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Paper Session III-B - Soybean and Corn Seed Germination in Space: The First Plant Study Conducted on Space Station Alpha

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Soybean and Corn Seed Germination in Space: The First Plant Study Conducted on Space Station Alpha.

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Abstract

The JOSE (JASON Outreach Seed Experiment) payload was the first plant study conducted on Space Station Alpha. The experiment consisted of having an on-orbit watering of eight seed pouches, each of which contained either six soybean or six corn seeds glued to a germination paper substrate. Two pouches containing corn plus two pouches containing soybean seeds were maintained in the light after watering. Two additional seed pouches of each species were maintained in the dark after watering. Digital photography was used to document the growth of the germinating seedlings in space. The images were down-linked and posted to a world wide web site for dissemination to students. Details relating to the experimental design are presented. "Within" species differences (between the light and dark grown seedlings) as well as "between" species differences (comparing corn and soybean) were observed.

Introduction

The Educational Seed Growth Kit (EDUC/SGK) Payload was initiated to support the education objectives of the JASON Going to Extremes Project. The mission of the JASON Foundation (www.jasonproject.org) is to excite and engage students in grades 4–9 in science and technology, and to motivate and provide professional development for their teachers through the use of advanced interactive telecommunications. Kennedy Space Center (KSC) personnel provided technical support in the development of the hardware and science protocols used to attain the objectives of the JASON Project. These efforts have been referred to as the JASON Outreach Seed Experiment (JOSE). The experiment utilized digital photography as a means of documenting the growth of germinating soybean and corn seeds under spaceflight conditions. Daily images of the developing seedlings were down-linked and posted to a world wide web site (www.jasonproject.org/jason11/) for dissemination to students for their evaluation. Parallel classroom investigations were conducted by the students.

Methodology

A maximum volume of 12" x 12" x 5" and a 5 lb weight restriction was available for the experiment. A seed kit was developed which fit within these constraints. It contained see-through seed pouches (CYG Seed Germination Pouches™) each of which contained 6 individual seeds of either soybean (*Glycine max* cv McCall) or corn (*Zea mays*). The seeds were glued to a germination paper substrate using a 1.2% guar glue solution. Twelve seed pouches were flown,

eight of which were germinated either under dark or lighted conditions. The remaining four were returned to KSC for ground control studies. Each seed pouch contained a 10 cm scale along its side to facilitate photo-based data extraction. Figure 1 presents an overview of the experimental design.

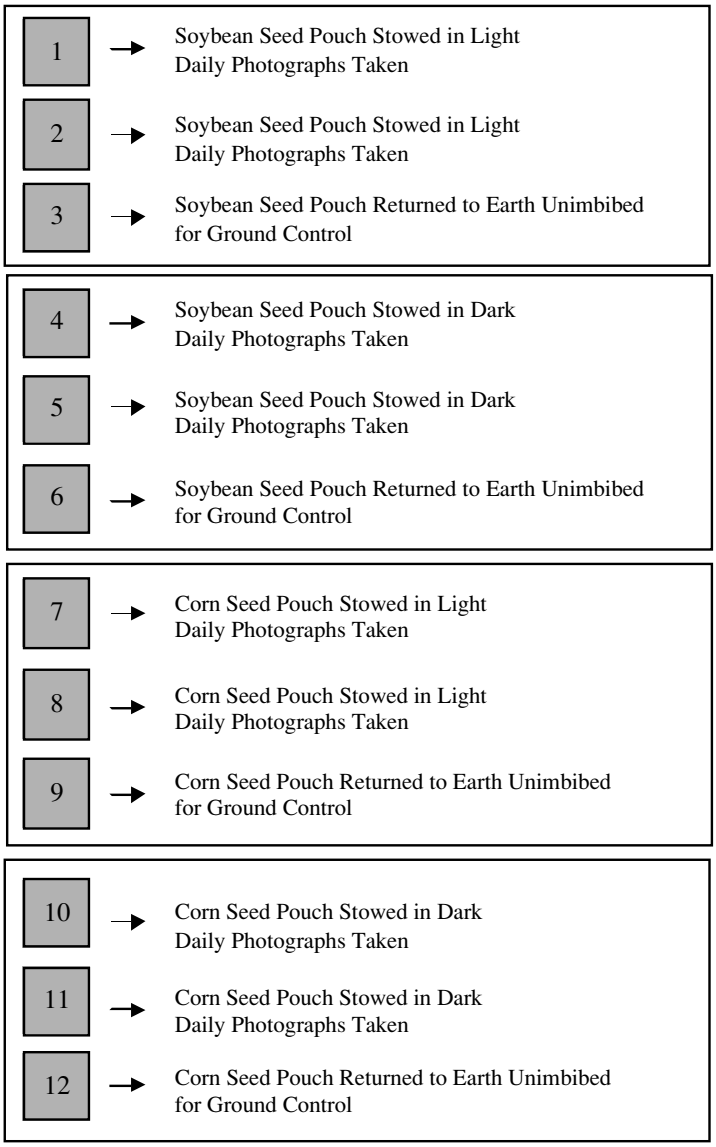

Figure 1. JOSE Experimental Design. Twelve seed pouches (six corn plus six soybean) were flown, with four returning unimbibed for ground control studies.

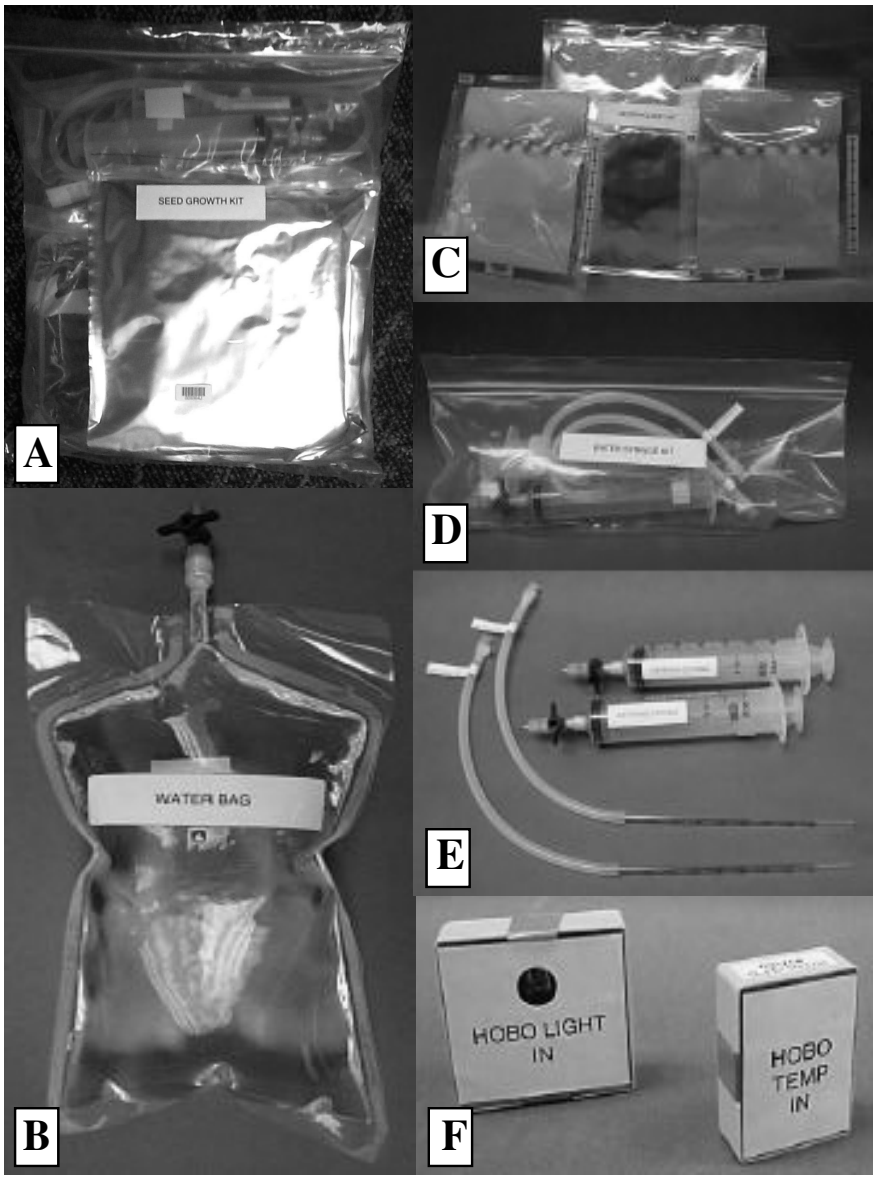

Figure 2. Seed Kit Components. A. Fully assembled seed growth kit. B. Teflon™ bag used as source of water for seed imbibition. C. Individual seed pouches for soybean (left) and corn (right). D. Water syringe kit as packed for flight. E. Water syringe kit components. F. HOBO™ temperature and light data loggers.

All of the seed kit components are presented in Figure 2. Polyethylene-coated foil (Bell Fibre Products Corp.) was heat-sealed to form the kit containment pouches (Figure 2a). The Teflon™ Water Bag (Figure 2b) was obtained from American FluoroSeal. Temperature and light HOBO™

data loggers (produced by Onset Computer Corp.) were used to continuously log environmental conditions in the vicinity of the seed pouches. A post-flight ground control experiment will be conducted at KSC within an Orbiter Environmental Simulator Chamber which will be programmed to mimic the on-orbit temperature and light conditions.

The payload was launched on the Orbiter Endeavour (STS-97; ISS Flight 4A) on 30 November 2000 at 10:06 p.m. EST. Endeavour docked to Space Station Alpha (Orbital altitude 189-248 nautical miles; Orbital inclination 51.6 degrees) on 2 December 2000, and the Seed Growth Kit was transferred to the Station on 8 December 2000. The eight seed pouches were each watered with 12 mL of distilled water on 5 January 2001. Figure 3 presents an overview of the in-flight operations as performed by Commander Bill Shepard.

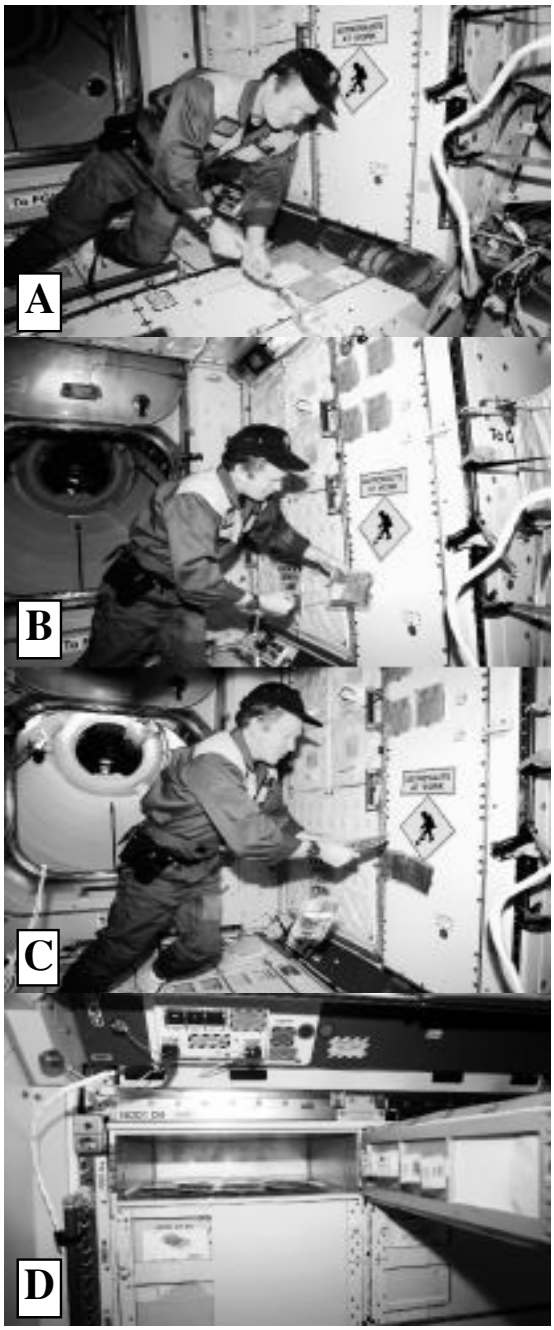

Figure 3. In-Flight Operations. A. Commander Shepard withdrawing water from the water bag. B. Injection of water into a seed pouch. C. Rotation of seed pouch to distribute the injected water. D. Unity Stowage Locker (NOD1D4-A1) in which dark germinated pouches were maintained.

Results

Figure 4 presents representative views of the seedlings at four days after watering. There is a clear difference in the timing of seed germination between the two species (as occurs on earth at 1g), with the corn seedlings (Figures 4a,c) having progressed significantly further that the soybean seedlings (Figures 4b,d). There is also a clear phototropic effect, with each of the light-grown corn seedlings in Figure 4a possessing a green shoot which is growing upward towards a source of light in the Node 1 (Unity Module) portion of Space Station Alpha. In contrast, the dark-grown corn shoots in Figure 4c are neither green (since chlorophyll synthesis has not been induced by light) nor are they growing in a uniform direction. In either case, the corn roots are growing in a random fashion, with some moving in an upward direction and others progressing downward. This reflects the lack of a gravitropic response, which is the usual (earth-based) mechanism dictating the direction of root growth.

For the four day (post-imbibition) soybean seedlings, the only difference evident between those germinated under the light vs dark conditions is the slight greening up of the seeds maintained in the presence of light (Figure 4b). The degree of root growth is comparable in seedlings maintained under either condition (light vs dark).

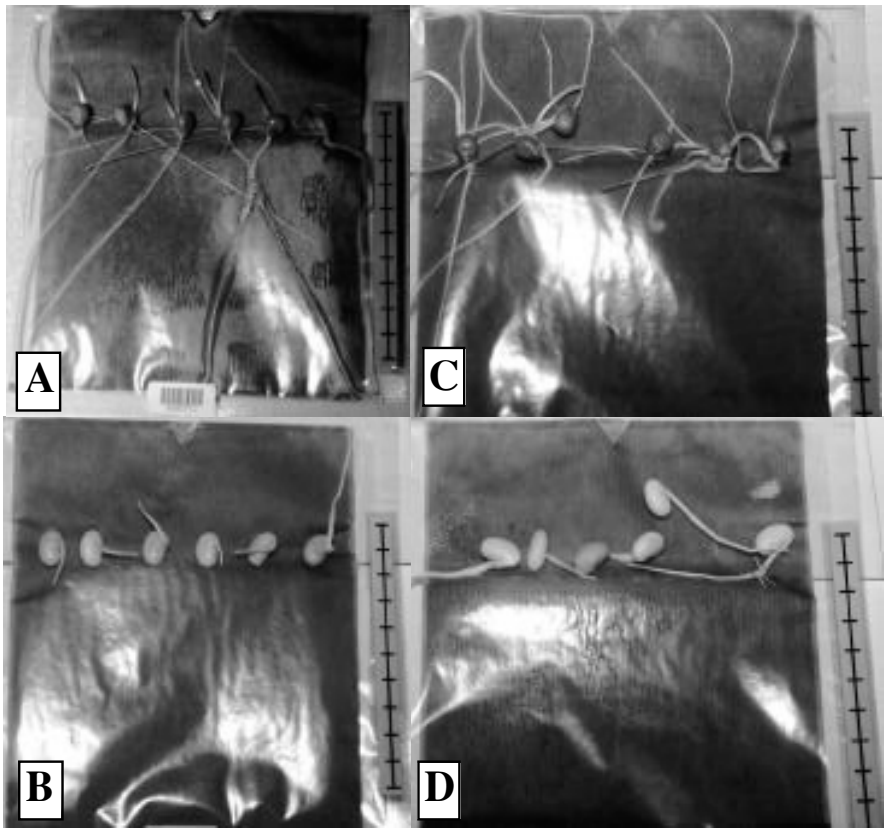

Figure 4. Seedlings at four days after watering. A. Corn seedlings germinated in the light. B. Soybean seedlings germinated in the light. C. Corn seedlings germinated in the dark. D. Soybean seedlings germinated in the dark. Scale = 10 cm.

Figure 5 presents representative views of the seedlings at seven days after watering. By this time the initial 12 mL of water added to each pouch was greatly diminished, although noticeably less so in the soybean pouches (Figures 5c,d). This is presumably due to the faster and overall greater growth exhibited by the corn seedlings, which resulted in a more rapid utilization of the available water. There is also a much more pronounced greening-up of the light-exposed soybean seedlings (Figure 5c) than was evident at day four (Figure 4b), with both the cotylendons and hypocotyl regions showing signs of chlorophyll synthesis.

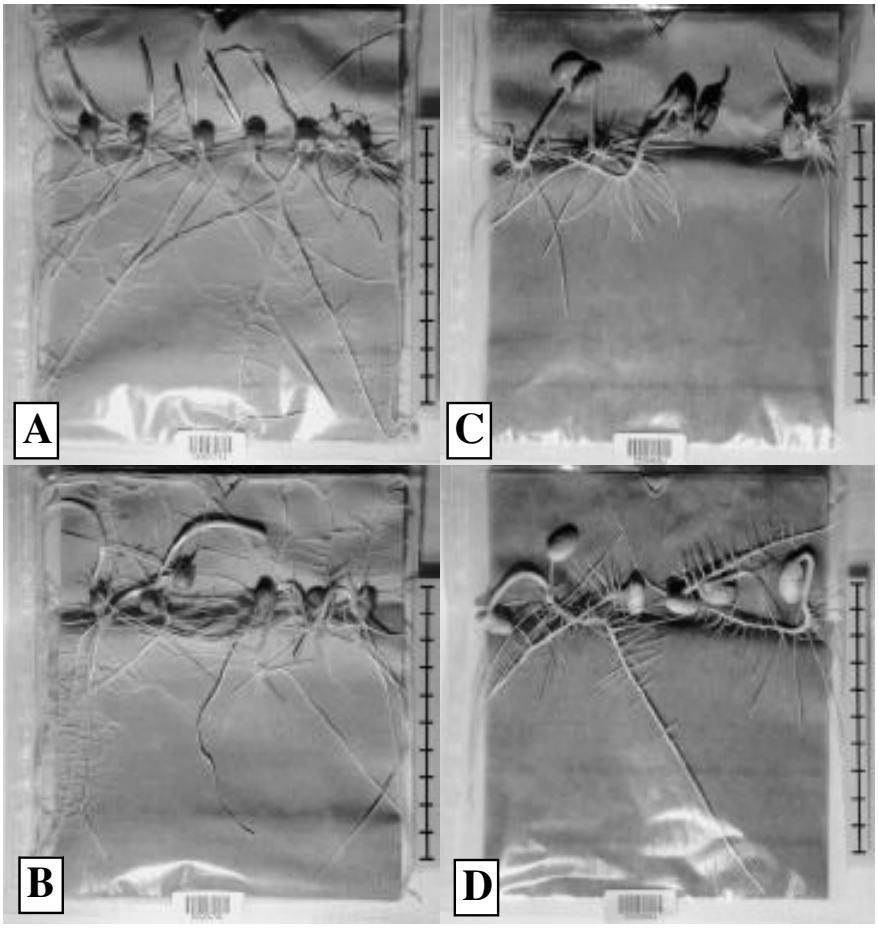

Figure 5. Seedlings at seven days after watering. A. Corn seedlings germinated in the light. B. Corn seedlings germinated in the dark. C. Soybean seedlings germinated in the light. D. Soybean seedlings germinated in the dark. Scale = 10 cm.

Conclusions

1) It is possible to design and implement relatively simple spaceflight experiments suitable for Space Station Alpha implementation with significant outreach potential.
2) There are no roadblocks to achieving normal corn and soybean seed germination in space.
3) The protocols employed in JOSE could lend themselves to relatively simple experiments relating to the light-mediated induction of chlorophyll synthesis, phototropism, gravitropism, and other basic plant processes.
4) Seedling growth studies using the JOSE protocols require additional water inputs if they are to proceed past the seven day interval.

Acknowledgements

We wish to gratefully acknowledge the assistance of the following groups and individuals: (1) the Johnson Space Center's (JSC) Education Outreach Office (and specifically Deborah Brown); (2) Diane McMahon and the JSC Crew Branch, which provided overall coordination of the EDU/SGK payload; (3) the KSC Life Sciences Payload Office (and specifically Bridgit Higgenbotham), which supported the payload at KSC; (4) Dr. James Orf (University of Minnesota) who provided the soybean seeds used in the study; and (5) Steve Voss and Nancy Philben of Pioneer Hi-Bred International, Inc., who provided the corn seeds used in the study. This project was conducted under NASA Contract NAS10-12180 to the Dynamac Corporation.