Leaf Wetting and Uptake of Fluid Foliar P Fertilizers for Wheat

Courtney Peirce, Craig Priest, Evelina Facelli, Therese McBeath, Victoria Fernández and Mike McLaughlin
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

<table>
<thead>
<tr>
<th></th>
<th>Upper leaf side</th>
<th>Lower leaf side</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stomata mm⁻²</strong></td>
<td>51 ± 6 a</td>
<td>39 ± 4 b</td>
</tr>
<tr>
<td><strong>Trichomes mm⁻²</strong></td>
<td>45 ± 22 a</td>
<td>5 ± 4 b</td>
</tr>
</tbody>
</table>

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

- Untreated leaves
- Stems
- Heads

<table>
<thead>
<tr>
<th>Ear emergence</th>
<th>Mid-anthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>low P</td>
<td>mid P</td>
</tr>
<tr>
<td>high P</td>
<td>low P</td>
</tr>
<tr>
<td>high P</td>
<td>high P</td>
</tr>
</tbody>
</table>

- a
- b
- c

- adaxial
- abaxial
### Effect on P Nutrition on Leaf Surface Properties

<table>
<thead>
<tr>
<th>P treatment (kg P/ha)</th>
<th>Stomata/mm²</th>
<th>Trichome/mm²</th>
<th>Contact angle of water (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>24</td>
<td>77&lt;sup&gt;c&lt;/sup&gt;</td>
<td>59&lt;sup&gt;c&lt;/sup&gt;</td>
<td>59&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>8</td>
<td>55&lt;sup&gt;b&lt;/sup&gt;</td>
<td>39&lt;sup&gt;b&lt;/sup&gt;</td>
<td>41&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>0</td>
<td>36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>P treatment (kg P/ha)</th>
<th>Radioactivity recovered</th>
<th>Foliar P translocated from treated leaf (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foliar P Absorption (%)</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>8</td>
<td>20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0</td>
<td>0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
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 wettablility 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

<table>
<thead>
<tr>
<th>Water</th>
<th>Contact Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advancing</td>
<td>159 ± 6</td>
</tr>
<tr>
<td>Receding</td>
<td>149 ± 10</td>
</tr>
</tbody>
</table>

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

Advaning Contact Angle (°)

Adjuvant Concentration (% w v⁻¹)

- Water
- LI700
- Agral
- Genapol
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
Short-term Translocation of Foliar P
-with Adjuvants

Translocation (% of spike in plant parts)

Agral | Genapol | Li700

- Tillers
- Ear
- Main Stem
- Treated leaf base
- Treated leaf tip

Legend:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Tillers</th>
<th>Ear</th>
<th>Main Stem</th>
<th>Treated leaf base</th>
<th>Treated leaf tip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agral</td>
<td>a</td>
<td>ab</td>
<td>b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genapol</td>
<td>b</td>
<td></td>
<td>c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Li700</td>
<td>c</td>
<td>a</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
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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