Group-based On-site Active Learning (GOAL): Technique for Investigating Nitrogen Management in Container Nurseries

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SUMMARY. Nitrogen (N) management in container nurseries is part of a complex system. Working within this system, nursery owners, managers and employees routinely make N management decisions that have consequences for the immediate nursery environment (e.g., plant growth, yield, disease susceptibility, water quality) as well as areas beyond nursery boundaries (e.g., surface and groundwater quality, public perception). Research approaches often address parts of the system associated with the immediate nursery environment and purpose. As a result, best management practices that contribute to greater N use efficiency have been developed. Research approaches that consider the whole system reveal novel relationships and patterns that identify areas for future research and may direct future management decisions. To investigate N management from a whole system perspective, a group of nursery managers from Oregon and scientists from Oregon State University met three times between 2001 and 2003. Growers drew their N management systems and identified components, relationships and feedback loops using an ActionGram technique. From this information, researchers developed Group-based On-site Active Learning

(GOAL). GOAL combines ActionGrams and the Adaptive Cycle at container nursery sites. In this case, N flow and management in container production systems served as the topic of active learning. Managers and employees from four wholesale container nurseries evaluated the GOAL exercise. After completing GOAL, 94% of participants indicated that they learned a new idea or concept about N cycling in their container nursery. Of those, 100% gained new ideas and concepts from peers and colleagues present at the meeting. In addition, 60% gained new ideas and concepts from researchers and 60% developed their own ideas and concepts. GOAL is a learning tool that provides a simple, convenient, interactive format for investigating complex systems.

Management of N in container nurseries is part of a complex system of decisions and actions with consequences that affect both the immediate time and space embodied in the nursery as well as scales far beyond the nursery boundaries. For instance, N management decisions will affect nitrate (NO_3^-) levels at the nursery as well as potentially affecting NO_3^- levels in the local watershed. Therefore, multiple stakeholders exist (e.g., neighbors, environmental groups, regulating agencies, academics, consumers, political factions) beyond the obvious economic interests of the nursery owner/manager. Effective and lasting solutions to N pollution must consider effects and consequences across several scales and the interests of all stakeholders.

Reductionist research investigates parts of the system resulting in improved water usage, water recycling, controlled release fertilizers, catch strips, and other best management practices that contribute to greater N use efficiency. However, the system as a whole may behave differently than the individual parts. Research approaches that consider the whole system reveal novel relationships and patterns that identify areas for future research and may direct future management decisions.

Two methods of investigating complex systems are ActionGrams (William, 2002) and the Adaptive Cycle (Holling, 1986). ActionGrams provide an interactive platform for mapping complex systems, and the

Adaptive Cycle presents a theory of system function over time.

The Adaptive Cycle is developed from a theory of ecosystem succession (Clements, 1916) based on the presence of and sequential domination by opportunistic (exploitation) species (*r*-species) in unpredictable environments and equilibrium (conservation) species (*K*-species) in predictable environments (MacArthur, 1960). *r*-species have a high reproductive potential, short life, high dispersal properties, small size and resistance to extremes and represent initial, exploitive species in a community. In contrast, *K*-species have lower reproductive potential, longer life, lower dispersal rates, larger size and effective competitive abilities and represent climax species of a community (Pianka, 1970). Clements' (1916) theory of ecosystem succession implies that communities reach and maintain a stable state in the *K* phase of succession (Fig. 1A).

Holling's (1986) Adaptive Cycle adds a "backloop" to the succession model and introduces two more phases, Ω (release) and α (reorganization), that complete the cycle (Fig. 1B). Ω occurs after the *K* phase and is defined as "creative destruction" (Holling, 1986). This phase represents a release of bound resources (accumulated during the progression from *r* to *K*) back to the system followed by immediate "reorganization" of resources and processes, assigned the symbol α (Gunderson and Holling, 2002; Holling, 1986). After the α phase, the system resumes an *r* phase, and the cycle continues.

Three parameters, potential, connectedness, and resilience, are significant measures of renewal and are incorporated by imposing a set of axes on the Adaptive Cycle (Fig. 1C). Potential may be defined in biological (e.g., biomass, nutrient accumulation, physical structure), social (e.g., network of relationships, trust, friendships), or economic (e.g., value of product, value of acquired skills, inventions) contexts. Connectedness is defined as the internal control that a system can exert over external variability and reflects the strength of connections between system components. Resilience is defined as the capacity of a system to experience disturbance and still maintain its fundamental functions and controls (Gunderson and Holling, 2002). Each of these parameters will increase and decrease as a system

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Fig. 1 A–C. (A) A succession model or growth curve illustrating the progression from r (exploitation) to K (conservation). (B) Addition of a backloop that introduces Ω (release) and α (reorganization) phases to the cycle. (C) Application of axes representing potential, connectedness, and resilience. Each parameter increases in the direction of the arrow.

evolves through the four phases of the Adaptive Cycle.

ActionGrams and the Adaptive Cycle can be used to clarify components and functions of complex systems. The objectives of this project were to: 1) use these techniques to gather information from nursery managers about their respective N management systems; 2) develop and implement an interactive exercise for learning about and communicating N management in container nurseries; and 3) have the exercise evaluated by nursery managers.

Materials and methods

ACTIONGRAMS: DIAGRAMMING N MANAGEMENT PRACTICES. A group of nursery managers and researchers from Oregon State University identi-

fied the components and relationships important to N management systems used in container nurseries. The group met three times: 23 Feb. 2001, 30 Oct. 2001, and 4 Mar. 2002. A core group of three researchers and two nursery managers attended each meeting. Two and four additional nursery managers attended the first and third meetings, respectively. At each meeting, participants were provided large sheets of paper and markers and asked to draw their respective N management systems according to the following directions:

- 1) List or name the components of your N management system.
- 2) Use arrows to indicate relationships between components.
- 3) Identify feedback loops. Are

they positive or negative? Do they balance?

Participants could work alone or in groups (two or three) and were asked to complete their ActionGram in about 15 min. After diagrams were complete, each person or group shared their diagram, and participants commented or asked questions. After presentations, each person or group was allowed 5 min to revise their diagram by adding or changing items discussed. After revisions, the group reassembled for a final debriefing of the N management diagramming exercise.

After the meetings, researchers summarized components and relationships of the ActionGrams. Analysis of the ActionGrams led to the pursuit of an integrative theory that accounted for the major drivers of N management systems while also considering the relationships of N management to related systems (e.g., pest management, water management, environment, public, neighbors, politics, etc.). During this process, we became aware of the Adaptive Cycle as described by Gunderson and Holling (2002) in their book on panarchy. This theory fit our criteria and represented a plant production cycle and the practices involved in the operation of a container nursery.

ADAPTIVE CYCLE. Initial analysis revealed that nursery production cycles follow a pattern similar to the Adaptive Cycle. The r (exploitation), K (conservation), Ω (release), and α (reorganization) phases of the Adaptive Cycle are analogous to the new crop, mature crop, shipping, and reorganization phases of a container nursery production cycle, respectively.

A laminated poster was developed for the Adaptive Cycle session (Fig. 2). The format had to: 1) be simple; 2) facilitate the investigation of time and spatial scales; 3) be interactive; and 4) be mobile, reusable, and easily prepared. The poster was designed with PowerPoint (Microsoft, Redmond, Wash.) and is 48 × 36 inches (121.9 × 91.4 cm). Because the poster is laminated it can be written or drawn on with Expo (Sanford, Bellwood, Ill.) dry erase markers and easily cleaned with a dry cloth. The Adaptive Cycle addresses the time scale of a container production cycle and is surrounded by borders representing the nursery, watershed, state, continent, biosphere, and atmosphere. These boundaries allow participants to address spatial

considerations related to N management in container nurseries. To describe potential, connectedness, and resilience of the system at different phases, a set of axes is imposed on the diagram (Fig. 3).

GROUP-BASED ON-SITE ACTIVE LEARNING (GOAL). Group-based On-site Active Learning (GOAL) combines the ActionGram exercise with a diagramming and discussion session centered on the Adaptive Cycle. The ActionGram exercise is intended to focus participants on the subject, and the Adaptive Cycle session is intended to promote interaction among participants as well as with the model.

To evaluate GOAL as a learning tool, the exercise was conducted on-site at four container nurseries. At each nursery, participants were asked to draw N flow within their respective nursery (ActionGram). This step focused participants on N flow and management. After the diagrams were completed, each participant explained his/her diagram to the group, and participants commented or asked questions. Next, the Adaptive Cycle poster was introduced to the group. The introduction included a brief history of Adaptive Cycle theory and an explanation of the various phases and boundaries. In addition, the participatory nature of the poster (drawing on it, erasing, and easy cleaning) was demonstrated. Participants began working with the model by drawing/writing on the poster in response to two questions:

- 1) Where does N enter the system?
- 2) Where does N leave the system?

As discussion proceeded, other questions were presented including:

- 1) What are the sources of N?
- 2) Ultimately, where does N used in container production systems originate?

- 3) Ultimately, where does N go that is used in container production systems?

After 30 to 45 min of interaction centered on the Adaptive Cycle poster, participants were asked to complete an evaluation form (Fig. 4). The evaluation employs a post-/pre-measure of learning (Davis, 2003; Pratt, 2001) followed by four questions specific to the participant's experience with the exercise. A total of 19 responses was collected across four nurseries. Two sample *t*-tests were performed using

Fig. 2. A laminated poster containing a nursery production cycle imposed on the adaptive cycle. Different colored boundaries represent spatial scales from the nursery to the atmosphere. r = exploitation phase, K = conservation phase, Ω = release phase, and α = reorganization phase. The poster is the central element of the Group-based On-site Active Learning (GOAL) exercise.

Fig. 3. The adaptive nursery cycle with three axes (potential, connectedness, and resilience) imposed on it. Each parameter increases in the direction of the associated arrow.

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Evaluation and assessment

- 5) Imagine that the meter below is a measure of your understanding of N flow in your nursery. Draw an arrow representing where on the meter your understanding of N flow is right now, *after* today's meeting. Next, draw an arrow representing where on the meter your understanding of N flow was *before* today's meeting. Indicate which arrow is which.

- 1) Did the position of the arrows change?
- 2) What things did you learn today that caused the position of the arrows on your meter to change?
- 3) If the position of your arrows did not change, please explain why.
- 4) The ideas and concepts that I learned today came from:
 - a. peers and colleagues
 - b. researchers
 - c. development of my own ideas

Fig. 4. Evaluation form presented to nursery managers after their participation in GOAL.

SAS version 8.02 (SAS Institute, Cary, N.C.).

Results and discussion

Results from the ActionGrams indicated that nursery managers viewed N management as a dynamic system (i.e., changing over space and time) integrated with other practices (e.g., water management, pest management, labor) essential to successful management of a container nursery. While the core components and relationships were similar, results from the ActionGrams revealed that individual circumstances within a nursery created specific combinations unique to that nursery. Nursery manager response to participation in the ActionGram exercise was similar to the response of undergraduate and graduate students, citizen groups, conference participants,

and university faculty and administration asked to participate in similar exercises (William, 2002). At initiation, some participants were hesitant; however, once engaged with the exercise they were able to take advantage of the format to illustrate the structure and function of N management in their particular nursery. Other studies have used similar participatory mapping techniques to describe complex agricultural, social, and natural systems (Campbell et al., 2001; van Noordwijk et al., 2001).

Figure 5A–D shows four diagrams developed by managers participating in the Adaptive Cycle exercise at their respective nursery. Common themes in the diagrams include recycling of irrigation runoff during the production season, loss of N during the production season, and spatial recognition of the

source and fate of N fertilizers used for container plant production. Participants from each meeting assigned the majority of N inputs within the *r* to *K* phase. Initial N inputs such as application of soluble N or incorporation of controlled-release fertilizers, a common practice in container nurseries, occur near the *r* phase when connectedness and potential of the nursery cycle are relatively low but resilience is relatively high. Fertilizer N is delivered at *r* to increase the potential of the system; however, excess N at *r* will leak from the system (or be scavenged by weeds, microbes, etc). Even with fast growing plants, recommended N rates may exceed plant demand resulting in N losses accumulating faster than N uptake by the plant from *r* to *K* (Sandroek, 2004). This is why it is essential that controlled-release fertilizer patterns match the needs of the crop (Sandroek, 2004).

Resilience at *r* is high because the crop is young and invested resources low. If a surprise or disaster (e.g., freeze, hurricane) were to occur and damage or eliminate the crop at this phase, it is likely that management and labor would have time and resources available to “bounce back” and start a new crop.

Potential and connectedness of the system increase and resilience decreases as the new crop matures. Participants identified periodic top-dressing, application of soluble N, and recycling of runoff water as additional N inputs that occur as the system moves from *r* to *K*. Addition of N to the system promotes growth of the crop and potential (monetary value, biomass, etc.) increases. Likewise, the addition of N increases the connectedness of the system as it moves from *r* to *K*, and components of the system become more dependent on each other for survival. For instance, plants near the *K* phase are more dependent on a regular irrigation schedule than plants near *r*. As potential and connectedness are increasing, resilience decreases. If the same surprise or disaster mentioned above were to occur near *K* and damage or eliminate the crop, losses would be much greater because of the invested capital, and it is doubtful that managers and workers would be able to replace the crop or its value. Obviously, managers hope to convert the high potential at *K* to dollars by selling the crop, but the crop becomes vulnerable at *K*, and

there are opportunities for pest or diseases to take advantage of the high potential for their own gains.

Participants identified multiple N “leaks” as the system moved from r to K including N leaching, N volatilization, removal of N in weeds, and loss of N from pruning. Fate of these N losses were discussed and the groups concluded that although N lost from containers remains for some time within the nursery (compost piles and collection ponds) or in the local watershed (leaching and runoff), it ultimately returns to the atmosphere via biological processes. Many participants recognized that the process of introducing fertilizer N to the biosphere was occurring faster than the biological processes responsible for returning N to the endogenous atmospheric pool, thus causing concern about N contamination in the environment.

Each nursery group identified the substantial amount of N that leaves the nursery when plants are sold. Participants affirmed that the goal of nursery managers was to have as much of the applied N in the plant or accompanying container when it leaves the property. Sale of nursery plants serves as a type of “creative destruction” ushering in the Ω and α phases of the cycle. The Ω phase is characterized by low potential because the crop is gone and payment has not yet been received.

The adaptive nursery cycle moves relatively quickly from Ω to α as connectedness decreases (e.g., fewer relationships between plants and cultural practices, labor and management, labor and plants) and potential and resilience increase. The system regains potential as accounts are paid (economic potential). Resilience increases as the production cycle approaches α because plants have been exchanged for cash or credit (economic liquidity). Adjustments within the nursery (e.g., to labor, production strategies, expansion) are relatively easy at this stage compared to other phases of the cycle. Resilience remains high during the α and r phases because the system is able to readily adapt or change to outside influences. For example, if labor availability decreases, managers can scale back production plans, or if market trends change, managers can adjust production strategies and goals to avoid losses and potentially benefit from those changes. The α phase is a period of reorganization when money

Fig. 5A–D. Diagrams developed by groups of managers and employees from four wholesale container nurseries. Participants were introduced to the model as seen in Fig. 2 and then drew or wrote their perspectives on N management and flow in their respective nursery. Diagrams were redrawn by the author to facilitate formatting to the text. (See next page for Fig. 5C–D.)

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that was received for plants sold can be routed to buy supplies (including N fertilizer) for the next cycle. This is also the period when decisions about production strategies, use of space, expansion, and labor are made in preparation for beginning the cycle again at the r phase.

When asked about GOAL, 18 of the 19 participants (94%) stated in response to Question 2 of the evaluation form (Fig. 4) that the position of their arrow changed on the post/pre meter. In other words, participants' understanding of N flow increased. By assigning the distance between each tick mark on the meter as 2 units (8 total units on the meter) the average distance that a participant's arrow moved was 1.9 units. The mean post-evaluation (5.7 units, $SD = 0.7$) was significantly higher ($\alpha = 0.05$) than the mean pre-evaluation (3.8 units, $SD = 1.4$). Seven participants (37%) indicated that their arrows moved from "medium understanding" to "strong understanding."

Responses to Question 3 indicated that participants gained a better understanding of the N cycle, ultimate sources and fates of N fertilizers used in container nurseries, role that container nurseries play in the N cycle, and scale of impacts of N management decisions.

In response to Question 5, 100% of participants indicated that they gained new ideas and concepts from peers and colleagues present at the meeting. In addition, 60% of participants gained new ideas and concepts from researchers, and 60% developed their own ideas and concepts.

As an extension method, GOAL is similar to the Resource Flow Diagram (RFD) method (Lightfoot et al., 1989) used with farmers in Asia, Malawi, and elsewhere. Both methods use participatory diagramming to encourage farm managers to actively investigate resource flow and use in their agricultural system. The ActionGram technique has been used to lead discussions among stakeholders with different perspectives (William, 2002). The Adaptive Cycle has been used, mostly by researchers, to analyze the function of systems (Carpenter et al., 1999; Gunderson and Holling, 2002). Yet, the theory is general and integrative by design and is therefore easily employed as a context for discussion of multiple issues within a system as well as among

multiple stakeholders. Combined in GOAL, the techniques can be used to explore the flow or use of other resources such as pesticides, labor, or money in a nursery production system. The integrative nature of GOAL allows participants with different perspectives (e.g., neighbors, government agencies, labor organizations) to communicate how and where their concerns or interests fit into a common system.

Results from this project confirm Gerber's (1992) assertion that participatory, on farm research and education may be used as one mode of inquiry to develop and adapt various ideas and practices. Managers concurred that the adaptive cycle is an accurate representation of container nursery production, matching the processes, events, and choices encountered during a production cycle. GOAL provides a simple but robust context for investigation of N flow and management validated by measured learning among participants. GOAL will be valuable in facilitating discussion and understanding of complex issues associated with nursery production (e.g., N, water, and pest management) amongst nursery personnel and may be an effective method of including stakeholders from other organizations (e.g., regulating agencies, environmentalist, the public) in future discussions. GOAL serves as a teaching or extension tool to promote participatory investigation of complex issues and to measure subsequent learning.

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