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Abstract

NASA Fundamental Biology Outreach (http://weboflife.arc.nasa.gov/) in collaboration with The Wisconsin Fast Plants Program at the University of Wisconsin-Madison (http://www.fastplants.org/) is sponsoring a project to provide activities centered on *Brassica rapa* plants and *Brassica* butterflies for teachers and students. This project, called *Brassicas* and Butterflies was designed to provide teachers and students with specific activities that could be conducted easily in a classroom and yet help them to design experiments to be conducted in space as well. The growth and development of the *Brassica* plant and the butterfly are parallel, demonstrating the process of coevolution. The plant germinates in less than two days and begins to flower in about two weeks. Following pollination, the plant produces seed in a total of thirty-five days. The butterfly hatches within a week, the larvae feed on *Brassica* plants and pupate in about two weeks. The butterfly pollinates the flowers and each of the organisms provides benefits for the other in a mutualistic relationship. A teacher workshop was held in November 2001 with additional workshops targeted for 2002. The intent is that students will conduct the research in the classroom and develop experiments for the NASA Student Involvement Program (http://education.nasa.gov/nsip/) to be conducted in space.

Introduction

The Wisconsin Fast Plants Program at the University of Wisconsin-Madison has established a close working relationship with NASA. The development of the Collaborative Ukrainian Experiment-Teachers and Students Investigating Plants in Space (CUE-TSIPS) was the start of a continuing relationship. The CUE-TSIPS program lead to the development of hands-on activities and training for teachers, both in the United States and in Ukraine. These activities allowed students to conduct the ground controls for a plant pollination experiment that flew on the Space Shuttle in December 1997 (Dreschel, et al., 1997, 1998). Following the completion of the CUE-TSIPS project, the Wisconsin Fast Plants Program developed an activity titled "Farming in Space" which is intended to allow students to conduct ground controls for an experiment with wheat and Fast Plants on the International Space Station called "Photosynthesis Experiment System Testing and Operation (PESTO)". This experiment is scheduled to go to space in the first quarter of 2002. Most recently, the Wisconsin Fast Plants Program has begun to develop materials for studying the development of a cabbage butterfly and its relationship with Fast Plants. The NASA Fundamental Biology Outreach Program decided to sponsor this activity to give it a "space biology spin". The activities of this program are focused on how gravity and/or altered gravity affect the growth, development of both the *Brassica* plant and the *Brassica* butterfly and how they interact with each other.

Prior Space Research with *Brassica rapa*

One of the key experiments conducted during the Collaborative Ukrainian Experiment revolved around a pollination activity in space using *Brassica rapa* as the model plant. This experiment was conceived and developed by Dr. Mary Musgrave from the U.S. and Dr. Antonina Popova from Ukraine. The CUE-TSIPS activity was designed to be student conducted ground controls for what was called the "B-Stic" experiment. The seed were planted and plants grown prior to launch so that flowers would be present while the plants were on orbit. There they were pollinated using bee abdomens glued to a small stick. The plants were returned to Earth where the embryos were fixed for microscopic examination or cultured to produce viable plants. Students performed the same activities in their classrooms. The life cycle of the *Brassica rapa* plants is presented in Figure 1.
The addition of the Brassica Butterfly to the equation adds a new dimension to the hands-on activities possible. The life cycles of these two coevolved organisms, one plant and one animal, serve as models under the topics of growth, development, reproduction, nutrition, and many other areas. In addition, the potential for utilizing these two organisms in space experiments should excite students in the study of gravitational effects on living systems. The life cycle of *Pieris rapae* is presented in Figure 2.
Figure 2. The Life Cycle of the Brassica Butterfly, *Pieris rapae*
The Brassicas and Butterflies Project

Using the CUE-TSIPS projects as a model, the Brassicas and Butterflies Project (B&B) is developed to be hands-on activities that are connected to a space flight experiment. The difference being, that this time, students and their teachers will have the opportunity to design the experiment that ultimately is flown in space, either on a sounding rocket, Space Shuttle, or International Space Station. There are two possible routes for this to occur. The NASA Student Involvement Project (NSIP) is a program for which students are able to propose space experiments. If selected, the experiment is conducted either on a sounding rocket or on a Space Shuttle mission. Alternately, there are several commercial space organizations that periodically offer space within their hardware when space is available. If no opportunities for space flight present themselves, the other options are to conduct the research on the NASA KC-135 aircraft. This is an aircraft that is flown out of Ellington Air Force Base performing parabolic maneuvers in order to provide short periods (20 seconds) of free-fall, simulating the space environment. Other options are to provide shorter periods of free-fall in the drop tower at NASA Glenn Research Center or to provide periods of multiple gravities on a large centrifuge at NASA Ames Research Center.

The students will also be able to build simple devices to expose the organisms to altered gravity in their classrooms. These include a clinostat, which provides a slow, constant rotation (on the order of one revolution per minute). A centrifuge that provides constant multiple gravities perpendicular to the normal gravity vector can be constructed from a phonograph turntable. Thirdly, a salad spinner, available at most department stores, can provide short-term exposure to multiple gravities and might be used to simulate launch and landing (Figure 3).

Procedures for constructing devices to culture both the Fast Plant and the Butterfly from recycled materials (trash) are included in the B&B activities. Both organisms can be easily grown in the classroom with a reasonable amount of care. The Fast Plants can be planted and grown in film canisters and deli containers or plastic soda bottles utilizing peat-vermiculite and water-soluble plant food. A plant light house is constructed from a copy-paper box, aluminum foil, and a compact fluorescent light and a Butterfly box with a similar design but with screen windows (Figure 4).
Figure 4. The Plant Light House and the Butterfly Box, Both Constructed from Copy Paper Boxes.

The culturing and breeding of the Butterflies can also be performed in deli containers using film cans. Male and female butterflies are placed together in the Butterfly Box with an ovipositor made from a film can with a Brassica leaf disk pasted to the top and a strip of wax paper wrapped and glued around the side. Females land on the leaf disk and deposit their eggs on the wax paper. The wax paper strip with eggs are placed "eggs down" on fast plants, collard greens, brussel sprouts, broccoli, or cauliflower on which they feed and grow. A recommended procedure is to place them on brussel sprouts in a "Brassica barn" (Figure 5). The larvae feed until they reach the L5 molt and then produces a chrysalis around itself. Within the chrysalis, the larva undergoes metamorphosis and then emerges as the adult butterfly (Figure 2).

Figure 5. Conceptual Drawings of The Film Can Ovipositor with a Female Butterfly Laying Eggs and the Brassica Barn with Larvae feeding on Brussel Sprouts.
When the adults emerge from the chrysalis, they are placed into the Butterfly Box where they feed on the nectar of Fast Plants (pollinating the flowers as well) or using a film can sugar feeder containing sugar solution with wicking material sticking out openings in the top (Figure 6).

Figure 6. Film Can Sugar Feeder to Provide Nourishment for the Butterflies.

Investigations suggested include food preference activities for both the larvae and adults, rate of digestion of the larvae, frass forensics (examination of feces), development rates of both the plant and butterfly, rate of egg laying, butterfly and flower interactions, color preferences of the butterfly, and many others. How altered gravity affects all of these processes and activities provides an exciting dimension for student research.
References


