Efficient Soil Phosphate Management for Cereal Crop Production:

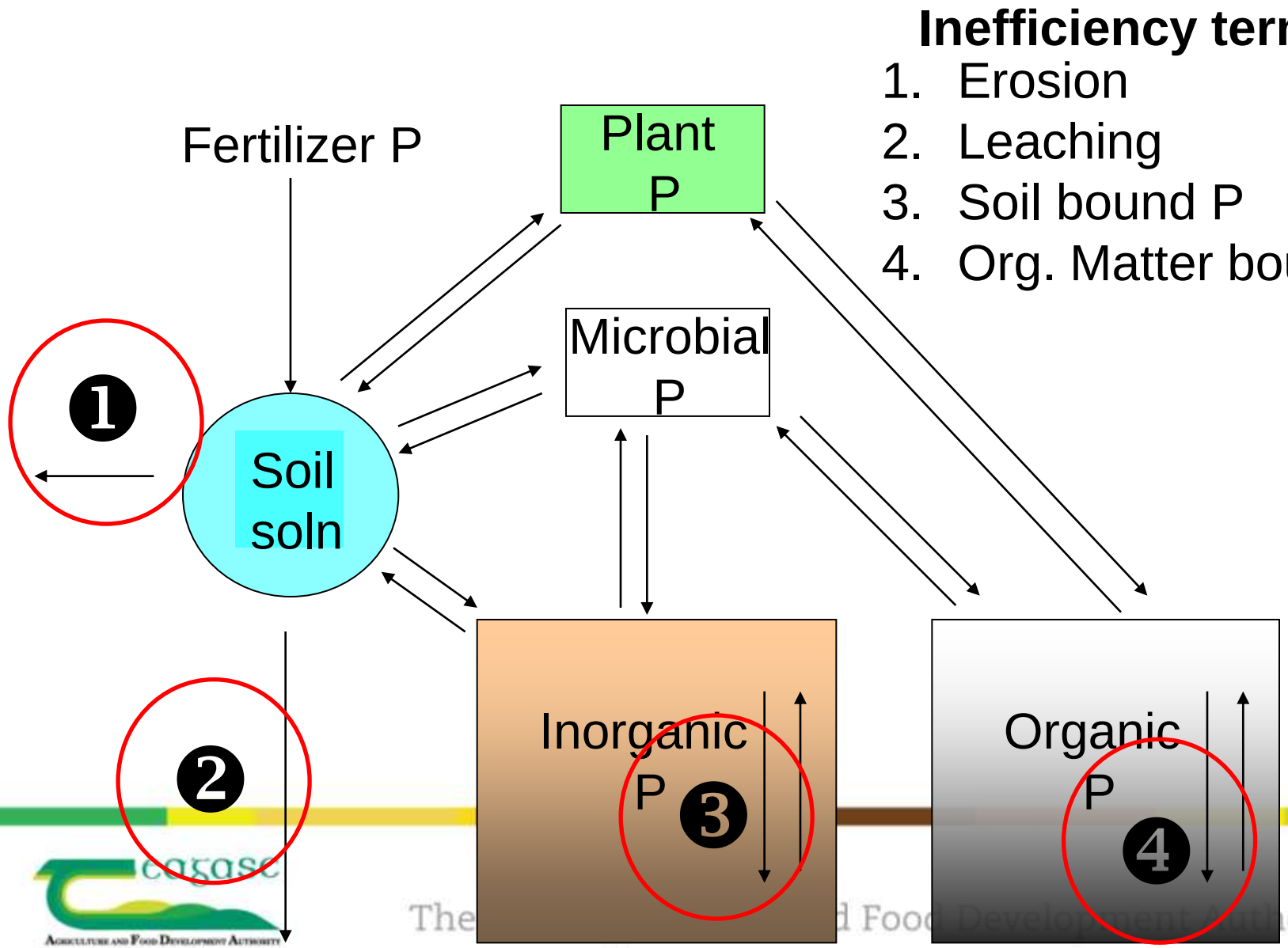
Agronomy and Business Management Conference for Arable Growers
CAFRE Greenmount Campus, Antrim
13th January 2015

Dr David. P. Wall[1],

[1] Teagasc, Crops Environment and Land Use Programme, Johnstown Castle, Wexford, Ireland

Soil reactions important for P fertiliser use efficiency (PUE)

Improving P fertiliser use efficiency (P_fUE)



adapted from McLaughlin *et al.,* 2011)

Current P fertiliser advice for cereal crops in Ireland

- Advice based on relationship between soil test and crop requirement
- Soil P Test (Morgan's extractable P) *1:5 (v/v), 10% sodium acetate + acetic acid, pH 4.8*

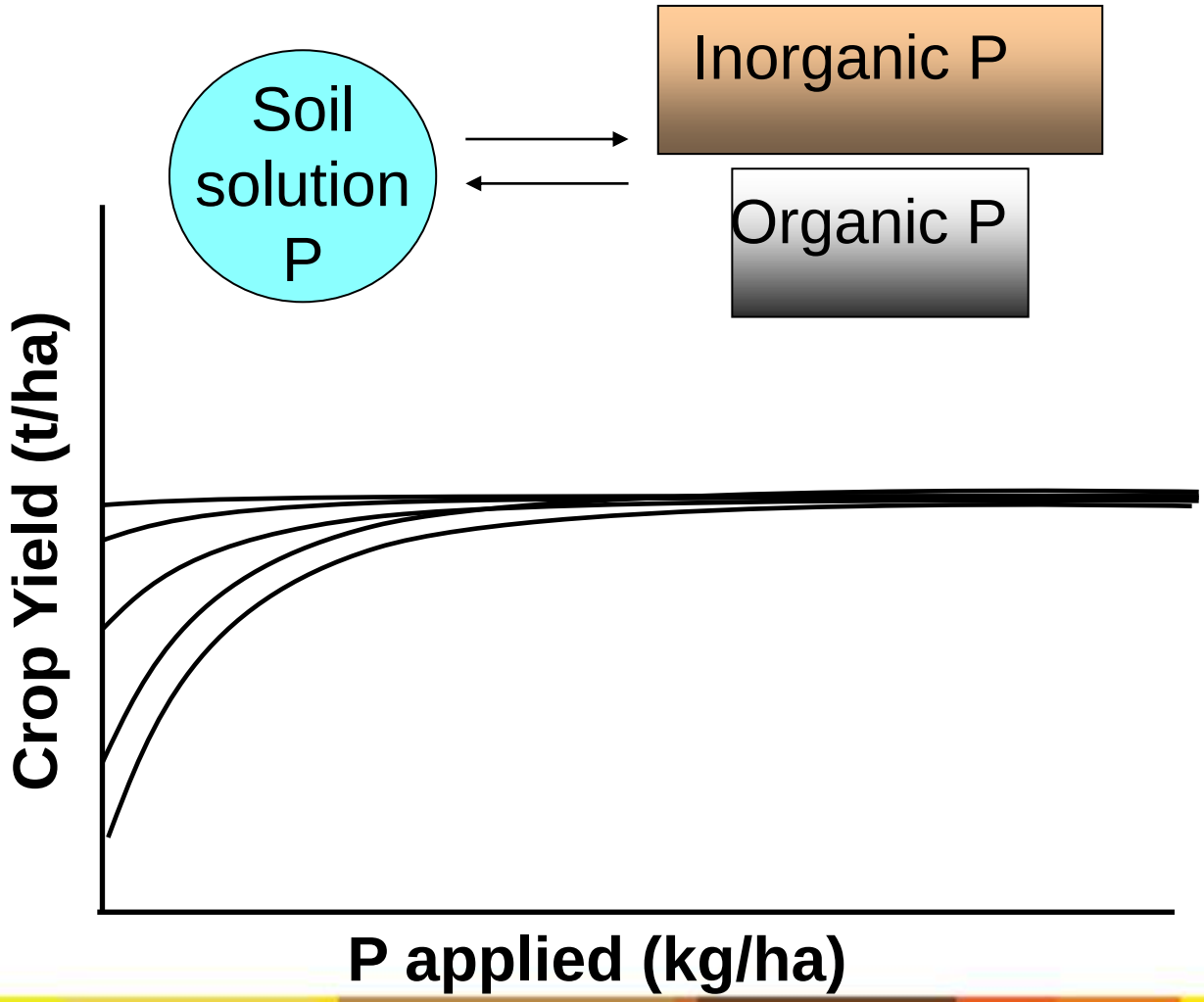
Table 1. The soil Index system used in Ireland for Phosphorus
(Coulter and Lalor, 2008)

Soil Index	Response to fertilisers	Soil test P (mg/L Morgan's Extractable P)	
		Grassland	Tillage
1	Definite	0 - 3.0	0 - 3.0
2	Likely	3.1 - 5.0	3.1 - 6.0
3	Unlikely /tenuous	5.0 - 8.0	6.1 – 10.0
4	None	>8.0	>10.0

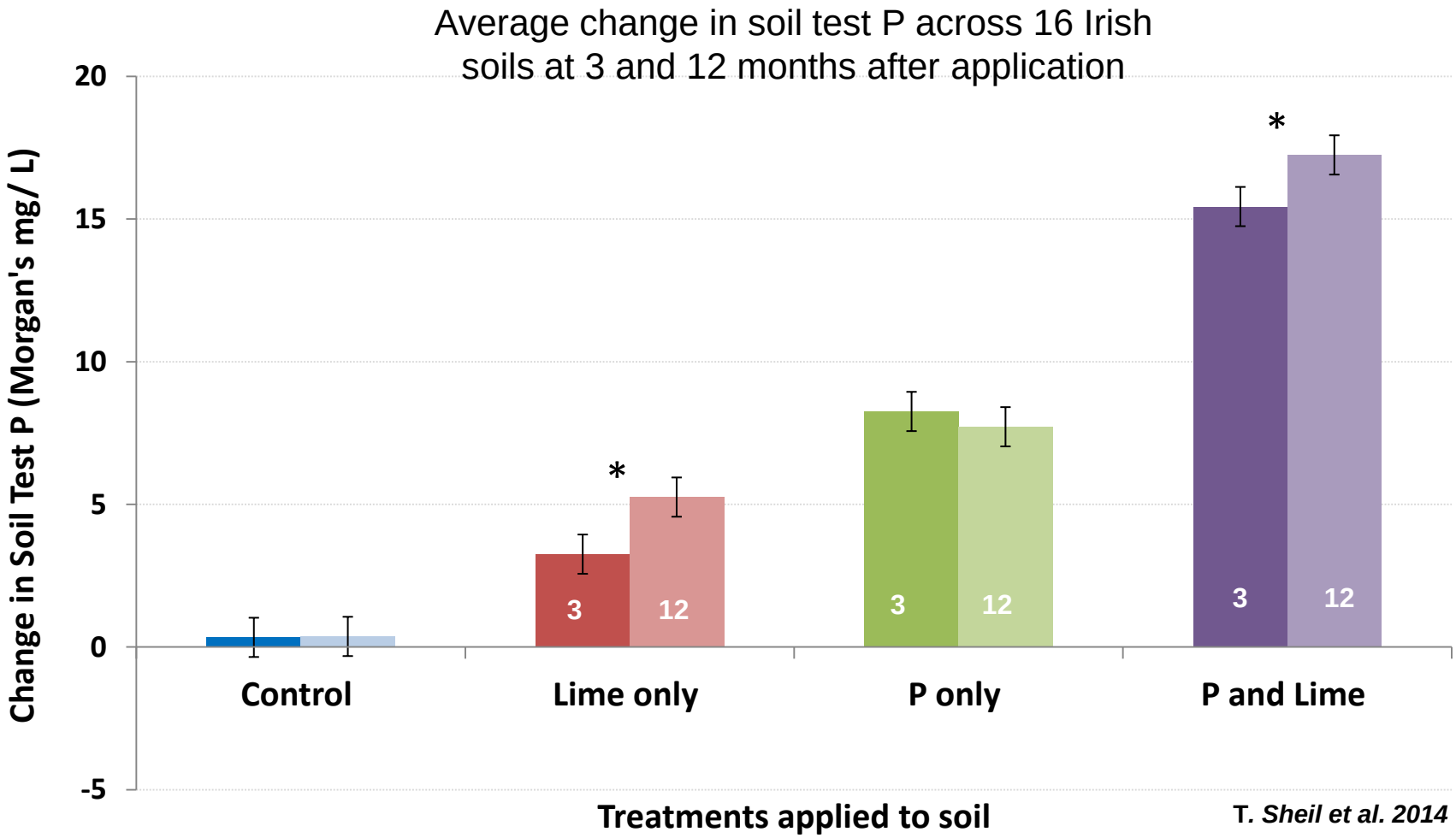
Application rates of phosphate described here are in kg P rather than kg P_2O_5

To change P to P_2O_5 multiply P by 2.2914

Response to P fertiliser additions over time



Effect of Lime and Phosphorus fertiliser on soil P availability



* *Optimising soil pH with lime is critical to maximise soil P availability and to increase fertiliser P efficiency*

Phosphorus requirement by crops

- What quantity of P is leaving the farm in product ?

  P off-take in grain, straw, tubers, roots etc.

Table 2. Typical P off-take for tillage crops, expressed as kg of P removed per tonne of harvested yield. ***(Coulter and Lalor, 2008; DEFRA, 2010)***

Crop type	Grain +/- straw removed	P off-take (kg/t yield)
All Cereals	Straw removed	3.8
	Straw not removed	3.4
Oilseed Rape	Straw removed	6.6
	Straw not removed	6.1
Peas		3.8
Beans		4.8
Beet		0.35
Potatoes (maincrop)		0.44

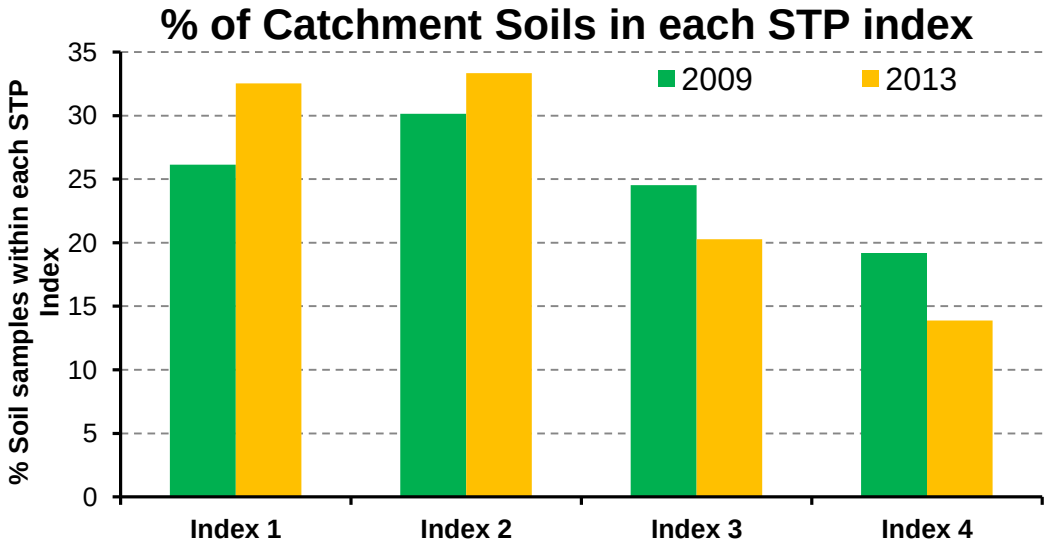
Soil test change

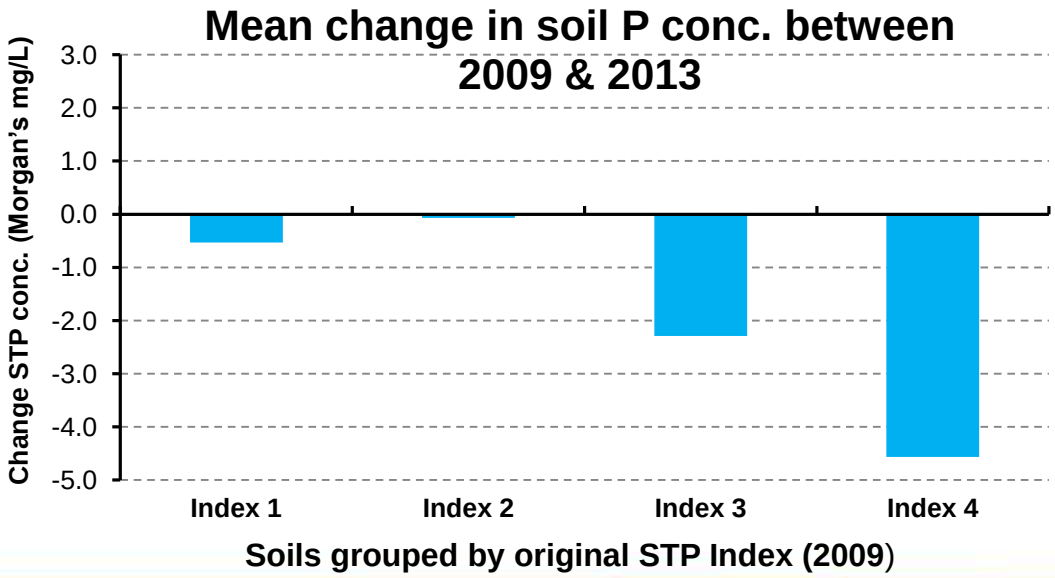
- 375 soil samples
  - *January 2009*
  - ***January 2013***

- ***Mean P fertiliser application***
  - *26 kg/ha P / yr*
  - *(0 – 61 kg/ha P)*

- ***Mean Crop P off-take***
  - *28 kg/ha P/ yr*
  - *112 kg/ha P over 4 years*

- **Mean STP change**
  - *~ 26 kg P /mg STP decline*





Source: Agricultural Catchments Programme, Teagasc.

Response to phosphorus in cereal crops

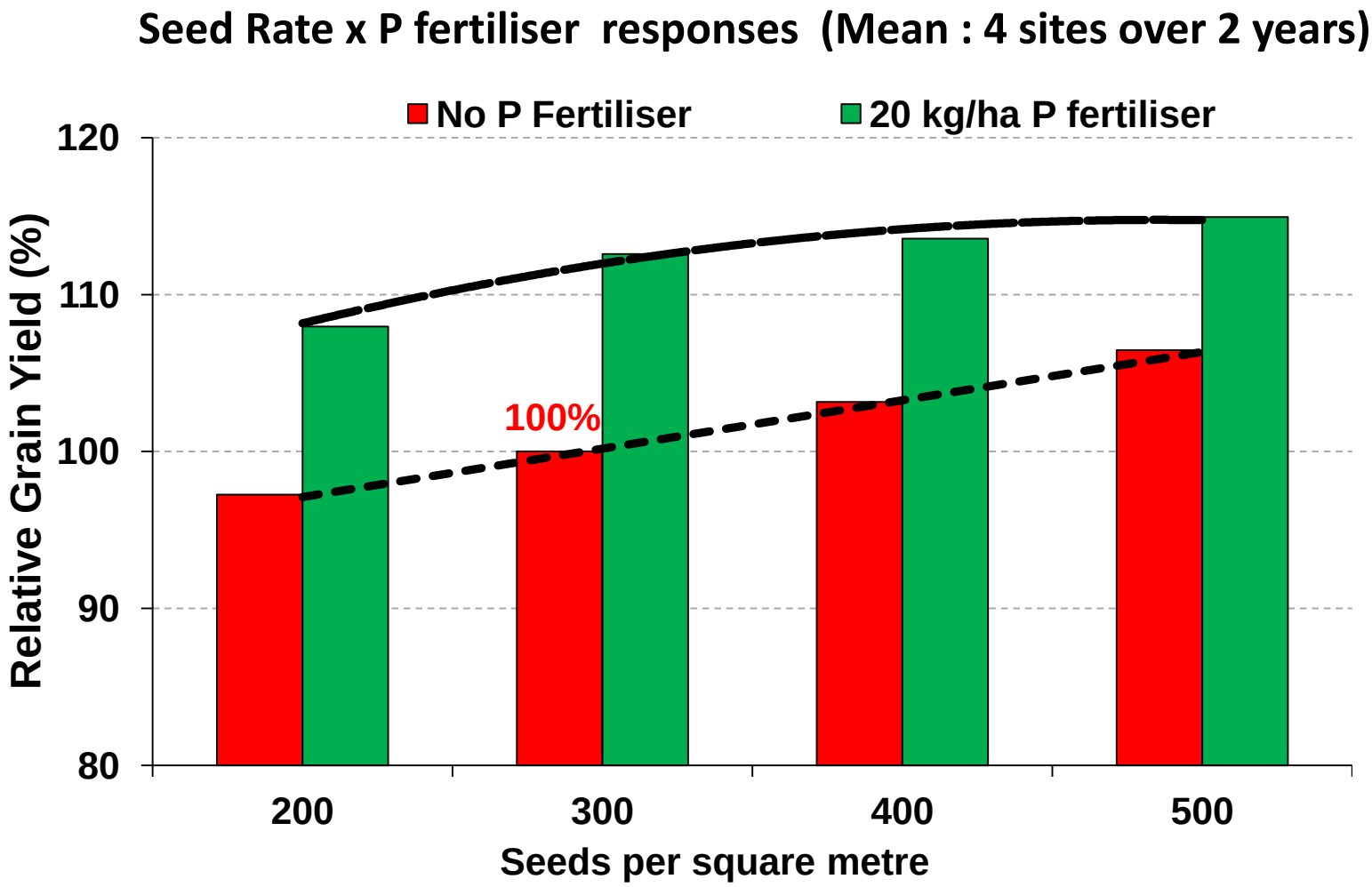
- Requirement to update crop response curves for P fertilisers

- Farmer and Advisory questions
  - *Can soils be managed at lower STP Index without the risk of yield loss?*
  - *What impact is the prohibition of autumn P applications on winter cereal yields having?*
- Experiments conducted in Spring Barley and Winter Wheat
  - Multiple years (2010 – 2014)
  - P fertiliser application rates: 0 – 60 kg /ha P
  - P fertiliser source: Triple Superphosphate (TSP) 16%
  - Different P fertiliser application methods
  - Effect of P at different seed rates

Effect of P on Rooting & Tillering

Very Low soil P fertility site
(1.38 mg/L Morgan's P)

Effect of P fertiliser on Spring Barley establishment



S. Barley grain yield response to P fertiliser

Table 3. Spring Barley P response sites

Site	Year	Soil test P level*	P Index†	Sowing date	Optimum P SB fertiliser rate‡	Grain yield optimum P rate	% grain yield response
		mg/L			*kg/ha*	*t/ha*	*Control = 100%*
1	2012	1.38	1	13th Mar.	50	6.2	137%
2	2013	1.88	1	5th April	40	5.7	125%
3	2014	2.05	1	24th April	30	7.8	107%
4	2013	2.36	1	4th April	40	7.7	106%
5	2010	2.42	1	16th Mar	20	7.4	108%
6	2012	2.62	1	29th Mar	40	6.8	115%
7	2014	2.74	1	14th April	50	8.3	107%
8	2014	5.20	2	12th April	30	8.5	112%
9	2010	8.13	3	13th April	0	8.6	100%
10	2014	10.64	4	14th April	0	8.2	100%
11	2013	13.93	4	8th April	20 *kg applied*	8.9	132%
12	2012	19.70	4	13th Mar	0	6.6	100%

** Morgan's extractable P is the standard agronomic soil test used in Ireland.*

†P Index, 1: 0-3.00 mg/L, 2: 3.01-6.00 mg/L, 3: 6.01-10.00 mg/L, 4: >10.00 mg/L Morgan's extractable P

‡All P fertiliser treatments surface broadcast (SB) at sowing time

- Large range in P fertiliser response across site-years
- Higher grain yield response to P fertiliser at low STP levels
- Climate and yield potential influence response to P fertiliser

W. Wheat grain yield response to P fertiliser

Table 4. Winter Wheat P response sites

Site	Year	Soil test P level*	P Index†	Sowing date	Optimum P SB fertiliser rate‡	Grain yield optimum P rate	% grain yield response
		mg/L			*kg/ha*	*T/ha*	*Control = 100%*
13	2011	1.26	1	2nd Nov	20	8.4	113%
14	2014	1.68	1	23rd Oct	0	9.0	100%
15	2012	1.99	1	7th Oct	0	8.5	100%
16	2014	2.27	1	23rd Oct	0	10.6	100%
17	2012	2.86	1	19th Oct	0	9.1	100%
18	2010	3.74	2	16th Oct	20	11.9	106%
19	2011	3.85	2	19th Oct	0	10.3	100%
20	2014	4.66	3	23rd Oct	0	10.8	100%

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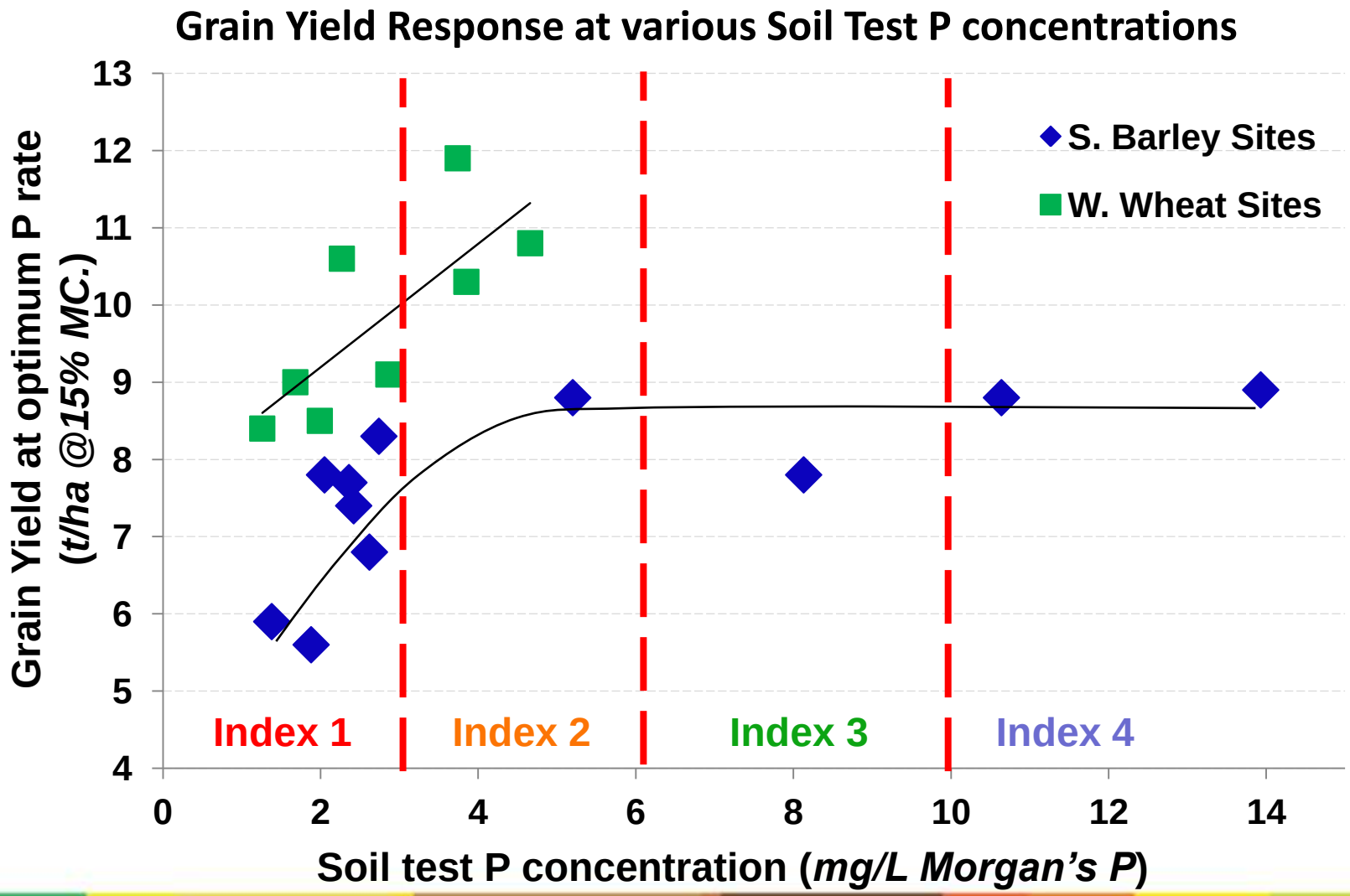
†P Index, 1: 0-3.00 mg/L, 2: 3.01-6.00 mg/L, 3: 6.01-10.00 mg/L, 4: >10.00 mg/L Morgan's extractable P

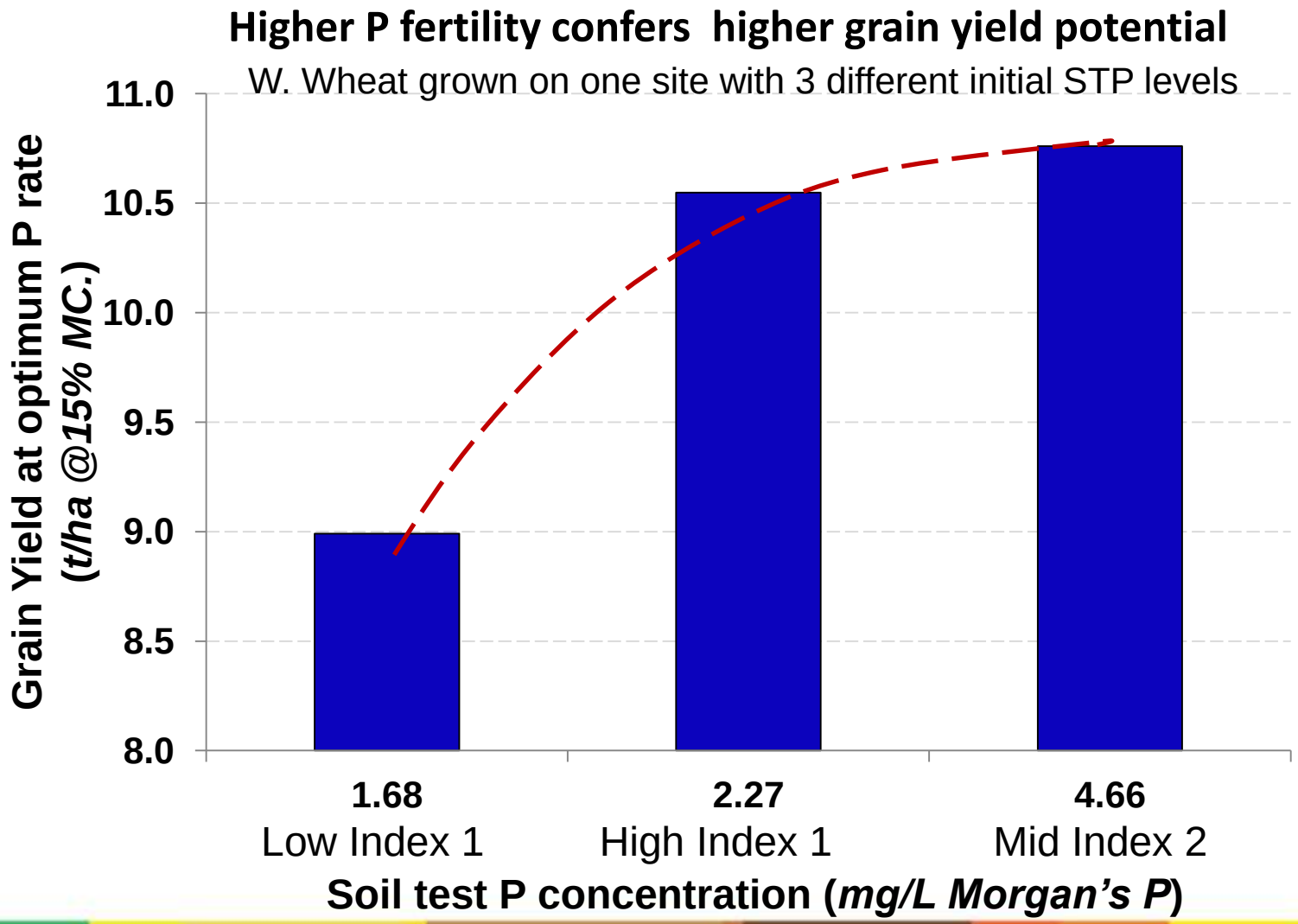
‡All P fertiliser treatments surface broadcast (SB) in spring at growth stage 25. (Zadocks)

- Limited response to P fertiliser across site-years
- Grain yield potential related to soil P fertility (STP levels)?
- Winter wheat seems to be less dependent on freshly applied P fertiliser

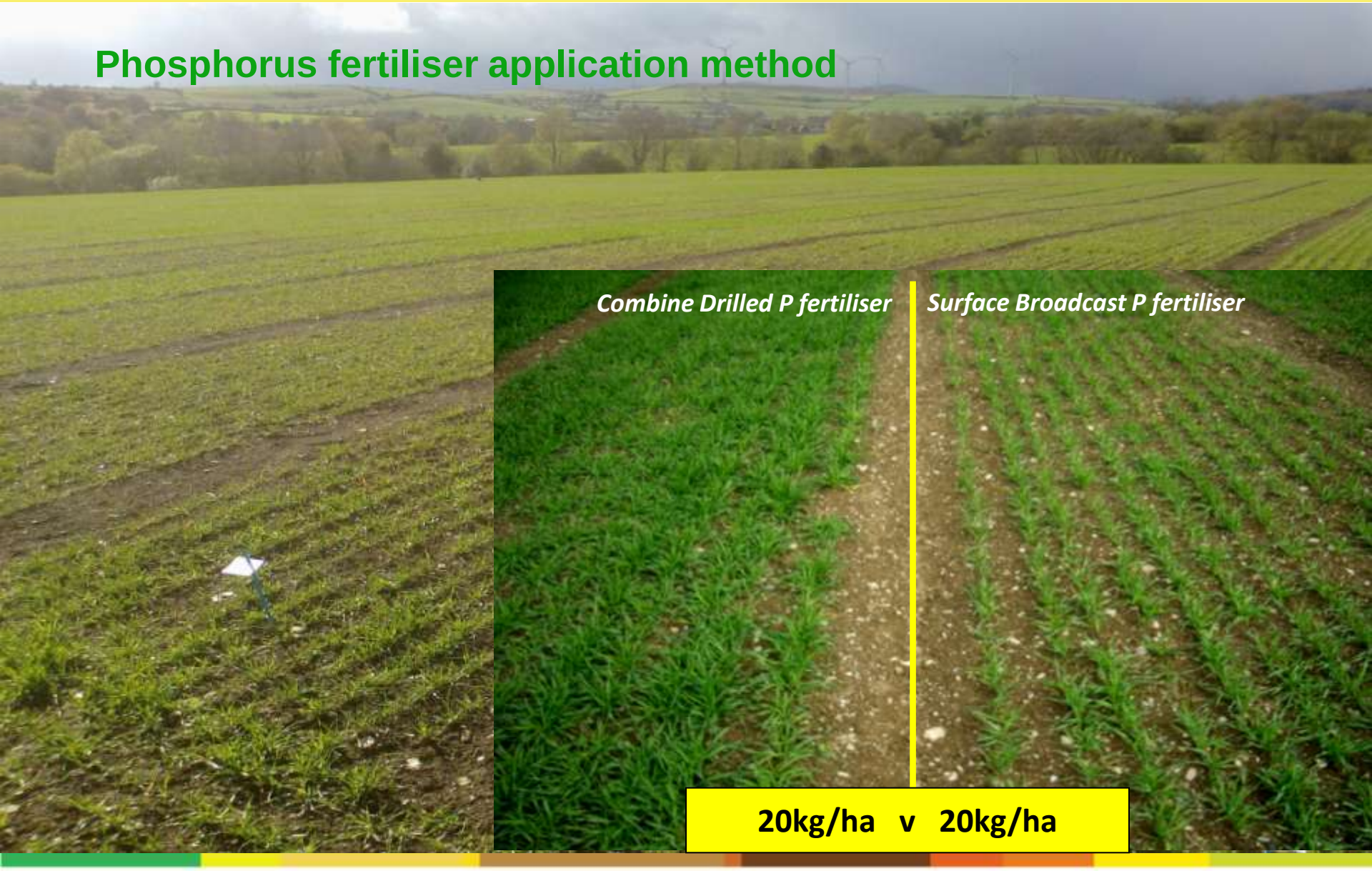
Cereal grain yield response to P fertiliser



Effect of Soil P fertility on Grain Yield Potential

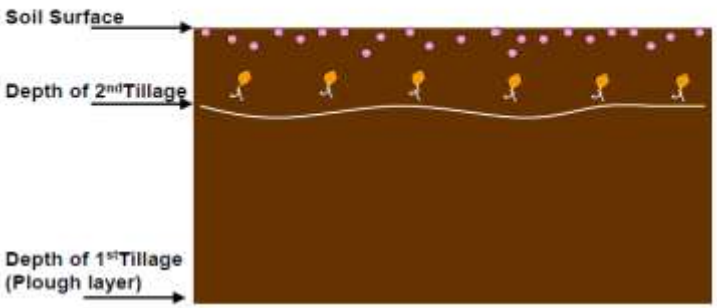


Phosphorus fertiliser application method

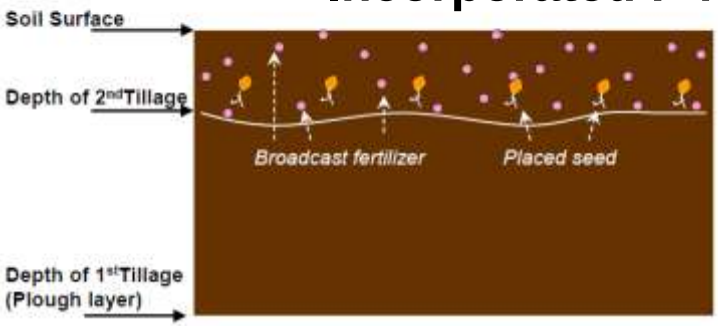


Phosphorus fertiliser application methods evaluated

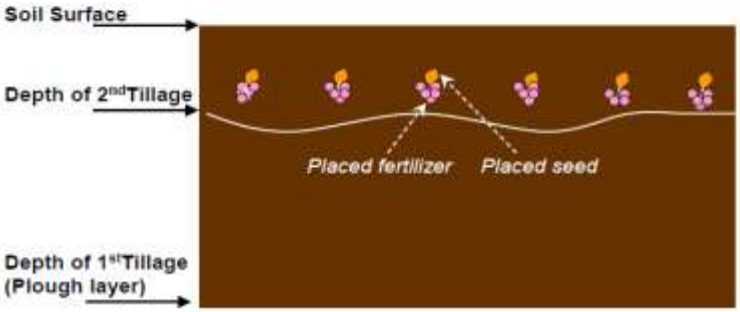
Surface Broadcast P fertiliser

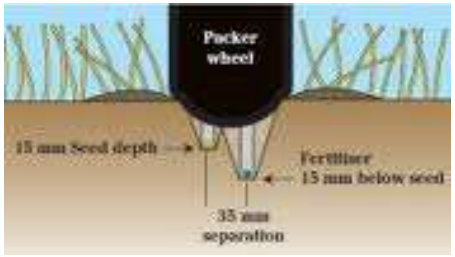


Incorporated P fertiliser



Combine drilled P fertiliser





Grain yield response to P fertiliser application methods

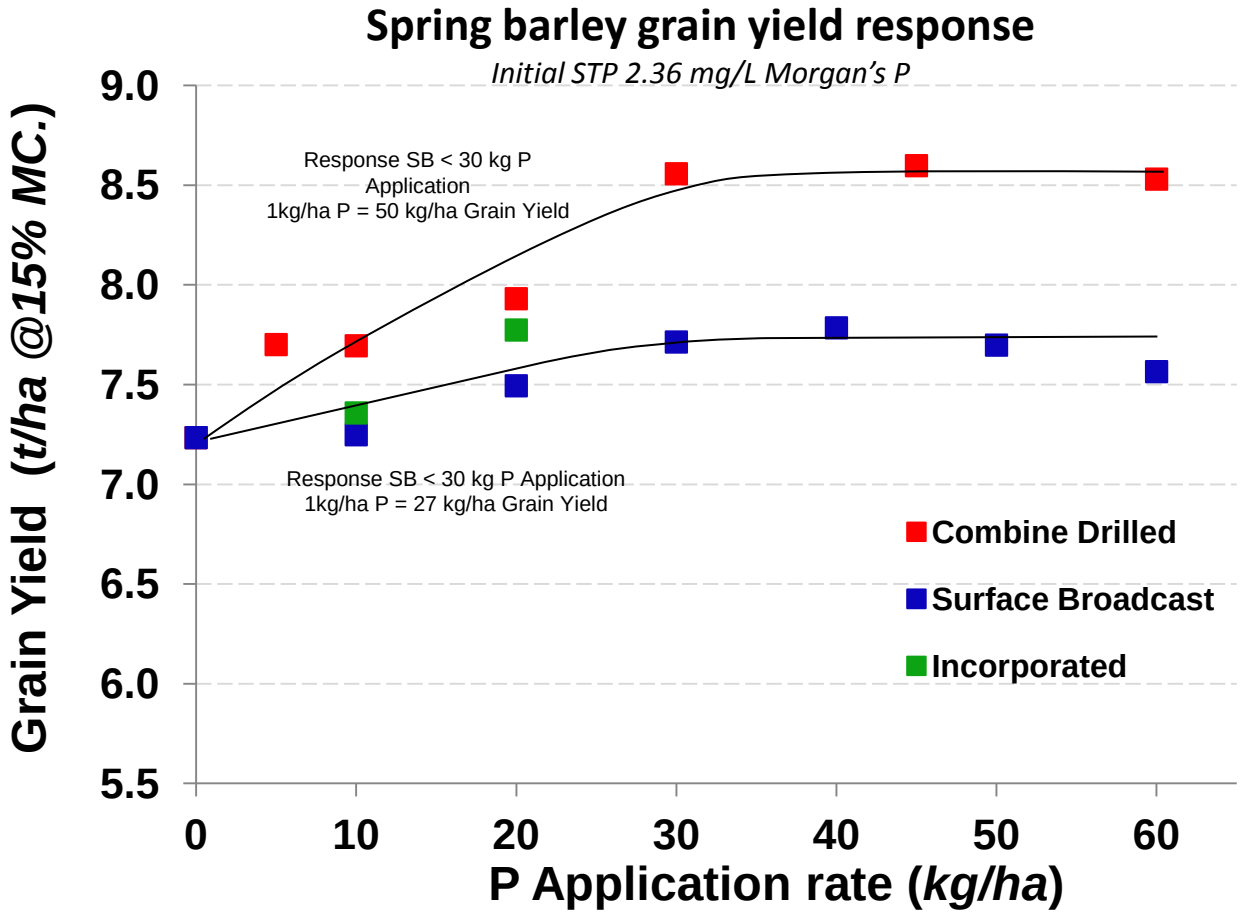
Year	Crop	P Index*	Optimum P fertiliser rate SB†	Optimum P fertiliser rate CD‡	Grain yield optimum P rate CD	Increase in grain yield CD
			kg/ha	*kg/ha*	*t/ha*	*t/ha*
2012	S.Barley	1	50	30	6.6	+0.3
2013	S.Barley	1	40	10	5.7	-
2014	S.Barley	1	30	20	7.8	-
2013	S.Barley	1	40	30	8.6	+0.9
2012	S.Barley	1	40	20	7.2	+0.5
2014	S.Barley	1	50	30	8.3	-
2014	S.Barley	2	50	20	8.9	+0.4
2014	S.Barley	4	0	10	8.4	+0.3
2013	S.Barley	4	20	20	8.9	-
2012	S.Barley	4	0	0	6.5	
			kg/ha	*kg/ha*	*t/ha*	*t/ha*
2011	W.Wheat	1	20	20	8.4	-
2014	W.Wheat	1	0	20	9.6	+0.6
2012	W.Wheat	1	0	0	8.5	-
2014	W.Wheat	1	0		10.6	-
2012	W.Wheat	1	0	0	9.1	-
2011	W.Wheat	2	0	0	10.3	-
2014	W.Wheat	3	0		10.8	-

†P Index, 1: 0-3.00 mg/L, 2: 3.01-6.00 mg/L, 3: 6.01-10.00 mg/L, 4: >10.00 mg/L Morgan's extractable P

†SB, Surface broadcast P application

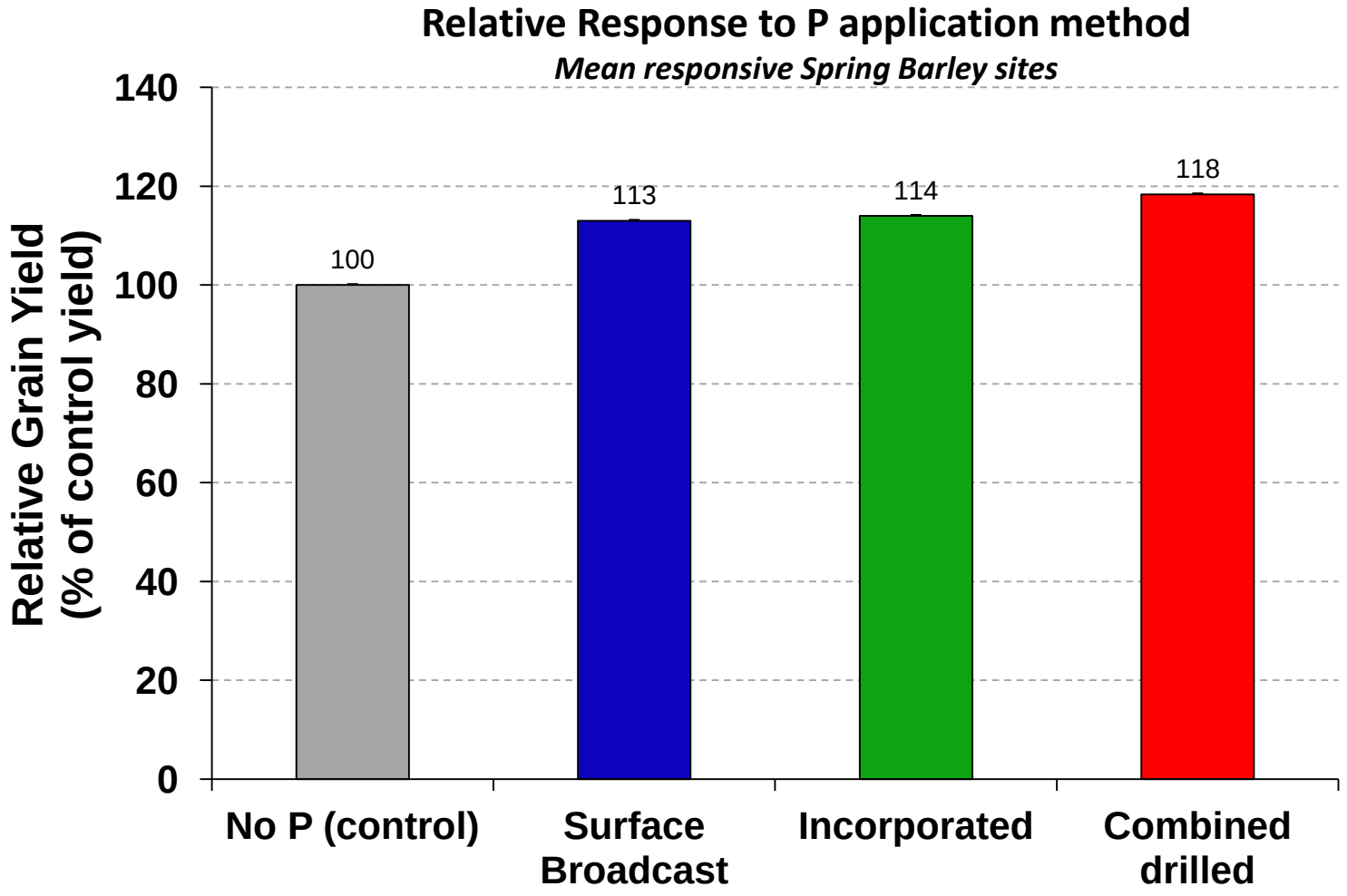
‡CD, Combine drilled P application with seed at sowing time.

Grain yield response to P fertiliser application methods



- Margin over P fertiliser cost for a 30 kg/ha application rate *(assumed P fertiliser cost €2.5/kg and grain price €150/t)*
- *Yield increase 0.5 t/ha for SB method & 1.3 t /ha for CD method*
- *Margin -€1 for Surface Broadcast, €124 for Combined Drilled*

Grain yield response to P fertiliser application methods



Conclusions

1. Phosphorus is a critical resource for agriculture and food production and needs to be used sustainably to protect the longevity of its supply.
2. Effective soil P management strategies need to be adopted on farms to maintain future soil productivity.
3. Better knowledge of soil types and their P dynamics is key to improving P advice and to target P fertiliser management
4. Soil P testing is a good indicator of P availability and crop response to P fertiliser.
5. Spring barley was more responsive to P fertiliser additions than winter wheat.
6. In general the apparent P fertiliser recovery of surface broadcast P fertiliser was low (<20%). Placing P fertilisers close to or with the seed on low P fertility soils was the most efficient method of applying fertiliser P.

Research to Advice

The work of this project is contributing to development of Teagasc Soil Fertility Management Advice & Knowledge Transfer initiatives

Acknowledgments

Farmers for providing field sites for experiements

Teagasc Advisors, Field and Lab Technicians at Oak Park and Johnstown Castle.