HelmholtzZentrum münchen
German Research Center for Environmental Health

Scientific Highlight November 2009

[X] co-ordinated with the Director of the Institute / Head of Department

Institute / Independent Department / Clinical Co-operation Group / Junior Research Group:
BIOP

PSP-Element:
G-504900-002

Person to contact for further enquiries:
Anton Schäffner, schaeffner@helmholtz-muenchen.de, Tel. 2930

Title of the Highlight:
Control of plant growth by cytoskeletal components: plant organs with an altered -tubulin are not able to expand in a straight way

Keywords:
Plant growth, sustainable bioproduction, cytoskeleton, directional growth, cell expansion

Central statement of the Highlight in one sentence:
Directional expansion of plant organs as a fundamental process of growth can be controlled by the cytoskeleton at the level of individual cells.

Text of the Highlight:
Efficient growth of plant tissue and yield in biomass is pivotal for sustainable supply with food, feed and bio-based energy sources. Besides proper adaptation of crop plants to environmental cues, it is important to understand underlying principles of growth. One fundamental problem of all multicellular organisms is to control directional expansion, which affects their stature and thus proper function and fitness. In plants, the microtubular cytoskeleton is crucial for orienting cell expansion, because it guides the directed incorporation of cellulose into cell walls.
The Research Group of Anton Schäffner at the Institute of Biochemical Plant Pathology investigates *tortifolia* (*tor*) mutants of the model plant *Arabidopsis thaliana*, which lost the ability to coordinate straight growth; instead, they exhibit consistently handed torsion of organs and indicate that independent mechanisms control the direction of organ expansion. In collaboration with the Helmholtz-University Young Investigator Group of Dierk Niessing and colleagues from the John Innes Centre in Nottingham they could show that the torsional phenotype of the *tor2* mutant is caused by a subtle change, the replacement of an arginine with lysine in the microtubular component α-tubulin. It forms dimeric

building blocks for cytoskeletal microtubules with β-tubulin. Structural modeling suggests that hydrogen bonds of α-tubulin with the GTPase domain of β-tubulin are interrupted in *tor2*. Consistent with this, microtubule dynamicity is reduced in the mutant as visualized by fluorescence-labeling. In addition to twisting organs, freely growing cells like leaf hairs or suspension cells also exhibit helical torsions. Thus, twisting of *tor2* mutant organs appears to be a higher order expression of the helical expansion of individual cells. Accordingly, the expansion of plant organs can be influenced by the directional growth of single cells. Therefore, future research will tackle the question whether developmentally different cell layers such as the epidermis can independently determine and guide organ expansion and how they communicate with each other.

Publication:
Buschmann H. et al., Plant Cell, 21, 2090–2106 (2009

Taking account of the HMGU mission and vision:
Plants provide the major source for renewable organic substances and a bio-based economy will play an even increasingly crucial role for the competitiveness of economies in the future. Understanding fundamental principles of plant growth enhances our ability to ensure sustainable bioproduction.

The internal HMGU co-operation partners with whom the Highlight was compiled, if appropriate:
Dierk Niessing, Helmholtz University Young Investigator Group,
PSP G-551400-001

Control of directional growth of plants by cytoskeletal components

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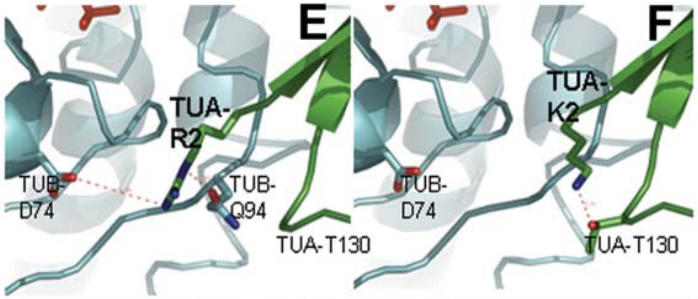
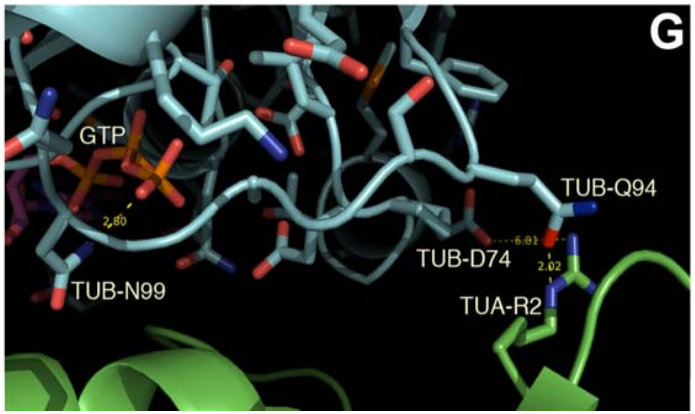
tor2 is due to a mutation of a highly conserved arginin (R2) of α-tubulin 4 putatively affecting the GTPase-function of β-tubulin



TUA4 ATG AGA GAG TGC ATT
M **R** E C I ...

tor2 ATG AAA GAG TGC ATT
M **K** E C I ...



➔ α-tubulins (TUA) and β-tubulins (TUB) form dimeric building blocks that polymerize in a dynamic fashion into cytoskeletal microtubules. The GTPase function of TUB is crucial for their polymerization/ depolymerization.

➔ Modeling predicts TUA-R2 to interact with TUB close to its GTPase domain (→ **E**,**G**). These contacts are replaced by intramolecular contacts in the mutant *tor2* (*tua-K2*), which could alter GTPase-dependent dynamicity (→ **F**).

Buschmann *et al.*, *Plant Cell* **21**, 2090 (2009)

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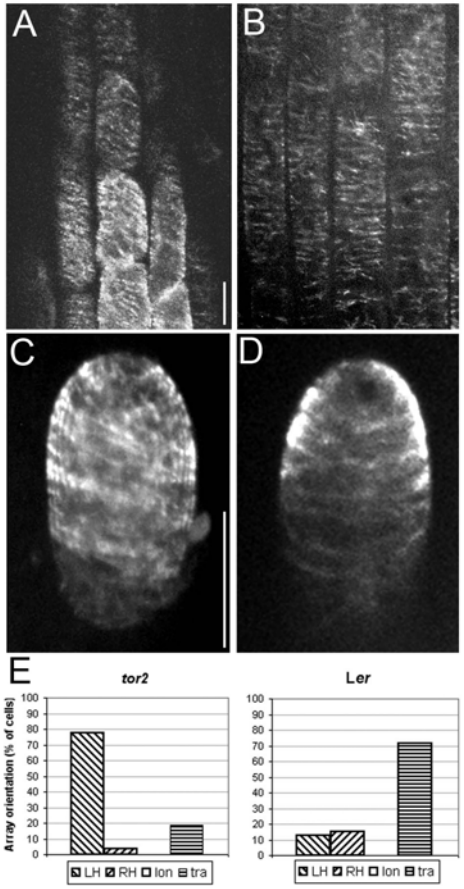
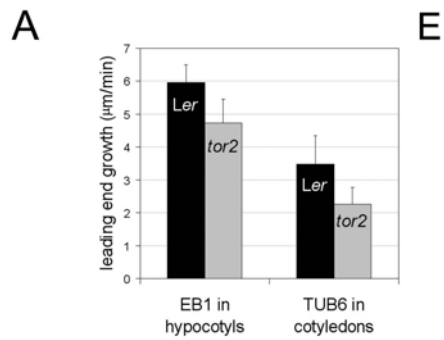
tor2 leads to altered orientation and dynamics of microtubules



Left-handed oriented microtubules are enriched in *tor2* mutant cells (**A,C,E**), whereas transverse microtubules dominate in wild-type cells (**B,D,E**).

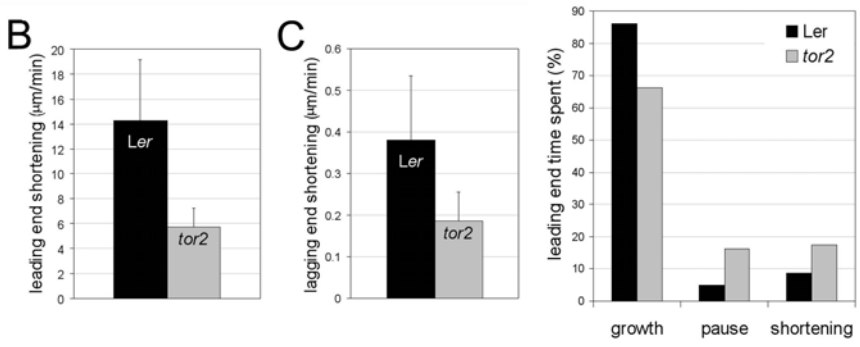
LH left-handed
RH right-handed
lon longitudinal
tra transverse

Parameters showing altered dynamicity of *tor2* microtubules *vs*. wild type (L*er*)



E

	Ler	*tor2*
Dynamicity (µm/min)	4.25	2.50
Catastrophe (s-1)	0.0036	0.0079
Rescue (s-1)	0.0036	0.0094



Buschmann *et al*., *Plant Cell* **21**, 2090 (2009)

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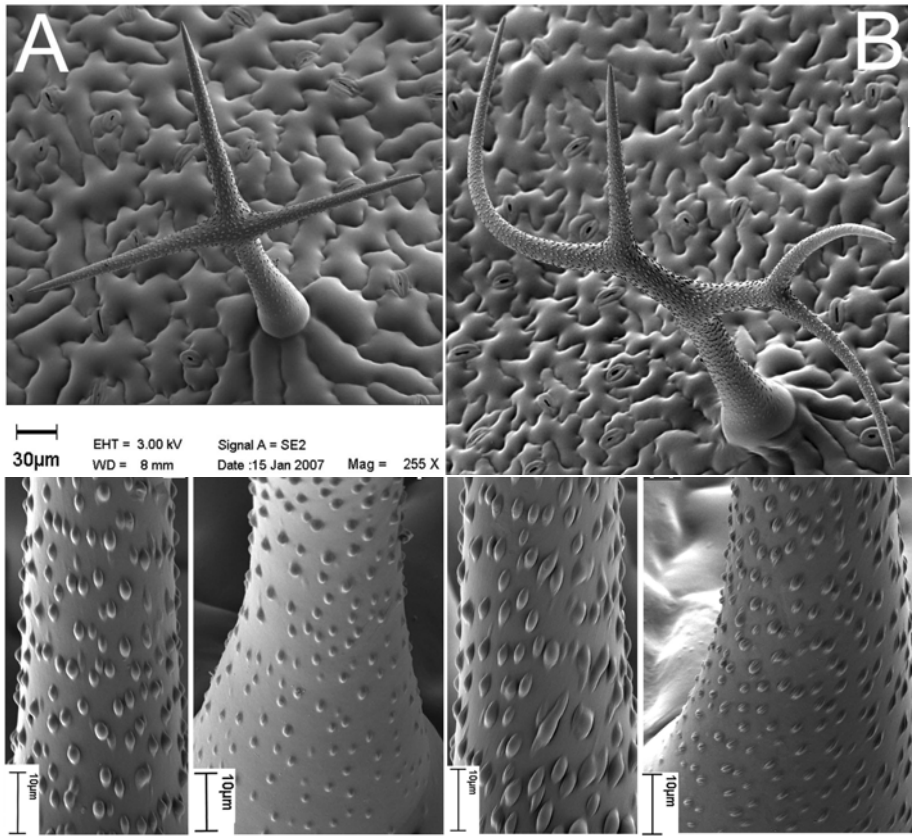
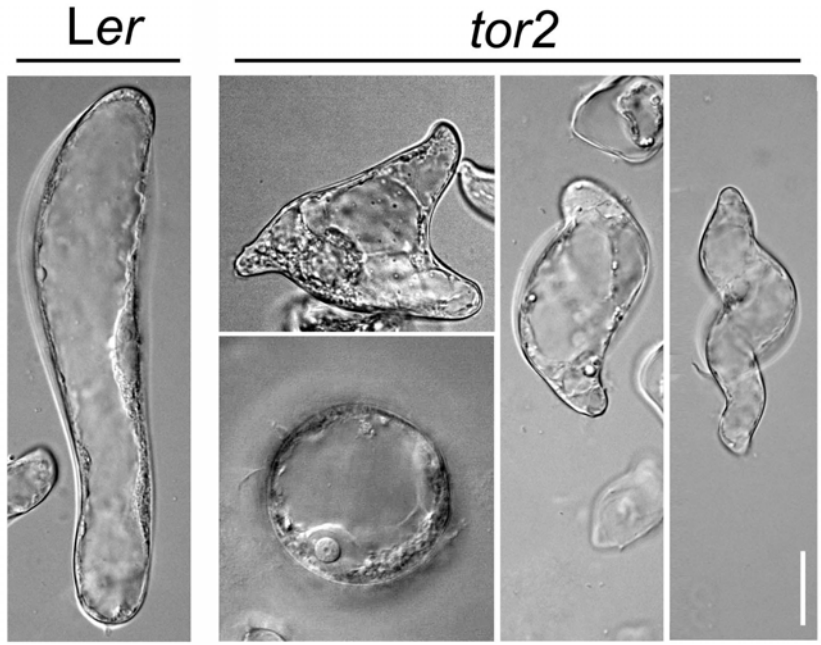
Straight vs. *twisting* organ growth can be based upon individual cells

Single-cell wild-type leaf hairs (**A**) vs. *tor2* (**B**)



Wild-type (**Ler**) vs. *tor2* cell culture



➔ Twisting of *tor2* organs appears to be a higher order expression of the helical expansion of individual cells

Buschmann *et al.*, *Plant Cell* **21**, 2090 (2009)