University of East Anglia

Evaluation and Licensing Opportunities

For further information on this technology and evaluation / licensing opportunities please contact:

Dr Lars von Borcke
lars@pbltechnology.com
Tel: +44 (0)1603 456500

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Patent Literature

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DMSP: stress tolerant crops

Production of DMSP in transgenic plants confers tolerance to a range of abiotic stresses

Pioneering breakthroughs to achieve DMSP production in plants

Tested in monocots and dicots

Dimethylsulfoniopropionate (DMSP) is one of Earth's most abundant and ecologically important organosulfur molecules. It is known to be involved in stress protection, notably in bacteria, with roles as an osmolyte, a cryoprotectant, an antioxidant and even as a baroprotectant and in chemotaxis. It is also a significant component in global carbon and sulfur cycling, and is a major source of climate-active gases. While marine algae and bacteria are major producers of DMSP, saltmarshes are global hotspots for DMSP cycling due to *Spartina* cordgrasses that produce exceptionally high intracellular concentrations of DMSP.

Very few plants produce DMSP at concentrations anything like these particular *Spartina* species (e.g. *S. anglica* and *S. alterniflora)*. In order to better understand DMSP and its role in plants, the team at the University of East Anglia led by Associate Professor Ben Miller set out to identify the genes involved in its synthesis. In doing so they have unexpectedly opened up a **biotechnological crop protection strategy** of enormous potential.

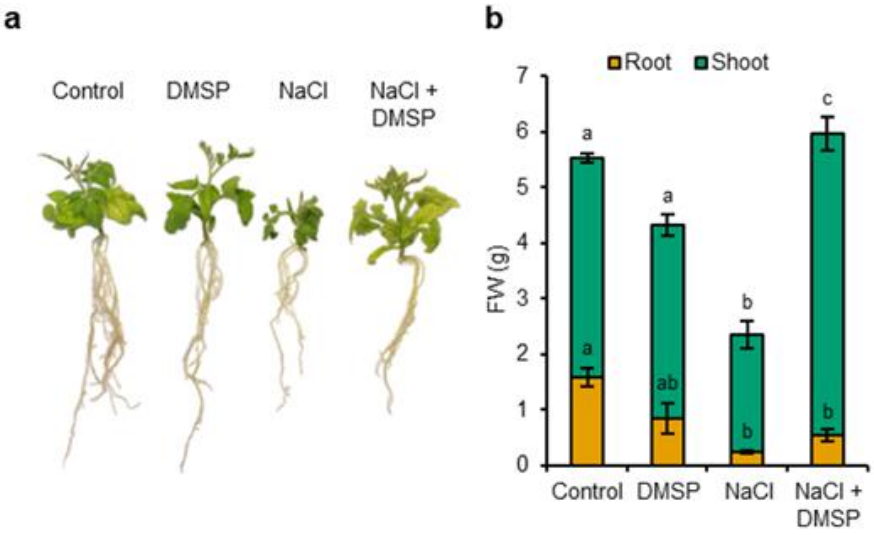
The UEA team have identified, for the first time, the three genes that underpin high-level DMSP synthesis in plants: **methionine S-methyltransferase (*MMT*)**, **S-methylmethionine decarboxylase (*SDC*)** and **DMSP-amine oxidase (*DOX*)**. Homologs of these enzymes are common in almost all plants, but differences in expression and catalytic efficiency explain why *Spartina anglica* accumulates such high DMSP concentrations and other plants only accumulate low concentrations. Furthermore, the UEA work has shown that DMSP accumulation in *S. anglica* is consistent with DMSP having a role in oxidative and osmotic stress protection. And importantly, over-expression *Spartina* DMSP synthesis genes in species that do not normally accumulate DMSP confers plant tolerance to salinity and drought offering a route for future bioengineering for sustainable crop production.

Not all *Spartina* spp. produce DMSP at high concentrations, indicating that phylogenetic relatedness is likely a poor indicator of DMSP production in plants. The fact that so few plant species produce DMSP at significant levels – sugar cane being an exception among cultivated plants – suggests that sources of natural variation (especially in crops) for high DMSP would be hard to find, and that a biotechnological approach could be an effective strategy.

The first phase of this important work is described in **Nature Communications** (https://doi.org/10.1038/s41467-024-51758-z, October 2024). *Spartina* produces DMSP from the amino acid L-methionine via a methionine methylation pathway. The UEA team's paper describes the candidate gene analysis and expression/protein activity studies that led to the successful identification of MMT, SDC and DOX as the three key steps in DMSP synthesis. The work also describes how DMSP varies across natural *Spartina* populations and this how variation is tied to the pattern of abiotic stress, associated with expression of known indicators of such stress types as drought, salt, submergence, oxidative and pathogen-related stress. Overall this work strongly supporting DMSP's role as a stress protection molecule.

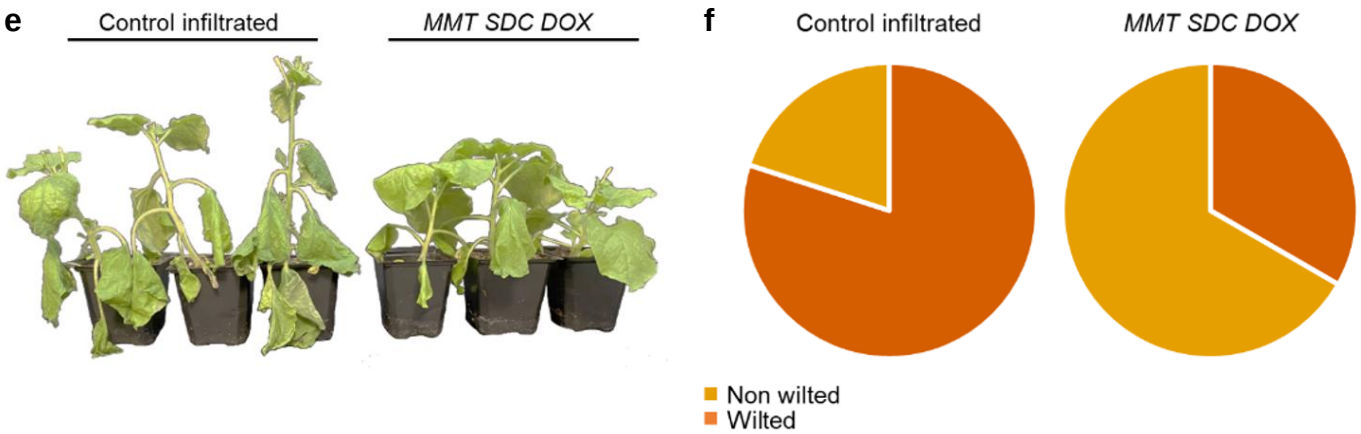
A phylogenetic and transcriptome analysis by the UEA group indicates that it is SDC activity, in particular, that is responsible for the high level of DMSP accumulation in *Spartina* spp. though not necessarily in other accumulators, such as sugar cane.

Salt stress experiments in tomato resulted in a 42% loss of biomass but – strikingly – this was completely recovered by supplying DMSP to the roots (Figs a and b, below), which is the **first demonstration of the protective effects of DMSP in plants**. The UEA paper describes the RNA-seq analysis of these plants, showing the pathways activated in the DMSP untreated/treated plants. In the latter many osmotic and oxidative stress protection genes are activated. These experiments also suggest that **DMSP likely acts in a conserved way across plant species.**



DMSP protects tomato plants from 100mM salt stress

Transient expression of *Spartina MMT*, *SDC* and *DOX*, alone and in combination, in *Nicotiana benthamiana* (infiltrating all leaves), showed that expression of all three genes together was necessary to elevate DMSP levels significantly. These transiently transformed plants **exhibited drought-resistance compared to control plants** (Figs e and f, below).



Expression of MMT/SDC/DOX reduces wilting in drought-stressed N Bentamiana

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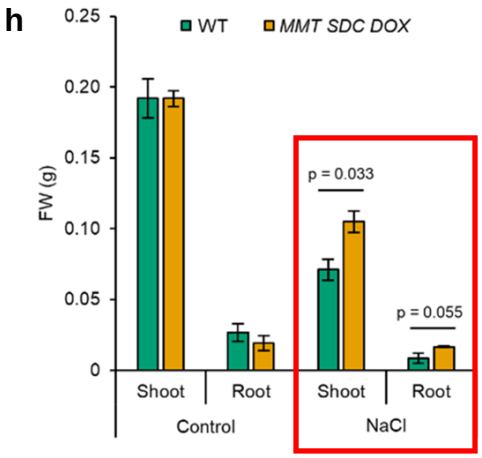
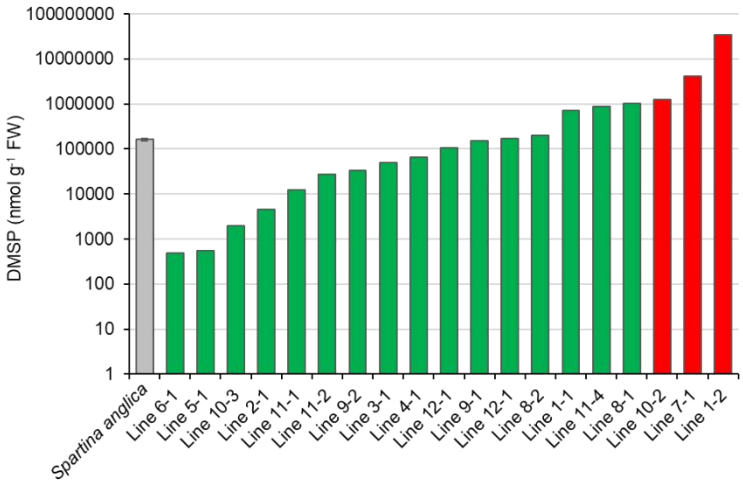
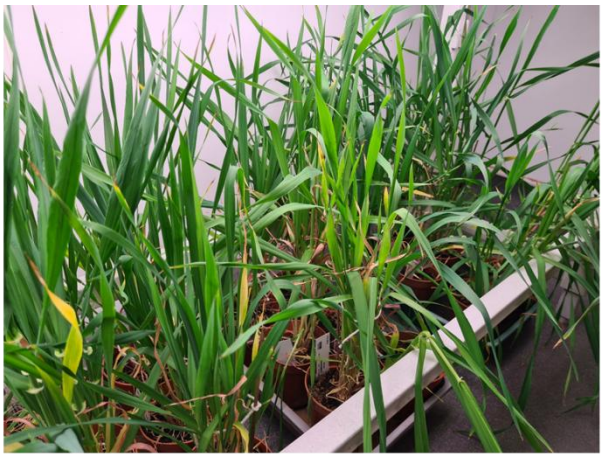
Remarkably, transgenic *Arabidopsis* (a low-DMSP accumulator) expressing all three genes, accumulated DMSP to levels equivalent to *S. anglica* and showed **no phenotypic abnormalities at all**. These DMSP-expressing *Arabidopsis* lines were subjected to salt stress experiments. Under 100mM NaCl, they showed a **significant increase in biomass** compared to control plants (Fig h, below).



Expression of MMT/SDC/DOX boosts fresh weight in salt-stressed Arabidopsis

Transgenic **barley** overexpressing all three *Spartina* DMSP-synthesis genes have been produced (see panel below). Some of the lines achieve levels 10-100x those of *Spartina anglica* and look phenotypically normal in regular growth conditions. Material is being generated for detailed phenotypic assessment. Transgenic **wheat** has also been produced for analysis by the UEA team.





T0 plants

Further characterisation of the biology of DMSP in plants is ongoing at UEA. For more information or licensing interest, please contact PBL.

References:

Payet, R.D., Bilham, L.J., Kabir, S.M.T. et al. Elucidation of *Spartina* dimethylsulfoniopropionate synthesis genes enables engineering of stress tolerant plants. Nat Commun 15, 8568 (2024). https://doi.org/10.1038/s41467-024-51758-z