KEY

Look at the sentences below and decide from which section of the article they are taken, the Introduction (I), Materials and Methods (M), Results (R), or Discussion (D).

I As the final step in gravity resistance, plants increase the rigidity of their cell walls via modifications to the cell wall metabolism as well as to the cell wall (apoplastic) environment. ***What we know already, generalisation, has been shown in the literature (simple present).***

D Because no clear differences were detected in the length or the growth rate between ground and on-orbit 1 g controls, stimulation of inflorescence growth may be caused by microgravity, not by space flight. ***Stating results and then commenting on findings, tentative explanations (modality/hedging).***

R The stems were 10–45% longer, depending on the day, under microgravity conditions than those at ground and on-orbit controls, and the differences were significant over a wide range of growth phases. ***Statement of results (simple past)***

I The important role of cortical microtubules in plant resistance to hypergravity has been suggested, as mentioned above. ***Reviewing the literature, what has been shown, present perfect.***

I However, it is uncertain whether the hypothesis is applicable to gravity resistance of plants to 1 g gravity, as to the resistance to hypergravity. ***Gap statement – what we don't know - leads to justification of study.***

D These results support the hypothesis that cortical microtubules play an important role in plant resistance to the gravitational force. ***Extrapolation from results.***

I To clarify this point, we conducted the space experiment using an Arabidopsis **a**-tubulin 6 mutant (tua6) in the Kibo Module on the International Space Station, as a part of the experiment termed Space Seed (PI, S. Kamisaka). ***Filling the gap, statement of objective.***

M Watering was carried out 6–14 times a day and relative humidity was kept between 70 and 80%.

Reorder the statements below to form the abstract of the article.

3 Growth of inflorescence stems was stimulated under microgravity conditions, as compared with ground and on-orbit 1 g conditions.

5 The degree of growth stimulation tended to be higher in the tua6 mutant than the wild-type Columbia.

2 To clarify this point, we cultivated anArabidopsis **a**-tubulin 6 mutant (tua6) in the Cell Biology Experiment Facility on the Kibo Module of the International Space Station, and analyzed growth and cell wall mechanical properties of inflorescences.

4 The stems were 10–45% longer and their growth rate 15–55% higher under microgravity conditions than those under both 1 g conditions.

1 Cortical microtubules are involved in plant resistance to hypergravity, but their roles in resistance to 1 g gravity are still uncertain.

7 No clear differences were detected in any growth or cell wall property between ground and on-orbit 1 g controls.

8 These results support the hypothesis that cortical microtubules generally play an important role in plant resistance to the gravitational force.

6 Under microgravity conditions, the cell wall extensibility in elongating regions of inflorescences was significantly higher than the controls, suggesting that growth stimulation was caused by cell wall modifications.

ABSTRACT

Cortical microtubules are involved in plant resistance to hypergravity, but their roles in resistance to 1 g gravity are still uncertain. To clarify this point, we cultivated anArabidopsis **a**-tubulin 6 mutant (tua6) in the Cell Biology Experiment Facility on the Kibo Module of the International Space Station, and analyzed growth and cell wall mechanical properties of inflorescences. Growth of inflorescence stems was stimulated under microgravity conditions, as compared with ground and on-orbit 1 g conditions. The stems were 10–45% longer and their growth rate 15–55% higher under microgravity conditions than those under both 1 g conditions. The degree of growth stimulation tended to be higher in the tua6 mutant than the wild-type Columbia. Under microgravity conditions, the cell wall extensibility in elongating regions of inflorescences was significantly higher than the controls, suggesting that growth stimulation was caused by cell wall modifications. No clear differences were detected in any growth or cell wall property between ground and on-orbit 1 g controls. These results support the hypothesis that cortical microtubules generally play an important role in plant resistance to the gravitational force.

The introduction

What we know already (generalisations, definitions, references to the literature).	**Justifying the study, indicating a gap**	**Objective of the study, filling the gap.**
L1-10 Defs – gravity/gravitropism/gravity resistance L15-28 Lit –own past study, gravity resistance – modifications to cell wall. L.29 Modifs to genes related to microtubules L45 Results of past studies with hypergravity – cortical micro-tubules are involved in gravity resistance - genes altered, cell wall changes	L.50 Role of microtubules suggested in past studies "however" uncertain whether can apply to 1g gravity as well as hypergravity so therefore did a study "to clarify…" "we" – tubulin mutants disordered growth in 1g and hypergravity	L.60 Hypothesis - Expected that mutants grow and develop normally in space (no need for gravity resistance) – so this paper looks at growth & cell wall properties in mutants under microgravity conditions in space.

Material and methods

How was the study done.	**Materials**	**Methodology**	**Analyses**
Microgravity & 1g Watering, humidity	Tubulin mutant PEU	Stems measured Frozen – ground experiments	Cell wall measurements Microarray analysis Statistical analysis – significance of diffs for ground/1g/microgravity

Results

What are the main findings	How are the findings substantiated
Stems longer under micro-gravity than both controls (10-45%) No diff btn ground and on-orbit 1g controls	Cell wall extensibility higher under microgravity than controls So stimulation of growth could be caused by microgravity and not space flight

Discussion

Expected/unexpected findings Expected "supports hypothesis" that microtubules play a important role in plant resistance
Tentative explanations No diff in controls (ground and on-orbit 1 g) so growth stimulation may be caused by microgravity
Comparison with other findings Growth stimulation under micro-gravity has been reported by other authors
Limitations Full analysis of growth & cell wall properties not carried out for wild-type Columbia
Implications Caused by cell wall modifications, helical growth may not be direct cause of dwarfism in tubulin mutants
Conclusions for future research Need to look at effects of microgravity on formation & orientation of cortical microtubule arrays Compare gene expression – transfer from 1g to microgravity Expression of genes encoding cell wall proteins may be responsible for increase in cell wall extensibility Tubulin mutants may become hypersensitive to gravitational force