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SOIL ECOLOGY CURRICULUM AT THE WORCESTER ECOTARIUM

An Interactive Qualifying Project Report

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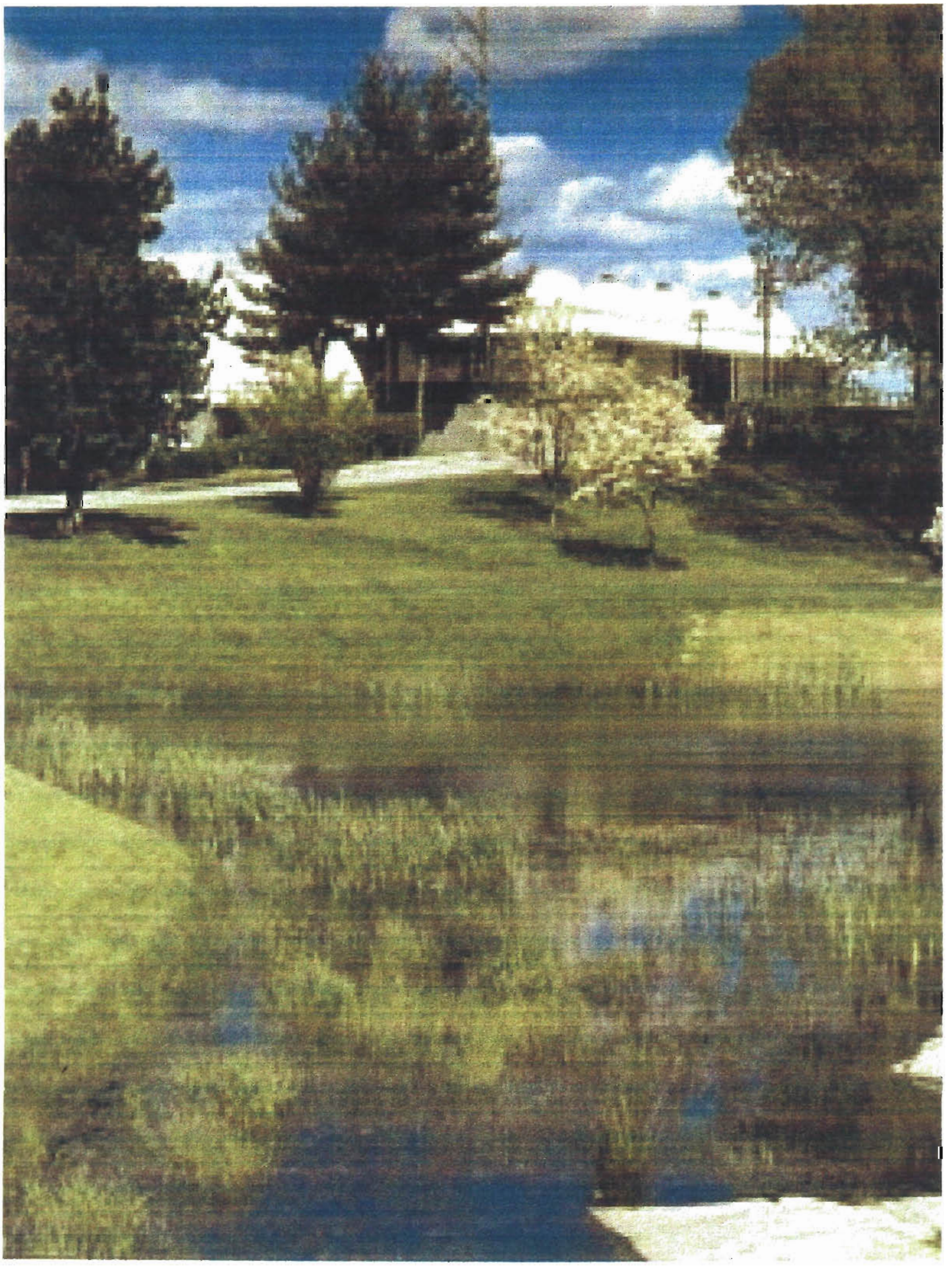

Abstract

Educational techniques are continually changing. In this Interactive Qualifying project, recent education trends, mainly the philosophy of constructivism, were researched. Some important aspects of constructivism, such as hands-on learning and discussion techniques were then implemented into an ecology curriculum for two student programs at the Worcester EcoTarium, a science center devoted to the environment. A chemical and physical baseline study of the three sections of EcoTarium soil that will be disrupted by heavy construction was completed and used as a hands-on teaching tool.

Acknowledgements

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Attribution Statement: The three members of this project team contributed equally to this report.

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Chapter One: Introduction

The EcoTarium of Worcester, Massachusetts is a science center devoted to educating the community and increasing awareness of the New England environment. Through its exhibits, many after-school programs, summer programs, and center activities, the EcoTarium entertains as well as educates people of all ages. The center employs a hands-on, interactive approach to its exhibits and functions. An important method of achieving its mission of environmental education is through the use of its many student programs. Our project entailed researching various educational philosophies and implementing them into a soil ecology curriculum for the use of two such student programs.

There are many educational philosophies that govern curriculum. These philosophies range from the traditional method of lecture and memorization to group-centered methods of active learning to completely radical methods of no testing, no memorization, and all hands-on activities. In the traditional view, the curriculum is based on memorizing and repeating facts and definitions. Students are expected to learn by listening to lectures and by reading their textbooks; team learning is not included. Conversely, other educational philosophies approach education in ways that utilize hands-on learning and group work. Students are expected to build understanding through creative, thought-provoking exercises. Educators have learned the importance of interactive and group learning versus the memorization and regurgitation of facts. These philosophies still find facts and figures to be an integral part of a curriculum; however, ideas and concepts constitute the major component. At some levels of education, such as kindergarten through middle school, group tables often have taken the place of individual desks in order to promote group learning and student-centered discussion. Students still learn some basic skills in the traditional fashions, such as grammatical skills, or multiplication tables, but students are then given time to apply what they have learned in group or hands-on activities. Even history classes can be taught using concepts and can be based on things other than the memorization of names and dates. These facts should still be taught, but incorporated into a general concept. Individual skills are important, but in a different way; a student's individual strengths and weaknesses often are considered before choosing groups in order to form a well-rounded team. These ideas are part of a current teaching philosophy known as constructivism. Constructivism aims to build and nurture understanding, while other, more traditional educational philosophies assume those understandings will come from acquiring facts.

In researching the types of available educational strategies, we found that there are several fundamental features essential to a successful curriculum. One of the most important features is a basic introduction of the subject matter, in our case soil ecology, is needed. Next should be a hands-on experience that enables the student to reinforce what was introduced as well as to explore new territory regarding the subject matter. This allows the student to raise questions to other group members or the teacher and to continue exploring the material. An important guideline for this is to allow the students sufficient time to struggle so they can learn strategies for dealing with stress, but not so much that they give up. Following these should be a student-centered discussion based on the ideas and concepts involved in the material.

The main focus of this project was to develop an ecology curriculum for the after-school group students at the EcoTarium that could be used now and in the future. The curriculum for the two groups was tailored to coincide with the specific goals of each group. An important feature of our project was to create a soil baseline study and to teach the students how to monitor the chemical and physical components of soil.

In this report, we will talk about the three main components of our project: science centers, education, and ecology. We will also explain what we discovered in our research and what we accomplished at the EcoTarium. Chapter Two discusses the role science centers play in education. This chapter will explain science centers, the EcoTarium, and the EcoTarium's youth groups. Chapter Three is a discussion of educational approaches and suggestions for building a curriclulum. Chapter Four, Our Project, discusses what we did at the EcoTarium with the after school groups and how we combined that experience with the information we gained from researching education to refine our soil ecology curriculum. Chapter Five explains our final results and conclusions.

This report is the final product of many, in a long evolving project. Much time and effort was put into meeting with the students on a weekly basis, preparing materials for each session, and analyzing the progress of the students. Time was put into researching the vast amount of information on the subjects dealt with such as ecology, education, and science centers, as well as gardening and database compiling. The experience we gained from doing this project was very rewarding. The knowledge we obtained will be extremely useful in the future especially our communication skills. We have a greater appreciation of the environment through this project and have learned a great deal about the learning process.

Chapter Two:
The Role Science Centers Play in Education

This chapter explains the role science centers play in education. Science centers are a wonderful resource for stimulating exploration into unknown information as well as expanding previous knowledge. We will contrast science museums to science centers and explain what makes science centers work so effectively. Science centers illustrate concepts in many ways, including visual displays, staffed and participatory exhibits, and programs designed to encourage patron involvement. "Science centers provide a whole new field of self-motivating experiences in learning, through environmental exhibits that appeal to the senses, emotions, and intellect" (Danilov 1982, 2).

Science Centers

The stereotypical image of traditional science museums is that of buildings with long, stuffy corridors and hushed galleries. Tour guides "[lead] school children through the museum's halls with occasional admonishments to be quiet and orderly. On weekends, families [arrive], the parents pulling kids along to expose them to a genuine cultural experience" (Danilov 1982, 3). Patrons usually read panels more than they ask questions. The noise level is generally quiet and the activity level is low. If patrons are guided, it is at the speed of the tour guide. Tour guides lead visitors through museums lecturing while questions are seldom encouraged because tours are usually on a set time schedule. Because of this, many patrons feel comfortable asking only short-answer, factual questions. The displays are mostly visual displays of artifacts with a lot of text and often are not interactive. The stereotypical museum follows a "hands-off, just look approach" (Danilov 1982, 3). Although the intentions of the museums are admirable, their atmospheres are at many times imposing and uninviting.

Science centers, on the other hand, are quite different. "They are basically contemporary, participatory, informal educational instruments rather than historic, 'hands-off' repositories of artifacts" (Danilov 1982, 2). All visitors are encouraged to explore and ask questions. Visitors are expected to walk through science centers at their own pace, and staff members are often readily available to answer questions. Exhibits are interactive more often than not and are designed with all ages in mind. As an example, the EcoTarium has a staffed exhibit called the MicroDiner. The exhibit is styled as a 1950's diner, where patrons can investigate microbes through the use of microscopes. Adults can enjoy this exhibit by discovering "the most dominant, yet nearly invisible species on Earth" (EcoTarium 1999a). Students can observe many everyday items from rotting wood to moldy bread through the microscope. Staff members can always be found at this exhibit to assist younger patrons who might not be able to use the equipment.

Science centers were developed to entertain and educate the general public (Danilov 1982). Most science centers include as many hands-on activities as possible to encourage active learning. Emphasis is placed on exploration. Unlike science museums, science centers include exhibits such as live animals and plants or objects to touch and explore. A very effective teaching technique used in science centers is free discovery. Free discovery is a method in which students are allowed to find out about something on their own. An example of this can be found at a physics playground in The New York Hall of Science. The directors of the program were unsure as to what types of labels and explanations to add to the exhibits (Raloff 1998). They left the exhibits without labels to determine fifth graders' responses towards the exhibits. Studies conducted on the response of the students showed that they learned more when they explored the exhibits and figured the purposes out for themselves, as opposed to reading the labels of the exhibits' functions. According to a staff member, "without explanatory labels the children felt it was okay to just go out and explore" (Raloff 1998).

The EcoTarium is an environmental science center, having a mission to "promote appreciation, increase knowledge and foster stewardship of our New England environment by stimulating learning about the world in which we live" (EcoTarium 1999b). Many science museums and science centers have become specialized in the areas of history, technology, or other specific subjects. Unlike science museums and other science centers, "the EcoTarium is the only museum in New England solely dedicated to environmental education" (EcoTarium 1998). The majority of the exhibits, presentations, and youth programs focus on teaching awareness of and having respect for our environment. Because of this focus on the environmental exploration, the EcoTarium is a unique location for teaching and learning.

The main teaching technique at the EcoTarium, like many science centers, is interactive learning through exploration. The combination of hands-on exhibits, small wildlife such as snakes, birds or fish, large wildlife such as a mountain lion and two polar bears, a planetarium, an observatory, and natural ponds form a unique learning experience. Instead of pictures with explanations of a wetland, for example, the EcoTarium has created an actual New England wetland, complete with birds, frogs, fish and insects. The EcoTarium also offers an astronomy exhibit. This exhibit, called the

"Astronomy Corner," details recent findings in space research. Students can then go to the center's planetarium and observatory to find the exact location of these discoveries.

The EcoTarium offers many interactive opportunities to follow up on their exhibits and programs. During one afternoon visit, we were greeted by a volunteer carrying a chinchilla. She was explaining about the animal's natural habitat and the life of the animal, and was encouraging youngsters to pet him gently. This is a very popular method for engaging students in learning activities. The involvement of many school-age volunteers is effective to teach young visitors. In our own experiences, we have found that students relate more, and therefore learn more, from people closer to their own age. Many of the volunteers at the EcoTarium are high school students and with whom the student groups feel comfortable interacting.

Youth Groups

The EcoTarium's mission is focused on the education of environmental issues concerning our world and especially the New England region. As discussed previously, the EcoTarium has found that one of the most productive methods for fulfilling its mission is through interactive programs. Although most programs are for student groups, by making the information interesting and stimulating the EcoTarium can appeal to all of its visitors regardless of age. In order to do this they have developed many educational programs for many types of groups.

The EcoTarium offers many types of activities for students to participate in, such as afternoon, weekend, over-night, and summer programs. The EcoTarium even reaches beyond its own grounds by conducting a program called "Outlook" in which staff members travel to schools with artifacts and wildlife for a classroom discussion. Programs at the center are targeted towards students of all ages, preschool through high school, and all emphasize inquiry, discovery, and learning via experimentation. "Feathered Friends," a program for grades K-2, involves the identification of birds by sight and song, from which students can observe and identify birds in their own backyards. Another program called "Closing the Circle" teaches students in grades 5-8 the why and how of "Reduce, Reuse, Recycle." One of the most popular programs at the EcoTarium is called Project JASON. Now in its tenth year, JASON is a state-of-the-art program that educates students as well as teachers about science and technology. While the students are learning about important issues, teachers and students have the opportunity to learn how to use advanced communications technology. This year, Jason scientists on site in a Peruvian rainforest are communicating with students at various museum sites around the country. Students can see and talk directly to the scientists via high-tech computers and telecommunication systems. This allows the students to ask questions and receive immediate answers from people thousands of miles away. Students find seeing live pictures of the rainforest on the computer and asking scientists direct questions much more exciting than seeing pictures in a textbook and reading the same material.

A very active group at the EcoTarium is the Hampshire League. The Hampshire League for Science Activity is a group intended to create an interesting after school experience focused on ecology at a time when many students lose interest in typical school sciences. Although the group contains both male and female members, a major emphasis is placed on recruiting girls of middle-school age, the age when many are steered away from science activities (Hampshire League 1996). The Hampshire League consists of a collaboration between Hampshire College in Amherst, MA, and eight science museums/centers in New England studying water ecology in pond, river, and ocean environments. At the EcoTarium, the focus is on the ecology of the Lower Pond. This pond is one of two that will be disrupted by construction on the EcoTarium grounds. This construction entails an entire renovation of the EcoTarium's building as well as the outdoor grounds. The construction is expected to disrupt the original environment.

Another active group at the EcoTarium is **SCOPE:** Science **C**an **O**pen **P**athways for **E**xploration. The primary sponsor of the SCOPE program is Girls' Inc., a foundation dedicated to involving girls in science and their community. Many girls are steered away from science and technology during their middle school years; parents, teachers, and other adults consistently expect less from girls than from boys in science and math related subjects (Girls Inc. 1999). A main focus of SCOPE is to keep female students interested in science. Girls are encouraged to explore, to learn from the mistakes they make, and get over the "yuck" factor. Most girls are trained from birth to avoid getting dirty. On the other hand, in programs similar to SCOPE they may be encouraged to take apart an automobile engine to see how it works, or to dig in the dirt in search of insects to study (Girl's Inc. 1999). They are taught how to resist the pressure to behave in sexual stereotypes.

The involvement of the youth groups at the EcoTarium plays a vital role in achieving its mission by educating and developing awareness and concern for the environment. These groups, through experimentation, exploration, and discovery, gain an appreciation for their environment. The projects in which the students participate include Earth Day presentations, community gardens, and neighborhood recycling programs. Through these projects, the students find an ability to improve their communities and allow them to educate others.

Chapter Three: Educational Approaches

In developing a soil ecology curriculum for the two after-school groups at the EcoTarium, the Hampshire League and SCOPE, we needed to research educational methods. However, due to time constraints, we began teaching our curriculum immediately. Through our research, we found that there were many theories pertaining to the most effective educational philosophy. The general concern is that traditional methods of education such as lecture, memorization, and repetition are not effective. Most of the philosophies agree that students need to have an active part in the learning process. One of the most common approaches that utilizes hands-on activities and group activities is called constructivism. Here we make a comparison of this philosophy with traditional styles, illustrating the benefits of a constructivist philosophy. Also, some suggestions are made for conducting a constructivist curriculum, including teacher behaviors, lesson techniques, and classroom arrangement.

Traditionally, learning has involved a combination of memorization and repetition. The students memorize new information and repeat it in reports, quizzes, and tests. In this method, there is no need for internal understanding or incorporation of the new knowledge. Students are viewed as empty heads into which "correct" ideas are placed. If not being lectured to, students are asked to read textbooks filled with new terms and factual information. Oftentimes, these texts are error-filled and offer little insight or inspiration (Beardsley 1992). Most of the curriculum is taught strictly from these textbooks without time allotted for deeper understanding (Brooks 1993). These books often do little to hold the interest of a student or even to present completely accurate material. The California Textbook League publishes a periodical newsletter that reviews all of the recently available textbooks for errors and misconceptions. In summary, the newsletter editor has stated that, with the exception of the advanced material, most of these books seem to be "written by clowns who knew nothing about the subject matter" (Beardsley 1992). One such example of wrongfully presented material can be found in the 1989 edition of a text entitled *Life Science*. The authors begin by telling the story of how some "biologists" in the 1800's found that sailors suffered from scurvy due to the absence of vitamin C in their diets. Upon addition of lemons, limes, and oranges to the sailor's daily diet, their symptoms disappeared. In reality, Capt. James Cook who was a naval officer, not a biologist, identified the cause and prevention of scurvy in the 1700's at a time when vitamin C was not yet discovered (Beardsley 1992). Tales such as this one are often used to relate information, such as vitamin C deficiency as a cause of scurvy. However, the students also retain the falsities in the story such as biologists discovering the cause of scurvy in the 1800's. Students are requested to memorize these kinds of extraneous, unrelated facts and vocabulary words on a daily basis. In order to successfully pass the tests and quizzes, students need only to parrot the vocabulary words presented to them. The students do not need to speak thoughtfully or integrate these words into their own vocabulary. New information is committed to short term memory for the sole purpose of repeating this information on a multiple-choice or short-answer test (Brooks 1993). This kind of teaching requires little effort on the part of the teacher and produces high test-grades. However, the students do not fully understand the material. Students are not motivated to be an active part of the learning process.

They do not feel the need to ask questions or discover ideas. As long as they are memorizing their facts and figures, they are receiving a "good" education (Brooks 1993).

Another complaint of traditional learning is that too many areas of science are reviewed, often too quickly to form any kind of understanding. Then, after testing day, the material learned is not touched upon again. Even the environment of the traditional classroom is not conducive to learning. The students all sit at individual desks while the teacher stands at the front of the room and lectures. This classroom arrangement does not encourage productive discussion among students and tends to be intimidating because the focus is on the teacher.

The constructivist philosophy aims at alleviating the problems mentioned above. Table 1 (see next page) compares traditional teaching with the hands-on constructivist approach. The constructivist classroom differs from a traditional one in the role of the teacher, the arrangement of the classroom, and the instructional methods. Teachers in a constructivist classroom have an interactive part with the students, while in a traditional classroom the teacher dominates. In a constructivist classroom, student desks are often grouped together in a constructivist classroom, instead of aligned in straight columns facing forward. The methods employed in the traditional methods are often lacking in student involvement while this is the focus of a constructivist classroom.

In the view of a constructivist educator, "students are not blank minds waiting for the teacher to place the correct explanation in. Instead the mind is constantly constructing possible hypotheses and explanations" (Krapfel 1999). It is important to give students relevant experiences in common with specific phenomena so that the prior understandings be reformulated and adapted to the new understandings (Krapfel).

Constructivism aims to help students "internalize and reshape, or transform new information" (Brooks 1993, 15). Real learning happens when a student is presented with new information and is inspired to use that information to rethink or transform prior ideas. The goal of constructive learning is to achieve a deep understanding of the ideas and concepts presented, rather than to repeat facts and to accumulate high test-grades on objective tests. However, to understand the practices of constructivism, one must pay

Table 1: A comparison of traditional and constructivist styles of teaching (Carin 1997, 56).

Characteristic	Traditional	Constructivist
Teacher	Autocratic	Democratic
	Curriculum Centered	Student Centered
	Direct	Indirect
	Dominative	Interactive
	Formal	Informal
	Informative	Inquiring
	Prescriptive	Reflective
Classroom	Teacher-centered	Student-centered
	Linear (seats facing front)	Grouped or Circular
Instructional Modes	Abstract Learning	Concrete Learning
	Teacher-centered Discussion	Discussions
	Lectures	Peer and cross-age coaching
	Competitive Learning	Cooperative Learning
	Some problem solving	Problem solving
	Teacher demonstrations	Student inquiries
	From simple to complex	Starting with complex tasks and using instructional scaffolding and dialogue
	Transmission of information from teacher to students	Reciprocal teaching, using dialogue between teacher and students

attention to the ideas and theories students bring with them to the classroom. Different students have different perspectives of the information presented and arrive at their conclusions through different processes. Recognizing these differences, the teacher can guide students in finding their own way to the final goal of understanding (Brooks 1993). Students can also benefit from one another by sharing their perspectives on a new idea.

There are a few guidelines in establishing constructivist curriculum (Loucks-Horsely *et al.* 1989). These range from relevancy of the subject matter to the application of learned knowledge. Specific teacher skills and attitudes can promote understanding, while others can deter it. Teaching certain scientific attitudes such as skepticism and inquiry gives the student tools that can be used in every subject and in everyday life.

Conceptual knowledge builds the foundation for further investigation. A discussion atmosphere, as opposed to a lecture atmosphere, can offer many opportunities for the students to become involved in their own educational process. Bringing science and technology into the classroom allows students to make the connection between science and real life. For example, a classroom in a small Massachusetts community communicated via internet with a classroom in a remote Alaskan community for an entire school year in 1989-90 (Morse 1999). Through this communication, the students exchanged weather information while they gained computer experience. A traditional weather and climate curriculum was greatly enhanced by this experience.

The environment of a constructivist classroom is quite different from a traditional one from the attitude and behavior of the teacher to the expectations of the students. In conducting a constructivist classroom, the teacher needs to have learned an important skill: to recognize the different ideas and attitudes the students bring with them to the class. Children develop through various stages, whether physically or mentally. A five year old child is not expected to understand the complexity of the metabolism of a cell, while, at the same time, a ten year old child will find it trivial and boring to recite the alphabet.

Knowing what stages of mental development one's students are at will help direct the depth of a topic. Jean Piaget, a Swiss psychologist and educational developmentalist, determined four stages of mental development through his research and interviews conducted with children. He found that these stages range from coordinate perception to abstract and logical thinking (see Table 2).

Table 2: Jean Piaget's four stages of mental development. (Howe, *et al.* 1993, 29)

Stage (years)	Development
Sensorimotor (0-2)	Learns to coordinate perception and action and to manipulate objects to attain goals; begins to use language
Preoperational (2-7)	Begins to think about his or her own actions, to plan, and to use language with clarity and precision; in problem solving, tends to focus on only one variable at a time; not aware of contradictions in logic
Concrete Operational (7-11)	Begins to think logically about things within own experience; can perform arithmetic operations; becomes aware of logical contradictions
Formal Operational (12 and over)	Becomes aware of the form as well as the content of problems; can think logically and abstractly about things and ideas outside own experience; can handle multiple variables and conflicting ideas

The sensorimotor stage begins at birth to two years of age. In this stage, a child learns various levels of coordination such as figuring out that the square block will not fit in the circular hole. Once the child is thoroughly comfortable at this stage, he will progress to the next, the preoperational stage. In the preoperational stage, a child learns such skills as the use of language. Once the child has completed this stage, he then can progress to concrete operational, where a child can think logically about his/her own experience. The last stage, which usually begins around twelve years of age, is the formal operational stage. In this stage the child is capable of forming abstract understandings. A child begins to understand such concepts as size scale, for instance the globe representing the Earth on a much smaller scale. A student that is learning at one particular stage cannot progress to the next unless they have fully developed the skills used in the present stage.

This development can be nurtured through appropriate applications. Two of these stages are prominent in grade school children, the concrete operational stage and the formal operational stage. It is critical that curriculum activities address the needs of these stages to develop these skills. Concrete examples and ideas are necessary in the concrete operational stage in order for the student to successfully learn the material and develop enough to progress into the formal operational stage where they can begin to understand more abstract ideas. Identifying the range of mental abilities of the students can help create understandings. However, a teacher does not want to categorize an individual student. The stages of development are meant to be used only as a guide in determining the level of complexity that a subject can be taught. However, some students may be slower or faster than others in this development. A teacher needs to be able to recognize and encourage this development.

Being able to encourage creative thinking and reasoning in a classroom is another skill teachers need. Students are often presented with two kinds of problem-solving tasks in the classroom, according to Jerome Bruner, a psychologist and developmentalist (Howe 1993). The first kind of task is found too often in classrooms: to find out what the teacher wants for an answer. The student does not think about strategic methods of attacking the problem but of recalling some memorized material. The student's first goal is to get the right answer to please the teacher, especially if a wrong answer brings feelings of rejection and humiliation for the student. These kinds of feelings can decrease the motivation to be involved in a classroom discussion. The other kind of problem-solving task facing students is not common enough in classrooms: the open-ended task with more than one solution and more than one process to reach the solution. Teachers need to be able to encourage students to think creatively and to draw from their own experiences in order to solve these kinds of questions. At the same time, teachers need to learn that certain phrases deter students from thinking and contributing to discussion. When students respond to a question posed by the teacher, they are making themselves vulnerable. If the teacher responds with "no," "uh-uh," "not quite," and finally "yes, that's it," students learn that the only acceptable answer is *the right* answer, so why risk the embarrassment. These kinds of responses by the teacher make the student feel invalidated and foolish (Brooks 1993). Not only do these kinds of questions set up the students for humiliation, but they also prevent the teacher from analyzing and correcting the thought process of the student. Questions in which students can explain their thinking processes are much more effective in illuminating the student's misconceptions so that they may be addressed. Teachers trying to create a constructivist atmosphere need to keep in mind that their purpose is to nurture the thinking skills of the students. They are there to guide the learning and mediate the discussion. Teachers need dismiss the notion that they are there primarily to impart knowledge and to accept their role as an interactive guide in the learning process of their students.

One of the principles of constructivism is to nurture conceptual understanding. Conceptual understanding is the process in which one explores his/her own conceptions, identifies a conflict, and resolves a new understanding (Collins 1992). The Conceptual Change Model (CCM) as developed by Posner, Strike, Hewson, and Gertzog, and later adapted by Hewson, describes a process of "capturing new conceptions, restructuring existing conceptions, or exchanging existing conceptions for new conceptions," (Treagust 1996, 132). In any topic, there are certain concepts that can lead to more understanding through the remodeling or exchanging of ideas. The National Center for Improving Science Education established a list of central themes in science that science curriculums should be tackling such as cause and effect, diversity and variation, structure and function, systems and interaction, and time and scale (Brooks 1993). Once students understand these basic concepts, other ideas can be nurtured. Traditional learning, conversely, often introduces several pieces of a concept and expects the connection to be made by the student. However, most often students see the pieces as the whole, get frustrated and never make the full connection (Brooks 1993). On the other hand, "when concepts are presented as wholes, students seek to make meaning by breaking the wholes into parts that *they* can see and understand" (Brooks 1993, 47). This relates to the different perspective each student brings to the classroom.

The Chicago Mastery Learning System illustrated the need to centralize learning around concepts (Brooks 1993, 46). This system presented approximately 300 reading skills to be mastered individually in a certain order by illiterate adults. Once one was mastered, the student would go on to the next skill. Some students were able to understand each skill as it was presented to them but had great difficulty putting all the skills together to read proficiently. Other students who were already accomplished readers had difficulty understanding the isolated skills. However, if students are allowed to take a whole concept and break it into skills *they* can understand, all students are more likely to succeed in improving their reading skills.

Another central element of constructivism is to promote a discussion rather than lecture approach to learning new topics. Keeping the student interested in the material and involved with the process of learning depends partly on the level of activity involved. Pupil involvement corresponds to the quality of engagement as well as the amount of time on task by a student (Howe 1993). A highly involved student will be more focused and interested in curriculum material while a less involved student tends to be distracted. Student involvement increases or decreases depending on the type of learning activity. Table 3 illustrates the level of involvement in different types of curriculum activities. Lessons involving computer programs or hands-on applications involve a high level of activity while lecture and demonstrations have a lower level of activity and causes students to be less attentive. Through teacher guidance in these high involvement activities, students should be able to discover concepts and ideas based on experience and evidence. This kind of learning environment allows students to develop insightful and creative thinking skills. The discussion atmosphere allows students to be part of the learning process by contributing ideas based on their own experience. It also allows for critical thinking and skepticism. If students are asked to come up with several explanations for specific phenomena, they must first create hypotheses based on previous understandings and then determine whether those hypotheses fully explain the phenomena. In this method, students must draw on past experiences and conceptual knowledge, thereby using previously learned material again and again.

Table 3: The relationship between activity type and involvement level. (Howe 1993, 65)

Involvement Level	Activity Type
HIGH ↑	Hands-on activites with concrete materials
	Computer activities
	Guided discussion
	Reading
	Listening and watching only
↓ LOW	Listening only

The use of hands-on applications is central to a constructivist curriculum. This method of teaching gives students some control over the manipulation of materials in order to get the most information from them. In this kind of activity, students gain greater interest and are more motivated to learn (Krapfel 1999). One example of such an approach is the battery discovery lesson. This lesson involves two separate experiments. First, students are given a light bulb, a piece of wire and a battery and are asked to make the bulb light up. The students are encouraged to find more than one solution and to explain their conclusions. Secondly, students take apart the battery themselves. As they do this, they are eager to find out what each part is and its function. This kind of discovery promotes enthusiasm for science. Students want to learn and find out more. While these topics could have been an intangible subject where students merely memorize the names of parts of the battery, the students gain some hands-on experience with them.

Another guideline to follow in developing a constructivist curriculum is to pose problems and questions of emerging relevance (Brooks 1993). The topics do not always have to start out with initial relevance, but somewhere in the curriculum the purpose of the material needs to become evident. One example is the subject of motion as a result of a collision. The relevant object of interest is a simple apparatus that many students have seen, a set of five hanging pendulums, in which each ball, at rest, just barely touches another, (see Figure 1). Through a guided lesson using this set of pendulums, a demonstration is performed illustrating the motion that results from colliding pendulums.

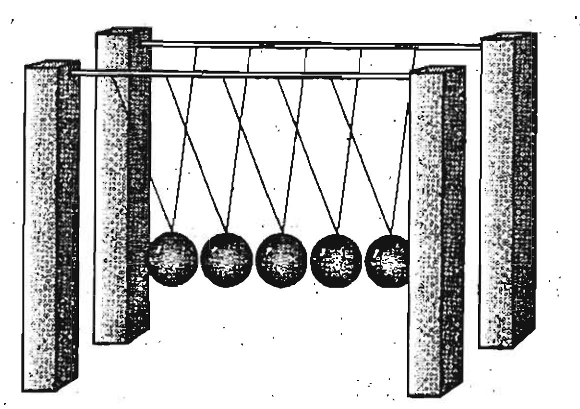


Figure 1: A set of five hanging pendulums.

One ball is pulled back from its vertical resting position while the other four are still at rest. When this ball is released, the ball at the opposite end swings outwards from its resting position, while the middle three balls appear to not have moved. When this demonstration is repeated, pulling back two balls from their resting position and are released, the result is that the two balls on the opposite side swing out, while the middle ball still appears to not have moved. After watching this demonstration the students are encouraged to form hypotheses about what would happen if three of the pendulums were raised from their resting positions and released. The students are asked to form and explain several hypotheses and to react to the ideas of others. Usually, the students come up with several possibilities such as two balls will swing out on the opposite side or the ball will go crazy. The students argue these possibilities and explain the assumptions they based these ideas on. The relevance of the material comes out as the students are trying to find an answer to a problem at hand. In this kind of lesson, the students also practice the critical and creative thinking skills needed in everyday life, as well as forming skills in discussion, group work, and skepticism.

In building a constructivist curriculum, one should also emphasize scientific skills and attitudes as important goals, such as skepticism, curiosity, humility, and determination (Carin 1997). All too often, students take what they read as truth without looking any further, instead of practicing skepticism. Students should be taught to reasonably question what they read and look for answers or evidence to support the theory. Theories are being disproved or amended all the time. Students should be encouraged to change or modify explanations in light of new evidence. At the same time, students should be taught that science is about trying, failing, and trying again. Many times students get frustrated and give up when the answer is not clearly in front of them. They should be guided to an understanding that the scientists they read about in textbooks probably experimented for years to achieve their goals. Students should learn how to accept mistakes humbly and to try again. The process of science is cyclic (Carin 1997). Scientists often begin with an idea, observe, experiment, and form hypotheses only to start all over again with a new idea. Students should also be encouraged to be curious about the world around them and to look for more than one answer or solution. Not all science is set in stone. New discoveries are being made daily. Students need to learn to accept the ambiguity of science and to respect other viewpoints unless undeniably disproved. Finally, students should learn that science is a cooperative effort. Many times, scientists from all over the world will collaborate on a single project. How to work as a team is an important part of science as well as everyday life and is a skill students should learn early in their education.

Another goal is to connect science to technology. Science has always been taught to benefit human welfare, such is the case of technology (Hurd 1997). Technology has an impact on society in every way, and relating it to science in a classroom makes the material more tangible for the student. Many organizations promote this kind of learning such as "Invent America!" and "Unified Science." Some institutions actually recruit professionals to come share their experiences with student. Northeastern University began a program called Project **RESEED** (**R**etirees **E**nhancing **S**cience **E**ducation through **E**xperiments and **D**emonstrations) (Carin 1997). This project's intention is to excite students about science by bringing retired scientists and engineers into classroom settings. The volunteers are first trained for twelve weeks and then spend at least one day in science classrooms a week to conduct demonstrations related to their area of expertise. For example, a demonstration might illustrate the effect of air pressure by pouring boiling water into a soda can, sealing it, then watching it collapse as the water cools. The students benefit greatly from this program. Ninety percent of the participating students surveyed said that they felt comfortable asking questions and that they learned a lot. RESEED has set up training sites throughout New England and is looking to expand nation-wide (Carin 1997).

Traditional curriculums are designed with the creation of miniature scientists in mind; however, only a small percentage of the students will actually choose a career in science. If so few do enter the field of science, why then go to such great lengths to teach it? The answer is that science is a part of everyone's lives. Science and technology touch us in everything we do, from taking our morning vitamins to the advances in communication. More and more advances are being made in every field of science. Because of the highly technical age we live in, students need to become people who can understand the changes being made. The thinking skills learned in science curriculum build the same kind of decision-making skills needed in life. According to the authors of *Elementary School Science for the 90's*, "...science capabilities will be required for individual decision making and for the economic and technological advantage of our country," (Loucks-Horsely 1989, 1). A well conducted science curriculum builds reasoning skills, better mental outlooks, and openness to new information, according to the author of *Engaging Children in Science* (Howe 1993). These are the same skills needed by citizens of the world to make independent, well-reasoned decisions about societal issues. By integrating science and technology in a classroom, teachers can help students make the important connection between science and the effects it has on humanity, culture, and society (Carin 1997).

Recent research efforts have shown that many science curriculums are failing to interest students, especially female and minority students, in the world of science and technology, thus creating a less scientifically and technologically literate society for the future. Research has shown that male students are called on 80% more than female students. In science classes, male students participate in 79% of demonstrations while females participate in only 21% (Carin 1997, 61). The problem is not just a gender bias, however. Female students are less likely to have outside experience with tools and simple machinery, making them less sure of themselves. While 51% of third grade boys have used a microscope, only 37% of girls had (Carin 1997, 61). Male students are more likely to jump up and down to participate in an activity, while a female student is likely to be more reserved and less obvious. Male student behavior tends to dominate the female behavior and over-shadow it in classroom setting. These types of experiences give male students an advantage on a science curriculum. Whatever the reasons, as a result, only a third of today's scientists are women. However, there are techniques teachers can employ to involve all students (Carin 1997). While teachers should keep in mind the number of times each gender is called upon, they should not make it obvious to the students. When asking for an answer to a question, the teacher should allow the students time to think about their answers. Also, the amount of time given for an answer should be equal for each student. Teachers should pay attention to the workings of groups. If it seems that male students are dominating use of the equipment, a teacher might try to provide time for the female students to use equipment separately, or even consider setting up all male and all female teams. While it is the responsibility of students to account for their own education, a teacher should encourage all students to get the most from a curriculum.

In researching different educational approaches, we found that there are some very effective ways to approach education as well as some ineffective ways. The memorization of vocabulary words and factual information does not necessarily mean the students understand the material. If understanding is the goal, then activities that nurture and build conceptual understanding are critical. We found that involving the students in hands-on activities was very effective in keeping them focused and interested in the subject matter. While conceptual knowledge is important in building understandings, we determined that some amount of factual knowledge is necessary. In understanding the functions of the various parts of a seed, the students still needed to know the names of these parts. However, instead of rote memorization, the students discovered each part and then learned the name and function. Adapting lessons to the stage of learning development of the students is also very important. We found that while there is no perfect educational method, a conglomeration of the various philosophies proved to be an effective technique. Using the techniques and suggested activity ideas described above, one can create a curriculum that encourages and reinforces conceptual understanding.

Chapter Four: Our Project

This project began as a soil ecology study in which our objective was to create a database of the various soil components at selected sites round the EcoTarium. The EcoTarium grounds were soon going to be under construction, and the staff wanted to track the effects of the renovation project on the soil quality nearby. Three sites were chosen that would potentially be greatly affected by the construction, under the Canopy Walkway, across the Pathway, and next to the Lower Pond.

The Canopy Walkway will be built from the top of a cliff through the trees. It is expected that the construction and later activity will cause changes in the soil composition. Increased activity in this area, caused by EcoTarium patron, will cause the various wildlife such as snakes, birds, small mammals, and insects to scatter from this area. The amount of sunlight reaching the forest may also be influenced due to the cutting down of trees. These changes will alter the soil pH levels, as well as the organic and nutrient content. This could possibly affect plant growth.

The Lower Pond is found at the edge of the EcoTarium grounds. The plans for this include draining, building a new dock, and flooding to increase the size of the pond. Measures are being taken to preserve some of the water wildlife. However, this action could cause significant changes in the water quality, the pond's soil bed, and the natural surrounding vegetation. Currently the pond is used for many after-school groups and projects. The EcoTarium plans to construct a nature walk around the pond bringing more activity to this area.

The Pathway was once a natural foot-trail leading from the Upper Pond to the building. Construction will bring a new parking lot to this area. The Pathway will be reconstructed as a paved path leading from this parking lot to the front door. The removal of several trees, shrubs, and leveling of the ground will drastically alter the area surrounding the paved path. This will significantly alter the soil conditions, along with every aspect of plant and animal habitation in this area. The major construction in process at the EcoTarium will affect every part of the land. The three areas we chose are very different from each other and are a good overall representation of the land at the EcoTarium.

Two EcoTarium staff members, Doug Potter and Joan Erler, were interested in this project. They not only wanted to sponsor the baseline study, but also wanted to involve their two after school groups, SCOPE and the Hampshire League. As discussed in Chapter Two, the Hampshire League studies water ecology and SCOPE is involved in building a garden. The students were interested in learning soil ecology. Our involvement with the students began in mid-October. At this point, we began general discussions of soil ecology including soil strata, soil composition, and soil wildlife and then began our chemical testing of the soil.

The goal of the project was to include the students as much as possible in the methods of creating a baseline soil study. This was a wonderful opportunity for us to incorporate science and technology to society, the objective of a WPI IQP project. Teaching soil ecology to a group of students fulfilled this goal. The teaching included the students in the majority of the soil test, along with teaching them the ideas and principles behind the soil testing.

Soil Ecology in the Classroom

The two groups we worked with, the Hampshire League and SCOPE, both had a fundamental knowledge of ecology. From their science classes, they have gained a working knowledge of subjects like pH, organic matter, and decomposition of plants and animals. The students were very capable of adapting previous knowledge to the material that we were presenting. This basic knowledge provided a platform from which we could help them build a greater understanding of soil ecology.

For the past two years, the Hampshire League has been working with EcoTarium staff member Joan Erler in the study of population ecology of the Lower Pond, as well as the chemical and physical properties of the pond water. When the construction at the EcoTarium began and the idea arose for a WPI IQP group to study the soil ecology, the integration of a soil ecology curriculum with the Hampshire League studies became a logical focal point.

Once a week for the months of October through February, we met with the Hampshire League at the EcoTarium. Activities began with demonstrations on how to collect a soil sample along with free discovery of the various soil wildlife. The students investigated such things as insects and animals in leaf litter on a macroscopic and microscopic scale. Further meetings included the discussion of the importance of inorganic and organic soil elements. Students were also involved in the actual testing of various nutrients. The students performed most of the tests themselves with our guidance. Our interaction with the students has prepared them to continue soil studies in the future. The students demonstrated an understanding of the material. They were able to discuss and share interpretations with each other regarding the test results.

Our involvement with SCOPE began when their leaders decided to build a community garden in order to combine the students' knowledge of science with the community. The SCOPE liaison at the EcoTarium, Doug Potter, suggested we incorporate SCOPE's plans for a community garden into our curriculum. The students are involved in every aspect of the project, from choosing where to plant the garden, what to plant, and the creation of a compost pile. Discussions with the SCOPE group centered on soil elements essential to garden growth, such as Phosphorous, Nitrogen and Potassium. After testing the EcoTarium's soil to teach the students how and why it is done, we tested the soil from their compost and soil from the future garden sites.

In order to conduct a soil ecology curriculum for these after school groups, we first needed to conduct our own study of soil ecology. We needed to understand the exact nature of soil. Soil is the naturally deposited material, which covers the earth's surface, whose chemical, physical, and biological properties are capable of supporting plant growth (LaMotte 1994). Soil is produced by the natural decomposition caused by forces acting upon native rock, vegetation, and animal matter over an extremely long period of time. There are many factors that make up the composition of soil. Living matter such as plants, animals, and microorganisms are some of these factors. Other factors include climate (temperature, precipitation, and wind), relief (slope and landform), time, and parent materials (particle size and chemical and mineralogical composition) (LaMotte 1994).

These topics were all covered in the discussions with the two groups, with a great emphasis on how to relate the ideas with their group projects. The students were not expected to memorize facts and definitions; the focus was completely on learning the concepts of ecology and grasping the knowledge that many factors influence soil composition. In learning the various nutrients of soil, repeated discussions involving these nutrients led to indirect retention. Instead of using objective tests to determine knowledge retention, we observed the application of knowledge by the students in these discussions. Instead of testing vocabulary, we discussed concepts and ideas that employed the terminology with the students. These discussions allowed us to ascertain the depth of understanding of the terms and concepts by the students. This proved to us that traditional memorization is not necessary in order to learn this type of material. As an alternative to traditional methods, the use of repetition and application accomplished our goals for the students. As mentioned in Chapter Three, we found that many of the methods that we employed followed the constructivist philosophy.

Soil Testing in the Classroom

Our involvement with the students began in late fall. In order to use soil sampling and testing as an educational tool, we needed to perform these tasks with the students before the ground froze. Because of these time limitations we began teaching before conducting our own study of various teaching methods. From our own learning experiences, we tried to provide interesting and stimulating sessions for the students.

In our involvement with the after-school groups at the EcoTarium, we intended to base our curriculum with the students in a completely hands-on fashion. This method of teaching allowed the application of basic knowledge in an active and exciting manner. In teaching soil ecology, we were also able to help the students understand the importance of taking care of our environment. Our goals were similar with both groups: to teach soil ecology in an interactive and hands-on manner. We centered the lesson plans on each group's needs (See Appendix I). We provided them with a soil ecology background and then allowed them to apply the information to their own project. In retrospect, we found that our teaching methods worked well with these groups. In repeating this project, we would employ similar techniques. However, through our research and experience, there are some general techniques that we would improve upon. One of these would be the way in which we sought feedback from the students. We would now try to have the students explain their thought processes that led to their conclusions. We wold also try to incorporate more open-ended questions to promote reasoning and logical thinking. The hands-on activities worked well to tie in the conceptual knowledge with practical applications of each individual group's project. We were able to provide a fun and interesting course for the students from which they gained a deeper understanding of the subject matter.

After the students established a basic background in soil ecology we used soil testing as a hands-on application. The testing provided an opportunity to build on the ecology concepts previously presented to the students. The concepts were used in interpreting the test results. Students also conducted discussions of which factors could be causing these results. We encouraged group work, discussions, and skepticism of their own ideas. To do this we used a soil testing kit to test specific soil samples. The soil samples were taken from three locations at the EcoTarium as discussed earlier: Canopy

Walkway, Lower Pond, and Pathway. Additional soil samples from the two SCOPE garden locations, Providence Street and Lincoln Street, were tested. Once the samples were tested, the results were discussed and evaluated as stated above. For the SCOPE group we also discussed possible remedial methods for adjusting nutrient levels for optimization of garden soil.

All of the chemical tests done in our project followed a set protocol. Because the tests will likely be repeated in future years and the results from each test will be compared, it is necessary that the procedures for each test be done the same way every time (See Appendix II, procedure section). For each individual test, many details were recorded, such as the name of the tester, the name and location of the sample, the date the sample was taken and the date it was tested, the name and results of the test, and any other relevant information (See Appendix III). The test results that were gathered from the initial testing for the EcoTarium and each SCOPE group were entered into a database (See Appendix IV). One database was created for our use, while another was created on the EcoTarium's software for use in further studies. The databases both include the results of each test from each of the three EcoTarium sites. Two other databases were created with the results from each of the different SCOPE sites.

A key feature in all of the chemical testing was an emphasis on safety. On the day of the first chemical tests with the Hampshire League and SCOPE, we had a long discussion about safety. Emphasis was placed on such things as hand washing and being aware of what chemicals were in use at all times. The LaMotte Soil Testing Kit provides Material Safety Data Sheets (MSDS) on all chemicals contained in the kit. MSDS are an excellent safety tool; each sheet, one for each chemical, lists all safety hazards, precautions that should be taken when handling the chemical, mechanical ventilation requirements, and preliminary actions in cases of spills or ingestion. We used the MSDS provided in the kit to create our own easy-to-read safety sheets. For quick reference, we made a spreadsheet listing each chemical and the precautionary measures that should be taken when using these chemicals as well as a quick first aid reference for direction of what to do if the chemical comes in contact with particular parts of the body. An example of what is included is the recommended treatment for eye contact with Sulfate Test Solution #1: "to flush the eyes with water."

Soil testing was an excellent means of teaching; we were able to implement many constructivist ideas. Discussions of the factors influencing soil ecology allowed us to determine any preconceptions the students held, while the actual chemical tests engaged all of the students in a hands-on application. The hands-on application combined the soil ecology curriculum with an every-day issue, thus connecting society to science and technology.

Women in Science

An activity we participated in at the EcoTarium was the "Women in Science Conference." This provided an opportunity to test the ideas we found in our study of teaching methods as well as our experience with the after-school students at the EcoTarium. The EcoTarium, as well as Girls' Inc. and the Office of Science Education at the University of Massachusetts Medical School, sponsors the event. The goal of the annual conference is to "expose 150 Worcester middle school young women to careers in science and to begin conversations with local women who do science in their professions" (Women in Science 1999). The 13 presenters, all women professionals, included an archeologist, a civil engineer, a mechanical engineer, a marine biologist, a midwife, and a forensic scientist. Each gave three 35-minute presentations to small groups of 8-12 students. The purpose of our presentation was to introduce the students to soil ecology. This activity gave us a great opportunity to analyze the effectiveness of our curriculum with students who had very little prior knowledge of soil ecology. Before the presentations, the students were asked a series of true/false questions to determine any preconceptions. These questions included ones such as "Women do not have the physical strength to become a veterinarian of large animals such as cows and horses" and "An archaeologist digs up dinosaur bones all day". At the end of the sessions, students were asked the same series of questions to determine if their preconception were changed. We also spoke with our individual groups to see what their preconceptions were about chemists and biologists. One girl responded "All I know is that there is a lot of math." This gave us an opportunity to discuss the fields and sub-fields of Chemistry and Biology. We explained the importance of math, but emphasized that it does not have a central role in these fields.

In keeping with constructivist ideas, the format was discussion as opposed to the traditional lecture, and the students responded favorably. At first, it was apparent that some of the students were very shy and were reluctant to participate. By the end of the discussion however, every member of the group had contributed.

The rest of the presentation was a guided discovery of the meaning of pH. Students were given litmus paper and tested household objects such as bleach, ammonia, milk, orange juice, water, and nail polish remover to determine whether each was acidic and basic. As a result of this experiment with familiar household liquids, acidity and basicity became a concrete example rather than an abstract idea. After the students had an idea of the significance of pH, we tested several soil samples, such as sand, potting soil, soil from the EcoTarium's Lower Pond and soil from underneath the future Canopy Walkway. After gaining a familiarity with pH, the students were able to identify possible causes of extreme pH levels in soils, such as acid rain, pollution, or dense vegetation.

This conference provided us with an opportunity to evaluate our understanding of education and teaching methodology. In these sessions, we were able to improve those general techniques as discussed in the previous section. Open-ended questions were employed in which the students could explain how they came to their conclusions. We had a better idea of how to encourage conceptual understanding in a discussion. From this conference, we were able to conclude that hands-on applications as well as in-depth student discussion play a central role in building conceptual understanding.

Chapter Five: Conclusions

Our Final Products

Our work at the EcoTarium involved developing and implementing a soil ecology curriculum. From this experience and from our study of educational approaches, we created a soil ecology curriculum to be used for future soil studies. The educational philosophy used in this curriculum is based on the philosophy employed by the EcoTarium in teaching after-school groups about soil ecology and soil analysis. As discussed in Chapter Two and Chapter Three, the EcoTarium employs a teaching method which utilizes hands-on applications and experimentation. In providing a soil ecology curriculum for a group of fifth grade students, we gained experience and knowledge in soil ecology as well as educational approaches.

Our final product from this project is multifaceted. Through this project, we developed a soil ecology curriculum, created two booklets containing a variety of useful information, and established a database at the EcoTarium, all of which can be used to conduct future studies. As a result of our research and experience, we developed a soil ecology curriculum, including a session-by-session lesson plan (see Appendix I) that can be used as a guide in future soil studies. The material taught in this curriculum can be applied to the everyday lives of the students. For example, the students are now aware that pollution can affect the pH of the soil and various other nutrients. The students learned about soil ecology and the analysis of soil. They learned about important features of soil and how they affect vegetative growth. They will be able to repeat the soil analysis they have learned in order to monitor and improve the soil around the EcoTarium (Hampshire League) and the Girl's Inc. garden locations (SCOPE).

To aid the students in monitoring the soil, we created a booklet for each group that contains background information on each of the nutrients they tested for, the procedures for testing, the results that were gathered by the initial testing, and suggests remedial measures for improving the quality of their soil. The booklet also contains safety measures and references that can be used to obtain more information about the components of soil and gardening, if needed.

The SCOPE booklet is geared to fit that group's gardening needs. They will be designing, planting, and caring for a community garden. The booklet contains the specific soil test results from each SCOPE location (at Lincoln Street and at Providence Street) along with the other components of the booklet mentioned above. The SCOPE group will use this booklet to monitor their garden soil, and to follow the suggested remedial measures for improving soil quality as necessary (see Appendix V).

The Hampshire League students are working on a different project. Specifically, they are monitoring the effects that the current construction is having on the EcoTarium's property. They will not necessarily be using the booklet to improve the soil, but will monitor the changes in the soil possibly caused by the construction. In the booklet are the results for the three areas tested, Canopy Walkway, Lower Pond, and Pathway, as well as the other components of the booklet as discussed above (See Appendix II).

Finally we established a database containing all of the EcoTarium's soil study results. This will be used by the Hampshire League as a reference for future studies as well as a tool for comparing changes caused by the construction on the EcoTarium's grounds. The database was created so that new information could easily be added and so that direct comparison could be made from year to year.

The lesson plan and the booklets allow the soil ecology curriculum we created to be applied for several years. Although we will no longer be working on the project, we have provided all the groups with enough information to continue the soil studies. The students and group leaders can use the database at their discretion to compare results as they see necessary.

Conclusions

The purpose of all IQP projects at WPI is to relate science and technology to the needs and interests of society. The focus of our IQP was to create a soil ecology curriculum for use with the school groups at the EcoTarium, thereby incorporating science into the everyday lives of school children.

To accomplish this we created a baseline soil study before a new construction project began at the EcoTarium. The purpose of this was so that the Hampshire League could continue to monitor soil conditions around the EcoTarium in future years and to be on the lookout for changes caused by the construction. During the course of this project, this goal was expanded to include SCOPE's current garden project. During the winter, the Hampshire League did not meet, so we continued to meet with the SCOPE students and tailored activities to their future garden. The focus of our IQP ultimately became to form a baseline soil study as well as create an ecology curriculum using the study of soil ecology as a teaching tool.

Our IQP was essentially divided into two parts: the EcoTarium component and the WPI component. Each of these parts had separate goals and purposes. The WPI component focussed mostly on research of science centers, ecology, and teaching techniques. The EcoTarium component focussed on the application of our research and the integration of science into the community. A challenging aspect of our IQP project was fitting these two parts together in a logical manner. We accomplished this by integrating teaching soil ecology to student groups with our soil baseline study, thus incorporating science and technology into their everyday lives.

We fulfilled the EcoTarium goals by creating a detailed baseline soil study that can be used for comparisons of soil conditions in future years. From our own observations, this was an effective teaching tool in applying the ideas that tie in with the constructivist approach for teaching science to children. The curriculum taught aspects of soil ecology and its importance to the environment. Also, through our own experiences, we were able to judge the effectiveness of many of the constructivist theories such as discussion and free discovery by the students. Through the course of the project we concluded that many of the constructivist methods were notably effective. From our own experience with the students, we found that lecturing to them was not productive: some students were not interested or attentive to the subject matter when we did all the talking. However, when interactively discussing the same material with the students, they were much more focused and involved. As an example, a brief lecture concerning the limitations of our soil resources was not well received by the students. We stressed the importance of soil conservation because of our dependency upon it and its limited quantity. Subsequently, we demonstrated the same idea in an interactive fashion, using only and apple and a knife, and the students were enthusiastic and captivated. This demonstration involved cutting off pieces of the apple to represent the many different parts of the earth. These pieces represented areas of the earth unusable for agricultural growth, such as areas covered with oceans, uninhabitable land, urban areas, swamps, deserts, etc. After cutting off all of these pieces, only a small portion, $^{1}/_{32}$, remained of the apple representing land capable of agricultural growth. The students were able to understand this concept of our limited soil resources much more than the lecture on the same topic. They were able to visualize just how little soil can be used to support all life on earth. The students learned a valuable lesson in soil conservation. Discussions and demonstrations like these led to high retention of concepts and ideas.

For the EcoTarium, we created a booklet that will be used to continue the soil studies. With the guidance of the EcoTarium staff and SCOPE leaders, the student groups will be able to repeat the tests and compare the results with those originally recorded in the databases. They will also use the databases as tools for recording their results. In this manner, all the results will be in a comprehensive format available for easy comparison using graphs and charts. From the on-going studies, the students will be able to apply their knowledge in the future, as opposed to memorizing facts for a test, and then forgetting them.

The WPI portion of our IQP requirement concentrated on what we learned and gathered from our research as well as our experience with the students. Because of weather constraints, we began our project by "jumping" right in. We had no teaching experience nor had we delved into a great deal of research on education. We began teaching the after-school groups and doing our best to make it fun, exciting, and educational. Even though we did not realize it, some of the methods we were using followed the philosophy of education that we would soon learn more about: constructivism. After we completed the sessions with the students, we immersed ourselves into a study of the "proper" way to conduct a curriculum. We learned that while not everything can be done as planned, experience is a very important component of teaching. With experience one learns what works, what captures the student's attention, and what makes them want to know more. This allowed us to discover for ourselves, by trial and error, the most effective methods for teaching these two particular groups. With a combination of experience and research, we developed an idea of what is behind the teaching methods of hands-on education and the philosophy behind constructivism. Then, through Women in Science Day Conference, we were able to teach soil ecology using the experience we gained with teaching SCOPE and the Hampshire League and the knowledge we acquired from researching educational philosophies. We conducted discussions, trying to include every student in the group, as opposed to lecture. During the pH testing, every student was able to come to the front of the group, hypothesizing possible results, and test common household chemicals. This integrated the constructivist techniques of student-centered discussions, hands-on activities, and guided discovery, which we found to be effective in teaching the Hampshire League and SCOPE students.

This project allowed us not only to relate science and technology to society, but also to better understand teaching techniques, specifically constructivism. We discovered that there are many educational philosophies. We focused on construcitivism because the philosophy agreed with many of the teaching methods we employed with the Hampshire

League and SCOPE. Through our own experiences, we were able to verify that many of the techniques that constructivism endorses, such as hands-on learning, experimentation, and guided discovery, were excellent in teaching our soil ecology curriculum.

This project served to be beneficial to us. We gained a great deal of respect for teachers and how they guide the learning process. Also, we now have a higher degree of respect for the environment. The support from the EcoTarium as well as the WPI faculty was essential in aiding our own learning process.

Appendix I:

Lesson Plans

Session 1: Introduction

Goals:

To introduce the student groups to our project and us.

Our Introduction:

We introduced ourselves to the students and discussed our project with them. We gave them the opportunity to ask us questions about us, our studies at WPI, and WPI itself.

Notes:

Because of limited time in this first session, we were only able to give a short introduction to our project. This was our first time with the group and we were not yet researching education techniques; we were unsure of how to conduct our introduction. A better first session could have included not only an introduction of us to the students, but also of the students to us. More open-ended questions should be incorporated into the session such as "Why did you choose to join this after-school group?" or "What do you like to do in your free time?" in order to better get to know the students.

It was apparent in this first session that the students were somewhat shy. However, we feel that our age (closer to their own ages than other teachers) and our appearance (casual dress similar to their own) helped to make the students more comfortable around us.

Session 2: Basic Introduction to Ecology

Goals:

To show the students that leaf litter is not "dead" matter. To show them that there are living things on the ground, both macroscopic and microscopic. To teach the students that earth contains many different layers such as topsoil and clay. To teach them the correct way to collect a leaf litter sample.

Leaf Litter Study:

We brought the students outside, showed them the locations of two of the sites (Pathway and Walkway), and showed them the correct way to collect leaf litter samples. The groups were then split into two groups, one for each site, and collected leaf litter. Every student was given a chance to participate by collecting his or her own samples.

We then returned to the classroom to study the litter on a macroscopic and microscopic scale. This was conducted as a guided discovery. The students each had their own samples to look at with a hand-held magnifying glass (macroscopic scale) and two different powered light microscopes (microscopic scale). They were encouraged to look through leaf litter, find insects, and share with the rest of the group. All students were given chances to use all equipment and ask questions. This gave the students an opportunity to learn from us as well as their peers.

What is Soil Made Up Of?:

We discussed the strata layers of soil as well as how the components of soil develop. As an example, we discussed the decay of plants and animals to form the organic content of soil.

Notes:

The guided discovery of the leaf litter was very successful; the students were eager to explore and discover for themselves. Because of the casual atmosphere, students felt comfortable asking questions of each other and us. Not only did they learn that soil contains many living things, they had a lot of fun; because of this, they retained a lot of information. This was evident in later sessions.

The discussion of the soil strata was not as successful. We did lecture *and* discuss the material, but the students probably would have retained the information more if we had followed up with a hands-on activity such as taking a core sample of the earth to actually observe the soil layers.

Session 3: Introduction to Soil Testing with the Hampshire League

Goals:

To stress safety when soil testing. To discuss pH and Humus, and their importance in the soil. To introduce soil testing as a hands-on activity.

Safety:

We went over the safety information that pertained to the soil testing kit's contents. We discussed precautionary measures such as washing hands after touching chemicals, being careful not to touch any part of the face while working with chemicals, and being aware at all times of who is working with the chemicals. We also briefly discussed first aid responses such as rinsing the skin or eyes with water in case of contact.

We stressed safety as an important part of soil testing, but we also told the students that only the WPI students would be working with any potentially dangerous chemicals.

Humus and pH tests:

A brief introduction was given to pH and Humus. We took the students outside and demonstrated how to correctly take a soil sample (take soil from several different places in the site and dig at least three inches down before collecting soil) and the students were given a chance to take their own samples. We then went back to the classroom, split into two groups, and tested the Humus content and the pH levels of this soil with the Hampshire League.

Results and Discussion:

Because of time limitations each group tested either pH or Humus and then reported the results to the other group. Possible reasons for the results were discussion such as acid rain resulting in a low pH, or a low Humus content because of the wooded location.

Notes:

The Humus and pH soil testing was extremely successful. Because each group reported to the other, we were able to observe how much information was retained. Both groups took part in the discussion of the results, proving that they not only learned the concept of pH and Humus, but they were also able to combine this new knowledge with old knowledge, such as explaining a low pH level because of acid rain.

Session 4: Introduction of SCOPE

Goals:

Same goals as Session 3, but for SCOPE instead of the Hampshire League.

Safety Review:

We reviewed the safety discussion we conducted in Session 2 for the SCOPE group.

Humus and pH Testing with the SCOPE Group:

We tested the Humus content and the pH levels of compost from the two different Girls' Inc. locations. This was conducted in a similar manner as Session 3 with the Hampshire League. However, each group had enough time to test both pH and Humus, so the groups did not report to each other.

Results and Discussion:

The test results and possible causes were discussed. This discussion was similar to that of Session 3. Possible methods for improving compost quality were discussed such as adding acidic fruits to lower pH or adding more leaves to raise Humus content.

Notes:

We had enough time for each group to test both pH and Humus, but this was not as effective as Session 3 because we were not able to immediately observe how much information the students retained. However, during the discussion, the students were able to apply the new knowledge with old knowledge in the same way the Hampshire League did.

Session 5: Continuation of Soil Testing with the Hampshire League and SCOPE

Goals:

To introduce the students to the three most important elements in soil: Nitrogen. Phosphorous, and Potassium. To test soil for these elements and discuss measures for improving them.

Soil Testing for Nitrogen. Phosphorous. and Potassium:

A discussion of these three elements was conducted. We first asked the students what they knew about the elements. We were surprised to find out that the students were far more knowledgeable than we predicted. For example, already knew that there are three forms of Nitrogen, that plants and humans use different forms, and that bacteria convert the unusable forms into usable ones. We explained to the students of the importance of these elements in fertilizer and how different fertilizers contain different ratios of the elements.

Soil samples previously taken from Pathway, Walkway, and SCOPE compost were tested; samples taken by the Hampshire League of a third site, Lower Pond, were also tested.

Results and Discussions:

We conducted a student-centered discussion of the results obtained, the possible reasons for the results obtained, and possible methods to improve these results, such as fertilizers or liming.

Notes:

The students had a solid background on these topics and we were able to go into more detail with the students than we originally had planned. Because of this, we learned to over-prepare for our sessions.

Session 6: Continuation of Soil Testing with the Hampshire League and SCOPE

Goals:

To briefly introduce Magnesium, Calcium, Sulfates, and Aluminum to the students. To discuss the importance these elements have in the soil. To test for these elements.

Testing for Magnesium, Calcium, Sulfates and Aluminum:

This session was conducted in the same manner as Session 5. The importance of these elements in the soil was discussed, such as Magnesium playing a central role in chlorophyll.

Session 7: Continuation of Soil Testing with the Hampshire League and SCOPE

Goals:

To briefly introduce Chlorides, Ferric Iron, and Manganese to the students. To explain the difference between macro- and micro-nutrients and the importance of each in soil. To test for these elements.

Testing for Chlorides, Ferric Iron, and Manganese:

We discussed the difference between macro- and micro-nutrients in the soil. We tested the soil for the three elements.

Results and Discussion:

We discussed the results with the students.

Notes:

The students might have benefited more from this session if we had guided the students into forming their own conclusions about macro-and micro-nutrients. For example, instead of telling the students what the difference was, they could have retained more if we had guided them into forming their own conclusions. We could have reviewed the test results,

Session 8: Discussion of all Test Results with SCOPE

Goals:

To discuss all obtained test results with SCOPE. To discuss remedial measure for improving the compost in order to promote better growth in their future gardens.

Discussion of Results:

The results from all the tests were reviewed and discussed. We discussed optimum levels of the nutrients in soil. We also discussed how to achieve these levels through adding fertilizer, lime, or compost.

March 20, 1999: Women in Science Conference

(For background information on the conference, see pages 36-37)

Goals:

To combine all of our experience teaching SCOPE and the Hampshire League with the research of teaching methods. To refine our own teaching methods and test their effectiveness on a group that had little previous knowledge of soil ecology.

Introduction:

First, we introduced ourselves and stated that we were Chemistry and Biology students. In order to get an idea of student preconceptions, we then asked what they thought chemists and biologists did for a living. This was a great way to determine preconceptions, good or bad, and address them. This also worked well as an "ice breaker" to help make the students feel more comfortable with us.

Guided Discovery of pH:

We brainstormed the significance of pH. During this time, we were merely guiding the discussion. We then gave the students litmus paper to test common household liquids such as milk, orange juice, nail polish remover, ammonia, water, vinegar, and bleach. Before testing the liquid, the students were asked for a hypothesis of the results, which were written down on the board. One student then picked a liquid and did the actual testing. Each student was given a turn to test something. We then discussed the results.

Notes:

This was an excellent opportunity to combine many constructivist techniques. The introduction gave us the opportunity to determine and try to correct any misconceptions. The brainstorming made the students eager to try and prove their hypothesis. The actual testing and guided discovery made the students think about previous knowledge and try to apply it. This hands-on activity engaged the students, kept their attention, and probably led to high retention of information. The student-centered discussion of the results allowed the students to think about the tests, and come to their own conclusions.

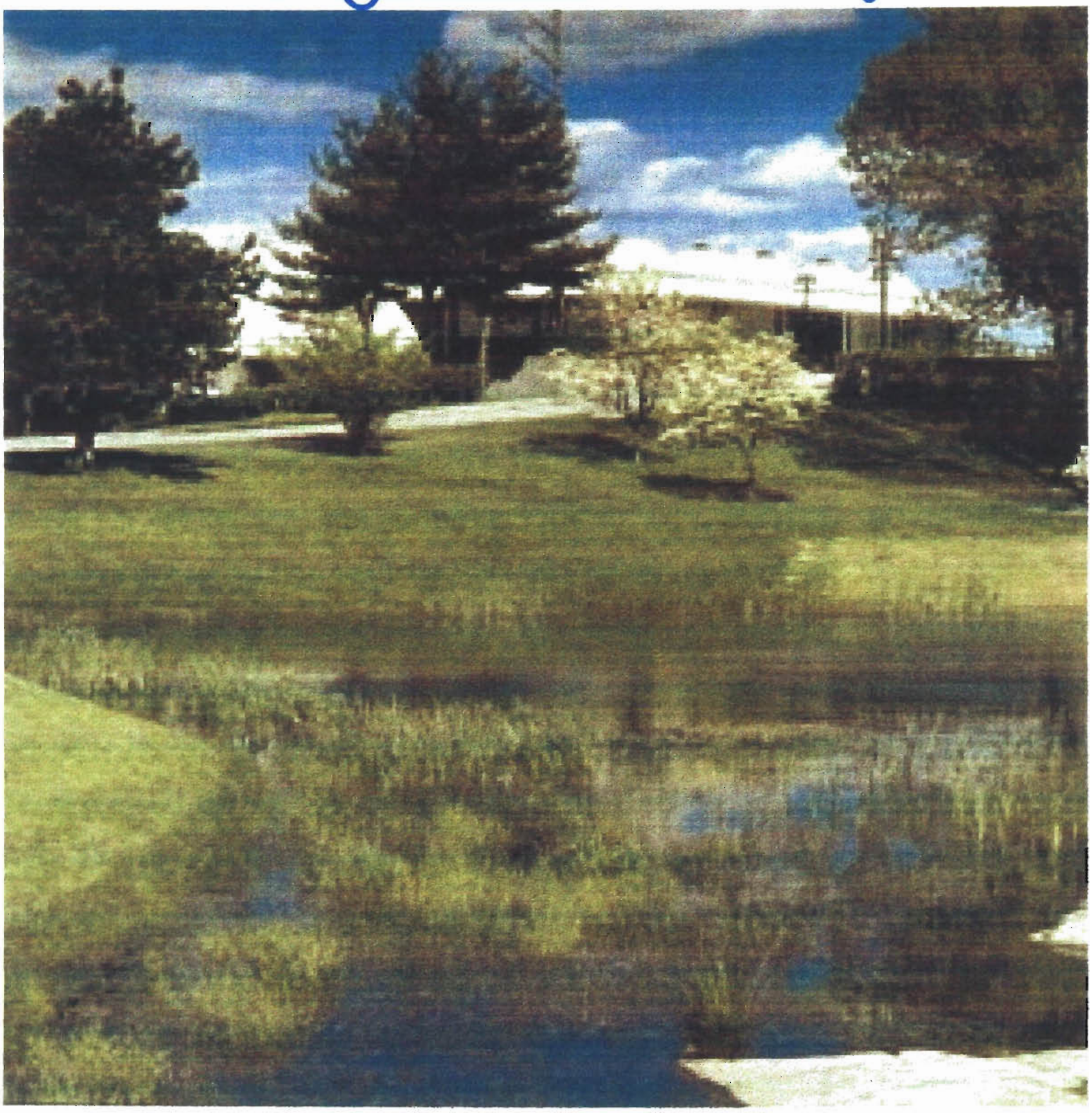
Soil Testing:

We then tested several different samples of soil such as sand, potting soil, soil from the Pathway, and soil from the Lower Pond. The students used the concepts they learned in the guided discovery and applied them to the soil testing. As an example, they accurately predicted that the potting soil designed for garden use would have a neutral pH for optimal garden growth.

Appendix II:

The EcoTarium Soil Testing and Analysis Booklet

EcoTarium Soil Testing and Analysis



Provided by WPI Students:
Andrea Feijo
Melissa Morse
Melissa Wright

Table of Contents

Introduction

This booklet is intended for the study of the chemical, mineral and organic content of soils surrounding the EcoTarium. The areas of the EcoTarium being studied are mostly wooded areas. The amount of humus, the pH level, and the amount of various nutrients at specific locations around the EcoTarium grounds have been measured and recorded. As reviewed in this packet, **Humus** is the part of soil that comes from rotted vegetables and decomposing animals; **pH** is a measurement of how acidic or basic the soil is; and **Nutrients** are all of the other materials important to plant growth. Three of the most important nutrients are Phosphorus, Potassium, and Nitrogen. We have compared our findings for each sample area and studied the areas undergoing construction. We have also discussed how these nutrients affect forest, "high traffic", and pond shoreline areas.

The tests in this booklet measure the amount of nutrients found in flower and vegetable gardens, as well as natural wooded areas like the EcoTarium's. These nutrients contribute to the overall health of soil. Not all types of gardens need the same amounts of nutrients, or even the same kinds. Flower gardens tend to need more nutrients than vegetable gardens. However, vegetable gardens need more Phosphorous than do flower gardens. Nitrogen is important for making plant leaves and stems healthy, green, and also helps the plants grow. Potassium helps plants produce chlorophyll and resist disease. Not all soils contain the necessary nutrients. Various nutrients are necessary for healthy plants, however. This doesn't mean that plants can't grow there, but certain measures need to be taken to make sure they grow healthy and strong. Some soils can contain too much of a certain nutrient which can be harmful to plants. There are steps to fix these kinds of situations as well. In the following pages, the different kinds of soil tests are listed along with how to fix unfavorable conditions and some examples from the tests performed at the EcoTarium.

Within this booklet you will find a description of each of the nutrients that have been tested, the results that were found, suggested remedial measures, test procedures, helpful tables, safety information, and locations of additional information for further study of soil ecology and plant growth.

Humus

One of the best ways to determine the overall health of a soil is to measure the humus content. Humus is the result of the decay of dead plant and animal matter. Bacteria and fungi are responsible for the breakdown of nutrients contained within this matter and the spreading of it throughout the soil. These organisms also contribute to healthy biological functions such as retention of water and aeration of the soil. Using the

Lamotte Humus Test, one wants values between 3 and 4 to ensure healthy humus content. One way to correct for humus deficiency is to apply compost matter, animal manure, or garden and crop "leftovers" such as stems and dead flowers. In the soils tested around the EcoTarium, only the soil under the future canopy walkway showed sufficient amounts (2.5) of humus. These areas should have compost matter applied to them. See Table One.

Humus Results:

Across Pathway: less than 1
Under Canopy Walkway: 2.5
Lower Pond Area: 1.75

pH

The pH of a soil is the measure of the soil's relative acidity or basicity. The pH scale ranges from 0 to 14. A pH of 7 indicates neutral, less than 7 means acidic, and above 7 means basic. Soils showing a high pH show reduced solubility of nutrients required for growth. This means the plants are not as able to obtain nutrients they need from the soil. Soils with extremely low pH are much more soluble to nutrients and tend to have nutrients at toxic levels. It is harmful if the plants get too much nutrients. The most suitable pH for plants is between 6.0 and 6.5. At these levels, microbiological activity is enhanced along with the reduction of soluble toxic minerals. The most effective way to correct for low soil pH is the addition of lime. Lime is a material that is mainly a chemical compound of calcium. Depending on the size of the garden, the type of soil, and the pH, different amounts of lime are needed. Use Table Six of this packet for a liming guide. The soils tested at the EcoTarium show pH levels that are slightly too low for agricultural growth. However, for the natural growth of these locations, the values are sufficient and support the life in these habitats. See Tables Two and Three for pH values (acidic/basicity).

pH Results:

Across Pathway: 4.6
Under Canopy Walkway: 4.8
Lower Pond Area: 5.4

Macronutrients

Macronutrients are those nutrients required in large amounts for healthy crops and gardens. These include Nitrogen, Phosphorous, and Potassium along with Calcium, Sulfur, and Magnesium. These nutrients are often released from the breakdown of rocks, the decomposition of plant and animal remains, water, and fertilizers.

Nitrogen, Phosphorous, and Potassium

The three most essential nutrients for any kind of soil are Nitrogen, Phosphorous, and Potassium. These nutrients are needed the most and used the fastest by plants.

Fertilizers often contain Nitrogen, Phosphorous, and Potassium and can vary in percentages of each. The percentage of Nitrogen, Phosphorous, and Potassium in fertilizers is given as ratios. As an example, a fertilizer may contain a 10-20-5 ratio of Nitrogen, Phosphorus, and Potassium. This means 10% of the fertilizer is Nitrogen, 20% is Phosphorous, and 5% is Potassium. The rest of the fertilizer is just filler. Filler is the component of fertilizer that has no nutrient value, but is important for water retention and to help evenly spread out the nutrients.

Nitrogen

Nitrogen is a major component in chlorophyll, proteins and vitamins. It stimulates leaf growth, improves the flavor of vegetables and increases fruit and vegetable size. Too much Nitrogen can have harmful effects, though, such as delayed growth, weakened stems, and potential health hazards by the accumulation of nitrates in fruits and vegetables. As measured by the LaMotte Soil Test, the amount of Nitrogen should be medium level. The soils tested at the EcoTarium show low levels of Nitrogen. One way to increase Nitrogen levels is to apply commercial fertilizers. These should be applied and worked into deficient soils. Another way to increase levels of Nitrogen is to apply compost matter. For the natural growth present in these locations a nitrogen level of low to medium is desired. This would measure out to 15-40 lbs./acre.

There are three forms of Nitrogens that we test for: Nitrate, Nitrite, and Ammonia. Nitrate and Nitrite Nitrogen are usually found in small quantities. Ammonia Nitrogen is most abundant form of Nitrogen. The desired amount of Ammonia Nitrogen is low to medium. Use Table Four for approximate values expressed in pounds/acre.

<u>Nitrate Nitrogen Results:</u>

Across Pathway: <10 lbs./acre
Under Canopy Walkway: <10 lbs./acre
Lower Pond Area: 11 lbs./acre

<u>Nitrite Nitrogen Results:</u>

Across Pathway: 3 lbs./acre
Under Canopy Walkway: 3 lbs./acre
Lower Pond Area: 2 lbs./acre

<u>Ammonia Nitrogen Results:</u>

Across Pathway: 25 lbs./acre
Under Canopy Walkway: 16 lbs./acre
Lower Pond Area: <10 lbs./acre

Phosphorus

Phosphorous contributes to the hardiness of plants. It stimulates root growth, increases total fruit and vegetable growth, and increases the rate at which plants grow and mature. Phosphorous also improves the taste of fruits and vegetables and plays an important role in the development of seeds and the defense against disease. Because Phosphorous is so important and utilized in many plant functions, it can be depleted quickly. For natural growth in these locations, at least 75 lbs. per acre, and as much as 200 lbs. per acre, is the desired amount for healthy soil. Phosphorous content should be monitored regularly. Soils deficient in phosphorous can be fixed by applying commercial fertilizers. Excessive amounts of Phosphorous have not been shown to be harmful to plant growth, so the more, the better! From the results below, it is obvious that the amount of phosphorous around the EcoTarium is very low and should be monitored.

Phosphorus Results:

Across Pathway: <20 lbs./acre
Under Canopy Walkway: <20 lbs./acre
Lower Pond Area: 34 lbs./acre

Potassium (Potash)

Potassium, commonly know as potash, is readily available in most soils. Clay soils tend to have the most Potassium, while sandy soils tend to have very little. Potassium increases resistance to disease, protects from water loss, strengthens stems and stalks, enhances fruit size, taste and texture, and is involved in chlorophyll production. The desired amount of potassium at the EcoTarium is low, around 200 lbs. /acre.

Potassium Results:

Across Pathway: 310 lbs./acre
Under Canopy Walkway: 400 lbs./acre
Lower Pond Area: 345 lbs./acre

The amounts of Potassium present in the EcoTarium are higher than desired, but are not at harmful levels.

Calcium

Calcium is very important in forming cell walls, stimulating root and leaf development, and boosting plant metabolism. Calcium also plays a very important role in neutralizing soil acidity, which in turn reduces poisonous effects. Soil that is deficient in Calcium is often also often exhibits a low pH level. Liming increases the amount of Calcium along with increasing pH. For a healthy forest soil, the level of Calcium should be between 7500-10000 lbs./acre. The results from the EcoTarium show very low levels of Calcium in the soil.
Liming and monitoring of the soil is recommended, especially for the soil across the Pathway and Under the Canopy Walkway.

Calcium Results:

Across Pathway: 1500 lbs./acre
Under Canopy Walkway: 1500 lbs./acre
Lower Pond Area: 5250 lbs./acre

Magnesium

Magnesium plays a central role in photosynthesis since, without Magnesium, chlorophyll would not exist. Magnesium also stimulates the uptake of other nutrients such as Phosphorous. Magnesium is often deficient in coastal soils and soils deficient in Calcium. Liming also increases Magnesium levels. Other than liming, Magnesium can be supplied in the form of magnesium salts. The soil across the pathway and under the canopy walkway has very low Magnesium amounts. The soil at the lower pond area has low to medium amounts of Magnesium.

Magnesium Results:

Across Pathway: 10 lbs./acre
Under Canopy Walkway: 10 lbs./acre
Lower Pond Area: 30 lbs./acre

Sulfates

Sulfates are the form of Sulfur that is essential to the formation of protein and affects various aspects of plant metabolism. The major sources of soil sulfates are fertilizers containing sulfate compounds and atmospheric sulfur dioxide carried into the soil by rain. The amount of sulfates in the EcoTarium soil ranges from low to medium (75-250 lbs./ acre).

Sulfates Results:

Across Pathway: 100 lbs./acre
Under Canopy Walkway: 150 lbs./acre
Lower Pond Area: 200 lbs./acre

Micronutrients

Micronutrients, needed in far less quantities that Macronutrients, include nutrients such as Manganese, Ferric Iron, Aluminum, and Chloride. Micronutrients are needed in plants for the formation of chlorophyll as well as plant growth. These nutrients are important to the organisms that consume the vegetation that grows in the soil. These Micronutrient organisms help with the building of flesh and blood and are extremely important in the diet of warm-blooded animals.

Manganese

Manganese plays an important role in formation of chlorophyll in plants. It is also important in many of the metabolic processes in plants such as germination, photosynthesis, and other important aspects of plant development. Low amounts of manganese can be corrected by application of a soluble manganese salt. High levels of Manganese can be corrected by liming. Even very low readings of manganese are sufficient for normal forest soil and are considered healthy. See Table Four for data analysis.

Manganese Results:

Across Pathway: 10 lbs./acre
Under Canopy Walkway: 15 lbs./acre
Lower Pond Area: <10 lbs./acre

Ferric Iron

Iron is essential to the formation of chlorophyll. An Iron deficiency in soil causes Chlorosis in plants. Chlorosis is the reduced amount of chlorophyll in plants that causes decoloration of the leaves and stems, loses their natural green. Low levels of Iron can be corrected by the application of ferrous sulfate or iron chelates. The levels of Iron found at the EcoTarium are low to medium amounts.

Ferric Iron:

Across Pathway: <10 lbs./acre
Under Canopy Walkway: 35 lbs./acre
Lower Pond Area: <10 lbs./acre

Chloride

Chloride is needed for normal plant growth. Excessive concentrations are toxic to plants, but no known Chloride deficiency problems exist in the soil. Trace amounts of Chloride are ample enough for plant growth. Chloride is known to be essential for normal plant growth, however little is known about what it does in plants. Application of fertilizer may increase Chloride levels. Chlorides are removed from the soil by leaching. The Chloride values at the EcoTarium range from medium to high.

Chloride Results:

Across Pathway: 100 lbs./acre
Under Canopy Walkway: 150 lbs./acre
Lower Pond Area: 300 lbs./acre

Aluminum

Aluminum falls under a category called "Trace Elements", which are needed for a healthy soil, but at very low levels. A high level of Aluminum can be toxic to plants and indicates an undesirable acidic soil. Liming can reduce levels of Aluminum. Plants that normally thrive on acid soils may fail in a soil with a high active Aluminum test reading. A medium test result is generally tolerable, especially for grasses. A low aluminum test result is preferable. The levels of aluminum found at the EcoTarium were very high. This should be monitored. The high levels may be caused by the industrial history of Worcester.

Aluminum Results:

Across Pathway: 250 lbs./acre
Under Canopy Walkway: 250 lbs./acre
Lower Pond Area: 250 lbs./acre

Summary Table of Test Results

Test	Desired Amounts	Across Pathway	Under Canopy Walkway	Lower Pond Area
Humus	3 to 4	less than 1	2.5	1.75
pH	6.0 - 6.5	4.6	4.8	5.4
Macronutrients				
Nitrate Nitrogen	15-40 lbs./acre	less than 10 lbs./acre	less than 10 lbs./acre	11 lbs./acre
Nitrite Nitrogen	15-40 lbs./acre	3 lbs./acre	3 lbs./acre	2 lbs./acre
Ammonia Nitrogen	15-40 lbs./acre	25 lbs./acre	16 lbs./acre	less than 10 lbs./acre
Phosphorous	75 - 200 lbs./ acre	less than 29 lbs./acre	less than 20 lbs./acre	34 lbs./acre
Potassium	200 lbs./ acre	310 lbs./acre	400 lbs./acre	345 lbs./acre
Calcium	7500-10000 lbs./ acre	1500 lbs./acre	1500 lbs./acre	5250 lbs./acre
Magnesium	50 lbs./ acre	10 lbs./acre	10 lbs./acre	30 lbs./acre
Sulfates	250 lbs./ acre	100 lbs./acre	150 lbs./acre	200 lbs./acre
Micronutrients				
Manganese	10 lbs./ acre	10 lbs./acre	15 lbs./acre	less than 10 lbs./acre
Ferric Iron	5 lbs./ acre	less than 10 lbs./acre	35 lbs./acre	less than 10 lbs./acre
Chloride	50 lbs./ acre	100 lbs./acre	150 lbs./acre	300lbs./acre
Aluminum	10 lbs./ acre	250 lbs./acre	250 lbs./acre	250 lbs./acre

Test Procedures

Soil Sampling

Soil samples should be taken from four to six inches below soil surface. Attention should be given to the terrain of the area and the different characteristics of the soil. Record these sampling areas and traits. Once the samples have been taken they should be mixed thoroughly to ensure accurate results. The samples then need to be dried completely and sifted to remove pebbles and debris. The sample is now ready for any chemical analysis.

Tests

- *For each piece of equipment and reagent a number is assigned for identification.*
- *Demineralized water bottle (1155) needs to stay full of water so that resin never goes dry. The bottle can be refilled with tap water.*
- *Parts per million can be converted to pounds per acre by multiplying the ppm value by two.*
  Example: 100 Parts/ million = 200 pounds/ acre)

pH

1. Fill test tube (0204) one third of the way up the tube with soil.
2. Add demineralized water (bottle 1155) to tube until it is one half of the way up of the tube.
3. Cap and shake well
4. Add 5 drops of Soil Flocculating Reagent (5643) to tube.
5. Cap the tube and shake well to mix. Allow contents to settle before proceeding to next step.
6. Transfer 1ml of the clear solution above the soil to one of the large depressions on a spot plate (0159).
7. Transfer a second 1 ml sample to a large depression on another spot plate.
8. To the first sample add two drops of Duples Indicator (2221) and compare color to Duplex Color Chart (1313).
9. The wide range pH test result indicates which narrow range indicator and color chart should be selected to perform a more precise pH test.
10. Choose the narrow range indicator and appropriate chart with a mid-point that is as close as possible to the value obtained in the wide range test. Add two drops of the chosen narrow range indicator to the second sample on the spot plate.
11. Compare the resulting color reaction against the appropriate color chart to obtain a precise soil pH reading.
12. Use Tables Two and Three in this packet for results.

Humus

1. Add two level measures of soil [use plastic soil measure (0819)] to a soil extraction tube (0704).
2. Fill tube to 14 ml line with demineralized water and shake well.
3. Use a 0.5 g spoon (0689) to add two level measures of Humus-Screening Reagent (5119).
4. Add 15 drops of Soil Flocculating Reagent (5643) to tube, cap, and mix gently. Allow settling for several minutes.
5. Use a piece of fluted filter paper (0465) and a plastic funnel (0459) to filter the mixture into a second extraction tube.
6. Compare the clear filtration in the second extraction tube with the Humus Color Chart (1384).
7. Use Table One for content of Humus in soil interpretation.

Chlorides

1. Fill a 5 ml soil tube (0249) with demineralized water to 5 ml line.
2. Use the plastic soil measure (0819) to add one level measure of the soil sample to the tube. Cap and shake well for 2-3 min.
3. Use a piece of fluted filter paper (0465) and a plastic funnel (0459) to filter the mixture into a second 5 ml soil tube.
4. Use a transfer pipet to transfer five drops of the filtrate in the second tube to a flat-bottomed turbidity vial (0242).
5. Add one drop of Chloride Test Solution (5111) to the vial. Gently mix.
6. Match the turbidity or amount of precipitation against the turbidity standards on the Chloride Chart (1304). Lay the chart flat under natural light and hold the turbidity vial ½ inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. Multiply the results by two to get pounds per acre.

   Example: A Turbidity reading of 50 = 100 pounds/acre

This extraction procedure will be used to make a soil extract for use in the soil tests that follow.

Extraction Procedure

1. Fill an Extraction Tube (0704) to the 14 ml line with the Universal Extraction Solution (5173).
2. Add two level measures (soil measure 0819) of the soil sample.
3. Cap and shake for a minute.
4. Filter the soil suspension into a second extraction tube (0704). The filtrate in the second extraction tube is the general soil extract for use in the soil test procedures listed below.

Nitrate Nitrogen

1. Transfer 1 ml of the soil extract to one of the large depressions on a spot plate (0159).
2. Add ten drops of Nitrate Test Reagent #1 (5146).
3. Use a 0.5 g spoon (0698) to add one level measure of Nitrate Reagent #2 (5147).
4. Stir thoroughly with a clean stirring rod (0519). Allow it to stand five minutes for full color development.
5. Match sample color with the Nitrate Nitrogen Color Chart (1315).
6. Record as pounds per acre nitrate nitrogen.

Nitrite Nitrogen

1. Transfer five drops of soil extract to a large depression on a spot plate.
2. Add 1 drop of Nitrite Nitrogen Test Reagent #1 (5151).
3. Add 1 drop of Nitrite Nitrogen Test Reagent #2 (5152) and mix well.
4. Add 3 drops of Nitrite Nitrogen Test Reagent #3 (5153) and mix. Wait for one minute.
5. Match sample color to a color standard on the Nitrite Nitrogen Color Chart (1310) and record as pounds per acre nitrite nitrogen.

Ammonia Nitrogen

1. Transfer four drops of the soil extract to one of the larger depressions on a spot plate.
2. Add one drop of Ammonia Nitrogen Test Solution (5103) and stir.
3. Allow standing for one minute.
4. Compare the resulting color against the Ammonia Nitrogen Color Chart (1302). The results are expressed in relative values of ammonia nitrogen from very low to very high.
5. Use Table Five of this packet for result interpretation.

Phosphorous

1. Use a transfer pipet (0364) to fill a "Phosphorous B" Tube (0244) to the mark with the soil extract.
2. Add 6 drops of Phosphorous Test Reagent #2 (5156). Cap and shake to mix.
3. Add one Phosphorous Reagent #3 Tablet (5157). Cap and shake until dissolved.
4. Immediately compare the color that develops in the test tube against the Phosphorous Color Chart (1312). Hold the tube about one inch in front of the white surface in the center of the color chart. View the chart and sample under natural light for optimum color comparison. The test result is read in pounds per acre Available Phosphorus.

Potassium (Potash)

1. Fill a Potash "A" Tube (0245) to the lower mark with the soil extract.
2. Add Potassium Reagent B Tablet (5161). Cap and shake until dissolved.
3. Add Potassium Reagent C (5162) until the Potash "A" Tube is filled to the upper mark. Allow the Potassium Reagent C (5162) to run slowly down the side of the tube and swirl the tube to mix. Precipitation will form if Potassium is present.
4. Stand the empty Potash "B" Tube (0246) on the Potassium Reading Plate (1107), a rectangular piece of white plexiglass with a solid black line down the middle. Place the tube directly over the black line.
5. Fill a transfer pipet (0364) with the test sample from the Potash "A" Tube.
6. Slowly add the test sample to the Potash "B" Tube, allowing it to run down the side of the tube. Observe the black line down through the Potash "B" Tube. Continue to add the test sample until the black line just disappears.
7. Record as pounds per acre Available Potassium where the level of the liquid meets the scale printed on the side of the Potash "B" Tube.
8. If the test result is equal to or greater than 400 pounds per acre, repeat the test on a diluted test sample as follows:

   A. Fill Potash "C" Tube (0247) to the lower mark with the general soil extract.
   B. Add Universal Extracting Solution (5173) to the upper mark and mix.
   C. Using this diluted extract follow Steps 1 through 7 above.
9. Multiply the test result by 2 to obtain pounds per acre Available Potassium.

Calcium

1. Add five drops of the soil extract to a flat-bottomed glass turbidity vial (0242).
2. Add one drop of Calcium Test Solution (5108) and mix.
3. Match the milky solution of the test sample against the turbidity standards on the Replaceable Calcium Chart (1303). Lay the chart flat under natural light and hold the turbidity vial ½ inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. Multiply the test result by 10 to obtain a result in pounds per acre.

   Example: A Turbidity reading of 350 = 3500 lbs./ acre

Magnesium

1. Transfer ten drops of the soil extract to one of the larger depressions on a spot plate (0159).
2. Add one drop of Magnesium Test Solution #1 (5140). Stir with a clean rod (0519). A pale yellow color will develop.
3. Add Manganese-Magnesium Test Solution #2 (5145) one drop at a time with stirring until the pale yellow color changes to one of the darker shades indicated on the Magnesium Color Chart (1306). The test results are expressed in a range of very low to very high. See Table Four in this packet for approximate corresponding value in pounds per acre.

Sulfate

1. Transfer five drops of the soil extract to a flat-bottomed turbidity vial (0242).
2. Add one drop of Sulfate Test Solution (5171). Swirl to mix.
3. Compare the turbidity of the sample to the turbidity standard of the Sulfate Chart (1314). Lay the chart flat under natural light and hold the turbidity vial ½ inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. Multiply the test result by two to obtain a result in pounds per acre.

   Example: A Turbidity reading of 100 = 200 lbs./ acre

Manganese

1. Add ten drops of the soil extract to one of the larger depressions on a spot plate.
2. Add one drop of Manganese Test Solution #1 (5143).
3. Add one drop on Manganese-Magnesium Test Solution #2 (5145) and immediately stir and compare

Twenty-two points, plus triple-word-score, plus fifty points for using all my letters. Game's over. I'm outta here.against the Manganese Color Chart (1307). The sample color may fade after 5-10 seconds so reading should be made within the first few seconds after mixing.

4. Use Table Four in this packet for result interpretation.

Ferric Iron

1. Transfer four drops of the soil extract to one of the larger depressions on a spot plate.
2. Use the 0.05g spoon to add one level measure of Iron Reagent Powder (5275) and mix.
3. Add one drop of Ferric Iron Test Solution (5116) and mix again.
4. Match the resulting color to the Ferric Iron Chart (1348). The test result is read in pounds per acre Ferric Iron.

Aluminum

1. Add two drops of the soil extract to one of the larger depressions on a spot plate (0159).
2. Add two drops of Universal Extraction Solution (5173).
3. Add one drop of Aluminum Test Solution (5101).
4. Stir and allow standing for one minute.
5. Match the resulting color with the Active Aluminum Color Chart (1301).
6. Use Table Four in this packet for result interpretation.

Conversion Factors and Tables

parts per million X 2 = pounds /acre

Humus

Table One: Humus Content in Soil

Humus Reading	1	2	3	4	5
Agricultural Soils	Low	Medium	High		
Garden Soils		Low	Medium	High	
Organic Soils			Low	Medium	High

pH

Table Two: Indicators for more precise pH testing

Indicator	pH Range	Indicator Code	Color Chart Code
Bromcresol Green	3.8-5.4	2207	1328
Chlorphenol Red	5.2-6.8	2209	1329
Bromthymol Blue	6.0-7.6	2210	1331
Phenol Red	6.8-8.4	2211	1332
Thymol Blue	8.0-9.6	2213	1335

Table Three: Relationship between pH, acidity, and basicity.

pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0	pH 9.0
Strongly acidic	Moderate to strong acidity	Slight to moderate acidity	Neither acidic nor basicity	Slight to moderate basicity	Moderate to strong basicity

Nitrogen, Magnesium, Aluminum, Manganese:

Table Four: Approximate Values Expressed in pounds per acre

Test Factor	Very Low	Low	Medium	High	Very High
Ammonia Nitrogen	10	20	80	200	300
Magnesium	10	20	50	160	300
Aluminum	10	20	60	160	250
Manganese	NA	10	24	50	80

Table Five: Average Amount of Hydrated Lime Needed For Different Acid Soils in Pounds per Yard

LaMotte Test Reading pH	Sandy Soil	Sandy Loam	Loam	Silt and Clay Loam
4	1/2	1	1 1/2	2
5	1/4	1/2	1	1 1/2
6	1/8	1/4	1/4	1/2
7	None	None	None	None
8	None	None	None	None

Table Six: Small Area Table for converting pounds per acre to amounts of fertilizer or lime required for small plots or gardens

25 lbs. per acre	1 lb. to a plot	10 ft. x 174 ft.
50 lbs. per acre	1 lb. to a plot	10 ft. x 87 ft.
100 lbs. per acre	1 lb. to a plot	10 ft. x 43.5 ft.
150 lbs. per acre	1 lb. to a plot	10 ft. x 29 ft.
200 lbs. per acre	1 lb. to a plot	10 ft. x 21.75 ft.
300 lbs. per acre	1 lb. to a plot	10 ft. x 14.5 ft.
400 lbs. per acre	1 lb. to a plot	10 ft. x 10.75 ft.
500 lbs. per acre	1 lb. to a plot	10 ft. x 8.5 ft.
1000 lbs. per acre	1 lb. to a plot	10 ft. x 8.5 ft.
2000 lbs. per acre	1 lb. to a plot	10 ft. x 4.5 ft.

Precautionary Measures

PRODUCT	Eye Protection	gloves	lab coat	mechanical ventilation	flammable
Aluminum Test Solution	goggles	Y	Y	Y	Y
Ammonia Nitrogen Test Solution	goggles	Y	Y	N	N
Calcium Test Solution	goggles	Y	Y	N	N
Chloride Test Solution	goggles	Y	Y	N	N
Ferric Iron Test Solution	goggles	Y	Y	N	N
Iron Reagent Powder	goggles	Y	Y	Y	Y
Magnesium Test Solution #1	goggles	Y	Y	Y	Y
Manganese Test Solution #1	goggles	Y	Y	N	N
Manganese-Magnesium Test Solution #2	goggles	Y	Y	N	N
Nitrite-Nitrogen Test Reagent #1	goggles	Y	Y	Y	N
Nitrite-Nitrogen Test Reagent #2	goggles	Y	Y	Y	N
Nitrite-Nitrogen Test Reagent #3	goggles	Y	Y	N	N
Nitrate Reagent #1	goggles	Y	Y	N	N
Nitrate Reagent #2	goggles	Y	Y	Y	N
Potassium Reagent B	goggles	Y	Y	N	N
Potassium Reagent C	goggles	Y	Y	Y	Y
Phosphorus Reagent 2	goggles	Y	Y	N	N
Phosphorus Reagent #3 tablets	none	N	N	N	N
Sulfate Test Solution	goggles	Y	Y	N	N
Universal Extracting Solution	goggles	Y	Y	N	N

First Aid

PRODUCT	eye contact	ingestion	inhalation	skin contact
Aluminum Test Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Ammonia Nitrogen Test Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Calcium Test Solution	flush w/water	drink plenty of water	~	wash & rinse w/water
Chloride Test Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Ferric Iron Test Solution	flush w/water	induce vomiting	remove to fresh air	wash & rinse w/water
Iron Reagent Powder	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Magnesium Test Solution #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Manganese Test Solution #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Manganese-Magnesium Test Solution #2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrite-Nitrogen Test Reagent #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrite-Nitrogen Test Reagent #2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrite-Nitrogen Test Reagent #3	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrate Reagent #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrate Reagent #2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Potassium Reagent B	flush w/water	induce vomiting	remove to fresh air	wash & rinse w/water
Potassium Reagent C	flush w/water	call physician	remove to fresh air	wash & rinse w/water
Phosphorus Reagent 2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Phosphorus Reagent #3 tablets	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Sulfate Test Solution	flush w/water	induce vomiting	remove to fresh air	wash & rinse w/water
Universal Extracting Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water

Interested in Finding Out More?

Web Sites:

www.hgtv.com

www.vg.com

www.netusa1.net/~lindley/

www.bhglive.com/gardening/index.html

www.flinet.com/~gallus/index.html

www.familygardening.com/

www.geocites.com/EnchantedForest/Glade/3313/

Additional Resources:

"Better Homes and Gardens Magazine"

"Home and Garden Television" - television station

Appendix III:

Sample of the Test Recording Sheet

Name: Date Sampled:

Sample Name: Date Tested:

Description of location and topography:

Texture: Color:

Test	Results	Comments
Humus		
Phosphorus		
Potassium		
Nitrate Nitrogen		
Nitrite Nitrogen		
Ammonia Nitrogen		
Magnesium		
Manganese		
Aluminum		
Calcium		
Chloride		
Ferric Iron		
Sulfate		

Appendix IV a:

SCOPE Database

Lincoln Street

Database of SCOPE Lincoln Street Test Results

Test	Desired Amounts	Front Yard	Back Yard
Humus	3 to 4	2	less than 1
pH	6.0 - 6.5	6.7	6.3
Macronutrients			
Nitrate Nitrogen	15-40 lbs./acre	15 lbs./acre	15 lbs./acre
Nitrite Nitrogen	15-40 lbs./acre	less than 1lbs./acre	less than 1 lbs./acre
Ammonia Nitrogen	15-40 lbs./acre	10 lbs./acre	10 lbs./acre
Phosphorous	75-200 lbs./acre	100 lbs./acre	10 lbs./acre
Potassium	200 lbs./acre	650 lbs./acre	236 lbs./acre
Calcium	7500-10000 lbs./acre	14000 lbs./acre	10000 lbs./acre
Magnesium	50 lbs./acre	50 lbs./acre	20 lbs./acre
Sulfates	250 lbs./acre	200 lbs./acre	200 lbs./acre
Micronutrients			
Manganese	10 lbs./acre	NA	NA
Ferric Iron	5 lbs./acre	less than 5 lbs./acre	less than 5 lbs./acre
Chloride	50 lbs./acre	100 lbs./acre	400 lbs./acre
Aluminum	10 lbs./acre	10 lbs./acre	20 lbs./acre

Dates of tests and test takers omitted here. For this information see Appendix III.

Appendix IV b:

SCOPE Database

Providence Street

Database of SCOPE Providence Street Test Results

Test	Desired Amounts	Garden	Compost
Humus	3 to 4	less than 1	4
pH	6.0 - 6.5	5.4	8.2
Macronutrients			
Nitrate Nitrogen	15-40 lbs./acre	25 lbs./acre	30 lbs./acre
Nitrite Nitrogen	15-40 lbs./acre	less than 1 lbs./acre	1 lbs./acre
Ammonia Nitrogen	15-40 lbs./acre	10 lbs./acre	10 lbs./acre
Phosphorous	75-200 lbs./acre	10 lbs./acre	200 lbs./acre
Potassium	200 lbs./acre	360 lbs./acre	460 lbs./acre
Calcium	7500-10000 lbs./acre	1400 lbs./acre	5600 lbs./acre
Magnesium	50 lbs./acre	20 lbs./acre	50 lbs./acre
Sulfates	250 lbs./acre	less than 100 lbs./acre	500 lbs./acre
Micronutrients			
Manganese	10 lbs./acre	NA	NA
Ferric Iron	5 lbs./acre	less than 5 lbs./acre	less than 5 lbs./acre
Chloride	50 lbs./acre	50 lbs./acre	200 lbs./acre
Aluminum	10 lbs./acre	250 lbs./acre	10 lbs./acre

Dates of tests and test takers omitted here. For this information see Appendix III.

Appendix IV c:

EcoTarium Database

Database of EcoTarium Test Results

Test	Desired Amounts	Across Pathway	Under Canopy Walkway	Lower Pond Area
Humus	3 to 4	less than 1	2.5	1.75
pH	6.0 - 6.5	4.6	4.8	5.4
Macronutrients				
Nitrate Nitrogen	15-40 lbs./acre	less than 10 lbs./acre	less than 10 lbs./acre	11 lbs./acre
Nitrite Nitrogen	15-40 lbs./acre	3 lbs./acre	3 lbs./acre	2 lbs./acre
Ammonia Nitrogen	15-40 lbs./acre	25 lbs./acre	16 lbs./acre	less than 10 lbs./acre
Phosphorous	75 - 200 lbs./ acre	less than 29 lbs./acre	less than 20 lbs./acre	34 lbs./acre
Potassium	200 lbs./ acre	310 lbs./acre	400 lbs./acre	345 lbs./acre
Calcium	7500-10000 lbs./ acre	1500 lbs./acre	1500 lbs./acre	5250 lbs./acre
Magnesium	50 lbs./ acre	10 lbs./acre	10 lbs./acre	30 lbs./acre
Sulfates	250 lbs./ acre	100 lbs./acre	150 lbs./acre	200 lbs./acre
Micronutrients				
Manganese	10 lbs./ acre	10 lbs./acre	15 lbs./acre	less than 10 lbs./acre
Ferric Iron	5 lbs./ acre	less than 10 lbs./acre	35 lbs./acre	less than 10 lbs./acre
Chloride	50 lbs./ acre	100 lbs./acre	150 lbs./acre	300lbs./acre
Aluminum	10 lbs./ acre	250 lbs./acre	250 lbs./acre	250 lbs./acre

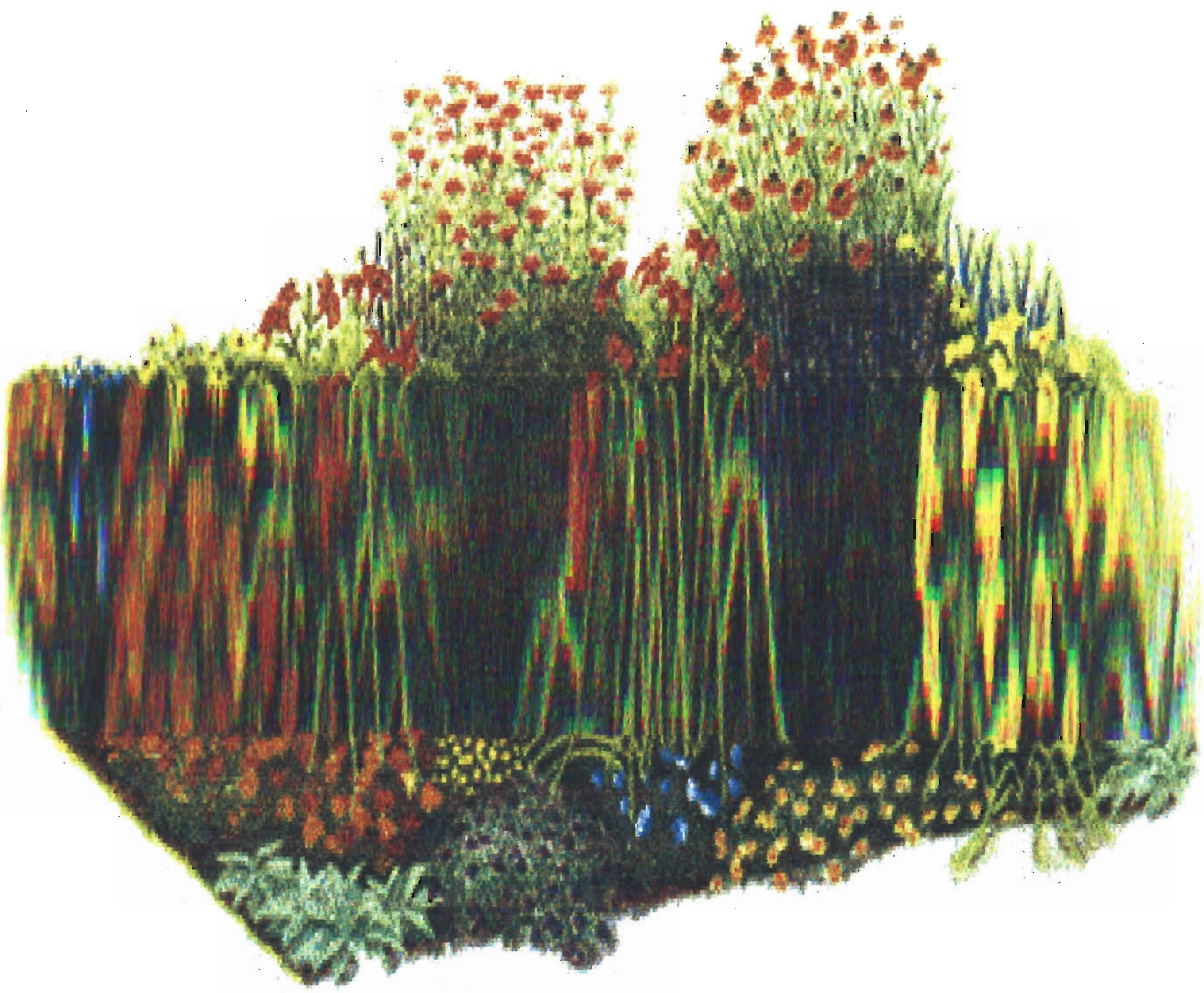
Dates of tests and test takers omitted here. For this information see Appendix III.

Appendix V a:

The SCOPE Groups Soil Testing and Analysis Booklet

Lincoln Street

SCOPE Soil Testing and Analysis



Provided by WPI Students:
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Melissa Morse
Melissa Wright

Table of Contents

Introduction

This booklet is intended for the study of the chemical, mineral and organic content of Girl's Incorporated garden soil. The amount of humus, the pH level, and the amount of various nutrients in the garden soil have been measured and recorded. This booklet is also for use in remedial measures for the garden soil. As reviewed in this booklet, Humus is the part of soil that comes from rotted vegetables and decomposing animals; pH is a measurement of how acidic or basic the soil is; and Nutrients are all of the other materials important to plant growth. Three of the most important nutrients are Phosphorus, Potassium, and Nitrogen.

The tests in this booklet measure the amount of nutrients found in flower and vegetable gardens. These nutrients contribute to the overall health of soil. Not all types of gardens need the same amounts of nutrients, or even the same kinds. Flower gardens tend to need more nutrients than vegetable gardens. However, vegetable gardens need more Phosphorous than do flower gardens. Nitrogen is important for making plant leaves and stems healthy, green, and also helps the plants grow.

Potassium helps plants produce chlorophyll and resist disease. Not all soils contain the necessary nutrients. Various nutrients are necessary for healthy plants, however. This doesn't mean that plants can't grow there, but certain measures need to be taken to make sure they grow healthy and strong. Some soils can contain too much of a certain nutrient which can be harmful to plants. There are steps to fix these kinds of situations as well. In the following pages, the different kinds of soil tests are listed along with how to fix unfavorable conditions and some examples from the tests performed on the initial soil tests.

Within this booklet you will find a description of each of the nutrients that have been tested, the results that were found, suggested remedial measures, test procedures, helpful tables, safety information, and locations of additional information for further study of soil ecology and plant growth.

Humus

One of the best ways to determine the overall health of a soil is to measure the humus content. Humus is the result of the decay of dead plant and animal matter. Bacteria and fungi are responsible for the breakdown of nutrients contained within this matter and the spreading of it throughout the soil. These organisms also contribute to healthy biological functions such as retention of water and aeration of the soil. Using the LaMotte Humus Test, one wants values between 3 and 4 to ensure healthy humus content. One way to correct for humus deficiency is to apply compost matter, animal manure, or garden and crop "leftovers" such as stems and dead flowers. The soil tested in the front yard garden had a humus content of two and the back yard garden soil had a content of less than one. The garden soil humus content is very low and needs to be adjusted and monitored. The addition of fertilizer would help bring the humus content to a sufficient level. See Table One.

<u>Humus Results:</u>

Front Yard: 2

Back Yard: less than 1

pH

The pH of a soil is the measure of the soil's relative acidity or basicity. The pH scale ranges from 0 to 14. A pH of 7 indicates neutral, less than 7 means acidic, and above 7 means basic. Soils showing a high pH show reduced solubility of nutrients required for growth. This means the plants are not as able to obtain nutrients they need from the soil. Soils with extremely low pH are much more soluble to nutrients and tend to have nutrients at toxic levels. It is harmful if the plants get too much nutrients. The most suitable pH for plants is between 6.0 and 6.5. At these levels, microbiological activity is enhanced along with the reduction of soluble toxic minerals. The most effective way to correct for low soil pH is the addition of lime. Lime is a material that is mainly a chemical compound of calcium. Depending on the size of the garden, the type of soil, and the pH, different amounts of lime are needed. Use Table Six of this booklet for a liming guide. The front yard garden soil showed a pH level that was slightly too high, but not too high for healthy plant growth. The back yard garden soil pH level was slightly low, but not at a harmful level. See Tables Two and Three for pH values (acidic/basicity).

<u>pH Results:</u>

Front Yard: 6.7

Back Yard: 6.3

<u>Macronutrients</u>

Macronutrients are those nutrients required in large amounts for healthy crops and gardens. These include Nitrogen, Phosphorous, and Potassium along with Calcium, Sulfur, and Magnesium. These nutrients are often released from the breakdown of rocks, the decomposition of plant and animal remains, water, and fertilizers.

Nitrogen, Phosphorous, and Potassium

The three most essential nutrients for any kind of soil are Nitrogen, Phosphorous, and Potassium. These nutrients are needed the most and used the fastest by plants. Fertilizers often contain Nitrogen, Phosphorous, and Potassium and can vary in percentages of each. The percentage of Nitrogen, Phosphorous, and Potassium in fertilizers is given as ratios. As an example, a fertilizer may contain a 10-20-5 ratio of Nitrogen, Phosphorus, and Potassium. This means 10% of the fertilizer is Nitrogen, 20% is Phosphorous, and 5% is Potassium. The rest of the fertilizer is just filler. Filler is the component of fertilizer that has no nutrient value, but is important for water retention and to help evenly spread out the nutrients.

Nitrogen

Nitrogen is a major component in chlorophyll, proteins and vitamins. It stimulates leaf growth, improves the flavor of vegetables and increases fruit and vegetable size. Too much Nitrogen can have harmful effects, though, such as delayed growth, weakened stems, and potential health hazards by the accumulation of nitrates in fruits and vegetables. The desired levels of Nitrogen range from low to medium. This would measure out to 15-40 lbs./acre.

There are three forms of Nitrogens that we test for: Nitrate, Nitrite, and Ammonia. Nitrate and Nitrite Nitrogen are usually found in small quantities. Ammonia Nitrogen is most abundant form of Nitrogen. Use Table Four for approximate values expressed in pounds/acre. The overall Nitrogen content for both locations were sufficient.

Nitrate Nitrogen Results:

Front Yard: 15 lbs./acre

Back Yard: 15 lbs./acre

Nitrite Nitrogen Results:

Front Yard: less than 1 lbs./acre

Back Yard: less than 1 lbs./acre

Ammonia Nitrogen Results:

Front Yard: 10 lbs./acre

Back Yard: 10 lbs./acre

Phosphorus

Phosphorous contributes to the hardiness of plants. It stimulates root growth, increases total fruit and vegetable growth, and increases the rate at which plants grow and mature. Phosphorous also improves the taste of fruits and vegetables and plays an important role in the development of seeds and the defense against disease. Because Phosphorous is so important and utilized in many plant functions, it can be depleted quickly. For natural growth in these locations, at least 75 lbs. per acre, and as much as 200 lbs. per acre, is the desired amount for healthy soil. Phosphorous content should be monitored regularly. Soils deficient in phosphorous can be fixed by applying commercial fertilizers. Excessive amounts of Phosphorous have not been shown to be harmful to plant growth, so the more, the better! The levels of Phosphorus in both locations were very low. The addition of fertilizer will increase the amount of Phosphorus in the soil.

Phosphorus Results:

Front Yard: 100 lbs./acre
Back Yard: 10 lbs./acre

Potassium (Potash)

Potassium, commonly know as potash, is readily available in most soils. Clay soils tend to have the most Potassium, while sandy soils tend to have very little. Potassium increases resistance to disease, protects from water loss, strengthens stems and stalks, enhances fruit size, taste and texture, and is involved in chlorophyll production. The desired amount of Potassium is low, around 200 lbs. /acre. The levels of Potassium for the two gardens are very high.

Potassium Results:

Front Yard: 650 lbs./acre
Back Yard: 236 lbs./acre

The amounts of Potassium present in the garden soils are higher than desired. A suggested remedial measure would be to add filler soil that has a low Potassium level.

Calcium

Calcium is very important in forming cell walls, stimulating root and leaf development, and boosting plant metabolism. Calcium also plays a very important role in neutralizing soil acidity, which in turn reduces poisonous effects. Soil that is deficient in Calcium is often also often exhibits a low pH level. Liming increases the amount of Calcium along with increasing pH. For a healthy soil, the level of Calcium should be between 7500-10000 lbs./acre. The amount of Calcium in the Front Yard is too high, but the Back Yard level is sufficient.

Calcium Results:

Front Yard: 14000 lbs./acre
Back Yard: 10000 lbs./acre

Magnesium

Magnesium plays a central role in photosynthesis since, without Magnesium, chlorophyll would not exist. Magnesium also stimulates the uptake of other nutrients such as Phosphorous. Magnesium is often deficient in coastal soils and soils deficient in Calcium. Liming also increases Magnesium levels. Other than liming, Magnesium can be supplied in the form of magnesium salts. The level of Magnesium in the Garden Soils were sufficient.

Magnesium Results:

Front Yard: 50 lbs./acre
Back Yard: 20 lbs./acre

Sulfates

Sulfates are the form of Sulfur that is essential to the formation of protein and affects various aspects of plant metabolism. The major sources of soil sulfates are fertilizers containing sulfate compounds and atmospheric sulfur dioxide carried into the soil by rain. The amount of Sulfates in the Garden Soils was slightly low, but sufficient for healthy growth. The addition of the Compost will adjust the garden sulfate level.

Sulfates Results:

Front Yard: 200 lbs./acre
Back Yard: 200 lbs./acre

Micronutrients

Micronutrients, needed in far less quantities that Macronutrients, include nutrients such as Manganese, Ferric Iron, Aluminum, and Chloride. Micronutrients are needed in plants for the formation of chlorophyll as well as plant growth. These nutrients are important to the organisms that consume the vegetation that grows in the soil. These Micronutrient organisms help with the building of flesh and blood and are extremely important in the diet of warm-blooded animals.

Manganese

Manganese plays an important role in formation of chlorophyll in plants. It is also important in many of the metabolic processes in plants such as germination, photosynthesis, and other important aspects of plant development. Low amounts of manganese can be corrected by application of a soluble manganese salt. High levels of Manganese can be corrected by liming. The levels of Manganese in the Garden Soils were so low they were not detected. The addition of Manganese salt is the best remedial measure for this situation. See Table Four for data analysis.

Manganese Results:

Front Yard: not detected
Back Yard: not detected

Ferric Iron

Iron is essential to the formation of chlorophyll. An Iron deficiency in soil causes Chlorosis in plants. Chlorosis is the reduced amount of chlorophyll in plants that causes decoloration of the leaves and stems, loses their natural green. Low levels of Iron can be corrected by the application of ferrous sulfate or iron chelates. The levels of Iron in the Garden Soils were low, less than 5 lbs./acre. The addition of iron chelates is recommended for remedial levels.

Ferric Iron:

Front Yard: less than 5 lbs./acre
Back Yard: less than 5 lbs./acre

Chloride

Chloride is needed for normal plant growth. Excessive concentrations are toxic to plants, but no known Chloride deficiency problems exist in the soil. Trace amounts of Chloride are ample enough for plant growth. Chloride is known to be essential for normal plant growth, however little is known about what it does in plants. Application of fertilizer may increase Chloride levels. Chlorides are removed from the soil by leaching. The Garden Soils contained high levels of Chloride. Leaching the soil will bring the Chloride levels to an acceptable level.

Chloride Results:

Front Yard: 100 lbs./acre
Back Yard: 400 lbs./acre

Aluminum

Aluminum falls under a category called "Trace Elements", which are needed for a healthy soil, but at very low levels. A high level of Aluminum can be toxic to plants and indicates an undesirable acidic soil. Liming can reduce levels of Aluminum. Plants that normally thrive on acid soils may fail in a soil with a high active Aluminum test reading. A medium test result is generally tolerable, especially for grasses. A low aluminum test result is preferable (10 lbs./acre). The level of aluminum found in the garden soils was good.

Aluminum Results:

Front Yard: 10 lbs./acre
Back Yard: 20 lbs./acre

Summary of Test Results

Test	Desired Amounts	Front Yard	Back Yard
Humus	3 to 4	2	less than 1
pH	6.0 - 6.5	6.7	6.3
Macronutrients			
Nitrate Nitrogen	15-40 lbs./acre	15 lbs./acre	15 lbs./acre
Nitrite Nitrogen	15-40 lbs./acre	less than 1lbs./acre	less than 1 lbs./acre
Ammonia Nitrogen	15-40 lbs./acre	10 lbs./acre	10 lbs./acre
Phosphorous	75-200 lbs./acre	100 lbs./acre	10 lbs./acre
Potassium	200 lbs./acre	650 lbs./acre	236 lbs./acre
Calcium	7500-10000 lbs./acre	14000 lbs./acre	10000 lbs./acre
Magnesium	50 lbs./acre	50 lbs./acre	20 lbs./acre
Sulfates	250 lbs./acre	200 lbs./acre	200 lbs./acre
Micronutrients			
Manganese	10 lbs./acre	NA	NA
Ferric Iron	5 lbs./acre	less than 5 lbs./acre	less than 5 lbs./acre
Chloride	50 lbs./acre	100 lbs./acre	400 lbs./acre
Aluminum	10 lbs./acre	10 lbs./acre	20 lbs./acre

Test Procedures

Soil Sampling

Soil samples should be taken from four to six inches below soil surface. Attention should be given to the terrain of the area and the different characteristics of the soil. Record these sampling areas and traits. Once the samples have been taken they should be mixed thoroughly to ensure accurate results. The samples then need to be dried completely and sifted to remove pebbles and debris. The sample is now ready for any chemical analysis.

Tests

- *For each piece of equipment and reagent a number is assigned for identification.*
- *Demineralized water bottle (1155) needs to stay full of water so that resin never goes dry. The bottle can be refilled with tap water.*
- *Parts per million can be converted to pounds per acre by multiplying the ppm value by two.*
  Example: 100 Parts/ million = 200 pounds/ acre)

pH

1. Fill test tube (0204) one third of the way up the tube with soil.
2. Add demineralized water (bottle 1155) to tube until it is one half of the way up of the tube.
3. Cap and shake well
4. Add 5 drops of Soil Flocculating Reagent (5643) to tube.
5. Cap the tube and shake well to mix. Allow contents to settle before proceeding to next step.
6. Transfer 1ml of the clear solution above the soil to one of the large depressions on a spot plate (0159).
7. Transfer a second 1 ml sample to a large depression on another spot plate.
8. To the first sample add two drops of Duples Indicator (2221) and compare color to Duplex Color Chart (1313).
9. The wide range pH test result indicates which narrow range indicator and color chart should be selected to perform a more precise pH test.
10. Choose the narrow range indicator and appropriate chart with a mid-point that is as close as possible to the value obtained in the wide range test. Add two drops of the chosen narrow range indicator to the second sample on the spot plate.
11. Compare the resulting color reaction against the appropriate color chart to obtain a precise soil pH reading.
12. Use Tables Two and Three in this packet for results.

Humus

1. Add two level measures of soil [use plastic soil measure (0819)] to a soil extraction tube (0704).
2. Fill tube to 14 ml line with demineralized water and shake well.
3. Use a 0.5 g spoon (0689) to add two level measures of Humus-Screening Reagent (5119).
4. Add 15 drops of Soil Flocculating Reagent (5643) to tube, cap, and mix gently. Allow settling for several minutes.
5. Use a piece of fluted filter paper (0465) and a plastic funnel (0459) to filter the mixture into a second extraction tube.
6. Compare the clear filtration in the second extraction tube with the Humus Color Chart (1384).
7. Use Table One for content of Humus in soil interpretation.

Chlorides

1. Fill a 5 ml soil tube (0249) with demineralized water to 5 ml line.
2. Use the plastic soil measure (0819) to add one level measure of the soil sample to the tube. Cap and shake well for 2-3 min.
3. Use a piece of fluted filter paper (0465) and a plastic funnel (0459) to filter the mixture into a second 5 ml soil tube.
4. Use a transfer pipet to transfer five drops of the filtrate in the second tube to a flat-bottomed turbidity vial (0242).
5. Add one drop of Chloride Test Solution (5111) to the vial. Gently mix.
6. Match the turbidity or amount of precipitation against the turbidity standards on the Chloride Chart (1304). Lay the chart flat under natural light and hold the turbidity vial ½ inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. Multiply the results by two to get pounds per acre.

   Example: A Turbidity reading of 50 = 100 pounds/acre

This extraction procedure will be used to make a soil extract for use in the soil tests that follow.

Extraction Procedure

1. Fill an Extraction Tube (0704) to the 14 ml line with the Universal Extraction Solution (5173).
2. Add two level measures (soil measure 0819) of the soil sample.
3. Cap and shake for a minute.
4. Filter the soil suspension into a second extraction tube (0704). The filtrate in the second extraction tube is the general soil extract for use in the soil test procedures listed below.

Nitrate Nitrogen

1. Transfer 1 ml of the soil extract to one of the large depressions on a spot plate (0159).
2. Add ten drops of Nitrate Test Reagent #1 (5146).
3. Use a 0.5 g spoon (0698) to add one level measure of Nitrate Reagent #2 (5147).
4. Stir thoroughly with a clean stirring rod (0519). Allow it to stand five minutes for full color development.
5. Match sample color with the Nitrate Nitrogen Color Chart (1315).
6. Record as pounds per acre nitrate nitrogen.

Nitrite Nitrogen

1. Transfer five drops of soil extract to a large depression on a spot plate.
2. Add 1 drop of Nitrite Nitrogen Test Reagent #1 (5151).
3. Add 1 drop of Nitrite Nitrogen Test Reagent #2 (5152) and mix well.
4. Add 3 drops of Nitrite Nitrogen Test Reagent #3 (5153) and mix. Wait for one minute.
5. Match sample color to a color standard on the Nitrite Nitrogen Color Chart (1310) and record as pounds per acre nitrite nitrogen.

Ammonia Nitrogen

1. Transfer four drops of the soil extract to one of the larger depressions on a spot plate.
2. Add one drop of Ammonia Nitrogen Test Solution (5103) and stir.
3. Allow standing for one minute.
4. Compare the resulting color against the Ammonia Nitrogen Color Chart (1302). The results are expressed in relative values of ammonia nitrogen from very low to very high.
5. Use Table Five of this packet for result interpretation.

Phosphorous

1. Use a transfer pipet (0364) to fill a "Phosphorous B" Tube (0244) to the mark with the soil extract.
2. Add 6 drops of Phosphorous Test Reagent #2 (5156). Cap and shake to mix.
3. Add one Phosphorous Reagent #3 Tablet (5157). Cap and shake until dissolved.
4. Immediately compare the color that develops in the test tube against the Phosphorous Color Chart (1312). Hold the tube about one inch in front of the white surface in the center of the color chart. View the chart and sample under natural light for optimum color comparison. The test result is read in pounds per acre Available Phosphorus.

Potassium (Potash)

1. Fill a Potash "A" Tube (0245) to the lower mark with the soil extract.
2. Add Potassium Reagent B Tablet (5161). Cap and shake until dissolved.
3. Add Potassium Reagent C (5162) until the Potash "A" Tube is filled to the upper mark. Allow the Potassium Reagent C (5162) to run slowly down the side of the tube and swirl the tube to mix. Precipitation will form if Potassium is present.
4. Stand the empty Potash "B" Tube (0246) on the Potassium Reading Plate (1107), a rectangular piece of white plexiglass with a solid black line down the middle. Place the tube directly over the black line.
5. Fill a transfer pipet (0364) with the test sample from the Potash "A" Tube.
6. Slowly add the test sample to the Potash "B" Tube, allowing it to run down the side of the tube. Observe the black line down through the Potash "B" Tube. Continue to add the test sample until the black line just disappears.
7. Record as pounds per acre Available Potassium where the level of the liquid meets the scale printed on the side of the Potash "B" Tube.
8. If the test result is equal to or greater than 400 pounds per acre, repeat the test on a diluted test sample as follows:

   A. Fill Potash "C" Tube (0247) to the lower mark with the general soil extract.
   B. Add Universal Extracting Solution (5173) to the upper mark and mix.
   C. Using this diluted extract follow Steps 1 through 7 above.

9. Multiply the test result by 2 to obtain pounds per acre Available Potassium.

Calcium

1. Add five drops of the soil extract to a flat-bottomed glass turbidity vial (0242).
2. Add one drop of Calcium Test Solution (5108) and mix.
3. Match the milky solution of the test sample against the turbidity standards on the Replaceable Calcium Chart (1303). Lay the chart flat under natural light and hold the turbidity vial ½ inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. Multiply the test result by 10 to obtain a result in pounds per acre.

   Example: A Turbidity reading of 350 = 3500 lbs./ acre

Magnesium

1. Transfer ten drops of the soil extract to one of the larger depressions on a spot plate (0159).
2. Add one drop of Magnesium Test Solution #1 (5140). Stir with a clean rod (0519). A pale yellow color will develop.
3. Add Manganese-Magnesium Test Solution #2 (5145) one drop at a time with stirring until the pale yellow color changes to one of the darker shades indicated on the Magnesium Color Chart (1306). The test results are expressed in a range of very low to very high. See Table Four in this packet for approximate corresponding value in pounds per acre.

Sulfate

1. Transfer five drops of the soil extract to a flat-bottomed turbidity vial (0242).
2. Add one drop of Sulfate Test Solution (5171). Swirl to mix.
3. Compare the turbidity of the sample to the turbidity standard of the Sulfate Chart (1314). Lay the chart flat under natural light and hold the turbidity vial ½ inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. Multiply the test result by two to obtain a result in pounds per acre.

   Example: A Turbidity reading of 100 = 200 lbs./ acre

Manganese

1. Add ten drops of the soil extract to one of the larger depressions on a spot plate.
2. Add one drop of Manganese Test Solution #1 (5143).
3. Add one drop on Manganese-Magnesium Test Solution #2 (5145) and immediately stir and compare

Twenty-two points, plus triple-word-score, plus fifty points for using all my letters. Game's over. I'm outta here.against the Manganese Color Chart (1307). The sample color may fade after 5-10 seconds so reading should be made within the first few seconds after mixing.

4. Use Table Four in this packet for result interpretation.

Ferric Iron

1. Transfer four drops of the soil extract to one of the larger depressions on a spot plate.
2. Use the 0.05g spoon to add one level measure of Iron Reagent Powder (5275) and mix.
3. Add one drop of Ferric Iron Test Solution (5116) and mix again.
4. Match the resulting color to the Ferric Iron Chart (1348). The test result is read in pounds per acre Ferric Iron.

Aluminum

1. Add two drops of the soil extract to one of the larger depressions on a spot plate (0159).
2. Add two drops of Universal Extraction Solution (5173).
3. Add one drop of Aluminum Test Solution (5101).
4. Stir and allow standing for one minute.
5. Match the resulting color with the Active Aluminum Color Chart (1301).
6. Use Table Four in this packet for result interpretation.

Conversion Factors and Tables

parts per million X 2 = pounds /acre

Humus

Table One: Humus Content in Soil

Humus Reading	**1**	**2**	**3**	**4**	**5**
Agricultural Soils	Low	Medium	High		
Garden Soils		Low	Medium	High	
Organic Soils			Low	Medium	High

pH

Table Two: Indicators for more precise pH testing

Indicator	pH Range	Indicator Code	Color Chart Code
Bromcresol Green	3.8-5.4	2207	1328
Chlorphenol Red	5.2-6.8	2209	1329
Bromthymol Blue	6.0-7.6	2210	1331
Phenol Red	6.8-8.4	2211	1332
Thymol Blue	8.0-9.6	2213	1335

Table Three: Relationship between pH, acidity, and basicity.

pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0	pH 9.0
Strongly acidic	Moderate to strong acidity	Slight to moderate acidity	Neither acidic nor basicity	Slight to moderate basicity	Moderate to strong basicity

Nitrogen, Magnesium, Aluminum, Manganese:

Table Four: Approximate Values Expressed in pounds per acre

Test Factor	Very Low	Low	Medium	High	Very High
Ammonia Nitrogen	10	20	80	200	300
Magnesium	10	20	50	160	300
Aluminum	10	20	60	160	250
Manganese	NA	10	24	50	80

Table Five: Average Amount of Hydrated Lime Needed For Different Acid Soils in Pounds per Yard

LaMotte Test Reading pH	Sandy Soil	Sandy Loam	Loam	Silt and Clay Loam
4	1/2	1	1 1/2	2
5	1/4	1/2	1	1 1/2
6	1/8	1/4	1/4	1/2
7	None	None	None	None
8	None	None	None	None

Table Six: Small Area Table for converting pounds per acre to amounts of fertilizer or lime required for small plots or gardens

25 lbs. per acre	1 lb. to a plot	10 ft. x 174 ft.
50 lbs. per acre	1 lb. to a plot	10 ft. x 87 ft.
100 lbs. per acre	1 lb. to a plot	10 ft. x 43.5 ft.
150 lbs. per acre	1 lb. to a plot	10 ft. x 29 ft.
200 lbs. per acre	1 lb. to a plot	10 ft. x 21.75 ft.
300 lbs. per acre	1 lb. to a plot	10 ft. x 14.5 ft.
400 lbs. per acre	1 lb. to a plot	10 ft. x 10.75 ft.
500 lbs. per acre	1 lb. to a plot	10 ft. x 8.5 ft.
1000 lbs. per acre	1 lb. to a plot	10 ft. x 8.5 ft.
2000 lbs. per acre	1 lb. to a plot	10 ft. x 4.5 ft.

Precautionary Measures

PRODUCT	Eye Protection	gloves	lab coat	mechanical ventilation	flammable
Aluminum Test Solution	goggles	Y	Y	Y	Y
Ammonia Nitrogen Test Solution	goggles	Y	Y	N	N
Calcium Test Solution	goggles	Y	Y	N	N
Chloride Test Solution	goggles	Y	Y	N	N
Ferric Iron Test Solution	goggles	Y	Y	N	N
Iron Reagent Powder	goggles	Y	Y	Y	Y
Magnesium Test Solution #1	goggles	Y	Y	Y	Y
Manganese Test Solution #1	goggles	Y	Y	N	N
Manganese-Magnesium Test Solution #2	goggles	Y	Y	N	N
Nitrite-Nitrogen Test Reagent #1	goggles	Y	Y	Y	N
Nitrite-Nitrogen Test Reagent #2	goggles	Y	Y	Y	N
Nitrite-Nitrogen Test Reagent #3	goggles	Y	Y	N	N
Nitrate Reagent #1	goggles	Y	Y	N	N
Nitrate Reagent #2	goggles	Y	Y	Y	N
Potassium Reagent B	goggles	Y	Y	N	N
Potassium Reagent C	goggles	Y	Y	Y	Y
Phosphorus Reagent 2	goggles	Y	Y	N	N
Phosphorus Reagent #3 tablets	none	N	N	N	N
Sulfate Test Solution	goggles	Y	Y	N	N
Universal Extracting Solution	goggles	Y	Y	N	N

First Aid

PRODUCT	eye contact	ingestion	inhalation	skin contact
Aluminum Test Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Ammonia Nitrogen Test Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Calcium Test Solution	flush w/water	drink plenty of water	~	wash & rinse w/water
Chloride Test Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Ferric Iron Test Solution	flush w/water	induce vomiting	remove to fresh air	wash & rinse w/water
Iron Reagent Powder	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Magnesium Test Solution #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Manganese Test Solution #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Manganese-Magnesium Test Solution #2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrite-Nitrogen Test Reagent #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrite-Nitrogen Test Reagent #2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrite-Nitrogen Test Reagent #3	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrate Reagent #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrate Reagent #2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Potassium Reagent B	flush w/water	induce vomiting	remove to fresh air	wash & rinse w/water
Potassium Reagent C	flush w/water	call physician	remove to fresh air	wash & rinse w/water
Phosphorus Reagent 2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Phosphorus Reagent #3 tablets	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Sulfate Test Solution	flush w/water	induce vomiting	remove to fresh air	wash & rinse w/water
Universal Extracting Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water

Interested in Finding Out More?

Web Sites:

www.hgtv.com

www.vg.com

www.netusa1.net/~lindley/

www.bhglive.com/gardening/index.html

www.flinet.com/~gallus/index.html

www.familygardening.com/

www.geocites.com/EnchantedForest/Glade/3313/

Additional Resources:

"Better Homes and Gardens Magazine"

"Home and Garden Television" - television station

Appendix V b:

The SCOPE Groups Soil Testing and Analysis Booklet

Providence Street

SCOPE
Soil Testing and Analysis

Provided by WPI Students:
Andrea Feijo
Melissa Morse
Melissa Wright

Table of Contents

Introduction

This booklet is intended for the study of the chemical, mineral and organic content of the Girl's Incorporated garden soil. The amount of humus, the pH level, and the amount of various nutrients in the garden soil have been measured and recorded. This booklet is also for use in remedial measures for the garden soil. As reviewed in this packet, **Humus** is the part of soil that comes from rotted vegetables and decomposing animals; **pH** is a measurement of how acidic or basic the soil is; and **Nutrients** are all of the other materials important to plant growth. Three of the most important nutrients are Phosphorus, Potassium, and Nitrogen.

The tests in this booklet measure the amount of nutrients found in flower and vegetable gardens. These nutrients contribute to the overall health of soil. Not all types of gardens need the same amounts of nutrients, or even the same kinds. Flower gardens tend to need more nutrients than vegetable gardens. However, vegetable gardens need more Phosphorous than do flower gardens. Nitrogen is important for making plant leaves and stems healthy, green, and also helps the plants grow.

Potassium helps plants produce chlorophyll and resist disease. Not all soils contain the necessary nutrients. Various nutrients are necessary for healthy plants, however. This does not mean that plants can not grow there, but certain remedial measures need to be taken to make sure they grow healthy and strong. Some soils can contain too much of a certain nutrient which can be harmful to plants. There are steps to fix these kinds of situations as well. In the following pages, the different kinds of soil tests are listed along with how to fix unfavorable conditions and some examples from the tests performed on the initial soil tests.

Within this booklet you will find a description of each of the nutrients that have been tested, the results that were found, suggested remedial measures, test procedures, helpful tables, safety information, and locations of additional information for further study of soil ecology and plant growth.

Humus

One of the best ways to determine the overall health of a soil is to measure the humus content. Humus is the result of the decay of dead plant and animal matter. Bacteria and fungi are responsible for the breakdown of nutrients contained within this matter and the spreading of it throughout the soil. These organisms also contribute to healthy biological functions such as retention of water and aeration of the soil. Using the LaMotte Humus Test, one wants values between 3 and 4 to ensure healthy humus content. One way to correct for humus deficiency is to apply compost matter, animal manure, or garden and crop "leftovers" such as stems and dead flowers. The soil tested in the garden had a humus content of less than one and the compost had a content of 4. The garden soil humus content is very low and needs to be adjusted and monitored. Adding compost to the garden soil is one suggestion or the addition of fertilizer. See Table One.

Humus Results:

Soil: less than 1

Compost: 4

pH

The pH of a soil is the measure of the soil's relative acidity or basicity. The pH scale ranges from 0 to 14. A pH of 7 indicates neutral, less than 7 means acidic, and above 7 means basic. Soils showing a high pH show reduced solubility of nutrients required for growth. This means the plants are not as able to obtain nutrients they need from the soil. Soils with extremely low pH are much more soluble to nutrients and tend to have nutrients at toxic levels. It is harmful if the plants get too much nutrients. The most suitable pH for plants is between 6.0 and 6.5. At these levels, microbiological activity is enhanced along with the reduction of soluble toxic minerals. The most effective way to correct for low soil pH is the addition of lime. Lime is a material that is mainly a chemical compound of calcium. Depending on the size of the garden, the type of soil and the pH, different amounts of lime are needed. Use Table Six of this packet for a liming guide. The garden soil showed a pH level that was slightly too low for healthy plant growth. However the compost pH level was very high. Mixing the compost into the soil may help with the adjustment of the pH level of the garden soil. See Tables Two and Three for pH values (acidic/basicity).

pH Results:

Soil: 5.4

Compost: 8.2

Macronutrients

Macronutrients are those nutrients required in large amounts for healthy crops and gardens. These include Nitrogen, Phosphorous, and Potassium along with Calcium, Sulfur, and Magnesium. These nutrients are often released from the breakdown of rocks, the decomposition of plant and animal remains, waters, and fertilizers.

Nitrogen, Phosphorous, and Potassium

The three most essential nutrients for any kind of soil are Nitrogen, Phosphorous, and Potassium. These nutrients are needed the most and used the fastest by plants. Fertilizers often contain Nitrogen, Phosphorous, and Potassium and can vary in percentages of each. The percentage of Nitrogen, Phosphorous, and Potassium in fertilizers is given as ratios. As and example, a fertilizer may contain a 10-20-5 ratio of Nitrogen, Phosphorus, and Potassium. This means 10% of the fertilizer is Nitrogen, 20% is Phosphorous, and 5% is Potassium. The rest of the fertilizer is just filler. Filler is the component of fertilizer that has no nutrient value, but is important for water retention and to help evenly spread out the nutrients.

Nitrogen

Nitrogen is a major component in chlorophyll, proteins and vitamins. It stimulates leaf growth, improves the flavor of vegetables and increases fruit and vegetable size. Too much Nitrogen can have harmful effects though, such as delaying growth, weakening stems, and potential health hazards by the accumulation of nitrates in fruits and vegetables. As measured by the LaMotte Soil Test, the amount of Nitrogen should be medium level. The garden soil tested varied in levels of Nitrogen, however the overall Nitrogen ranges from low to medium. This would measure out to 15-40 lbs./acre.
There are three forms of Nitrogens that we test for: Nitrate, Nitrite, and Ammonia. Nitrate and Nitrite Nitrogen are usually found in small quantities. Ammonia Nitrogen is most abundant form of Nitrogen. The desired amount of Ammonia Nitrogen is low to medium. Use Table Four for approximate values expressed in pounds/acre.

Nitrate Nitrogen Results:
Garden Soil: 25 lbs. /acre
Compost: 30 lbs./acre
Nitrite Nitrogen Results:
Garden Soil: less than 1 lbs. /acre
Compost: 1 lbs. /acre
Ammonia Nitrogen Results:
Garden Soil: 10 lbs./acre
Compost: 10 lbs./acre

Phosphorus

Phosphorous contributes to the hardiness of plants. It stimulates root growth, increases total fruit and vegetable growth and increases the rate at which plants grow and mature. Phosphorous also improves the taste of fruits and vegetables and plays an important role in the development of seeds and the defense against disease. Because Phosphorous is so important and utilized in many plant functions, it can be depleted quickly. For natural growth in these locations, at least75 lbs. Per acre, and as much as 200 lbs. Per acre, it the desired amount for healthy soil. Phosphorous content should be monitored regularly. Soils deficient in phosphorous can be fixed by applying commercial fertilizers. Excessive amounts of Phosphorous have not been shown to be harmful to plant growth, so the more, the better! The levels of Phosphorus in the Garden Soil are very low, however the amount in the Compost is terrific. Mixing Compost into the Garden Soil should adjust the Phosphorus levels in the Garden Soil to an optimal level.

Phosphorous Results:

Garden Soil: 10 lbs. /acre
Compost: greater than 200 lbs. /acre

Potassium (Potash)

Potassium, commonly know as potash, is readily available in most soils. Clay soils tend to have the most Potassium while sandy soils tend to have very little. Potassium increases resistance to disease, protects from water loss, strengthens stems and stalks, enhances fruit size, taste, and texture, and is involved in chlorophyll production. The desired amount of Potassium is low, around 200 lbs./acre. The levels of Potassium for the garden and compost are very high.

Potassium Results:

Soil: 360 lbs. /acre
Compost: 460 lbs. /acre

The amount of Potassium present in the garden soil and compost are higher than desired. A suggested remedial measure would be to add filler soil that has a low Potassium level.

Calcium

Calcium is very important in forming cell walls, stimulating root and leaf development, and boosting plant metabolism. Calcium also plays a very important role in neutralizing soil acidity, which in turn reduces poisonous effects. Soil that is deficient in Calcium is often also exhibits a low pH level. Liming increases the amount of Calcium along with increasing pH. For a health soil, the level of Calcium should be between 7500-10000 lbs./acre. The results from the garden soil are very low. Adding compost will improve the level of Calcium in the garden soil. Liming will also improve the level of Calcium in the garden and compost.

Calcium Results:

Soil: 1400 lbs. /acre
Compost: 5600 lbs. /acre

Magnesium

Magnesium plays a central role in photosynthesis since, without Magnesium, chlorophyll would not exist. Magnesium also stimulates the uptake of other nutrients such as Phosphorous. Magnesium is often deficient in coastal soils and soils deficient in Calcium. Liming also increases Magnesium levels. Other than liming, Magnesium can be supplied in form of magnesium salts. The level of Magnesium in the Garden Soil was low, but the addition of compost will adjust the Magnesium to a desired amount.

Magnesium Results:

Garden Soil: 20 lbs./acre
Compost: 50 lbs./acre

Sulfates

Sulfates are the form of Sulfur that is essential to the formation of protein and affects various aspects of plant metabolism. The major sources of soil sulfates are fertilizers containing sulfate compounds and atmospheric sulfur dioxide carried into the soil by rain. The amount of Sulfates in the Garden Soil is very low. The addition of the Compost will adjust the garden sulfates level.

Sulfates Results:

Garden Soil: less than 100 lbs. /acre
Compost: 500 lbs. /acre

Micronutrients

Micronutrients, needed in far less quantities that Macronutrients, include nutrients such as Manganese, Ferric Iron, Aluminum, and Chloride. Micronutrients are needed in plants for the formation of chlorophyll as well plant growth. These nutrients are important to the organisms that consume the vegetation that grows in the soil. These Micronutrient organisms help with the building of flesh and blood and are extremely important in the diet of warm-blooded animals.

Manganese

Manganese plays an important role in formation of chlorophyll in plants. It is also important in many of the metabolic processes in plants such as germination, photosynthesis, and other important aspects of plant development. Low amounts of manganese can be corrected by application of a soluble manganese salt. High levels of Manganese can be corrected by liming. The levels of Manganese in the Garden Soil and the Compost were so low they Manganese was not detected. The addition of Manganese salt is the best remedial measure for this situation. See Table Four for data analysis.

Manganese Results:

Garden Soil: not detected
Compost: not detected

Ferric Iron

Iron is essential to the formation of chlorophyll. An Iron deficiency in soil causes Chlorosis in plants. Chlorosis is the reduced amount of chlorophyll in plants that causes decoloration of the leaves and stems, loses their natural green. Low levels of Iron can be corrected by the application of ferrous sulfate or iron chelates. The levels of Iron in the Garden Soil and Compost were low, less than 5 lbs./acre. The addition of iron chelates is recommended for remedial levels.

Ferric Iron:

Garden Soil: less than 5 lbs. /acre
Compost: less than 5 lbs. /acre

Chloride

Chloride is needed for normal plant growth. Excessive concentrations are toxic to plants, but no known Chloride deficiency problems exist in the soil. Trace amounts of Chloride are ample enough for plant growth. Chloride is known to be essential for normal plant growth, however little is known about what it does in plants. Application of fertilizer may increase Chloride levels. Chlorides are removed from the soil by leaching. The Garden Soil contained a sufficient amount of Chloride, but he Compost contained too much.

Chloride Results:

Soil: 50 lbs. /acre
Compost: 200 lbs. /acre

Aluminum

Aluminum falls under a category called "Trace Elements", which are needed for a healthy soil, but at very low levels. A high level of Aluminum can be toxic to plants and indicates an undesirable acidic soil. Liming can reduce levels of Aluminum. Plants that normally thrive on acid soils may fail in a soil with a high active Aluminum test reading. A medium test result is generally tolerable, especially for grasses. A low aluminum test result is preferable (10 lbs./acre). The levels of aluminum found in the garden soil were very high. This should be monitored. The high levels may be caused by the industrial history of Worcester. The addition of compost could bring this level down to a tolerable level.

Aluminum Results:

Soil: 250 lbs./acre
Compost: 10 lbs./acre

Summary Table of Results

Test	Desired Amounts	Garden	Compost
Humus	3 to 4	less than 1	4
pH	6.0 - 6.5	5.4	8.2
Macronutrients			
Nitrate Nitrogen	15-40 lbs./acre	25 lbs./acre	30 lbs./acre
Nitrite Nitrogen	15-40 lbs./acre	less than 1 lbs./acre	1 lbs./acre
Ammonia Nitrogen	15-40 lbs./acre	10 lbs./acre	10 lbs./acre
Phosphorous	75-200 lbs./acre	10 lbs./acre	200 lbs./acre
Potassium	200 lbs./acre	360 lbs./acre	460 lbs./acre
Calcium	7500-10000 lbs./acre	1400 lbs./acre	5600 lbs./acre
Magnesium	50 lbs./acre	20 lbs./acre	50 lbs./acre
Sulfates	250 lbs./acre	less than 100 lbs./acre	500 lbs./acre
Micronutrients			
Manganese	10 lbs./acre	NA	NA
Ferric Iron	5 lbs./acre	less than 5 lbs./acre	less than 5 lbs./acre
Chloride	50 lbs./acre	50 lbs./acre	200 lbs./acre
Aluminum	10 lbs./acre	250 lbs./acre	10 lbs./acre

Test Procedures

Soil Sampling

Soil samples should be taken from four to six inches below soil surface. Attention should be given to the terrain of the area and the different characteristics of the soil. Record these sampling areas and traits. Once the samples have been taken they should be mixed thoroughly to ensure accurate results. The samples then need to be dried completely and sifted to remove pebbles and debris. The sample is now ready for any chemical analysis.

Tests

- *For each piece of equipment and reagent a number is assigned for identification.*
- *Demineralized water bottle (1155) needs to stay full of water so that resin never goes dry. The bottle can be refilled with tap water.*
- *Parts per million can be converted to pounds per acre by multiplying the ppm value by two.*
  Example: 100 Parts/ million = 200 pounds/ acre)

pH

1. Fill test tube (0204) one third of the way up the tube with soil.
2. Add demineralized water (bottle 1155) to tube until it is one half of the way up of the tube.
3. Cap and shake well
4. Add 5 drops of Soil Flocculating Reagent (5643) to tube.
5. Cap the tube and shake well to mix. Allow contents to settle before proceeding to next step.
6. Transfer 1ml of the clear solution above the soil to one of the large depressions on a spot plate (0159).
7. Transfer a second 1 ml sample to a large depression on another spot plate.
8. To the first sample add two drops of Duples Indicator (2221) and compare color to Duplex Color Chart (1313).
9. The wide range pH test result indicates which narrow range indicator and color chart should be selected to perform a more precise pH test.
10. Choose the narrow range indicator and appropriate chart with a mid-point that is as close as possible to the value obtained in the wide range test. Add two drops of the chosen narrow range indicator to the second sample on the spot plate.
11. Compare the resulting color reaction against the appropriate color chart to obtain a precise soil pH reading.
12. Use Tables Two and Three in this packet for results.

Humus

1. Add two level measures of soil [use plastic soil measure (0819)] to a soil extraction tube (0704).
2. Fill tube to 14 ml line with demineralized water and shake well.
3. Use a 0.5 g spoon (0689) to add two level measures of Humus-Screening Reagent (5119).
4. Add 15 drops of Soil Flocculating Reagent (5643) to tube, cap, and mix gently. Allow settling for several minutes.
5. Use a piece of fluted filter paper (0465) and a plastic funnel (0459) to filter the mixture into a second extraction tube.
6. Compare the clear filtration in the second extraction tube with the Humus Color Chart (1384).
7. Use Table One for content of Humus in soil interpretation.

Chlorides

1. Fill a 5 ml soil tube (0249) with demineralized water to 5 ml line.
2. Use the plastic soil measure (0819) to add one level measure of the soil sample to the tube. Cap and shake well for 2-3 min.
3. Use a piece of fluted filter paper (0465) and a plastic funnel (0459) to filter the mixture into a second 5 ml soil tube.
4. Use a transfer pipet to transfer five drops of the filtrate in the second tube to a flat-bottomed turbidity vial (0242).
5. Add one drop of Chloride Test Solution (5111) to the vial. Gently mix.
6. Match the turbidity or amount of precipitation against the turbidity standards on the Chloride Chart (1304). Lay the chart flat under natural light and hold the turbidity vial ½ inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. Multiply the results by two to get pounds per acre.

   Example: A Turbidity reading of 50 = 100 pounds/acre

This extraction procedure will be used to make a soil extract for use in the soil tests that follow.

Extraction Procedure

1. Fill an Extraction Tube (0704) to the 14 ml line with the Universal Extraction Solution (5173).
2. Add two level measures (soil measure 0819) of the soil sample.
3. Cap and shake for a minute.
4. Filter the soil suspension into a second extraction tube (0704). The filtrate in the second extraction tube is the general soil extract for use in the soil test procedures listed below.

Nitrate Nitrogen

1. Transfer 1 ml of the soil extract to one of the large depressions on a spot plate (0159).
2. Add ten drops of Nitrate Test Reagent #1 (5146).
3. Use a 0.5 g spoon (0698) to add one level measure of Nitrate Reagent #2 (5147).
4. Stir thoroughly with a clean stirring rod (0519). Allow it to stand five minutes for full color development.
5. Match sample color with the Nitrate Nitrogen Color Chart (1315).
6. Record as pounds per acre nitrate nitrogen.

Nitrite Nitrogen

1. Transfer five drops of soil extract to a large depression on a spot plate.
2. Add 1 drop of Nitrite Nitrogen Test Reagent #1 (5151).
3. Add 1 drop of Nitrite Nitrogen Test Reagent #2 (5152) and mix well.
4. Add 3 drops of Nitrite Nitrogen Test Reagent #3 (5153) and mix. Wait for one minute.
5. Match sample color to a color standard on the Nitrite Nitrogen Color Chart (1310) and record as pounds per acre nitrite nitrogen.

Ammonia Nitrogen

1. Transfer four drops of the soil extract to one of the larger depressions on a spot plate.
2. Add one drop of Ammonia Nitrogen Test Solution (5103) and stir.
3. Allow standing for one minute.
4. Compare the resulting color against the Ammonia Nitrogen Color Chart (1302). The results are expressed in relative values of ammonia nitrogen from very low to very high.
5. Use Table Five of this packet for result interpretation.

Phosphorous

1. Use a transfer pipet (0364) to fill a "Phosphorous B" Tube (0244) to the mark with the soil extract.
2. Add 6 drops of Phosphorous Test Reagent #2 (5156). Cap and shake to mix.
3. Add one Phosphorous Reagent #3 Tablet (5157). Cap and shake until dissolved.
4. Immediately compare the color that develops in the test tube against the Phosphorous Color Chart (1312). Hold the tube about one inch in front of the white surface in the center of the color chart. View the chart and sample under natural light for optimum color comparison. The test result is read in pounds per acre Available Phosphorus.

Potassium (Potash)

1. Fill a Potash "A" Tube (0245) to the lower mark with the soil extract.
2. Add Potassium Reagent B Tablet (5161). Cap and shake until dissolved.
3. Add Potassium Reagent C (5162) until the Potash "A" Tube is filled to the upper mark. Allow the Potassium Reagent C (5162) to run slowly down the side of the tube and swirl the tube to mix. Precipitation will form if Potassium is present.
4. Stand the empty Potash "B" Tube (0246) on the Potassium Reading Plate (1107), a rectangular piece of white plexiglass with a solid black line down the middle. Place the tube directly over the black line.
5. Fill a transfer pipet (0364) with the test sample from the Potash "A" Tube.
6. Slowly add the test sample to the Potash "B" Tube, allowing it to run down the side of the tube. Observe the black line down through the Potash "B" Tube. Continue to add the test sample until the black line just disappears.
7. Record as pounds per acre Available Potassium where the level of the liquid meets the scale printed on the side of the Potash "B" Tube.
8. If the test result is equal to or greater than 400 pounds per acre, repeat the test on a diluted test sample as follows:

   A. Fill Potash "C" Tube (0247) to the lower mark with the general soil extract.
   B. Add Universal Extracting Solution (5173) to the upper mark and mix.
   C. Using this diluted extract follow Steps 1 through 7 above.
9. Multiply the test result by 2 to obtain pounds per acre Available Potassium.

Calcium

1. Add five drops of the soil extract to a flat-bottomed glass turbidity vial (0242).
2. Add one drop of Calcium Test Solution (5108) and mix.
3. Match the milky solution of the test sample against the turbidity standards on the Replaceable Calcium Chart (1303). Lay the chart flat under natural light and hold the turbidity vial ½ inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. Multiply the test result by 10 to obtain a result in pounds per acre.

   Example: A Turbidity reading of 350 = 3500 lbs./ acre

Magnesium

1. Transfer ten drops of the soil extract to one of the larger depressions on a spot plate (0159).
2. Add one drop of Magnesium Test Solution #1 (5140). Stir with a clean rod (0519). A pale yellow color will develop.
3. Add Manganese-Magnesium Test Solution #2 (5145) one drop at a time with stirring until the pale yellow color changes to one of the darker shades indicated on the Magnesium Color Chart (1306). The test results are expressed in a range of very low to very high. See Table Four in this packet for approximate corresponding value in pounds per acre.

Sulfate

1. Transfer five drops of the soil extract to a flat-bottomed turbidity vial (0242).
2. Add one drop of Sulfate Test Solution (5171). Swirl to mix.
3. Compare the turbidity of the sample to the turbidity standard of the Sulfate Chart (1314). Lay the chart flat under natural light and hold the turbidity vial ½ inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades. Multiply the test result by two to obtain a result in pounds per acre.

   Example: A Turbidity reading of 100 = 200 lbs./ acre

Manganese

1. Add ten drops of the soil extract to one of the larger depressions on a spot plate.
2. Add one drop of Manganese Test Solution #1 (5143).
3. Add one drop on Manganese-Magnesium Test Solution #2 (5145) and immediately stir and compare

Twenty-two points, plus triple-word-score, plus fifty points for using all my letters. Game's over. I'm outta here.against the Manganese Color Chart (1307). The sample color may fade after 5-10 seconds so reading should be made within the first few seconds after mixing.

4. Use Table Four in this packet for result interpretation.

Ferric Iron

1. Transfer four drops of the soil extract to one of the larger depressions on a spot plate.
2. Use the 0.05g spoon to add one level measure of Iron Reagent Powder (5275) and mix.
3. Add one drop of Ferric Iron Test Solution (5116) and mix again.
4. Match the resulting color to the Ferric Iron Chart (1348). The test result is read in pounds per acre Ferric Iron.

Aluminum

1. Add two drops of the soil extract to one of the larger depressions on a spot plate (0159).
2. Add two drops of Universal Extraction Solution (5173).
3. Add one drop of Aluminum Test Solution (5101).
4. Stir and allow standing for one minute.
5. Match the resulting color with the Active Aluminum Color Chart (1301).
6. Use Table Four in this packet for result interpretation.

Conversion Factors and Tables

parts per million X 2 = pounds /acre

Humus

Table One: Humus Content in Soil

Humus Reading	1	2	3	4	5
Agricultural Soils	Low	Medium	High		
Garden Soils		Low	Medium	High	
Organic Soils			Low	Medium	High

pH

Table Two: Indicators for more precise pH testing

Indicator	pH Range	Indicator Code	Color Chart Code
Bromcresol Green	3.8-5.4	2207	1328
Chlorphenol Red	5.2-6.8	2209	1329
Bromthymol Blue	6.0-7.6	2210	1331
Phenol Red	6.8-8.4	2211	1332
Thymol Blue	8.0-9.6	2213	1335

Table Three: Relationship between pH, acidity, and basicity.

pH 4.0	pH 5.0	pH 6.0	pH 7.0	pH 8.0	pH 9.0
Strongly acidic	Moderate to strong acidity	Slight to moderate acidity	Neither acidic nor basicity	Slight to moderate basicity	Moderate to strong basicity

Nitrogen, Magnesium, Aluminum, Manganese:

Table Four: Approximate Values Expressed in pounds per acre

Test Factor	Very Low	Low	Medium	High	Very High
Ammonia Nitrogen	10	20	80	200	300
Magnesium	10	20	50	160	300
Aluminum	10	20	60	160	250
Manganese	NA	10	24	50	80

Table Five: Average Amount of Hydrated Lime Needed For Different Acid Soils in Pounds per Yard

LaMotte Test Reading pH	Sandy Soil	Sandy Loam	Loam	Silt and Clay Loam
4	1/2	1	1 1/2	2
5	1/4	1/2	1	1 1/2
6	1/8	1/4	1/4	1/2
7	None	None	None	None
8	None	None	None	None

Table Six: Small Area Table for converting pounds per acre to amounts of fertilizer or lime required for small plots or gardens

25 lbs. per acre	1 lb. to a plot	10 ft. x 174 ft.
50 lbs. per acre	1 lb. to a plot	10 ft. x 87 ft.
100 lbs. per acre	1 lb. to a plot	10 ft. x 43.5 ft.
150 lbs. per acre	1 lb. to a plot	10 ft. x 29 ft.
200 lbs. per acre	1 lb. to a plot	10 ft. x 21.75 ft.
300 lbs. per acre	1 lb. to a plot	10 ft. x 14.5 ft.
400 lbs. per acre	1 lb. to a plot	10 ft. x 10.75 ft.
500 lbs. per acre	1 lb. to a plot	10 ft. x 8.5 ft.
1000 lbs. per acre	1 lb. to a plot	10 ft. x 8.5 ft.
2000 lbs. per acre	1 lb. to a plot	10 ft. x 4.5 ft.

Precautionary Measures

PRODUCT	Eye Protection	gloves	lab coat	mechanical ventilation	flammable
Aluminum Test Solution	goggles	Y	Y	Y	Y
Ammonia Nitrogen Test Solution	goggles	Y	Y	N	N
Calcium Test Solution	goggles	Y	Y	N	N
Chloride Test Solution	goggles	Y	Y	N	N
Ferric Iron Test Solution	goggles	Y	Y	N	N
Iron Reagent Powder	goggles	Y	Y	Y	Y
Magnesium Test Solution #1	goggles	Y	Y	Y	Y
Manganese Test Solution #1	goggles	Y	Y	N	N
Manganese-Magnesium Test Solution #2	goggles	Y	Y	N	N
Nitrite-Nitrogen Test Reagent #1	goggles	Y	Y	Y	N
Nitrite-Nitrogen Test Reagent #2	goggles	Y	Y	Y	N
Nitrite-Nitrogen Test Reagent #3	goggles	Y	Y	N	N
Nitrate Reagent #1	goggles	Y	Y	N	N
Nitrate Reagent #2	goggles	Y	Y	Y	N
Potassium Reagent B	goggles	Y	Y	N	N
Potassium Reagent C	goggles	Y	Y	Y	Y
Phosphorus Reagent 2	goggles	Y	Y	N	N
Phosphorus Reagent #3 tablets	none	N	N	N	N
Sulfate Test Solution	goggles	Y	Y	N	N
Universal Extracting Solution	goggles	Y	Y	N	N

First Aid

PRODUCT	eye contact	ingestion	inhalation	skin contact
Aluminum Test Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Ammonia Nitrogen Test Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Calcium Test Solution	flush w/water	drink plenty of water	~	wash & rinse w/water
Chloride Test Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Ferric Iron Test Solution	flush w/water	induce vomiting	remove to fresh air	wash & rinse w/water
Iron Reagent Powder	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Magnesium Test Solution #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Manganese Test Solution #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Manganese-Magnesium Test Solution #2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrite-Nitrogen Test Reagent #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrite-Nitrogen Test Reagent #2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrite-Nitrogen Test Reagent #3	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrate Reagent #1	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Nitrate Reagent #2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Potassium Reagent B	flush w/water	induce vomiting	remove to fresh air	wash & rinse w/water
Potassium Reagent C	flush w/water	call physician	remove to fresh air	wash & rinse w/water
Phosphorus Reagent 2	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Phosphorus Reagent #3 tablets	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water
Sulfate Test Solution	flush w/water	induce vomiting	remove to fresh air	wash & rinse w/water
Universal Extracting Solution	flush w/water	drink plenty of water	remove to fresh air	wash & rinse w/water

Interested in Finding Out More?

Web Sites:

www.hgtv.com

www.vg.com

www.netusa1.net/~lindley/

www.bhglive.com/gardening/index.html

www.flinet.com/~gallus/index.html

www.familygardening.com/

www.geocites.com/EnchantedForest/Glade/3313/

Additional Resources:

"Better Homes and Gardens Magazine"

"Home and Garden Television" - television station

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