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A Case Study to Teach the Diagnostic Process: Determining the Cause of Chlorosis in a Crop of Cut Dicentra

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Teaching Methods

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SUMMARY. This universally accessible, Web-based decision case presents the challenge of determining the cause of foliar chlorosis in a crop of dicentra (*Dicentra spectabilis*) being forced as a cut flower for Valentine's Day sales. The case study serves as a tool to promote the development of diagnostic skills for production dilemmas, including nutritional disorders, disease problems, and evaluation of the appropriateness of cultural practices. Cut dicentra is a minor crop and standard production practices are not well established. Solving this case requires that students research production protocol, as well as nutritional and pest problems, and determine whether they have enough information to recommend a solution. In this case study, a grower at Flint's Flower Farm must determine the cause of foliar chlorosis that is slowly appearing on about half the plants of her cut dicentra crop. The condition could be related to a number of possible problems, including a nutritional disorder, disease infection, or production practices. Resources are provided to aid students in gathering background information. Data accumulated by the grower are presented to allow students to eliminate unlikely solutions logically. The solution, which is unique to this crop, is provided along with detailed objectives and discussion points in teaching notes. This case study is complex in nature and is intended for use with advanced students in upper-level undergraduate courses of floriculture production, nutrient management, and plant pathology who have been previously exposed to the diagnostic process.

Case studies are a way to bring real-world problems into the classroom. The case-study method places the student in the role of decision maker, mimicking situations that they may encounter in future employment. Students are presented with a dilemma, detailed background information, and supporting materials. They are asked to evaluate the situation and consider possible solutions. This case study is designed to provide a tool to develop diagnostic skills for ornamental crop production dilemmas, including nutritional disorders and pest problems, and to evaluate cultural practices and environmental conditions related to crop growth and development. Because cut dicentra is a very minor crop, standard production practices are not well established. Solving this case requires that students become familiar with production protocol as well as disorders incited by both biotic and abiotic factors.

Part of this assignment also includes evaluating the costs, in terms of both time and money, of using various diagnostic tools. These tools include contacting extension specialists in horticulture, entomology, and plant pathology; nutrient analyses; and pathology tests. The "time and money budget form" (TMBF), which was refined in 2006 (Fig. 1), is designed to help students appreciate the costs of each available tool. Completion of the TMBF could be a

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
1	ppm	$mg\cdot L^{-1}$	1
(°F − 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

required assignment before a class discussion to help ensure that students thoroughly peruse the case study. The TMBF allows students to select only five of the 10 possible actions to emphasize the limits of time and money when diagnosing most production dilemmas. However, ideally students could choose to explore all the possible diagnostic actions before selecting what to record on the TMBF. This activity exposes them to many of the diagnostic options, but they still must make a judgment regarding which strategies they believe will be most successful to resolve the situation. The revised 2006 TMBF requires students to evaluate the given information rather than resolve the situation. The ultimate solution to the case is not revealed in the results of any of the diagnostic options.

Objectives of this case

After completing this case study, students will further develop the following knowledge and skill sets:

1. Knowledge about factors a grower should consider when a problem arises in a production setting
2. An understanding of the diagnostic process for disorders incited by environmental, disease, or nutrition problems
3. Appreciation for the limits of time and money when seeking solutions to a problem
4. Confidence to work through the diagnostic process, sometimes with limited knowledge about the cause of a problem

Ancillary objectives of this case study that the instructor may have include the following:

1. An introduction to niche marketing concepts such as forcing specialty cut flowers
2. A discussion of appropriate nutrient analyses techniques, which depend upon the root medium used for production
3. An understanding of options and procedures for plant disease diagnosis

The decision case

Note that the case-study text and other tools, such as video clips and Web links to external resources that augment presentation of this decision case, are available to students and instructors (Spaw et al., 2004a).

Time & Money Budget Form

Select up to five in-house and/or outsource Diagnostic Actions that will help you reach a diagnosis of the problem. Keep track of how much time and the cost that each action requires. Remember, the goal is to come to the correct solution by spending the least amount of money, but time is of the essence because the market date is nearing and the symptoms of the disorder are worsening.

Next, answer the questions below to present what you have sorted out.

Diagnostic Action	Time	Cost
Total Cost ——→		

You may answer on the back of this sheet.

1) Do you have enough information from the crop history and results of the diagnostic actions that you recorded on your Time & Money Budget Form to decide what caused the chlorosis on the cut dicentra?

a. If so, what do you believe is the cause of the chlorosis, and what specific information led you to this conclusion?

b. If you are not confident about the cause of the problem based on a review of the crop history and results of the diagnostic actions, what steps or diagnostic actions can you take next to determine what caused the chlorosis?

www.hightunnels.org/dicentracasestudy.htm

Fig. 1. The "time and money budget form" was revised in 2006 to direct student focus on the diagnostic process rather than prematurely determining a specific solution. Completion of this form may be assigned before class discussion about the case study. This exhibit is available as a .pdf file on the website (Spaw et al., 2006b).

The grower, Maria Flint, is forcing dicentra for the first time as a cut flower crop for Valentine's Day sales. Although dicentra is common in spring perennial gardens across the central Great Plains, it is not often found as a cut flower crop. Because it blooms from late April until early June under natural environmental conditions, it must be forced into flower for Valentine's Day sales. However, with arching racemes of delicately formed heart-shaped flowers from which it takes its common name, bleeding heart, it is an appropriate crop for the Valentine's Day market.

Flint's Flower Farm specializes in the production of unique cut flowers for local markets in Lincoln and Omaha, NE. The flower farm is located between these two population centers in Cass County in the eastern third of the state, and the farm falls at 41°N latitude. Flint's Flower Farm produces cut flowers in the field, in high tunnels, and in one heated greenhouse, so production and cash flow is year-round. The farm uses municipal water for irrigation.

Although dicentra can be produced from seed, this species is typically grown from crowns for cut flower production. For cut dicentra stems to be ready for harvest by Valentine's Day, a 5- to 8-week cropping cycle is recommended (Smith, 2001). Maria purchased her dicentra crowns from a major supplier of

Your assignment is to put yourself in Maria's shoes: Decide what test(s) you would run to sort out the problem. Justify your decision to run each test and keep track of the costs by completing the TMBF. The goal is to solve the problem while spending the least amount of money, but time is of the essence because the market date is nearing and the symptoms of the disorder are worsening.

The starting point is to determine what the crop's history reveals about the problem. Chlorosis can be incited by many things, certainly, but you can glean several probable leads from what is known. What information do you need to validate or eliminate a particular known cause of the type of chlorosis described?

The "diagnostic action chart" (Fig. 2) provides the means, via the website, to gain additional information to solve the problem. For example, the diagnostic action "plant tissue analysis" (Fig. 3) provides information about how to sample tissue properly, analytical techniques, and test results as well as standard acceptable ranges. Some information can be gathered quickly "in-house" by Maria herself whereas other information may be provided as test results or from a conversation with an expert in the field. Answer the questions on the TMBF to justify your conclusions.

Interpretive or teaching notes

The teaching notes are located at the same website as the case study; however, it is a hidden link (Spaw et al., 2006a). Presumably only the instructor would gain access to this link, which provides further explanation, discussion aids, and solution of the case study. This case study is intended for upper-level under graduate courses of greenhouse management, plant pathology, floriculture production, and nutrient management.

Contingent on the course objectives, size of the class, and instructional style of the educator, this case may be tailored to fit the specific needs of a course. It may be assigned to individuals or as a group project, either outside of class or during class time. Ideally, a designated computer laboratory would be available for those who may not otherwise have access to a computer. For example, an instructor may choose to combine the assignment of this case study and its discussion with a laboratory to instruct techniques of in-house root medium testing or use of simple ImmunoStrip test kits (Agdia, Elkhart, IN) for virus testing. Both procedures are explained within the case study.

The questions on the TMBF require students to justify their conclusions. Having the students explain how they arrived at their particular diagnosis reveals their true understanding of the situation (Stewart, 2004) and helps them delineate the process that they went through to come to a decision. The 2004–2005 TMBF questions were framed so the students' focus was finding a solution (Table 1). The TMBF was changed in 2006 (Fig. 1) to encourage students to focus on the process of crop diagnosis instead of formulating a premature solution (Table 1).

Additional questions that may elicit some discussion include the following:

1. Reflecting on your first impression, what was your initial thought about what might be wrong with the dicentra?
2. What steps of the diagnostic process helped you confirm or decide against your initial impression?

In addition to presenting an opportunity for class discussion of the problem and the diagnostic process, discussion could be focused in a number of ways.

Diagnostic process. Throughout the case study, the diagnostic process is encouraged as a way to discover the cause of the problem with the dicentra crop. A trade journal article that addresses these concepts (Daughtrey, 2002) is linked to the website for ease of student access. However, the specific steps of the process may not be self-evident to students. Although the diagnostic process is not limited to a specific list of steps to follow, a methodical approach to diagnosing a plant problem is recommended. This approach includes 1) defining the problem, 2) looking for patterns, 3) delineating time development of the damage pattern, 4) determining causes of the

Cut Flower Case Study

Action Type	Diagnostic Action	Time	Cost
In-House	Research Reference Books	1 Day	$0
	Plant Inspection & Sticky Card Count Record	1 Day	$0
	Follow-up Conversation with Extension Horticulturist after completing in-house pH and Electrical Conductivity (EC) tests	2 Days	$0
Outsource: Nutrition	Water-based Media Extraction	6 Days	$63 including overnight shipping
	Acid-based Soil Extraction	6 Days	$69 including overnight shipping
	Water Analysis	5 Days	$52 including overnight shipping
	Plant Tissue Analysis	8 Days	$40
Outsource: Disease	Conversation with Extension Plant Pathologist	7 Days	$0
	Commercial Diagnostic Disease Lab	5 Days	$94
Outsource: Insect	Email Exchange with Extension Entomologist	4 Days	$0

Fig. 2. A screen shot of the website that contains the "diagnostic action table" is provided. The table provides information about each diagnostic action: whether it is performed by the grower or outsourced, the cost incurred, and the time involved to complete it. More information can be gathered by clicking on the specific diagnostic actions. This exhibit is available as a part of the website (Spaw et al., 2004a).

Plant Tissue Analysis

Action-type	Action	Time	Cost
Outsource: Nutrition	Plant Tissue Analysis	8 Days	$40

Description

A plant tissue analysis offers a snapshot of the plant's tissue nutrient content at the time of sampling. An early analysis allows for deficiencies and toxicities to be detected, and proper corrective actions to be implemented before permanent physiological damage occurs. Unless otherwise specified, the youngest fully-expanded lead should be sampled. Maria decides to send in a sample of youngest, fully-expanded leaves collected from several plants exhibiting symptomology.

Sampling the youngest fully expanded leaf.

Results

Macronutrients (%)	Test Result	Acceptable Ranges[a]
N	4.01	3.71-5.24
P	0.66	0.60-0.70
K	3.20	2.24-3.18
Ca	0.58	0.38-0.64
Mg	0.44	0.19-0.35
S	0.66	0.66-0.69
Micronutrients (ppm)		
Fe	74	74-79
Mn	931	891-1504
B	20	20-24
Cu	6	4-6
Zn	103	87-101
Mo	0.89	0.66-1.08
Nonessential Elements (ppm)		
Na	55	42-60
Al	64	23-210

Fig. 3. The "plant tissue analysis" diagnostic action contains information about the procedures for plant tissue sampling as well as test results and acceptable ranges of tissue concentrations for the sample of dicentra submitted. This exhibit is available as a part of the website (Spaw et al., 2004b).

plant damage, and 5) synthesizing the information to determine probable causes (Green et al., 2004).

To initiate discussion about the diagnostic process, have students state what questions and observations were a part of their decision-making process. These may include the following: What is the overall pattern of injury in the production space? How uniformly are the symptoms distributed? What and where are the symptoms on the individual plants? Are symptoms on the upper or lower foliage or upper or lower leaf surfaces? What does the root system look like? What are the cultural and environmental requirements of this crop? What is the root medium and water quality chemistry?

Another way to introduce the ideas behind the use of a methodical diagnostic process is to ask students to define the process that they go through when they put a jigsaw puzzle together. For example, most people do not just randomly pick pieces out from a pile and start trying to fit them together; instead, they usually sort the pieces by separating those that comprise the corners and border and then set the rest of the pieces into groups based on similar color and patterns. The same concept applies to the diagnostic process: Note the obvious symptoms first, to set some boundaries, and then focus on the overall pattern of the symptoms to delineate categories of possible causes. Discussion to make students aware of how to develop a sequential approach to diagnosis may give them the confidence to follow a methodical process themselves.

TIME: YOURS VERSUS OTHERS. This topic may distinguish the "economists" from the "accountants" in your class, and may provide a lively debate. On the TMBF, costs for procedures that Maria can perform herself are assigned a "cost" of $0. However, these actions take time, which potentially results in lost productivity for Maria's operation. How valuable is the grower's time? Do actions performed by the grower really cost nothing? How does a grower decide how much time to spend on investigating a problem?

Another aspect of time for students to consider is that, although it might cost nothing to seek advice from extension specialists, the schedules of these busy professionals often result in delayed responses. Sending samples out for testing often requires money, and this emphasizes the value of gaining skills in diagnostic techniques appropriate to the production systems.

An instructor might ask if there is a point at which the solution to the dilemma just does not matter. Students may argue that because the timeline was so short for Maria to accomplish corrective actions for her Valentine's Day crop that it would not be worth investing time and money to determine the cause of the foliar chlorosis. They may argue that the impact of the disorder is at best negligible and at worst irreversible at the point in the cropping cycle that the students enter the scenario. However, the counterargument could be made that Maria must get to the bottom of the problem to provide information to prevent it in the future, understand how it will affect

Table 1. A comparison is shown of questions on the 2004–2005 "time and money budget form" (TMBF) with those on the revised 2006 TMBF.

2004–2005 TMBF	2006 TMBF
1. At this point, what do you think is the most likely cause of the chlorosis on the cut dicentra?	1) Do you have enough information from the crop history and results of the diagnostic actions that you recorded on your TMBF to decide what caused the chlorosis?
2. What specific information from the crop history and from the diagnostic actions that you have recorded on your TMBF has resulted in your solution?	a. If so, what do you believe is the cause of the chlorosis and what specific information led you to this conclusion?
3. Are you confident about your solution? Why or why not?	b. If you are not confident about the cause of the problem based on review of the crop history and results of diagnostic actions, what steps or diagnostic actions can you take next to determine what caused the chlorosis?

future crops from the same crowns (for later, alternative market dates such as spring weddings as well as next year's crops), and to guide decisions about disposal of symptomatic dicentra plants.

Appropriate root medium extraction techniques. Ornamental crops are typically grown in soilless root media high in organic matter components such as sphagnum peatmoss or composted pine bark. Standards for nutrient levels in soilless media have been established for several water-based extraction techniques, including saturated medium extract (Lang, 1996) and PourThru methods (Whipker et al., 2000). Agronomic soil testing laboratories typically conduct nutrient analyses on soil samples following acid extraction techniques, but such extraction procedures produce meaningless, inflated results when used on soilless root media, as was the case for Maria in this instance in the case study. This could be a tricky point for students to discern if they have not been instructed in appropriate nutrient extraction techniques for soilless media.

A discussion of root medium extraction techniques for nutrient analyses based on whether the sample is a soilless root medium or field soil could help students appreciate the importance of selecting a laboratory that conducts an appropriate extraction procedure based on sample type. This discussion might be combined with a laboratory exercise to instruct students in simple water-based extraction techniques for in-house determination of pH and EC, as Maria did in the case study (Bailey et al., 2004; British Columbia Ministry of Agriculture and Food, 1999).

Plant disease diagnostic options. Even a seasoned plant pathologist or other diagnostician may follow many different routes to determine the cause of a problem that is affecting a crop. The case study and teaching notes each include a video clip of an extension pathologist walking through the questions that she asks as she addresses a new problem. A discussion of plant disease diagnostic options might be combined with a laboratory exercise to instruct students in the easy-to-use ImmunoStrip test kits for determination of tospoviruses or cucumber mosaic virus. This hands-on activity provides students an opportunity to develop practical skills with the reward of determining positive or negative results on a plant sample.

Closure: Diagnosis of the problem and what Maria did

The plant disorder was determined to be tobacco rattle virus [TRV (tobravirus)]. The virus was identified when an extension plant pathologist compared symptomatic foliage with an image posted to the Web (Lane, 2006). The diagnosis was confirmed by sending tissue to Agdia and specifically requesting an assay for TRV, a virus that is not included in the results of the "ornamental screen" presented in the case study. Therefore, students did not have these results available to them in the diagnostic action chart because additional work by the extension plant pathologist was required after the initial, general virus screen. This may contribute to frustration for the students as they work to complete the case study, but it provides an opportunity for discussion to reveal how the extension pathologist continued the diagnostic process after the initial road block: She went to the Agdia website (Agdia, 2006), noted other ornamental viruses, conducted a Web search using keywords "dicentra" and "tobacco rattle virus" (as well as other general ornamental viruses), came upon a photo that matched the symptoms, and confirmed her diagnosis by sending a second sample to Agdia with the specific request to test for TRV.

Tobacco rattle virus is spread by trichodorid nematodes and is normally restricted to roots. Dicentra is one of the few plant species in which the virus becomes systemic. Because the virus is spread by nematodes, it was determined that infected crowns must have been shipped to Maria. The supplier was contacted about the TRV-infected plants and they indicated that they were aware of the industrywide problem but their root stock, received from Europe, was also often infected. They did not indicate if they routinely screen for the virus.

Maria harvested all the cut stems that she could, taking care not to spread the virus from infected to uninfected plants. She culled all the plants that were showing symptoms of TRV. Because this was a new crop for her, it was unclear whether her stem yield was dramatically affected. In the future, Maria intends to order rootstock from another supplier to determine whether this helps alleviate the virus problem.

Student feedback on use of case study

Students in four floriculture production classes over 3 years—three classes at Kansas State University (KSU) and one class at University of Nebraska–Lincoln (UNL)—were asked to respond to pretest and posttest questionnaires about the dicentra case study. The questions assessed perceived value of the case study as well as confidence in completing the diagnostic process (Tables 2 and 3).

Table 2. Means of student responses to statements about their use of the dicentra case study from the pretest and posttest questionnaire.

Statement	Confidence and understanding of dicentra case study (1–6-pt scale)[z]							
	UNL 2004 (n = 11)		KSU 2004 (n = 17)		KSU 2005 (n = 21)		KSU 2006 (n = 9)	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
A. I am confident that I know the factors a grower should consider when a problem arises during crop production.	4.36 (0.20)	4.64 (0.20)	4.65 (0.12)	4.59 (0.17)	4.43 (0.15)	4.71 (0.17)	4.78 (0.22)	4.67 (0.24)
B. I can work through the steps of the diagnostic process, regardless of whether a problem is incited by environment, disease, nutrition, or insect problems.	4.00 (0.23)	4.27 (0.20)	4.18 (0.10)	4.47* (0.13)	4.14 (0.13)	4.52* (0.18)	4.67 (0.17)	4.67 (0.24)
C. I understand how environmental conditions contribute to plant disorders.	4.82 (0.23)	4.55 (0.25)	4.94 (0.16)	4.76 (0.11)	5.00 (0.12)	4.81 (0.18)	4.89 (0.20)	4.89 (0.26)
D. I have a good understanding of damage incited by insect pests.	4.55 (0.25)	4.55 (0.28)	5.12 (0.15)	5.03 (0.13)	4.62 (0.16)	4.43 (0.15)	4.78 (0.15)	4.44 (0.18)
E. I am confident about being able to make decisions about corrective actions for various crop problems.	3.64 (0.24)	4.00 (0.19)	4.24 (0.10)	4.35 (0.12)	4.10 (0.17)	4.29 (0.17)	4.56 (0.24)	4.11 (0.11)
F. I understand how to decide between the use of different nutrient analysis techniques.	3.45 (0.25)	4.36* (0.28)	4.29 (0.14)	4.41 (0.13)	4.19 (0.15)	4.33 (0.14)	4.67 (0.29)	4.44 (0.18)
G. I understand the difference between soil testing techniques for agronomic crops versus ornamental crops.	3.00 (0.30)	3.82* (0.38)	4.59 (0.24)	4.94 (0.23)	4.79 (0.18)	5.14* (0.19)	4.56 (0.29)	4.78 (0.40)
H. I understand the diagnostic options and procedures for plant diseases.	3.73 (0.24)	4.18** (0.23)	4.12 (0.08)	4.65** (0.12)	4.24 (0.17)	4.57 (0.15)	4.44 (0.24)	4.56 (0.24)

[z]The scale ranged from 1 point (strongly disagree) to 6 points (strongly agree) with six possible ratings. SE is reported in parentheses. Significance is derived from paired *t* test analysis of the four groups individually.
*Significant difference between pretest and posttest at a level of $\alpha \leq 0.06$. **Significant difference between pretest and posttest at a level of $\alpha \leq 0.0$.
KSU, Kansas State University; UNL, University of Nebraska–Lincoln.

Table 3. Means of student opinions about the dicentra case study.

Statement	Posttest assessment of dicentra case study (1–6-pt scale)[z] UNL 2004 (n = 11)	KSU 2004 (n = 17)	KSU 2005 (n = 21)	KSU 2006 (n = 9)	All (n = 58)
I. The background information supplied was sufficient to understand the situation.	5.18* (0.12)	3.35** (0.28)	4.48*** (0.24)	4.78 (0.28)	
J. It was worthwhile to solve this case study.					5.17 (0.01)
K. The solution to the case study was unexpected.					4.71 (0.14)
L. This case study could be used effectively without a group discussion.					2.48 (0.15)
M. The website was logically designed and easy to navigate.					5.11 (0.10)
N. The supporting material on the website (fact sheets, digital video, images) enhanced the case study.	5.64* (0.15)	4.94** (0.14)	5.00** (0.15)	5.44 (0.18)	

[z]Questions were only on the posttest questionnaire. The scale ranged from 1 point (strongly disagree) to 6 points (strongly agree) with six ratings possible. SE is reported in parentheses. Significance is derived using one-way analysis of variance.

*,**,***Values were significantly different at $\alpha < 0.05$, $\alpha < 0.01$, and $\alpha < 0.00$ respectively.

KSU, Kansas State University; UNL, University of Nebraska–Lincoln.

All data were analyzed using the nonparametric Mann-Whitney statistical procedure and Exact tests of SPSS (Graduate Pack, 11.5 for Windows; SPSS, Chicago). Exact tests is an SPSS software addendum that calculates exact *P* values for small and nonuniformly distributed data.

Comparison of 2004–2005 posttest with pretest student responses shows a general trend of increasing confidence in diagnostic procedures after the completion of the case study (Table 2): In 2004, both KSU and UNL student groups reported a significant increase in understanding the diagnostic options and procedures (Table 2, H). In addition, UNL 2004 and KSU 2005 both reported a significant increase in understanding the difference in soil testing between agronomic crops and ornamental crops (Table 2, G), which is a unique focus of the case study. Furthermore, in KSU 2004 and KSU 2005, a significant increase in confidence was reported in ability to complete the diagnostic process after completing the case study (Table 2, B).

An exception is that all student groups trend toward less understanding about the damage incited by insect (arthropod) pests. This may be attributed to the lack of focus on arthropod pests in the dicentra case study: The grower reports no significant insect infestations. During group discussion, the solution revolves around nutrition and viral diseases, not insects.

Group discussion enhances learning if students are permitted to discuss problems, solutions, and explanations that they have generated (Gall and Gillett, 1980). With the dicentra case, all groups recognized that for the case to be effective, a group discussion was necessary (Table 3). All student groups were in agreement that the solution to the case was unexpected (Table 3). This speaks to the complicated nature of this case study. The balance needed when using the case study method is creating enough cognitive dissonance to cultivate learning without fostering frustration. Cognitive dissonance is commonly resolved when the student processes new information to make a decision, but because a straightforward solution is not obvious from the background information provided in this particular case study, the class discussion is an integral part of the resolution process.

In 2006, the TMBF was modified by changing the student response questions (Table 1) to improve development of problem-solving skills. The solution-based questions of the 2004–2005 TMBF required students to specifically identify the *cause* of the chlorosis. With this focus, students scramble for an answer that is most likely to maximize their grade (Johnson et al., 2002). This contributes to overconfidence, which masks the need for new information to determine an accurate solution (Blanton et al., 2001). One way to avoid overconfidence is to require students to focus on *process* rather than solution. With the process-based questions of the 2006 TMBF, students must define information needed to proceed, which is a major objective of case studies (Johnson et al., 2002).

Although this change to the 2006 TMBF did not contribute to a trend of significant increase in student confidence in their diagnostic skills, it can be argued that refining problem-solving skills is an appropriate goal late in the undergraduate's educational career. Case studies, with process-based assessment and group discussion, provide a means to develop problem-solving skills, which is an elusive but often sought-after characteristic by their future employers (e.g., Berle, 2007).

The dicentra case study was developed for advanced students with previous exposure to the case study method. Student assessment data indicate that students can substantially benefit from the experiences of working through this complicated case study. All student groups felt that solving the case study was a worthwhile exercise (Table 3). Students acknowledged their role as a decision maker, which is a goal in learning processes using a case study (Hoag et al., 2001). The dicentra case study is a novel learning tool that can be used to minimize student overconfidence while developing and refining more advanced problem-solving skills.

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