Hydroponics for Food Production in Space: History and Current Efforts

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Goals of Food Production in Space

- NASA Human Research Program (HRP) near-term food production systems - supplement key nutrients (Vitamins B_1, C, K and potassium) that degrade to inadequate levels on exploration class missions.
- Study behavioral health aspect – caring for plants and improving the acceptability of the astronaut diet by supplementing it with fresh produce (currently anecdotal).
- Develop sustainable water delivery technologies – current TRL 9 particulate based systems (ie used in research conducted in plant growth facilities APH, Veggie, BPS, LADA, SVET) require resupply of bulky consumables and generate waste media.

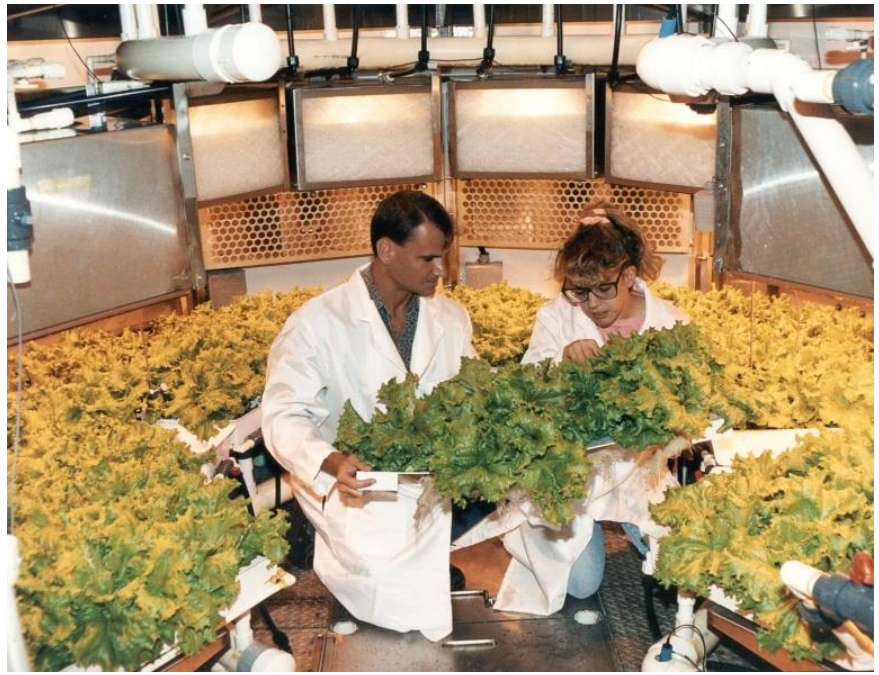
The NASA HRP risks being targeted are:

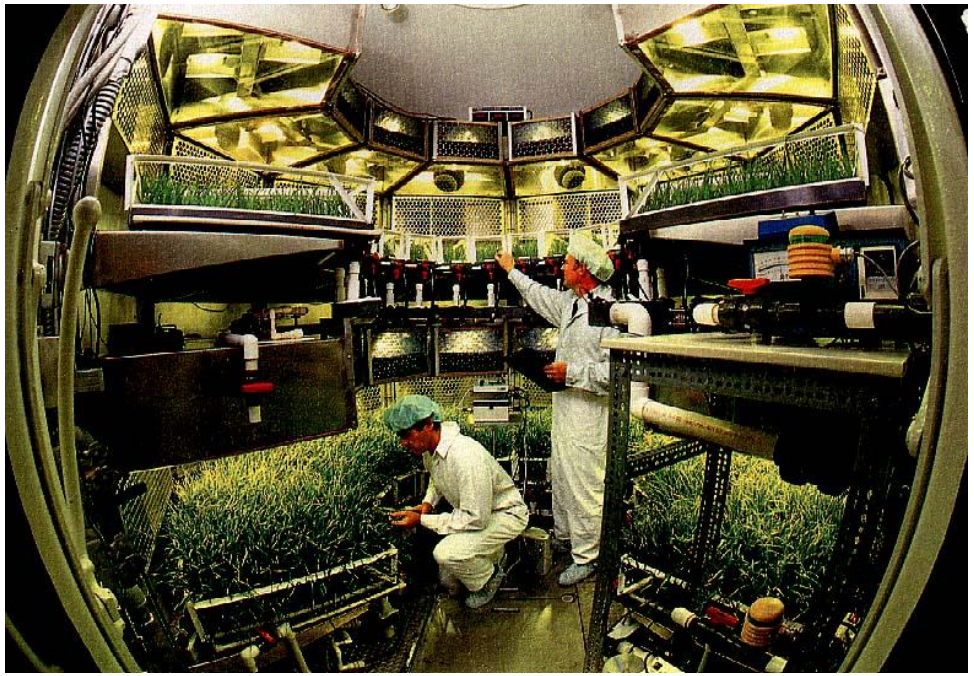
- Inadequate nutrition.
- Performance decrement and crew illness due to an inadequate food system.
- Adverse cognitive or behavioral conditions and psychiatric disorders.

Life support functions:

- Develop sustainable and robust plant growth subsystems.
- Work towards autonomous food production in space.

The human exploration of other planets (surface systems) will require bioregenerative life support systems. Hydroponic plant production for life support is desirable due to reduced weight requirements.

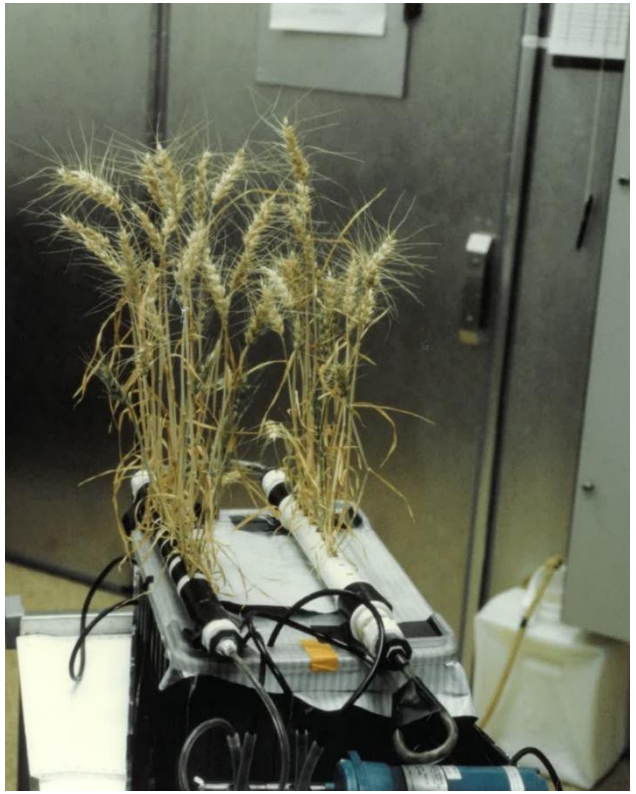




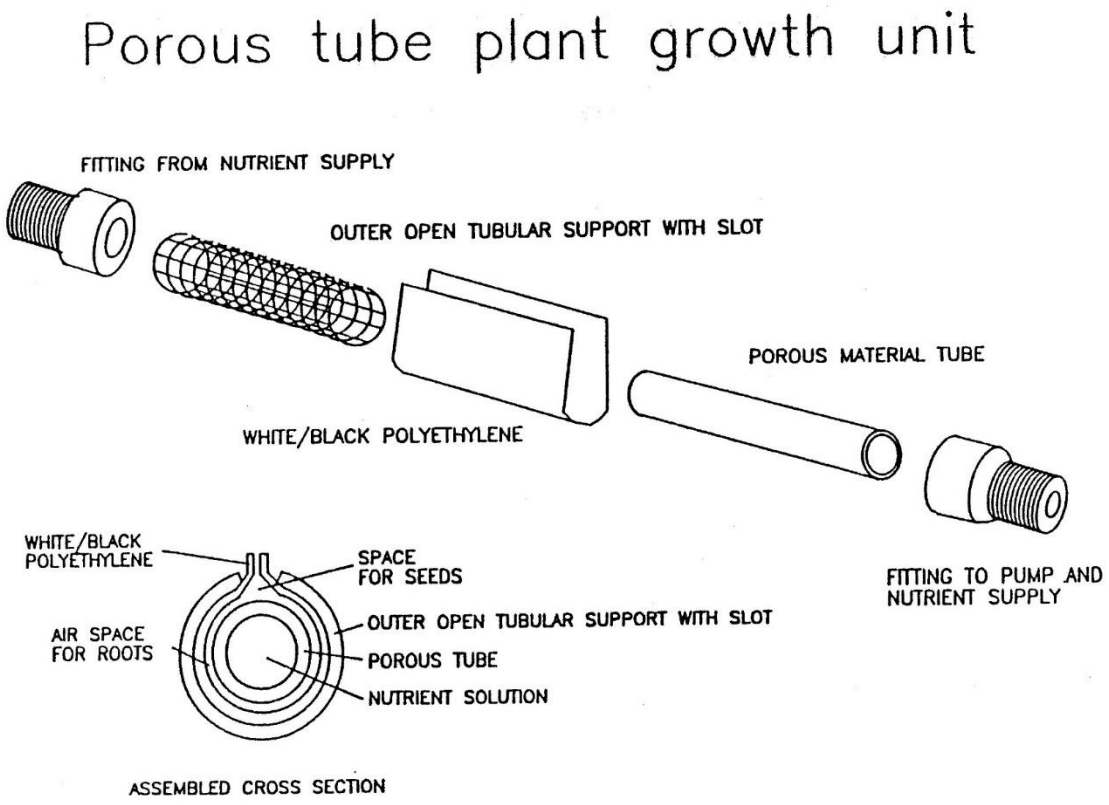
Porous Tube Nutrient Delivery System

- Developed at KSC from late 1980s to 2005.
- Eliminates need for bulky media.
- Plants grow and thrive on the surface of a porous tube.
- Nutrient rich water is held in the tube under suction.
- Requires a nutrient solution.

An initial (hydroponic) porous tube nutrient delivery system (PTNDS) utilized a conventional acrylic membrane, sewn into tubes and supported by a tubular plastic mesh.

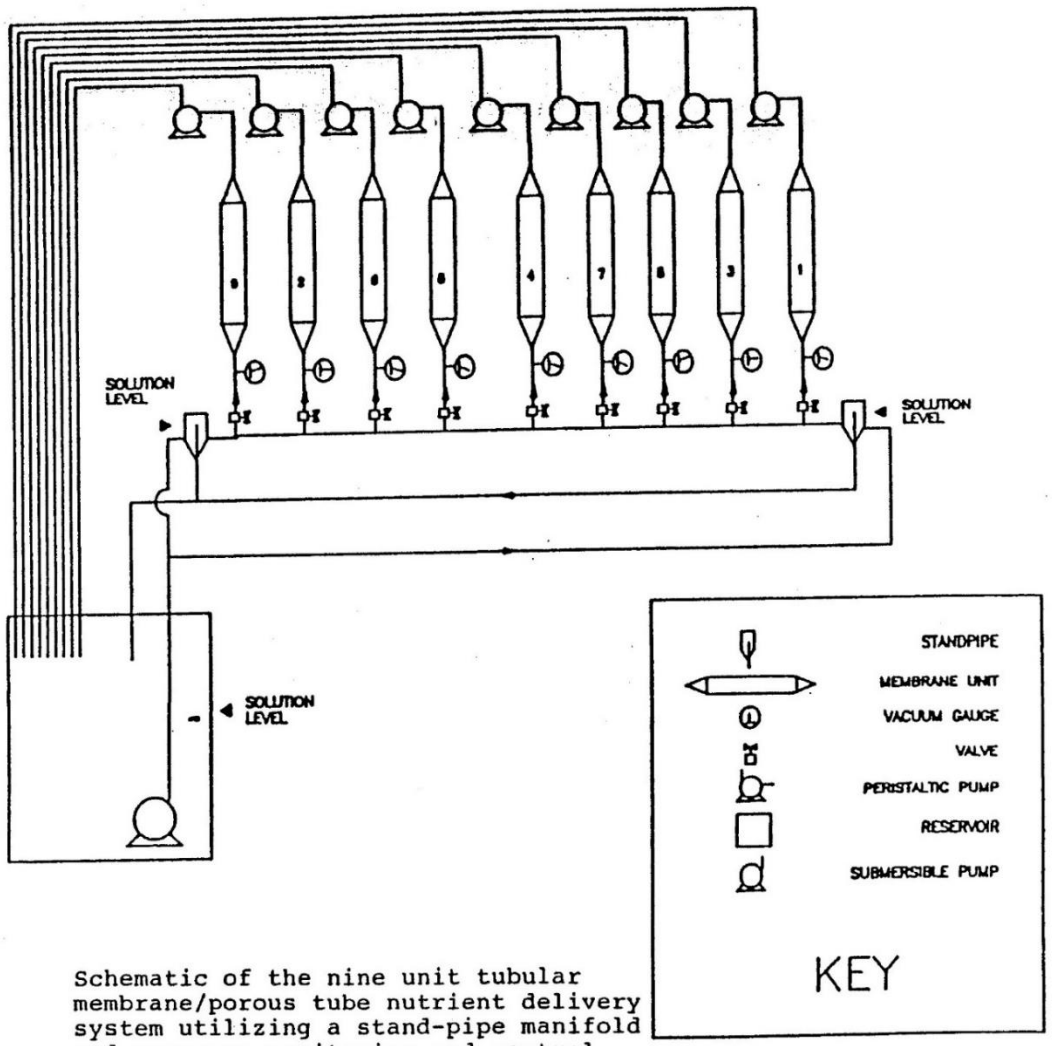


A variety of different porous tube materials and configurations were tested.



Schematic diagram of the second design of the porous tube plant growth unit.

Pressure control is critical to the operation and success of this system, thus standpipes were incorporated to aid in this control.



Schematic of the nine unit tubular membrane/porous tube nutrient delivery system utilizing a stand-pipe manifold and pressure monitoring and control.

Various crop plants were grown under controlled conditions.






- Systems sized for a Space Shuttle mid-deck locker were developed and ground tested.
- Super-dwarf wheat was grown in an inverted orientation from seed to seed within a mid-deck locker simulator.

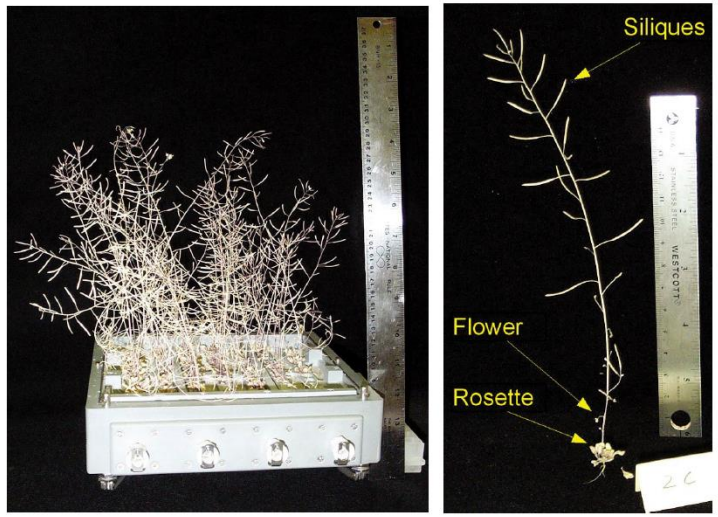
CURRENT SYSTEMS

- A number of plant growth systems using porous tubes have been developed and flown on the Space Shuttle and the ISS.
- These are Astroculture systems, the Biomass Production System, and currently the Advanced Plant Habitat.

Advanced Astroculture (Space Shuttle mid-deck)

Utilized a porous tube watering system embedded in a root module containing arcillite and slow-release fertilizer.

The ASTROCULTURE™ plant growth unit (ASC-GC).

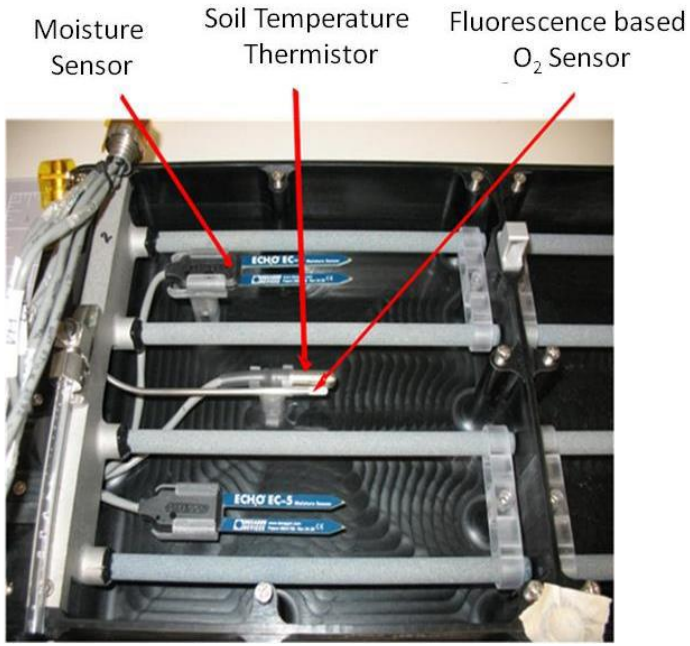


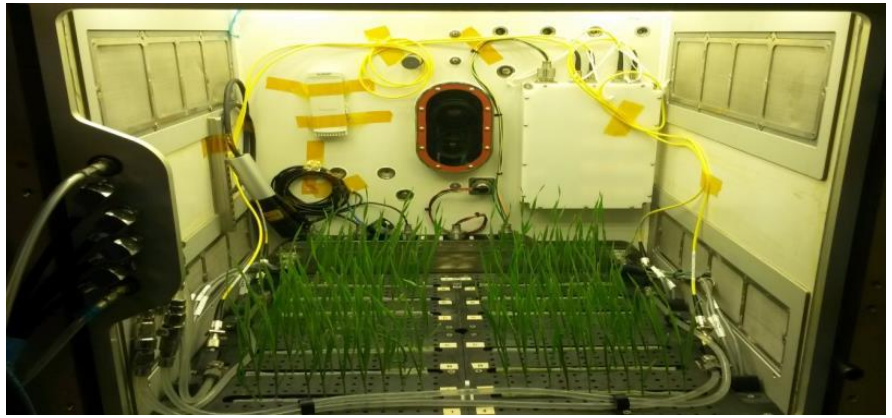
Arabidopsis plants (left) in the root tray retrieved from the STS–104 mission. Representative single *Arabidopsis* plant (right).

Biomass Production System on ISS

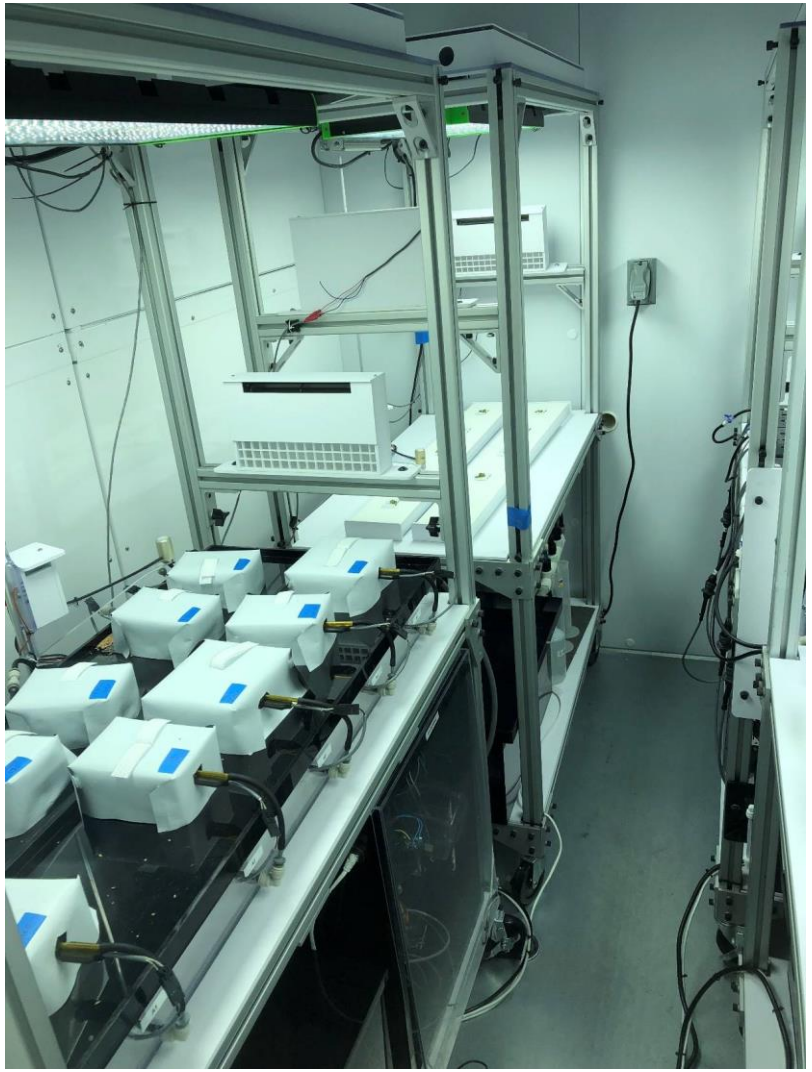
Utilized a porous tube watering system embedded in a root module containing arcillite and slow-release fertilizer.

The Advanced Plant Habitat on the ISS, also uses porous tubes in a bed of arcillite and slow-release fertilizer.





The current testing of the PTNDS is a side-by-side comparison with current earth-based and current and proposed microgravity systems: Nutrient Film Technique, Advance Plant Habitat Science Carrier and an On-Demand System.

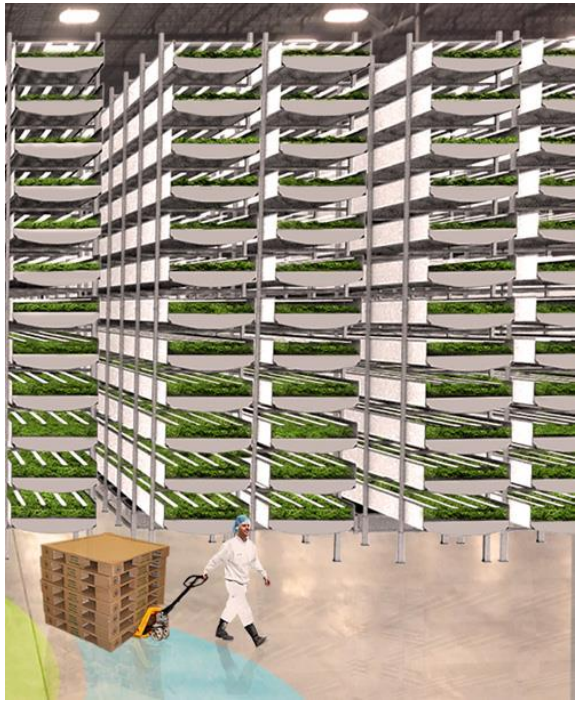


CURRENT STATUS

- PTNDS continues to be a candidate for food plant production for space missions.
- To date, porous tube systems have been used in space but as a plant root watering system with arcillite media and slow-release fertilizer pellets.
- Growing plants without resupplying media is more sustainable and desirable.

APPLICATIONS AND CHALLENGES

- The PTNDS has a potential application for vertical farming and also growing plants on recycled waste streams (being microporous, it can provide a barrier to prevent bacteria to actively enter the root system from solution).
- Current challenges are in maintaining proper pressure control (for microgravity) and testing various scenarios for plant nutrient delivery, planting and harvesting in space.



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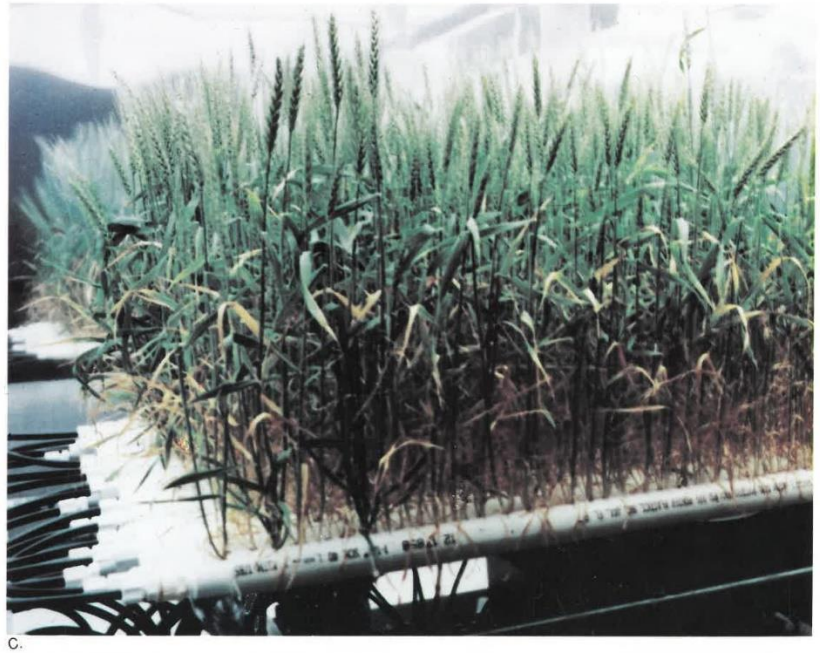
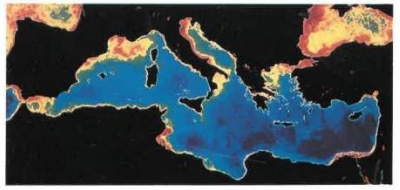
NASA





QUESTIONS?