

Leaf Wetting and Uptake of Fluid Foliar P Fertilizers for Wheat

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Tactical Foliar P Fertilization

- ▶ Fertilizer P is a very high input cost and represents a high financial risk to growers in regions with variable seasonal rainfall
- ▶ Tactical application as a “top-up” of P in good seasons on marginally deficient soils
- ▶ Higher efficiency of fertilizer P uptake through the foliar route
 - ▶ Limit to the total amount of P that can be supplied



Major Factors Affecting Foliar Fertilizer Efficacy

Plant-related factors

- Leaf wettability
- Leaf surface morphology

Formulation factors

- Adjuvants
- pH of formulation
- Form of P

Environmental factors

- Temperature
- Wind
- Relative humidity



Plant-Related Factors

- ▶ **Morphology and foliar P uptake of:**
 - ▶ Adaxial (upper) vs. abaxial (lower) leaf sides
 - ▶ Varying levels of P nutrition

- ▶ **Measured by:**
 - ▶ Impressions of leaves using cyanoacrylate adhesive
 - ▶ Scanning Electron Microscopy of fresh and fixed leaves
 - ▶ Leaf wettability by static advancing and receding contact angles
 - ▶ Tracer studies using ^{32}P and ^{33}P to give foliar-applied fertilizers a unique fingerprint



Foliar P Uptake Methods - Leaf Side

- ▶ 2 foliar application timings
 - ▶ ear emergence 39DAS and mid-anthesis 49DAS
- ▶ 3 ^{32}P and ^{33}P labelled fertiliser rates (0.6, 1 and 2.6 kg P/ha)
 - ▶ ^{33}P applied to lower side
 - ▶ ^{32}P applied to upper side
- ▶ Leaves not washed after treatment but translocation reported as a % of foliar P recovered in the plant
- ▶ Plants harvested during maturity

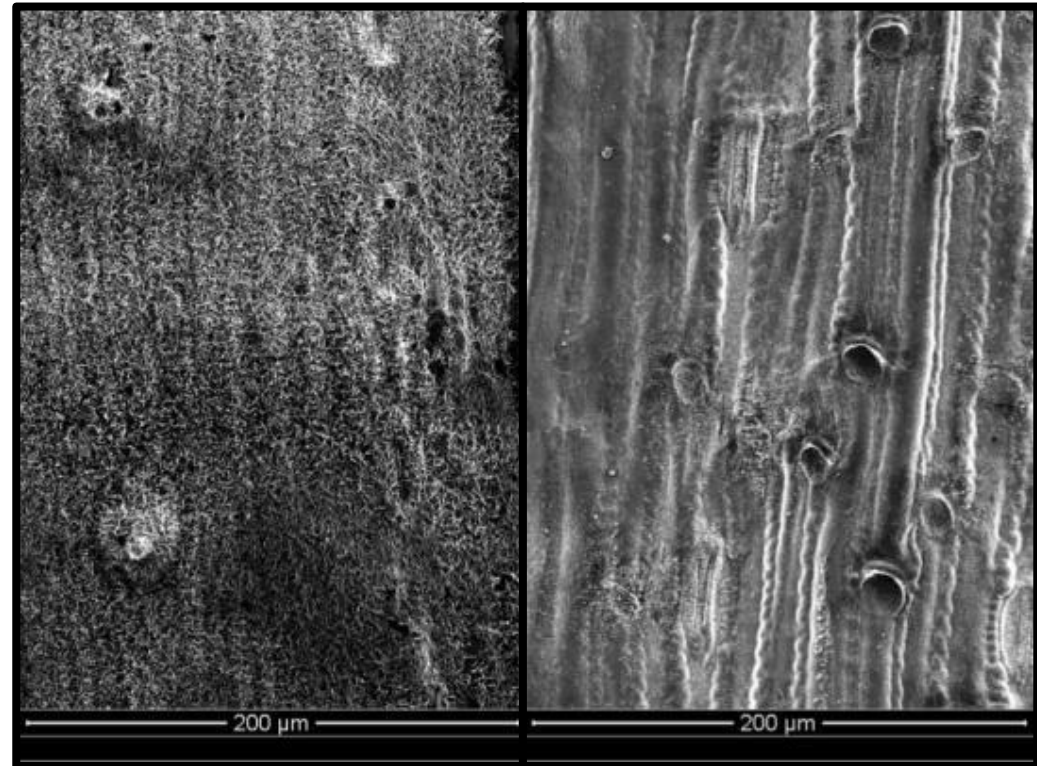
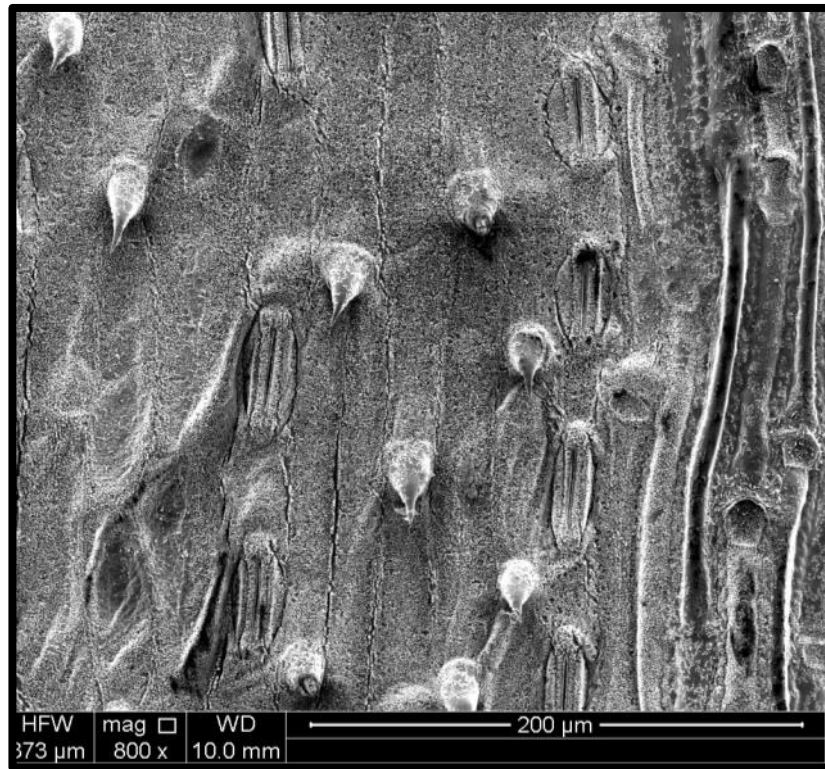


Wheat Leaf Scanning Electron Microscope Images

-leaf side

▶ Upper side

▶ Lower side

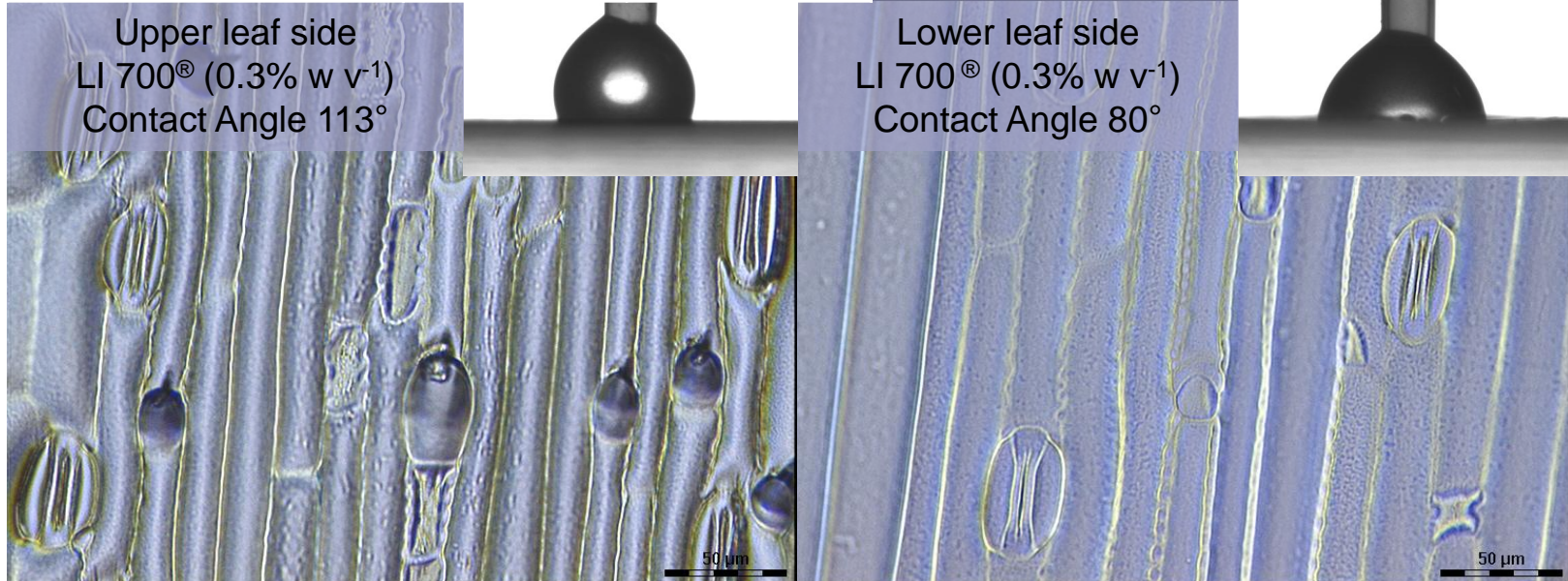


▶ 800x magnification: fresh leaves sampled at 44DAS

Wheat Leaf Morphology – Leaf Side

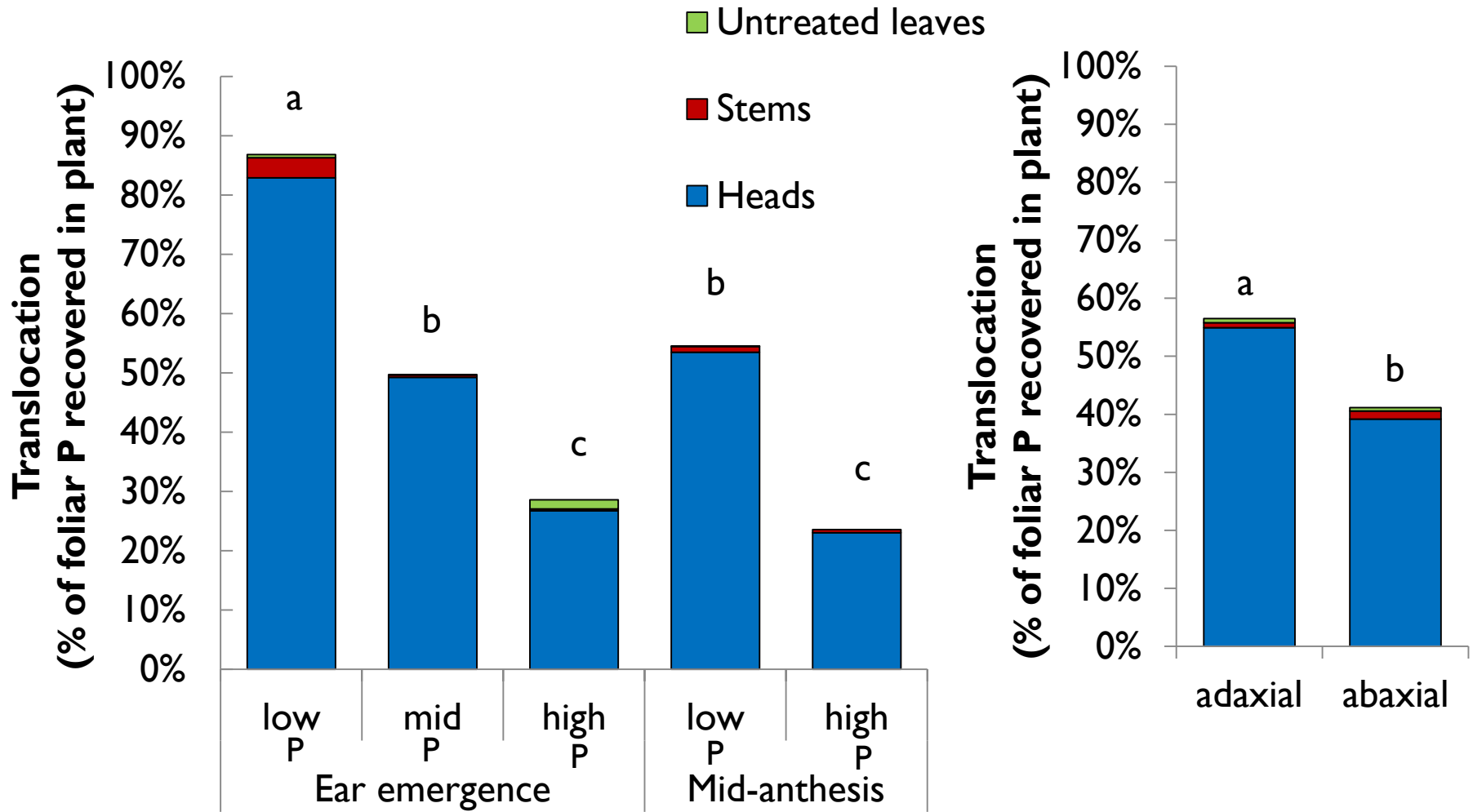
| | Upper leaf side | Lower leaf side |
|----------------------------|-----------------|-----------------|
| Stomata mm ⁻² | 51 ± 6 a | 39 ± 4 b |
| Trichomes mm ⁻² | 45 ± 22 a | 5 ± 4 b |

Trichomes increase surface roughness and decrease leaf wettability



LSD (P ≤ 0.05) side effect: stomata 2, trichomes 6

Foliar P Translocation to Plant Parts – Leaf Side



Effect on P Nutrition on Leaf Surface Properties

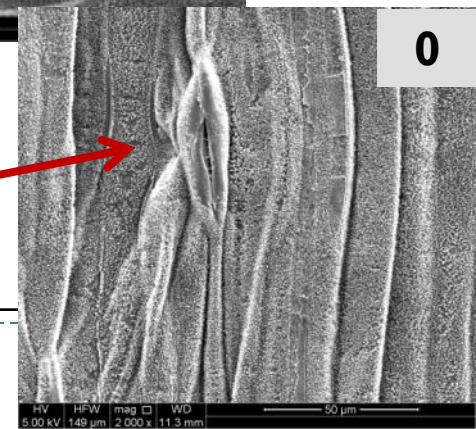
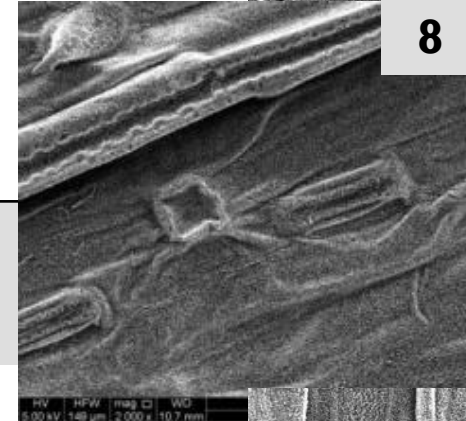
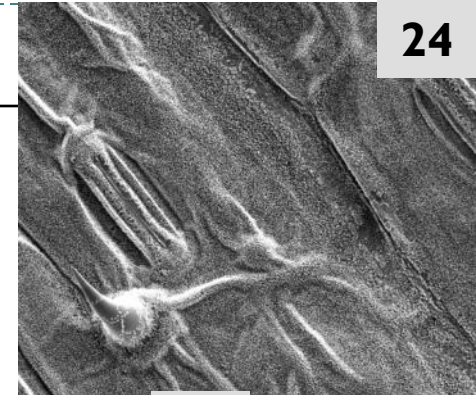
| P treatment (kg P/ha) | Stomata /mm ² | | Trichome /mm ² | | Contact angle of water(°) | |
|--------------------------|-----------------------------|-----------------|------------------------------|----------------|------------------------------|--------------------|
| | Upper | Lower | Upper | Lower | Upper | Lower |
| 24 | 77 ^c | 59 ^c | 59 ^c | 7 ^c | 143.2 ^b | 117.7 ^a |
| 8 | 55 ^b | 39 ^b | 41 ^b | 3 ^b | 139.3 ^{ab} | 112.8 ^a |
| 0 | 36 ^a | 29 ^a | 5 ^a | 0 ^a | 123.2 ^a | 103.2 ^a |

P deficiency decreases the leaf surface hydrophobicity

- ▶ Fernández et al. (2014) “Effect of wheat phosphorus status on leaf surface properties and permeability to foliar-applied phosphorus” Plant and Soil (*in press*)

Effect on P Nutrition on Foliar P Absorption

| P treatment (kg P/ha) | Radioactivity recovered | |
|--------------------------|-------------------------|---|
| | Foliar P Absorption (%) | Foliar P translocated from treated leaf (%) |
| 24 | 33 ^a | 34 ^a |
| 8 | 20 ^b | 35 ^a |
| 0 | 0 ^c | 0 ^b |



Summary of Previous Experiments

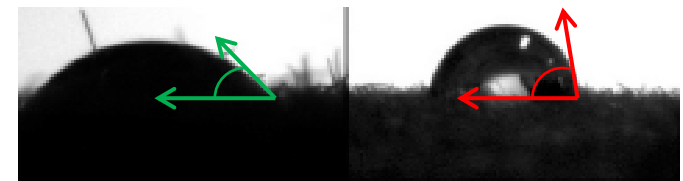
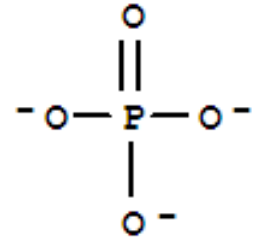
- ▶ Different surface morphology between leaf sides
 - ▶ Upper leaf side less wettable than lower leaf side
 - ▶ Higher foliar uptake from adaxial leaf side
 - ▶ Implication for crops with horizontal leaf orientation

- ▶ P Nutrition affects morphology and wettability of leaves
 - ▶ Deficient leaves have less trichomes and stomata
 - ▶ Severely deficient leaves are unable to take up foliar-applied P



Plant x Formulation Mechanism

- ▶ Foliar P in the form of orthophosphate
 - ▶ Charged anion but leaf surface hydrophobic
 - ▶ Phosphoric acid more penetrative than ammonium phosphates
- ▶ Use of adjuvants
 - ▶ Surfactants to increase retention on leaves (spreading and lowering contact angles)
 - ▶ Humectants to keep nutrients in solution longer



Experiment Protocol – Adjuvant Effect

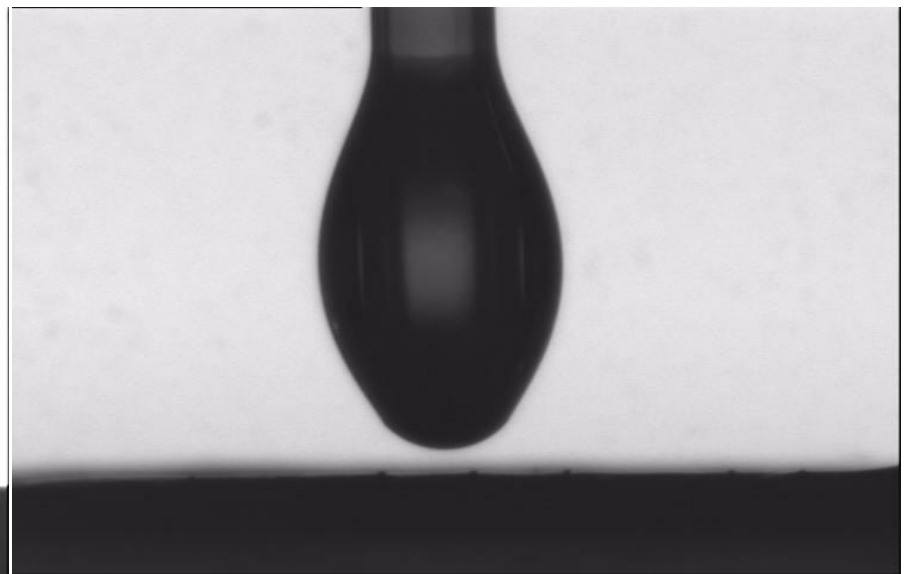
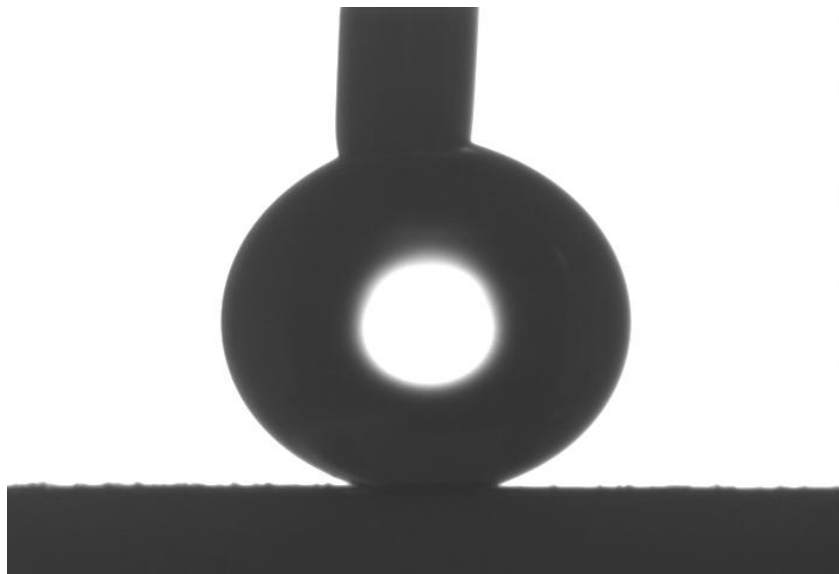
- ▶ Contact angle measurements of water and fertilizers on wheat leaves
 - ▶ GS early booting to early ear emergence
 - ▶ Concentrations ranging from 0.01 – 0.3 % w v⁻¹
 - ▶ Adjuvants:
 - ▶ Agral[®] (Active ingredient: 63% nonyl phenol ethylene oxide condensate)
 - ▶ LI 700[®] (Active ingredients: 35% w v⁻¹ soyal phospholipids, 35% w v⁻¹ propionic acid)
 - ▶ Genapol[®] X-080 (Polyethylene glycol monoalkyl ether)
- ▶ Short-term foliar uptake of phosphoric acid + adjuvant
 - ▶ 1.85 % P w v⁻¹ applied at mid-late booting
 - ▶ ³³P tracer added to fertilizers
 - ▶ Harvested 7 days after application



Static Contact Angles – Adjuvant Effect

| Water | Contact Angle (°) |
|-----------|-------------------|
| Advancing | 159 ± 6 |
| Receding | 149 ± 10 |

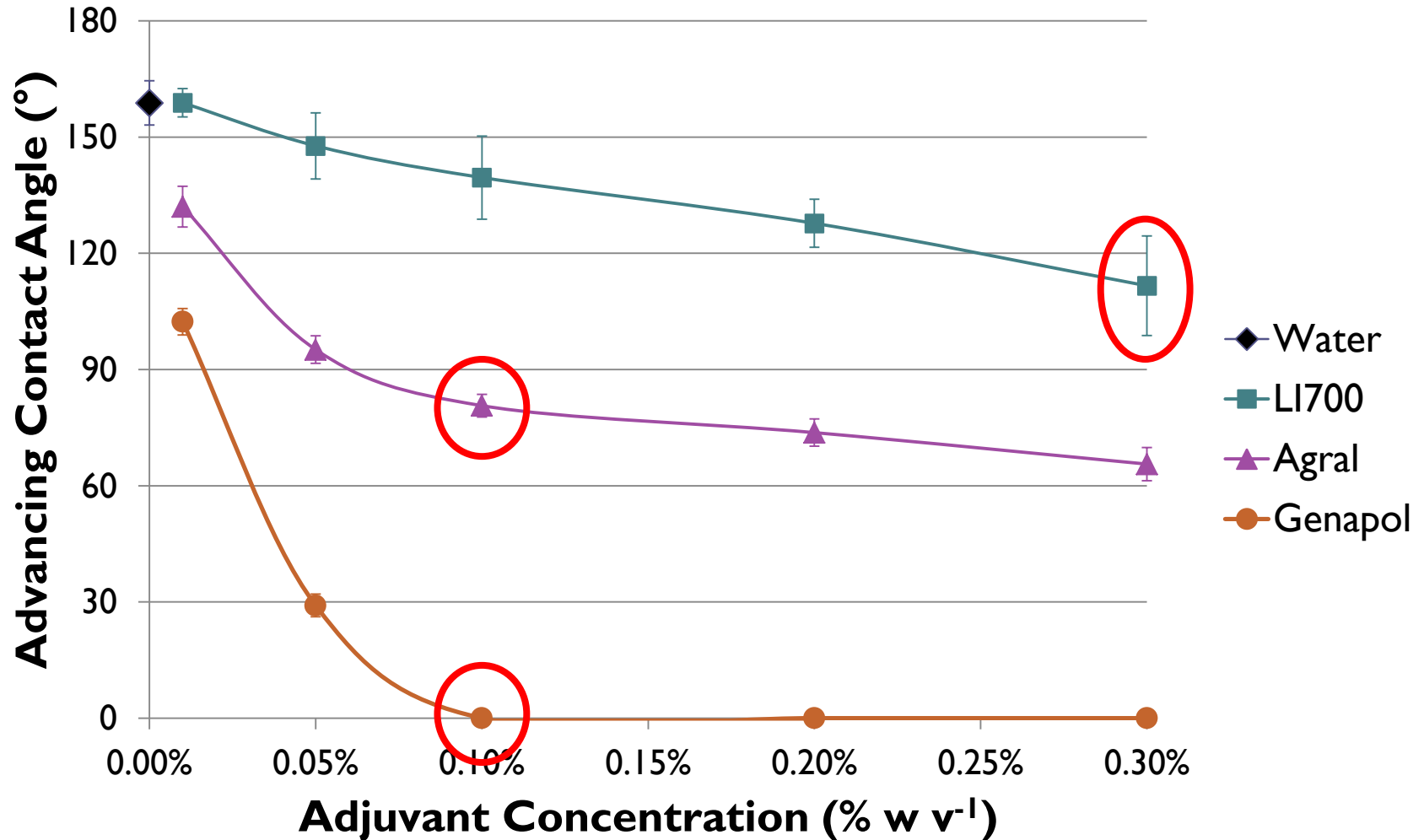
Wheat leaf surface is superhydrophobic due to high advancing contact angle and small hysteresis



▶ Advancing contact angle of water

Genapol® X-080 at 0.05 % w v⁻¹

Adjuvant Effect on Leaf Wettability



Short-term Uptake of Foliar P

-with Adjuvants

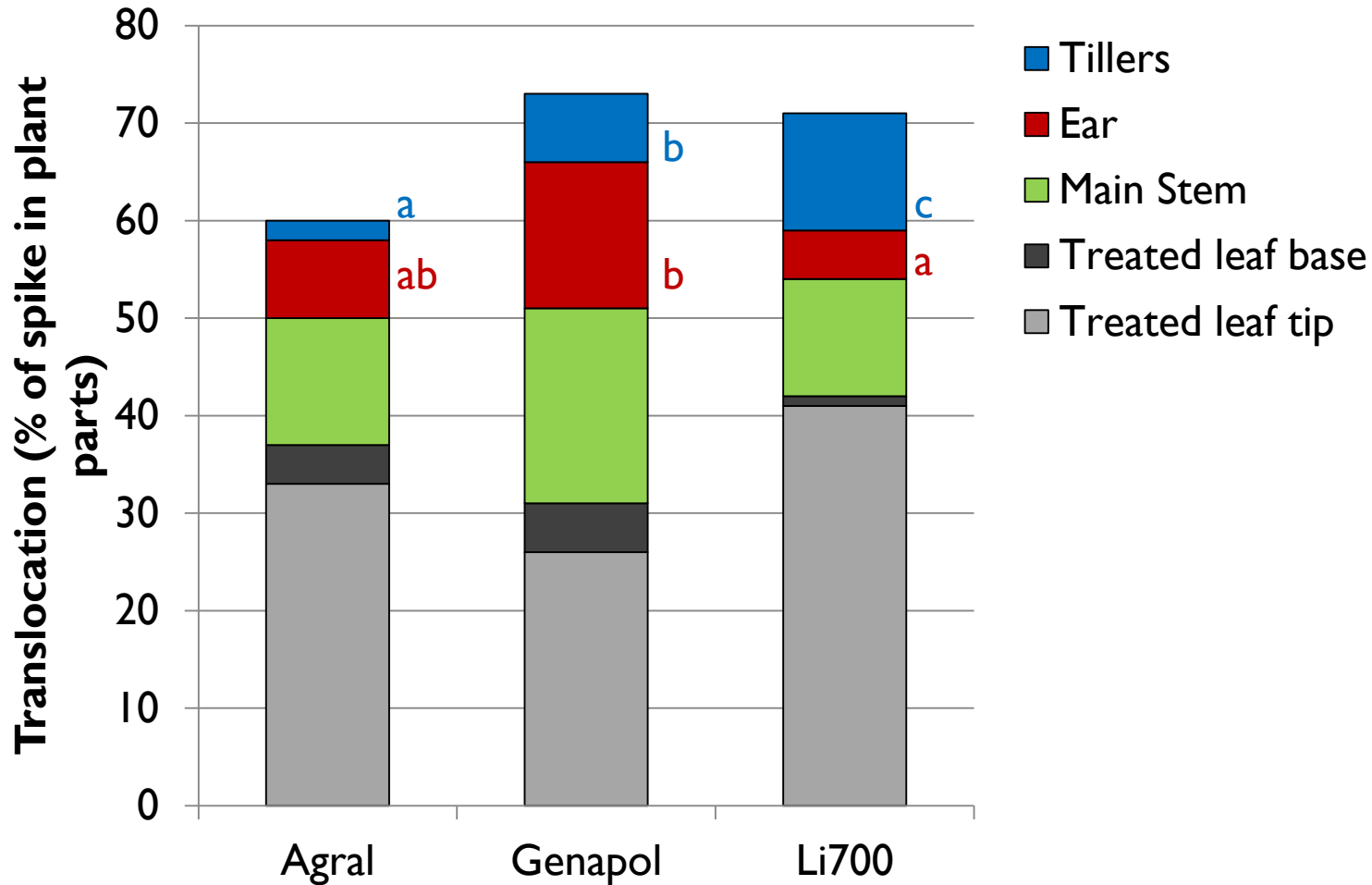
- ▶ 94% of foliar applied P absorbed by the leaves for all treatments
 - ▶ 3% washed off the leaves
 - ▶ <3% not recovered
- ▶ Plant separated into parts after washing to measure translocation from treated area
 - ▶ Treated leaf tip and base
 - ▶ Ear (from main stem)
 - ▶ The rest of the main stem
 - ▶ Tillers



Treated leaf

Short-term Translocation of Foliar P

-with Adjuvants



Summary– Effect of Adjuvant

- ▶ Wheat leaves are superhydrophobic
- ▶ Contact angle of fertilizers vary with different adjuvants
- ▶ Short-term uptake of P does not vary for adjuvants with different contact angles



Practical Implications

- ▶ Without use of adjuvants, wheat leaves are very difficult to wet resulting in loss of foliar fertilizer to soil
- ▶ The foliar uptake of P is high regardless of the adjuvant used
- ▶ The effect of time-to-drying vs. leaf coverage by fertilizer should be further investigated
 - ▶ Possible trade-off helps explain the results from this study



Any Questions?

► Acknowledgements

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