Leaf Wetting and Uptake of Fluid Foliar P Fertilizers for Wheat

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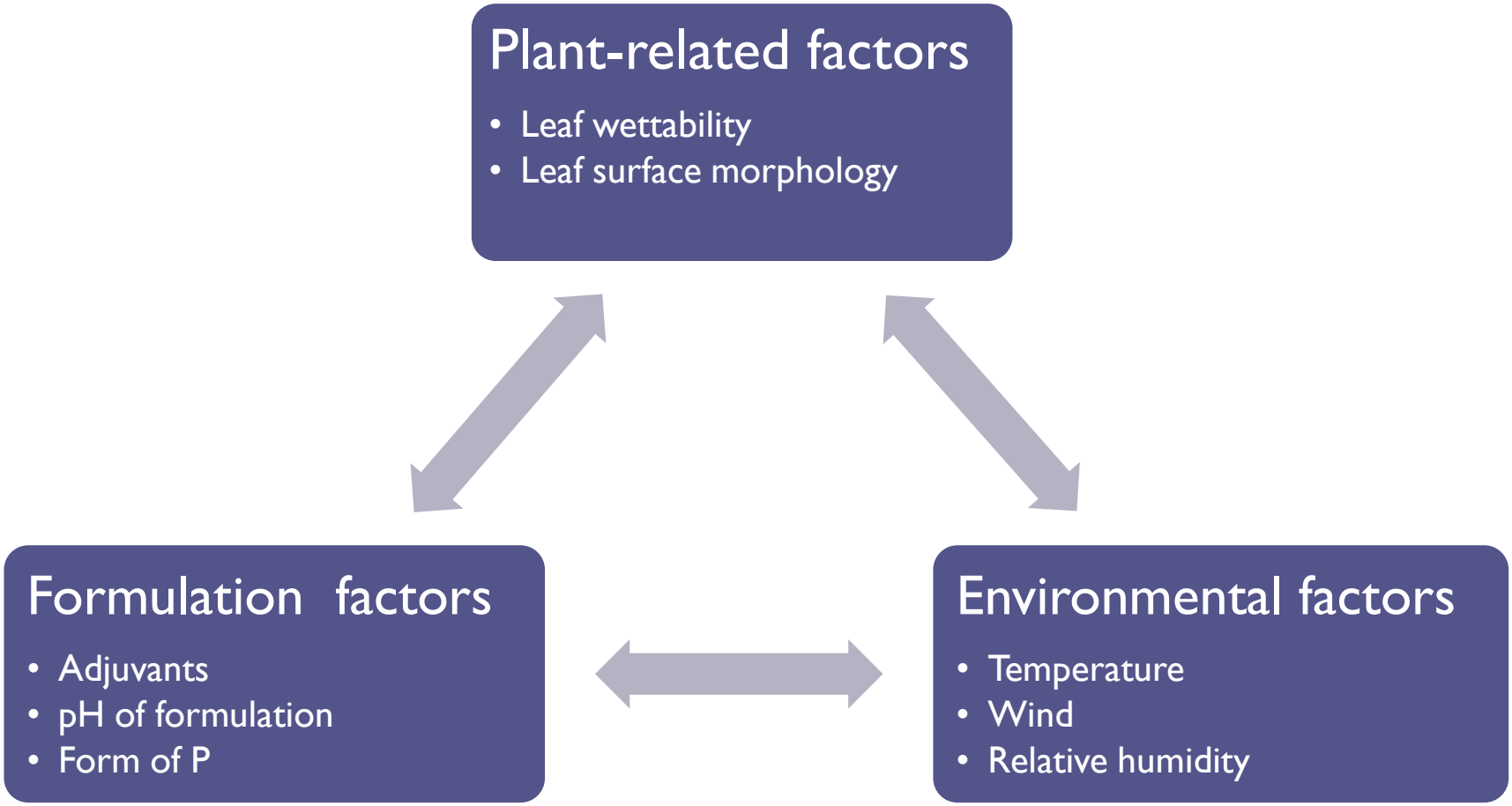
Tactical Foliar P Fertilization

- 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

- 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

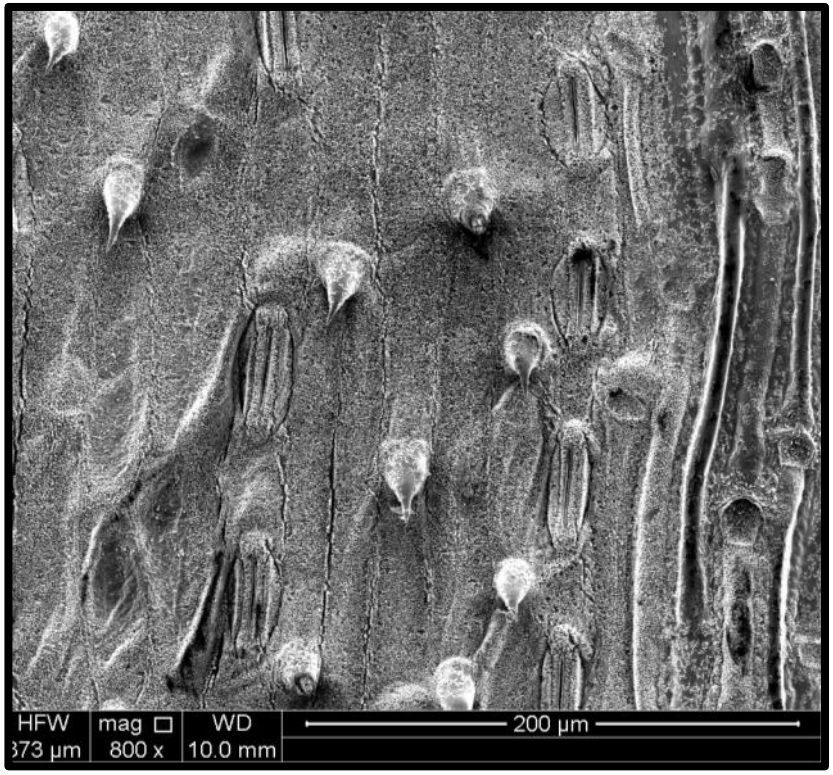
Foliar P Uptake Methods - Leaf Side

- 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

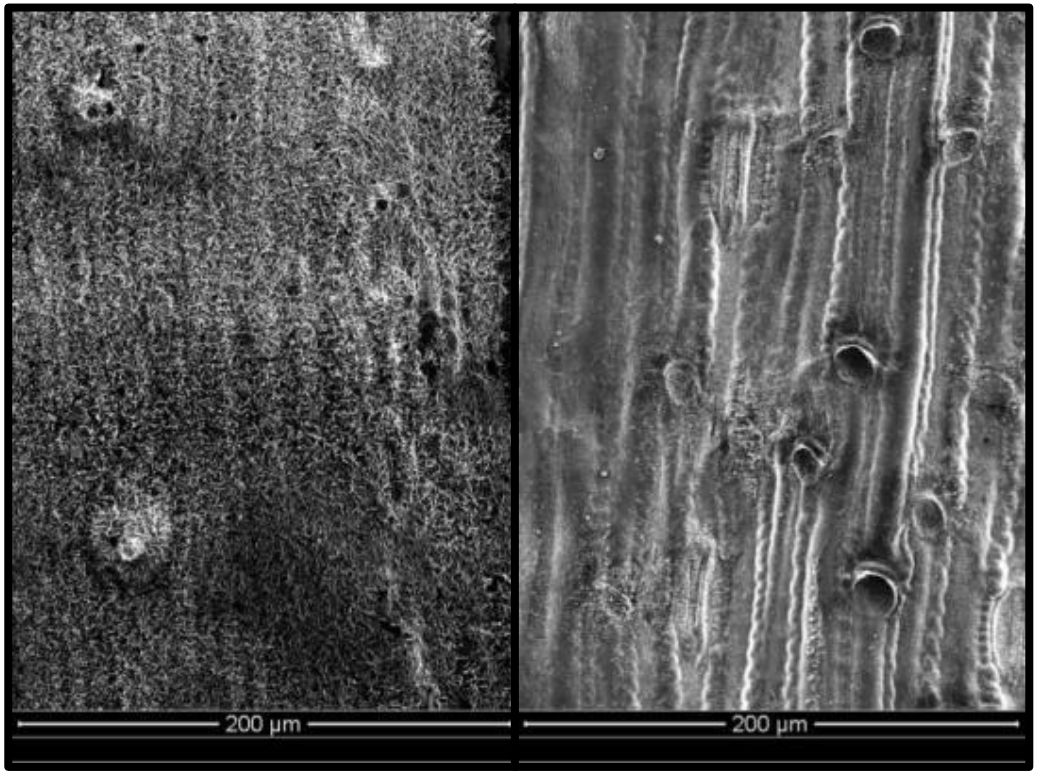
Wheat Leaf Scanning Electron Microscope Images

-leaf side

- Upper side



- Lower side

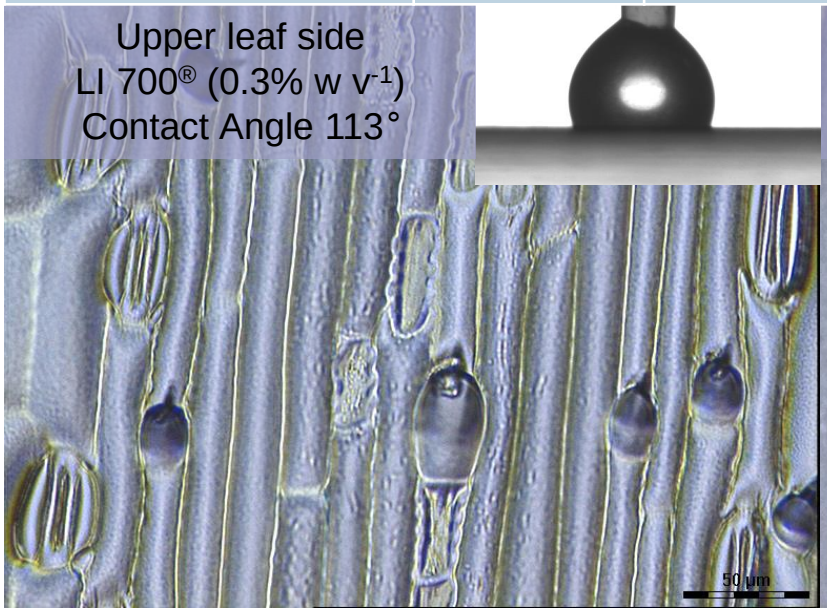


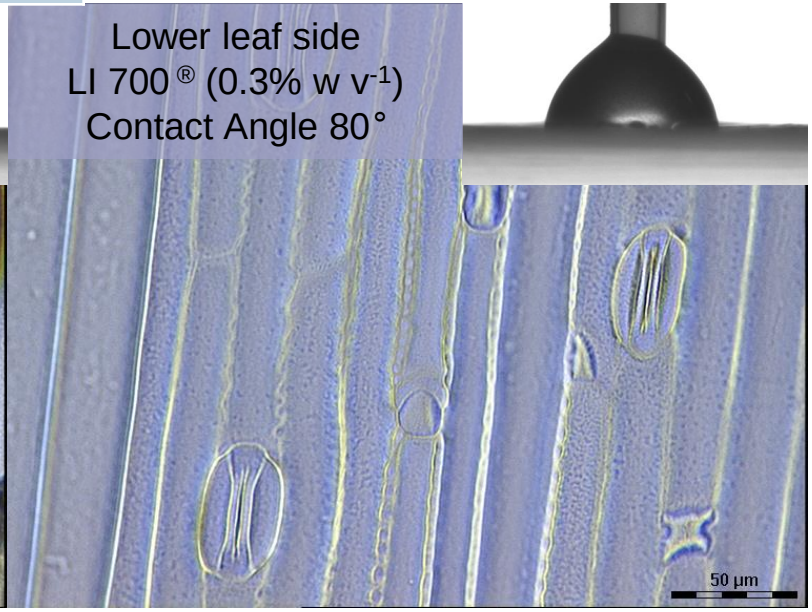
- 800x magnification: fresh leaves sampled at 44DAS

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

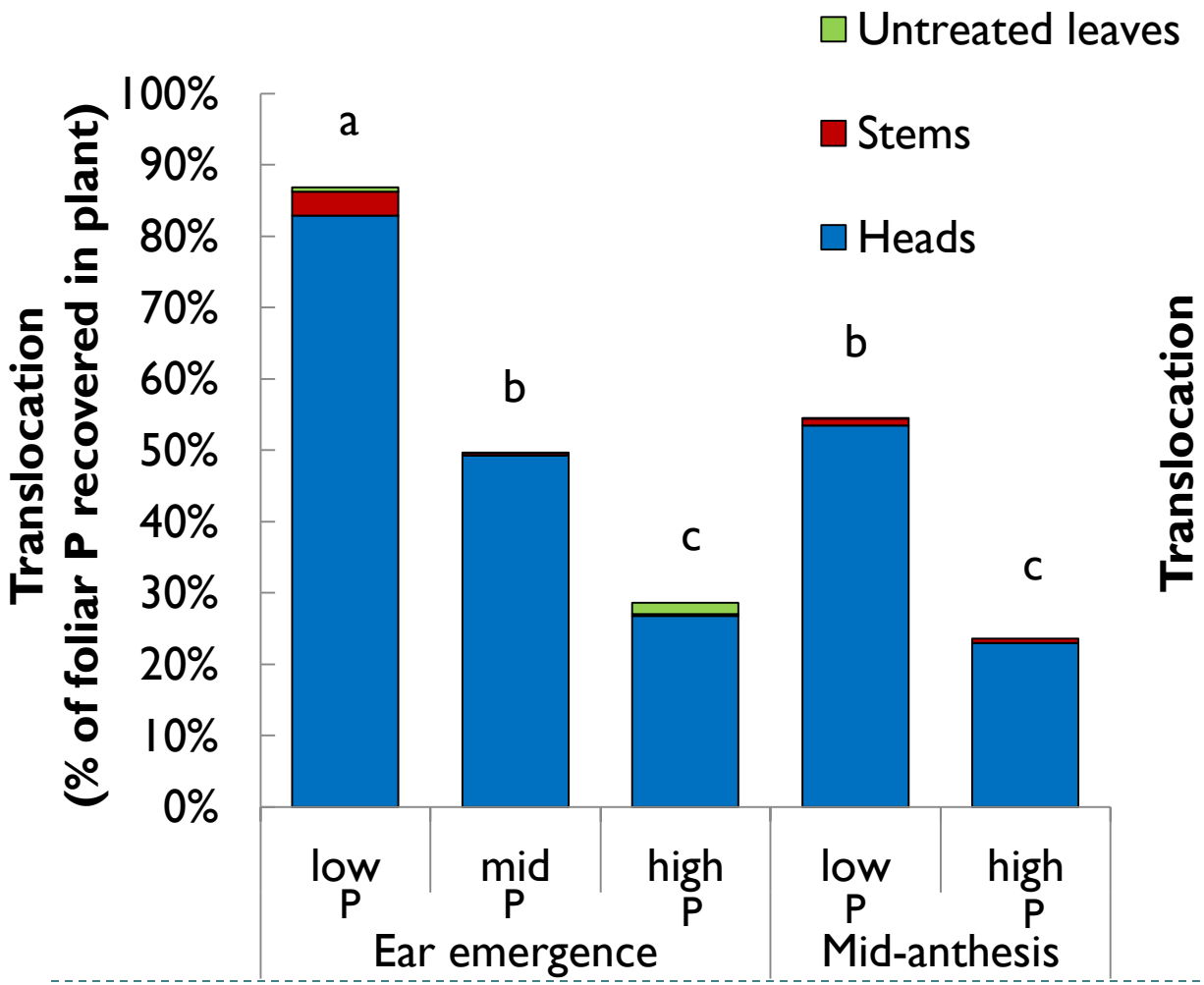
Trichomes increase surface roughness and **decrease leaf wettability**

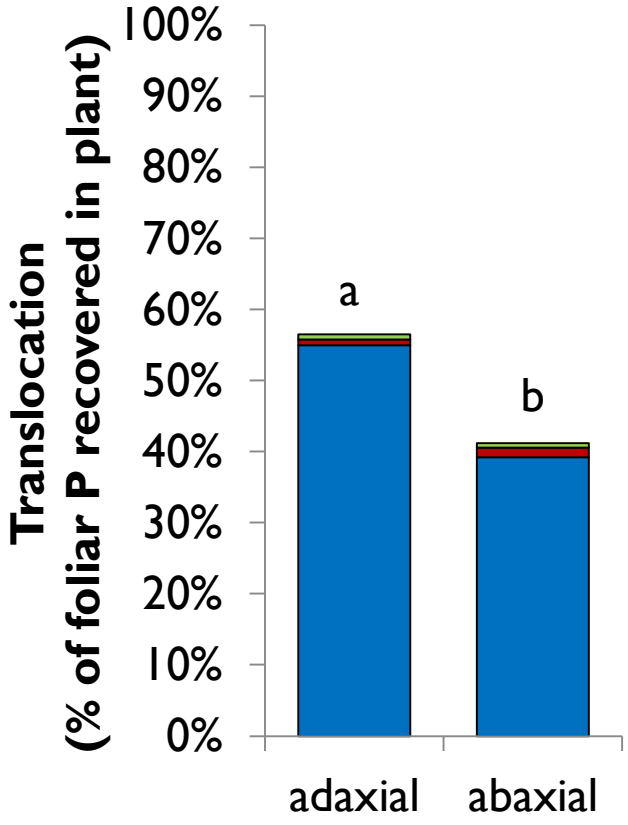




LSD (P ≤0.05) side effect: stomata 2, trichomes 6

Foliar P Translocation to Plant Parts – Leaf Side





Effect on P Nutrition on Leaf Surface Properties

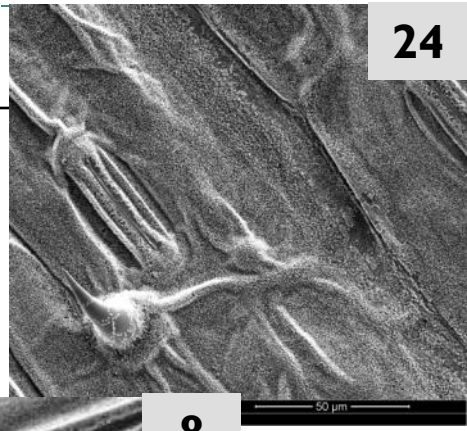
P treatment (kg P/ha)	Stomata /mm²		Trichome /mm²		Contact angle of water(°)	
	Upper	Lower	Upper	Lower	Upper	Lower
24	77^{c}	59^{c}	59^{c}	7^{c}	143.2^{b}	117.7^{a}
8	55^{b}	39^{b}	41^{b}	3^{b}	139.3^{ab}	112.8^{a}
0	36^{a}	29^{a}	5^{a}	0^{a}	123.2^{a}	103.2^{a}

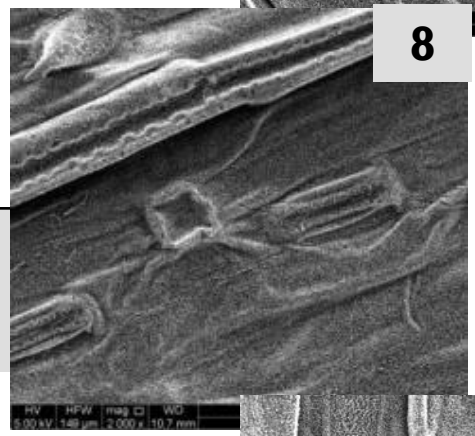
P deficiency **decreases** the leaf surface hydrophobicity

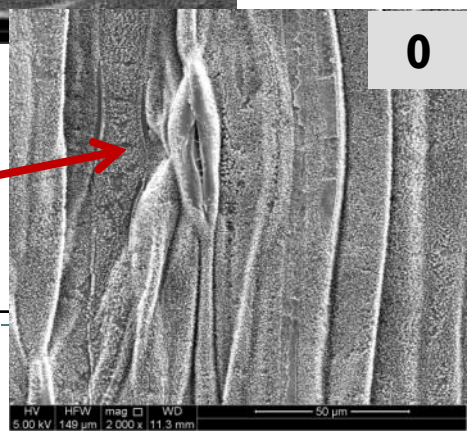
- Fernández et al. (2014) "Effect of wheat phosphorus status on leaf surface properties and permeability to foliar-applied phosphorus" Plant and Soil (*in press*)

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]





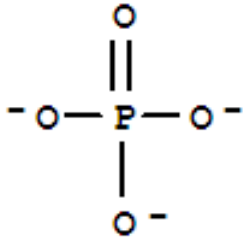


Summary of Previous Experiments

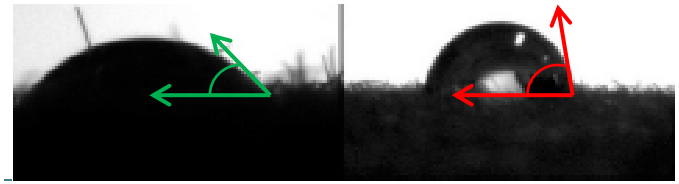
- Different surface morphology between leaf sides
  - Upper leaf side less wettable than lower leaf side
  - Higher foliar uptake from adaxial leaf side
  - Implication for crops with horizontal leaf orientation

- 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

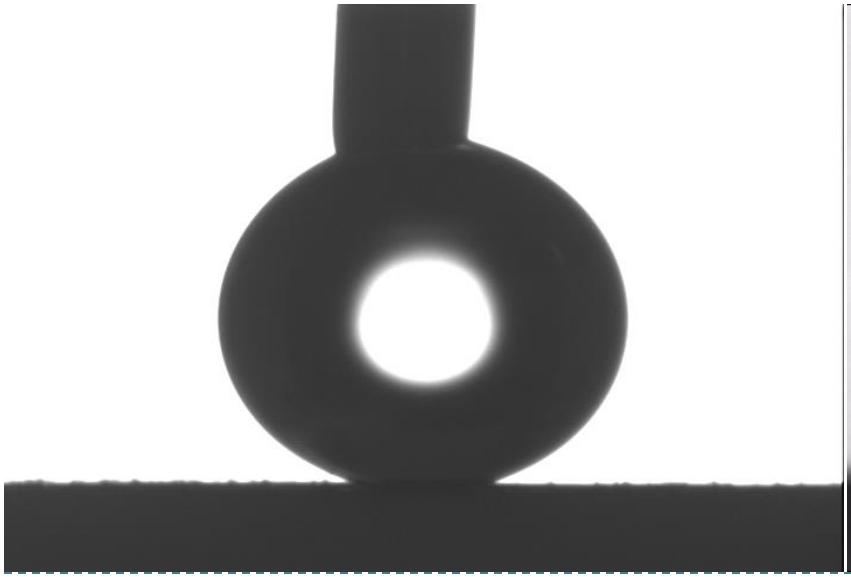
- Contact angle measurements of water and fertilizers on wheat leaves
  - GS early booting to early ear emergence
  - Concentrations ranging from 0.01 – 0.3 % w v^{-1}
  - Adjuvants:
    - Agral® (Active ingredient: 63% nonyl phenol ethylene oxide condensate)
    - LI 700 ® (Active ingredients: 35% w v^{-1} soyal phospholipids, 35% w v^{-1} propionic acid)
    - Genapol ® X-080 (Polyethylene glycol monoalkyl ether)

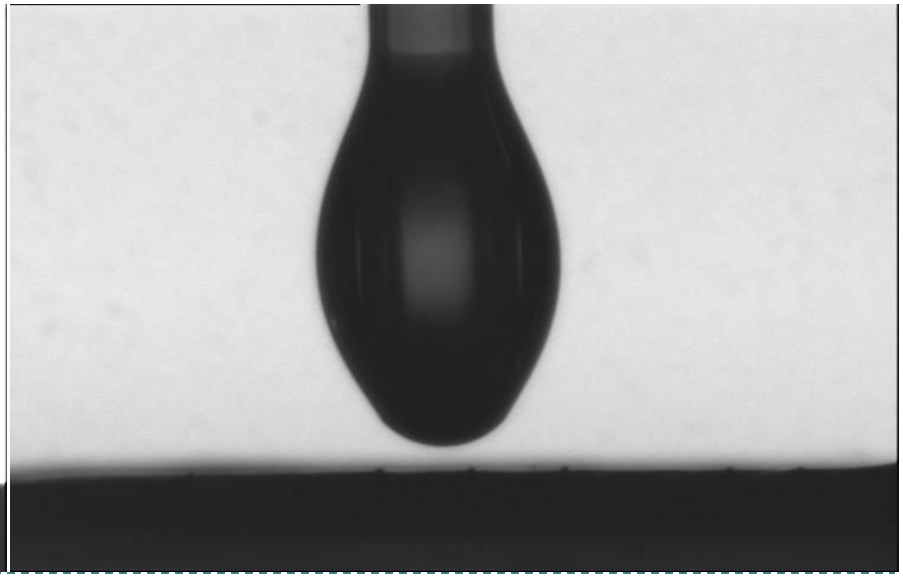
- Short-term foliar uptake of phosphoric acid + adjuvant
  - 1.85 % P w v^{-1} applied at mid-late booting
  - ^{33}P tracer added to fertilizers
  - Harvested 7 days after application

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

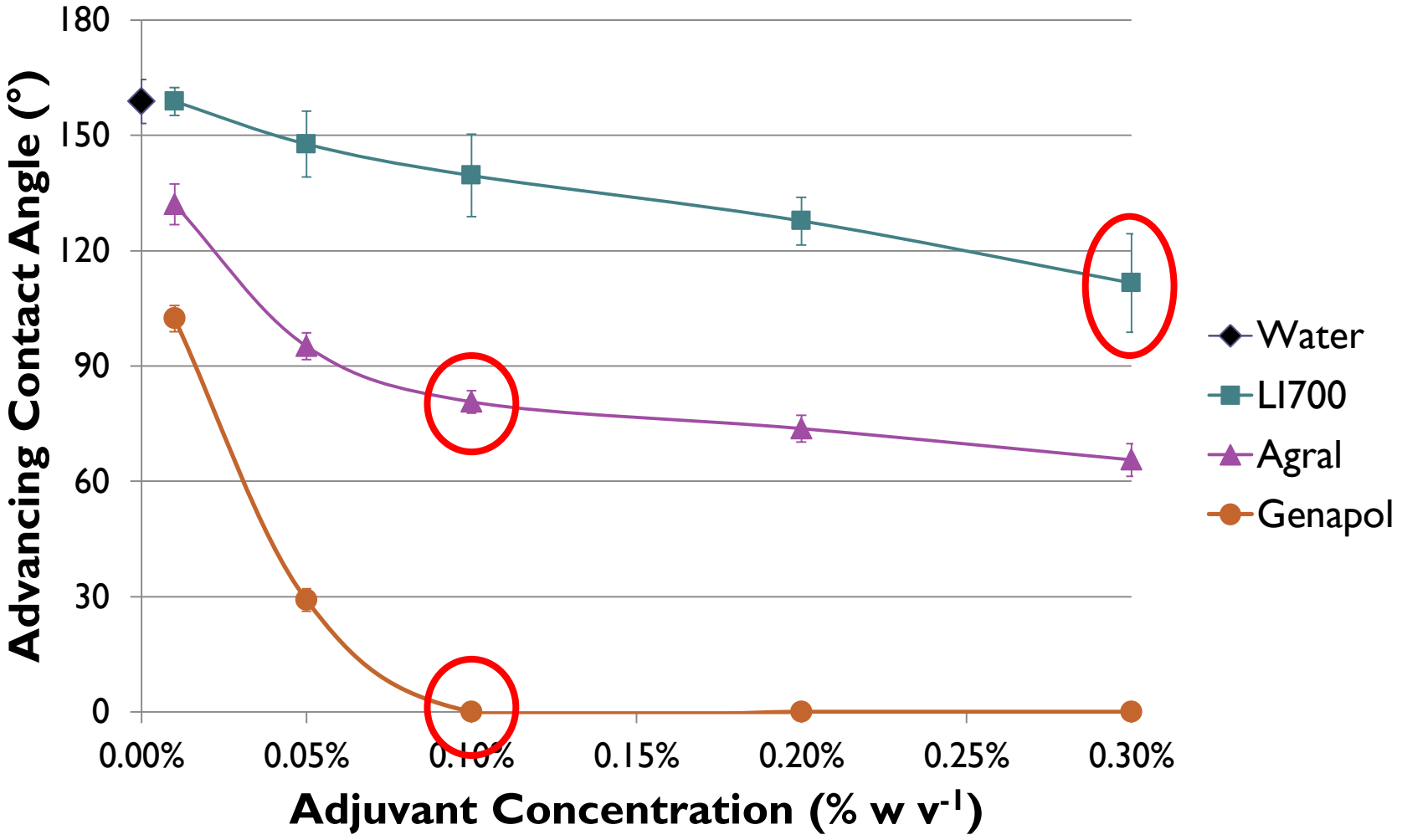




- Advancing contact angle of water

Genapol ® X-080 at 0.05 % w v^{-1}

Adjuvant Effect on Leaf Wettability



Short-term Uptake of Foliar P

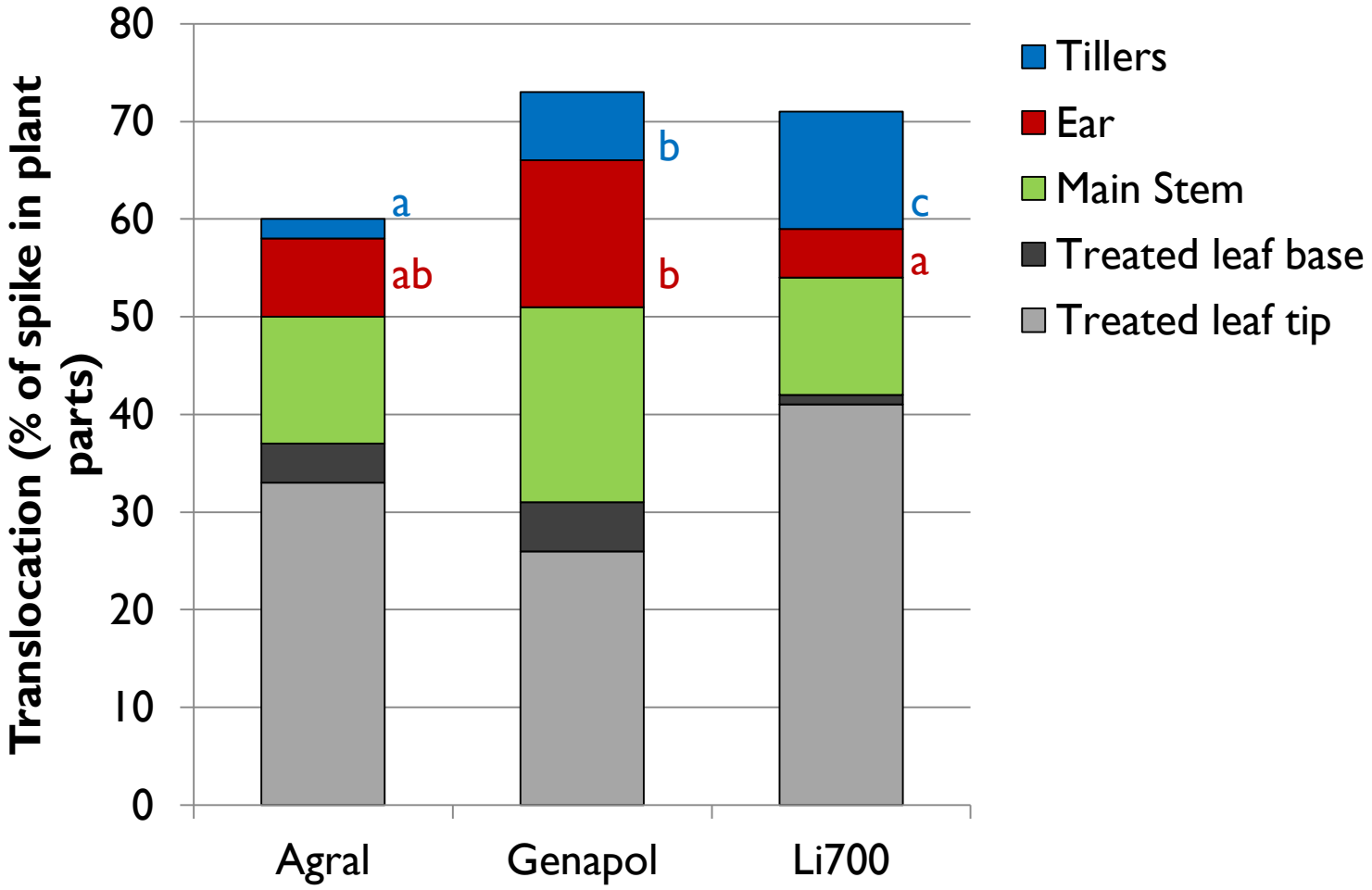
-with Adjuvants

- 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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