Capsella bursa-pastoris L. Medik. (shepherd's purse) myxospermous seed mucilage mechanically stabilises clay soil

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Introduction

- *Capsella bursa-pastoris* L. Medik (shepherd's purse) seeds are myxospermous. That is, they exude mucilage upon hydration.
- Myxospermy appears to be of great ecological importance in water limited environments.
- The utility of the mucilage to improve soil mechanical properties was investigated.
- Rheology measures assessed the physical properties of a model (clay) soil, before and after the addition of extracted seed mucilage.

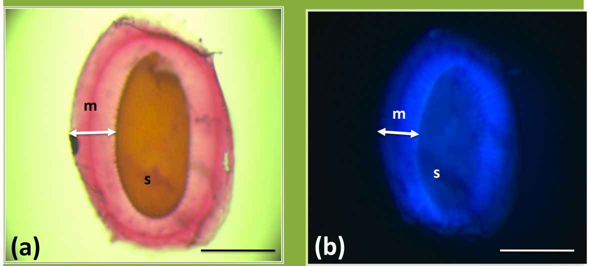

Figure 1. Light micrographs of shepherd's purse seeds visualized after: (a) ruthenium red staining and illumination with white light, showing the localisation of pectin; (b) calcofluor and illumination with UV light, showing cellulose. Where 'm' denotes the mucilage, and 's' the seed. Note that the mucilage is a bilayer structure comprising pectin had cellulose - the cellulose concentrated at the inner layer. Scale bar = 500µm.

The theory of rheology

- Rheology is the science of material deformation and flow.
- Materials may range from ideal-elastic to ideal-viscous.
- The parameters assessed for this study are defined below.

Parameter	Rheology
τ	Rotational shear stress (Pa), applied force
γ	Shear strain (1)
η	Viscosity (Pa·s),
G^*	Complex shear modulus (Pa), a measure of stiffness,
G'	Storage modulus (Pa), represent elastic behaviour,
G''	Loss modulus (Pa), represent viscous behaviour,
tan δ	Loss factor (1), where is the phase shift angle,
τ_y	Yield stress (Pa), represent a critical stress that causes irrecoverable deformation
τ_f	Stress at flow point (Pa), where material start to flow

Methods:

Seeds were washed in d.H_2O (1:10 [w/v]) with shaking, 8h. After centrifugation (5000 rpm, 20 min), the mucilage-containing supernatant was freeze-dried. Mucilage was added to soil (a Ca-montmorillonite (clay) at 0, 0.5 and 1 % [w/v], at soil water contents ranging from 140 - 200 % [w/v] of clay weight. Shear stress (τ) was applied (0.1 - 10000 Pa @ Temp. = 20 °C ; frequency = 0.5 Hz; gap = 2 mm).

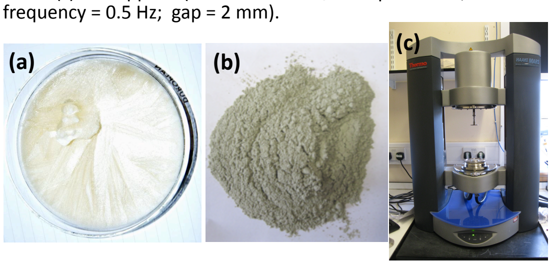

Figure 2. (a) freeze dried mucilage; (b) Ca-montmorillonit; (c) Rotational rheometer

Results

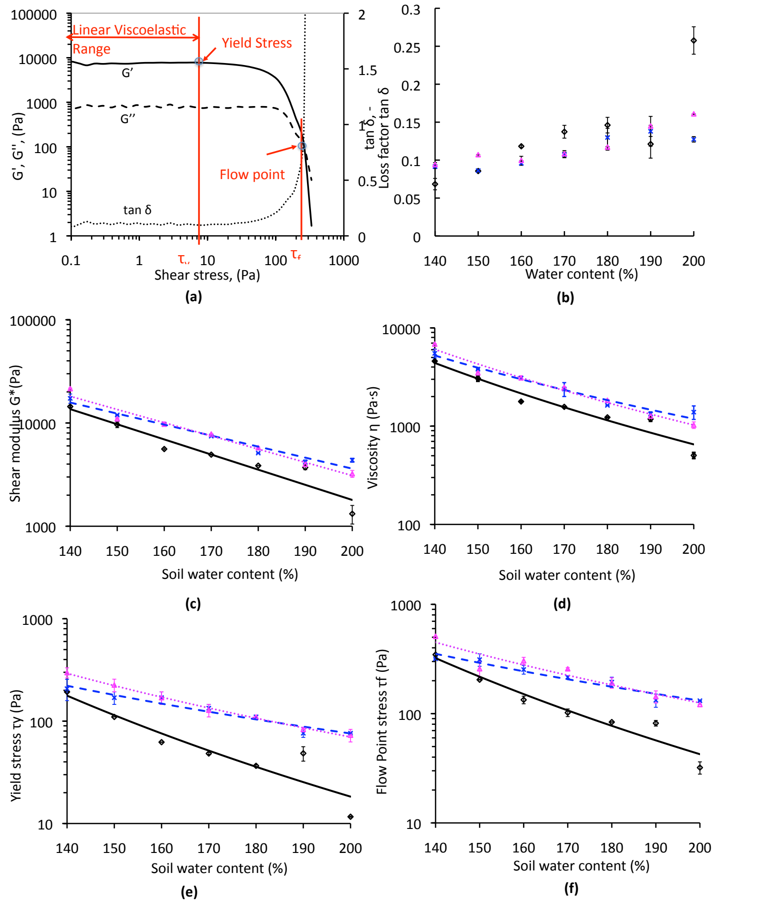

Figure 3. (a) typical flow curve of an 'oscillatory stress sweep test'. (b) – (f) Plots of rheology parameters : loss factor, shear modulus, viscosity, yield stress and flow point stress *versus* soil water content (%) (respectively), for clay soils containing no mucilage (black diamond/solid line), 0.5 % (blue cross/dashed line) and 1 % (pink triangle/dotted line) mucilage at 20 °C. All experimental data were fitted using an exponential curve, and errors bars denote the SE of the mean.

Conclusions

- Soil rheology parameters (G^*, η, τ_y, τ_f) decrease as water content increases.
- The rate of this decrease is reduced when is seed mucilage present.
- There is less affect of seed mucilage of soil shear modulus and viscosity .
- The greatest affect of the seed mucilage is seen for yield- and flow-stress (soil stiffness).
- This influence is greatest at high soil water content, even for only 0.5 [w/w] mucilage .
- At low water contents 1 % mucilage has greater influence than 0.5 % mucilage.
- Soil water content and rheology-measure relationships are explained by exponential curve fits.
- Seed mucilage increases soil resistance to mechanical stress, even at low concentrations
- **This insight will be exploited using mathematical modelling, to facilitate an assessment of the ecosystem services provisions that might be made by myxospermous seeds.**

Further Reading

Iannetta 2010. *Capsella*. Springer. ISBN 978-3-642-14870-5
Penfield *et al.* 2001. *Plant Cell* **13**: 2777-2791.
Puoci *et al.* 2008. *Amer. J. Agri. Biol. Sci.* **3**: 299-314, 200
Van Oudtshoorn, Van Rooyen 1999. *Dispersal biology of desert plants*. Springer. ISBN 978-3-642-08439-3

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