

DOES GROWTH IN VARIABLE GRAVITY ALTER ENERGY CONTENT OF PLANTS

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WHY?

Why grow crops in a microgravity environment, such as that of space?

REASONING

Why do we need to grow more energy efficient plants?

The power of population is indefinitely greater than the power in the earth to produce subsistence for man". An Essay on the Principle of Population



The worlds population currently stands at 9 billion, and is set to double in the next 50 years.



PRESERVATION OF ECOSYSTEMS



NORMAN BORLAUG- FATHER OF THE GREEN REVOLUTION



- It was estimated that when he died he had saved a billion lives through his actions.
- Between 1965 and 1970, wheat yields nearly doubled in Pakistan and India.

POTENTIAL SOLUTIONS

- **GMOs:**

It is largely accepted in the scientific community that genetic engineering is a solution to the world food crisis, however the public remain skeptical

- **Alternatives:**

There is the possibility of expansion into space.

Could it be possible to improve harvest yield or the energy density of the crop?

WHY INVESTIGATE SPACE?

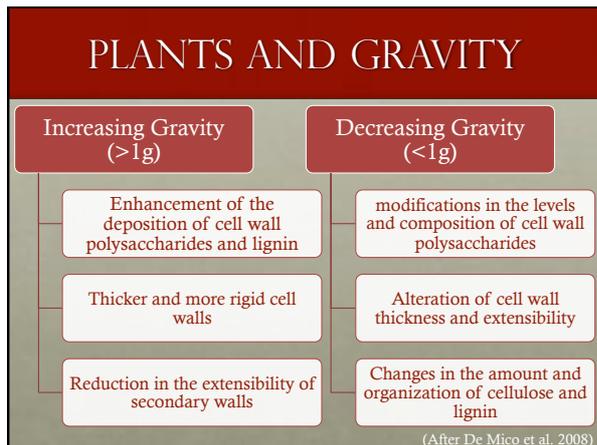
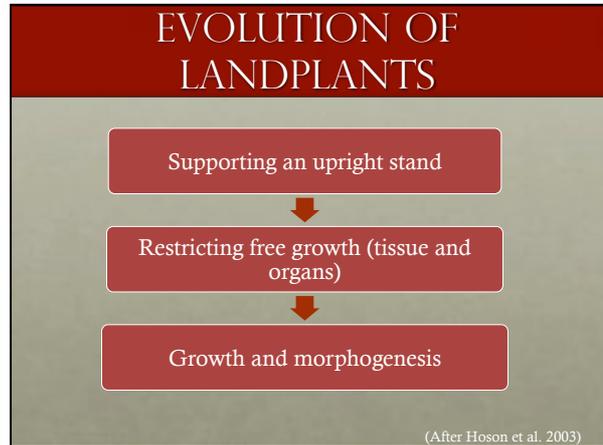
It is theoretically possible and large land availability means large scale production could be feasible.



Current evidence also suggests that crop yields could be improved through cultivation in microgravity environments, like that of space.



EXISTING EVIDENCE & BACKGROUND



EXISTING EVIDENCE

Sustainable Alternative Fuel Feedstock Opportunities, Challenges and Roadmaps for Six U.S. Regions

Chapter 8
Oilseed and Algal Oils as Biofuel Feedstocks

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Characteristics of Plant Cell Walls Affecting Intake and Digestibility of Forages by Ruminants¹

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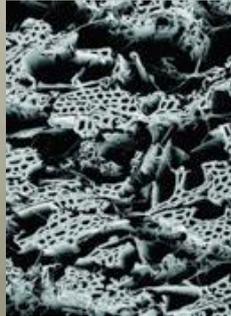
LIGNIN

Fills spaces in cell wall (secondary cell walls):

- Cellulose
- Hemicellulose
- Pectin components (xylem tracheids, vessel elements and sclereid cells).

Covalently linked to hemicellulose → crosslink different plant polysaccharides

Both add mechanical strength to the cell wall



EXISTING EVIDENCE

(Merkys et al. 1981) *Gravity has an effect on the growth rate of lettuce (104h).*

(Honson et al. 1992) *Gravity has no effect on growth rate of cress, rice, maize and beans (72h).*

(Levine et al. 2001) *Gravity has no effect on the growth rate of wheat, neither on lignin production (240h).*

EXISTING EVIDENCE

Species	Conditions	Relative lignin content for a g-value (relative) of				
		0	1	25	50	75
Anagallis	Climostat/centrifuge	0.32	1.00	2.07	3.11	2.60
Cucumber	Climostat, flotation centriuge	0.45	1.00	1.69	2.30	3.12
Elodea	Centrifuge	1.00	1.00	—	—	3.74
Bean Cotyledo	Centrifuge	—	1.00	—	—	1.81
Mangrove	Centrifuge	—	1.00	6.78	10.22	12.82
Marigold	Climostat, flotation	0.64	1.00	—	—	—

Siegel et al. 1979

HYPOTHESIS

Growth of crops in reduced gravity will increase the energy content of the food produced.

VARIABLES TO CONSIDER

Gravity
 Temperature
 Cosmic radiation
 Light availability
 Humidity
 pH/ nutrients
 Pollination
 Atmospheric composition

WHAT MUST BE CONTROLLED?

Gravity
 Temperature
 Cosmic Radiation
 Light Availability
 Water Availability
 Nutrients & pH
 Pollination
 Atmospheric Composition

INSPIRATION FROM THE ISS...

- Temperature & Cosmic radiation

The facility is coated with Multi Layer Insulation (MLI) that is made from:

Mylar- stretched polyester film fused with aluminium

Dacron: fabric between sheets of mylar to prevent heat conduction

- Light Availability

Windows used to allow in sunlight must be small and the thickness will depend on the pressure and atmosphere of the planet.

Alternatively solar powered electric lighting could be investigated

OTHER ISSUES... (1)

- Water Availability

Probes will be used to inject water directly into the soil to ensure even distribution and attempt to avoid problems of drainage and excess water around the roots.

- Nutrients & pH

Measure soil quality on the planet- may need to use soil/ supplements from Earth.

Issues include high heavy metal content in soil therefore the crops are not suitable for human consumption.

OTHER ISSUES... (2)

- Pollination

Will initially need to be pollinated by hand.

Could generate wind inside the facility to allow wind pollination when producing on a larger scale.

- Atmospheric Composition

A gas exchange system will be used to ensure atmospheric conditions similar to those of the Earth will be maintained- 78% N, 21% O₂, 0.036% CO₂ and 0.964% other.

EXPERIMENTAL PROCEDURE

- Species of tomato, cucumber, wheat, lettuce and Arabidopsis will be used during the experiment with 20 individual plants per species.

- Variables will be controlled using previously stated techniques.

- 10 of each species will be grown on Earth, acting as the control at 0.997g gravity. The other 10 plants will be grown in a microgravity environment on the ISS at almost 0g gravity.



EXPERIMENTAL PROCEDURE

- The seedlings will germinate in sample cartridges.
- 10 individuals of each species on Earth and 10 on a designated area of ISS.
- Once they have out-grown the container they will be transferred to larger individual chambers and grown to maturity.
- Samples will be tested for lignin levels, energy content and protein levels.
- This will be repeated for 5 years, allowing several generations to be grown and analysed.



European Modular Cultivation Systems (EMCS)



EXPECTED RESULTS

Experimental vs. control

EXPECTED RESULTS

With decreased gravity we predict that lignin levels will decrease and the energy content of the plant will increase.

In a microgravity environment plants don't require as many structural components such as: cellulose, hemicellulose and lignin.

Therefore, the surplus energy will be put into the energy stores of the plant in the form of protein and starch.



SAMPLE ANALYSIS & INTERPRETING THE RESULTS

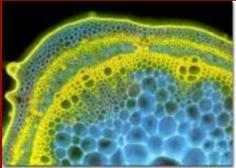
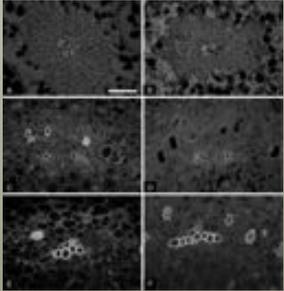
Determine energy content of samples collected

- Grain structure
- Bomb calorimetry
- Rapid protein analyser

LIGNIN CONTENT

UV induced fluorescence of lignin
Excitation 330–385 nm
Emission 400–420 nm

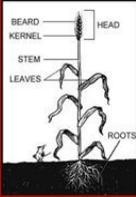
Interference microscopy

From: De Micco et al. 2008

Swicofil.com

CROP STRUCTURE

- There is three parts to the kernel: bran, endosperm and germ.
- Energy is stored in the form of starch and protein in the endosperm of the grain.
- Therefore, samples will be taken from the endosperm of the crop.

ENERGY CONTENT

Triticum aestivum (Common wheat)

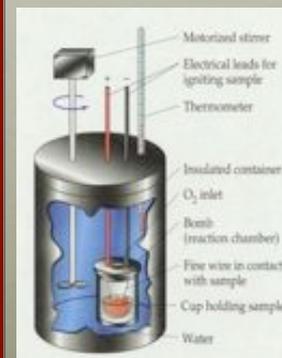


The Law of Conservation of Energy states that 'energy can neither be created nor destroyed, it can only be converted into different forms'.

All forms of energy can be converted into heat, therefore the **gross energy** (energy stored in the chemical components of the food) can be calculated as the amount of heat released during complete oxidation.

BOMB CALORIMETRY

- Samples are prepared from crops grown in both experimental and control conditions.
- As the sample is burned the heat given off/ heat of combustion is measured.
- The technique is a form of direct calorimetry.
- The energy is measured using this technique is termed gross energy kJ/g



RAPID PROTEIN ANALYSER

- It allows the measurement of true protein, not nitrogen.
- Using *itag* technology proteins are tagged to allow the direct measurement of protein levels.
- Non-toxic substances used
- 2 minute test time
- Performed at room temperature



APPLICATION & PROBLEMS

Application of our findings
Future Possibilities
Problems

APPLICATION & FUTURE POSSIBILITIES

- Potential expansion into livestock feed production
- Use as biofuel e.g. oilseed rape
- Use in projects such as MELiSSA
- Investigation and growth of GMOs



PROBLEMS?

- Investigate other methods of irrigation- drainage and rot problems
- Threat of disease and viruses
- Logistical problems- transfer of samples to Earth for analysis
- Water supply



THANK YOU!

