CROPPING ALTERNATIVES TO INCREASE OPTIONS, EFFICIENCY AND PROFIT

Protein Crops & Other Alternatives

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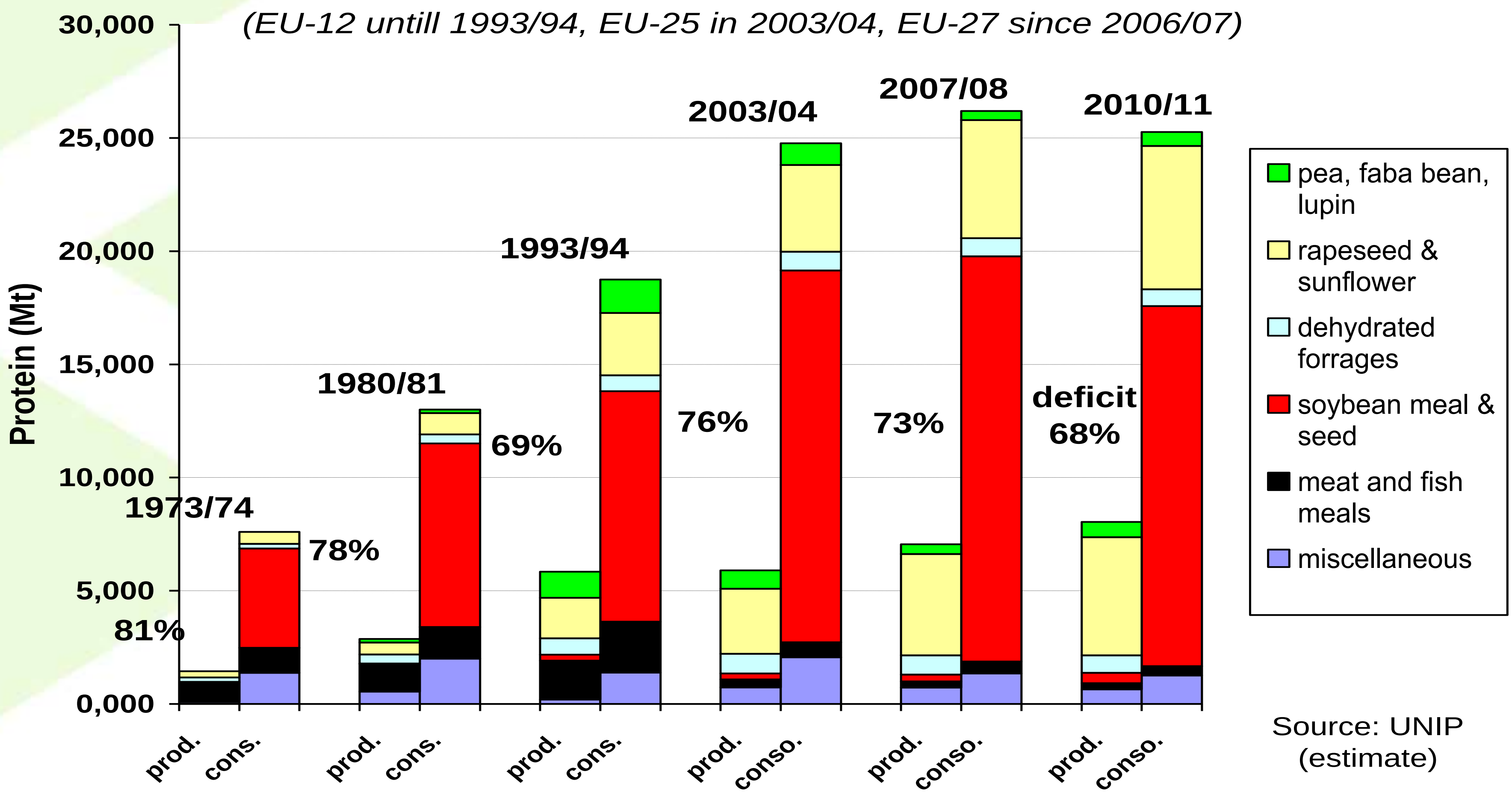
Leading the way in Agriculture and Rural Research, Education and Consulting

Why consider growing protein crops?

EU is deficient in protein feedstuffs



Protein crops for Livestock

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- **Rationale**
  - Livestock production systems relies heavily on our ability to provide our livestock with sufficient quantities and quality of (metabolizable) energy and nutrients
- **We focus here on protein supply**
  - Often first limiting and most expensive ingredient
  - Protein supply to ruminants (cows, sheep, deer)
    - Forages and concentrates
    - High quality protein from rumen and by-pass
  - Protein supply to monogastrics (pigs, poultry, salmon)
    - Concentrates
    - High quality protein all from diet directly

Protein crops for Livestock

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- Concentrates are supplement to forages (ruminants) or sole feeds (monogastrics)
- Protein feeds in concentrates
  - **Pulses**
  - Oilseed co-products
  - Animal origin (under severe restriction)
  - Milk protein
  - Cereals contribute significantly to protein supply
    - traditionally seen as the energy providing ingredients
- Overall, a **net deficit of home grown protein** supply to meet demand

Protein crops for Livestock

- **Great reliance on soya bean meal (SBM)**
  - Co-product from soya oil production
    - Benefits: great palatability, high protein level, high quality (composition and digestibility) and consistent availability
    - Concerns: environmental footprint, price fluctuations, GM, and potentially availability issues going forward
- **Can we reduce reliance on imported SBM?**
  - Forages
    - Increased protein levels in whole crop forage (silage)
  - Concentrates
    - SBM replacement with home grown alternatives
    - Home-grown soya

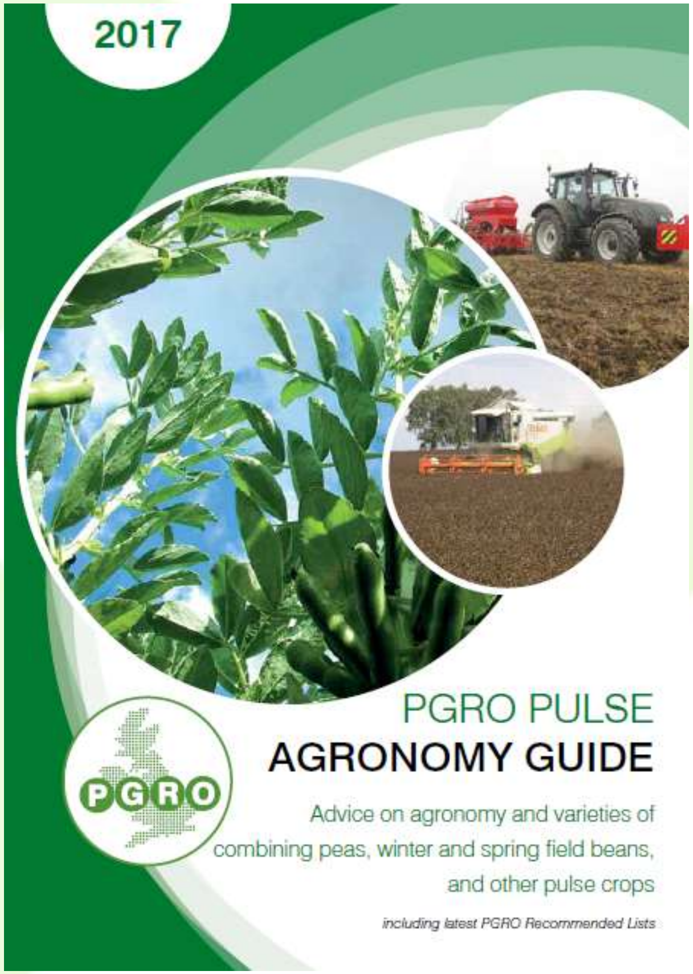
UK Bean & Pea Production

	Year									
Commodity	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
Bean area (10^3 ha)	105	103	71	34	43	33	76	48	139	122
Pea area (10^3 ha)	68	67	54	15	15	5	na	na	72	82

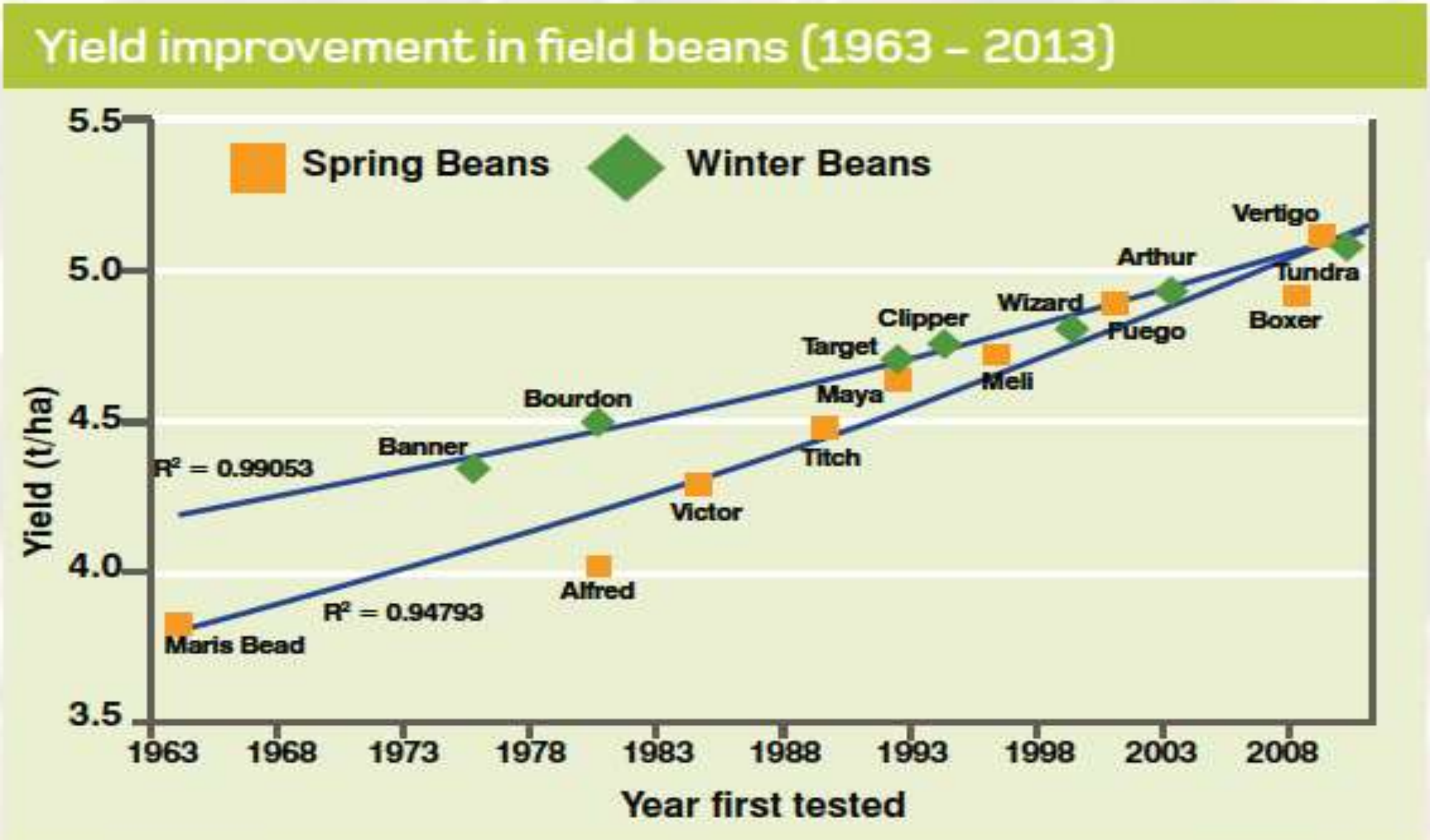
	Year									
Beans	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Area (10^3 ha)	184	123	118	190	168	125	96	118	107	170
Yield (t ha^{-1})	3.4	3	4.5	3.8	3.5	3.4	3.3	3.2	4.2	4.4
Volume (10^3 t)	613	375	526	722	580	419	317	378	448	740
Value incl. subsidy (£ 10^6)	59	65	73	86	92	72	74	90	84	97

	Year									
Peas	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Area (10^3 ha)	37	26	21	28	23	12	11	13	18	25
Yield (t ha^{-1})	3.3	3.1	4	5	3.5	4.1	2.4	3.7	4.0	4.1
Volume (10^3 t)	122	80	85	141	81	49	26	48	70	101
Value incl. subsidy (£ 10^6)	11	14	12	17	12	8	6	10	13	13

Protein crop Agronomy information



Bean yield improvements



Source: NIAB TAG's Landmark bulletin, January 2014, gives full details of the increase in yield attributable to variety improvements

Spring Bean Varieties RL (2017)

Variety / type	Pale hilum							Black hilum Tic
	Lynx P2	Vertigo R	NEW LG Cartouche P1	Fanfare R	Fury R	Fuego R	Boxer R	Maris Bead R
UK Agent see appendix	LSPB	LSPB	LUK	LSPB	LSPB	LUK	Sen	WAC
Yield as % control (5.44 t/ha) 5 year mean	103	103	102	101	99	97	97	85
Agronomic characters								
Flower colour (C=coloured)	C	C	C	C	C	C	C	C
Earliness of ripening	6	7	7	7	8	7	7	6
Shortness of straw	5	5	7	5	7	6	6	4
Standing ability at harvest	8	6	8	7	7	8	7	5
Resistance to Downy mildew	7	6	4	5	6	4	4	7
Seed characters								
Thousand seed weight (g)(@15%mc)	509	564	535	527	512	550	547	388
Protein content (%dry)	27.4	27.6	29.8	28.3	27.8	27.7	27.5	29.3
Year first listed	2016	2013	**2017**	2013	2010	2005	2012	1964

Spring Bean Variety testing specific to Scotland

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PGRO / SRUC variety trials 2011-2013

Control Yield Fury/Fuego 4.78t/ha

Variety (n) = no. of trials	Yield as % control	Maturity 1 = Late 9 = Early	Chocolate spot 1 = susceptible 9 = resistant	Plant Height 1 = short 9 = tall	Brackling 1 = poor 9 = good
Babylon	108	6.7	8.0	7	7
Boxer	103	6.8	7.5	7	7
Fuego	100	6.5	6.5	6	5
Fury	100	6.7	8.0	6	6
Maris Bead	99	6.3	6.0	8	5
Pyramid	103	7.0	7.0	7	7
Fanfare	98(2)	7.0	7.0	6	*
Vertigo	104(2)	6.9	6.5	6	*

Fertiliser for Spring Beans

The fertiliser requirements of beans (kg/ha)				
Soil index# N,P or K	N	P_2O_5	K_2O*	MgO
0	0	100	100	100
1	0	70	70	50
2	0	40	40(2-) 20(2+)	0
>2	0	0	0	0

Soil index (0- vey low; 1 = low; 2 = moderate)

<50kg/ha K_2O should be combine-drilled as germination might be affected

Peas are N fixers, so shouldn't require N fertiliser

(PGRO 2017 Agronomy Guide)

Spring Bean Gross Margin

Spring Beans			
Production level	**Low**	**Average**	**High**
Yield: tonnes per ha (tons per acre)	2.8 (1.1)	3.7 (1.5)	4.6 (1.9)
	£	£	£
Output	644 (261)	851 (345)	1,058 (428)
Variable Costs:			
Seed……………………………………		84 (34)	
Fertiliser………………………………		37 (15)	
Sprays…………………………………		109 (44)	
Total Variable Costs		230 (93)	
Gross Margin per ha (acre)	**414** (168)	**621** (252)	**828** (335)

(Graham Redman, The Anderson Centre 2015)

Pea Varieties RL (2017)

Variety/ type: all varieties are semi-leafless	White peas					Large blue peas								Small blue	Maple peas		Marrowfat peas		
	NEW Karpate P1	Salamanca R	Kareni P2	Mascara R	Gregor R	NEW LG Stallion P1	Bluetooth R	Prophet R	NEW Vertix P1	Daytona R	Crackerjack R	Kingfisher P2	Campus R	NEW Greenwood P1	Mantara R	Rose R	Aikido P2	Sakura R	Genki R
UK Agent: see page 8 for key	Sen	LSPB	Sen	Sen	LSPB	LUK	LSPB	LUK	Sen	Agrii	Dalt	LUK	LSPB	IARA	LUK	Dalt	LSPB	Dalt	Dalt
Yield as % Control (4.81 t/ha) 5 year mean	105	101	101	99	97	102	102	101	100	99	98	97	97	95	93	90	90	88	83
Agronomic characters																			
Earliness of ripening	5	5	5	6	5	5	5	5	4	6	5	6	5	6	5	6	5	5	4
Shortness of straw	5	4	5	5	5	4	5	5	5	5	5	4	4	6	7	5	4	5	5
Standing ability at harvest	6	7	6	4	5	6	5	5	6	6	4	6	8	4	5	5	6	5	6
Resistance to Pea wilt (Race 1)	R	R	R	R	R	R	R	R	R	R	R	R	R	-	R	S	R	R	R
Downy mildew	6	6	6	7	5	6	7	7	7	7	5	6	6	5	7	7	6	5	5
Seed characters																			
Thousand seed weight (g)(@15%mc)	287	265	283	277	298	262	271	290	268	274	287	264	276	253	236	250	373	377	413
Protein content (%dry)	22.4	22.6	23.6	22.0	23.8	22.4	23.5	21.6	23.1	22.4	22.4	21.1	22.5	21.0	22.5	25.2	23.3	23.4	23.8
Year first listed	**17**	11	16	07	09	**17**	15	07	**17**	10	08	16	14	**17**	10	06	16	08	07

Other pea varieties also available with suitability for Scotland

E.g. Zero-4

- Semi-leafless small seeded blue variety
- Very early maturing
  - Northern or late maturing areas
- Straw relatively short
  - Good standing ability
- Good resistance to downy mildew
- Can have lower yields if higher plant density not used (110 seeds/m2)

Fertiliser for Spring Peas

The fertiliser requirements of peas (kg/ha)				
Soil index# N,P or K	N	P_2O_5	K_2O*	MgO
0	0	100	100	100
1	0	70	70	50
2	0	40	40(2-) 20(2+)	0
>2	0	0	0	0

Soil index (0- vey low; 1 = low; 2 = moderate)

<50kg/ha K_2O should be combine-drilled as germination might be affected

Peas are N fixers, so shouldn't require N fertiliser

(PGRO 2017 Agronomy Guide)

Peas Gross Margin

Blue Peas

Production level	Low	Average	High
Yield: tonnes per ha (tons per acre)	3.0 (1.2)	3.75 (1.5)	5.0 (2.0)
	£	£	£
Output	780 (316)	975 (395)	1,300 (527)
Variable Costs:			
Seed……………………………………		99 (40)	
Fertiliser………………………………		38 (15)	
Sprays…………………………………		124 (50)	
Total Variable Costs		261 (106)	
Gross Margin per ha (acre)	**519** (210)	**714** (289)	**1,039** (421)

(Graham Redman, The Anderson Centre 2015)

Rhizobium inoculation (?)

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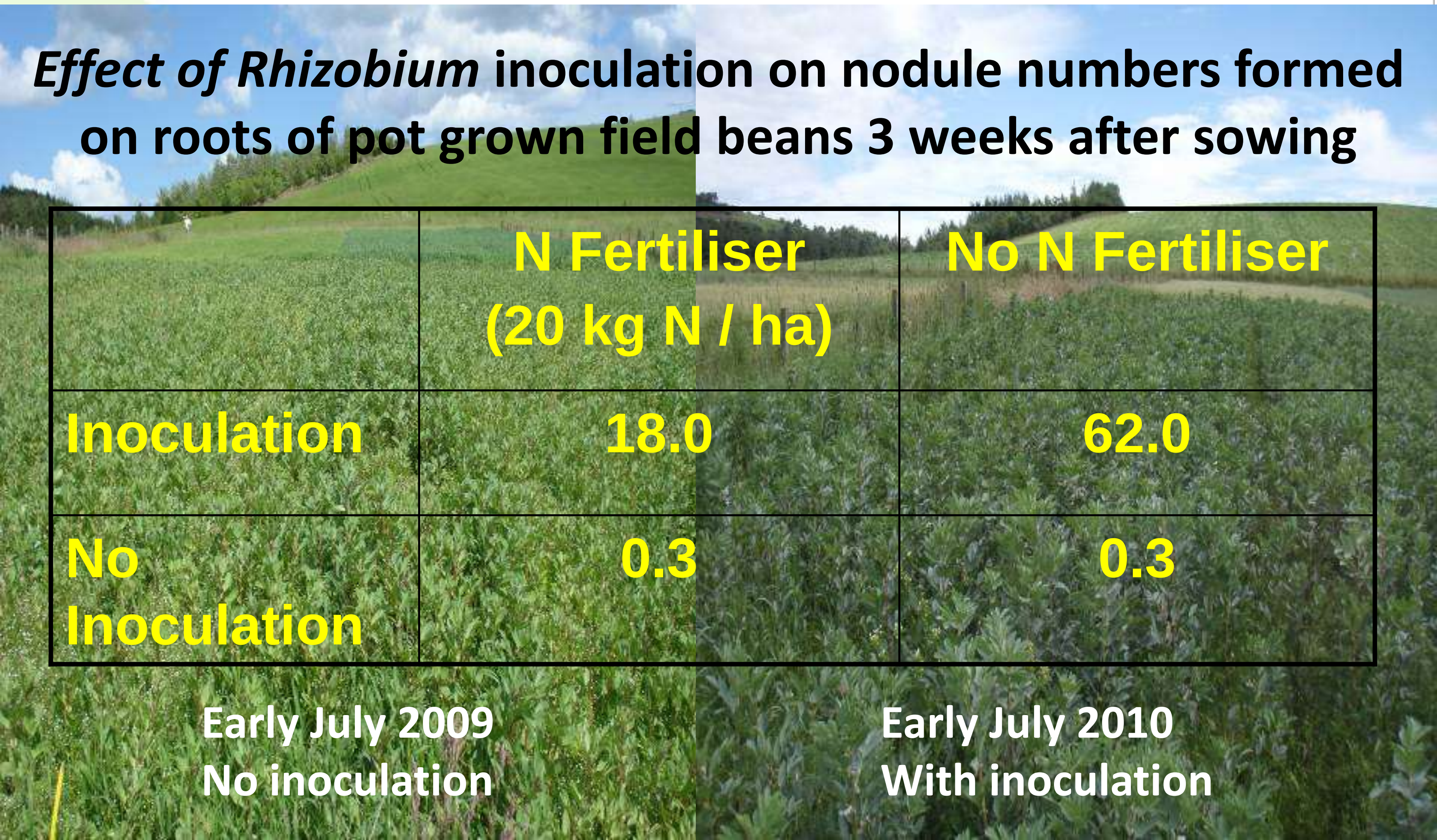
Effect of Rhizobium **inoculation on nodule numbers formed on roots of pot grown field beans 3 weeks after sowing**

	N Fertiliser (20 kg N / ha)	No N Fertiliser
Inoculation	18.0	62.0
No Inoculation	0.3	0.3



Early July 2009
No inoculation

Early July 2010
With inoculation

In field diversity - Intercrops

- **Intercrops with legume component**
  - LER often > 1.2
- **CAP Greening**
  - strict rules – not always sensible!
  - Cover Crops
  - N Fixing Crops
- **Protein Crops**
- **Multifunctional end-uses**

SRUC work on protein crops

- **12 treatments (low input system)**
  - Lupins (one variety, with or without spring barley)
  - Peas (one variety, with or without spring barley)
  - Beans (one variety, with or without spring barley)
  - Soya (4 varieties)
  - Lentils (2 varieties; spring oats as scaffold)
- **Productivity**
  - Grain yields (85% DM)
  - Biomass yields for micro-silage
- **Feeding value**
  - Analysis of micro-silage
  - Pulse use in broiler studies

Peas, beans and lupins

Sole

Inter-cropped

Peas | Beans | Lupins

Lentils (oats as scaffold)

Anicia

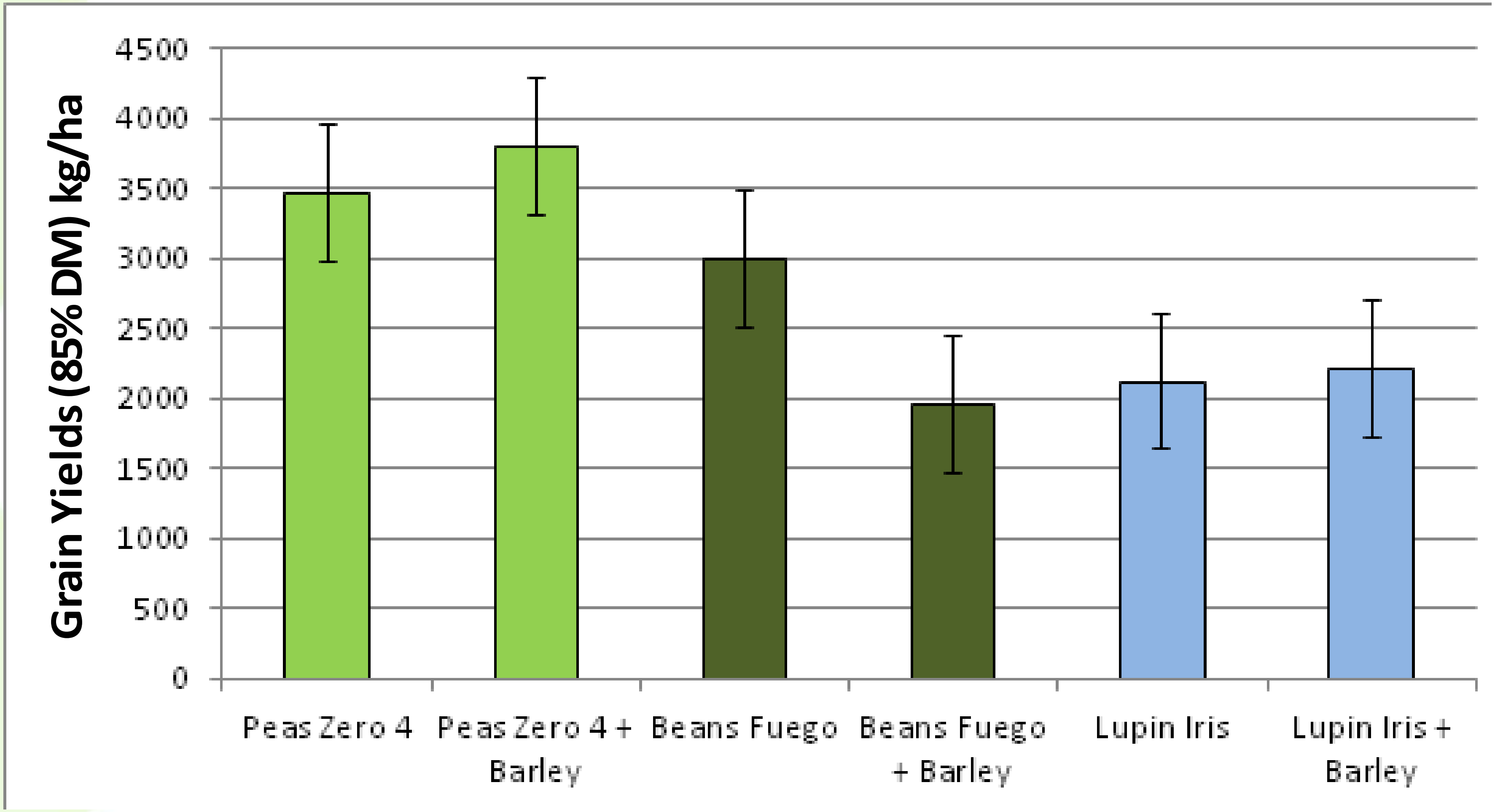
Gotland

Soya .... hmmmmmm

Merlin

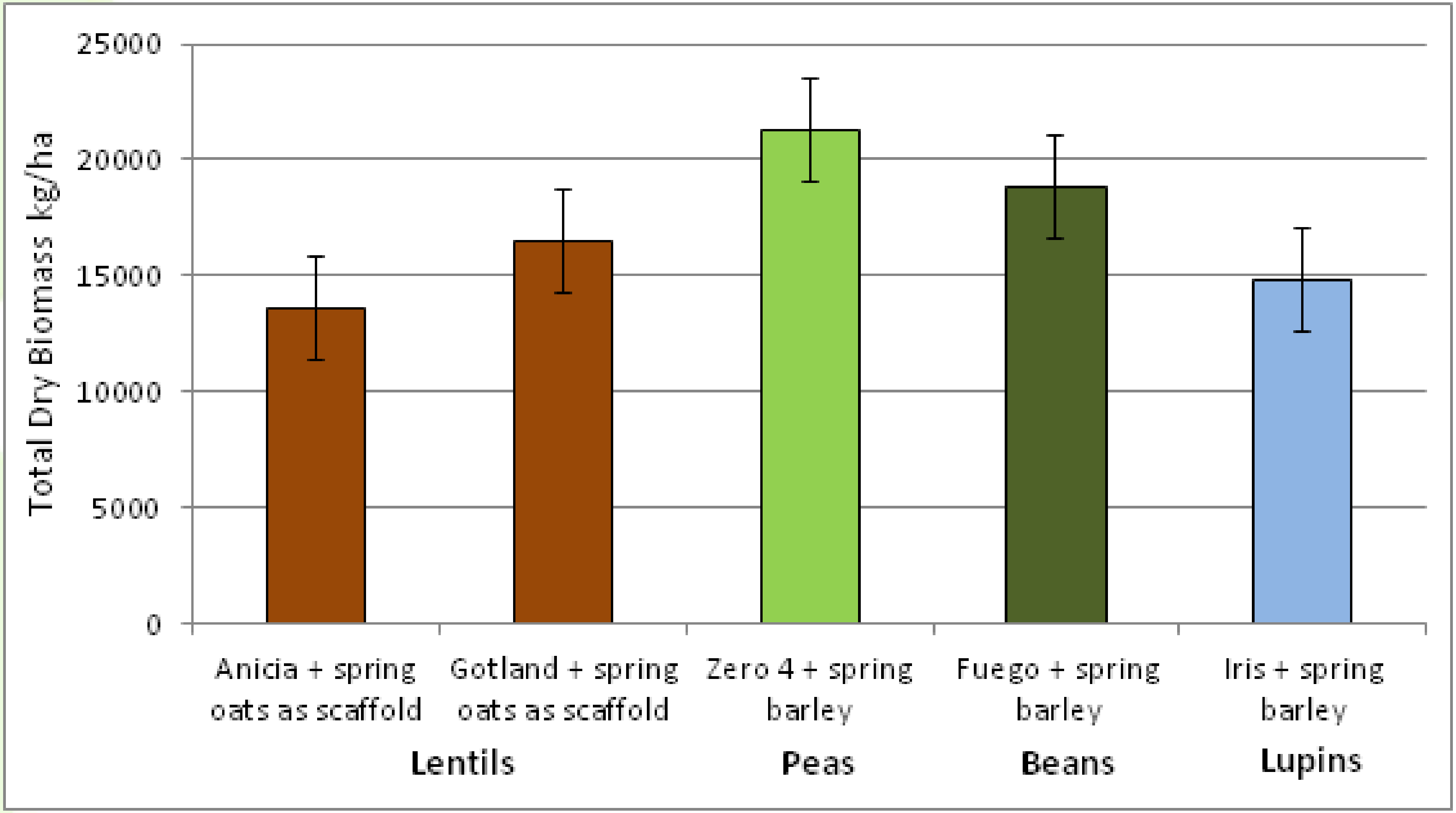
- Merlin
  - maybe try again
- Bohemia (X)
- Protibus (X)
- Sultana (X)

Legume grain yields (total)



(Low input: No fertiliser, no herbicide, no fungicide)

Dry biomass yields (made into micro-silage)



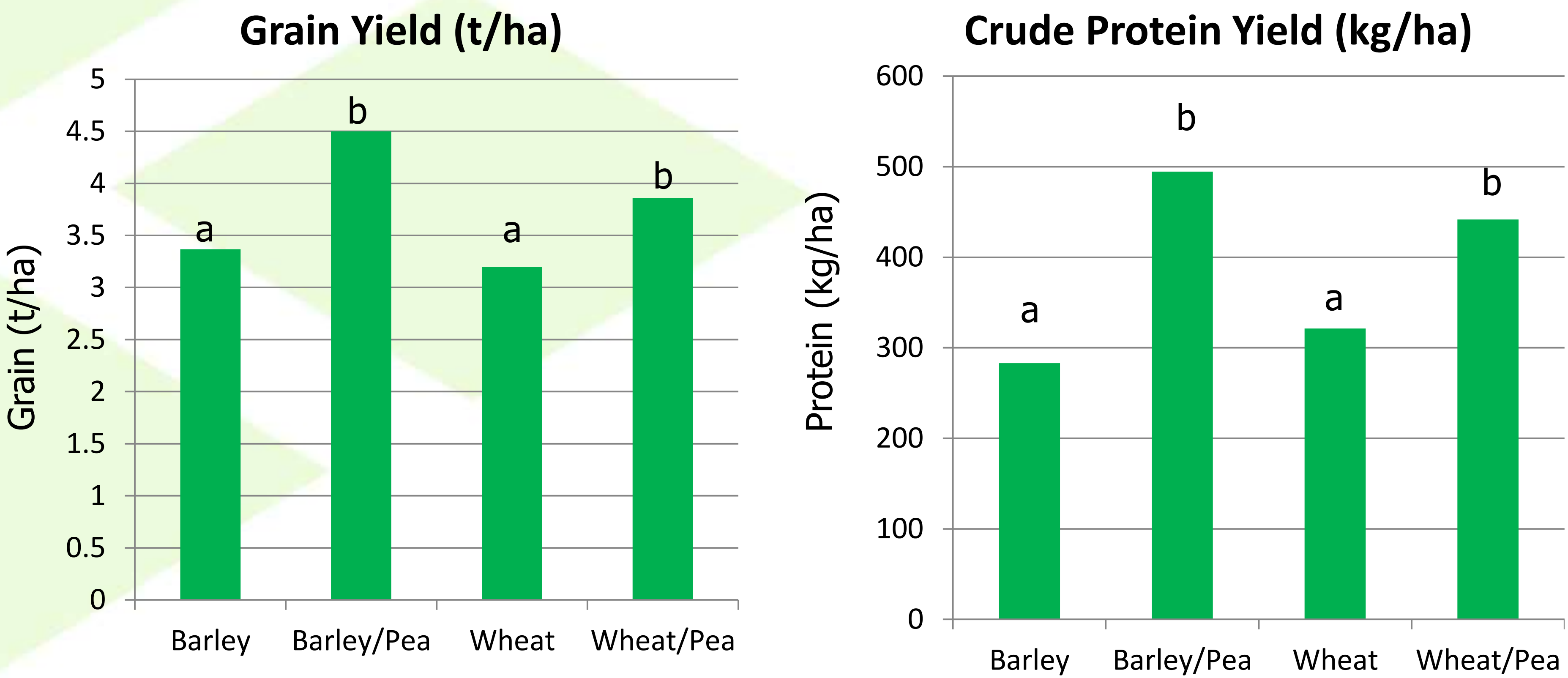
(Low input: No fertiliser, no herbicide, no fungicide)

Intercropping with peas as an option to increase cereal grain protein

- Undertaken on organically certified land
  - In Wales
- Trying to increase protein content of cereals and in particular wheat for bread making quality
  - Intercropped with peas
- Varieties
  - Spring Wheat (Tybalt)
  - Spring Barley (Westminster)
  - Pea (Prophet)

Intercrops: Grain & protein yield

- LER (Land equivalence ratio) ~ 1.2
- Intercropping increased protein in barley grain but not wheat BUT did increase protein on an areas basis

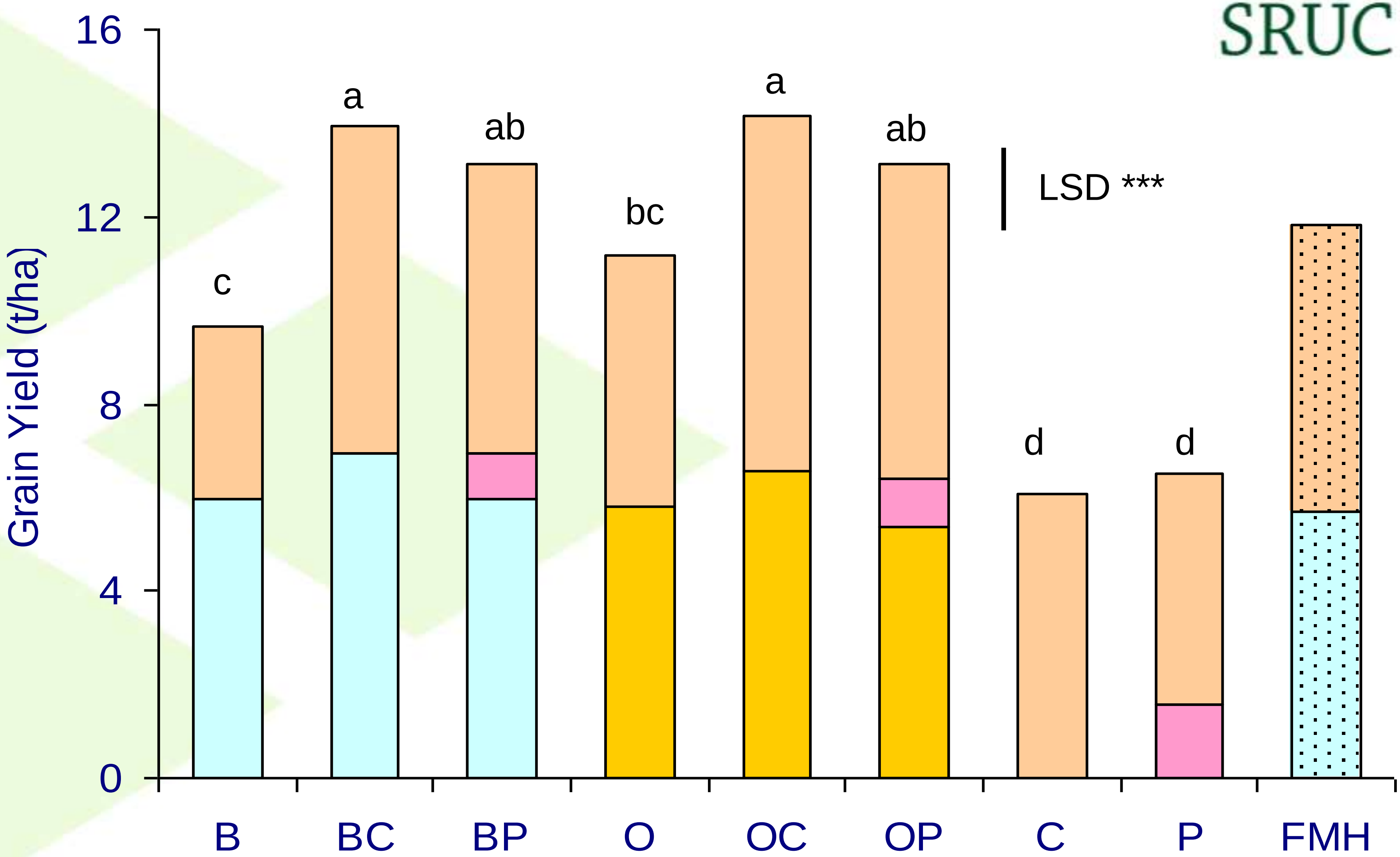


John Faulconbridge (SRUC MSc thesis)

What does this all mean?

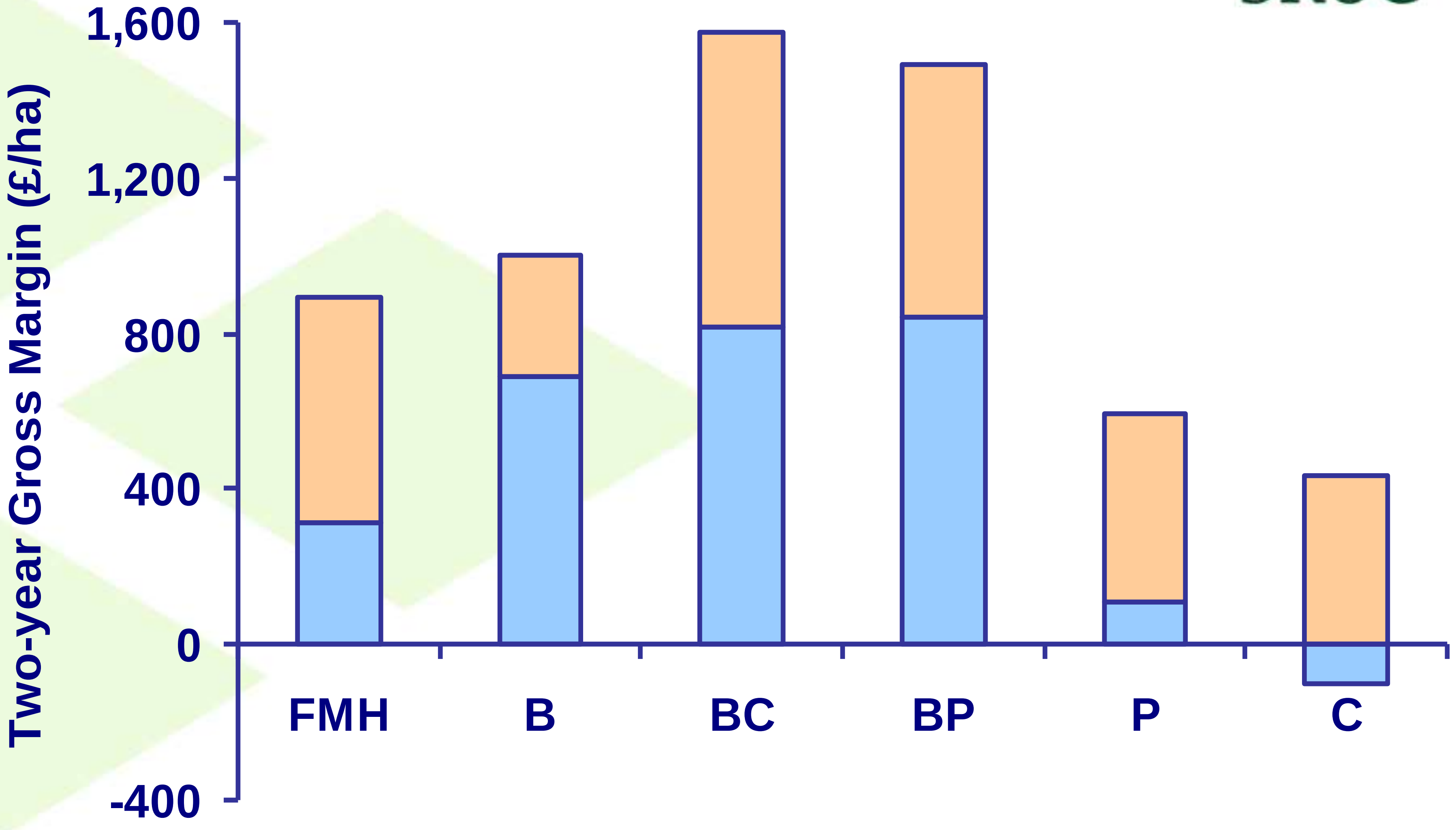
- Need to take into account several factors
  - Yield (LER) of intercrops
  - Yield impact on following crop
  - Impact on quality (e.g. protein content)
  - Can influence Gross Margins across more than one year

Total Grain Yields – both years



P = Pea; C = Clover; B = Barley; O = Oat, FMH = conventional reference

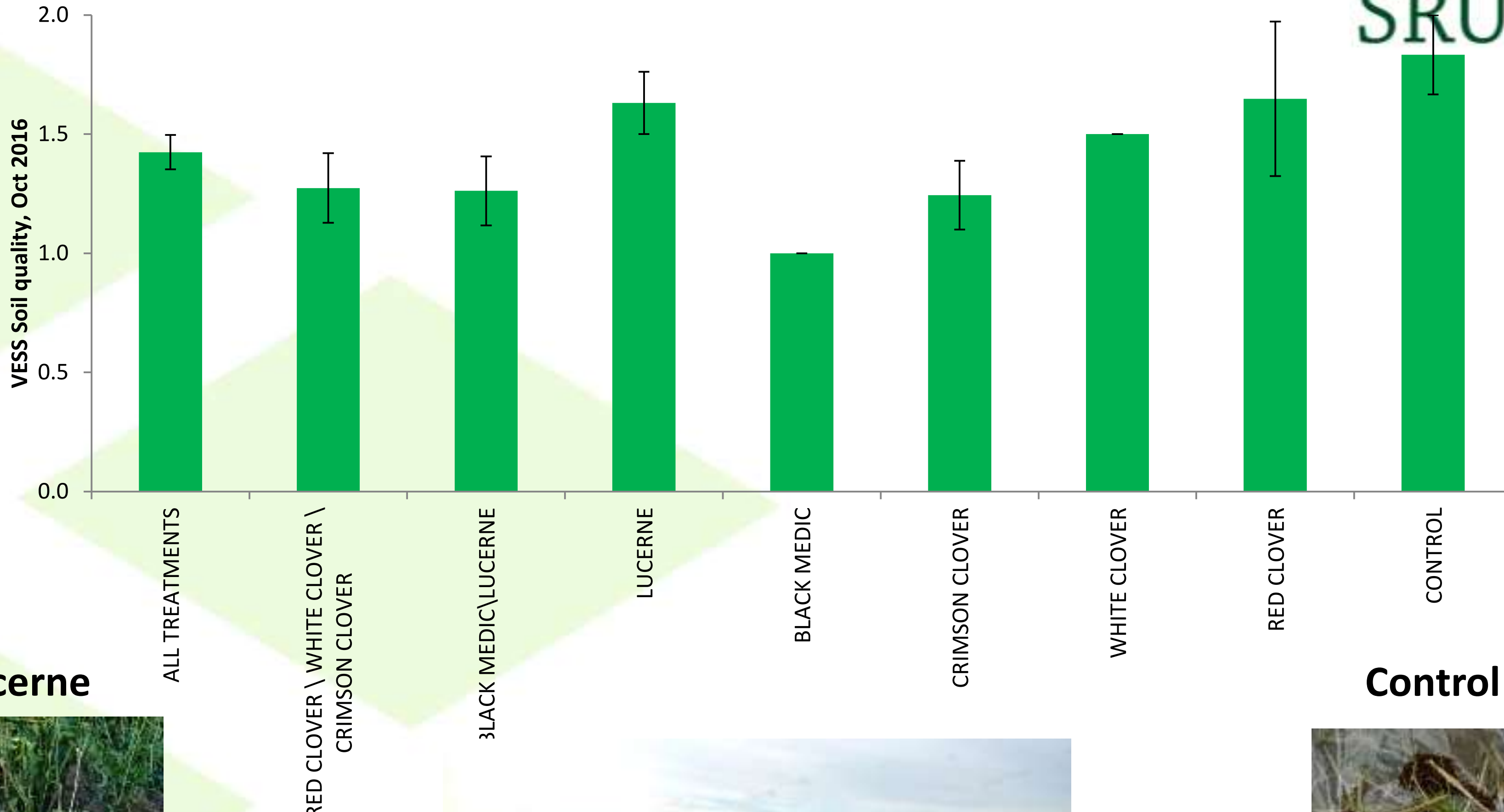
Gross Margins



P = Pea; C = Clover; B = Barley; FMH = conventional reference

Structure quality	Size and appearance of aggregates	Visible porosity and Roots	Appearance after break-up: various soils	Appearance after break-up: same soil different tillage	Distinguishing feature	Appearance and description of natural or reduced fragment of ~ 1.5 cm diameter
Sq1 Friable Aggregates readily crumble with fingers	Mostly < 6 mm after crumbling	Highly porous Roots throughout the soil			 Fine aggregates	 The action of breaking the block is enough to reveal them. Large aggregates are composed of smaller ones, held by roots.
Sq2 Intact Aggregates easy to break with one hand	A mixture of porous, rounded aggregates from 2mm - 7 cm. No clods present	Most aggregates are porous Roots throughout the soil			 High aggregate porosity	 Aggregates when obtained are rounded, very fragile, crumble very easily and are highly porous.
Sq3 Firm Most aggregates break with one hand	A mixture of porous aggregates from 2mm -10 cm; less than 30% are <1 cm. Some angular, non-porous aggregates (clods) may be present	Macropores and cracks present. Porosity and roots both within aggregates.			 Low aggregate porosity	 Aggregate fragments are fairly easy to obtain. They have few visible pores and are rounded. Roots usually grow through the aggregates.
Sq4 Compact Requires considerable effort to break aggregates with one hand	Mostly large > 10 cm and sub-angular non-porous; horizontal/platy also possible; less than 30% are <7 cm	Few macropores and cracks All roots are clustered in macropores and around aggregates			 Distinct macropores	 Aggregate fragments are easy to obtain when soil is wet, in cube shapes which are very sharp-edged and show cracks internally.
Sq5 Very compact Difficult to break up	Mostly large > 10 cm, very few < 7 cm, angular and non-porous	Very low porosity. Macropores may be present. May contain anaerobic zones. Few roots, if any, and restricted to cracks			 Grey-blue colour	 Aggregate fragments are easy to obtain when soil is wet, although considerable force may be needed. No pores or cracks are visible usually.

VESS scores: nitrogen-fixing cover crop plots (SRUC Aberdeenshire)



Lucerne

Control

Intercrop Conclusions

- The yield and environmental benefits of intercrops may not be apparent in the year of growth
- May show in quality aspects as well as productivity
- Multi-year perspective vital
- Intercropping offers a pathway to increase productivity and reduce adverse environmental impacts of agriculture whilst promoting diversity, a key measure in CAP “greening”.

Protein crops produced, where can they be utilised?

Recent and current SRUC work on protein crops and feeding trials

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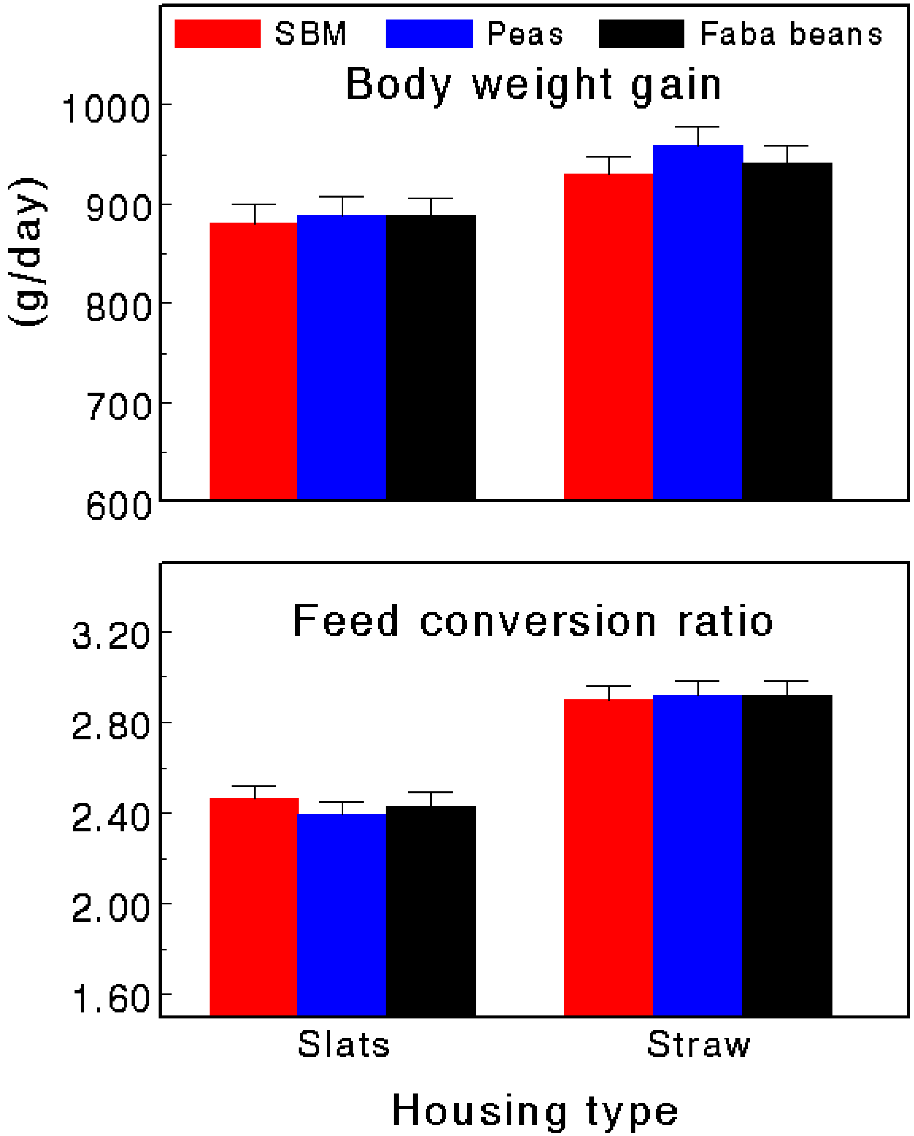
- Feeding value of micro-silage being assessed
  - NIR (whole crop scan):
    - DM, D-value, ME, CP, NDF, WSC, Oil Ash, TFA, pH, Lactic Acid, Ammonia
  - Underpinned with wet chemistry
  - Watch this space

- Plans for Year 2 of protein crop work are under development
  - Including continuing work on micro-silages
- Making use of grain beans and lupins from Year 1
  - Feeding trial (broilers)
  - Antimicrobial assessments (*in vitro* and *in vivo*)

Small scale studies

- Peas and faba beans can completely replace SBM in nutritionally balanced grower and finisher pig diets
- Compared to SBM controls, diets with 30% peas or faba beans resulted in similar performance, N-balance and carcass traits (e.g. P2)
- Popular myths surrounding pea and faba bean use have been debunked
  - No detrimental effects on skatole and faecal DM contents

Large scale confirmation



- Using >1200 pigs, feeding treatment did not affect gain, intake (not shown) or FCR
- Clear effect of housing type
  - Pigs on slats grew and ate less at better FCR than pigs on straw

Pulses and older pigs

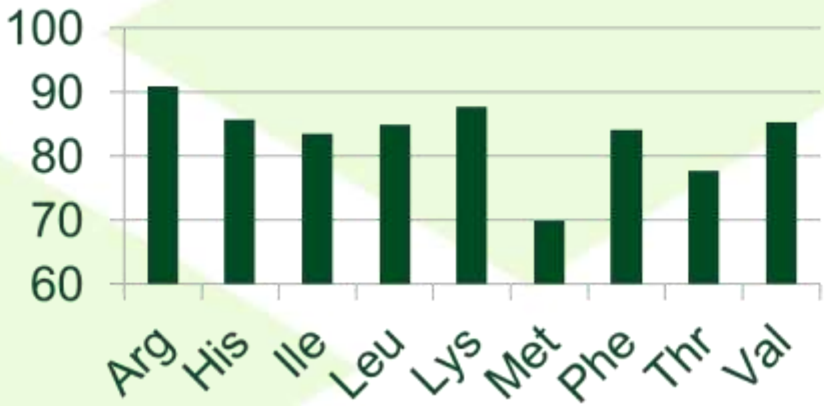
Provided that commercial availability constraints can be overcome,

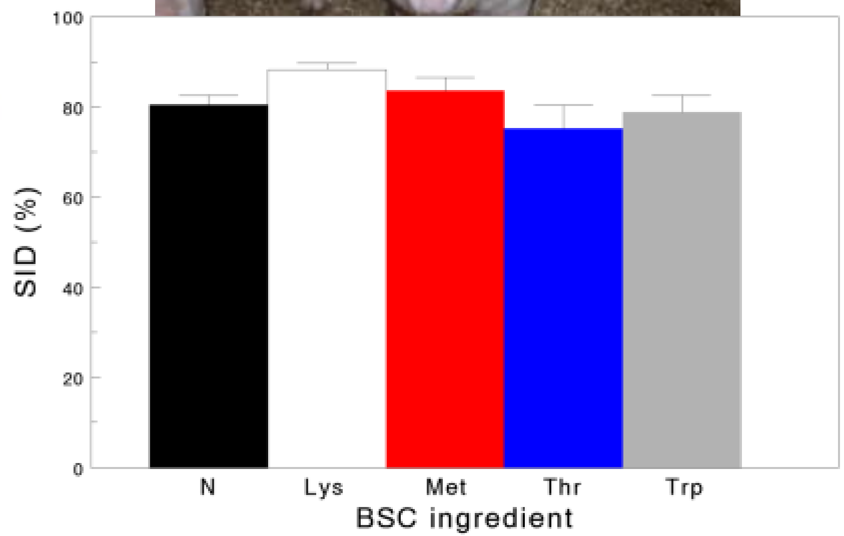
peas and faba beans are viable home grown alternatives to SBM in nutritionally balanced diets for grower and finisher pigs

Bean fractions

- Feedstuffs may be separated in different fractions based on particle weight through air classification
- Air fractionation of dehulled faba beans results in two fractions:
  - Bean protein concentrate
  - Bean starch concentrate (BSC)
- BSC has moderate residual protein levels
- Nutritional value determined for poultry and pigs

Ileal digestibility in broilers and pigs

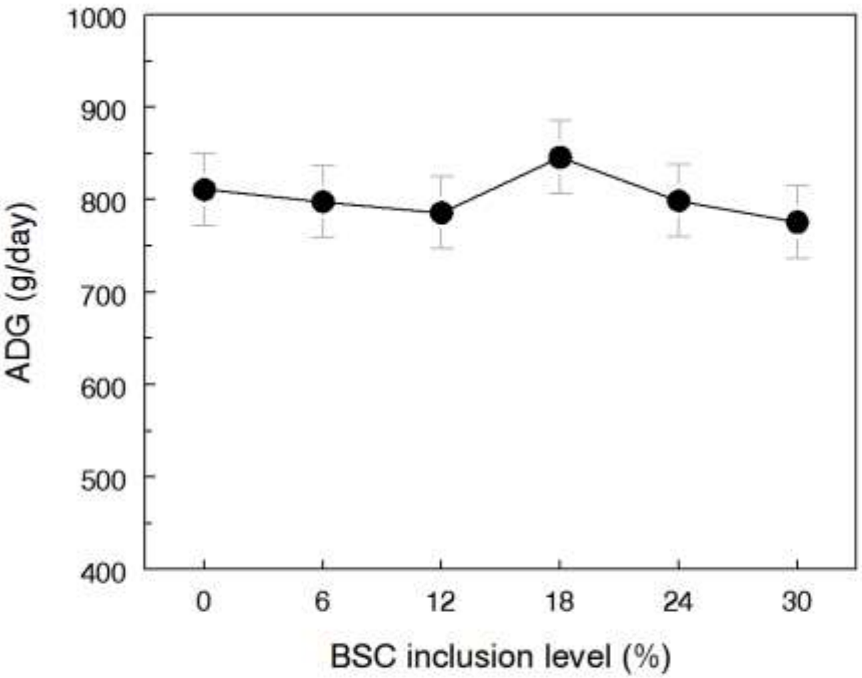


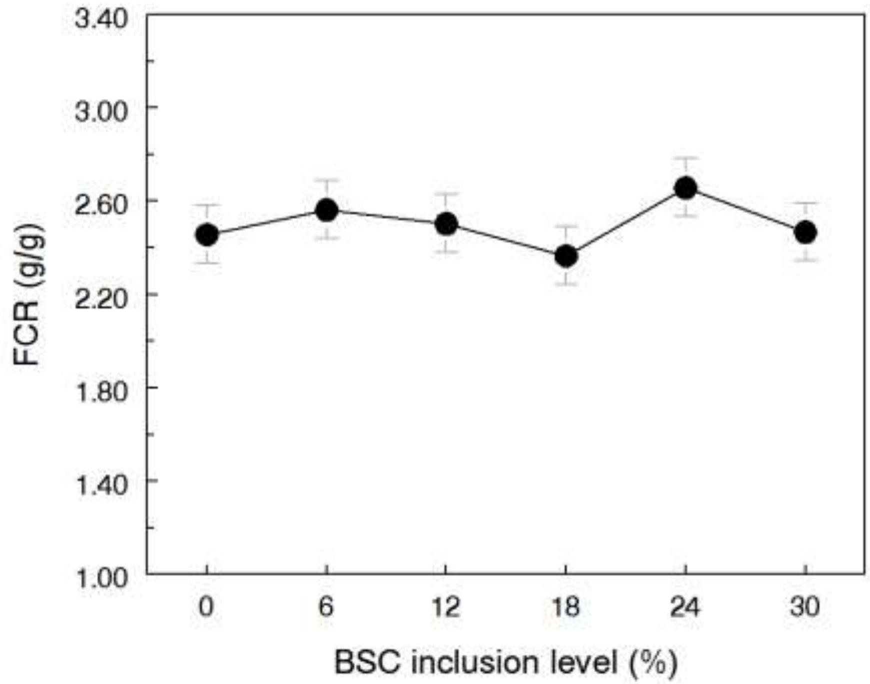


Standardised digestibility for essential amino acids ranged from 70 to 90%

Pig performance on bean fractions

- Gradual exchange against SBM did not impair grower pig performance
- As for whole peas and beans, BSC may assist to reduce reliance on SBM





Current feeding trials

- **Preliminary nutritional value evaluation**
  - **Young broilers** (0-21 day of age; trial is at day 10)
    - Lupins, beans, and bean/barley intercropping
    - Exchanged against soya bean meal
  - **Read outs**:
    - Growth performance and apparent ileal nutrient digestibility
    - Microbial assessment of digesta for key bacterial species
- **Challenges**
  - Trade-off benefits of anti-microbial properties and SBM replacers with costs from anti-nutritional factors
  - Dose-response required under varying conditions
  - Test product volume limitations

Future work (Year 2)

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- Focus is broilers and potentially weaner pigs
- Explore nutritional value of quinoa
  - Target is human nutrition
  - If out of spec, pigs and poultry may be alternative
- Dose-response for upper limit of SBM replacement
- Grass protein / other forage species
  - Novel crop?
  - Extract protein prior to anaerobic digestion
    - Significant levels of protein (~38% in DM)
  - If feasible, great potential
    - Protein nutritional value as SBM replacer
    - Potential benefits to fatty acids / egg quality

Conclusions

- Great potential to utilize more home grown protein sources, based on historic evidence and current work going forward
- Knowledge gaps:
  - How can farmers reliably grow "standard" home grown protein crops?
  - Can intercropping cereals with legumes to produce novel whole crop silage with greater levels of protein reduce reliance on concentrate supplementation?
  - Optimal level of bioactive alternative feed ingredients for more sensitive stock (broilers, weaner pigs)
  - Use of novel sources e.g. grass protein, quinoa, others

Bean Yield Challenge


PULSE PROGRESS

DEADLINE EXTENDED TO

PGRO

BEAN YIELD Challenge

GROWING A 10T/HA FIELD BEAN CROP BY 2020

A generation ago, the Ten Tonne Club for wheat helped to change the aspirations of the best growers to their wheat growing.

THE RULES

GROWING A 10t/ha FIELD BEAN CROP BY 2020

- PGRO believe it is now time to do the same for the bean crop that has been done for wheat in the past
- Any UK-based grower of any commercial UK-grown grain crop and will run annually until crop 2020 – or until the first 10t/ha crop is validated

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Thank you for your attention!

Thank-you also to Scottish Government RESAS for providing funding towards this work programme

The Scottish Government
Riaghaltas na h-Alba