Chapter 29

Problem Solving in Forest-Tree Nurseries with Emphasis on Site Problems

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Abstract

Problems are defined as the difference between "what is" and "what should be," and their definition is based on value judgments. Many production problems in Northwest bareroot nurseries are due to site; 68% of site problems are soil related, 25% climate related, and 7% water related. Many people rely solely on their own training and experience to solve problems, but integrating creative techniques with a systematic approach can reveal new solutions. A creative problem-solving system consists of five steps: the problem is identified and then analyzed, Ideas are generated, hypotheses are developed and tested, and the resulting solution is implemented. Nursery managers can become better problem solvers by increasing their knowledge about nursery science and gaining direct and indirect experience in the field.

29.1 Introduction

We all experience problems in our daily lives. Many people develop their own techniques to solve problems reasonably effectively through personal experience and training. Because every problem is different, however, someone's "pet" problem-solving technique may not be the best or the most efficient for all problems. Methods based on trial and error, for example, may be useless in a crisis situation when time is at a premium.

Problems are nothing new to nursery managers. Administrative constraints, site deficiencies, and equipment breakdowns are just a few of the problems that occur daily in tree nurseries. Good managers realize that problems are a natural part of any operation and must be dealt with directly, quickly, and effectively.

This chapter discusses the nature of problems and looks in particular at site problems in Northwest nurseries and some of their solutions. The basic elements of creative problem solving are presented in the hope that practicing forest-nursery managers can use these techniques to improve their problem-solving abilities.

29.2 What Constitutes a Problem?

"Well, I tell you there's no problems, only solutions..."
—John Lennon

My favorite definition of a problem is **any situation in which there is a difference between "what is" and "what what should be"** [6]. This definition emphasizes the relative nature of all problems. Defining problems always involves value judgments—what is a problem to one person may not be to another. The values or objectives of an organization will at least partially define the nature of its problems.

A complicating factor is that the differences between "what is" and "what should be" are frequently dynamic. In the case of seedling quality, the "what is" aspect changes with the physiological and developmental status of the seedling during the growing season or with short-term changes in weather. The "what should be" aspect of seedling specifications changes from year to year and from customer to customer. Any time that these "differences" reach significant levels, a problem may arise.

29.3 Site Problems in Northwest Nurseries

Many production problems in bareroot forest nurseries are related to site. As biological systems, nurseries are susceptible to many problems because of the numerous uncontrollable variables that affect seedling production. This high level of variability is a principal source of differences between "what is" and "what should be."

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Although all nursery managers can describe the perfect nursery site, most realize that their particular site has certain deficiencies. Very often, nursery sites are selected for nonbiological reasons such as land cost or availability; these suboptimal locations can lead to site-related problems. Other problems can be attributed to the "off-site" nature of most forest nurseries; that is, many forest-tree seedlings are produced for high-elevation plantings, whereas most nurseries are situated at lower elevations to take advantage of the more level topography and longer growing season. In the mountainous terrain of the Northwest, many nurseries are located in river valleys where the variable alluvial soils can cause problems.

The intensive cultural practices of nurseries today also can lead to site problems. Heavy machinery used during the lifting season when soils are wet can damage soil structure and result in undesirable soil compaction. Frequent irrigation and heavy nitrogen fertilization can hasten organic matter decomposition and thus decrease soil productivity.

On the basis of the response frequency of Northwest nursery managers (OSU Nursery Survey; see chapter 1, this volume), soil-related problems account for 68% of the site problems in Northwest nurseries, climate-related problems for about 25%, and water-related problems for the remaining 7% (Table 1).

Table 1. Site problems in Northwest bareroot nurseries as rated by nursery managers (OSU Nursery Survey).

	Response frequency, %	x	Problem priority[1]	=	Priority rating	Top-5 ranking
Soil						
Acidity	4.1		2.9		12.0	
Alkalinity	1.0		2.0		2.0	
Salinity	0.0		0.0		0.0	
Too heavy	6.2		2.2		13.8	
Too light	2.1		3.3		7.0	
Too variable	6.2		2.4		15.0	
Soil compaction	13.4		1.9		26.0	3
Poor internal drainage	9.3		3.3		31.0	2
Rocks	4.1		2.9		12.0	
Organic matter maintenance	13.4		3.0		40.3	1
Soil splash	3.1		2.2		6.9	
Tilth	0.0		0.0		0.0	
Uneven topography	5.2		3.1		16.0	
% of Total	68.1					
Water						
Poor quality	1.0		3.0		3.0	
High water table	2.0		1.0		2.0	
Availability	4.1		2.7		11.2	
% of Total	7.1					
Climate						
Intense rainfall	2.1		2.8		6.0	
Frost damage	6.2		2.9		18.0	5
Frozen soil	5.2		1.7		9.0	
High temperatures	2.1		2.8		6.0	
Wind damage	7.2		3.0		21.7	4
Late snowfall	1.0		3.0		3.0	
Erosion	1.0		5.0		5.0	
% of Total	24.8					
	100.0%					

[1]Based on 1 (negligible) to 5 (severe) rating.

29.3.1 Soil-related problems

The large percentage (68%) of site problems related to soil (Table 1) reflects the Critical importance of the soil component in forest-nursery operations.

29.3.1.1 Organic matter maintenance

The #1 rating of organic matter maintenance reflects both the perceived importance of organic matter in nursery management and the concern over a projected decrease in available and affordable sources (see chapters 7, 9, and 10, this volume).

Nursery managers are addressing this problem through the traditional techniques—adding amendments and growing a green manure or cover crop during the normal rotation (Table 2). The most commonly used organic matter amendments are raw materials such as sawdust or peat moss, although some alternative sources such as mint sludge are now being applied. Several nursery managers expressed skepticism about the ability of green manure or cover crops to actually increase the soil organic matter level. Several Northwest nurseries are also experimenting with composting organic materials such as sewage sludge before incorporation into nursery soil.

29.3.1.2 Poor internal drainage and soil compaction

Although they can be caused by different factors, these two soil conditions are considered together because the corrective treatments are similar. Poor internal drainage can be caused by soil compaction but also can result from naturally formed impermeable layers that often develop in fine-textured soils.

Subsoiling (deep ripping) is, the most common treatment for soil compaction and also improves soil infiltration and percolation rates (Table 2). Subsoiling physically fractures the restrictive layers in the soil with tractor-drawn ripping teeth, usually during the fallow year. Some nurseries even rip the tractor paths between seedbeds during the rotation (see chapters 6 and 13, this volume).

Subsoil drainage systems can relieve drainage problems (Table 2), and surface ditches can control water runoff in nurseries with low infiltration rates and heavy rainfall.

Several cultural practices can help reduce soil compaction and increase internal drainage (Table 2). Incorporating organic matter into the soil profile will improve soil structure and retard the formation of hardpan layers. Grading and leveling nursery blocks and raising seedbeds can help drain surface soils.

Because nursery equipment is a major cause of soil compaction and resultant drainage problems, several nurseries mentioned corrective treatments involving equipment use (Table 2). Limiting the number of times that tractors enter a field and avoiding tractor entry during wet periods can reduce compaction in the tractor paths between seedbeds. Crawler tractors cause less compaction than wheel tractors. Wheel tractors can be equipped with special tracks that more evenly distribute tire pressure; dual wheels could be used when the field is not in seedbeds. Tilling equipment such as rototillers destroy soils structure and should not be used on fine-textured or poorly structured soils.

29.3.2 Climate-related problems

Northwest nursery maqagers found 25% of their site problems related to climate (Table 1). Wind damage and frost damage were the most common, ranking fourth and fifth in overall importance.

29.3.2.1 Wind damage

This type of injury includes both abrasion from blowing soil particles and winter drying. Windbreaks, either vegetative or mechanical, were the most commonly listed treatment for wind protection (Table 2). Standard woody-plant windbreaks

Table 2. The five most important site-related problems in Northwest nurseries and their current remedies (OSU Nursery Survey).[1]

Problem	Remedy
Organic matter maintenance	Raw organic amendments (sawdust, peat moss, mint pulp, sludge) Green manure or cover crops Composed organic amendments (sludge and commercial mixes)
Poor internal drainage, soil compaction[2]	Subsoiling (deep ripping) Subsoil drainage systems Added organic matter to improve soil structure Surface ditches to control runoff Limited tractor use, especially on wet soils Use of wide tires or tracks on tractors Subsoil tractor paths during rotation Raised seedbeds Avoid machinery (e.g., rototiller) that destroys soil structure Land leveling Avoid growing tree crops in problem areas
Wind damage	Windbreaks Snowfence along irrigation lines Corn barriers in fields
Frost damage	Irrigation to protect succulent seedlings Sawdust mulch for frost heaving Perimeter vegetation removed to promote air movement

[1]Problems and remedies ranked according to relative importance: see also Table 1.

[2]Considered together because corrective treatments are similar.

are effective but occupy a considerable amount of growing space and may serve as sources of disease inoculum (see chapter 19, this volume). Some nurseries string snowfencing along the irrigation line between the seedbeds to reduce wind exposure; however, snowfences can interfere with the distribution pattern of the irrigation system (see chapter 11, this volume). One nursery used rows of corn to reduce wind exposure in seedbeds but reported only minimal effectiveness.

29.3.2.2 Frost damage

Both frost heaving and freezing injury are included in this category. Irrigation for frost protection was the most commonly listed solution for frost injury to succulent seedlings (Table 2), but its perceived effectiveness varied considerably, however, probably due to differences in technique (see chapter 12, this volume).

Frost heaving is most common with small seedlings or recent transplants in fine-textured soils. Winter mulches of materials such as sawdust provide protective insulation at the soil surface and reduce the damaging sequence of alternating periods of freezing and thawing. Removing woody vegetation surrounding the nursery promotes cool air drainage and helps eliminate frost pockets.

29.3.3 Water-related problems

Water-related problems were least troublesome to Northwest nurseries (Table 1). Poor water quality or a high water table were not common problems, but water availability was of some concern. One nursery was connected to a domestic water source which increased water cost and sometimes restricted availability. Slow recharge of irrigation wells, another problem, was remedied by drilling additional wells. Water availability also can be limited during winter, which is a problem when it is required for frost protection.

29.4 Problem-Solving Techniques

The soil-, climate-, and water-related problems (see 29.3) faced by Northwest nursery managers and staff are varied and complex. Simple solutions rarely satisfy because problem conditions are often interrelated; eliminating one problem may heighten or even create another. Managers must rely on their own experience and analytical skills, and many have developed their own personal problem-solving techniques. However, those who rely on the more conventional approaches (see 29.4.1) probably will have less success than those who try to solve problems creatively (see 29.4.2).

29.4.1 Conventional problem-solving approaches

As already mentioned, many managers have developed their own personal problem-solving techniques. Before we discuss more scientific problem-solving methods, let's look at some of the more popular approaches.

Those who use the **ostrich approach** ignore problems in the hope that they will go away. Some problems do seem to solve themselves, or, if ignored long enough, may be solved for us. More often, though, problems that are ignored become even more serious or spawn a second generation of problems.

The **panacea approach** is the universal application of a "tried and true" solution without regard to its suitability for different problem situations [6]. This approach is a favorite of experienced managers who have achieved positive results in the past but who overlook the variable nature of most problems and the advent of new technology.

People who use the **shotgun approach** do not take the time to approach problem solving systematically but believe that if enough solutions are tried, one of them should surely work [6]. Many people, when confronted with a problem, feel that it is best to "do something" as quickly as possible; the danger is that some of these haphazard solutions may actually make the problem worse.

29.4.2 Creative problem solving

Creative problem solving can be defined as the incorporation of creative processes into a systematic approach for solving problems.

29.4.2.1 The creative process

"Genius is the capacity for seeing relationships where lesser men see none."

—William James

Some people think of creativity as an artistic attribute and do not associate it with science or technology. Actually, truly revolutionary scientific theories result from creative thinking. In developing his theory of relativity, Einstein used the abstract concept of imagining himself riding on a beam of light [4].

Even though everyone is familiar with the concept of creativity, it still has no generally accepted definition [4]. Creative people are often at a loss to explain their special talent. Yet, in spite of their inability to explain or define it, most people recognize creativity when they see it. For our purposes here, creativity can be thought of as the ability to develop fresh insights about situations and formulate innovative ways of dealing with them.

Campbell [2] views the creative process as a series of separate but sometimes overlapping mental phases:

- The gradual, long-term process of accumulating and updating knowledge from both formal training and personal experience forms the basis for creativity. The more information we have about a particular problem, the better we will be able to solve it. This **preparation** phase never ends because new knowledge that may be relevant to future problems is constantly being generated.

- Once enough information has been gathered, all aspects of the problem are carefully analyzed. The length of this period of **concentration** will depend on the complexity of the problem and the amount of information available.
- Next, the problem should be temporarily abandoned for an unspecified period of time to allow the unconscious mind to mull over the details. The custom of "sleeping on it" before making a decision exemplifies this phase. Unfortunately, this **incubation** process is frequently neglected because many people become obsessive when dealing with a problem and think that they can solve it only by intense and continuous concentration or immediate action.
- Flashes of insight—often symbolized as a brightly shining light bulb in the comics—are the most familiar phase in the creative process. Most inventors and other innovative people have experienced these sudden insights, which often reveal previously unknown relationships. Although this **illumination** phase is the most exciting aspect of creativity, it is virtually impossible without proper preparation.
- Finally, the newly conceived ideas are tested to determine if they really solve the problem. During this **verification** process, many initially attractive ideas are found to be faulty upon closer inspection.

Although many techniques have been developed to stimulate creativity in problem solving, the underlying principle of each is to temporarily suspend critical judgment while developing the widest range of ideas [4].

29.4.2.2 Roadblocks to creativity

"Everyone is a prisoner of his own experiences.
No one can eliminate prejudices—
Just recognize them."
—Edward R. Murrow

Some people are naturally creative, but most of us have to work at it. Unfortunately, the human mind has several inherent processes that inhibit creative thinking;

- Most people develop a certain fixed way of thinking based on their previous knowledge and training [1]. Once a thought process is formed, it is usually very difficult to overcome. Most professional groups are guilty of such **conditioned thinking—**and nursery managers are no exception. Realizing this common pitfall is the first step in dealing with it.
- Having committed an error once, we often have an unconscious tendency to repeat the error again and again [1]. Apparently, the human mind is unable to detect these **persistent errors.** Often, a fresh perspective—or someone else double-checking our work—is needed.
- **Functional fixedness** is the tendency to see only one use for an object. Campbell [2] calls this the "inability to consider uncommon uses for common objects." Unfortunately, the more highly specialized a person's field is, the more likely that person is to fall victim to this trait. People who are good with hammers see every problem as a nail [2].

29.4.2.3 Overcoming roadblocks to creativity

"Facts do not cease to exist because
they are ignored."
—Aldous Huxley

Realizing that roadblocks to creative problem solving exist, we can take measures to counteract them by rethinking the problem, discussing it with other people, or abandoning it temporarily. Rethinking the problem requires starting at the very beginning and developing a new perspective. This is often very difficult to do because most people are accustomed to looking at a situation from only one angle. Writing a review of the problem is sometimes helpful because the physical process of translating concepts into written words can provide new insights. Discussing the problem with other people—particularly people not directly involved—can also be a good way of obtaining new perspectives. Temporarily abandoning a problem forces complete detachment from it for a few days. This mental break may allow new ideas to surface by permitting the unconscious mind to consider other alternatives or to put all aspects of the problem into their proper perspective.

29.5 Five Steps to Creative Problem Solving

Creative problem solving incorporates creativity into a basic problem-solving system (Fig. 1) comprising five steps: (1) identifying the problem, (2) analyzing the problem, (3) generating ideas, (4) developing and testing hypotheses, and (5) implementing a solution. Adopting a standard system is essential to preclude the testing of possible solutions before the real problem has been identified.

This five-step system can best be illustrated by following an actual nursery problem through all the steps. Our sample problem is a nutritional disease, characterized by irregular patches of stunted and chlorotic seedlings, which is encountered in bareroot nurseries containing areas of alkaline or calcareous soil.

Before actual problem solving begins, however, make sure that a real problem exists—some **apparent** problems can be resolved by merely taking a closer look at the situation.

29.5.1 Step 1—Identifying the problem

"Trouble that is easily recognized is half-cured."
—St. Francis de Sales

A problem has to be identified before it can be solved. Problem identification requires knowledge and experience because a manager must know what is right before being able to recognize what is wrong: nursery managers must know what a healthy seedling looks like before they can identify a sick one.

Managers must be observant and open minded. They must become sensitized to the differences between "what is" and "what should be"; because problems often develop gradually, these individual differences may go unnoticed until the situation reaches a critical level. Problem identification is also subject to changes in the state of knowledge about an operation. An increased understanding of a certain procedure can expose problems where they either did not exist before or lay unseen.

In our sample illustration, it was clear that a severe problem existed. We had no difficulty determining that a sizable portion of the seedlings was so stunted that those seedlings would not reach merchantable size by the end of the rotation.

29.5.2 Step 2—Analyzing the problem

"Thinking a problem through is hard for the
untrained mind."
—Anonymous

Problem analysis begins with the development of a clear statement about the problem. Once identified, the problem should be described as accurately as possible; the terms *what*,

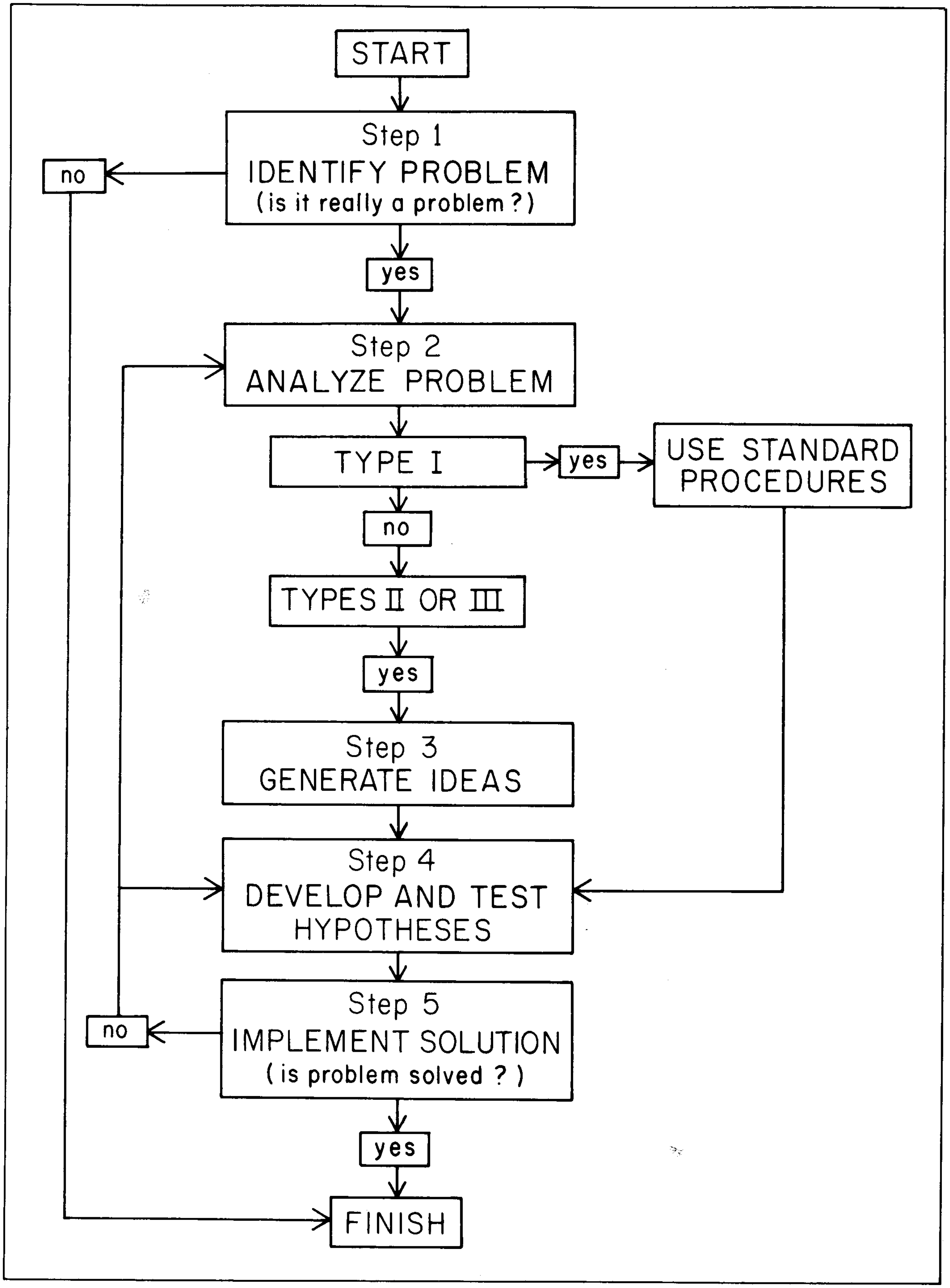

Figure 1. Flow chart illustrating a basic problem-solving system.

when, *where*, and *how much* are often helpful. Make a list of knowns and unknowns to order your observational data in some way. Carefully delineate the boundaries of the problem before attempting to solve it.

Try to observe with an impartial, open mind and not to confuse symptoms with causes. Because it is impossible to observe everything closely, be discriminating; try to identify the significant characteristics. Often, the exceptional phenomenon is the critical element and can lead to the explanation of the usual [1]. Double-check to be sure that the **stated** problem is the **real** problem; too often it is not. Furthermore, the real problem can be easier to solve than the stated one because it is almost impossible to solve a poorly diagnosed problem [3].

Once the significant information has been gathered and organized, the problem should be ranked in terms of importance, urgency, and change [5]:

- The **importance** of the problem will dictate whether it is worth solving, assuming it is solvable at all [3]. Specify the available resources (money, personnel, time) that can be expended on the solution; some problems cannot be solved economically.
- The **urgency** of the situation will determine whether it must be dealt with immediately or can be postponed. Consider the amount of time that can be allotted to the given problem.
- The **change** in nature, if any, of the problem also must be evaluated. Determine whether the problem is getting better or worse or remaining the same; a situation that is deteriorating will be more threatening than one that is improving.

The problem should next be classified into some sort of order. Van Gundy [6] uses a functional approach, separating problems into three types based on the amount of information available.

- Type I problems are **well structured.** These are the routine problems that occur daily. Their main characteristic is that all the information needed to solve them is already available. Problems in this category have probably occurred before and can usually be solved by standard procedures. Expertise for solving these problems can normally be found at the nursery, so outside help is not required.
- Type II problems are **semistructured.** This is an intermediate category—some information about the problem is available, but some degree of uncertainty also exists. These problems may have occurred before but something about them makes them different. Existing techniques must be adapted to solve this type of problem, and some expert help may be needed. The final solution is probably a combination of standard and newly developed methods.
- Type III problems are **poorly structured.** Their distinguishing characteristic is that little or no information is available about them. These are the problems never encountered before; therefore, expert help should be sought and the information needed to solve these problems generated through the problem-solving process. Solutions to poorly structured problems usually have to be custom made and require creative problem-solving techniques.

The effect of each of these three problem types is illustrated in Figure 1. Type 1 problems are usually solved with standard operating procedures, whereas Types II and III require more creative steps.

We diagnosed our sample problem as a Type III because it was a new situation we knew little about. The stunted, chlorotic seedlings were restricted to specific areas in the nursery; some nursery managers reported that they had observed the same condition in those same areas in previous crops. Everyone agreed that the problem was serious and should be dealt with immediately. The disease did not appear to be getting worse but would most likely reappear in future crops in susceptible areas of the nursery. Because the type of problem was new, we planned to consult nursery experts.

29.5.3 Step 3—Generating ideas

"In every work of genius, we recognize our own rejected thoughts."

—Ralph Waldo Emerson

29.5.3.1 Information gathering

A good knowledge base—the primary prerequisite for the creative process—can usually be obtained from nursery literature, staff discussions, and experts in the forest-nursery field.

Nursery literature includes manuals, technical books, and research publications. Publications in the fields of agronomy and horticulture or other related sciences can be valuable sources of new ideas; many of the cultural practices now used in tree nurseries were originally developed for other crops and later converted for use in tree-seedling nurseries. Older nursery publications should not be ignored because many "outdated" ideas may be able to be modified for solving the problems of today.

The nursery staff is a valuable source of information. Many of these people have accumulated a considerable amount of experience over the years. By presenting a problem at a staff meeting, nursery managers can benefit from a variety of different experiences and gain valuable new perspectives of the situation.

It is important to realize that one single source of information may not provide the solution to a problem. More often, information from a number of separate sources must be synthesized to generate new ideas. As with medical problems, it is often wise to solicit a second opinion. The amount of time and effort that can be dedicated to information gathering depends, of course, on the importance and urgency of the problem (see 29.5.2).

29.5.3.2 Creative techniques

Ideas can be generated by either single individuals or groups. Group sessions have the benefit of a variety of people with different perspectives, and the interaction of experts and untrained individuals can sometimes result in innovative ideas [4]. Groups that contain individuals of different status in an organization, however, can actually stifle creative expression because lower ranked employees may feel intimidated.

In contrast, certain problems are better suited for solution by individuals because some highly trained people may feel restricted or encumbered by group approaches to problem solving. Creativity may actually be stimulated in isolation due, perhaps, to a sort of sensory deprivation phenomenon [4]; most people would agree that creativity is inhibited in an atmosphere filled with distractions.

Brainstorming is a creative technique that can be used by either individuals or groups and deliberately encourages irrational thinking to produce a wide range of ideas. This process, however, can be quite difficult for highly trained individuals who have been "programmed" into a set pattern of logical thinking and find it hard not to judge ideas prematurely.

Individuals or groups can sometimes use analogies to generate new ideas. This creative technique forces us to look at the parallels or similarities between objects or situations to generate new perceptions about them. Very often, analogies prove effective in circumventing conditioned thinking (see 29.5.2).

Keep in mind that being creative does not always require discovering new facts—it often relies only on seeing new relationships between already known facts. A new use for a piece of already existing equipment is such an example.

We gathered information about our sample problem by first carefully observing the symptoms of the stunted, chlorotic seedlings. The newly developed secondary needles were generally more chlorotic than the older needles. We collected and analyzed soil and foliage samples from both normal and symptomatic seedlings for all nutrient elements. Consulting both the standard nursery literature and that on general plant nutrition added to our information base. The nursery experts provided diagnoses based on their assessments of the situation. Armed with a good perception about the seedling disorder, we were prepared to weave our ideas into a hypothesis.

29.5.4 Step 4—Developing and testing hypotheses

"One of the great tragedies of science is the slaying of beautiful hypotheses by ugly facts."
—T. H. Huxley

Once generated, a list of ideas must be evaluated and decisions made so that ideas can be converted into hypotheses. In most cases, information will not point clearly to one hypothetical solution, and managers will have to make decisions based on incomplete evidence (see chapter 28, this volume). However, most decisions are made under some degree of uncertainty because all the facts are never known [3].

A manager must keep an open mind during the evaluation process and take time to consider all aspects of the situation. The most obvious solutions are not always the best, and once an opinion has been formed, it is more difficult to think of alternatives. Beveridge [1] cautions us to beware of ideas that seem obvious and are accepted without question. In evaluating various ideas, it is important to consider all possible consequences so that the solution to one problem does not generate a new problem.

Managers must accept the fact that some ideas simply are not practical operationally. However, ideas that initially seem impractical may be able to be modified to a more practical form. Ideas should be judged in the light of all their attributes until testing is completed.

Hypotheses are only possible explanations and need to be empirically tested under actual conditions. Beware of the natural tendency to adopt an attractive hypothesis regardless of any data to the contrary. Most people are inclined to judge in the light of their own experience, knowledge, and prejudices rather than on the actual evidence [1]. Initially, hypotheses may not provide a complete solution and may need to be modified. Beveridge [1] warns about adopting an inflexible "all or nothing" attitude whereby a hypothesis that does not provide a complete solution the first time is discarded. Remember that hypothesis testing takes time. If a problem requires an immediate solution, implementing an interim procedure may be wise until adequate testing can be completed.

In our sample problem, we hypothesized that the problem was a micronutrient deficiency. The chlorosis of the younger needles indicated that the deficient element was immobile in the seedling. Soil tests showed that the soil in the affected areas was alkaline or that high levels of calcium were present. Foliar analysis revealed that whereas some micronutrient concentrations were lower in the chlorotic seedlings, iron concentration was usually high compared to that in normal seedlings. The soil-fertility literature stated that many micronutrients are unavailable to plants in soils with a high pH and that a nutritional disorder called iron chlorosis was common when conifers were planted on alkaline or calcareous soils. Even though some of the evidence was contradictory, we hypothesized that our seedlings had an iron deficiency caused by high soil pH or excessive soil calcium levels.

To test this hypothesis, we decided to apply a specially formulated iron-chelate fertilizer to the diseased seedlings. The liquid fertilizer was applied over the seedbeds as a spray that could be absorbed either directly into the foliage or through the roots. Although seedling response was variable, we had generally favorable results. The foliar chlorosis was alleviated, which supported our hypothesis that the seedlings were iron deficient.

29.5.5 Step 5—Implementing a solution

"A man's legs must be long enough to reach the ground."
—Abraham Lincoln

The last step in the problem-solving system is testing the hypothesis operationally. Some hypotheses may seem adequate on an experimental basis but may fail under operational conditions.

Once a hypothesis has been tested and implemented, a decision must be made as to whether the problem is completely solved. If the hypothesis provides an acceptable solution to the problem, then problem solving is complete. If not, then it is necessary to return to Step 4 to develop an alternative hypothesis or to Step 2 to reanalyze the problem (Fig. 1). Several different hypotheses may need to be tested before an acceptable solution is found.

In our sample problem, the fact that the chlorotic seedlings did respond favorably to iron fertilization was not proof that the overall problem was solved. The special chelate fertilizer was very expensive and, even though the foliar chlorosis was cured, the affected seedlings were still too small to make shippable grade. We needed to develop a permanent, practical, and economical solution to the iron-chlorosis problem.

After returning to the nursery literature and discussing the situation with our technical experts, we designed a long-term soil-amendment program to help prevent iron deficiency. We planned to (1) add sulfur and sawdust during the fallow year of the crop rotation to lower soil pH and help reduce the adverse effects of high soil calcium and (2) incorporate or band the iron-chelate fertilizer into the seedbed before sowing to make the fertilizer available to young seedlings and prevent stunting and chlorosis.

29.6 Becoming Better Problem Solvers

"Nature never overlooks a mistake, or makes the smallest allowance for ignorance."
—T. H. Huxley

The basic role of management is to achieve certain specified objectives. The objective in a tree-seedling nursery is obvious: to produce a specific number of healthy seedlings on a given date and at a reasonable cost. Most problems in tree nurseries arise when this objective is not met, either directly or indirectly.

Because problems are a predictable consequence of any operation, managers should attempt to become more adept in the art of problem solving. Nursery managers can become their own problem-solving experts by gaining the knowledge and experience necessary for making those intuitive associations that provide shortcuts to solutions.

Nursery managers must realize that learning is a continuous process but that they can never learn enough about the technical aspects of their operation. New information is constantly being generated, and managers must attempt to stay abreast of new developments.

Pure knowledge about nursery science is not enough, however; it must be tempered by actual field experience. **Experts** can take shortcuts in problem solving because their knowledge is functionally organized; such organization derives from a great deal of practical experience [4]. Experience can be acquired directly through time on the job, or indirectly, through visits to other nurseries and discussions with other nursery managers. Experience can either help or hinder the creative process, however; for example, it can lead to functional fixedness, which can stifle creativity (see 29.4.2.2).

An excellent (non-nursery) example of the benefit of actual experience in problem solving was the recent success of the Gossamer Condor, a light-weight human-powered aircraft, in navigating a difficult figure-8 pattern course and winning the Kremer prize. The Kremer prize of $86,000 had been unattainable for almost two decades until a Californian named Paul MacCready decided to try a novel approach. Instead of working from "high-tech" engineering design and aeronautical theories, he built a craft out of cheap, available materials. Because the Condor could be repaired quickly, MacCready was able to launch nearly 500 test flights using 12 significantly different models of the aircraft in a little over 1 year. He had found a way to gain experience quickly and inexpensively "instead of merely applying the logical consequences of theory" [7].

Planning is one of the most effective techniques in good problem management. Although problems cannot always be avoided, their effect can be minimized if they are planned for. Yet nursery managers must be flexible and realize that plans may need to be modified during the season. Good plans include contingencies that outline alternative management strategies for circumventing problems as they are encountered. Many problems lose much of their initial impact if a manager deals with them quickly and efficiently.

Realizing that problems are to be expected—and that they can be handled—can make a manager's job much more enjoyable. Problem solving, though frustrating, can also be very rewarding.

29.7 Conclusions and Recommendations

- All problems are relative because their definition depends upon value judgments. Problems in forest-tree nurseries are dependent upon the objectives and expectations of the nursery manager.

- Site-related problems are some of the most common and damaging problems in Northwest nurseries. Over 2/3 of site problems are soil related and about 1/4 climate related; water-related problems are of minor consequence.

- Creative problem solving is defined as the incorporation of creative processes into a systematic approach to problem solving. Creative techniques can provide new insights into the nature of a problem and lead to novel solutions. Many specialized people, including nursery managers, have a fixed way of thinking based on previous training and must be aware of such possible roadblocks to creativity.

- Successful problem solving requires a systematic approach: a problem must be identified and analyzed, ideas for solving it generated, hypotheses developed and tested, and the proposed solution implemented operationally. It is important to approach a problem methodically and take each step in proper sequence.

- Nursery managers should strive to become better problem solvers by increasing their knowledge base and gaining as much direct or indirect experience as possible. Because knowledge about tree-nursery management is continually increasing, managers must try to keep abreast of new developments by attending nursery workshops and technical meetings and by reviewing the literature. Although direct on-the-job experience is invaluable, experience can also be gained indirectly by visiting other nurseries and discussing technical matters with other nursery workers.

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