Eric Allen Memorial Lecture
"Understanding how potatoes grow determines how to grow potatoes"

Mark Anthony Stalham,

Marc Allison & all other members of the CUF team

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Scene II. – The Auditorium

“Friends, potato growers, CUPGRA, lend me your ears. I come to bury Eric, not to praise him….the good is oft interred with the bones.”

CUPGRA friends, let me not stir you up to a sudden flood of mutiny…even though Eric did so regularly! Let’s see how this pans out the ‘Plebeians’…

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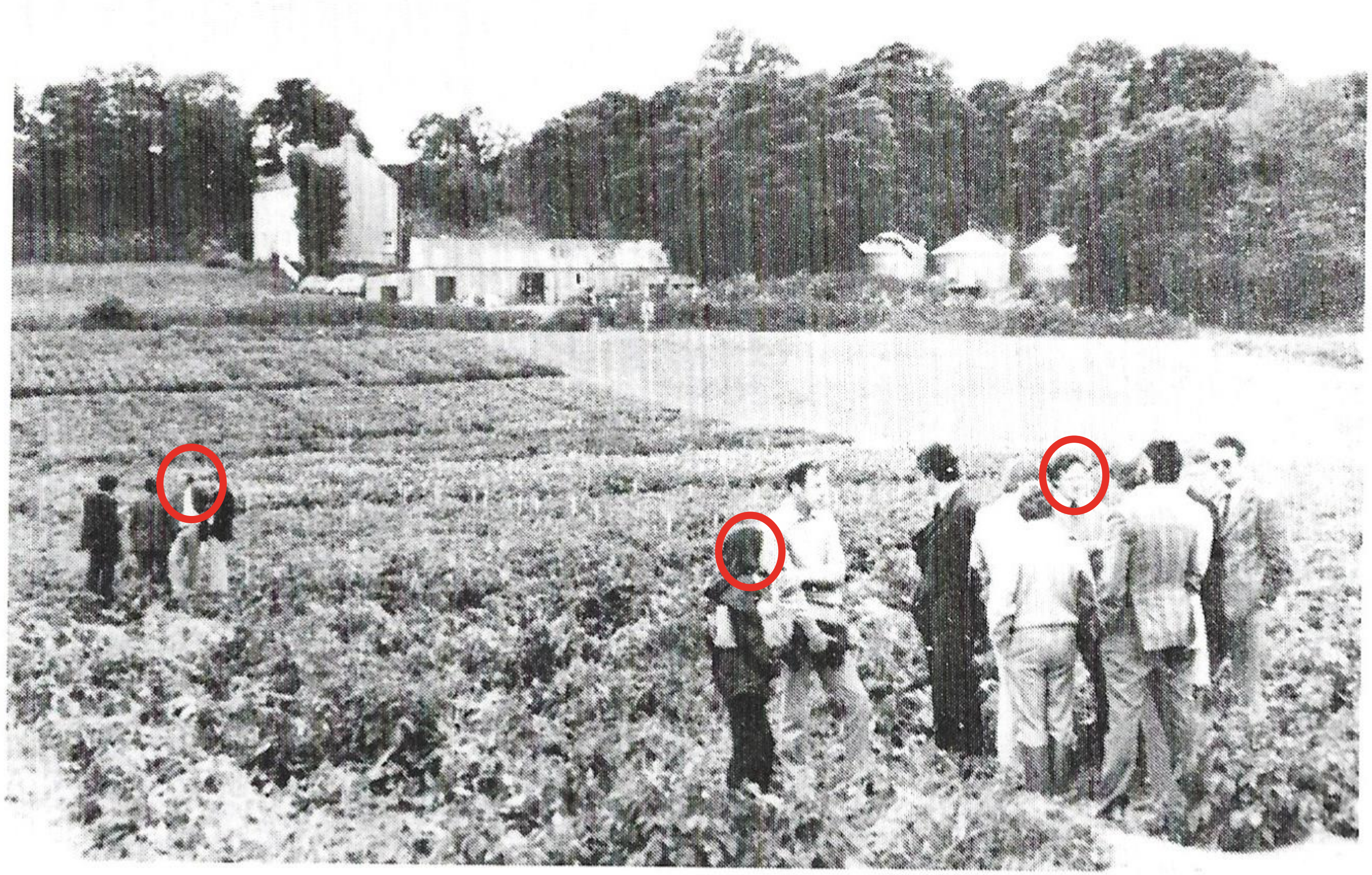
Source: William Shakespeare, 1599

It started in Wales, not Cambridge



Potato research at Trefloyne Farm, 1980

Man's Proper Study. A History of Agricultural Science Education in Aberystwyth 1878-1978. Richard J Colyer

Inspiring formative potato agronomists

- Debbie Winstanley: “I can remember Eric being underwhelmed when three 18-year-old females arrived in his office in 1977. Lots of grunts, as I remember. What we did not realise, was that Eric was ‘looking’ for help for his potato trials work!”
- Jeff Beever kept quiet.

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Eric’s truths that you may not wish to hear (again)

- An **improvement in returns** or a **reduction in costs** (or both) is needed
- The balance between cost and return is essentially **technical**
- If yield increases are reaching a plateau, the future of potato production would be bleak (**unless the value of the crop increased**)
- Most recent research has been devoted to **acute (**fire-fighting) problems e.g. CIPC, nematicide withdrawal, desiccants, changes in blight populations etc.
- There are **chronic** issues to overcome e.g soils, diseases, water, tuber quality). Research is a marathon not a sprint
- The **roller coaster** of problem-fix-problem-fix will not solve the cause
- Agronomists: are they still **blocking uptake** of research as they strive daily to overcome acute problems?
- Lack of consistency of research protocols **confuses the interpretations** of results
- Scientists: ignore project milestones and **follow interesting ideas**
- **Everything must be challenged**!

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10 things to ponder…….

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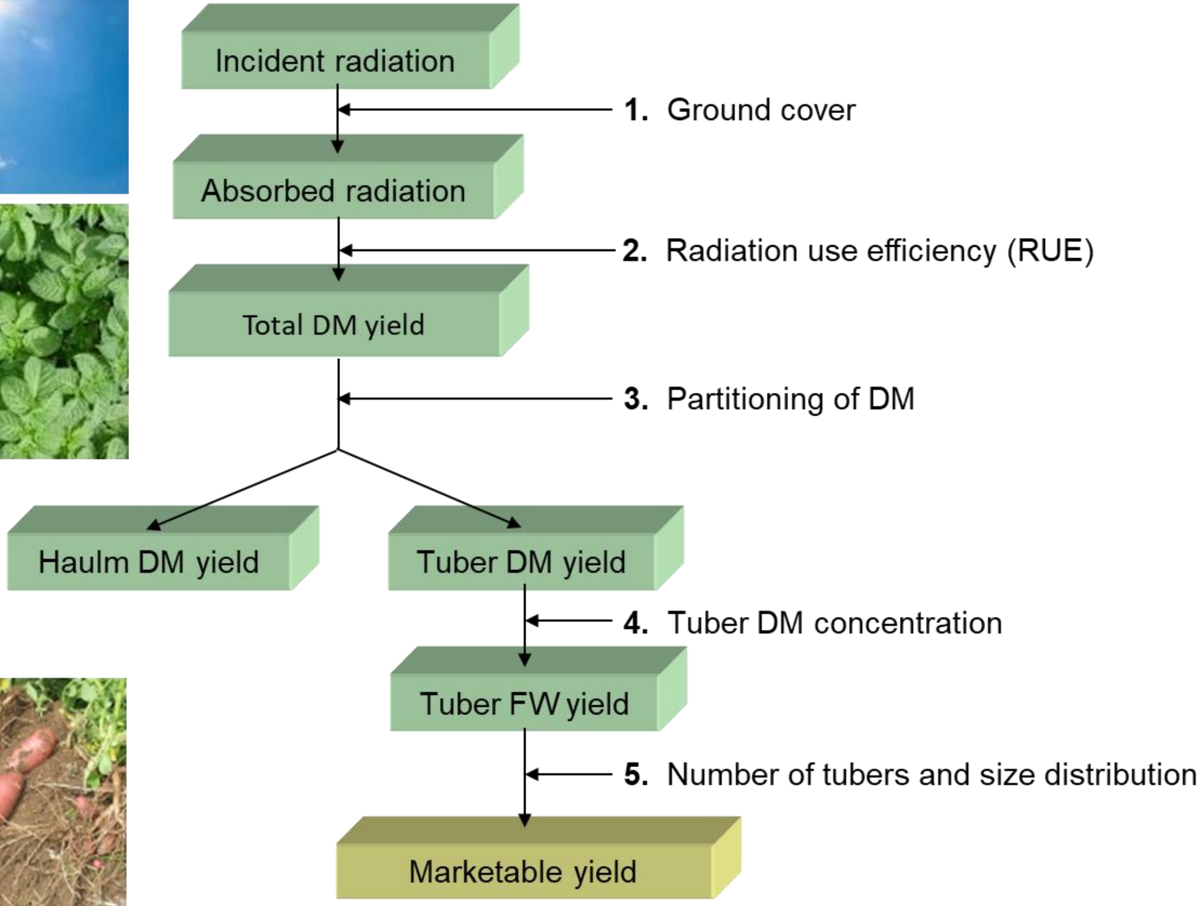
1. Yield is driven by radiation absorption: The process of yield formation



Yield is driven by radiation absorption
(Monteith,1977)

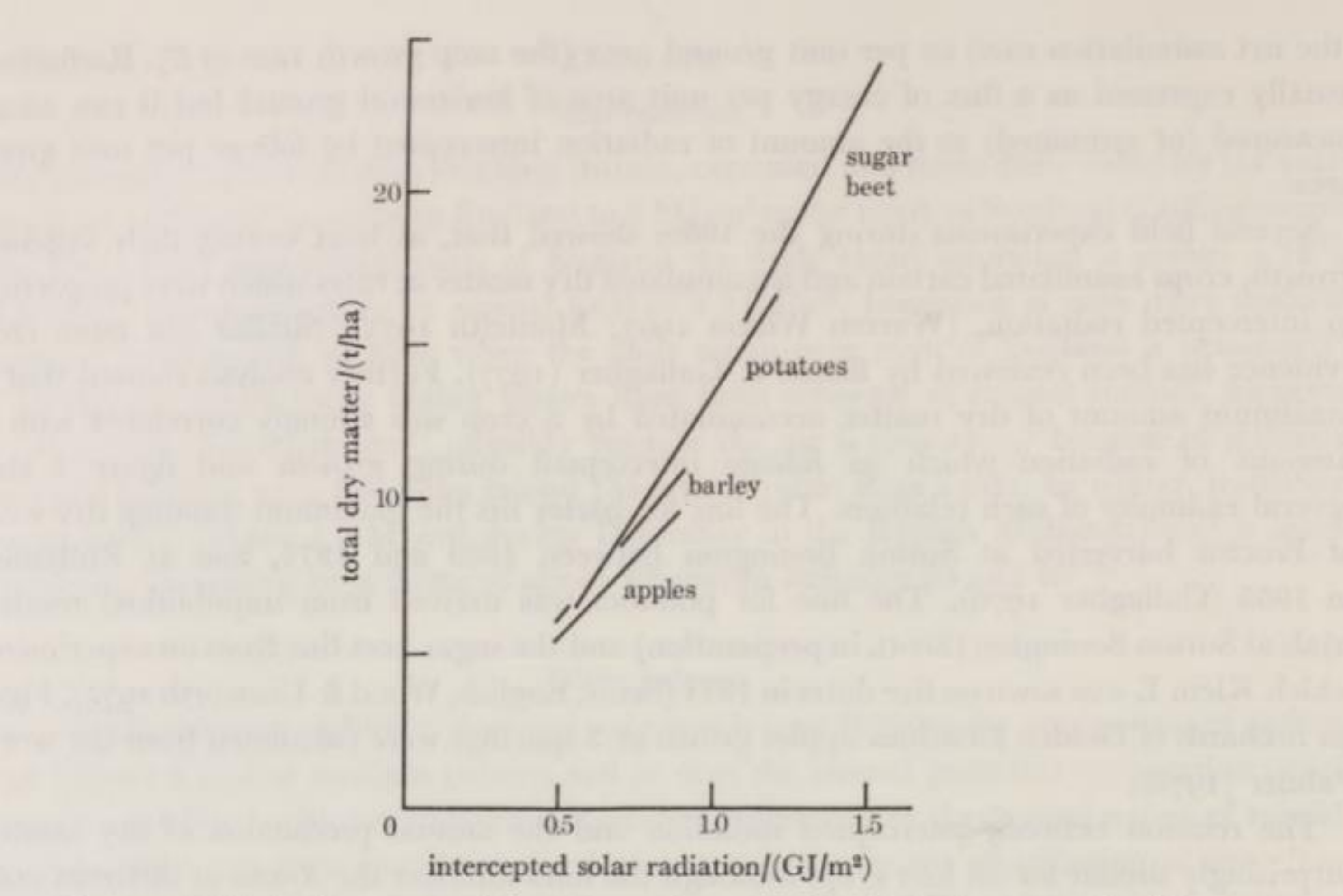
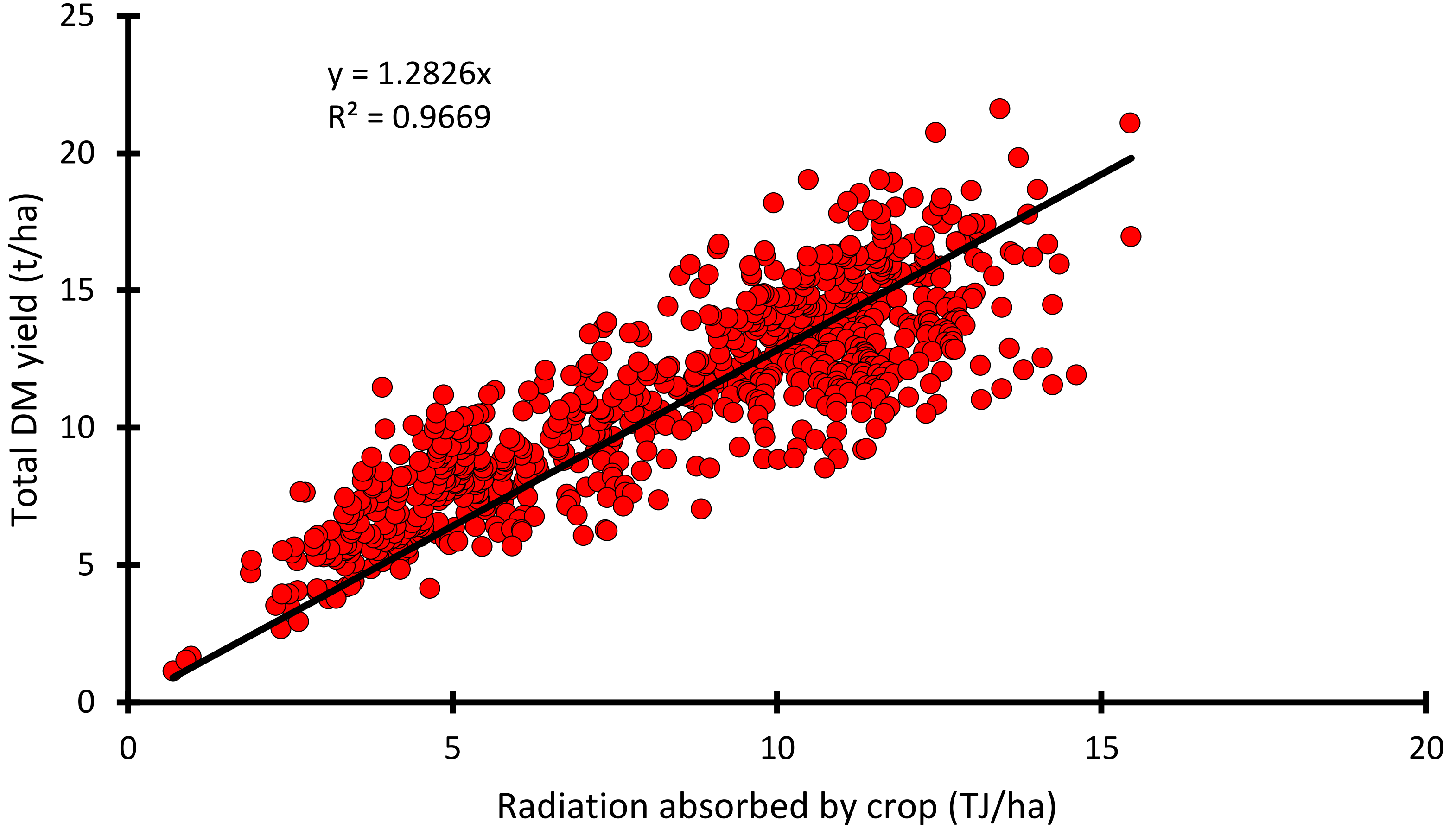


FIGURE 1. Relation between total dry matter at harvest and radiation intercepted by foliage throughout growing season: correlations from measurements discussed in text.

Relationship between total dry matter yield and radiation absorption in commercial processing crops 2010-2013



Source: Allison, 2014. N=798 (each a mean of a minimum of 3 replicates)

Yields have plateaued, what can we do?

- **Yields are crucial**
    - **Difficult to compare** equitably
    - Allow little **interpretation of the effects** of the component **agronomy** of the system
- **Understand the component processes** in yield formation to guide further improvement
- Has been a **central part of research at CUF** for 40 years and understanding has increased to the point at which commercially-useful systems (e.g. NIAB CUF Potato Yield Model, Crop4Sight, Tuberzone Cropcast etc.) can **calculate potential yield with sufficient accuracy** to use in assessments of the value of agronomic treatments and the real performance of crops

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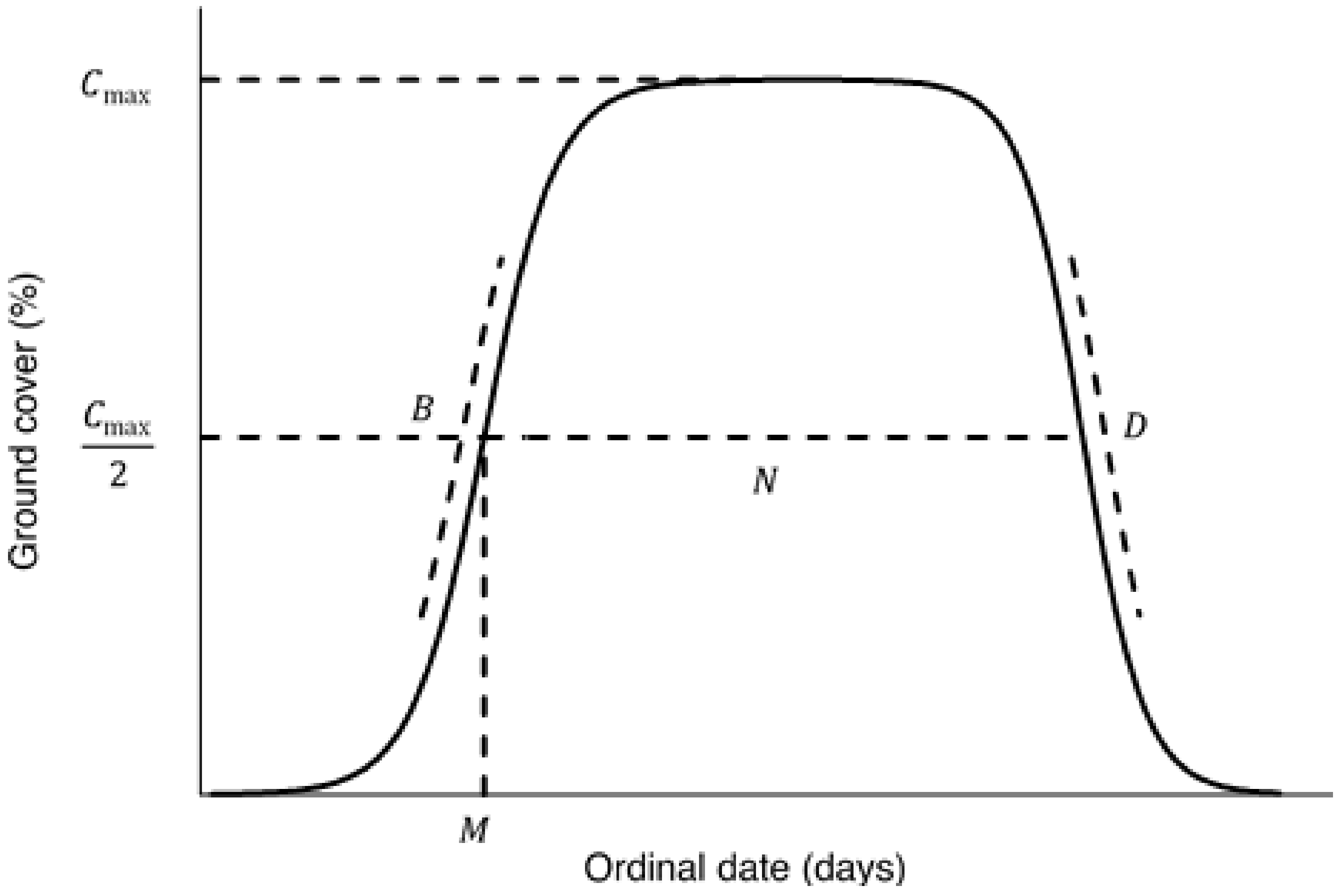
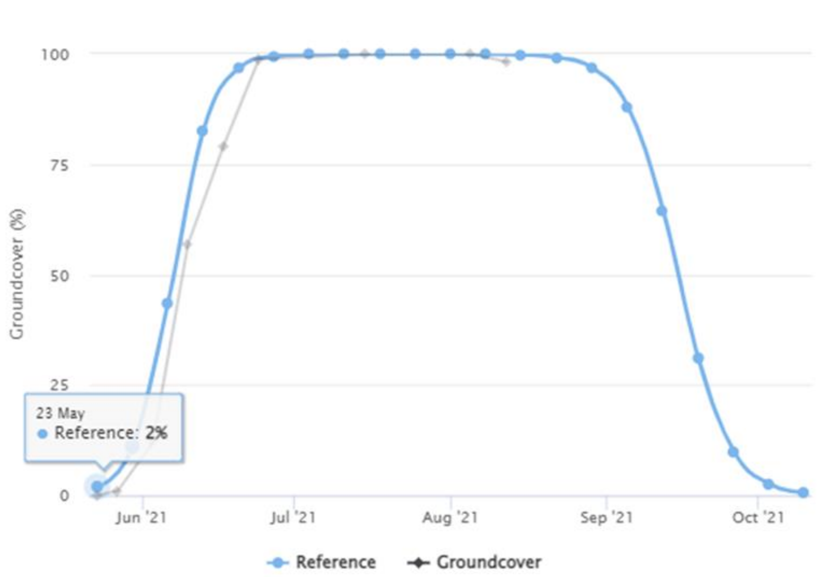
Potato canopy development



- C=Cmax1+e-BO-M-Cmax1+e-DO-M-N
- C; canopy ground cover
- Cmax; maximum percentage ground covered
- B; dimensionless unit linked to rate of canopy expansion
- D; dimensionless unit linked to rate of canopy senescence
- M; ordinal date at which growing canopy reaches 50 % of maximum ground cover
- N; number of days after M, at which senescing canopy reaches 50 % of maximum ground cover
- Specific ordinal dates are represented by O

Source: Roberts, 2021

Crop groundcover and reference curve



Crop groundcover ranking

Crop groundcover milestones

Date of 50% Emergence	23/05/2021
Days to 50% Groundcover	17
% Groundcover at 30 days	93
% Groundcover at 45 days	99
% Groundcover at 60 days	100

Crop reference milestones

Date of 50% Emergence	15/05/2021
Days to 50% Groundcover	16
% Groundcover at 30 days	98
% Groundcover at 45 days	100
% Groundcover at 60 days	100

Yield average

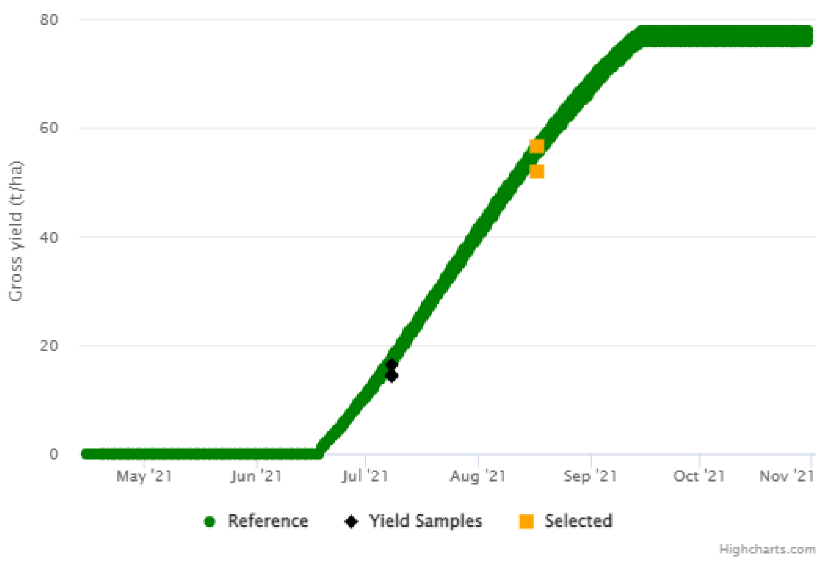
Dig date: 17/08/2021

Size specifications: Standard commercial

☑ **Benchmark yield dig**

☐ **Size distribution**

Crop yield samples and reference curve



Sample summary

Status

Gross Yield	54.3 t/ha
Net yield	53.4 t/ha

Size specifications

Under 45 mm	0.9 t/ha
45 - 65 mm	25.0 t/ha
65 - 85 mm	28.4 t/ha
Over 85 mm	0 t/ha

Other

Plant population	28,571 /ha
Stem population	118,681 /ha
Tuber population	318,681 /ha
Dry matter	19.7%
Tuber count (per 10kg)	52 per 10kg
% over 90mm length	32%

Sample status key

Poor Fair Good

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Crop4Sight

Haverkort & Struik (2015) summary

- **Potential** yields may be as high as **160 t/ha** (but need abundant irrigation, high radiation levels and long seasons)
- **Actual** yields of above **120 t/ha** have been **observed**
- However, short-cycle crops reduce yield potential
- **Still 30-40 % gap** between actual and potential yields
- Great yield improvement potential provided inputs are **economically feasible**
- Yields should increase with climate change, **provided water supply remains adequate** (and **new pests don’t materialize**)

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Yields at WSU Late Tri-State Trial, Othello, WA, 2008-2020: best clone/variety yields

Year	Variety	FW yield (t/ha)	Tuber DM yield (t/ha)
2020	Ranger Russet	**119**	24.3
2019	AOR08540-1	**117**	24.2
2018	OR12133-10	**142**	29.5
2010	A02060-3TE	**113**	25.7
2009	A00324-1	**115**	24.4
UK			
2013	Maris Piper	**98**	22.3
2013	Volare	**124**	18.7

Sources: Washington State University Potato Research Group Potato Cultivar Yield and Postharvest Quality Evaluations, 2008-2020; Stalham, 2013

Fallacy: yield is restricted if you have too few tubers

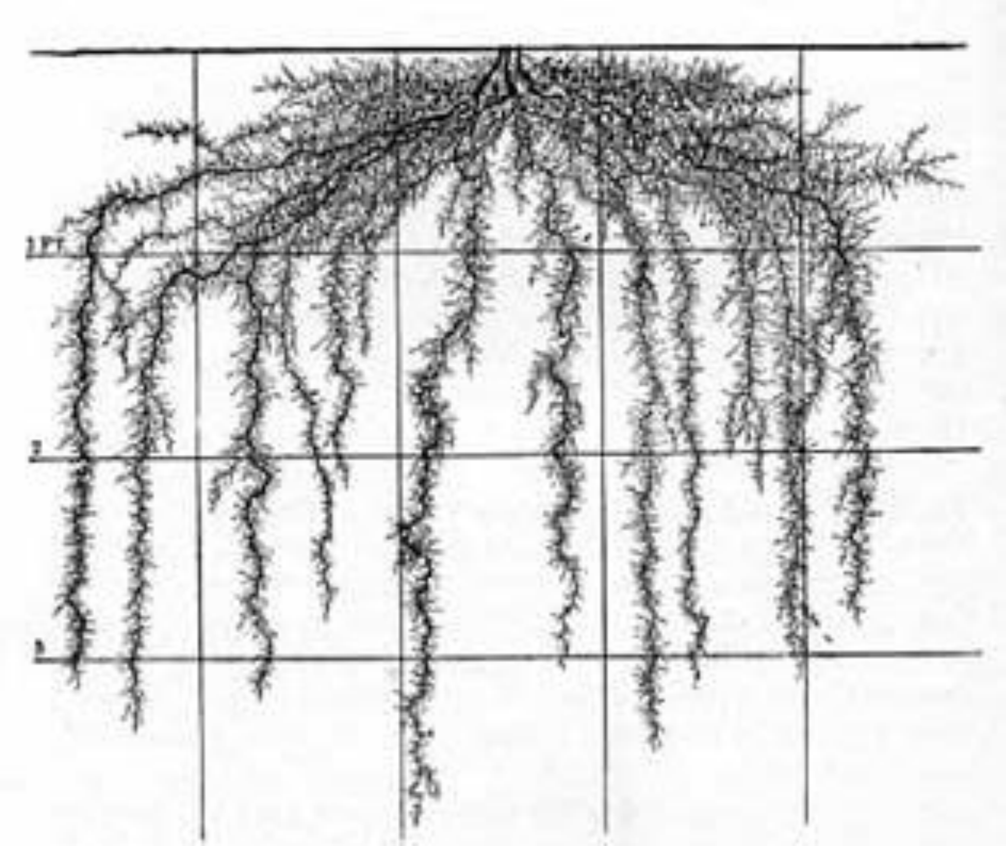
Variety	Yield (t/ha)	No. of tubers (000/ha)	No. tubers/plant	Yield >80 mm (t/ha)
Maris Piper	93.1	557	12.7	4.3
Safari	94.0	262	6.0	52.4

"Doug", 7.8 kg, New Zealand

Source: Stalham, 2015

2. Potatoes are shallow-rooting

FIG. 3.—One end of the first trench used for the study of root systems. Pullman, Washington, 1914.



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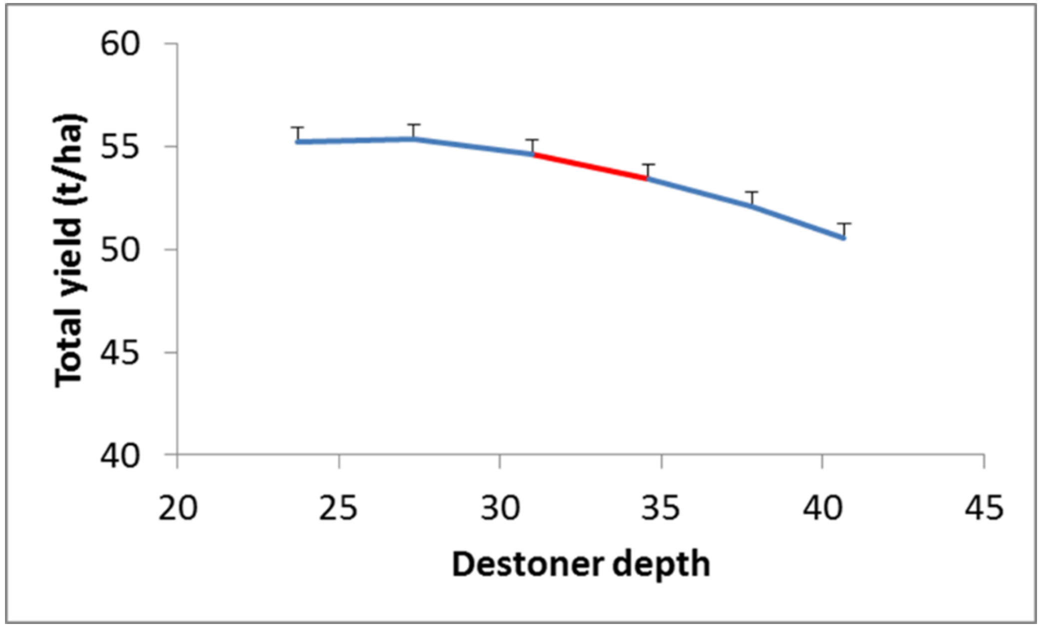
No, they aren’t, but the way we grow them restricts rooting:

- PCN (and FLN) grazing
- Root pathogens
- Compaction from
  - Poorly-timed cultivations
  - Excessive numbers of operations
  - Incorrect cultivation depth in relation to the critical depth
  - Uncontrolled traffic in a ‘controlled traffic’ system

Shallow compaction is worse than deep

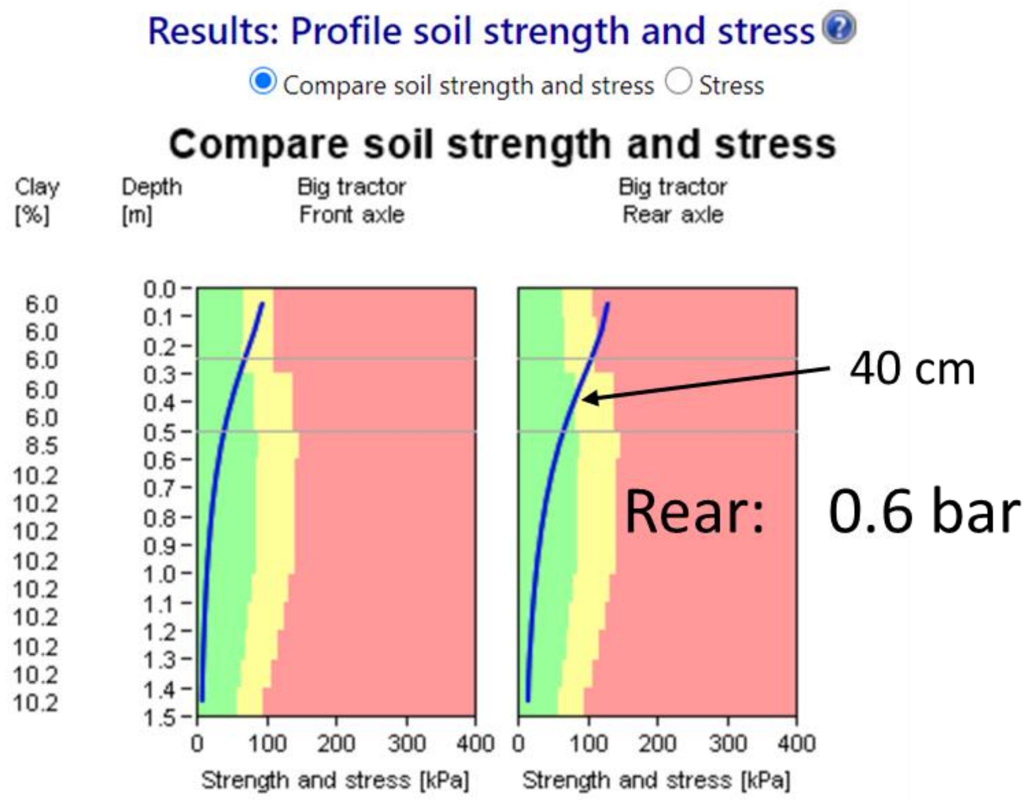
	No compaction	10 cm compaction	40 cm compaction	10+40 cm compaction
Yield (t/ha)†	80.9	**52.9**	72.2	**51.9**
S.E.	3.98			

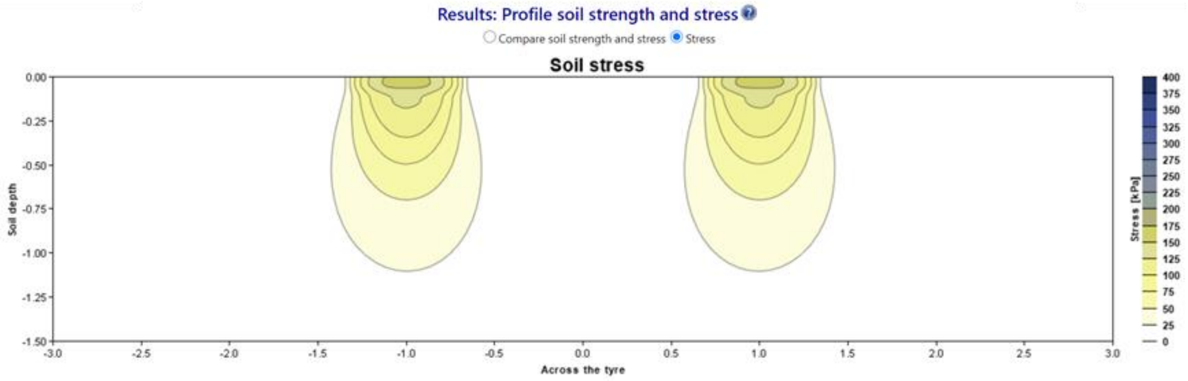
†Mean of unirrigated and irrigated treatments

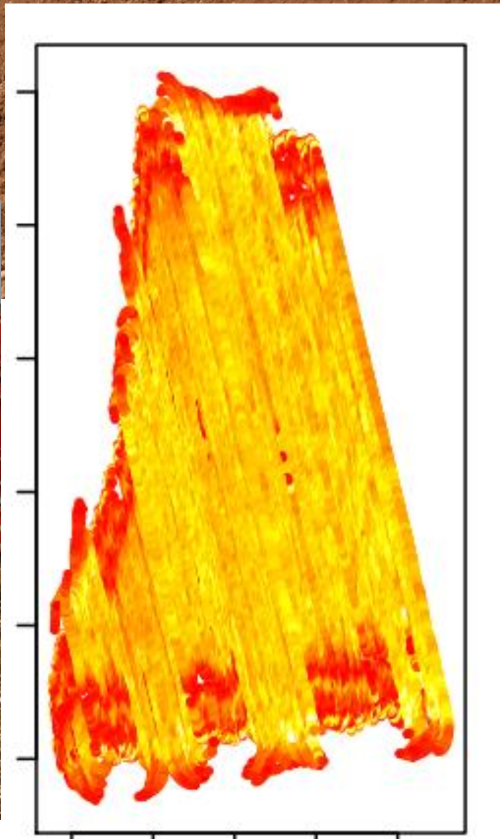


Sources: Rosenfeld, 1997; Stalham *et al.*, 2007; Stalham & Allison, 2015

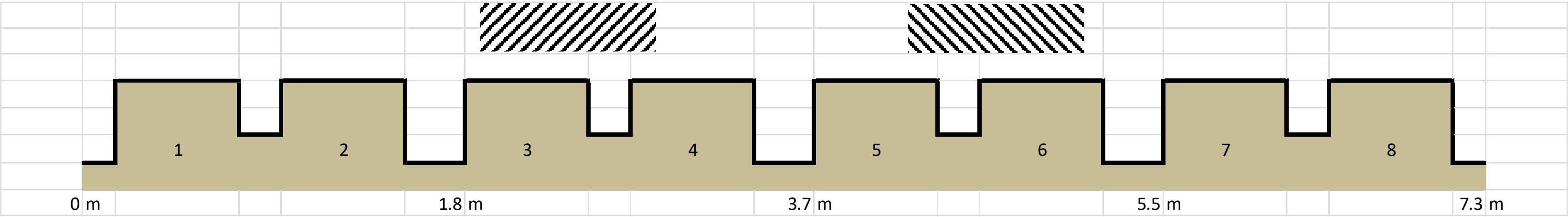
Controlled traffic?







Effect of tyre pressure on yield (t/ha) across rows



Rear tyre pressure (bar)	Row 1/8	Row 2/7	Row 3/6	Row 4/5	Mean	Yield loss from traffic
1.00	59.8	58.8	53.0	54.0	56.4	**5.8**
0.57	60.6	58.7	55.9	56.6	58.0	**3.4**
S.E.	2.01	2.47	1.99	2.11	1.59	
Yield gain from lower pressure	0.8	-0.1	2.9	2.6	**+1.55**	

Source: MSPC Ltd, 2021

Economic value of benefits from lowering tyre pressures in field from 1 to 0.57 bar

- Central Tyre Inflation Systems (CTIS): **£8,500**
- New Michelin Axiobib 710/85/R38 tyres: **£10,400**
- 100 ha x 1.55 t/ha x £160/t: **£24,800**
- Benefit in **one season and one crop**: **£5,900**

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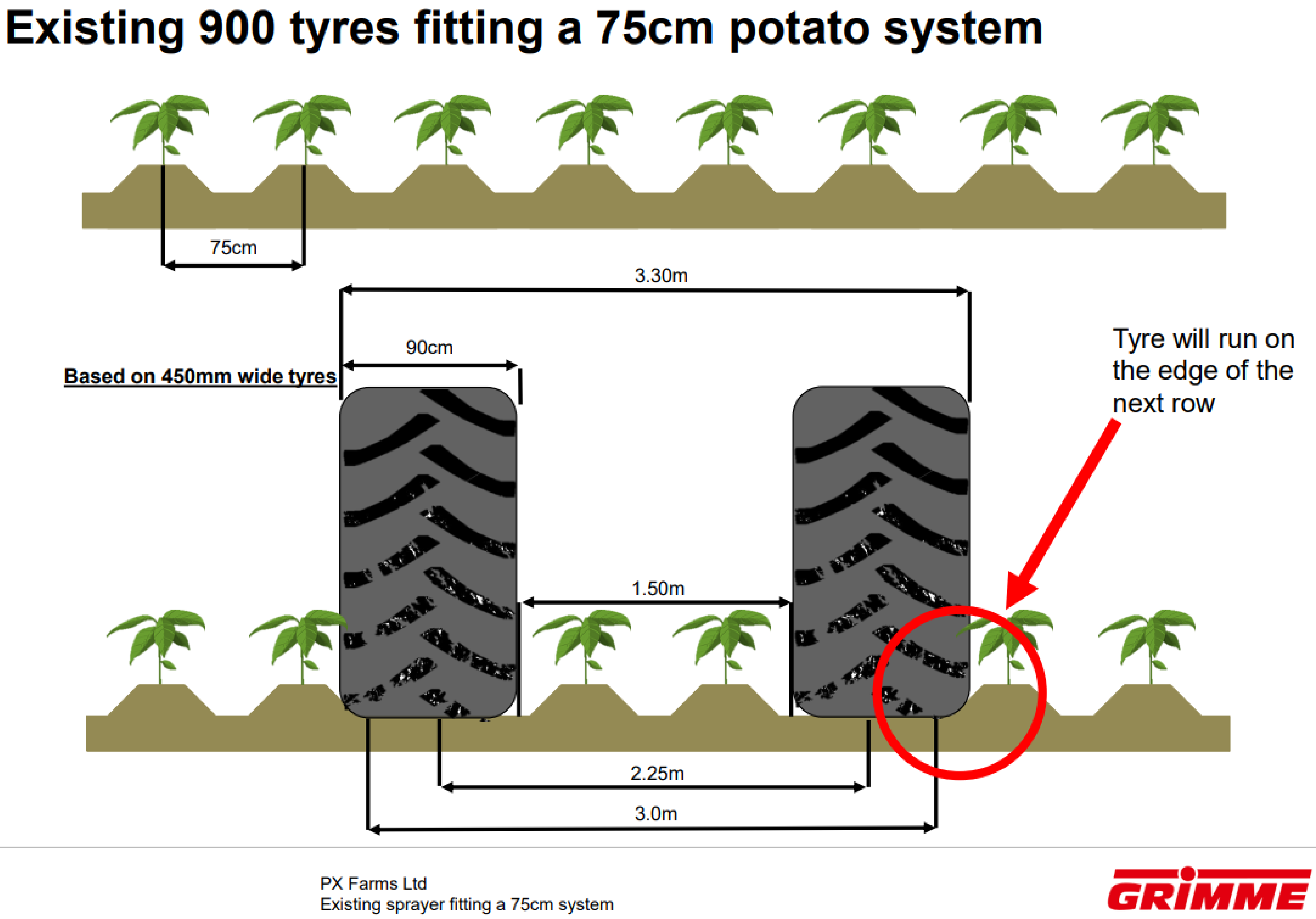
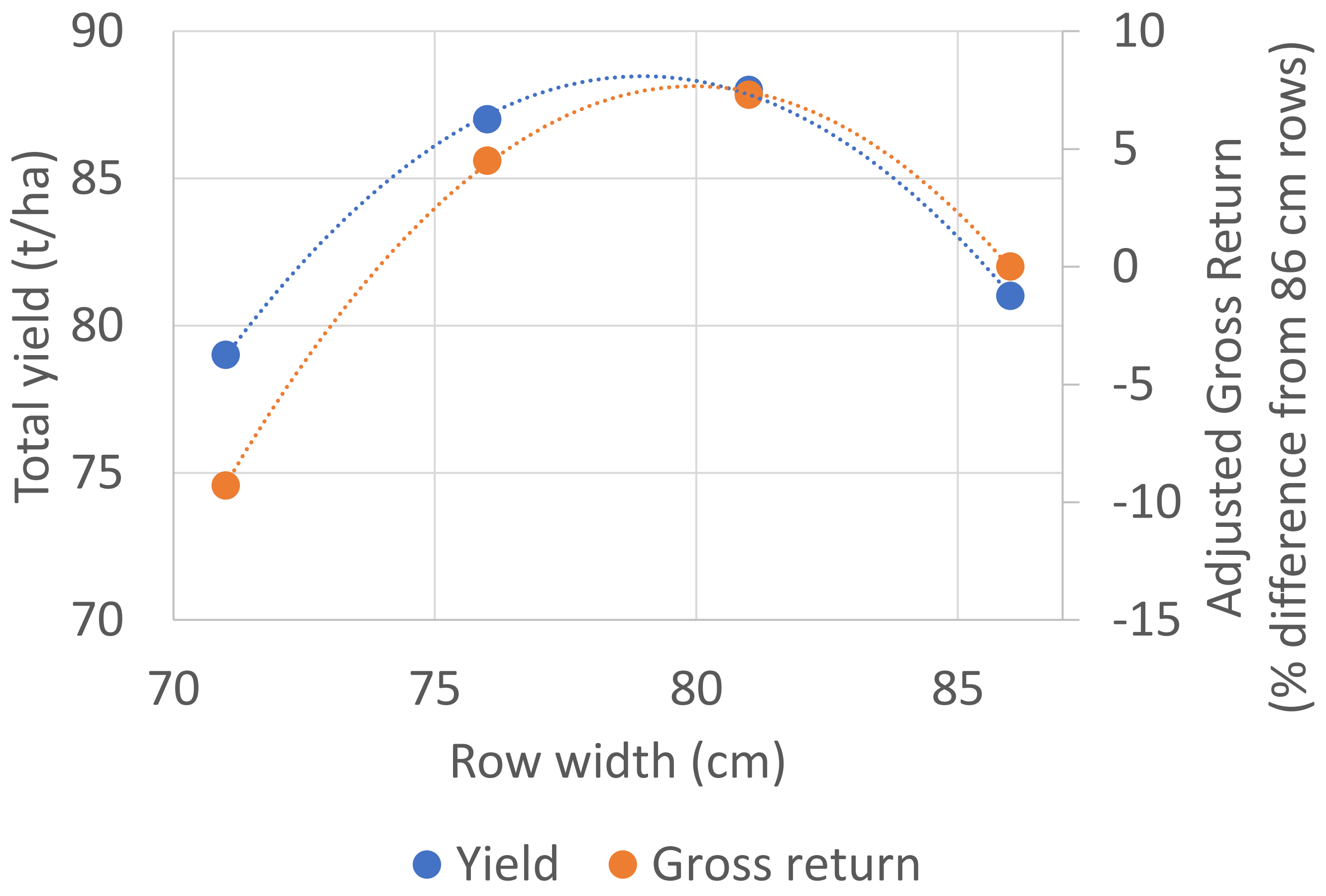
One solution?



3. Narrow rows are only for early crops and low yields



CUF Experiments in 2013

75 cm (t/ha)	91 cm (t/ha)
75.4	65.0

Sources: Pavek *et al.*, 2018; Stalham, 2013

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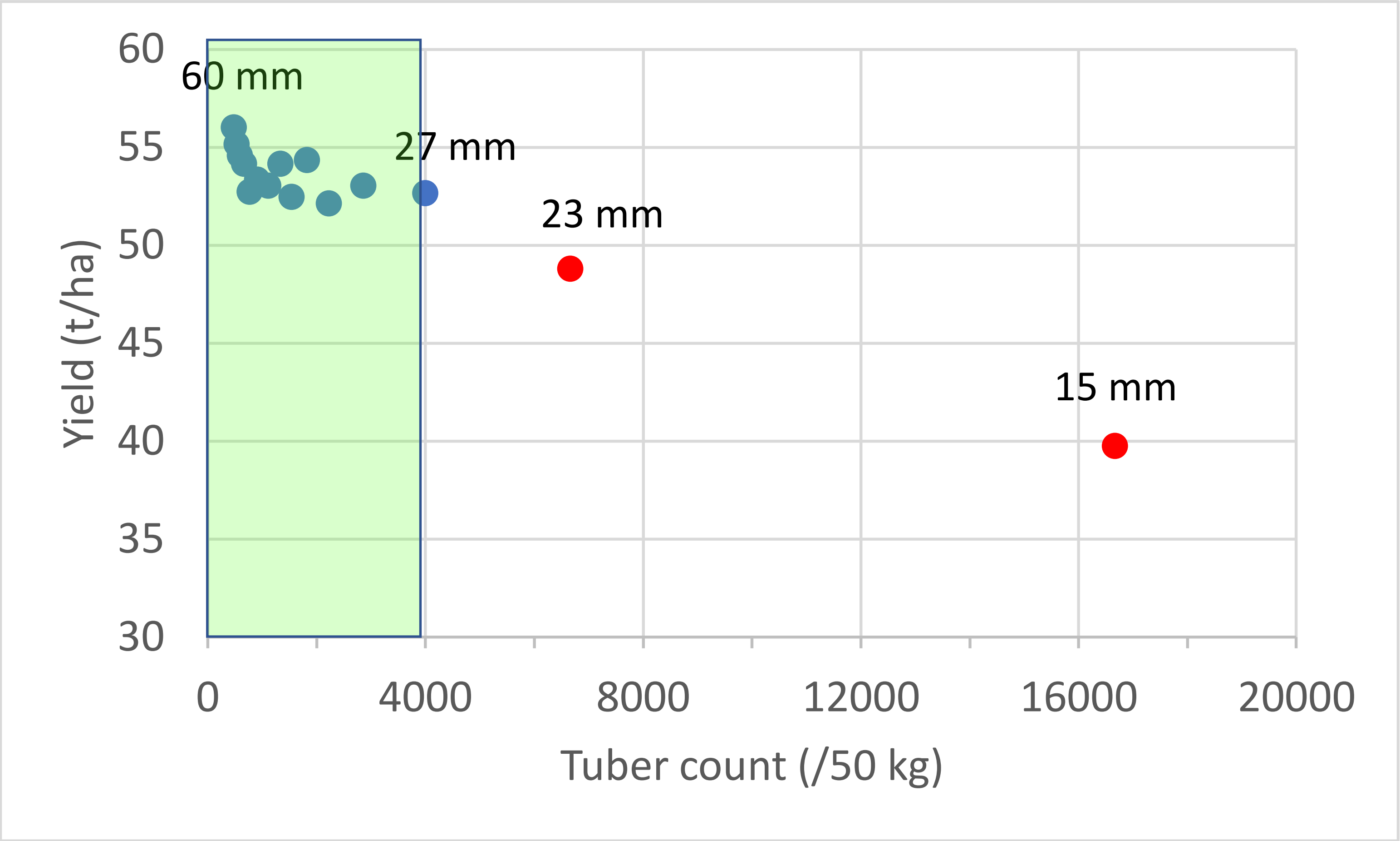
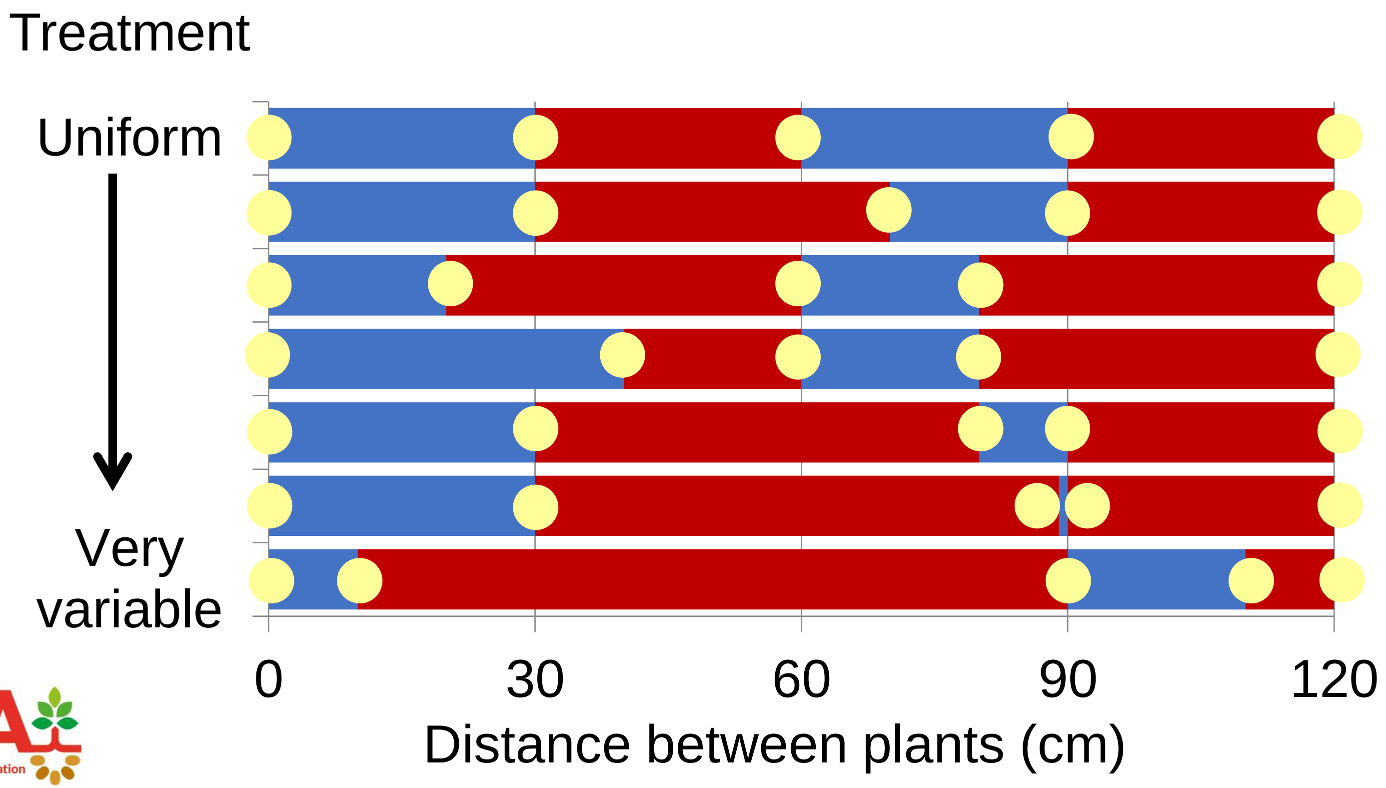
4. Small seed lacks the vigour to perform (N.B. 8-12 cm planting depth to TOP of seed tuber)



Source: Allen *et al.*, 1992

Consistent planting depth is more critical than spacing in achieving tuber size uniformity



COV of tuber size (%)	Yield (t/ha)
16.9	68.6 ab
17.9	69.6 ab
17.9	74.1 b
18.4	73.1 b
17.3	70.4 ab
18.2	62.2 a
18.7	75.1 b
S.E. 0.70 p=0.54	S.E. 2.05 p=<0.01

Source: Smart, 2016

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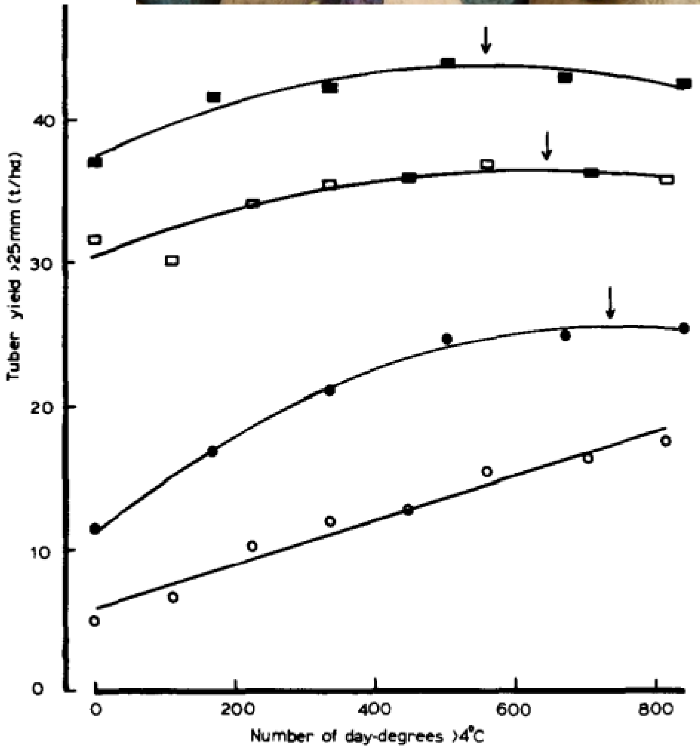
5. Physiological and chronological age: what is the difference?

- Physiological age
  - Contained in the sprout (and lost when the sprout gets detached)
  - Advances emergence and therefore shifts the time course of leaf development and expansion
  - Sprouting advances early yield



Source: O'Brien et al., 1986

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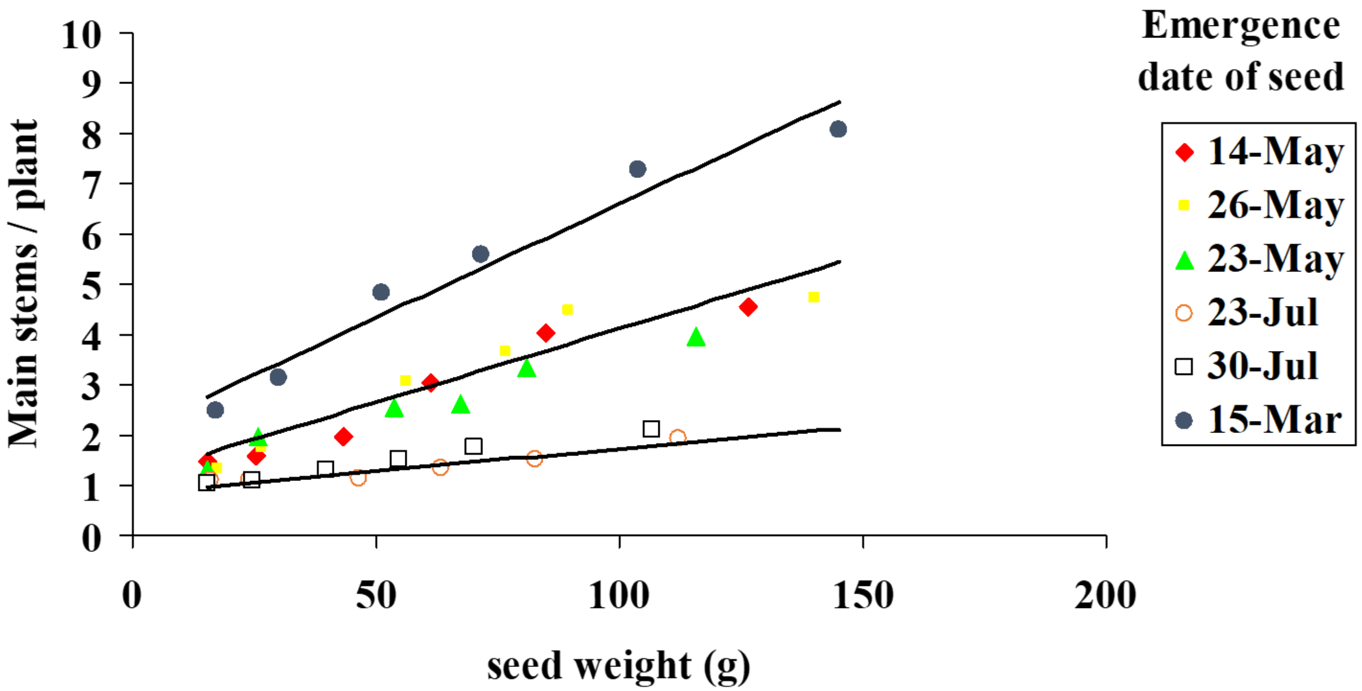
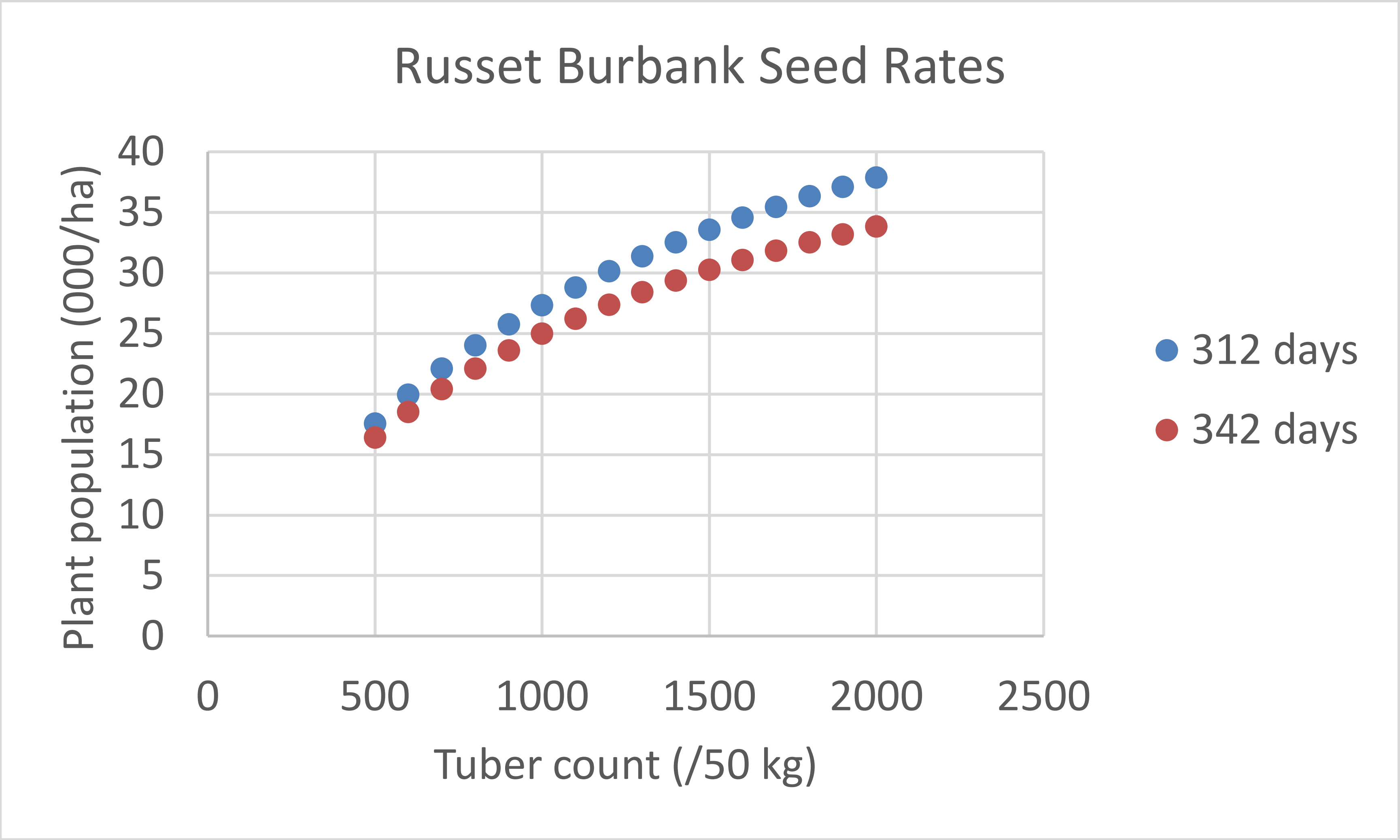
Chronological age

- The time intervals (days) between tuber initiation of the seed crop and the re-planting of the ware crop (better to use emergence date)
- The longer the interval, the greater the number of sprouts liberated from apical control and the more stems produced = more tubers



Source: Firman & Shearman, 2010

Chronological age: crucial for seed rates



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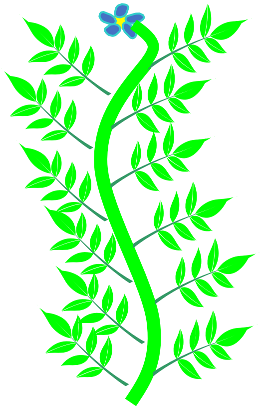
6. Split N applications are better for the crop

Total N applied (kg N/ha)	N applied at planting (%)	Yield (t/ha)
160	**50**	**42.3**
160	75	50.1
160	**100**	**54.0**
190	**42**	**42.8**
190	63	52.1
190	**84**	**52.4**
220	**36**	**48.3**
220	55	47.5
220	**73**	**53.7**

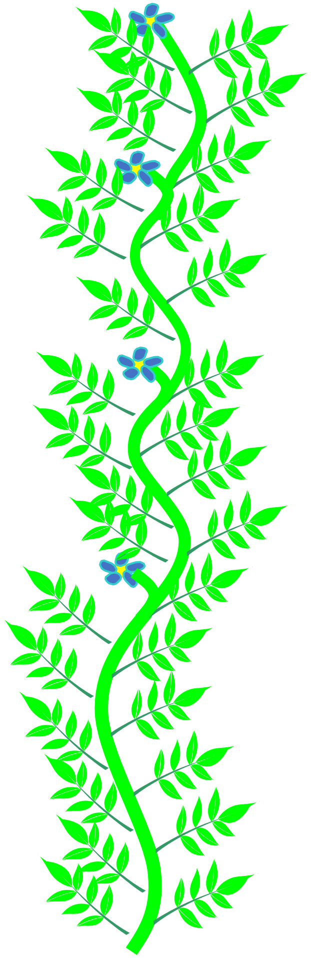
S.E. (6 D.F., different basal N) 3.08
S.E. (36 D.F., same basal N) 2.91

Allison *et al.,* (2015). Lady Rosetta, Swaffham, 2010

1980's: blanket N rates for all varieties. CUF developed determinacy and variety-specific N rates

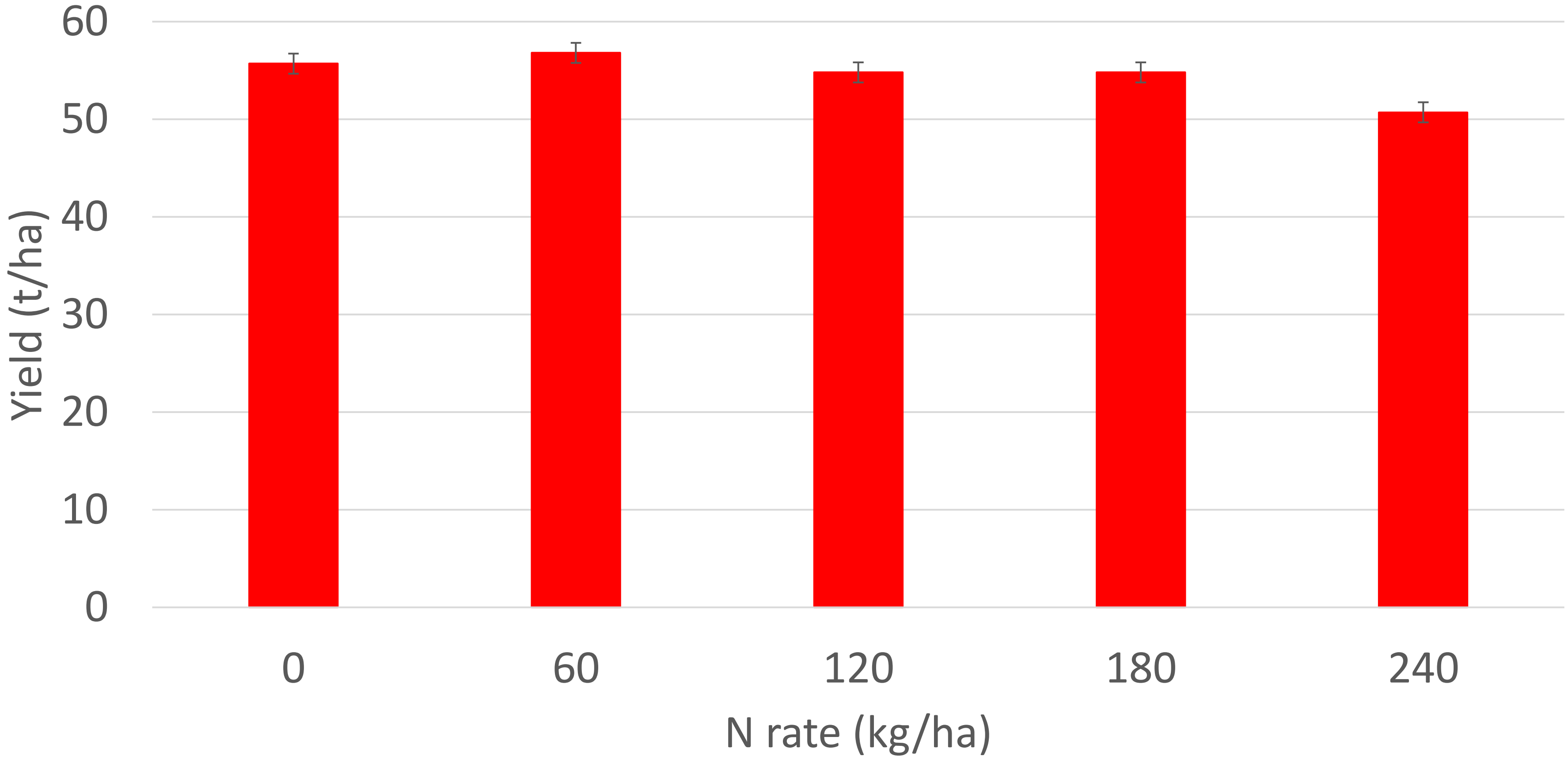


Determinate variety



Indeterminate variety

Response to N on peat soils (1985-1987)
Savings for three CUPGRA Members: **£239K p.a.**



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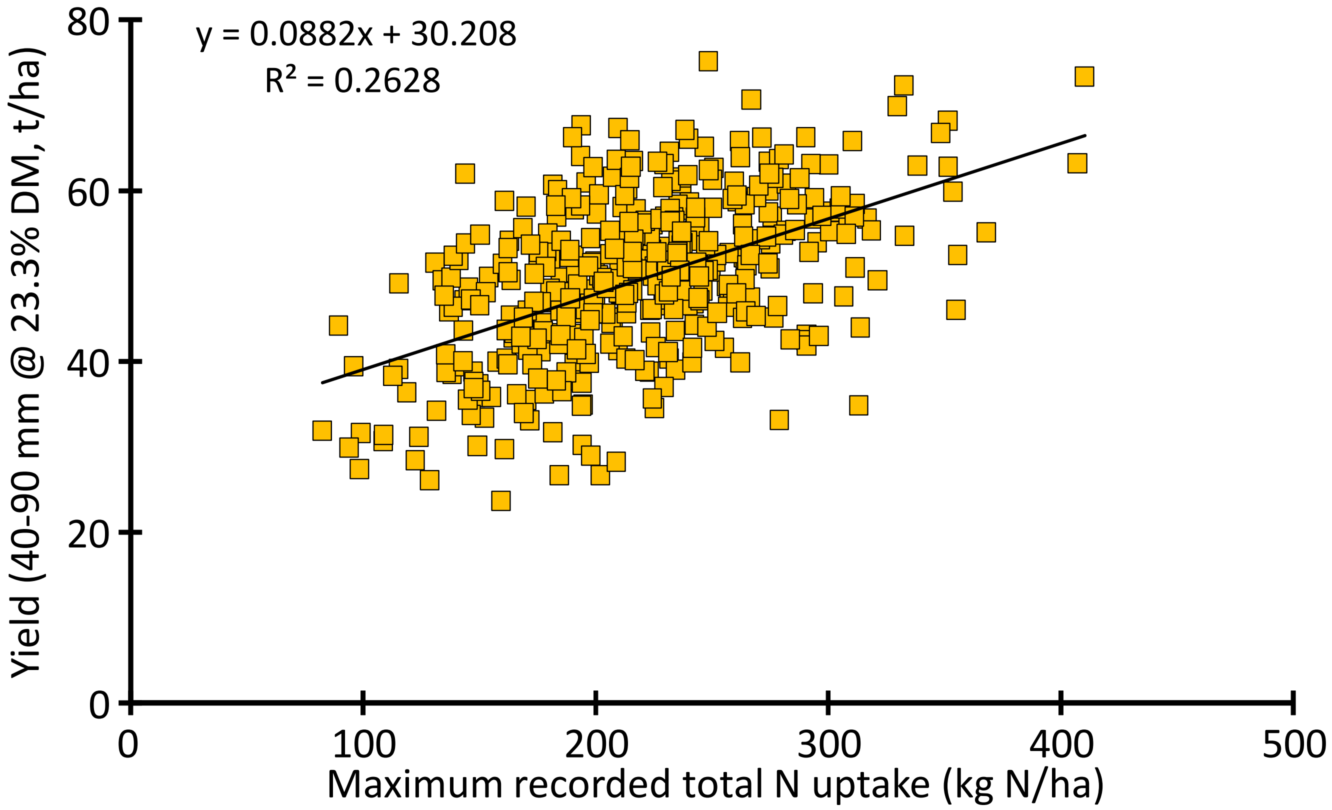
Large N uptake = big yield?

Data from 402 processing crops 2010-2015 where N uptake was measured
Mean ware yield at 23.3 % DM = 49.6 t/ha
Mean total N uptake = 220 kg N/ha



Source: Allison *et al.* 2016

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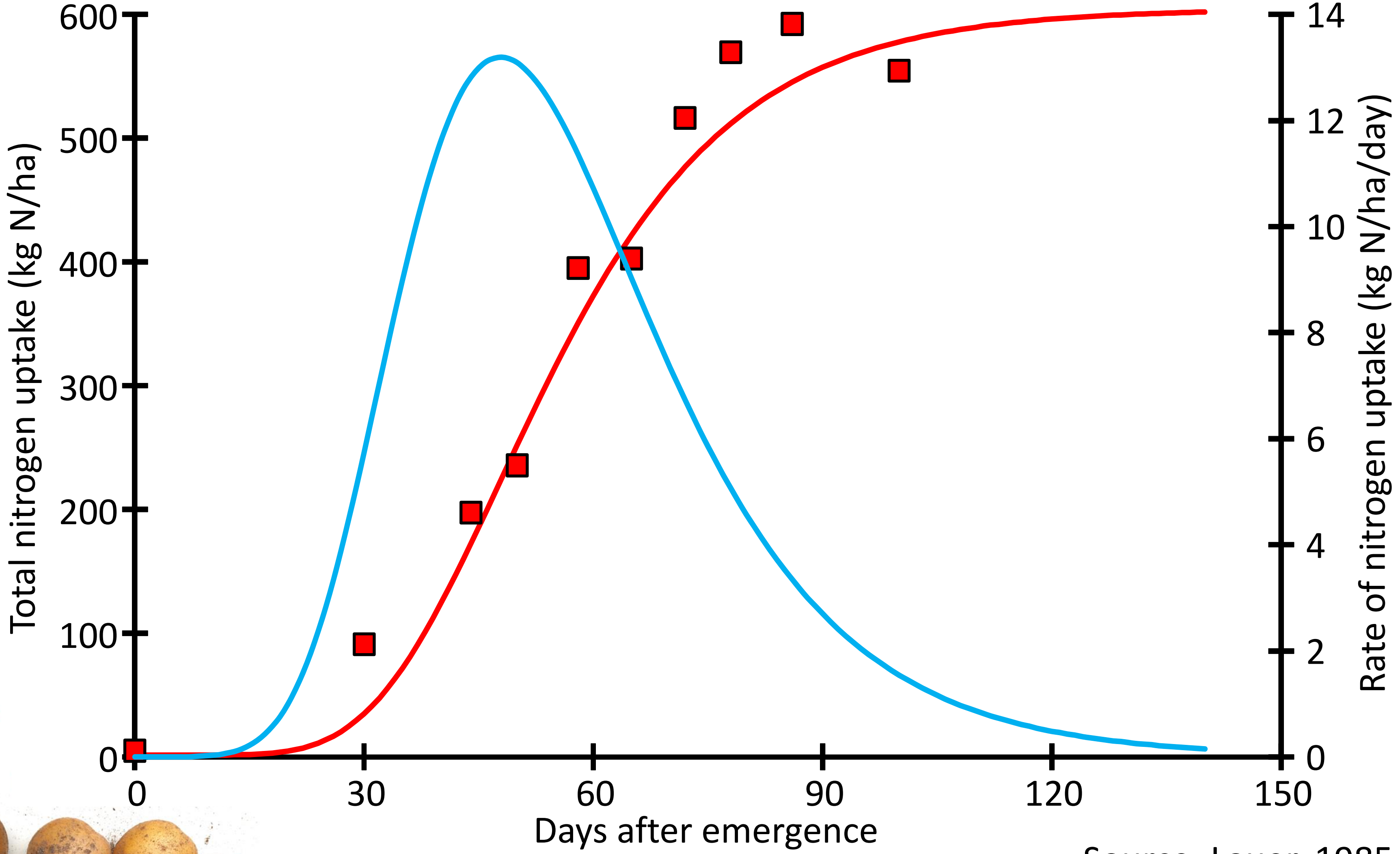
N uptake in very high-yielding (>90 t/ha) crops



Source: Lauer, 1985

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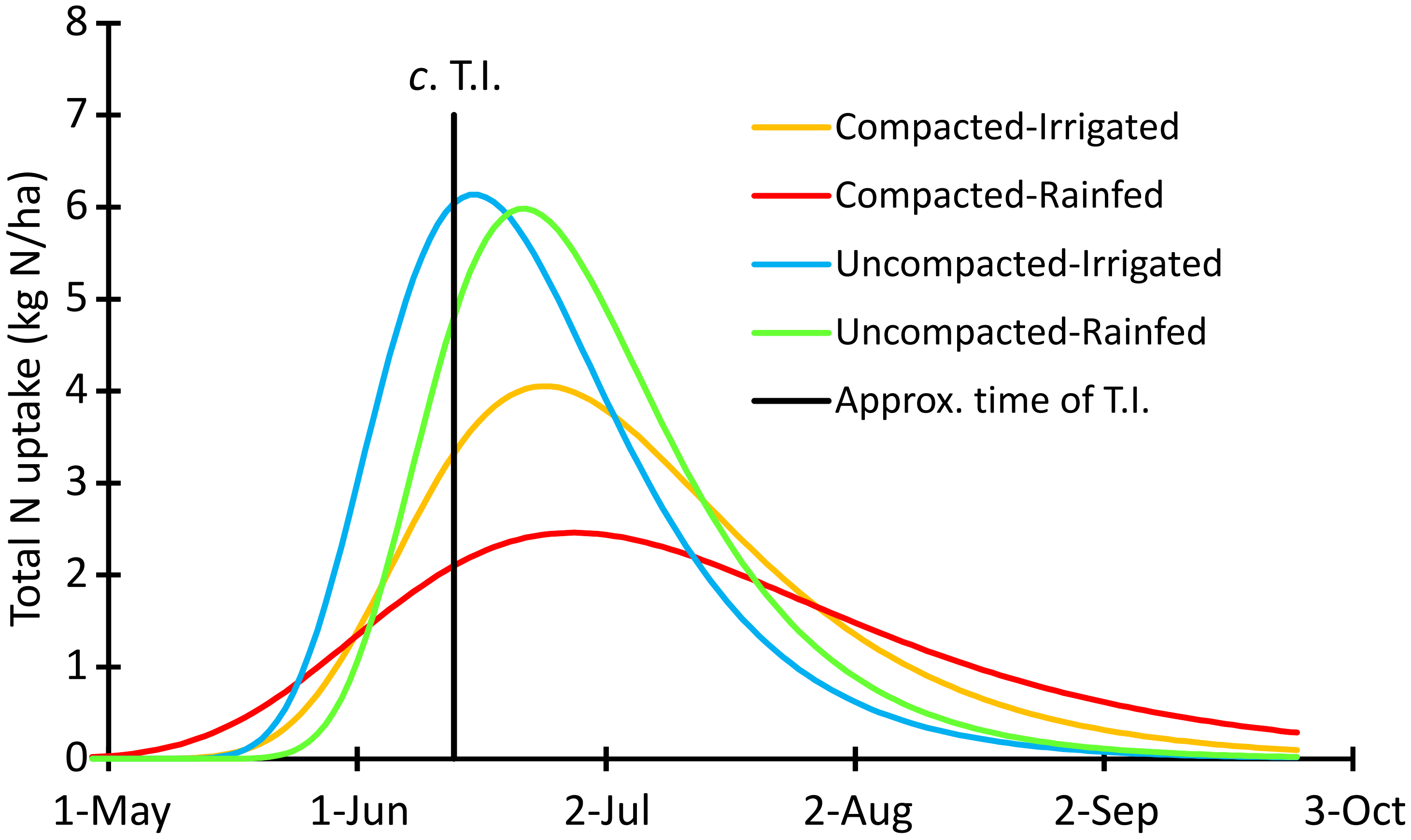
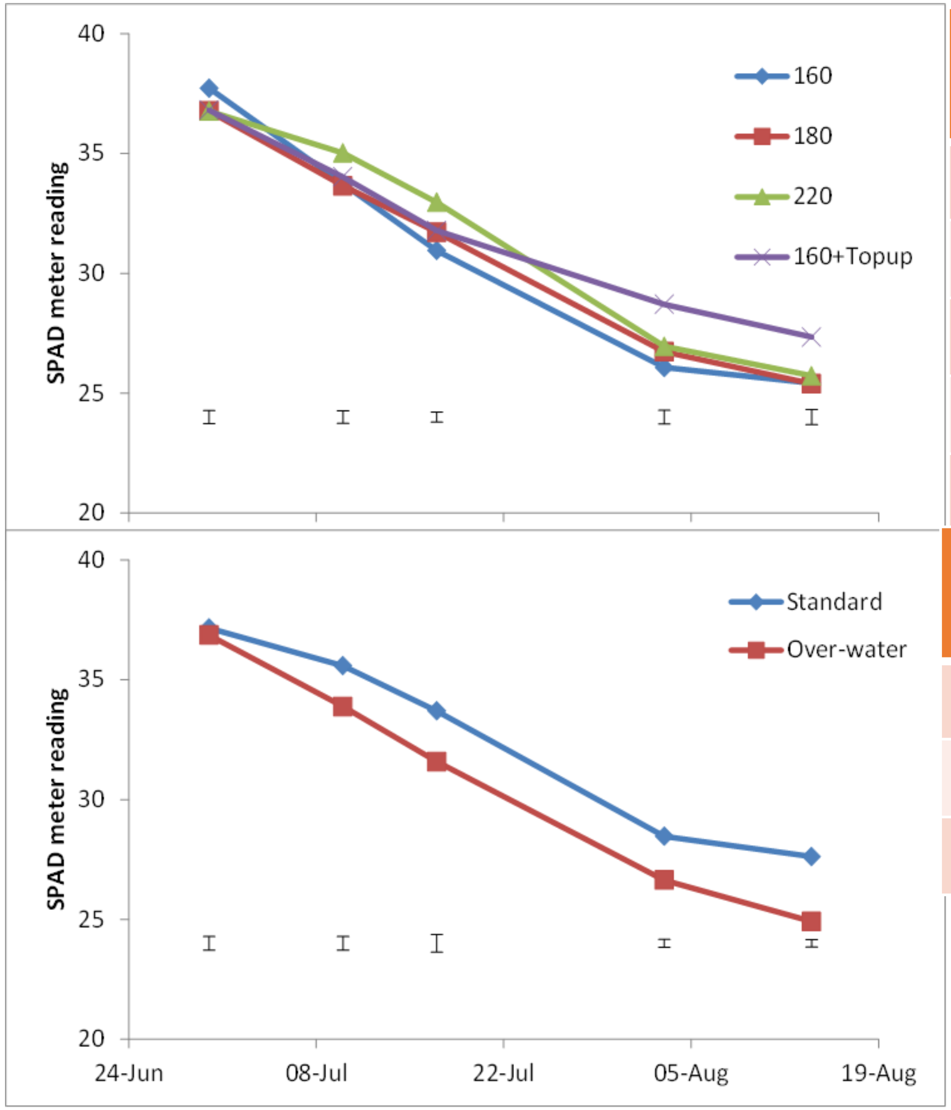
Rapid early N uptake is crucial to high yields (>60 t/ha)



Source: Allison & Stalham (2007)

Effect of late N on canopy colour and yield



N applied (kg N/ha)	Total yield (t/ha)
160	65.0
180	62.0
220	63.1
160 + 30	64.6
S.E.	4.13

Irrigation	Total yield (t/ha)
Standard	63.2
Over-watered	59.9
S.E.	2.92

Source: Stalham, 2018

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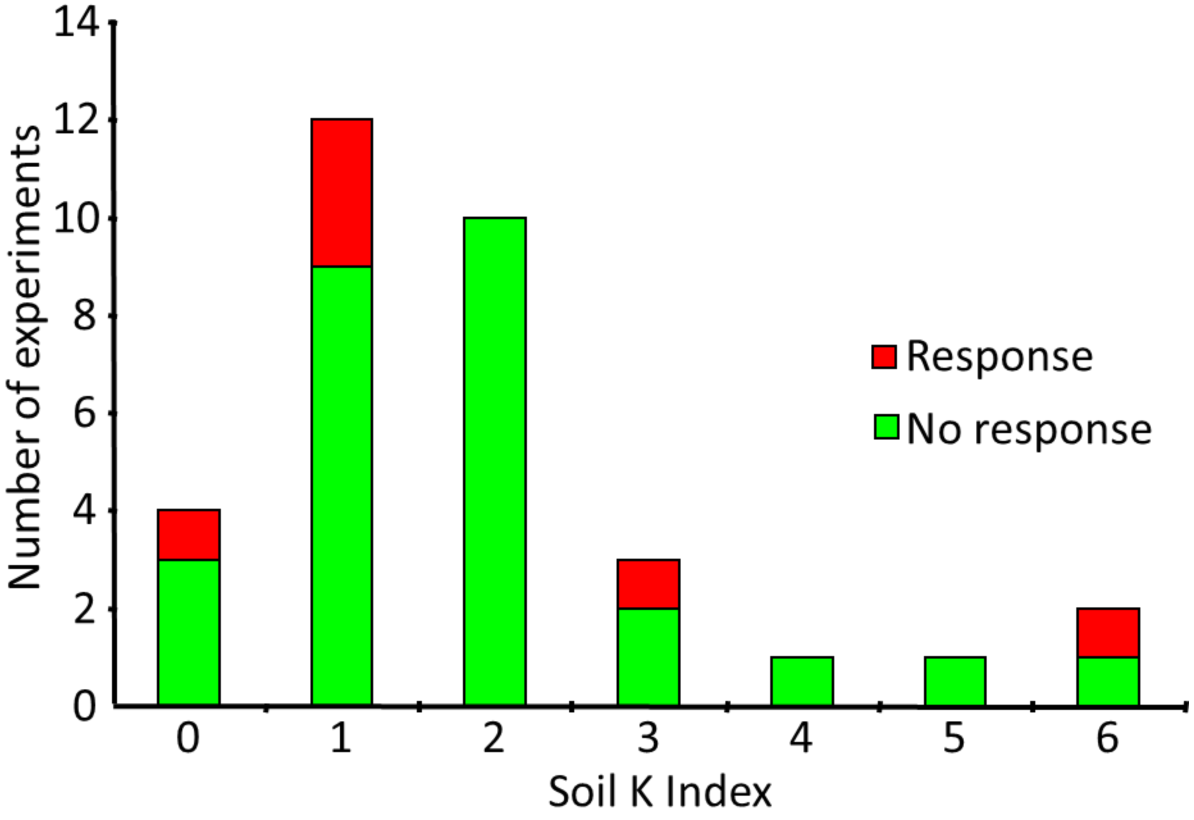
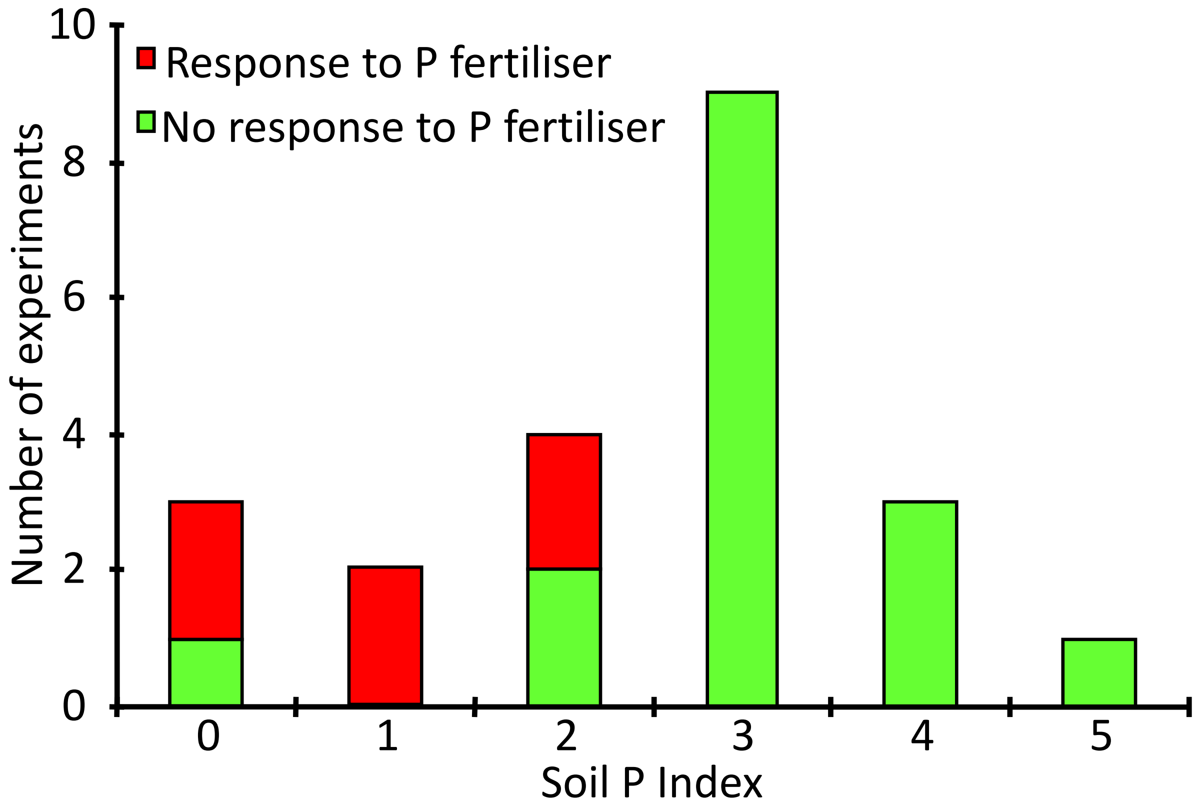
7. Potatoes are responsive to K



- Range of low to high yields
- Sand- to clay-textured soils
- Chance of a response almost random
- Only 25% probability of response at Indices 0 and 1
- Response maximized between 100-200 kg K_2O/ha: big errors
- Offtake: 300 kg K_2O/ha
- Maximum applic. 250 kg K_2O/ha
- K vacation at Index >3?

Source: Allison *et al.*, 2001b

8. Potatoes are sensitive to low P



- Range of very low to high yields
- Sand- to clay-textured soils
- Response likely at Indices 2 or lower
- Optimal rate typically <100 kg P_2O_5/ha
- P vacations above Index 2

Source: Allison *et al*. 2001a

9. Shooting yourself in the foot….

Not many GREEN cells, with a lot of RED

Table 2. A summary of the evidence for positive biostimulant effects on plant nutrition, growth and stress tolerance for any plant species, based on information summarised in AHDB Review No. RR89

		Promote plant nutrition?			Improve plant growth and yield?			Promote biotic stress tolerance?	
Group	Product type	Nitrogen	Phosphorus	Other nutrients	Hormonal	Growth	Yield	Pathogen	Pest
Non-microbial	Seaweed extracts	Red	Red	Red	Amber	Amber	Amber	Red	Red
	Humic substances	Amber	Red	Red	Red	Amber	Amber	Grey	Grey
	Phosphite and other inorganic salts	Grey	Grey	Grey	Red	Amber	Amber	Amber	Grey
	Chitin and chitosan derivatives	Grey	Grey	Grey	Red	Amber	Amber	Green	Red
	Anti-transpirants	Grey	Grey	Grey	Green	Grey	Amber	Grey	Grey
	Protein hydrolysates and free amino acids	Red	Grey	Red	Grey	Red	Red	Grey	Grey
Microbial	Plant growth promoting bacteria	Amber	Amber	Red	Red	Green	Green	Amber	Red
	Non-pathogenic fungi	Red	Red	Red	Red	Amber	Amber	Amber	Grey
	Arbuscular mycorrhizal fungi	Red	Amber	Red	Grey	Amber	Amber	Red	Red

Green: Good evidence base (including multiple field-based experiments on cereals or oilseed rape)

Amber: Moderate evidence base (good number of experiments, including some field-based experiments on cereals or oilseed rape)

Red: Low evidence base (principally laboratory-based experiments with little or no data on cereals or oilseed rape)

Grey: No evidence base (not enough evidence available)

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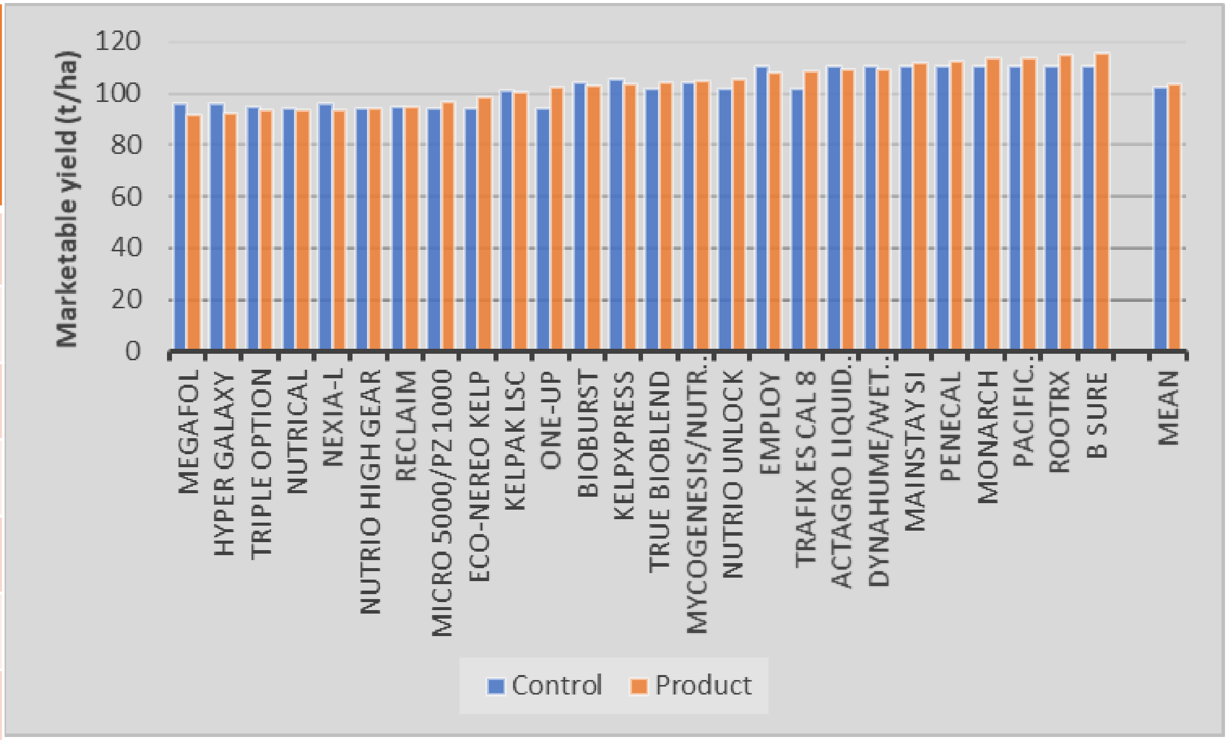
Biostimulants: USA experience

Product	Total yield (t/ha)	Total yield excl. culls (t/ha)	40-80 mm yield (t/ha)	>80 mm yield (t/ha)
None	62.8	59.4	47.2	11.9
Rootella	59.6	56.5	46.2	10.1
MycoGold	63.0	59.8	47.0	12.6
Accomplish LM	62.9	59.9	46.2	13.4
Heliae	59.3	56.4	44.7	11.4
Soil Pro	63.2	59.8	45.0	14.6
S.E. (69 D.F.)	1.80	1.80	1.44	0.86
Fprob	0.415	0.443	0.766	**0.010**



N.B. These are all big to very big yields. Marc Allison and I never found anything significant either in over 30 years at CUF!

In summary: Eric’s hard truths

- Many aspects of agronomy contribute to future success – soil cultivations, inadequate water supply, excessive N applications, control of diseases and the presence of nematodes
- There is **developed** knowledge in **most** of these areas, but it is **still** in need of interpretation before it can be applied
- It is also quantitative and mathematical and as such does not appeal to many in the industry. As a consequence, it is not well applied
- This will have to change if substantial progress is to be made
- Eric wrote this in **2006:** does it still read the same in 2021?

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In summary: how to do it

- **Clearer definition of the target**(s) for each crop – timing, size, quality
- All **planning decisions** must be taken against these targets and judged accordingly. The decisions themselves require **greater definition** e.g. holistic seed production vs choosing 25 cm as a spacing in April
- Emergence, tuber initiation, leaf growth, number of tubers – need to be recorded so that the progress of the crop towards its target can be continuously assessed. This allows some remedial agronomic action in the current year and **provides the basis for improvement** in subsequent years (sometimes by avoiding identified errors and at others by changing individual components e.g. seed density, N rate etc.)
- **More detailed involvement in crop recording** and **management** than is (still) currently practised or will be welcomed. Essentially, it makes agronomy **real time and prospective**, rather than retrospective and thereby superficial. There is, however, considerable value in the change which the industry cannot afford to miss if it is to survive

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Agronomic management ("Understanding how potatoes grow determines how to grow potatoes") must be:

- Quantitative
- Real time
- Informed
- Willing to involve a greater element of risk: trust the science
- Communicated – talk to the growers – they are the ones with money invested after all

Give scientists the facilities to allow them to think and work effectively and they will flourish

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The duke's new invisible umbrella…remember to challenge everything!

Thank you for hearing me out. Have a great and safe Christmas!

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