Why plant experiments in space?

Guest Editor

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The Norwegian history of space biology studies goes back to the early 1980s when scientific groups at the University in Trondheim prepared and performed short–term experiments (i.e. up to 15 days) using the space shuttle and Spacelab. Using both plant cells and intact plants, trends and non-conclusive evidence were obtained over a ten year period that indicated the micro-gravity environment apparently seemed to have an effect on the plant cell structure and early development of the plants. The design and building of a plant growth facility (EMCS) as well as access to the International Space Station (ISS) from 2006 represent a breakthrough for the possibility of gaining more basic knowledge via plant generation studies over longer periods of time. The knowledge here obtained will be of the utmost importance for human planetary exploration.

For a decade, ESA has been a front-runner in biological science in space. As an example, The European Programme for Life and Physical Sciences and Applications in Space (ELIPS) was started in 2002. Presently ESA is evaluating this programme in order to see if the impact, achievements and opportunities of ELIPS in a prospective manner have been fulfilled. The hope is that the Ministerial Council and the national agencies will support the continuation of this programme. The attitude in ESA is that Europe is now in a position to become a world leader in the areas covered by the ELIPS programme provided the current financial support is continued.

The building of the International Space Station (ISS) has also been a major step in offering biologists new opportunities for space research. Based on an evaluation from the European Space Science Committee (ESSC) as the European Science Foundation (ESF) Expert Committee on space research it has been recommended that ESA should maintain its efforts to provide access to space for basic and applied research and in this context develop a plan for reliable European utilisation of the ISS. As we know from NASA, the existing shuttle flights will terminate in 2010 and in the event of complete cessation of shuttle flights; ESA should develop alternatives quickly for utilisation of the ISS.

As a consequence of these political space aspects, the potential user of the ISS should clearly see the new opportunities offered, e.g. for *long duration* biological experiments. In the biology field it is also hoped that ESA will continue to develop new facilities to improve the laboratory conditions on the ISS. Presently we are lacking standard preservation facilities, quick freezing and deep-freezing facilities, advanced microscopy with observation possibilities of flight samples on the ground, automated facilities to support development, growth and harvesting of model systems – e.g. samples from the model plant *Arabidopsis thaliana*. The use of such model organisms is encouraged by ESA.

Why do we want to grow plants in space? For the last 20 years the primary goal has been to increase our basic cell biological and physiological knowledge. However, as a consequence of the changed NASA view on future space activities with focus on exploratory missions to the Moon and to Mars, growing plants in space will add a new dimension to human spaceflight, the distance of travel, the radiation environment, gravity levels, the duration of the mission, and the level of confinement and isolation to which the crews

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Tor-Henning Iversen, dr. philos. , has been professor in plant cell biology at the University in Trondheim (NTNU) since 1974. For the last ten years he has been Head of Plantebiosenteret, Department of Biology. As a senior scientist he has more than 300 publications and technical reports in the fields of plant physiology, plant cell biology and plant biotechnology. He is also used as referee in a large number of international scientific journals. In space biology he has been PI (Principal Investigator) and CoI for 6 experiments performed on the Space Shuttle. He is now Head of N-USOC which is one of 10 centres in Europe responsible for specific research facilities onboard The International Space Station.

The International Space Station (ISS). Illustration by: David Ducros – ESA

will be exposed. For a plant biologist, this includes a major focus on development of life support systems including bioregenerative approaches. The life support task is to achieve and control a physiologically acceptable environment within the habitat. Efficient environmental control and life support systems (ECLSS) essentially take charge of two complementary functions in a balanced and controlled manner: providing input resources required for humans and other biological species to live and survive in this habitat and the regeneration of human and other wastes. A bioregenerative life support system (BLSS) uses higher land plants, cyanobacteria and bacteria - often coupled with plants. One disadvantage of using plants is their high sensitivity to plant diseases and to chemicals. Ethylene produced by plants is the most damaging gas in a closed system. In the EMCS this problem has been solved by trapping the gas as it is produced.

Both algae and higher plants can be used for air revitalisation and as food sources. The existing species of higher culture plants require substantial areas for growth. Limited as this is in a space environment, it is probably realistic to imagine that plants used for Mars expeditions will have to be genetically modified. In existing plants, water occupies up to 90% of the organism; for food processing in a space vehicle, the plants should be modified to contain 90% of nutrients and only 10% of water.

In which way can the plant biologists at NTNU support the activities and preparation for human planetary exploration? Mars is considered as the prime candidate for colonisation of life beyond Earth. It is recommended that within the ELIPS programme and with other relevant programmes, ESA should support interdisciplinary cooperation in the preparation of human exploratory missions. This includes the development of life support systems with bioregenerative approaches. The focus should be on detection and prevention of microbial contamination, investigation of the radiation field in space and its biological effects, e.g. on normal plant development. The studies require the use of the ISS and on a mini-scale, the ongoing activities linked to the EMCS represent a step in the right direction. The scientific approach using molecular biological techniques for mapping the gene expression under space conditions (cf. MULTIGEN Part II) as well as the special qualifications the NTNU-scientists have in the field of plant gene modification (cf. gene-modified strawberries), make them well qualified for interdisciplinary cooperation in the preparation of human exploratory missions.

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Colonisation of Mars?