will start soon if not. Dollar spot potential. *Dethaching to take place the week of September 18th, tentative.*

- Composting asap after verticut 1/2 yard Premium compost per 1000 sqft. *Composting to take place the week of September 25th, tentative. Area is roughly 65,000 sqft. Premium Compost is $20.50 per 1000 sqft = 1339.90. That is 32 yards. Up to 20 yards available at baseyard. Leaving you with the need of 12 yards at a cost of $492.00. As decided in the meeting, the pitchers mound area and infield will be composted. The outfield will be composted lightly with what is left of the 20 yards or done fully at a later date, when more compost is available.*

- Anderson's Humic DG at 2# per 1000sqft Simplot $42.60 for a 40# bag. *Area is roughly 65,000 sqft. One application of Anderson's Humic DG 4 bags covers 80,000 sqft = $170.40 plus tax. Take the cost from the $460.00 currently allotted to Granular Fertilizer and you are left with $298.60.*

Attachment #3

EDAPHIC PERSPECTIVE
P.O. BOX 2059 Wailuku, Hawaii 96793 T 808-269-0885 E duane.ep808@gmail.com

- Organic Molasses at 1oz per gallon water per 1000sqft Wholefoods 32oz bottle $15.00. *Area is roughly 65,000 sqft. One application of Organic Molasses $.50 per 1000 sqft = $32.50. Take that cost from the remaining $298.60 allotted to Granular Fertilizer and you are left with $266.10. Put this $266.10 toward more compost.*

- Consider water timing for this field after application. Building the proper fungal and bacterial colonies need time to get growing. *Please work with Day to day irrigation team to get this field watered first thing in the morning, as a regular routine. Added watering times will be needed after dethatching and composting is completed.*

- Signs of sedge indicate over saturation. *Sprinkler needs adjustment so not to put too much water in one spot. Last resort, if a selective herbicide is used in an area, make sure to use these methods, listed above, to get things in that area back on track to stay away from chemical inputs.*

I will be coming by the parks on Monday's to check on things, if at any point you have questions, please reach out to me for assistance. Please get me any points of contact for AYSO and Baseball Leagues, I can reach out to them for community work days to help with the field weeding and divot filling that may be needed. As more of the items from the Beyond Pesticides report become available, here, I will introduce you to them and their costs. Call, email, text and please include any photos for reference. That was a great meeting today, and I look forward to working with you.

Mahalo, Duane Sparkman Edaphic Perspective