Pulse grower: Soil Health Hero or Villain?

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Soil health is …

- a term used to assess the ability of a soil to:
  - Sustain plant and animal productivity and diversity;
  - Maintain or enhance water and air quality; and,
  - Support human health and habitation
- a critical component of a sustainable production system

Do pulse crops influence soil health ?

Focus on two indicators:

1) Soil organic carbon status (SOC)
2) Nitrous oxide emissions (N_2O)

- Why SOC ?
  - central component of soil health
  - important to nutrient supply, soil structure, biological activity, disease suppression
- Why N_2O ?
  - principle greenhouse gas produced from farming practices
  - Integral aspect of soil N cycling

Field Pea Frequency Study

- Established in 1995 at the Indian Head Research Farm

  ("thin" black, heavy clay soil)

- Three rotations with varying frequencies of field pea:

  1) continuous pea, 2) wheat-pea, and, 3) wheat-wheat-pea

- Wheat crops received recommended rates of N & P

- Soil samples collected in the fall of 1994 prior to the start of the study and again in 2005 (after ten years) to assess changes in SOC status.

- Nitrous oxide (N_2O) sampling underway since 2004

Soil organic carbon status on three rotations at Indian Head

Year	Pea-wheat	Cont. Pea	Wheat-Wheat-Pea	p-value
		kg C ha^{-1}		
	0-15 cm			
1994	19002	16253	16514	0.008
2005	20141	18002	19210	0.068
Difference (2005-1994)	**1139**	**1749**	**2696**	0.03
	15-30 cm			
1994	19542	19327	20006	ns
2005	21148	22297	20920	ns
Difference (2005-1994)	**1606**	**2970**	**913**	ns
	0-30 cm			
1994	38543	35580	36520	ns
2005	41289	40299	40130	ns
Difference (2005-1994)	**2746**	**4719**	**3610**	-

Soil Organic Carbon change

$$\Delta SOC = C\ added - C\ lost$$

Where:

C added = crop residue C

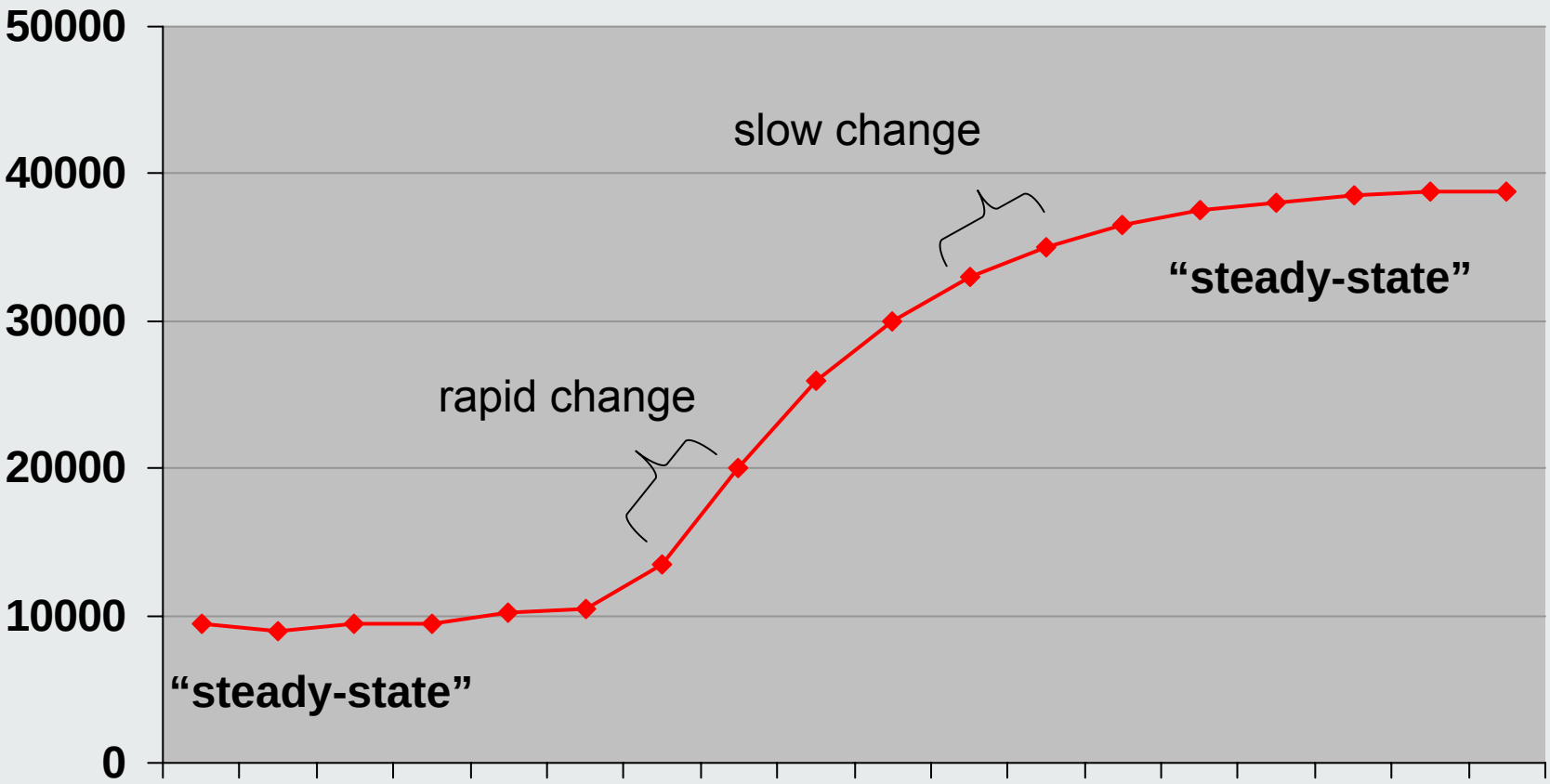
C lost = decomposition of residue C + existing SOC

Soil organic carbon status and residue carbon additions for two rotations at Indian Head, SK.

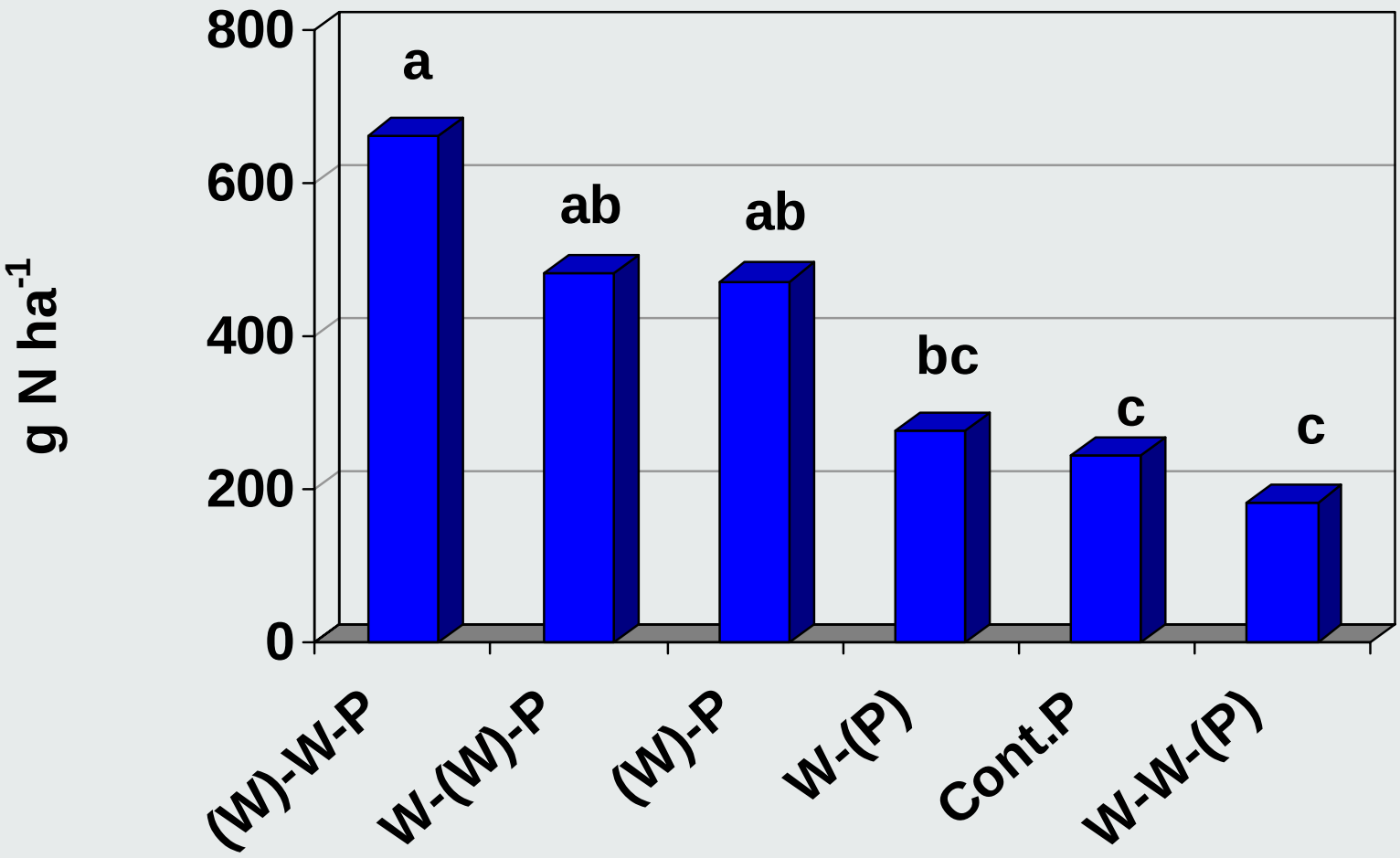
Year	Pea-wheat	Cont. Pea
	kg C ha^{-1}	
1994	38543	35580
2005	41289	40299
Difference (2005-1994)	2746	4719
Carbon Inputs [z] (1994-2005)	24037	21576
Residue C stabilized	11 %	22 %

[z] carbon inputs estimated using grain yield data and assuming a harvest index of 0.36 and a root:shoot ratio of 0.27

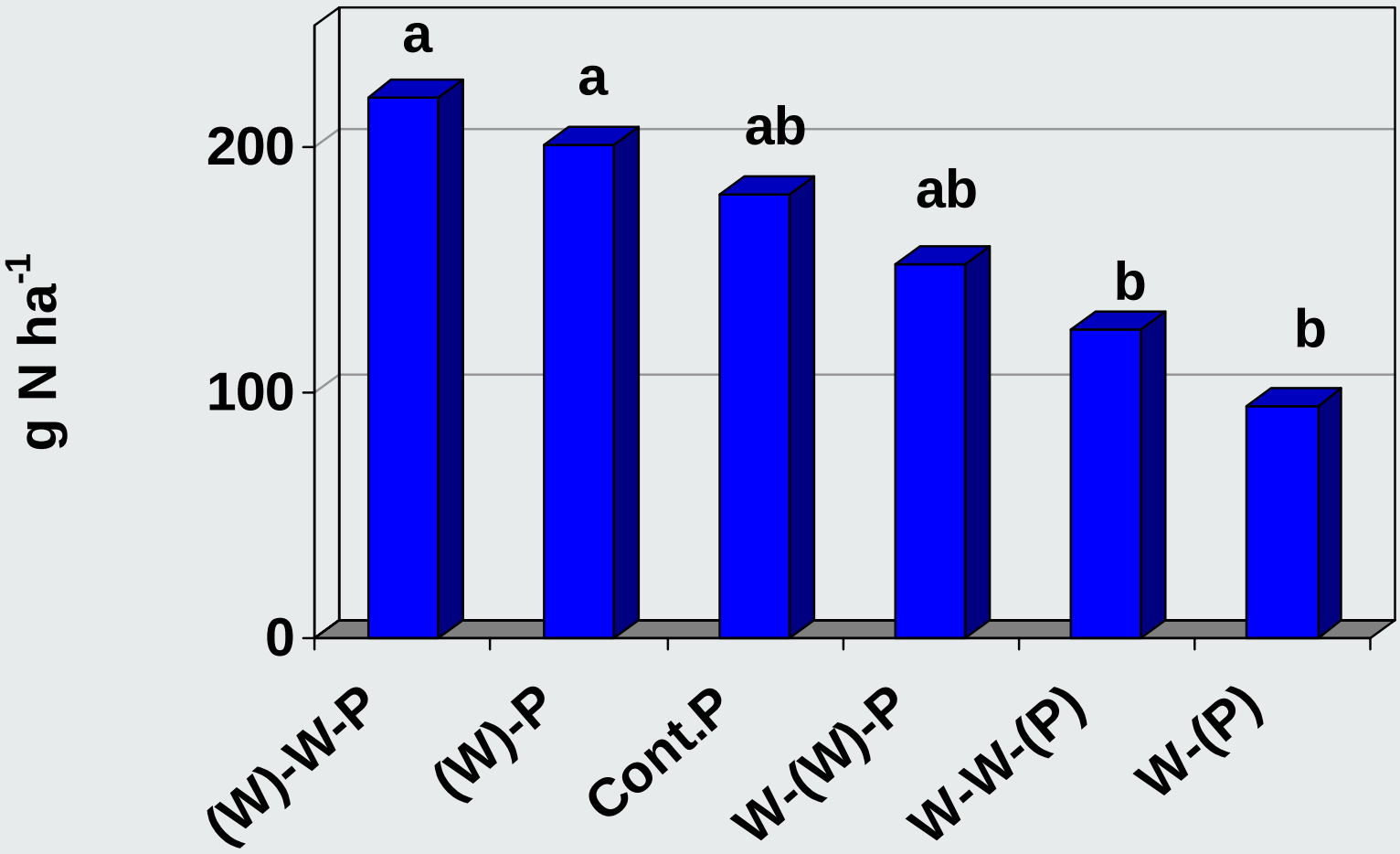
Conceptual representation of Soil Organic Carbon change due to a change in farm practice and/or environmental conditions



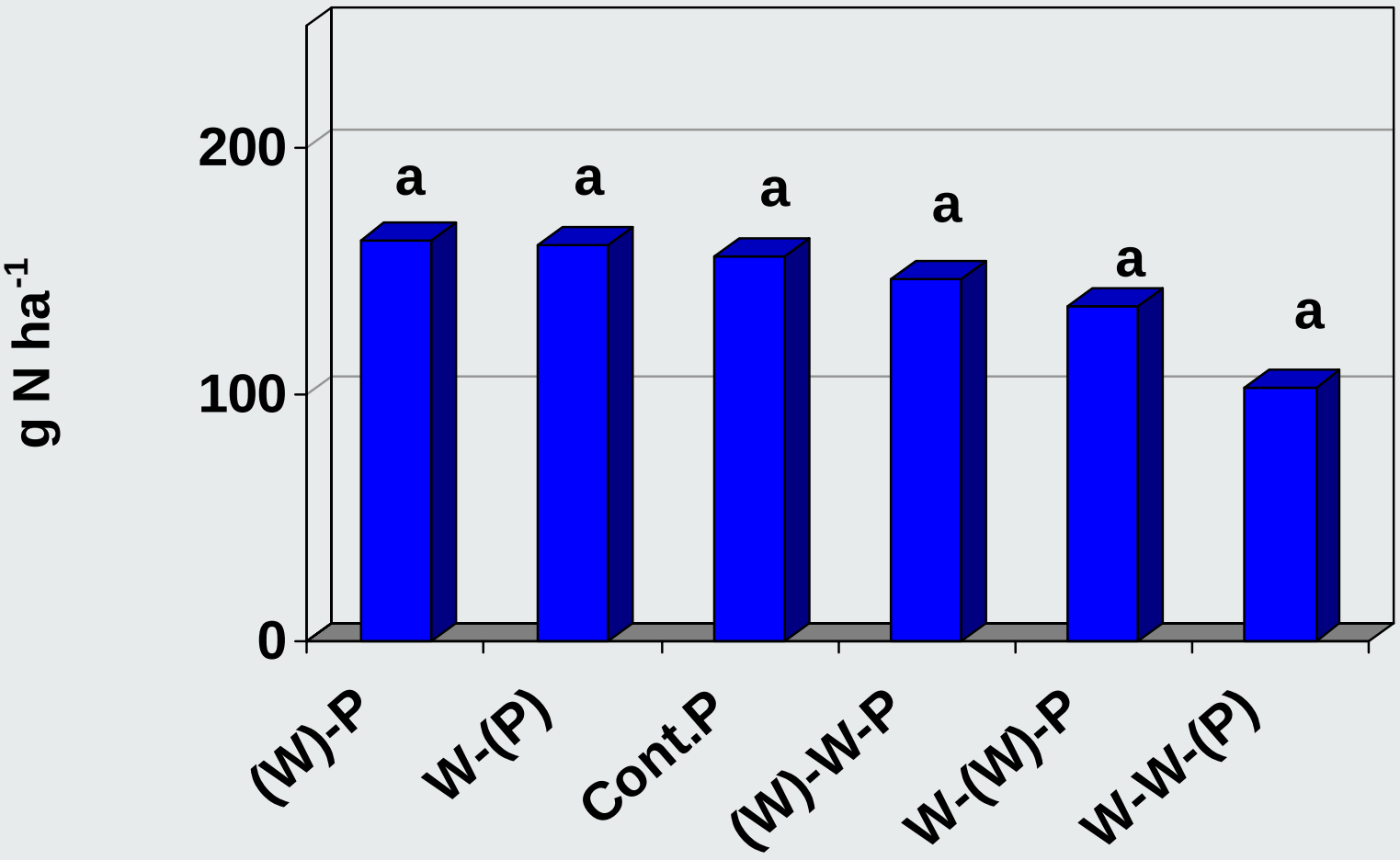
Cumulative N_2O loss during the 2004-2005 experimental cycle



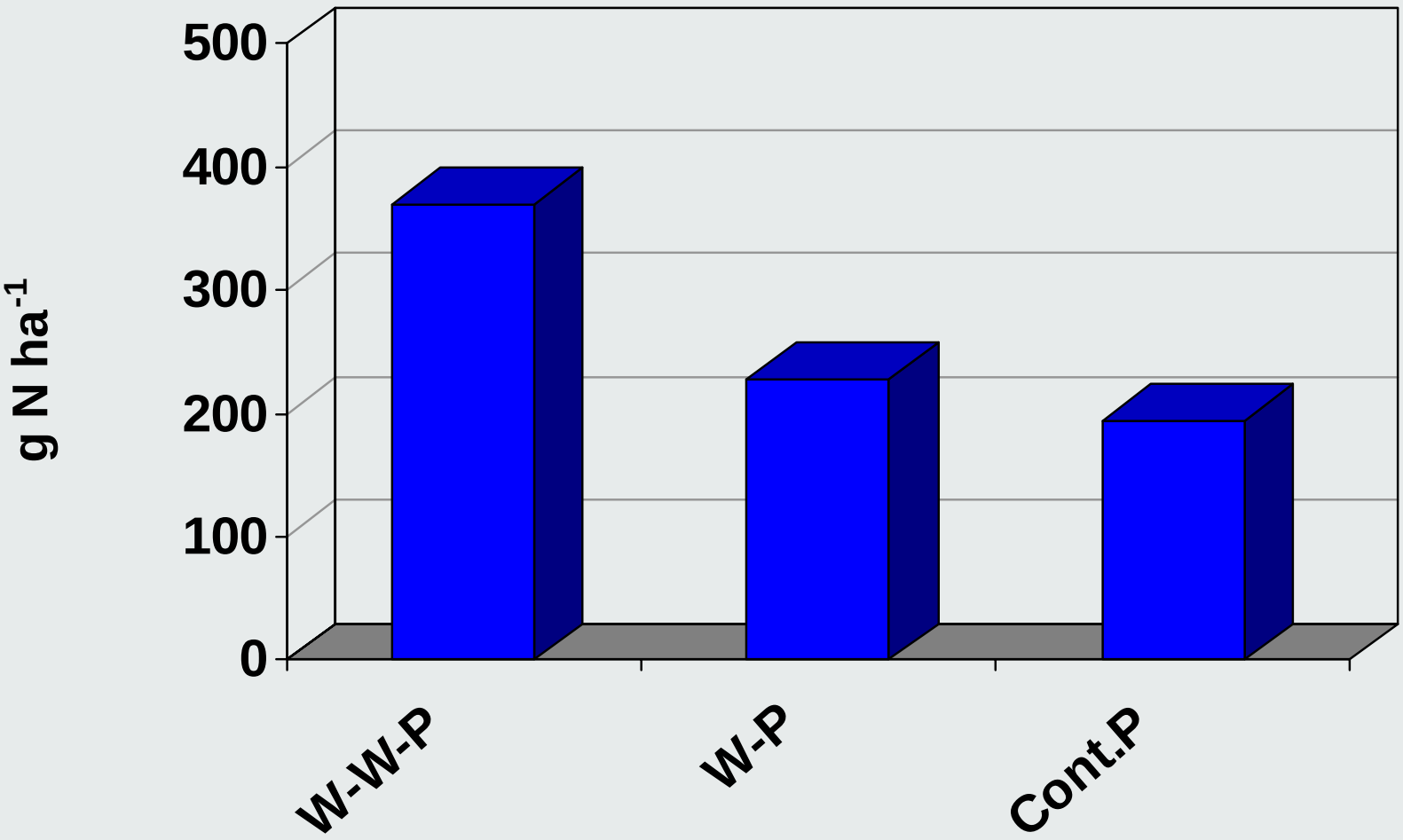
Cumulative N_2O loss during the 2005-2006 experimental cycle



Cumulative N_2O loss during the 2006-2007 experimental cycle



Mean yearly N_2O loss by rotation (2004-2007)



Conclusions

- Soil carbon levels increased with increasing frequency of field pea during the study period
- The changes in soil carbon may have been confounded by other factors, but results do suggest that field peas have favorable influence on SOC
- Increased SOC means decreased atmospheric CO_2
- Nitrous oxide emissions tended to decrease as field pea frequency increased
- Based on these two indicators, field peas had a beneficial influence on the sustainability of cropping systems at this location

Thank you for your kind attention!!!

Rotational Benefits of Green Crops

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BB F 4242

How to attain Farm Profitability

- Rank the following:easiest to hardest
  - Increasing yields
  - Getting higher than average prices
  - Reducing costs
  - Reducing tillage
  - Increasing planting intensity
  - More rented acres
  - Bigger farm size

How to attain Farm Profitability

- Easiest to hardest
  - Reducing costs
  - More rented acres
  - Increasing planting intensity
  - Bigger farm size
  - Reducing tillage
  - Increasing yields
  - Getting higher than average prices

Terry Kastens, Kevin Dhuyvetter, 2005 Kansas State University Study
800 farms, over 10 years: 1995-2004

Reduce costs

- Reduced purchased nitrogen
- Reduced weeds

Quote from L.H. Bailey 1910

- Some farmers are always asking how to kill weeds, as if this were the chief end of farming. But good farmers seldom worry about weeds, because the management of the farm that makes the land the most productive is also the one which prevents the weeds from gaining a foothold.

Quote from John Bracken 1921

- In a sense farming is a continual warfare against weeds, the contending forces being people and crops on the one side and weeds on the other, with nature the neutral onlooker, but one ready to lend her aid to the side showing the greatest persistence.

John Bracken (continued)

- A knowledge of the habits of weeds places man in an enlightened position in the struggle. It remains only for him to create conditions favorable for the one and unfavorable for the other.

Conditions that favor the crop

- Low disturbance seeding
- Low nitrogen fertilizer in pulse year
  - Reduced weed numbers by up to 50%
  - Reduced weed seed size
  - Therefore reduce weed vigor the next year
- Well placed fertilizer to favor the crop

Source: Kimberly Tungate et al, Altered weed reproduction and maternal effects Low nitrogen fertility, Weed Science, 54:847 (2006)

Common Farm Product: High Quality Energy

- Energy in/out of different systems

Rotation	treatment	energy out/in
WPWF	organic	10.4
WPWF	conventional	6.8
WAAF	organic	11.9
WAAF	conventional	7.4

J.W.Hoeppner, M.H.Entz, Energy use and efficiency in two Canadian Organic and conventional crop production systems, Renewable agriculture and food systems 19(2): 1-8

Manitoba Zero Till Research Farm

Crop in rotation	Energy Out/In
Flax	5.4
Spring wheat	6.7
Winter wheat	6.9
Canola	7.0
Peas	20.6

M. Khakbazan, A.Moulin, and C.Hamilton, Economics of Mixed Crops and Livestock Production at the Manitoba Zero Till Farm (2005)

Grain: 23,490,000 BTU/acre

Minus dockage 2%: 470,000 BTU/acre

Straw: 21,325,000 BTU/acre

Chaff: 3,915,000 BTU/acre

Total energy/acre not sold: 52%

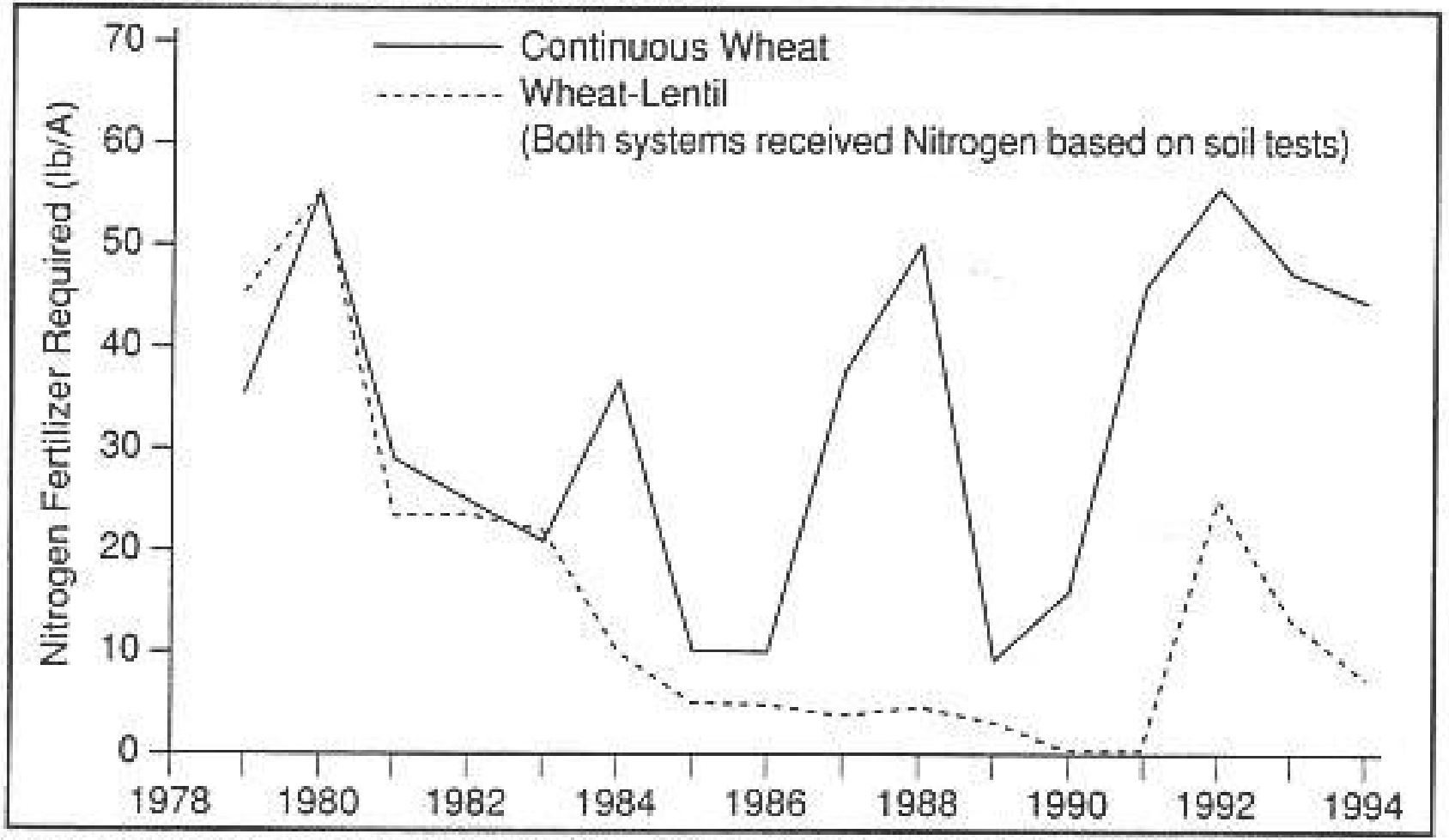
Soil Improvement

- Enhance N supplying power of the soil
- Increase soil reserves of organic matter
- Stimulate soil biological activity
- Improve soil structure
- Increase soil aeration
- Improve soil water holding capacity
- Make soil easier to till (or seed into)

http://www.agriculture.gov.sk.ca/Default.aspx?DN=4b50acd7-fb26-49a9-a31c-829f38598d7e

Soil Improvement

Figure 4. Effect of Grain Legume in Rotation with Wheat on N Fertility of a Loam at Swift Current, Saskatchewan



Source: adapted from C.A. Campbell et al., Can J. Plant Sci., Volume 72:1091-1107 (1992)

Increase planting intensity

- Use “shoulder” periods
  - Relay legume in winter wheat
- Intercropping
  - Overyielding: peas and canola
- Catch crops after peas to hold nitrogen
  - N losses: MAC 2007 Mario Tenuta’s talk

Increase diversity, increase yield

Crop Sown	Previous Crop (Stubble)					
	RS Wheat	Barley	Oats	Arg. Canola	Flax	Field Peas
	Relative Yields (% of Average)					
RS Wheat	90	98	99	106	103	108
Barley	101	88	97	105	107	107
Oats	99	90	87	108	107	100
Arg. Canola	100	101	103	88	104	113
Flax	102	102	101	92	69	NSD*
Field Peas	101	101	93	89	82	NSD

Manitoba Agricultural Services Corporation, www.mmpp.com

Grow Your Own Nitrogen

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AAFC Lethbridge Research Station

What we know….

- Well-inoculated pulse crops have the potential to fix significant quantities of N
- The amount of N fixed depends on a variety of factors including fertilizer/soil N availability, inoculation success, and crop health
- Most well-inoculated pulse crops fix enough N to meet crop requirements

Pulse Crop Benefits

- Well-documented positive effects of including pulses in rotation (e.g., Beckie et al. 1997; Stevenson and van Kessel 1997; Miller et al. 2003, 2005; Bullied et al. 2002; Przednowek et al. 2004)
- Rotation benefits typically attributed to ‘N benefits’ (i.e., enhanced N availability) and ‘non-N benefits’ (e.g., disease and weed break)

What we assume….

- The N benefit is due to N fixation
- Pulse crops fix more than enough N required to maximize production, and then some (????)
- Pulse crops lead to a positive soil N balance, i.e., growing pulses increases the amount of N left in the soil (????)

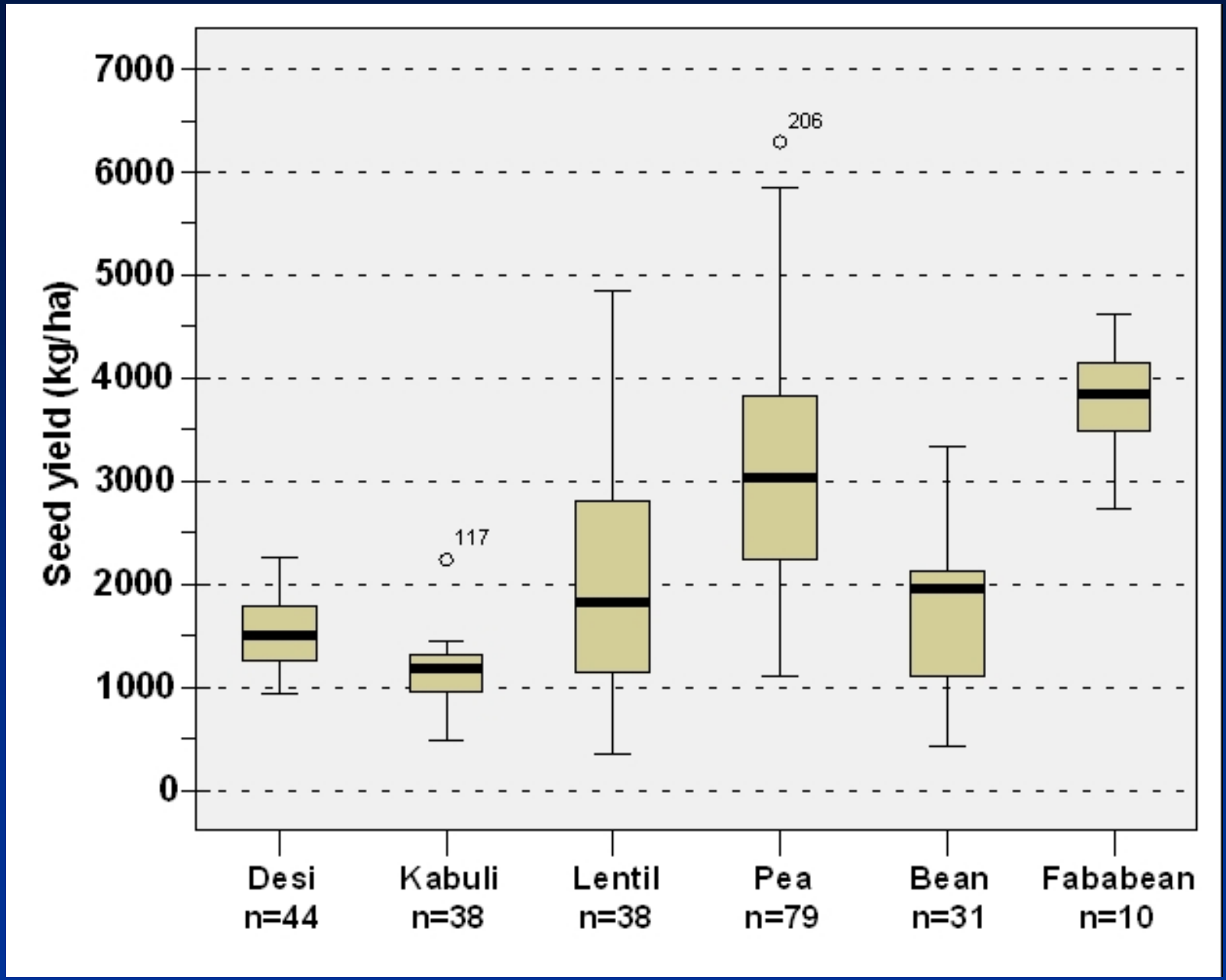
Can we grow pulses to grow N?

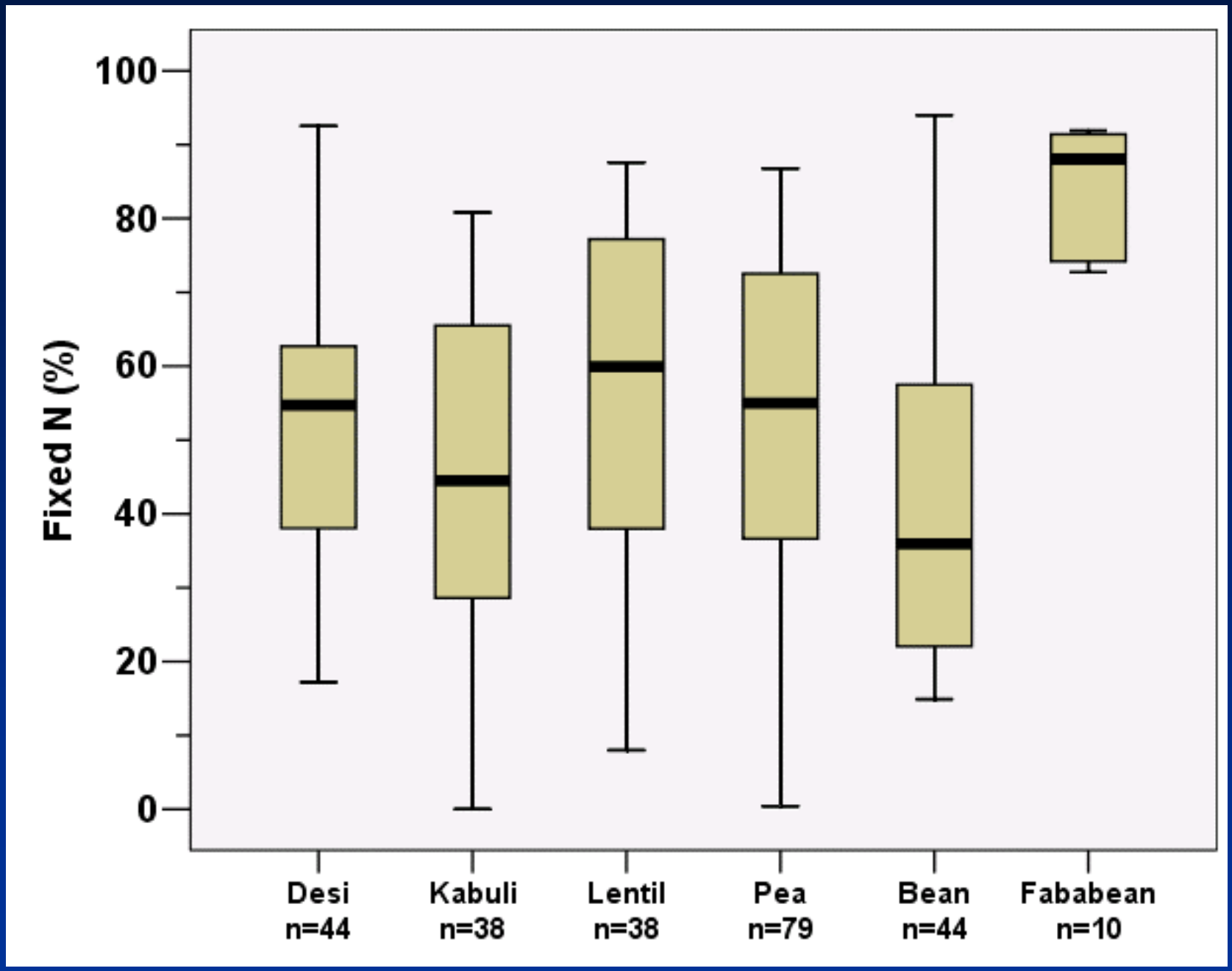
- How much N do pulses fix?
- Is the pulse being grown as a green manure plow-down or for grain production?
- How much N is harvested in the grain (and thereby exported from the cropping system)?
- Relationship to soil N testing – “N credits”

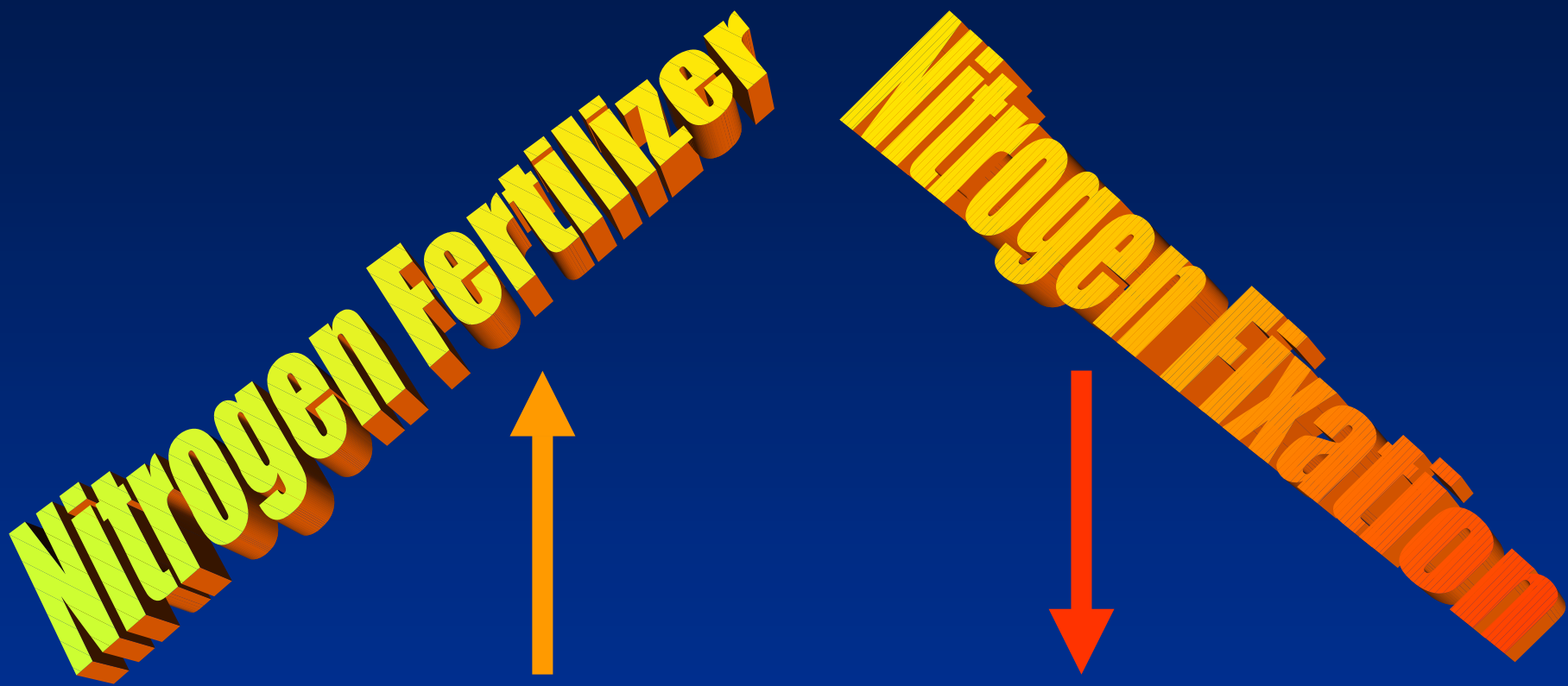
Estimating N Contributions

- Compiled published data from the Northern Great Plains for N_2 fixed and yield parameters for pea, lentil, chickpea, fababean and bean
- Calculated potential N additions

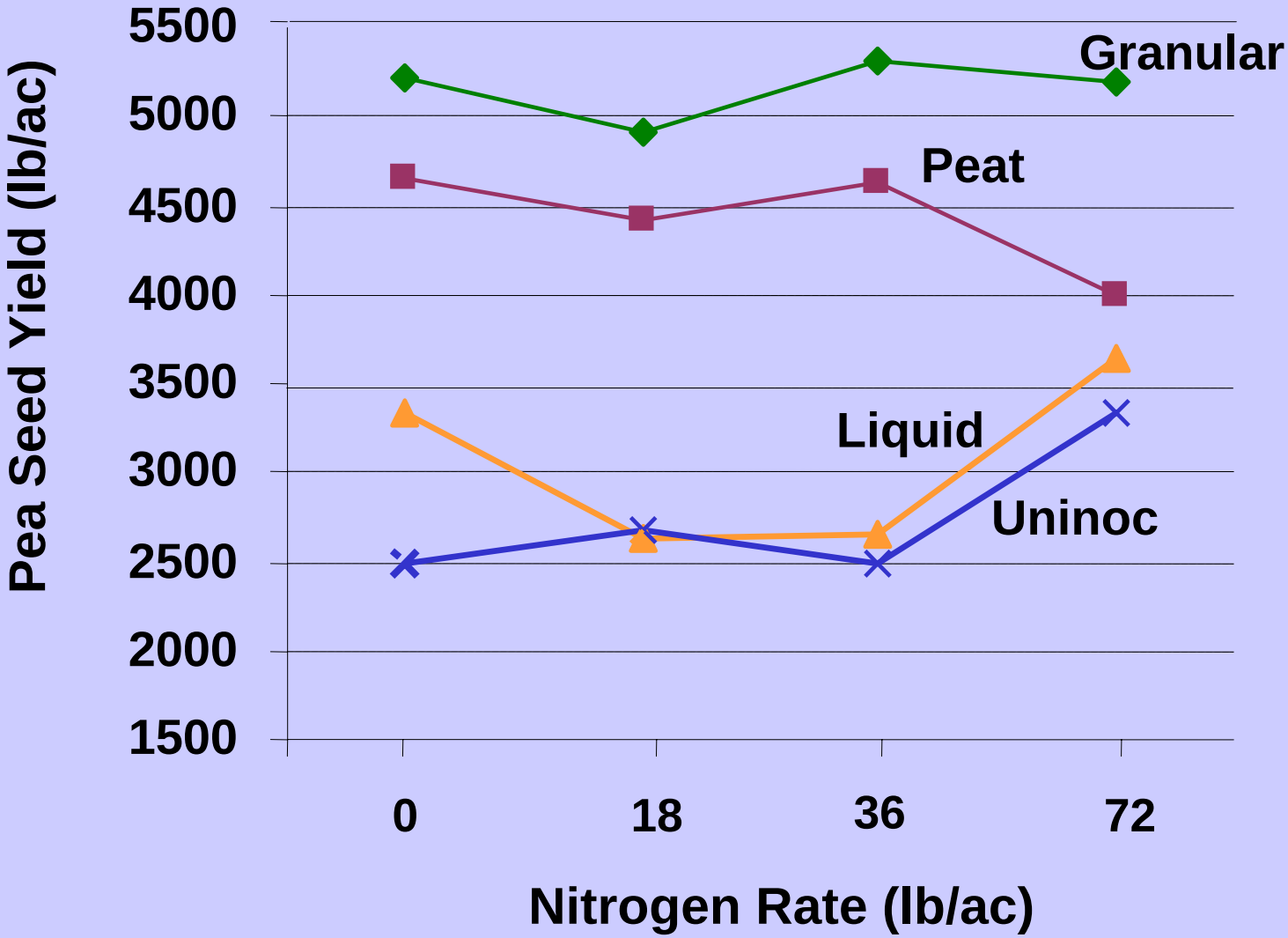
Crop	Reference
Pea (n = 79)	Rennie and Dubetz 1986; Cowell et al. 1989; Kucey 1989; Androsoff et al. 1995; Waterer et al. 1994; Clayton et al. 1994a,b; Soon and Arshad 1994; Stevenson et al. 1996; Beckie et al. 1997; Matus et al. 1997; Moolecki 2000; Soon et al. 2004
Lentil (n =38)	Rennie and Dubetz 1986; Bremer 1987,1991; Cowell et al. 1989; Van Kessel 1994; Matus et al. 1997; Moolecki 2000
Chickpea (n = 82)	Rennie and Dubetz 1986; Kyei-Boahen 2000; Kyei-Boahen et al. 2002, 2005; Fu 2000; Walley 1999, Walley et al. 2001,2005
Fababean (n= 10)	Rennie and Dubetz 1986
Bean (n = 31)	Kucey 1989; Shirtliffe 1994; Kyei-Boahen et al. 2005


Seed yield (kg/ha)
7000
6000
5000
4000
3000
2000
1000
0
206
117
Desi
n=44
Kabuli
n=38
Lentil
n=38
Pea
n=79
Bean
n=31
Fababean
n=10


Fixed N (%)
100
80
60
40
20
0
Desi
n=44
Kabuli
n=38
Lentil
n=38
Pea
n=79
Bean
n=44
Fababean
n=10

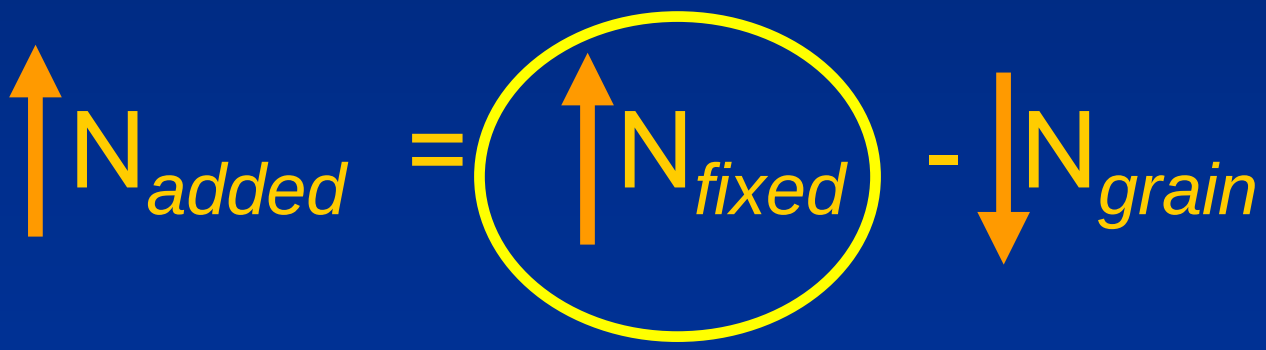

Nitrogen fertilizer
Nitrogen Fixation

Fertilizer X Inoculant Interactions
Beaverlodge AB - Clayton et al. 2004

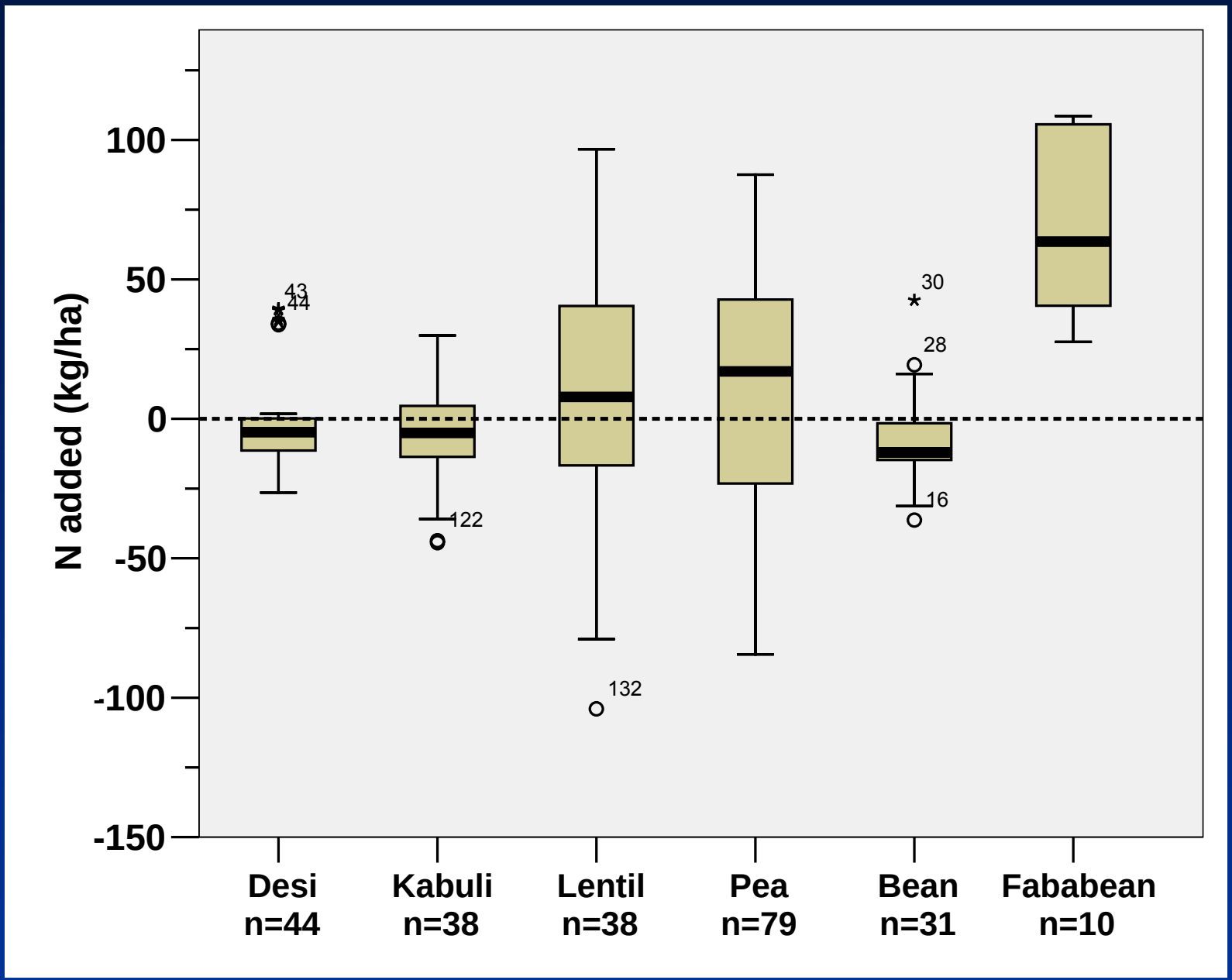


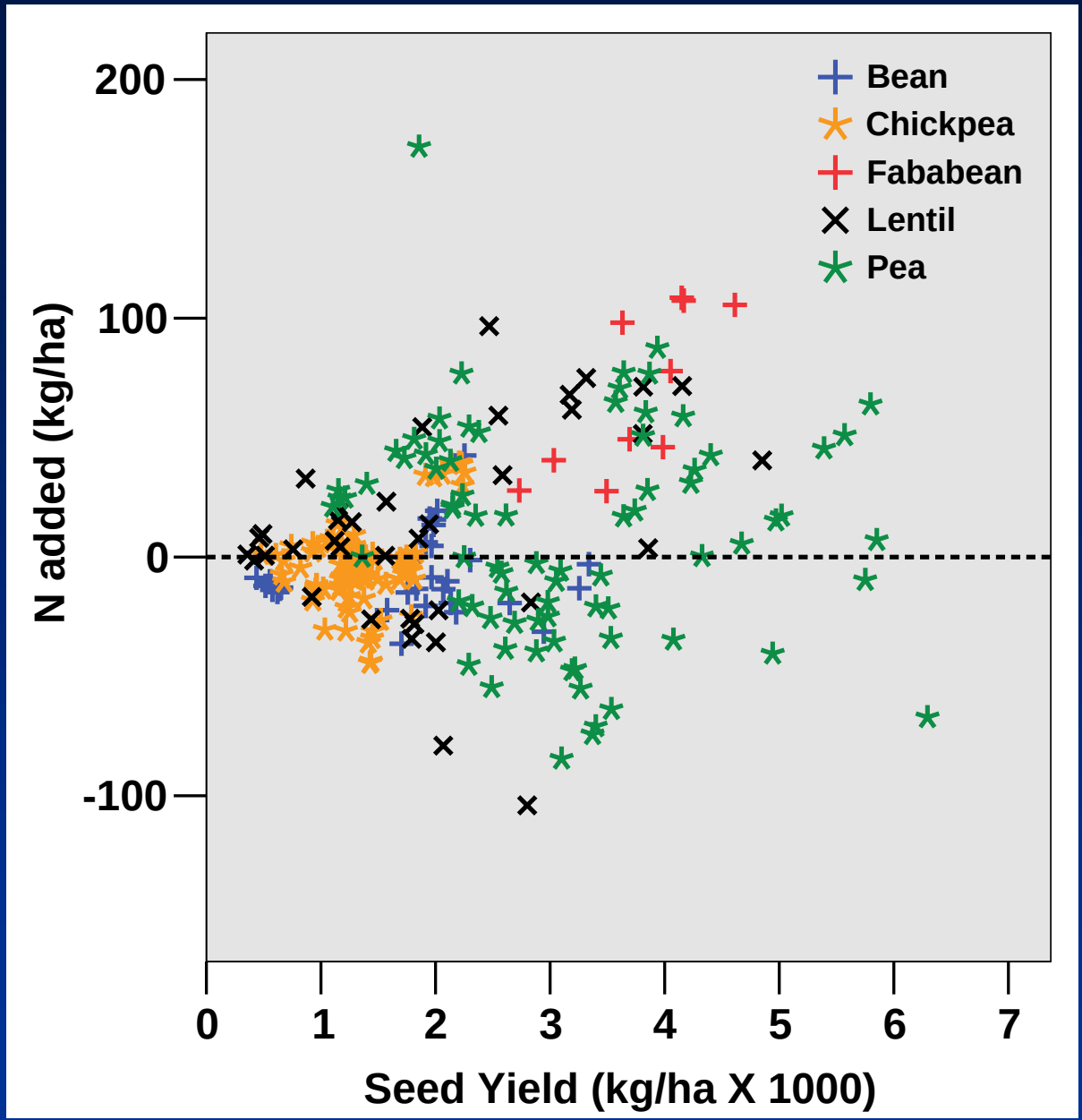
Do pulses contribute to added soil N?

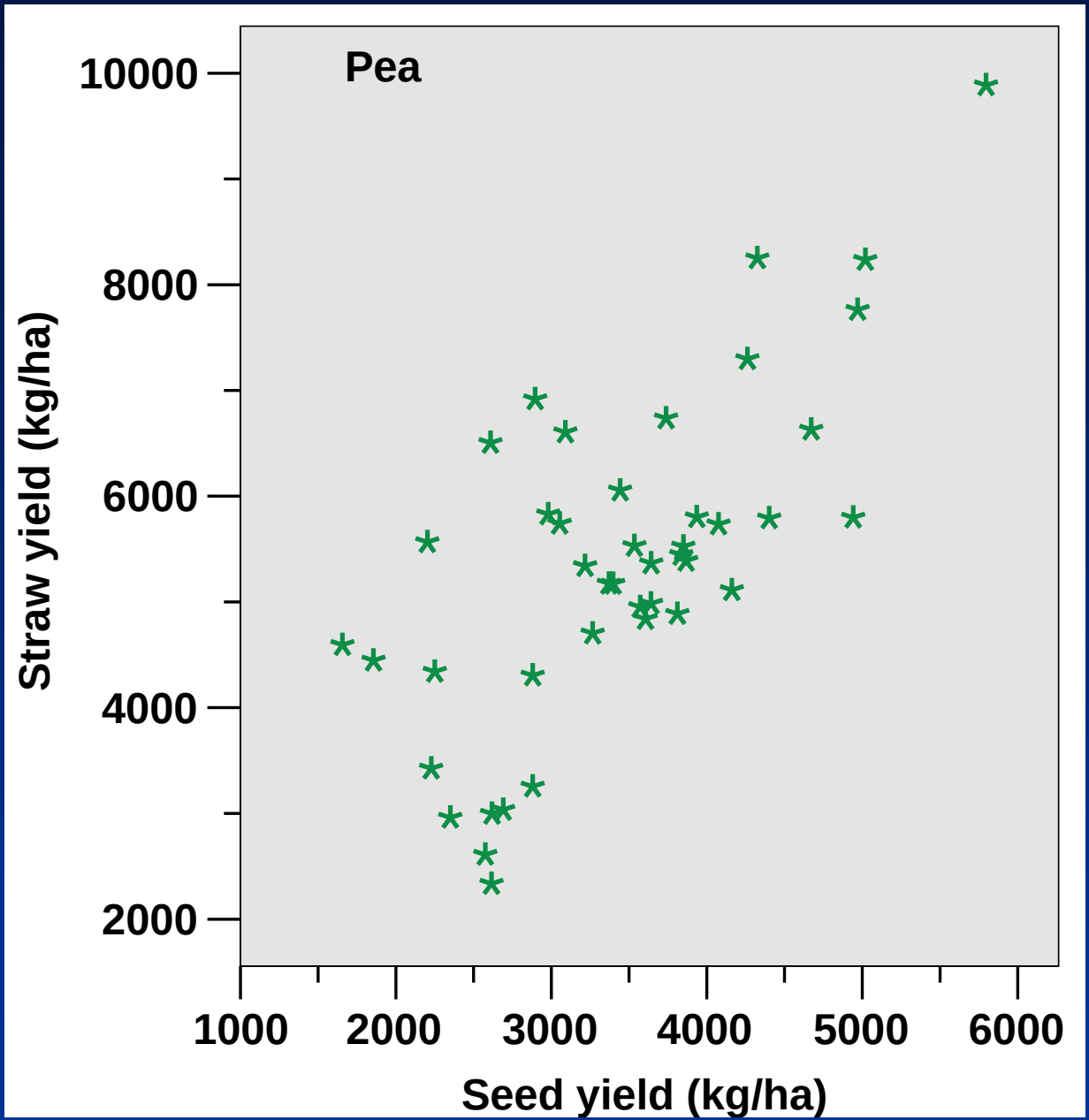
- Pulse crops will increase total soil N only if the amount of N fixed exceeds N removed in the grain
- N added (a.k.a. N balance) is calculated as:

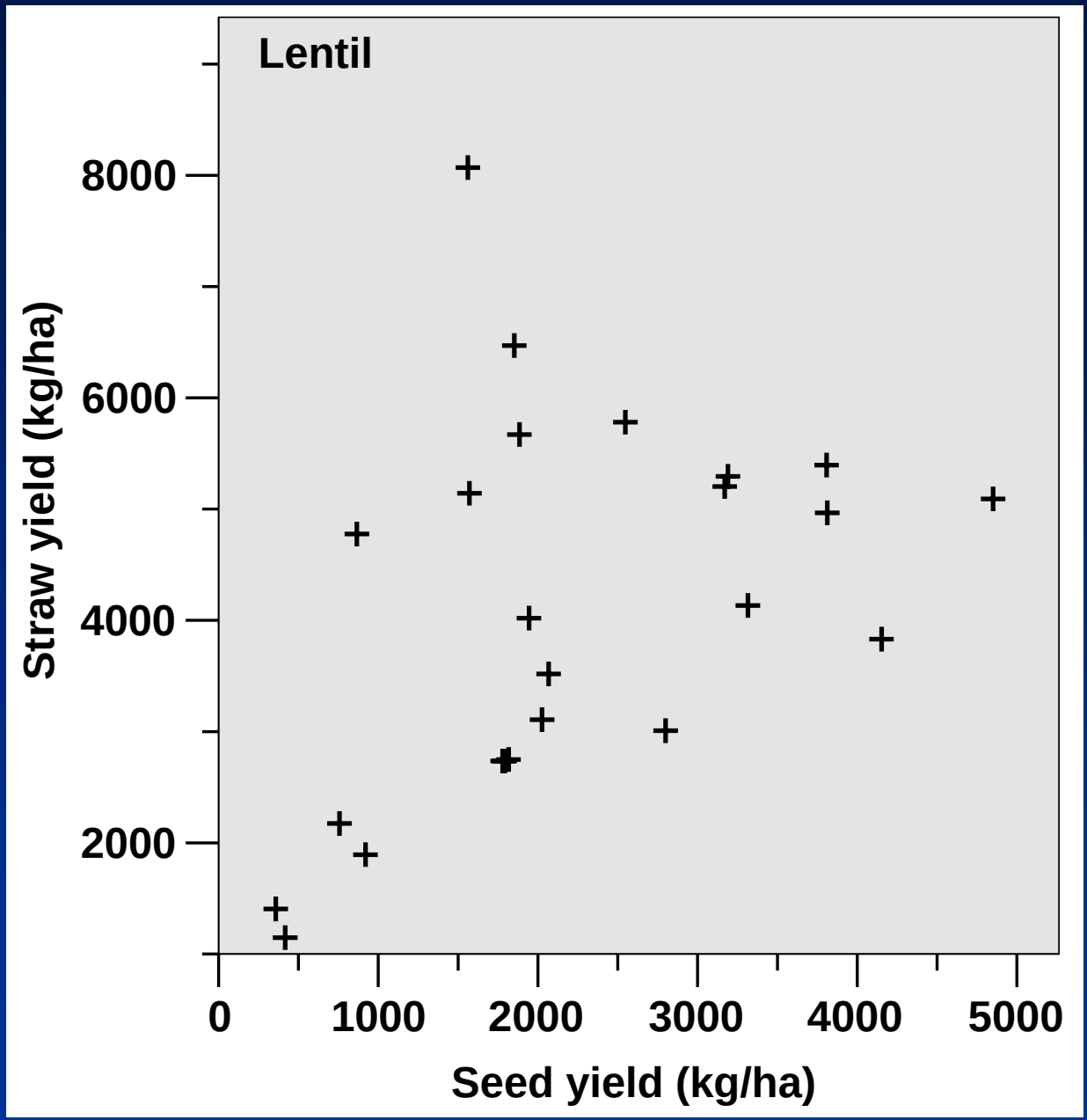


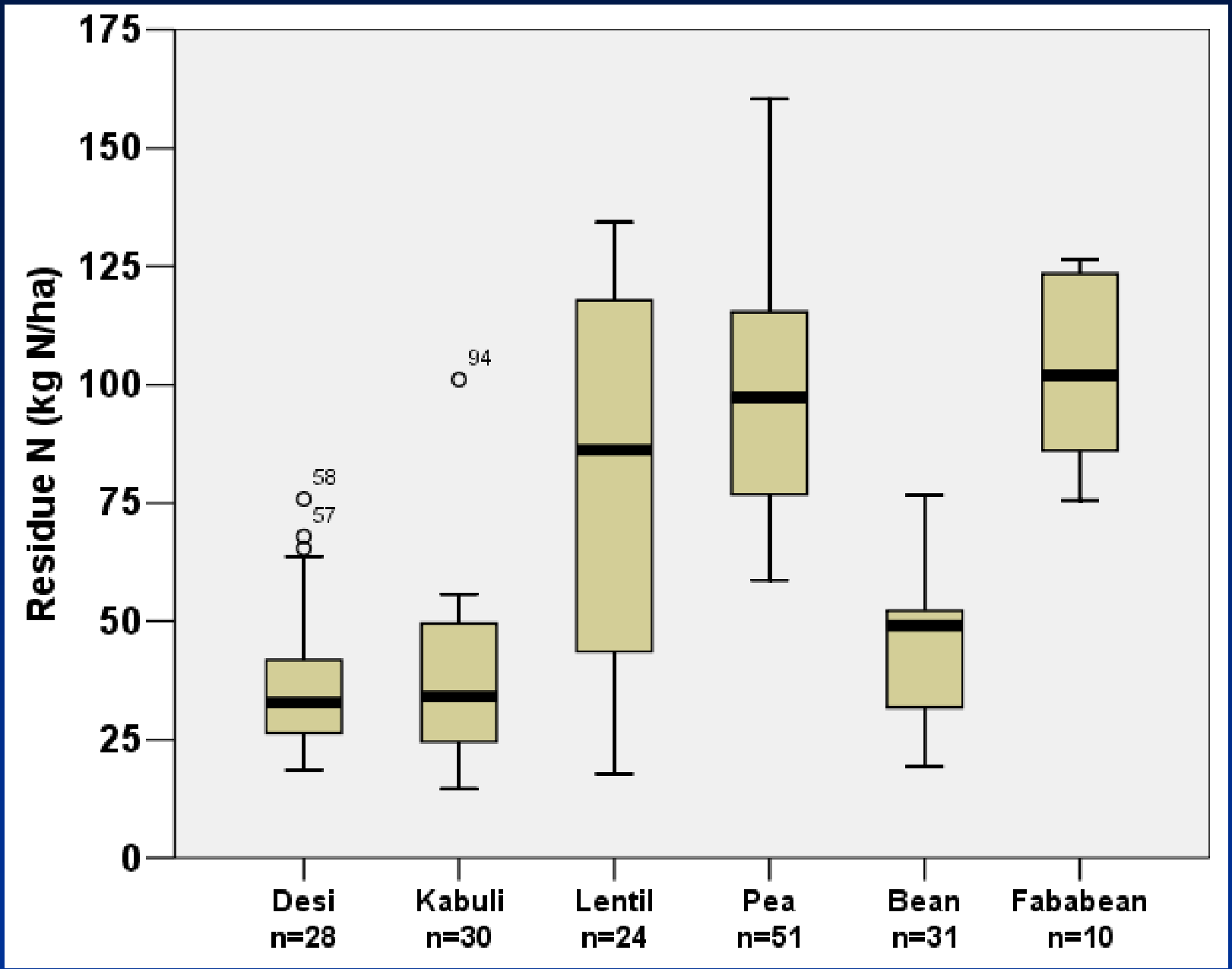
(Evans et al. 2001)

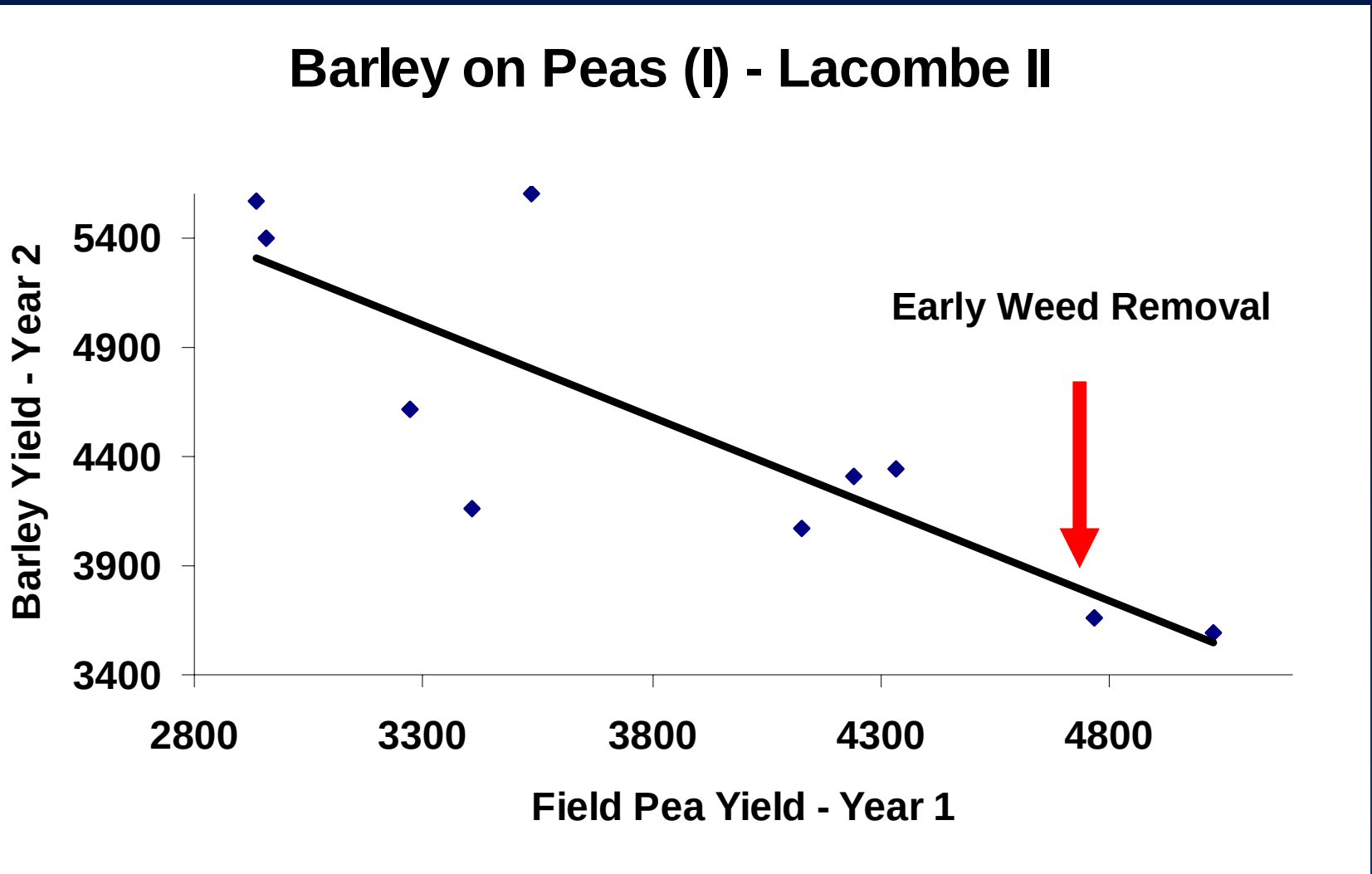

N added (kg/ha)
100
50
0
-50
-100
-150
43
44
30
28
122
132
16
Desi
n=44
Kabuli
n=38
Lentil
n=38
Pea
n=79
Bean
n=31
Fababean
n=10


Bean
Chickpea
Fababean
Lentil
Pea
200
100
0
-100
N added (kg/ha)
0
1
2
3
4
5
6
7
Seed Yield (kg/ha X 1000)


Pea
10000
8000
6000
4000
2000
Straw yield (kg/ha)
1000
2000
3000
4000
5000
6000
Seed yield (kg/ha)


Lentil
Straw yield (kg/ha)
8000
6000
4000
2000
0
1000
2000
3000
4000
5000
Seed yield (kg/ha)


Residue N (kg N/ha)
175
150
125
100
75
50
25
0
94
58
57
Desi
n=28
Kabuli
n=30
Lentil
n=24
Pea
n=51
Bean
n=31
Fababean
n=10



Clayton et al. 2005

Summary

- For Western Canada, N added to the overall soil N budget is highly dependent on N fixation
- N fixation is highly variable for all crops and varies between crops. In general:

Bean<Kabuli<Desi
<Lentil≤Pea<Fababean

Summary

- Average N fixation values typically are lower than required to achieve positive N additions for chickpea and bean
- Pea and lentil contributed to positive N additions in more than 50% of the cases.
- Fababean always led to positive N additions.
- N additions are highly variable and are not related to shoot dry matter or grain yield
- High pulse yields may be associated with reduced yields in subsequent crops if no additional N is applied

Can pulses be used to grow N?

- Absolutely, but remember that much of the N that is grown is harvested in the pulse grain
- Pulses grown as a green manure will add N because N is the only harvestable product.

Thank you