“eyeSpot” – leaf specific herbicide applicator for weed control in field vegetables

Nikolaos Koukiasas and Alistair Murdoch
University of Reading

Co-funders: Douglas Bomford Trust; AHDB Horticulture; Reading University
Collaborators: Concurrent Solutions llc; Knight Farm Machinery Ltd.

16 August 2017

Context of research

- Respond to concerns about the loss of herbicide actives due to legislation
- Meet demand for more environmentally-friendly crop production by:
  - ✓ minimizing herbicide inputs
  - ✓ eliminating drift
  - ✓ reducing the run-off to the soil
  - ✓ reducing residues in the crop

- Overall aim: to develop an autonomous platform (robot) for weed control using targeted droplets

eyeSpot project activities since May 2016

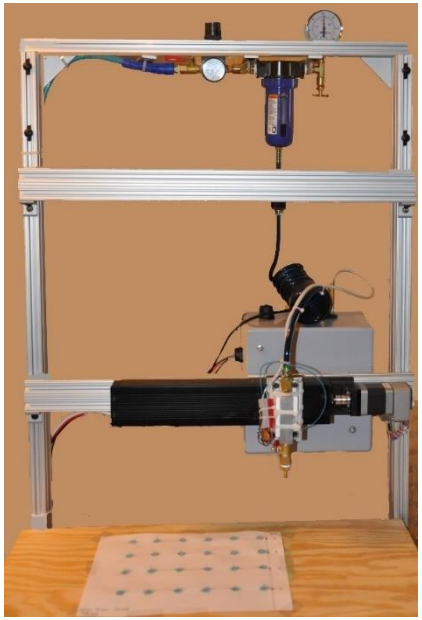
Crop and weed studies in glasshouse and field

- Glasshouse trials: Dose-response studies in the glasshouse with glufosinate-ammonium and glyphosate
  - Extending range of species (*Stellaria media; Amaranthus retroflexus*)
  - Testing glufosinate-ammonium as an alternative to glyphosate (*Urtica urens, Chenopodium album, Amaranthus retroflexus*)
- Field trials to prove the concept that herbicide droplet applications can satisfactorily control weeds in field vegetables
  - Summers 2016 and 2017: Cabbages and leeks (Glyphosate)
  - Summer 2017: Cabbages and Leeks (Glyphosate & Glufosinate-ammonium)

eyeSpot project activities since May 2016

Engineering-related activities

- Herbicide applicator trials: testing accuracy of targetting:
  - Summer 2017 (USA): Moving and static applicator tested at different distances from target, at different pressures and wind speeds
- Image capture to assist in the development of algorithm for weed id:
  - Summers 2016 and 2017: In cabbage and leek crops (UK)
  - Summer 2017: In soyabean (USA)



- Various presentations and media interviews and reports

Dose-response studies for *A. retroflexus*

Glyphosate (Envy Six Max, 697 g/l)

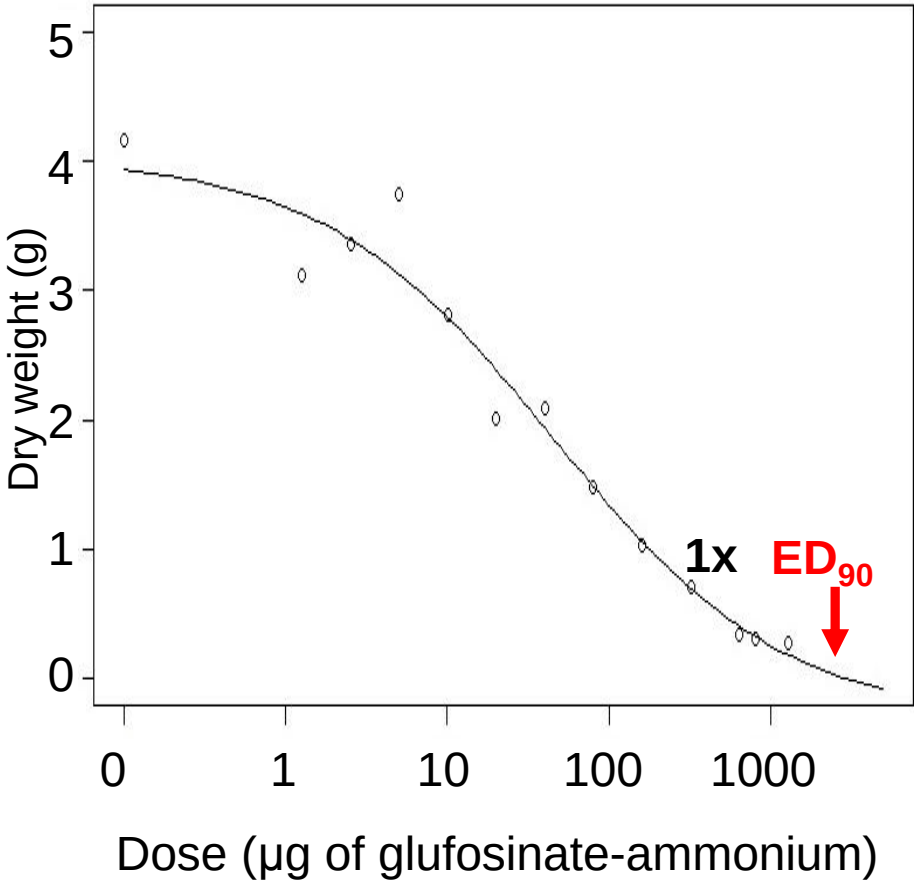
Control 1/256 1/128 1/64 1/32 1/16 1/8 1/4 1/2 1x 2x 4x Gly

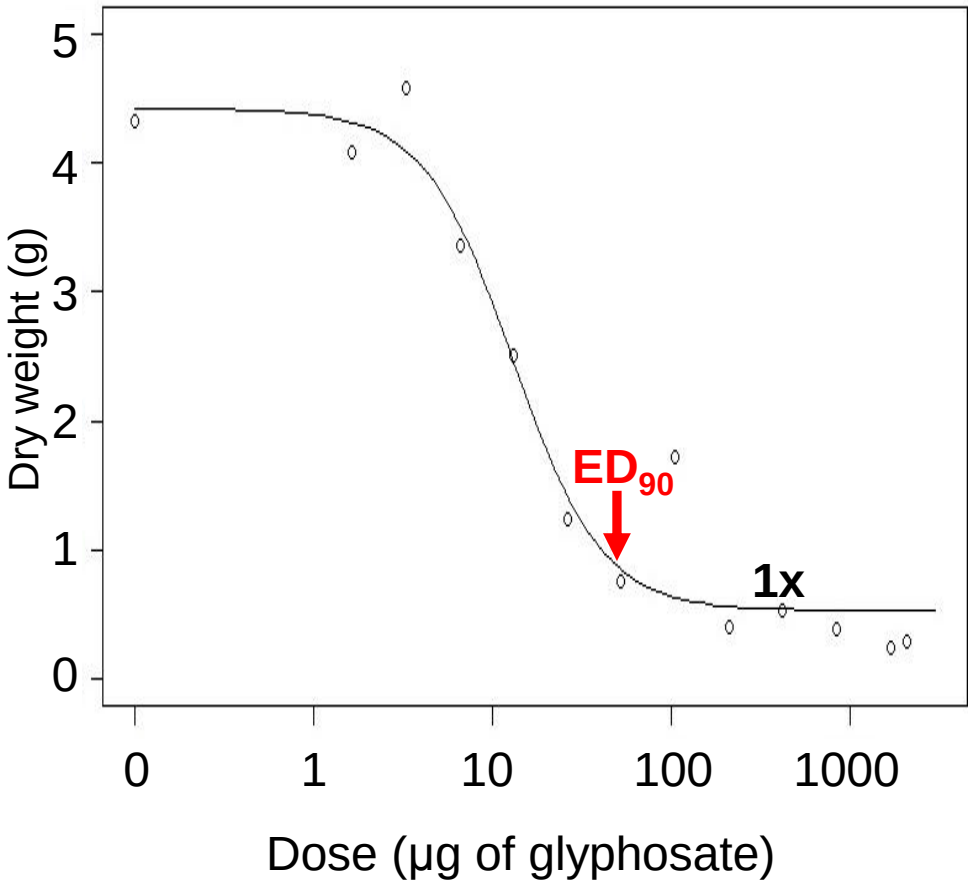
Glufosinate-ammonium (Liberty, 280 g/l)

Control Conadj 1/256 1/128 1/64 1/32 1/16 1/8 1/4 1/2 1x 2x 4x Glu

Dose-response curves

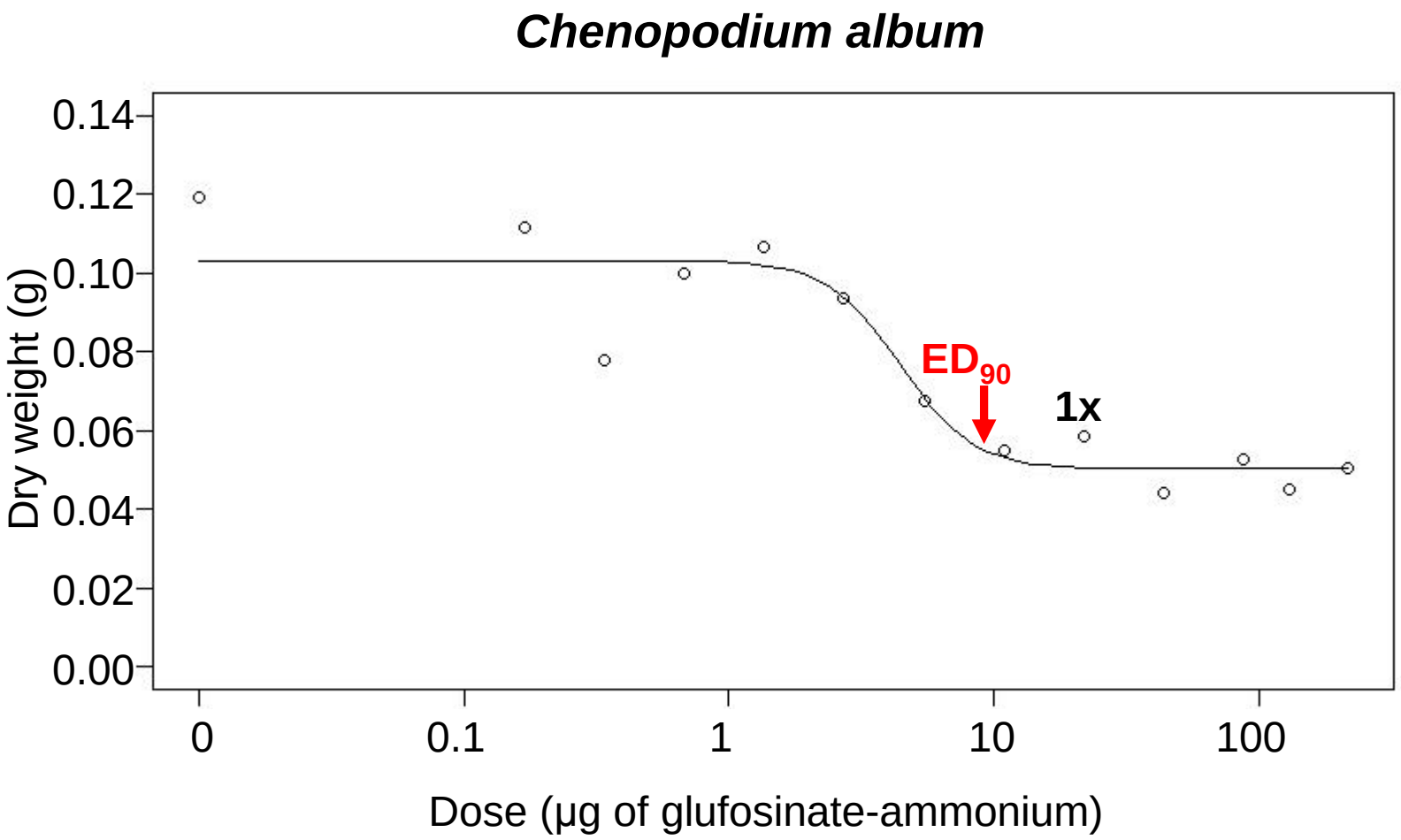
Amaranthus retroflexus





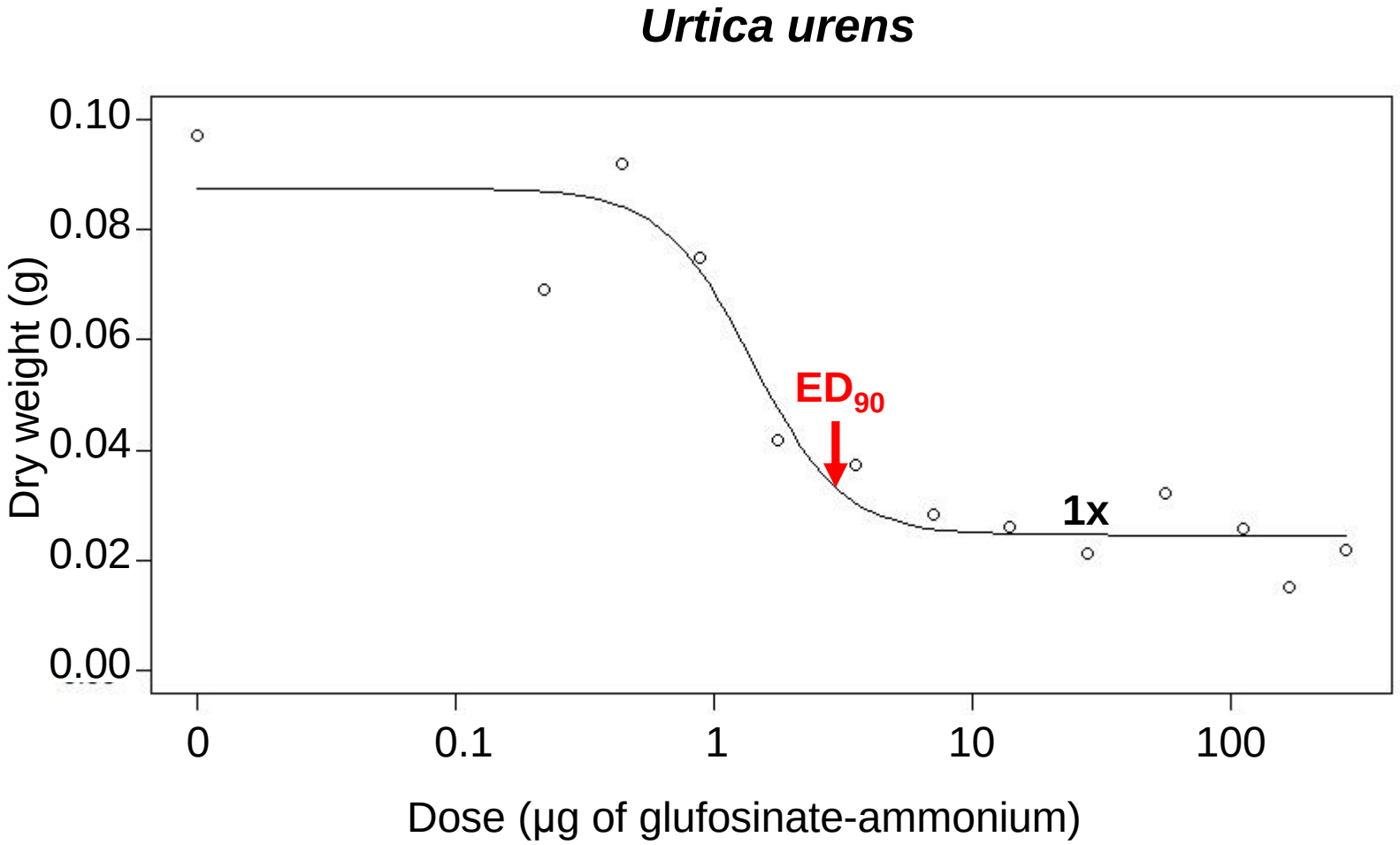
Dose-response curves

- Dose-response studies using droplets of glufosinate-ammonium



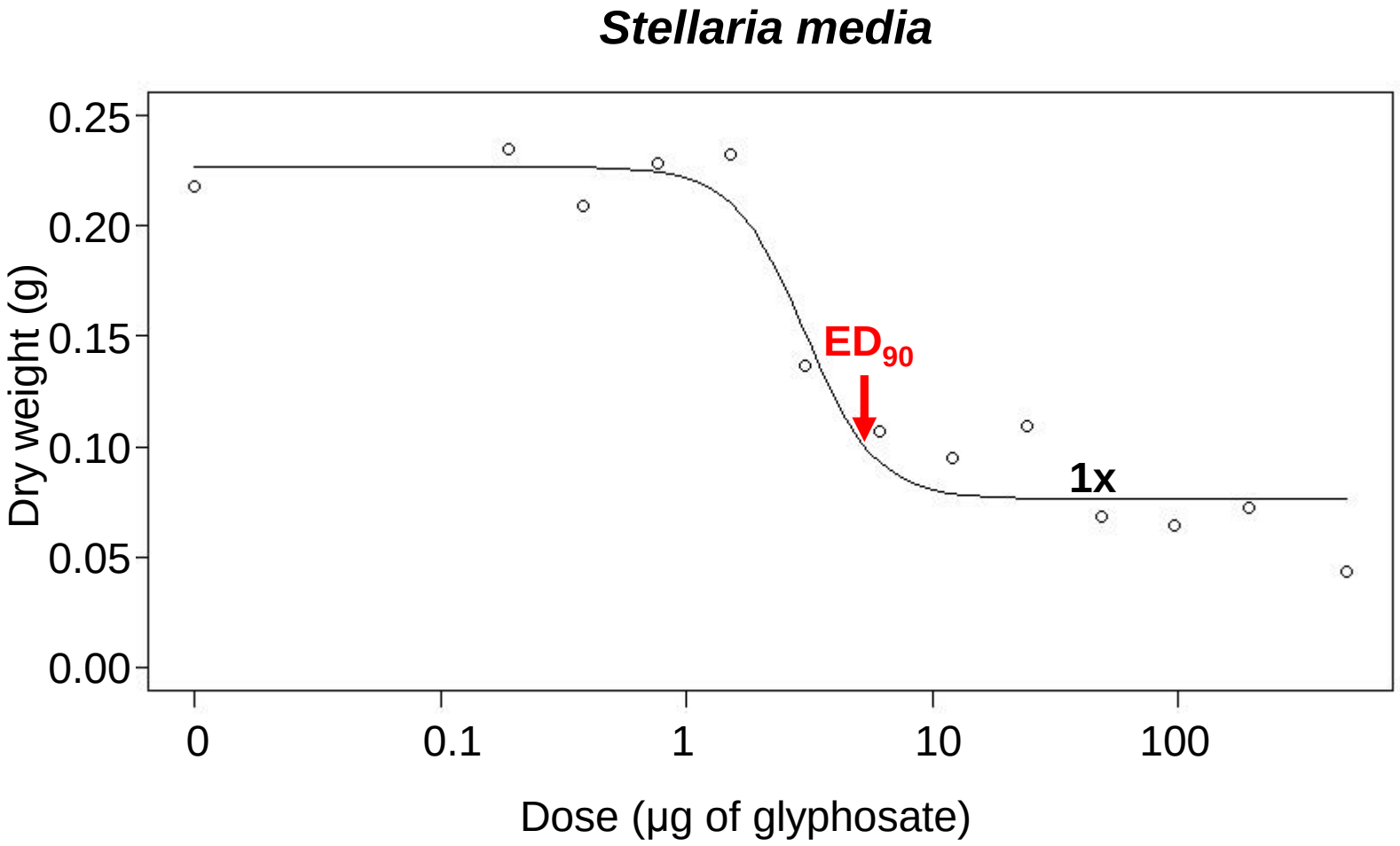
Dose-response curves

- Dose-response studies using droplets of glufosinate-ammonium



Dose-response curves

- Dose-response studies using droplets of glyphosate



Cabbage Field Trial 2016

- Manually-applied droplets of glyphosate were compared with pre-emergence and inter-row spraying

Weedy | **Weed-free** | **Pre-emergence** | **Droplet x3 gly**

Savoy cabbage plots seven weeks after transplanting

Droplet x3: droplets applied 3, 5 and 7 weeks after planting

Cabbage Field Trial 2017

- Manually-applied droplets of glyphosate and glufosinate-ammonium were compared with pre-emergence and post-emergence spraying

Weedy | **Weed-free** | **Pre-emergence** | **Droplet x3 gly**



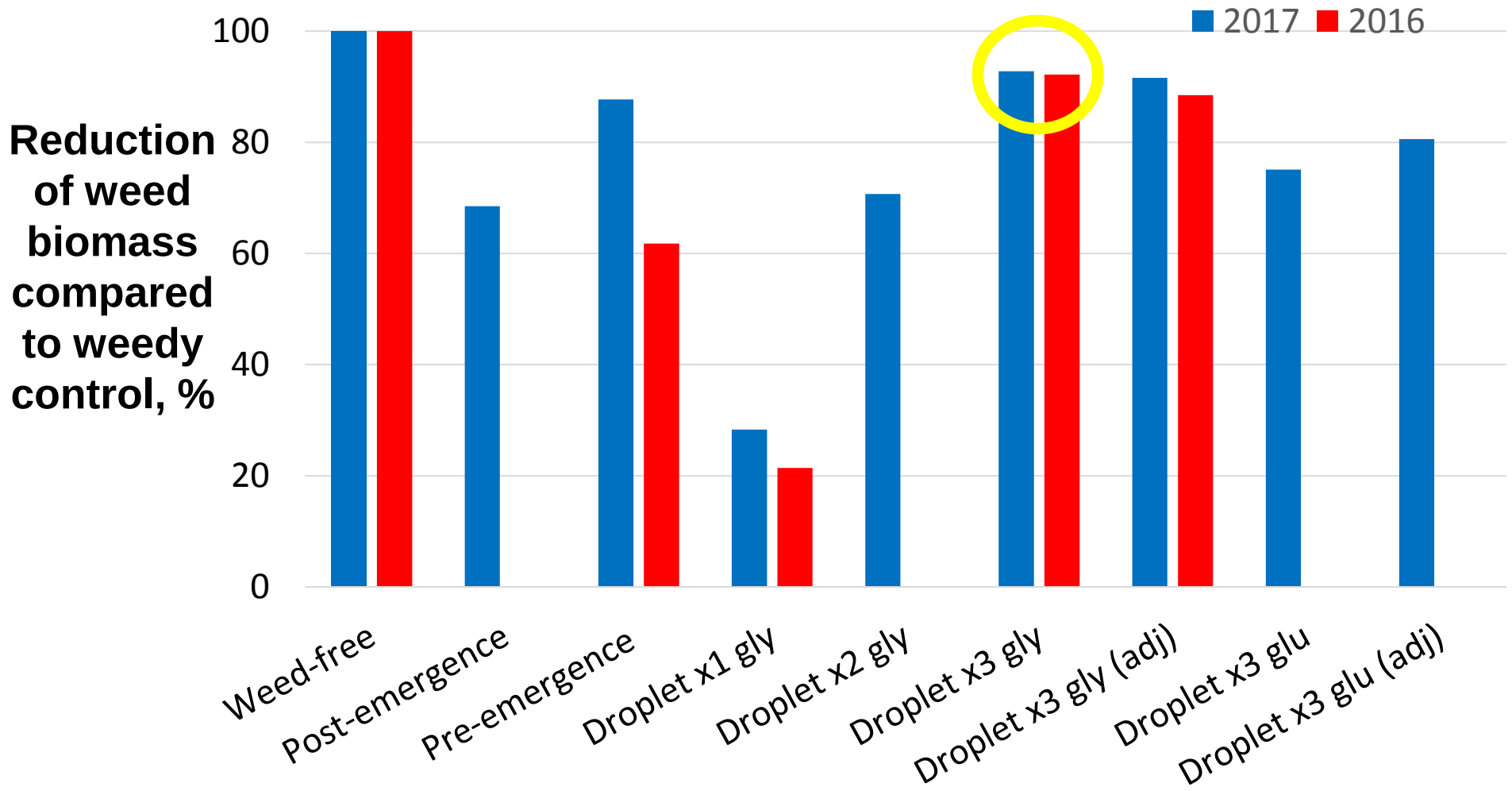

Savoy cabbage plots nine weeks after transplanting

Droplet x3: droplets applied 2, 4 and 5 weeks after planting

Efficacy of weed control for cabbages

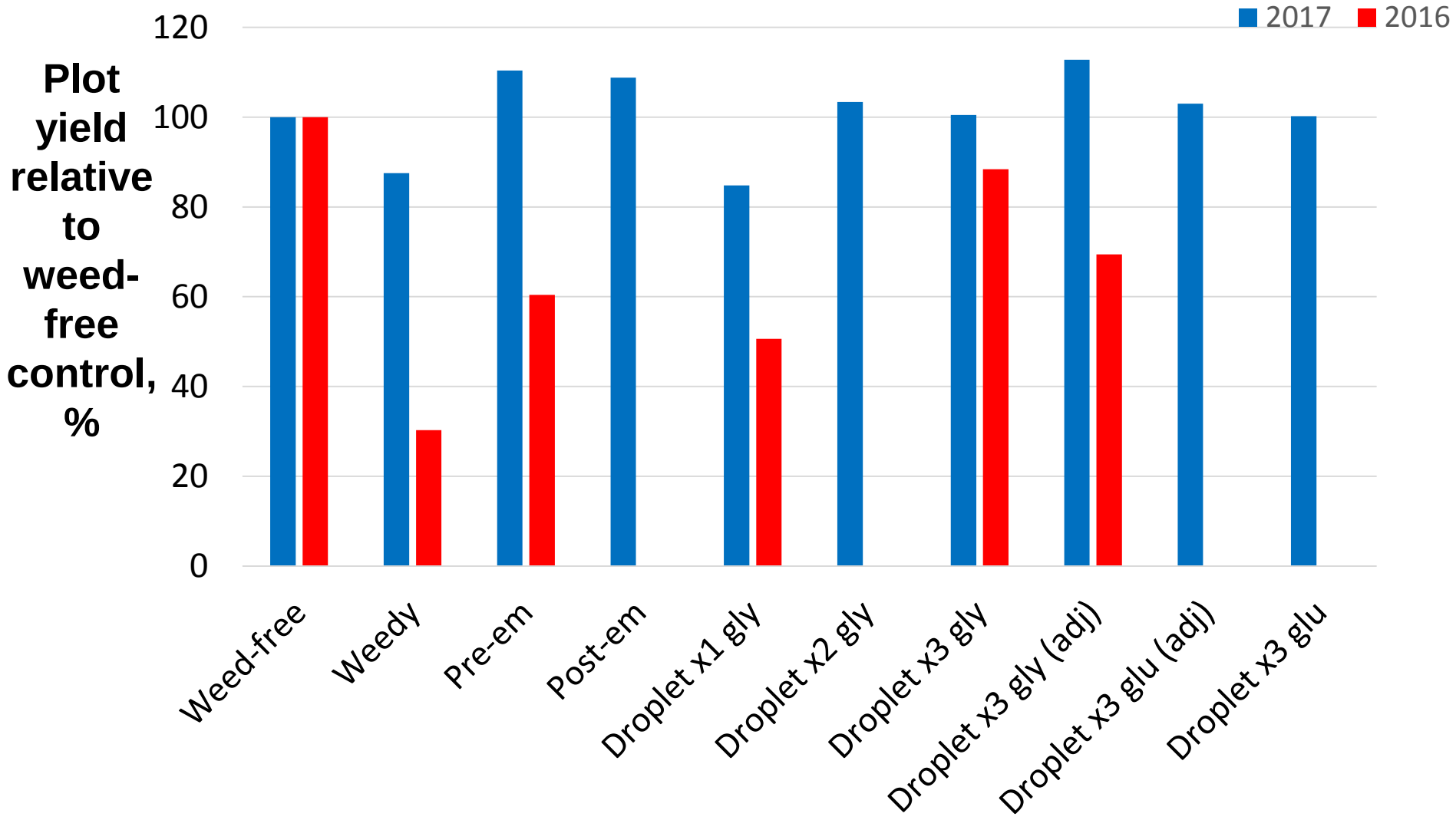
(at crop harvest)

- Droplet x3 (for both years)
  - reduced weed biomass by 92%
  - gave better control than the pre-emergence spray



Crop yield for cabbages

- Yield of Droplet x3 gly (adj) was significantly higher than the Weedy and Droplet x1 gly (2017)
- Yield of Droplet x3 gly did not differ significantly from Weed-free (2016)



Herbicide reductions (%) relative to Pre-emergence* treatment in cabbages

Treatments	2017	2016
Droplet x1 gly	98.8	95.9
Droplet x2 gly	96.9	NA
Droplet x3 gly	96.1	93.7
Droplet x3 gly (adj)	97.9	91.0
Droplet x3 glu	92.1	NA
Droplet x3 glu (adj)	97.0	NA
Post-emergence	43.2	NA

*1319.5 g of pendimethalin / ha

NA: not applicable

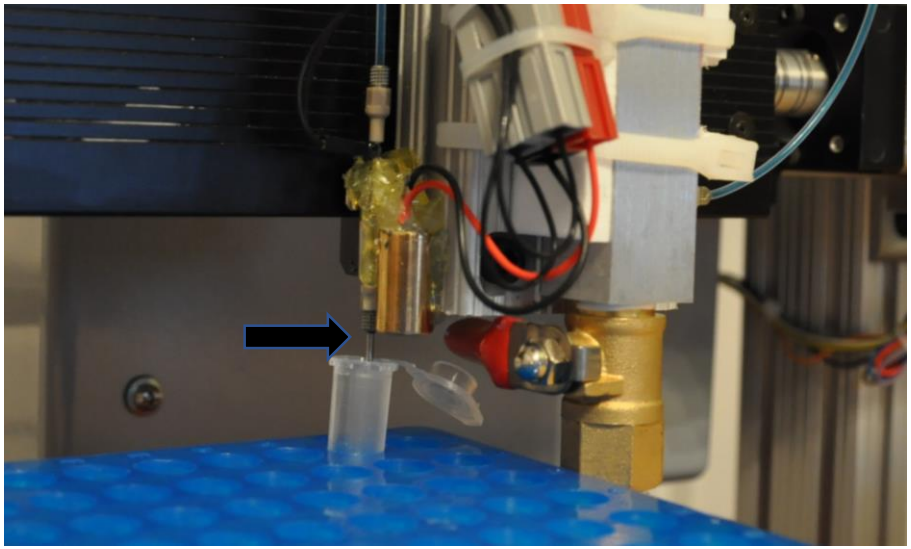
Herbicide applied and reduction (%) relative to conventional spray in leeks

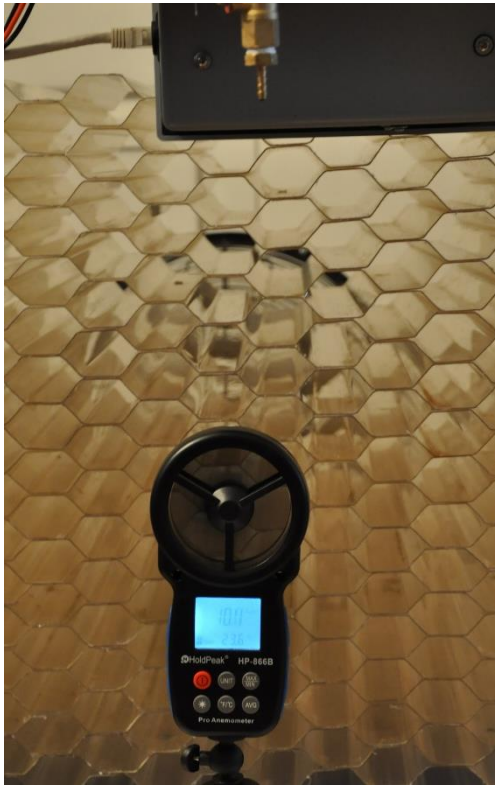
Treatments	Average amount of herbicide applied (g of ai/ha)	% Reduction relative to Pre-emergence	% Reduction relative to Post-emergence
Droplet x5 gly	700	47.0	-3.7
Droplet x10 gly	930	29.5	-37.8
Droplet x10 gly (adj)	340	74.2	49.6
Droplet x10 glu	2121	-60.7	-214
Droplet x10 glu (adj)	646	51.0	4.3
Pre-emergence	1320	NA	-95.5
Post-emergence	675	48.8	NA

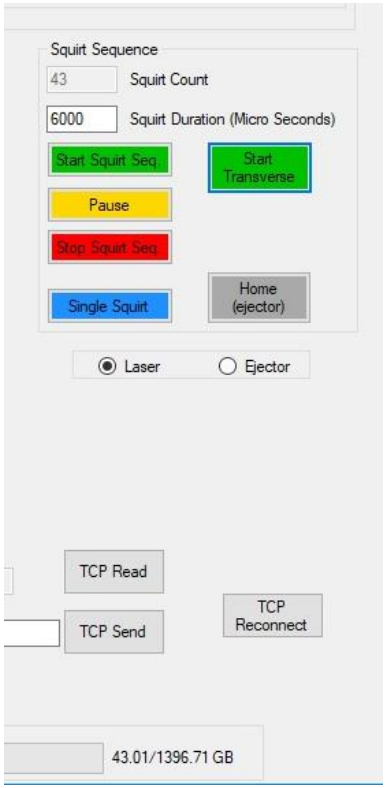
NA: not applicable

Herbicide droplet applicator tests

- Tests carried out with both a static and moving applicator:
  - Initial calibration determined time to dispense 1 µl at different pressures
  - Effect of pressure and distance from target on targeting accuracy
  - Effect of wind, pressure and distance from target on targeting accuracy

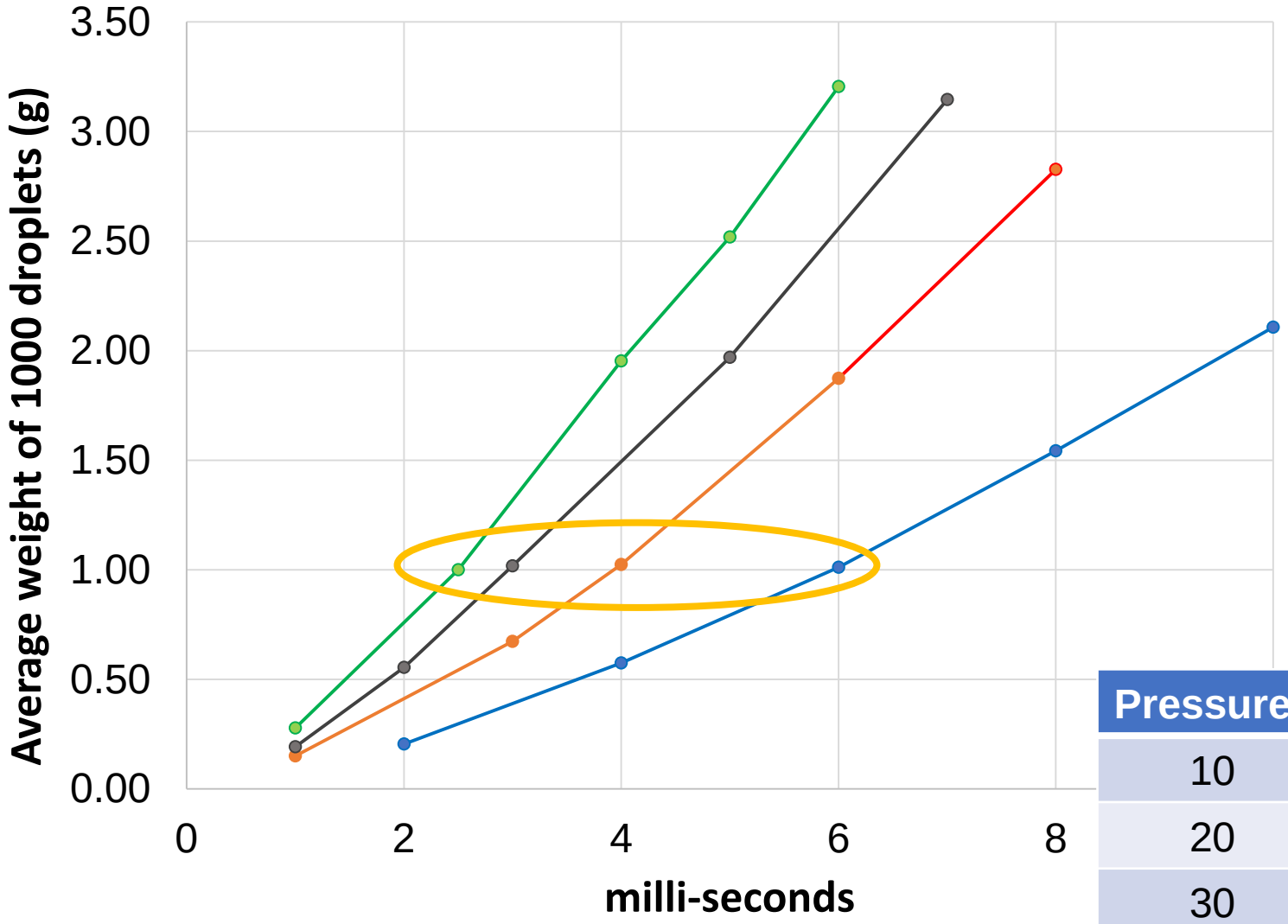






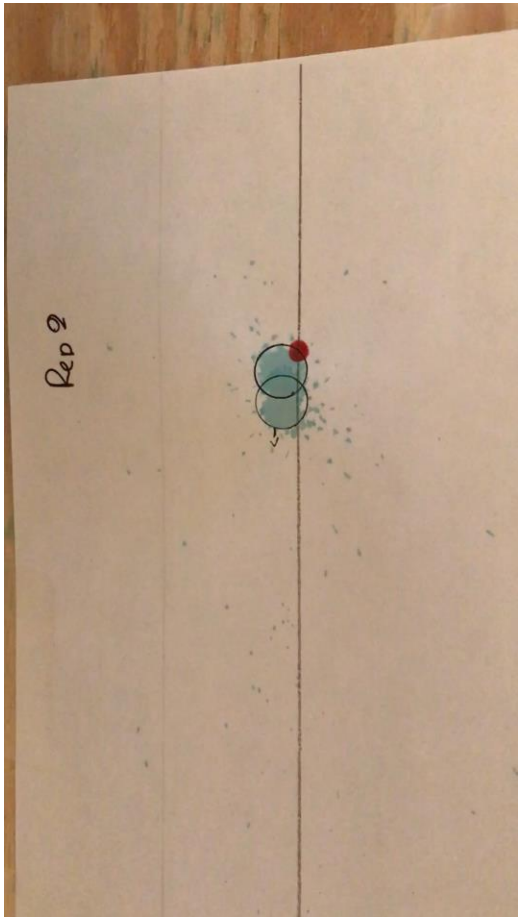
Calibration Test

- Weight of micro-tube after 1000 droplets of water were applied using different psi

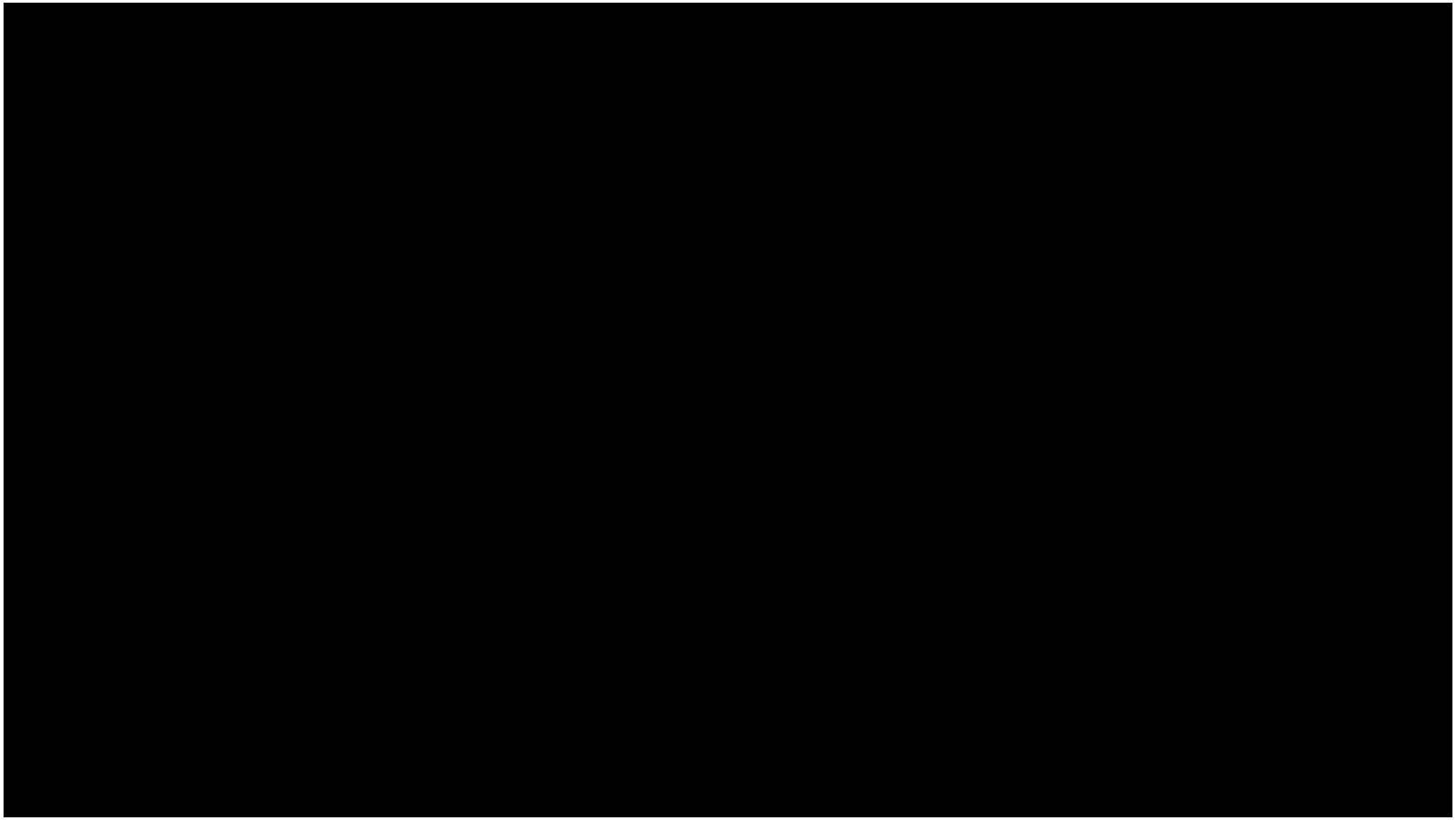


Pressure	Milli-seconds
10	6
20	4
30	3
40	2.5

Static applicator, 15cm from target, 10 psi, windspeed 10 km/h

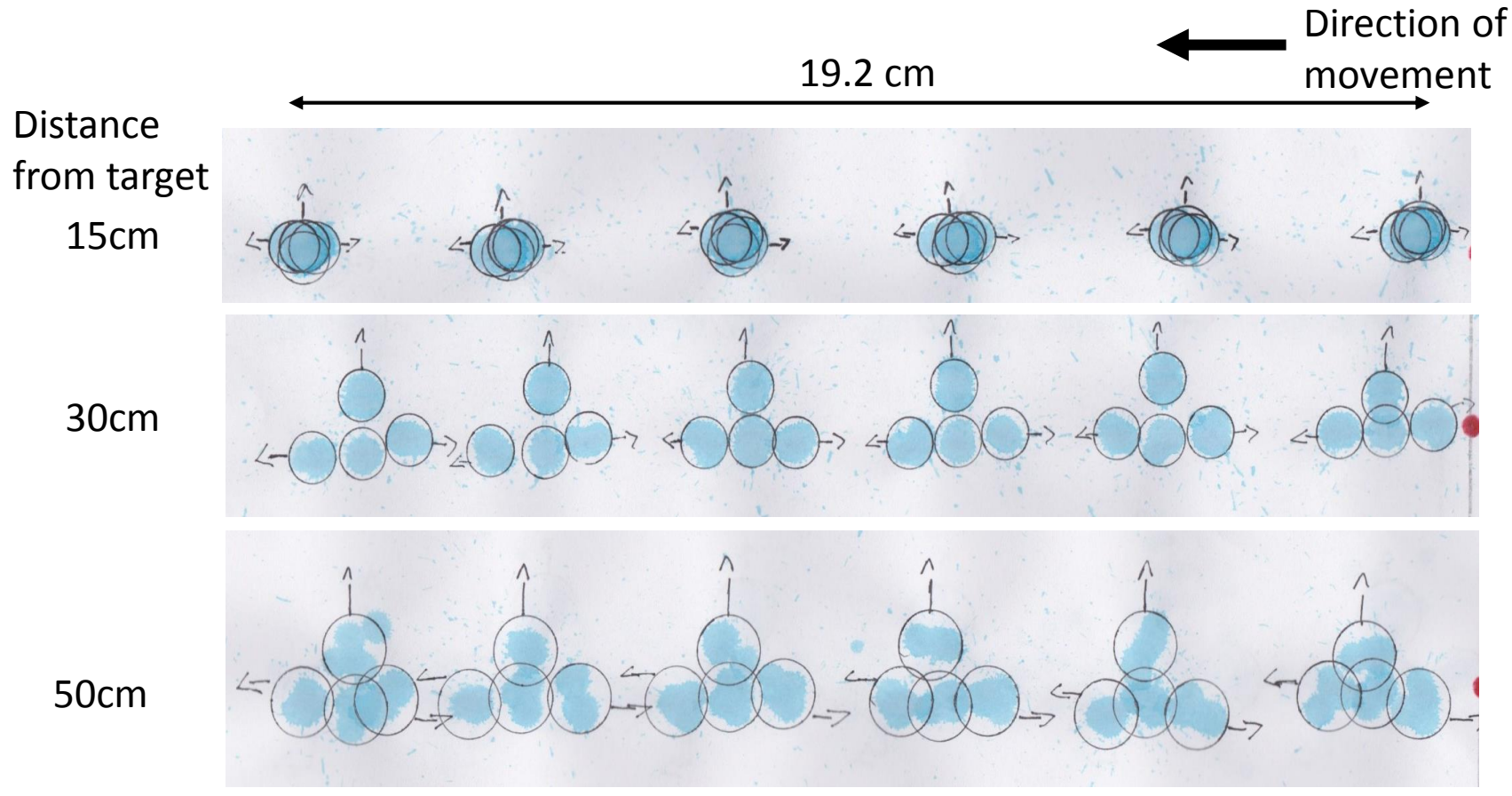


Moving applicator, 50 cm from target, 20psi, 0 wind



Preliminary results with applicator mounted on a gantry system

- Applicator pressure 20 psi; gantry speed: 1 km/h; windspeed: 10 km/h
- Applying water with blue dye to uncoated paper
- Apparent spattering is because gantry traversed 5 x over a short period of time and applied to the wet surface before previous application had dried



Preliminary results with applicator mounted on a gantry system

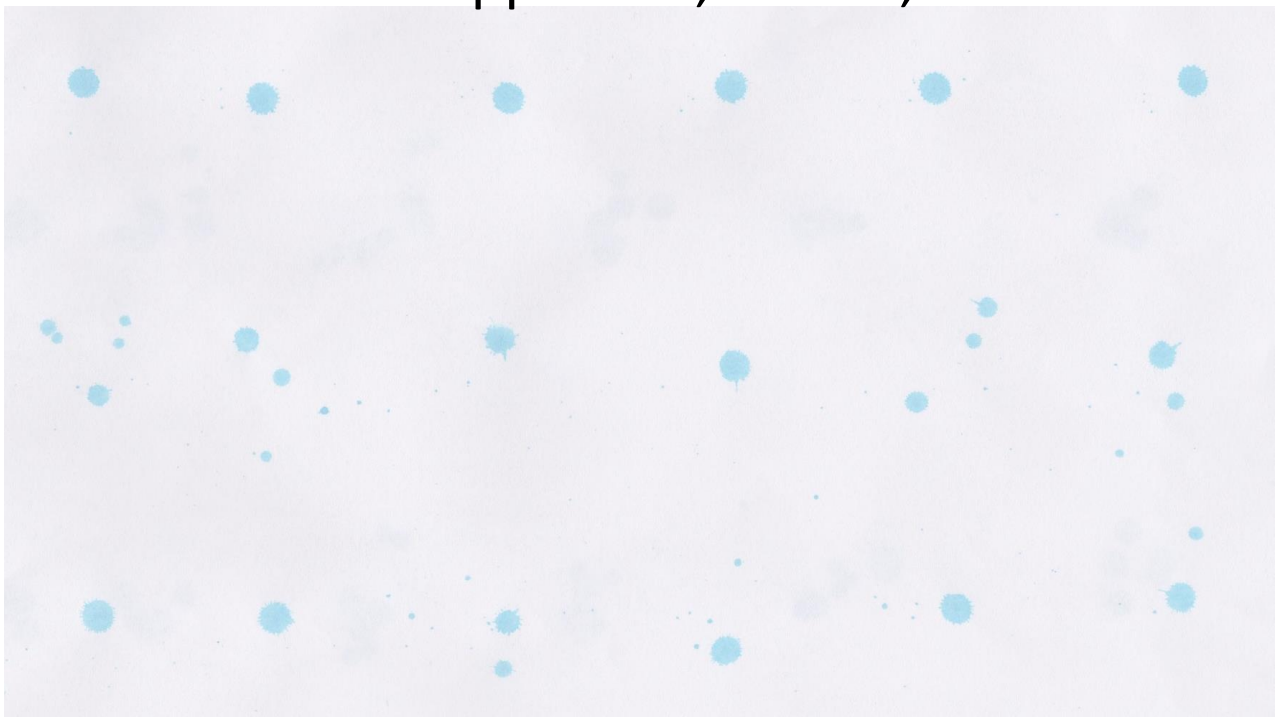
- No spatter from 20 psi applications even with a 50 cm separation between nozzle and paper(split droplets from 10 psi; spattering and some splitting from 30 and 40 psi)

50 cm from applicator, 0 wind, 1 traverse

20 psi

30 psi

40 psi



Conclusions

Dose-response studies

- Glyphosate: both species tested, approximately 1/8 of the dose caused 90% biomass reduction
- Glufosinate-ammonium: *A. retroflexus* required 5x the recommended dose to be controlled.

Glyphosate			
Weed species	1x (µg)	ED50 (µg) (±SE)	ED90 (µg) (±SE)
Stellaria media	48.8	3.04 (1.1)	6.3 (7.8)
Amaranthus retroflexus	419.8	13 (2.05)	46 (19)
Glufosinate-ammonium			
Amaranthus retroflexus	321.6	45.3 (21.4)	1683 (2145)
Chenopodium album	21.8	4.4 (1.2)	9 (6.1)
Urtica urens	28.1	1.4 (0.3)	3.4 (2.4)

Conclusions

Field trials

- Three applications with droplets of glyphosate:
  - Achieved 92% weed control for both years
  - Reduced herbicide inputs by 94% to 98% compared to Pre-emergence for 2016 and 2017 respectively
  - Achieved yields not significantly lower than weed-free plots
- Other observations: one droplet per plant vs one per leaf

Conclusions

- Applicator:
  - Time needed to apply a droplet of 1 µl was 4 ms at 20 psi

- When applicator operates at 20 psi:
  - No spatter was observed even with a 50 cm separation between nozzle and paper
  - Negligible displacement of droplets with 10 km/h front, tail and side wind and 15 cm separation. Consistent displacement with larger distances from target (meaning it could be modelled and predicted)

Future work

- Dose-response studies testing more weed species
- Field trials 2018
  - Simple automated platform for droplet application to leeks and cabbages at Sonning Farm. Replicating some the treatments used in 2016 and 2017 with controls (weed-free, weedy, post-em, pre-em)
  - Some manual applications for both actives
- May explore alternatives to glufosinate-ammonium and use of herbicide mixtures
- Algorithm development (mainly Concurrent Solutions)
- Assessment of economics of the system for field veg in the UK
- Publishing DRC paper (Weed Rersearch?)
- Publishing field trials paper (Weed Research?)
- Presentations (AAB, EWRS, ICPA?)
- Note: PhD funding runs to March 2018; project to September 2018.

- Thank you for listening and funding

- Any questions?