2008 PROGRESS REPORT

Submitted to Monsanto Fund
by Dr. Claire Hemingway, Education Director and William Dahl, Executive Director
Botanical Society of America

I. OVERVIEW OF PROJECT OBJECTIVE AND FUNDED PROJECT ACTIVITIES

The specific objective of the PlantingScience program supported by the Monsanto Fund is to:

Develop and test inquiry teaching and learning resources that integrate plant science content and process and address National Science Education Standards: We aim to improve understanding of plant biology and the process of science and to escalate the significance of plants in classrooms. We will develop and field test a set of engaging, standards-aligned online (downloadable) materials that allow teachers to replace or supplement current lessons with flexible open-ended, active-learning approaches using plants as model organisms.

In August, 2007, the BSA hosted an inquiry writing retreat at our St. Louis headquarters. The participants included:

- K-12 teachers (Valdine McLean, Toni Lafferty, Jane Metty)
- Plant scientists (Drs. Paul Williams, Gordon Uno, Marshall Sundberg, Larry Griffing)
- Curriculum/science education specialists (Drs. Ethel Stanley and Carol Stuessy)
- BSA Education Director Dr. Claire Hemingway, who coordinated and facilitated the inquiry writing retreat and subsequent classroom testing and reflection on progress.

During this writing retreat, we began by reviewing the criteria for writing new inquiries that had been circulated prior to the meeting to ensure that the community of contributors had a common understanding of the project goals. We also sought feedback on the format and presentation of the inquiry materials and discussed an overall scheme for developing a full range of plant inquiries and illustrating the connections between them and the underlying theme of evolution across them. We then identified three new inquiry units accessible to learners of different levels of investigation experience and biology content knowledge. The inquiry writing teams were formed, the frameworks for the investigations planned, and text drafted. As the inquiry chosen modules represent three levels of difficulty, they, not surprisingly, have progressed to various stages since the August writing retreat. Each of the new units, contributors, and activities associated with writing and field-testing are described below.

Genetics – intended for students ready for sophisticated, extended investigations
Scientist-teacher writing team: Paul Williams, Wisconsin Fast Plants; Larry Griffing, Texas A&M University; Valdine McLean, Pershing County High School, Lovelock, Nevada
Curriculum Specialist: Ethel Stanley, BioQUEST Curriculum Consortium

The aim of this unit is to introduce students to genetic and environmental components of heritability and natural and artificial selection. Two options will be available: using markers in Rapid Cycling Brassica rapa (RCBs) –extending the materials available on Qualitative and Quantifiable Mendel content on www.fastplants.org-- or recombinant inbred lines of Arabidopsis Columbia and Landsberg parent lines. Students also learn how to use digital images and JImage software to record and analyze plant growth. In the initial concept draft, an option using dwarf barley was also considered, but this did not grow well in either the classroom or greenhouse. Alpha testing: 2 high school classrooms, 2 high school teachers, 54 students, 11 scientist mentors: Alpha classroom testing took place with V. McLean's honor's biology class working in 6 teams, with Griffing and Williams each connected as mentors to the teams. T. Lafferty also conducted the genetics inquiry with her freshman biology students; these 9 teams were mentored by regular PlantingScience mentors. In both cases, the investigations spanned >10 weeks. V. McLean's class investigated both RCBs and Arabidopsis. T. Lafferty's class investigated RCBs only. On April 18, 2008 the Genetics writing team reassembled to begin revising the two routes of the genetics units. Williams and Griffing are currently experimenting with new lines using markers that will be evident to students at the seed and seedling stage and growth conditions to bullet proof the system and develop ~5- and 8-week options. Another classroom test is planned for fall.

Respiration – intended for intermediate students
Scientist-teacher writing team: Marshall Sundberg, Emporia State University; Toni Lafferty, C.H. Yoe High School, Cameron, Texas
Curriculum Specialist: Ethel Stanley, BioQUEST Curriculum Consortium

This unit will be to connected with the current Power of Sunlight inquiry on photosynthesis within an energy and carbon cycle inquiry thread. The aim of the unit is to explore cellular respiration and quantify using a simple constructed respirometer the net difference of carbon dioxide produced less the oxygen consumed. Alpha testing: 1 high school classroom (30 freshmen biology students) communicating 9 scientist mentors and 1 undergraduate botany classroom. Both T. Lafferty and M. Sundberg conducted respiration projects in their respective classrooms. The high school students gained proficiency with the technique after the initial trial and demonstrated feasibility and promise for this unit to be ready for broad dissemination in the next academic year. E. Stanley is currently reviewing the current draft and incorporating appropriate supporting resources. This summer, T. Lafferty and M. Sundberg will participate in the first PlantingScience Teacher Institute, to be held at Texas A&M University, and will demonstrate the technique and open-ended student-directed possibilities to participating teachers.

Corn Competition – intended as an introduction to experimental design
Scientist-teacher writing team: Gordon Uno and Toni Lafferty
Curriculum Specialist: Ethel Stanley, BioQUEST Curriculum Consortium

Alpha testing: 1 high school classroom (30 freshmen biology students) communicating 9 scientist mentors and 1 undergraduate biology classroom. Both T. Lafferty and G. Uno conducted the corn competition in their respective classrooms. This "invitation to inquiry" was readily accepted by the high school students. The unit will be polished and formatted for a PlantingScience module and, we expect, released for the Fall 2008 session. We anticipate this will be a very popular unit by first-time PlantingScience teachers.

The initial writing and classroom testing experiences have proved to be valuable learning experiences, and new writing templates, helps, and procedures for team communication, such as regular telephone conversations prior to, during, and after the classroom field testing, are now in place. A major lesson learned by Hemingway is that writing teams require more structure and support than anticipated. Additional time will be devotee to working closely with the writing teams and curriculum specialist to ensure steady progress.

Planning is underway for the next round of inquiry writing retreats. Three topics tentatively planned will address pollination, invasive species, and phenology. Contributing scientists are identified, but contributing teachers are not yet confirmed. Both V. McLean and T. Lafferty wish to remain engaged in developing new inquiry units.

II. Overview of Project Progress

To address the success of our program goals, we have developed a series of focus indicators regarding (1) scientific mentoring and discourse, (2) the use of plants as models to teach and learn science, and (3) the perceptions of participants' roles in the enterprise of science education. We are currently using pre- and post-tests to provide information on students' skills, science understanding, and attitudes. To assess short-term progress, we will use online surveys once implementation in classrooms is underway to gather information about teachers' facility and comfort using the open-ended plant inquiry materials. To gauge whether teachers are infusing the use of plants as model organisms for inquiry-based teaching in their classrooms, we will collect counts of the frequency of use of inquiry modules. To gather more in-depth understanding of the impact on teaching and learning, data will also be collected from on-site observations, written artifacts, and online discourse.

In the section that follows, some information provided will be specific to the inquiry units under development, much will pertain to the project at large. We have developed a series of queries of the PlantingScience database to automate many of the counts and frequencies indicated in the Focus Indicator table below.

Focus Indicators

Project Outcome	Measurement and Scoring	Collection / Reporting Status
Scientific Discourse Focus Indicator		
Plant scientists engaging in scientific discourse with teachers and students	Frequencies of engagement - Counts Levels and types of discourse - Coding via rubric	Ongoing count data **reported Table 1** Preliminary discourse collection; preliminary data **reported below**
Students engaging in extended dialogue with scientists and peers	Length of dialogue - Counts Website discussions - Coding via rubric	Ongoing count data **reported Table 1** Partial discourse collection
Scientific Mentoring Focus Indicator		
Plant scientists mentoring teachers and students in inquiry planning, design and implementation	Website discussions on forum – Counts and coding Workshop interactions - Observations	Ongoing count collection / **Data reported below** Coding pending Observations beginning this summer
Teachers mentoring other teachers in design of classroom inquiries	Website discussions on forum – Counts and coding Workshop interactions - Observations	Ongoing count collection / **Data reported below** Coding pending Observations beginning this summer
Students mentoring other students in their planning, design, and implementation of inquiries	Students' website discussions - Coding via rubric re: types of questions, quality of responses	Preliminary website discourse collection
Use of Plants as Models to Teach and Learn Science Focus Indicator		
Students developing good scientific questions about plants and designing methods for answering them	Students' website discussions and posted work - Coding via rubric re: types of questions, quality of inquiries	Preliminary data collection
Students demonstrating logical reasoning in their dialogue	Analysis of evidence-based conclusions – Web content analysis & written artifacts	Collection pending
Students posting their own work	Website content – Counts and coding	Ongoing count collection / **Data reported Table 2**
Students developing abilities to work in teams to solve scientific problems	Students' website discussions - Online content analysis	Collection pending
Science teachers infusing the use of plants as model organisms for inquiry-based science teaching	Frequency of use of modules	Ongoing count collection / **Data reported below and under use**
Science teachers engaging in the development of technology-rich, web-based inquiry science materials	Surveys, interviews, observations of design experiences	Ongoing and pending collection
Perceptions of Participants Roles in the Enterprise of Science Education Focus Indicator		
Scientists perceiving their roles as agents of change in science education	Surveys and interviews	Ongoing and pending collection / **Data reported under survey**
Teachers perceiving their roles as agents promoting career awareness	Surveys and interviews	Ongoing and pending collection / **Data reported under survey**
Students assessing own abilities as individuals who can "do science"	Surveys and interviews	Ongoing and pending collection

Discourse and Mentoring. The discourse among student team members, scientist mentors, and students from other research teams on team research web pages over the last year is summarized below in Table 1. The averages reported below do not provide an adequate picture of the degree of exchanges, as the range could occasionally be wide, particularly for the students, with the maximum number of postings by an individual student reaching 58.

Table 1. Contributions to dialog on Student Team Research Web Pages

Postings on Student Team Web Page		Middle School			High School		
		By Team members	**By Scientist mentors**	**By Other students**	**By Team members**	**By Scientist mentors**	**By Other students**
Fall 2007	Average number	5.4	4	1.6	5.1	4.2	2.6
Spring 2008	Average number	14.9	7.5	3.6	10.8	6.4	2.9

Carol Stuessy, Internal Evaluator and Lead of Science Education Research component, has analyzed dialog content from the proof-of-concept. C. Stuessy found that students require support to effectively engage in science discourse and keep science journals and that most teachers require pedagogical and assessment support for successful classroom implementation. In response, we added a check-brick and preliminary investigation toolkit to the website, as long as 10 top tips for students. Preliminary of the online discourse were presented at the 2007 NARST meeting. We have established procedures for extracting and scoring discourse from the project database.

The 2007-2008 Academic year saw an increase in the use of the discussion forums, which were initially seeded with comments by Hemingway, with individuals voluntarily posting subsequently. Thus, the interactions suggest that scientists and teachers are engaging in community mentoring beyond the overt focus on mentoring student research projects.

- The Mentor forum now has a total of 88 posts, and particular threads such as the Friday Reflections are heavily viewed (n= 11 replies, n=102 views).
- The Schedule thread of the Teacher and Mentor Forum has 32 posts and 243 views.
- The Teacher-to-Teacher Forum, the least used thus far, has 5 postings, 42 views.

Use of Plants for Inquiry Teaching and Learning. Students are relatively successful in developing research questions, predictions and research designs. They provide a variety of supporting documentation for their plant investigations, primarily research journals and data sheets, although there is an increase in posting of images (Table 2). For data on teachers infusing plants in the classroom, see the section on Counts of use and participation.

Table 2. Percentage of student teams posting particular types of data and information.

Team Postings	Photo	Research question	Prediction	Research Design	Conclusion	Research Journal	Data Sheets	Final Presentation	Images	Movie
Fall 2007 (total of 226 Teams)	89.4 % n=202	85.4% n=193	79.2% n=179	75.2% n=170	45.6% n=103	40.7% n=92	30.5% n=69	19.5% n=44	25.7% n=58	1.33% n=3
Spring 2008 (total of 150 Teams)	96.7 % n=145	91.3% n=137	87.3% n=131	72.7% n=109	40.7% n=61	44.0% n=66	24.0% n=69	13.3% n=36	42.7% n=20	0.67% n=1

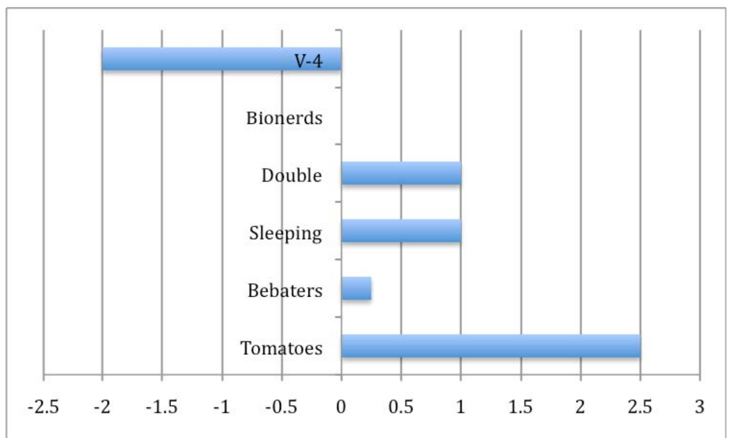
Learning Outcomes: Pre- and Post-Tests and Written Artifacts

We know from tabulation of the 166 secondary students surveyed in fall 2005 that 78% reported that coming up with a research question was a new experience for them. Thus, one direct impact on students is the opportunity to engage in a fundamental part of the inquiry cycle. Across all pilots, over three-quarters of secondary students (n=270) reported that they highly valued their online interactions with scientists and peers.

Our current strategy for pre- and post-tests is to provide participating teachers with a selection of possible content questions as a starting point and ask the teacher to select 3 questions regarding plant biology and the process of science that they would like to use in pre- and post-tests tailored for their class. We changed procedures following the initial pilots to more closely match the specific learning objectives individual teachers set for their classes. This, of course, complicates analysis, while ensuring the test questions are more relevant to students in individual classes.

Below are highlights of pre- and post-tests and learning outcomes of two of the new units under development. Additional data and copies of student work and teaching portfolios are available upon request.

Genetics Pre- and Post-Test Results. The pre- and post-tests include Likert scale questions regarding attitudes and skills as well as three content questions. Analysis of the average change in Likert scale responses between pre- and post-tests is shown for V. McLeans's 6 student teams at right. With the exception of one team, all teams showed increases in attitudes and skills. Analysis of the open content questions is ongoing, as the Spring session only recently completed. V. McLean also assessed student understanding though student essays that were written about a genetics case "Good cabbage" that applied concepts they had encountered during the course of the genetics investigation and classroom instruction.

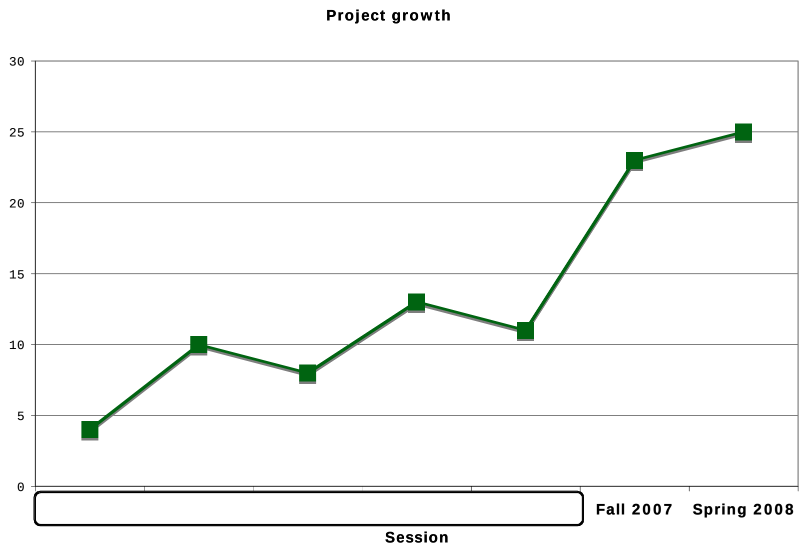


Corn Competition Learning Outcomes.
Assessment of the Corn Competition diverged from the standard pre- and post-test, as the primary goal is to introduce the need for a control sample in experimental designs. As a "messing about" activity, it allows students to learn from failure in a safe way. The intention is that this experience for novice learners would generate productive mentoring interactions and follow up investigations.

	High school freshmen	Intro botany non-majors students
Number of pots returned with at least living corn plant after 3 weeks	21 / 31 (8 students took one pot and 13 students took two pots)	85 / 96
Mentioned control	2	22
Implied control	3	18
Other comments by educators on student understanding	4 mentioned fertilizer of some sort 16, water and light together 3, "I think I drowned the seeds"	47 students had no understanding of a control

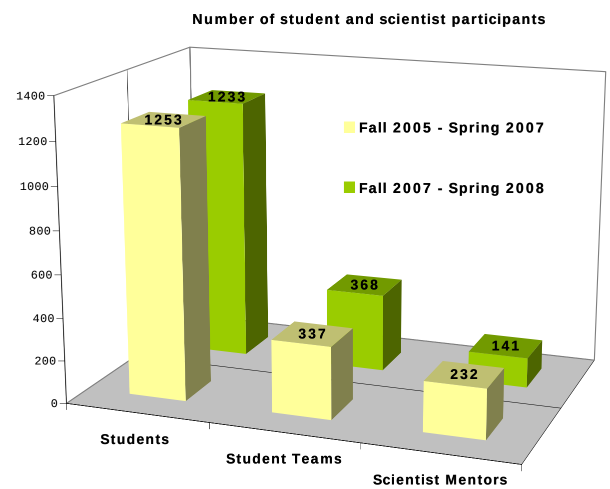
Frequency Counts of Inquiry Use and Participation

To date, the PlantingScience project has reached 2,486 students from 25 states across the nation working in 705 teams with online scientist mentors.



The 2007-2008 Academic year was a year of a tremendous growth for the project, compared to the relatively stable status from Fall 2005 to Spring 2007. During that two year period, a given PlantingScience session involved on average 274 students from 7 schools working in 74 online teams.

Fall 2007 saw a doubling of participants (n = 23 schools, 649 students, 210 online teams). Spring 2008 participation sustained the growth spurt (n = 25 schools/classes, 584 students, 158 online teams).



To put this year's growth spurt in perspective, the figure at right compares the cumulative number of participants during the two-year period from Fall 2005 to Spring 2007 with participant numbers during the current academic year. We communicated with, accommodated, and supported online similar volume of participants this academic year as in the two years previous.

Fueling the growth was increased enrollment by both middle schools and high schools. Sessions prior to this academic year saw an average of 2.25 middle schools taking part, whereas 7 middle schools enrolled in the Fall 2007 session and 6 in Spring 2008. High school participation likewise jumped from an average of 4.75 classes taking part to 11 enrolled in the Fall 2007 session and 18 in the Spring 2008. Thus, it appears that we are reaching our initial target audience of high school teachers and students and increasing the pool of middle school participants.

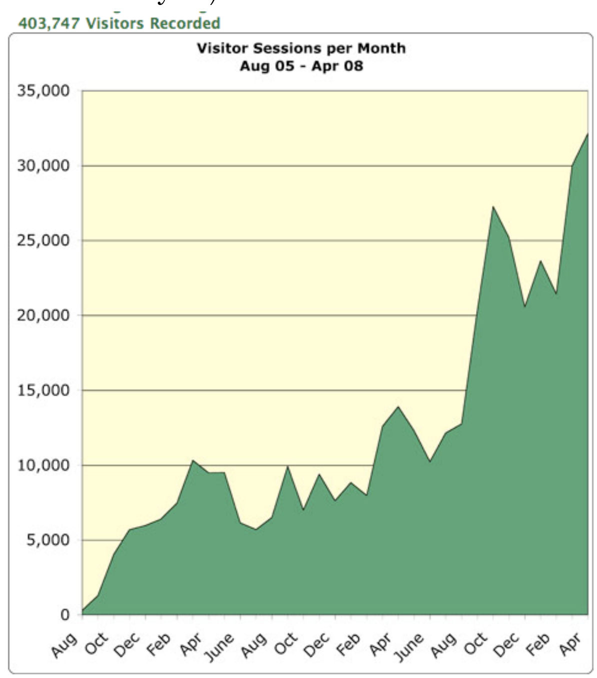
Counts by module: The Wonder of Seeds (the first inquiry available in the program) remains the most popular. In Fall 2007, 18 participating classes signed on for the Wonder of Seeds Inquiry (the first inquiry available) and 5 signed on for the Power of Sunlight. In Spring 2008, 20 participating classes signed on for the Wonder of Seeds Inquiry (the first inquiry available) and 5 signed on for the Power of Sunlight.

"repeat" teachers	42% n=16
"first-timers"	58% n=22

Participation by teachers: Maintaining a core for each inquiry session is a set of "repeat" teachers, who return to participate with new classes. The majority of the repeat teachers have taken part twice thus far (n=8). But other teachers return regularly (6 teachers have participated 4 or 5 times thus far) and one (Marshall Sundberg) has participated in all seven sessions with out fail. T. Lafferty, new to the program this year, has engaged her freshman biology class this year in all possible inquiries: Corn Contest, The Wonder of Seeds, The Power of Sunlight, Respiration, and Genetics. Her experience leading extended inquiries in the classroom and sequencing multiple plant investigations with the same class over the course of a school year has given us great insights.

Several of the repeat teachers have taken on teacher leader roles. V. McLean and T. Lafferty are both already Teacher Leaders, well respected regionally and nationally. They are actively involved in the development of new inquiries. C. Packard is active in promoting the role of middle schools in the project and disseminating the project at national science education meetings. P. Skinner has actively promoted the project to her colleagues. A. Landry and T. Lafferty will join the first PlantingScience Teacher Institutes in Teacher Leader roles.

Participation by mentors: Over 120 scientists have signed on as scientist mentors since the project began. In a given session, the average number of mentors taking part has climbed from 56.2 per session (between fall 2005 and spring 2007) to 70.5 (during this academic year). Note that the dramatic increase in the number of participating schools and student teams has been accommodated by rather modest increases in the number of mentors. This has been possible due to contributions of the Master Plant Science Team, which was sponsored by both the BSA and ASPB this year.



Website access: The website is widely accessed, with over 400,000 visitors recorded. As expected, visitor sessions peak during the fall and spring online sessions. The rapid growth in project participation is mirrored in general visits to the website during 2007. Thus, more individuals are both accessing the website and choosing to participate in the project.

Online Surveys

Participating teachers are provided a link to an anonymous online survey following each session. Scientists volunteering as scientist mentors are surveyed once per academic year. Beginning this summer, the external evaluator will collect additional information on the perspective on the project from participating teachers, students, and scientists and the internal evaluator will begin classroom observations.

Teacher survey results of note: Teachers report that the students' performance exceeded the learning objectives the teacher planned for the inquiry (67% in Fall 2007, 90% in Spring 2008). And they felt that the PlantingScience design enabled their students to conduct scientific investigations very well (77% in Fall 07, 60% in Spring 08). Primary barriers to classroom implementation are school schedules and perceptions that students are not ready.

Mentor survey results of note: 61% will definitely participate again (time is the limiting factor); 57% felt students' abilities were lower than expected for age group; 56% are not at all satisfied with the communication with classroom educators; 50% are greatly satisfied with the website. Recurring themes from the open-ended questions are greater interaction/communication before projects begin, more feedback from students and others. Encouragingly, although sample size is low, mentors appear to be interacting and thinking in new ways outside the program.

Feedback from teachers participating in field testing of new inquiry units is obtained via online surveys and email exchanges, thus far. For consistency's sake, feedback from T. Lafferty is provided.

Toni Lafferty of C.H. Yoe High School (Cameron, TX) :
"They had a great time...I'm taking class time on Tuesday for the students to measure the corn...I'll take pictures and send you one. I gave points to everyone returning growing corn....I'll give a grand prize to one on Tuesday.
I'm using the corn experiment as a contrast to an enzyme lab the students just finished...in that lab they designed the question,hypothesis,collected data and analyzed data...they also did revisions...
AND...It is a perfect intro to the next objectives we're covering...
AND ...one of the elementary teachers borrowed a growing corn pot for a demo to accompany a corn book she was reading with her students.
In a week, we'll be officially working through Planting Science for photosynthesis and respiration...we're looking forward to more fun. Thanks for your input." [Corn Competition Unit Field Testing Fall 2007]

"Their round table discussions were amazing…I wish you could have heard them defending their projects!!!!!!!!!!"
[Respiration Unit Field Testing Fall 2007]

"Hi Claire, The kids saw their F1 generation plants yesterday and they were able to have REAL conversations about traits being passed from parents to offspring...I was hearing heterozygous homozygous geneotype phenotype dominant and recessive in real conversations!!!!!" [Genetics Unit Field Testing Spring 2008]

III. EXPENDITURE

To date we have used $25,377.86 of the $40,000 provided for the current year. We ask that you consider an extension in using this years funds. You will find we are fiscally responsible and that the team has worked to keep expenditure to a minimum. We also ask that you consider holding the discussed funding of $40,000 in year two for use when required. Your participation and support is important. Our aim is to use the funds responsibly and in a timely manner that fits with our development.

IV. CLOSING COMMENTS

On behalf of the Botanical Society of America and the participating Societies, we thank the Monsanto Fund for supporting the PlantingScience program. Over the coming year we hope to complete and open the three inquiry units currently in trial. We will also add several new Society members and their pool of scientists to the program. This is an exciting development as it will open the possibility for quicker inquiry unit development and include phytochemistry and soil/agriculture based scientists.

More importantly, by the end of the Spring 2009 session, we hope to double participation and have supported and mentored over 5,000 students involved in hands on plant research.

Please contact us if you have any questions or comments. We appreciate your feedback and support.

Sincerely,

William Dahl and Claire Hemingway