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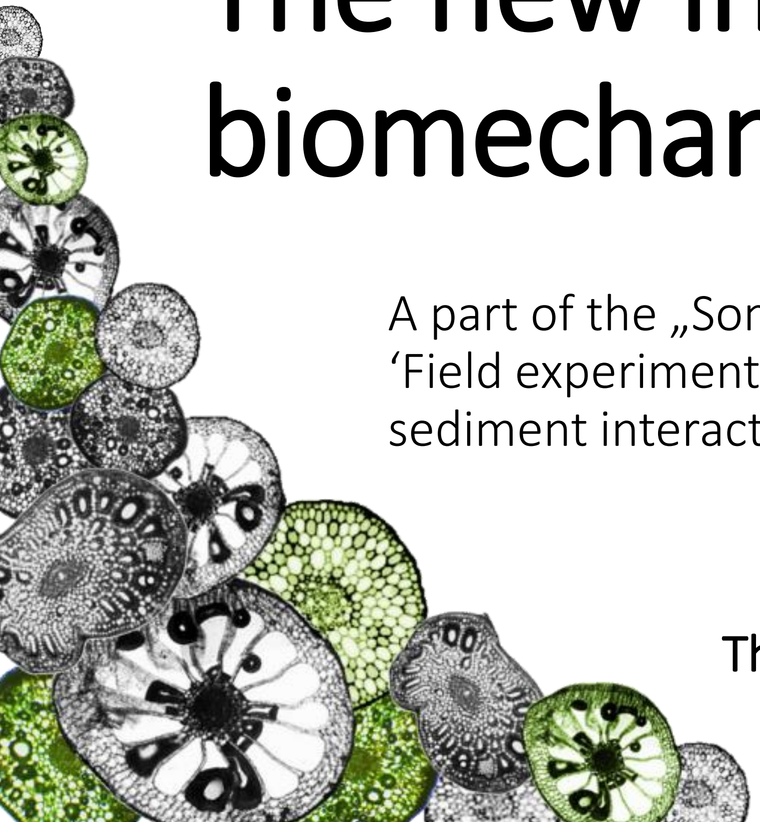
Institute of Geophysics
Polish Academy of Sciences

The new insights on the study of biomechanics of aquatic plants



A part of the „Sonata" grant project:
'Field experimental investigation of hydrodynamics of water flow-vegetation-sediment interactions at the scale of individual aquatic plant'.

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May 24, 2017

The subject of study

<u>Based on papers under review in:</u>

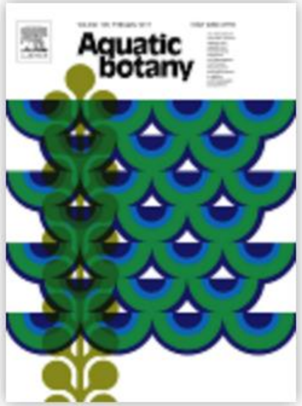
Frontiers in Plant Science:

Łoboda, A.M., Przyborowski, Ł., Karpiński, M., Bialik, R.J., Nikora, V.I. Biomechanical properties of river plants: the effect of test conditions

frontiers in Plant Science

Aquatic Botany:

Łoboda, A.M., Bialik, R.J., Przyborowski, Ł., Karpiński, M. The seasonality of changes in biomechanical properties of Elodea canadensis Michx.



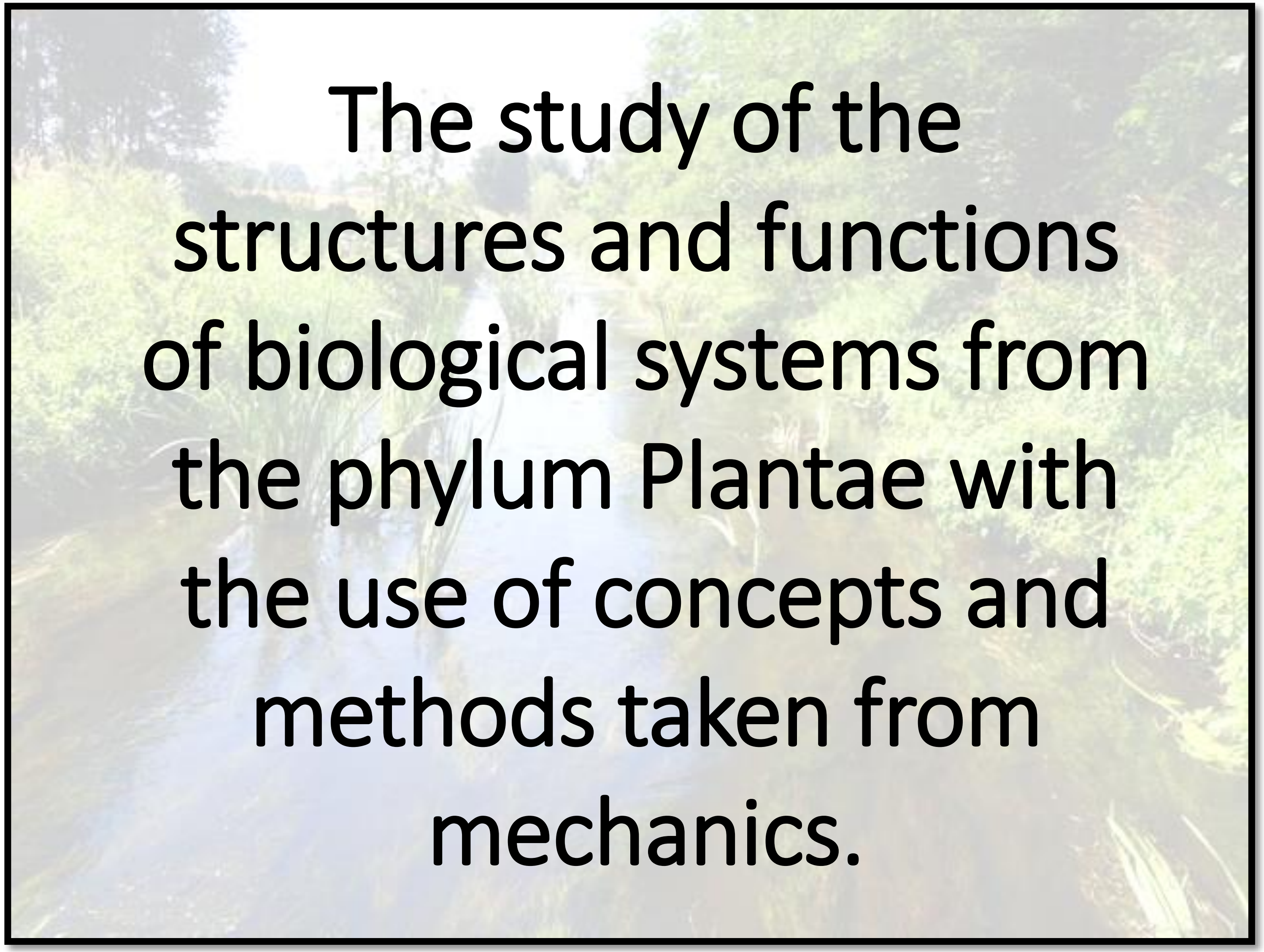
Presentation Outline

- Motivation for this research
- Identification of plants
- Methodology
- Results
- Conclusions
- References

The motivation for this research

Fig. 1. River vegetation (http://galeria.swiatkwiatow.pl)

The motivation for this research



The study of the structures and functions of biological systems from the phylum Plantae with the use of concepts and methods taken from mechanics.

Fig. 1. River vegetation (http://galeria.swiatkwiatow.pl)

The motivation for this research

Fig. 2. Vegetated river (http://www.kubg.edu.ua)

The interest of the phenomena occuring in the vegetated rivers is still growing.
Lots of lab research are concentrated on study of velocity distribution, flow resistance and turbulence with use of artificial plants made from different materials.

Why the biomechanics is important?

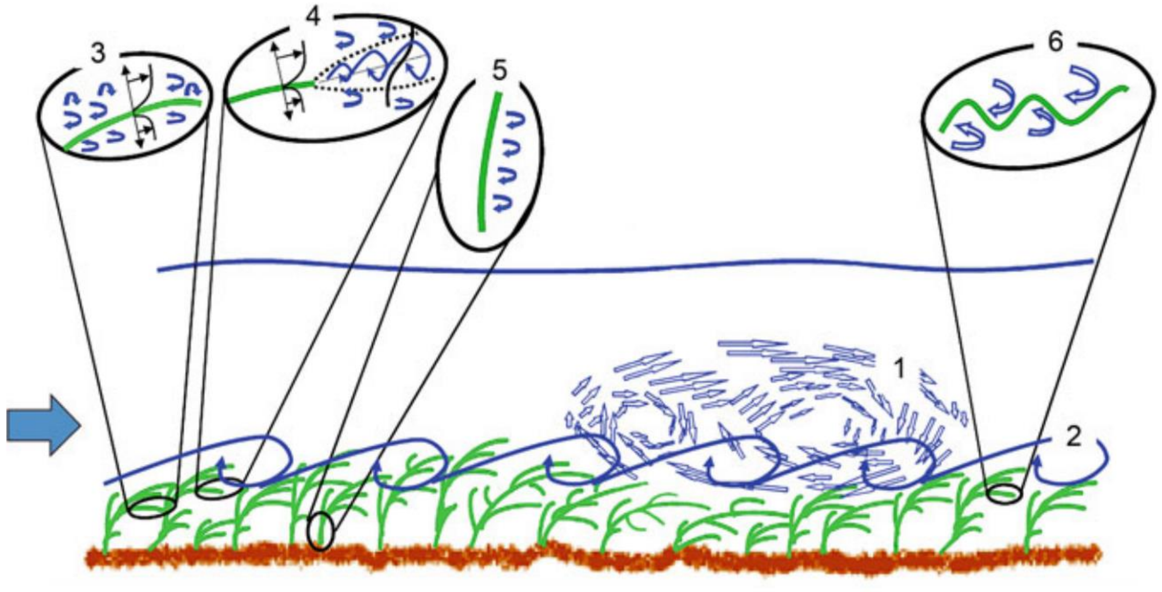


Fig. 3. Side view of multi-scale flow patterns in vegetated channels. (Aberle and Järvelä 2015)

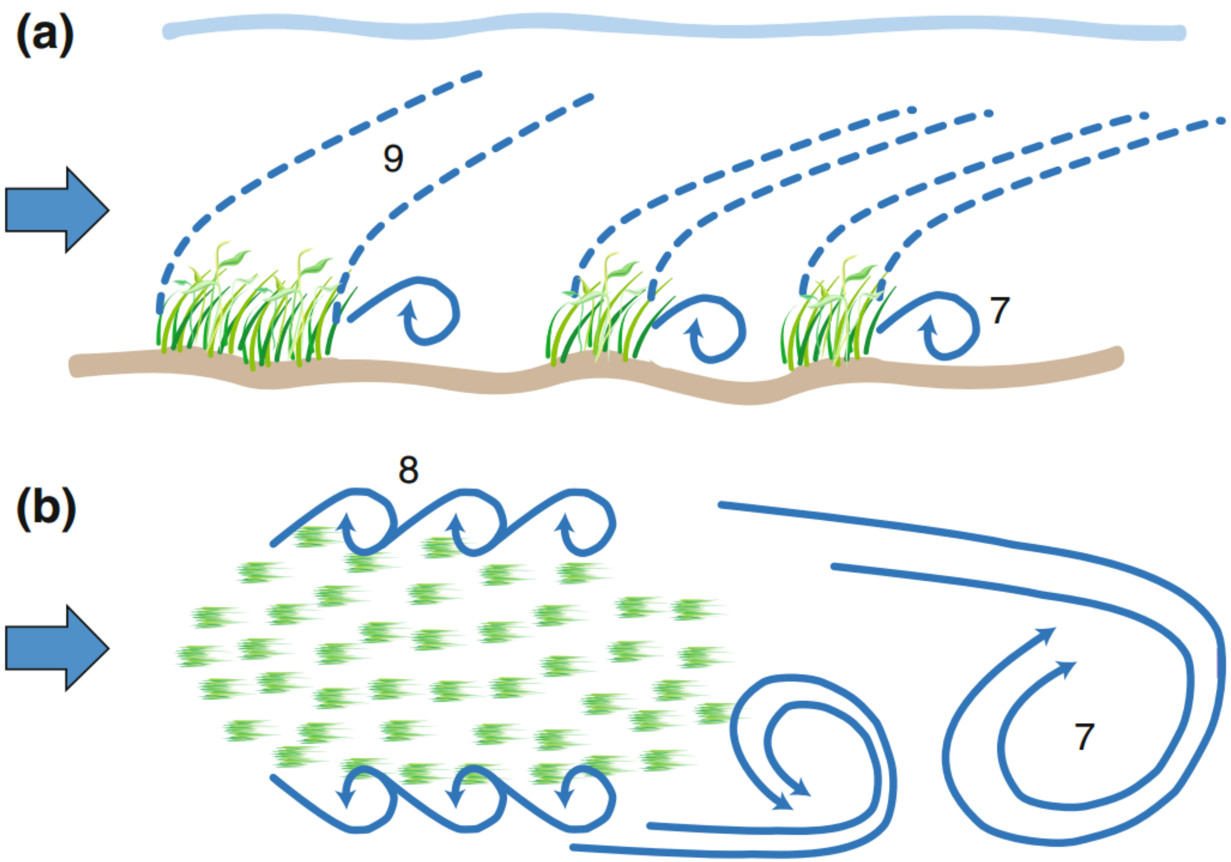


Fig. 4. Flow patterns at patch scale: (a) side view considering patch mosaic structure and (b) plan view at patch scale (Aberle and Järvelä 2015)

The main goals

- What is the difference in outcomes between tests conducted in dry and wet conditions?
- How important is measuring of biomechanical properties of aquatic plants in wet conditions?
- How one of the most common submerged macrophytes, namely Elodea canadensis Michx. changes the biomechanical properties during its life cycle?

Sampling sites

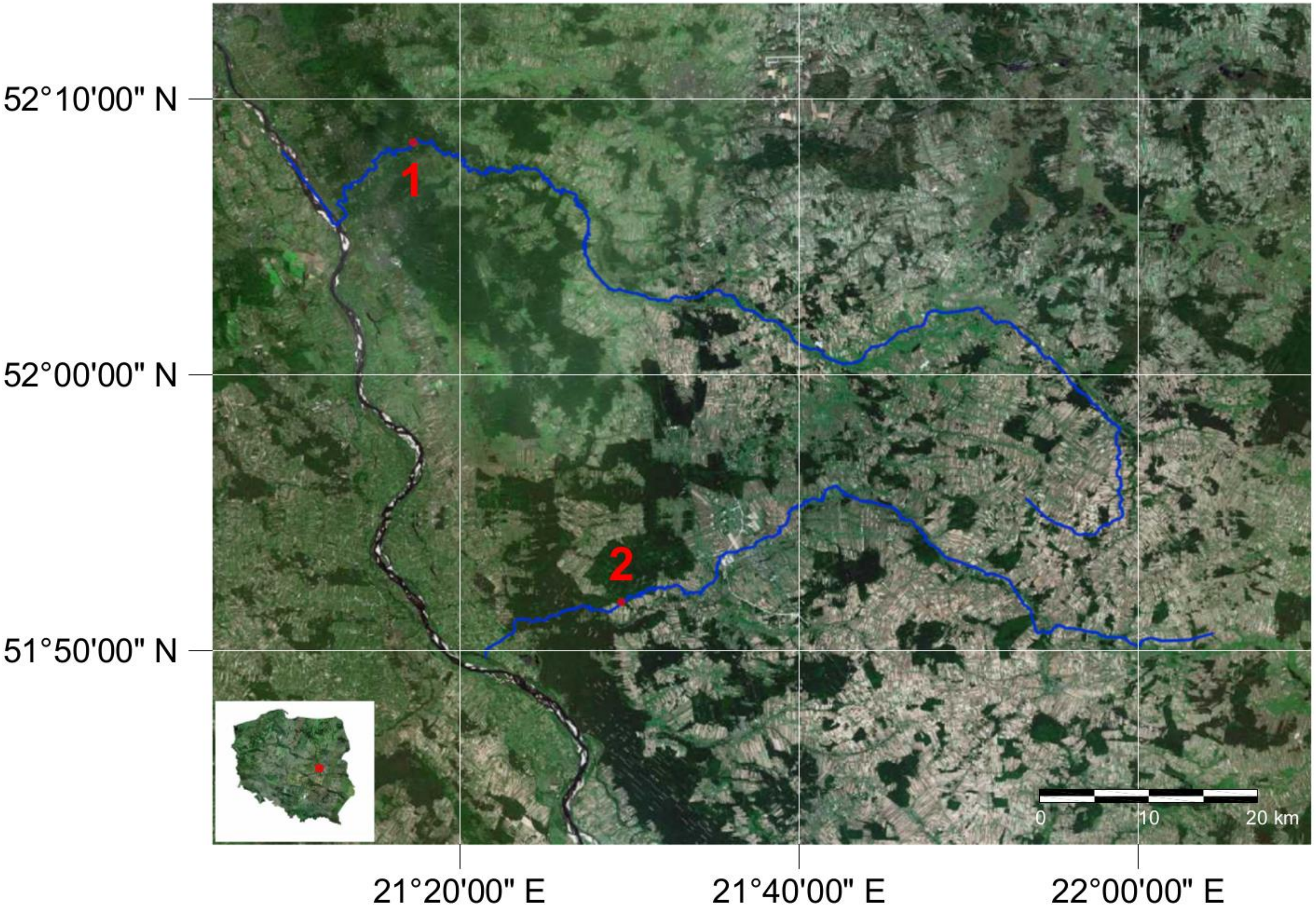


Fig. 5. Sampling sites on the Świder River (1) and the Wilga River (2) (www.geoportal.gov).

<u>Plants from the Świder River:</u>

Potamogeton pectinatus L.

Potamogeton crispus L.

Myriophyllum spicatum L.

Ceratophyllum demersum L.

<u>Plants from the Wilga River:</u>

Potamogeton pectinatus L.

Potamogeton crispus L.

Elodea canadensis Michx.

Identification of plants

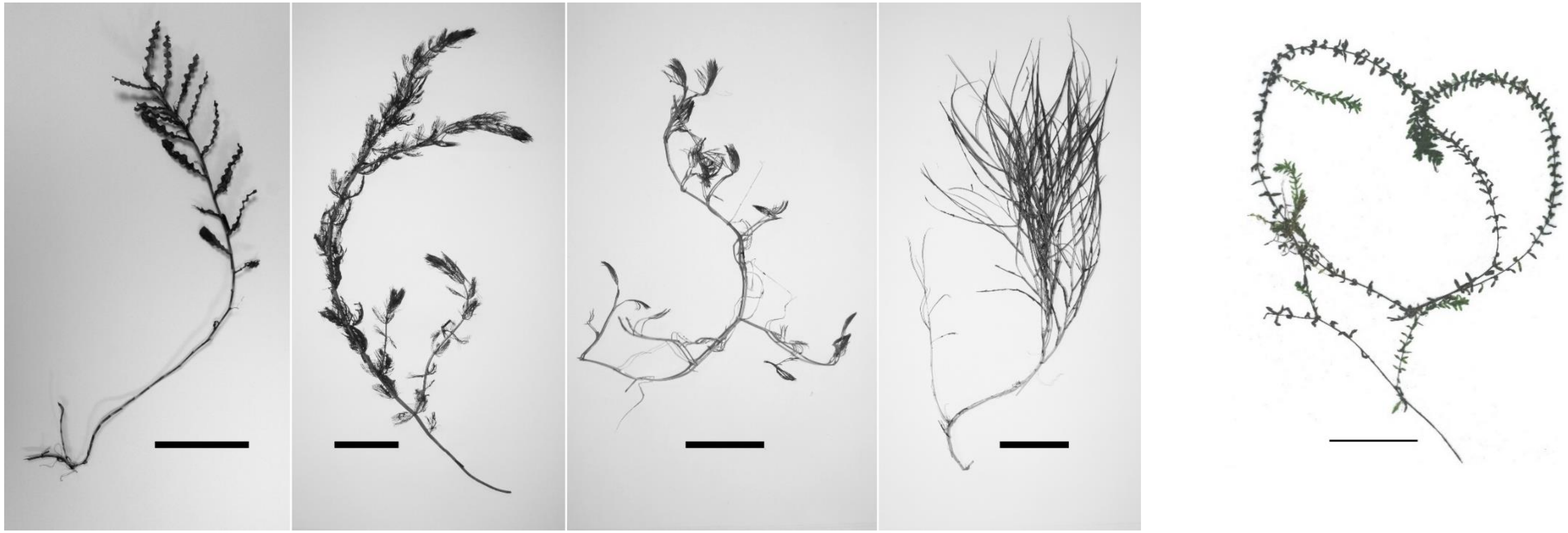


Fig. 6. Photographs of tested specimens, from the left to right: *P. crispus L., M. spicatum L., C. demersum L., P. pectinatus L., E. canadensis Michx.* The bar has lenght of 50 mm.

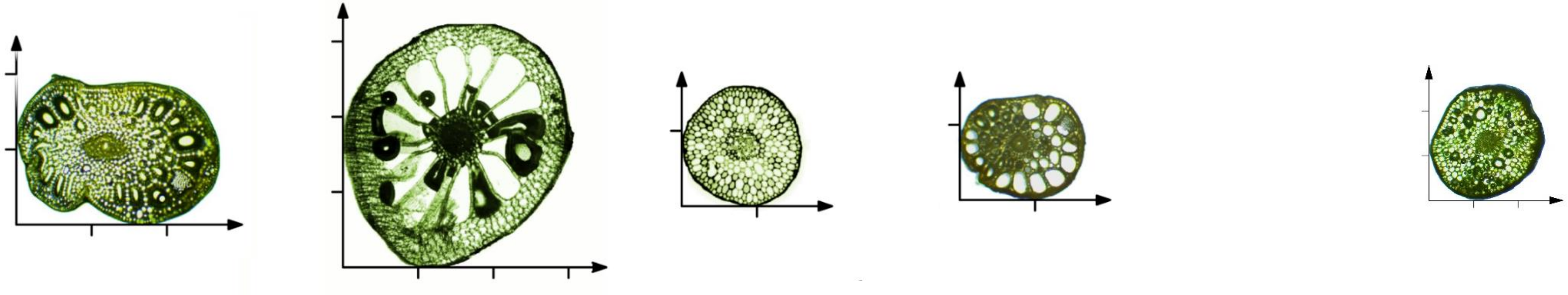


Fig. 7. Cross-sections of tested plants, from the left to right: *P. crispus L., M. spicatum L., C. demersum L., P. pectinatus L., E. canadensis Michx.*

Methodology: Equipment – Bench Top Testing Machine

A)

B)

C)

Fig. 8. Photographs of Bench Top Testing Machine.

Methodology: Why the wet conditions are important?

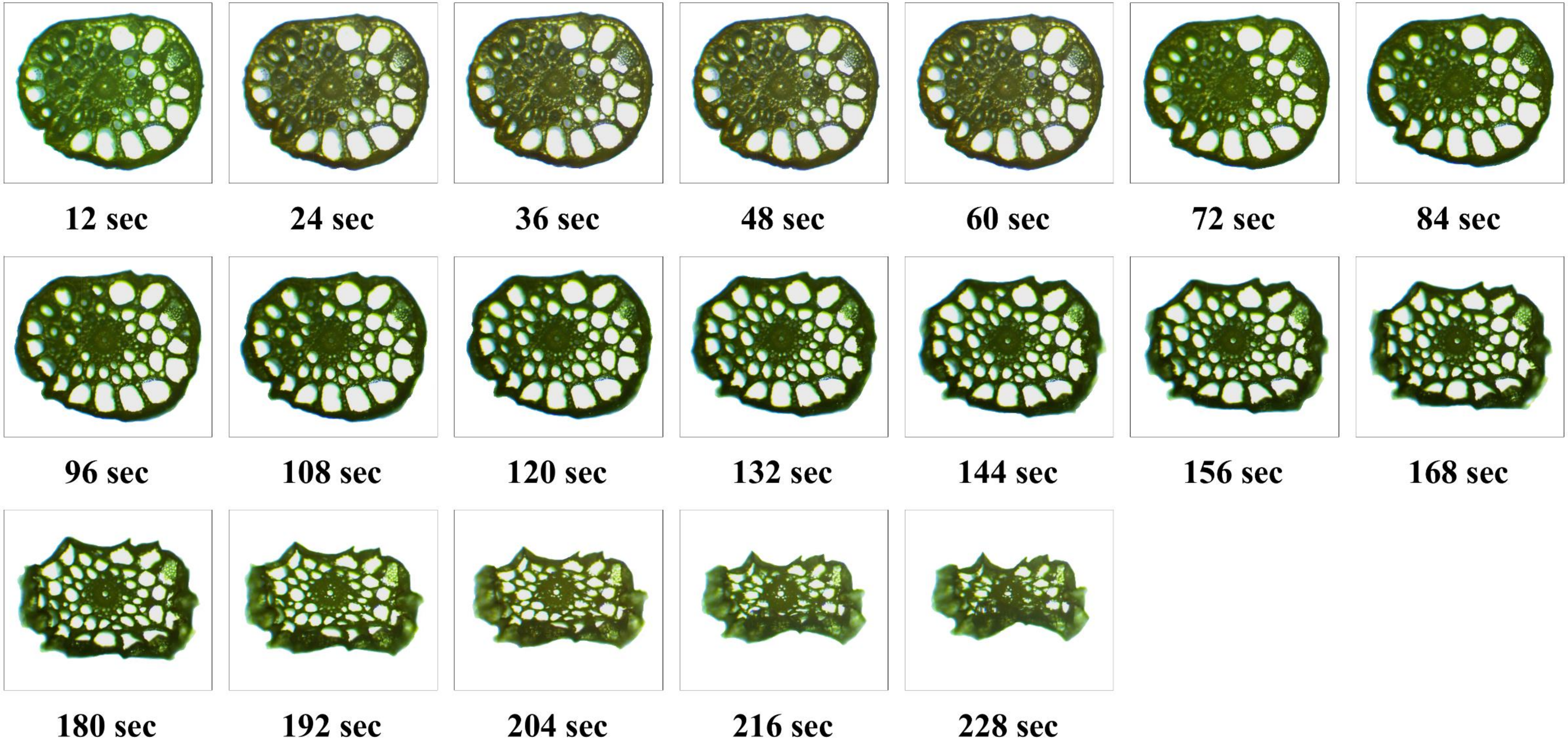


Fig. 9. Changes of diameter of stem cross-section of Potamogeton pectinatus L. within 4 minutes.

Methodology: *Why the wet conditions are important?*

Tab. 1. Outcomes of the three-point bending tests for Potamogeton pectinatus L., Potamogeton crispus L. and Myriophyllum spicatum L. under dry and wet conditions.

PARAMETER		*POTAMOGETON PECTINATUS L.*		*POTAMOGETON CRISPUS L.*		*MYRIOPHYLLUM SPICATUM L.*	
		dry conditions	wet conditions	dry conditions	wet conditions	dry conditions	wet conditions
		108 samples	111 samples	159 samples	159 samples	20 samples	20 samples
		Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
Diameter	[mm]	1.23 ± 0.36	1.35 ± 0.40	1.96 ± 0.35	2.04 ± 0.40	2.24 ± 0.40	2.30 ± 0.26
Maximum force	[N]	0.023 ± 0.017	0.026 ± 0.027	0.059 ± 0.044	0.064 ± 0.043	0.042 ± 0.028	0.054 ± 0.033
Maximum stress	[MPa]	0.0037 ± 0.0055	0.0023 ± 0.0023	0.0194 ± 0.0116	0.0191 ± 0.0095	0.0103 ± 0.0063	0.0123 ± 0.0069
Flexural strain	[%]	4.70 ± 1.69	4.81 ± 2.56	7.15 ± 2.21	7.66 ± 2.47	8.68 ± 1.66	10.18 ± 1.50
Maximum deflection	[mm]	14.14 ± 3.39	13.17 ± 6.23	13.38 ± 3.20	13.81 ± 3.49	14.31 ± 1.54	16.36 ± 2.24
Sec. m. of area	[mm^4]	0.178 ± 0.224	0.261 ± 0.328	0.861 ± 0.576	1.045 ± 0.715	1.406 ± 0.688	1.432 ± 0.556
Flexural rigidity	[$N \cdot mm^2$]	6.48 ± 6.21	10.76 ± 11.73	25.96 ± 25.75	36.96 ± 32.06	12.90 ± 7.28	13.94 ± 6.86
Flexural modulus	[MPa]	61.41 ± 58.15	77.77 ± 85.01	38.96 ± 42.60	49.74 ± 52.00	10.86 ± 6.22	11.30 ± 7.72

Methodology: Why the wet conditions are important?

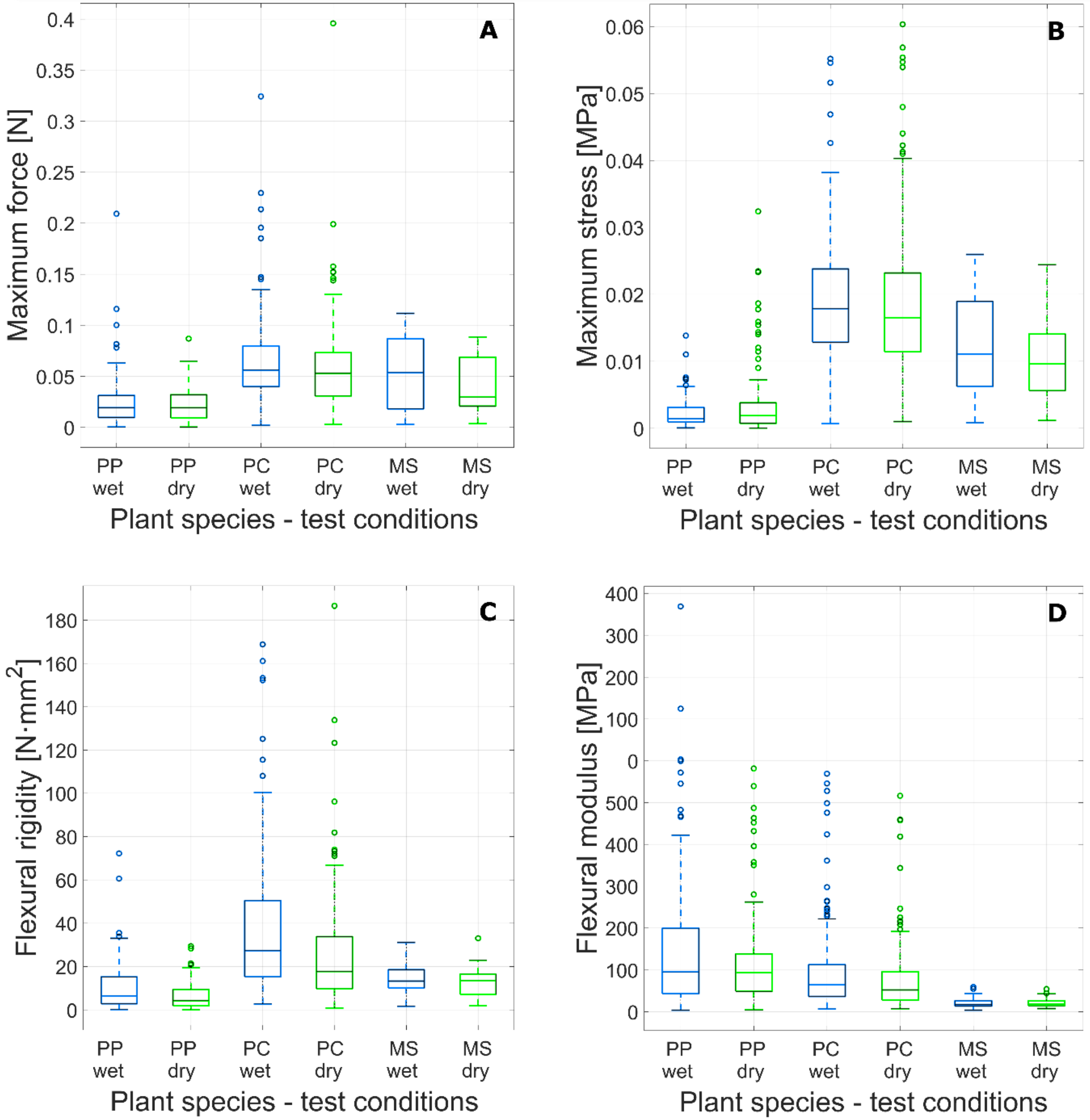


Fig. 11. Photographs of three selected species (from left): *Potamogeton crispus L.*, *Myriophyllum spicatum L.* and *Potamogeton pectinatus L.*

Fig. 10. The maximum force (A), maximum stress (B), flexural rigidity (C) and flexural modulus (D) from the three-point bending tests of the plant stems under different test conditions: P. pectinatus L. (PP), P. crispus L. (PC) and M. spicatum L. (MS)

Results: *Three-point bending tests*

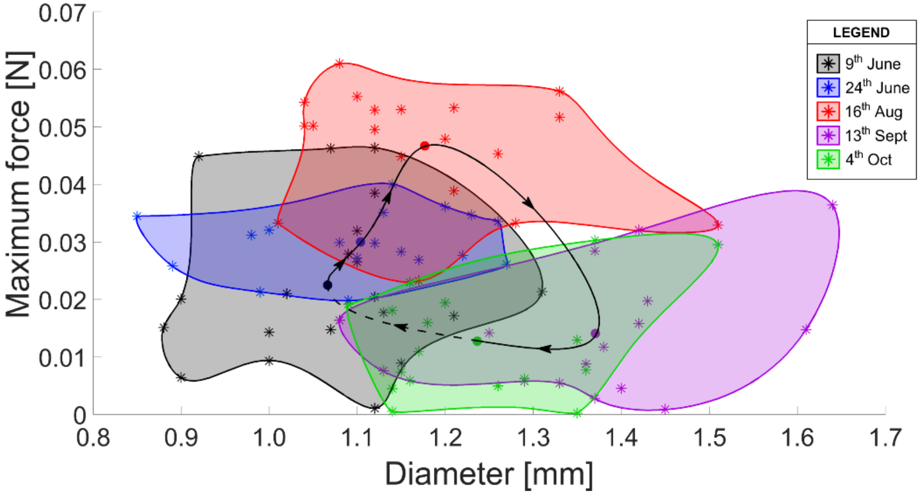


Fig. 12. The relationship between maximum force and diameter for the whole periods of measuring in the three-point bending tests.

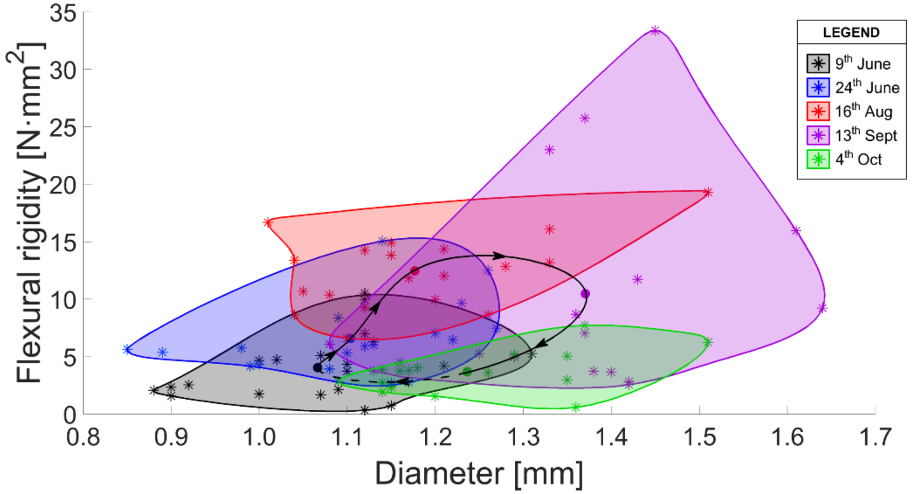


Fig. 13. The relationship between flexural rigidity and diameter for the whole periods of measuring in the three-point bending tests.

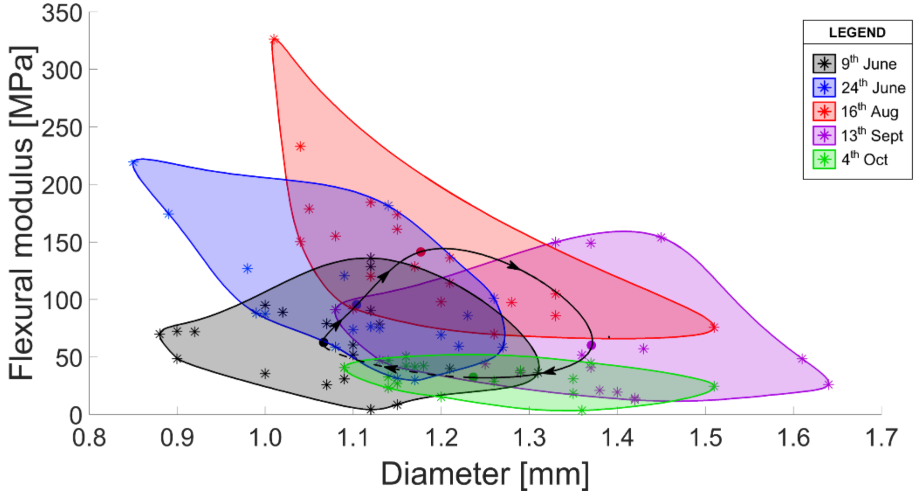


Fig. 14. The relationship between flexural modulus and diameter for the whole periods of measuring in the three-point bending tests.

Results: Three-point bending tests

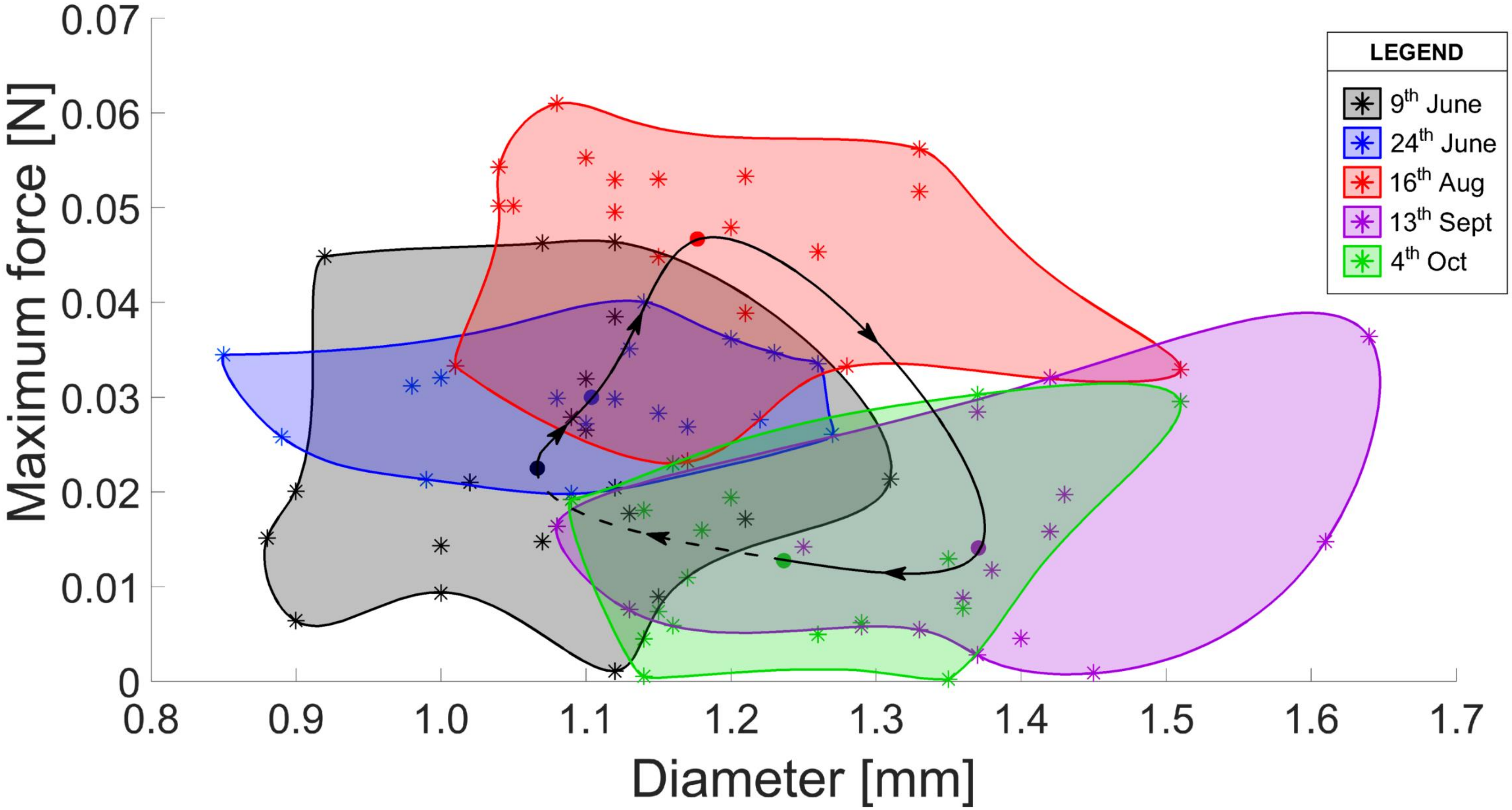


Fig. 12. The relationship between maximum force and diameter for the whole periods of measuring in the three-point bending tests.

Results: *Three-point bending tests*

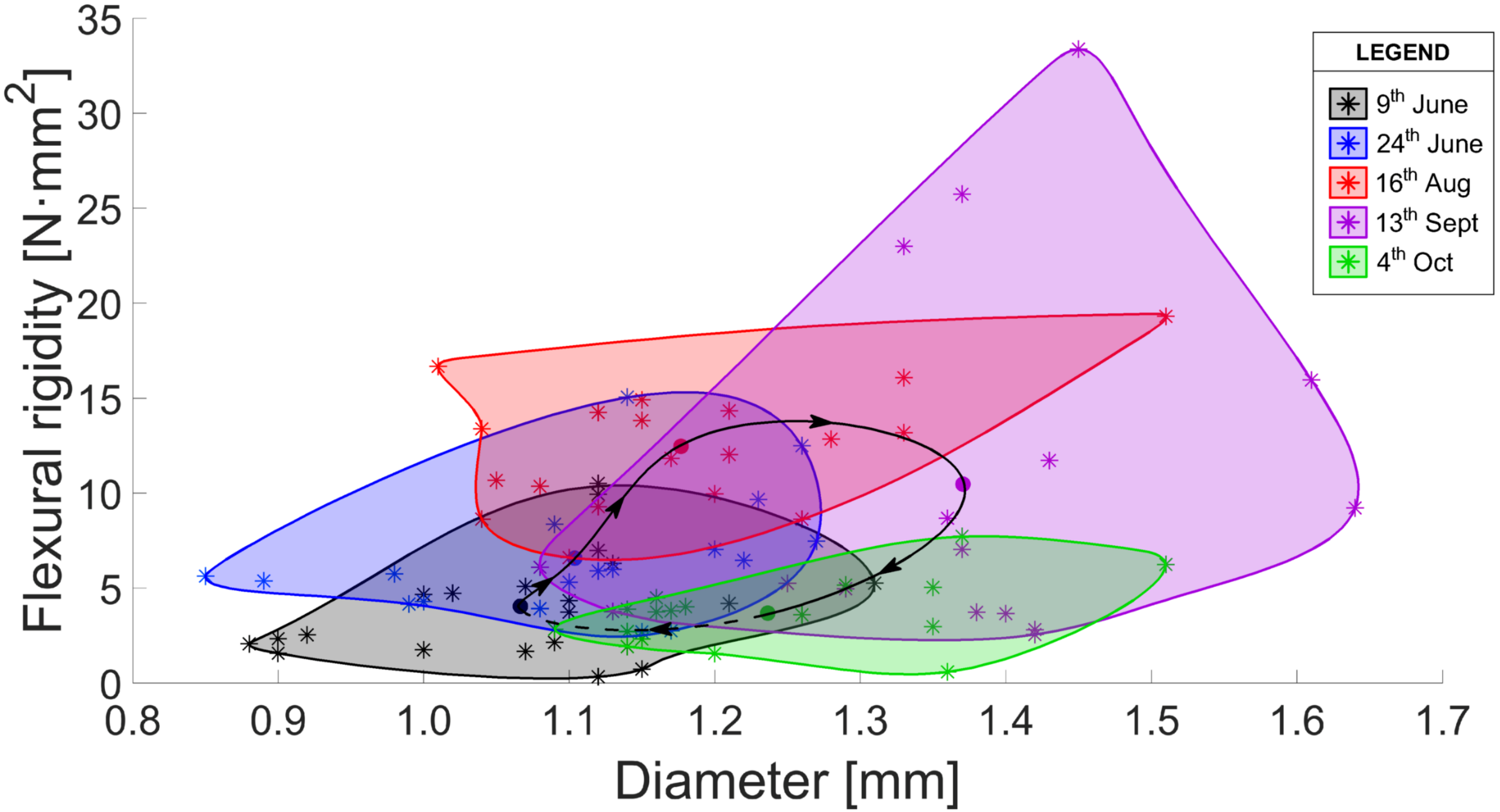


Fig. 13. The relationship between flexural rigidity and diameter for the whole periods of measuring in the three-point bending tests.

Results: Three-point bending tests

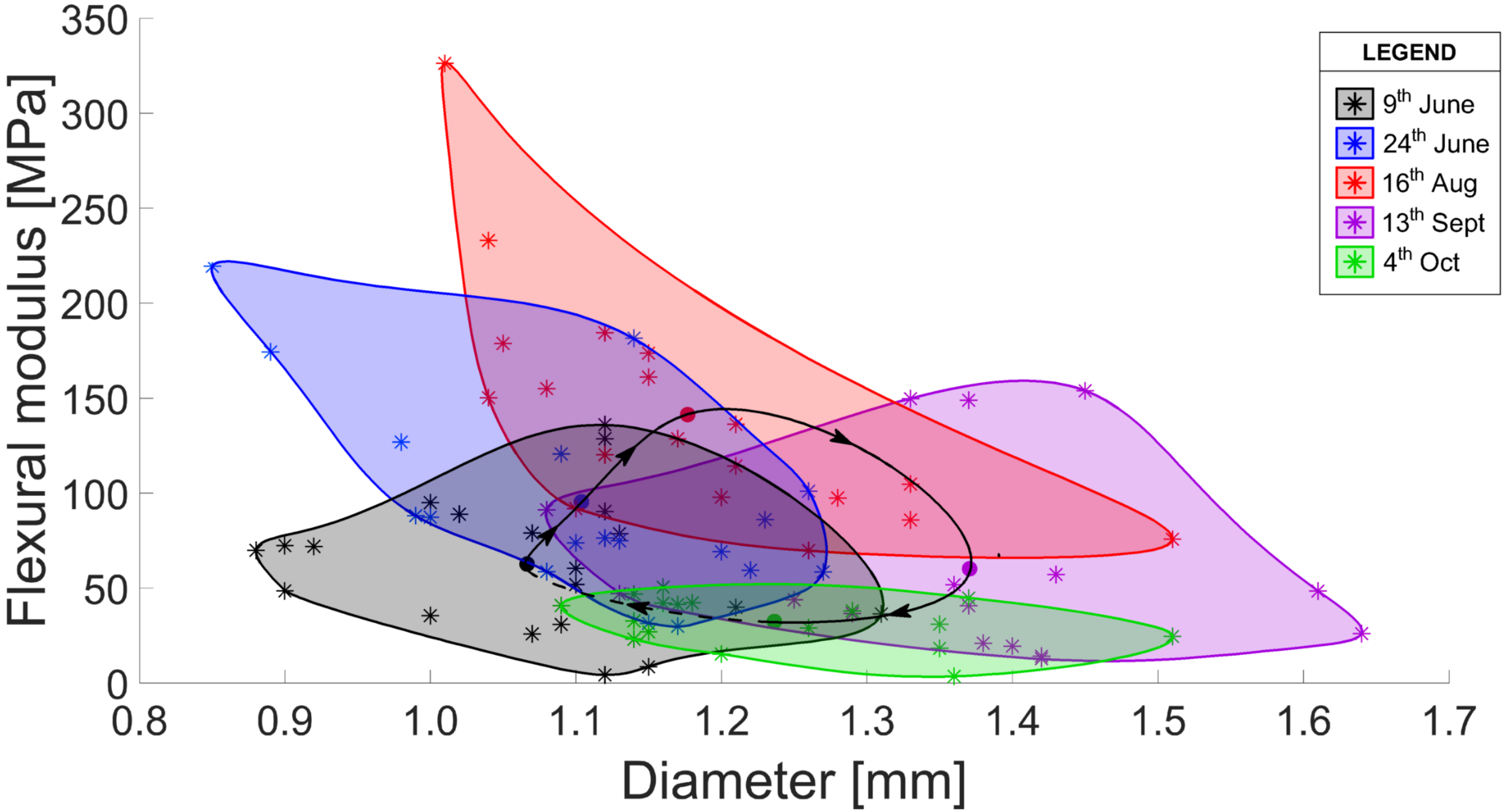


Fig. 14. The relationship between flexural modulus and diameter for the whole periods of measuring in the three-point bending tests.

Results: Tension tests

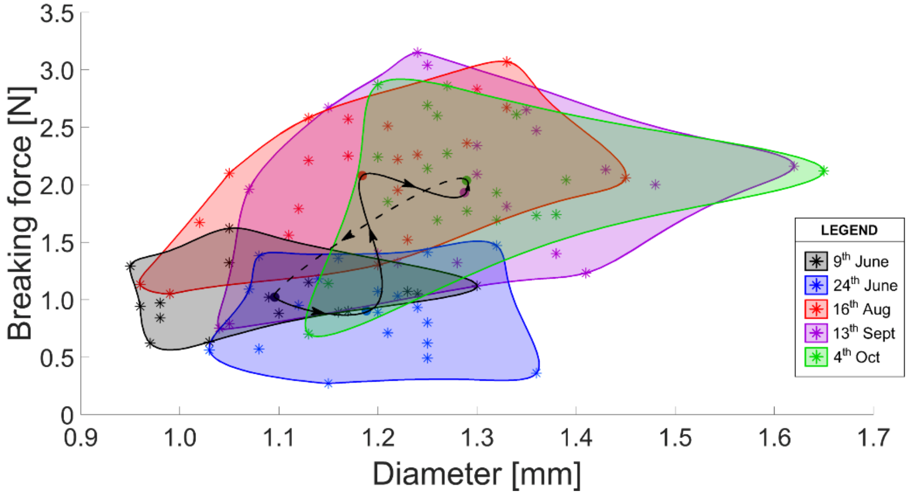


Fig. 15. The relationship between breaking force and diameter for the whole periods of measuring in the tension tests.

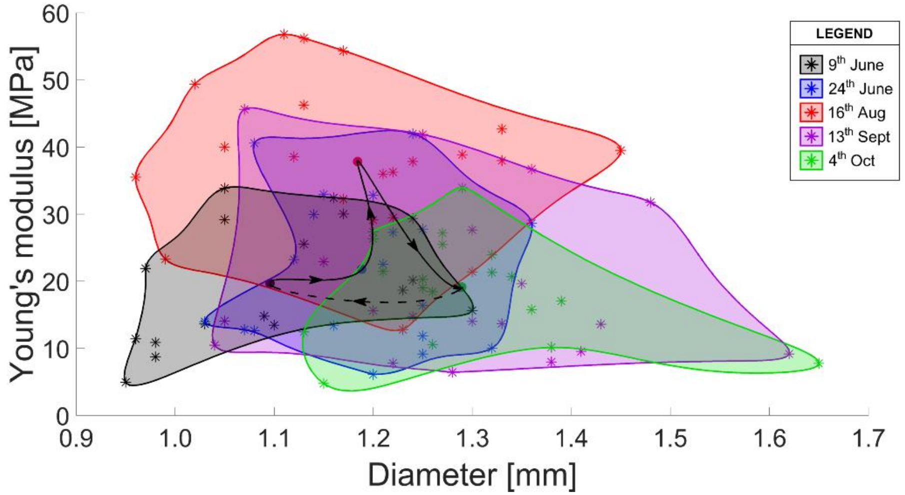


Fig. 16. The relationship between Young's modulus and diameter for the whole periods of measuring in the tension tests.

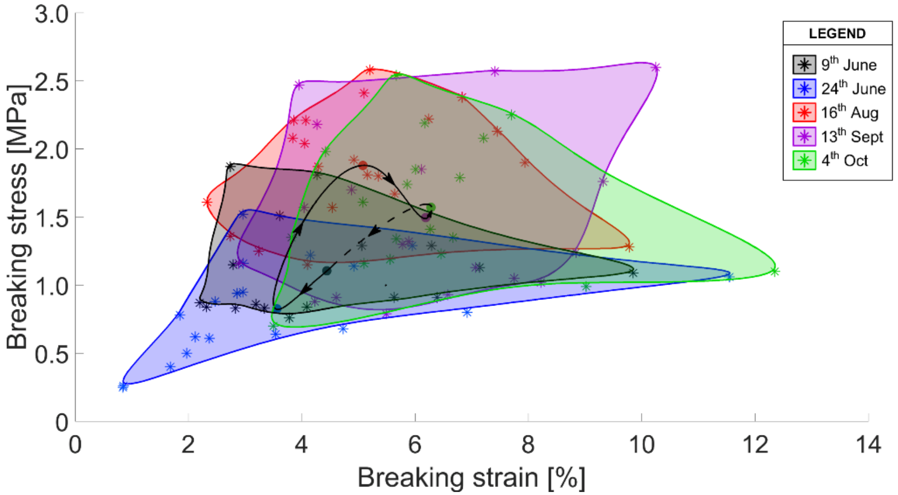


Fig. 17. The relationship between breaking stress and breaking strain for the whole periods of measuring in the tension tests.

Results: Tension tests

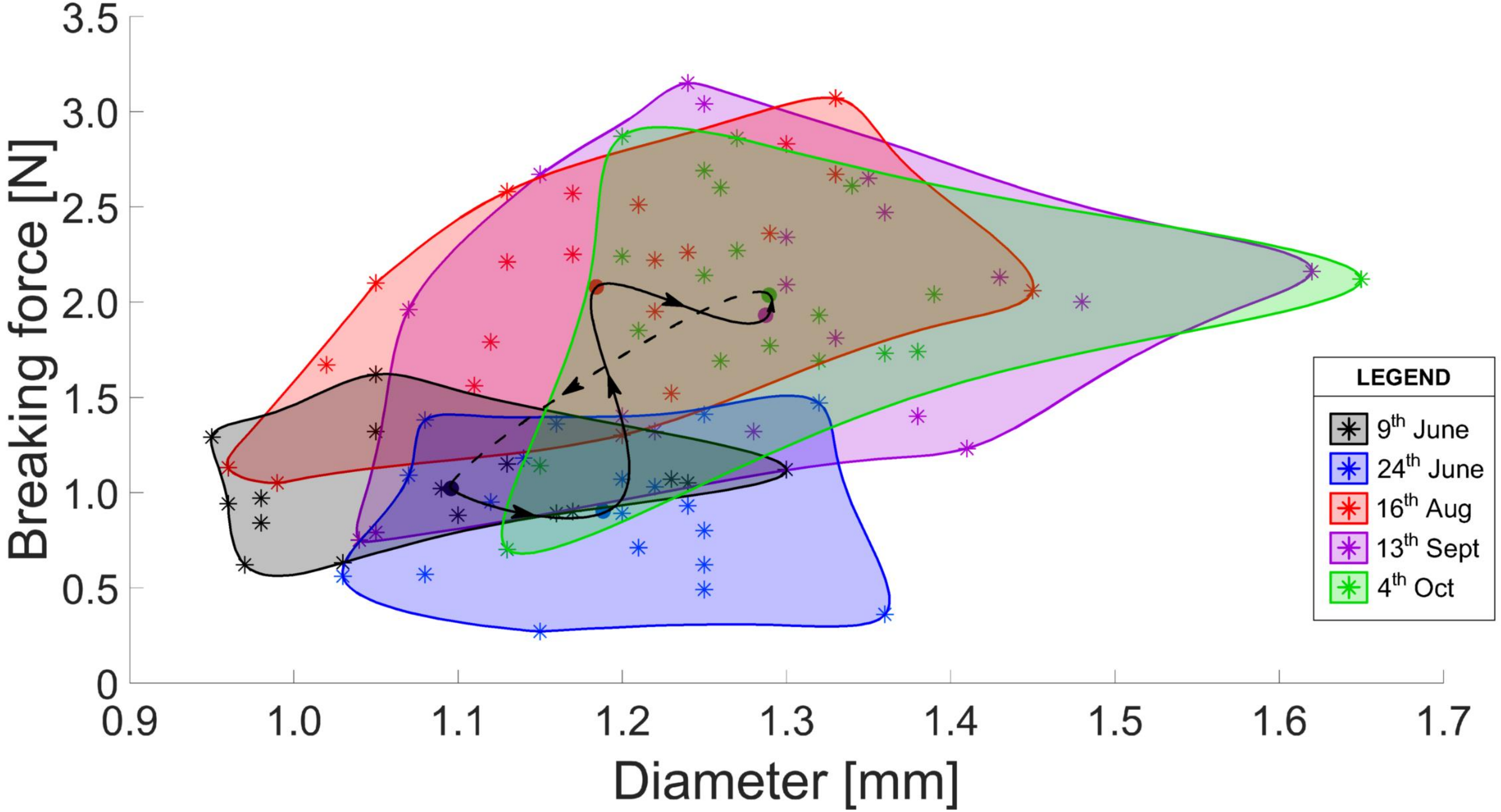


Fig. 15. The relationship between breaking force and diameter for the whole periods of measuring in the tension tests.

Results: Tension tests

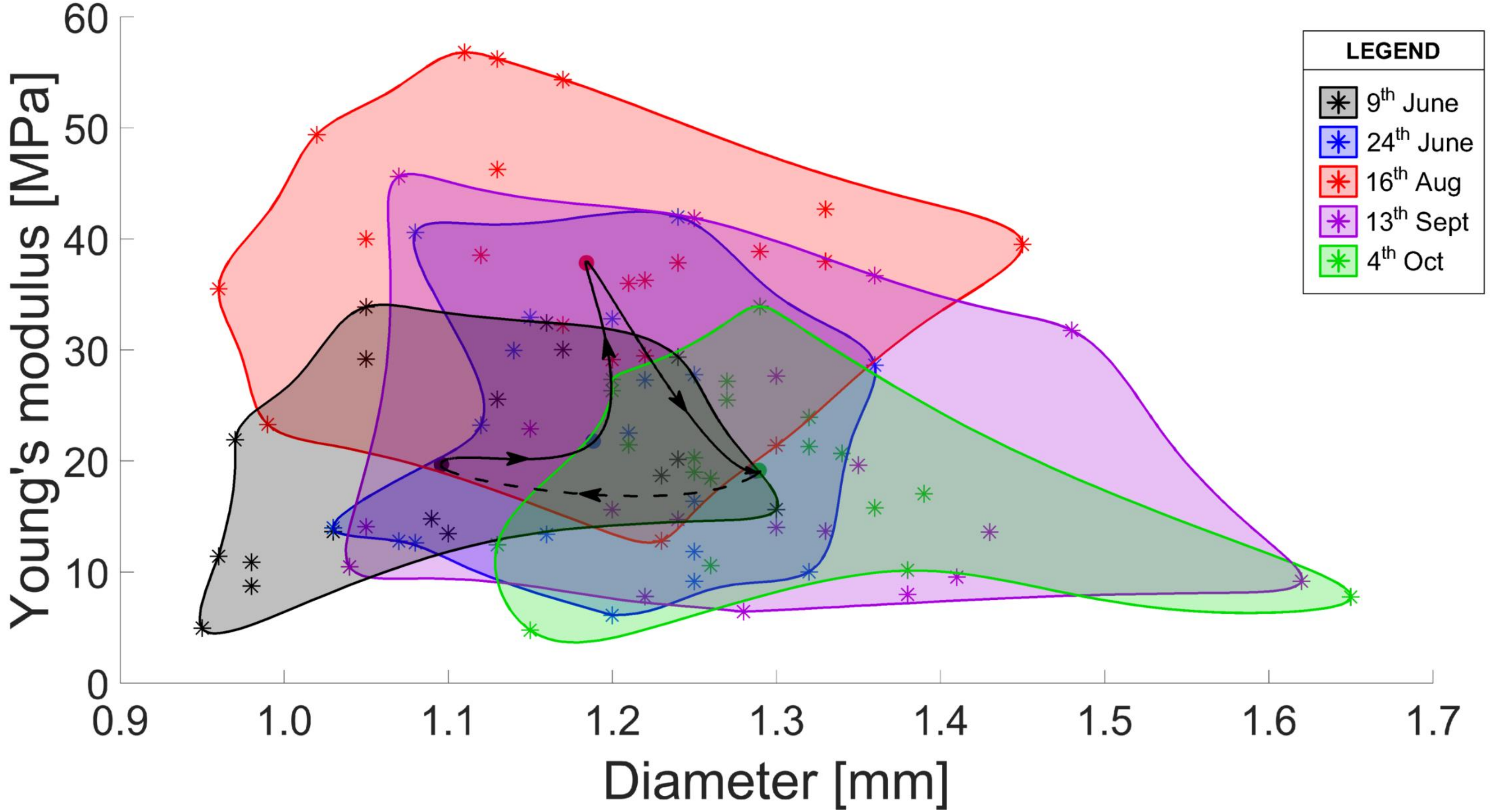


Fig. 16. The relationship between Young's modulus and diameter for the whole periods of measuring in the tension tests.

Results: *Tension tests*

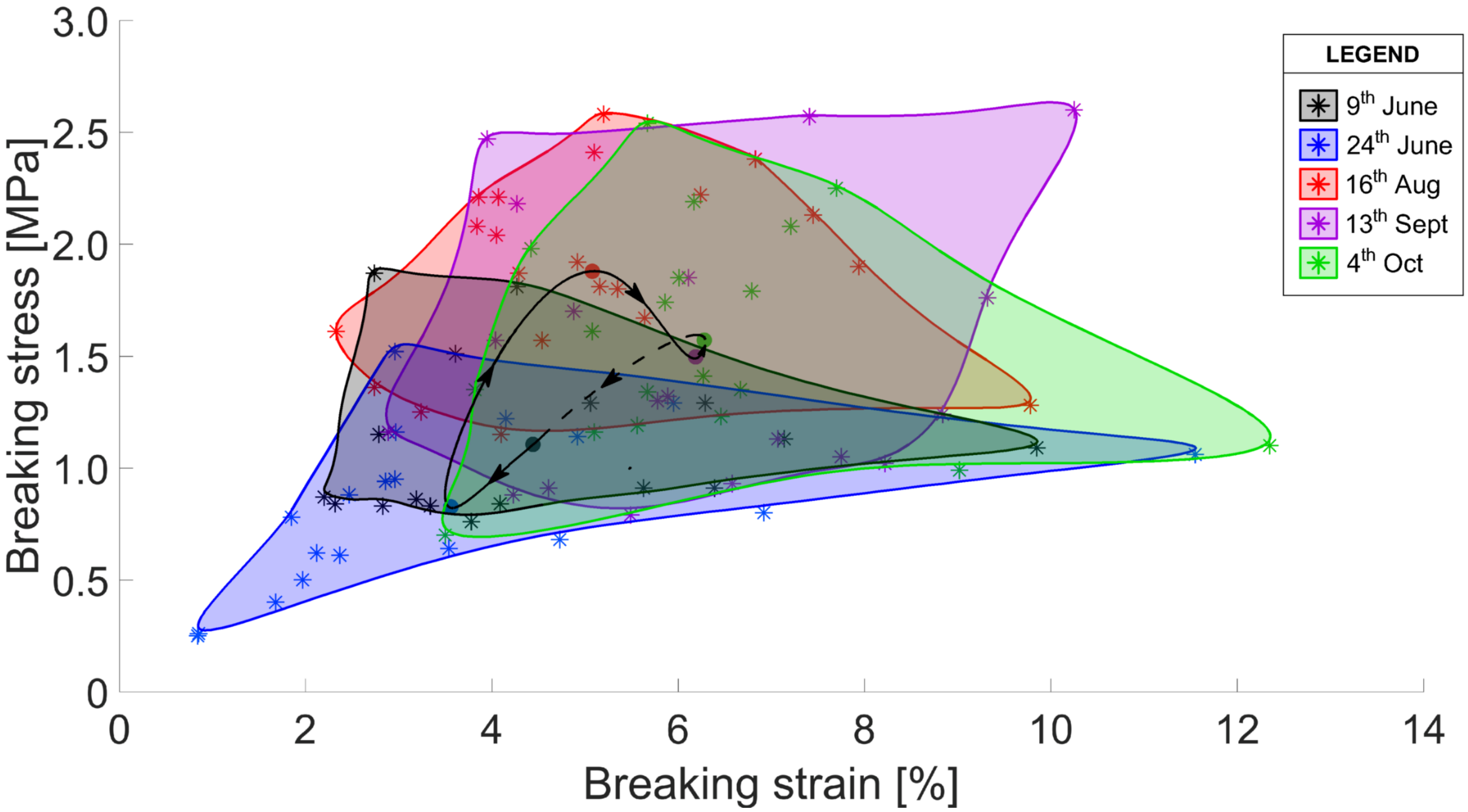


Fig. 17. The relationship between breaking stress and breaking strain for the whole periods of measuring in the tension tests.

Conclusions

- The results show significant differences between values obtained from tests under dry and wet conditions.
- The biomechanical parameters of fresh specimens, even when they kept in water before testing in air, are very sensitive to fast drying.
- The knowledge of the seasonality of changes in biomechanical properties may be important factor in study of processes occuring in vegetated channels due to influence on distributions of water velocities.
- The use of artificial elements imitating vegetation can lead to misinterpretation of results from laboratory experiments due to the changes in biomechanical properties of this species.
- This investigation will allow to more accurate choice of methods and materials used in experiments of flow-biota interactions both in the field and in the laboratory conditions.

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Thank you for your attention.

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