PEI Potato Conference 2019

Alternative Irrigation Technology in the United Kingdom

Dr Mark Stalham

Background to UK irrigation

- In 2010, 36 000 ha of potatoes were irrigated (120 000 ha grown)
- They consumed 54 % of all irrigation applied
- Typical average annual application for maincrops during 2001-2010 was 104 mm
- Water abstraction for spray (and now drip) irrigation is licensed by the Environment Agency (National Government)
- Only 50 % of growers used a numeric or measurement method of scheduling from the early 1980s until 2005
- Water Framework Directive (2008) stimulated an increase in scheduling to 62 %
- 78 % of growers use methods based on crop inspection and soil feel (may be in combination with measurement methods)
- What will happen in the future (e.g. climate change, licencing?)

Sources: MAFF; Weatherhead *et al.* (2005); Defra (2011)

UK irrigation equipment usage by area

• Hosereel + raingun	76 %
• Hosereel + boom	17 %
• Drip	4 %
• Solid set sprinklers	2 %
• Centre pivot and linear move	1 %

Majority of systems are high pressure, high flow

Source: Defra (2011)

Water abstraction in England & Wales

- Agriculture 184 Mm^3 (livestock 41 %, irrigation 38 %)
- Licence required for spray and drip irrigation
- Water sources
  - Groundwater (41 %)
  - Surface abstraction (52 %)
  - Rain-fed reservoir (rare, filled with above)
  - Winter vs summer abstraction licences
- Licence application upheaval 2017-2027

Licenses

- Licences include limitations on
  - Total volume extracted
  - Hourly abstraction rate
  - Limitation on abstraction if river levels are low
- Some ‘licences of right’ exist where the restrictions on abstraction are limited: being revoked
- Transfer licence (from one abstraction point to another)
- Licence trading

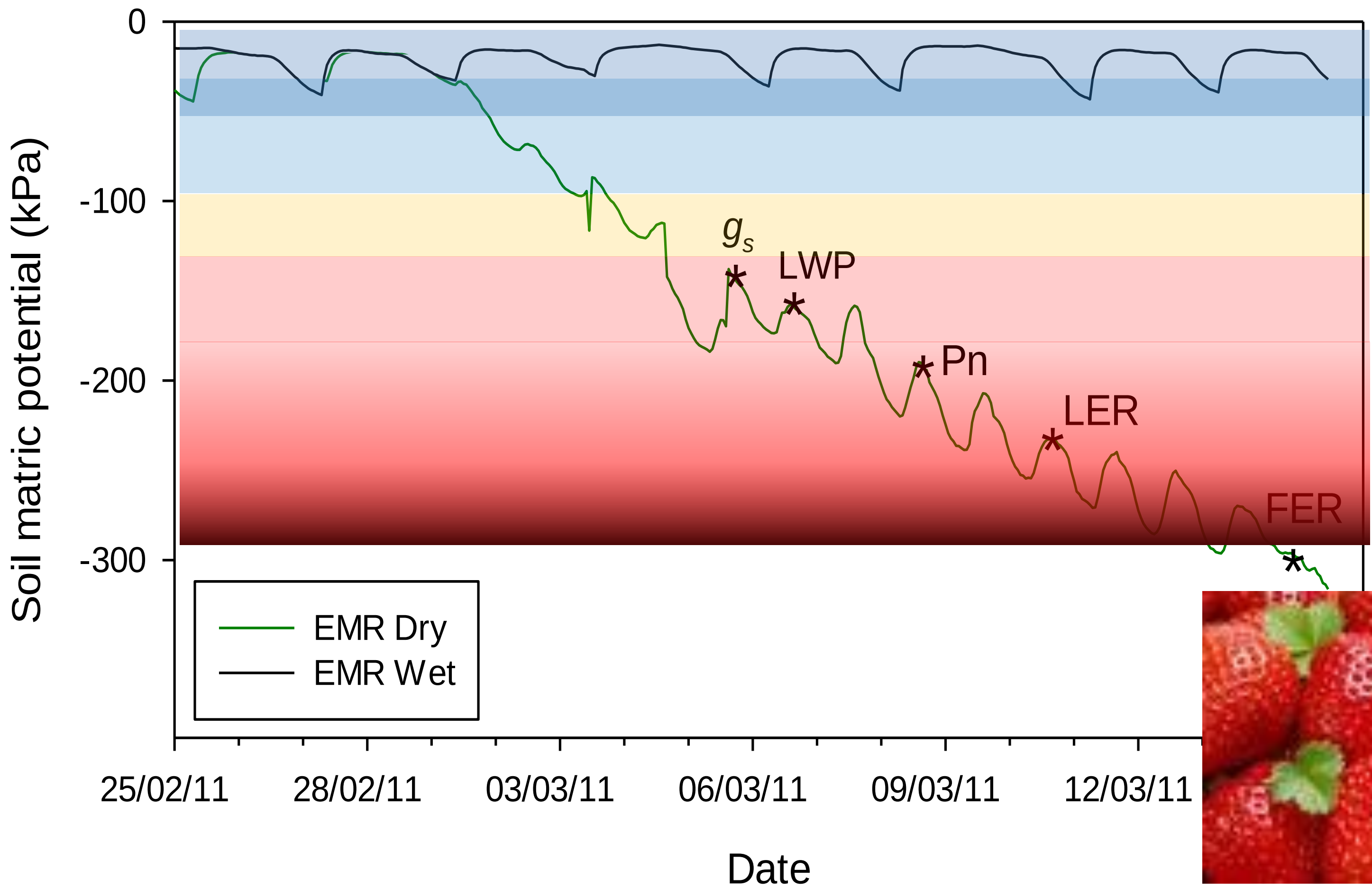
What is licencing really about?

- Introduce controls on more licences to better **protect the environment,** particularly at low flows
- Cap licences to prevent increased abstraction **damaging the environment**
- Fine-tune the use of surface water and groundwater sources to make the best use of water when it is available while **protecting the environment**
- Support rapid water trading where it is needed most to allow abstractors to share access to water quickly
- Allow some winter abstractors to take water at the highest flows in the summer to boost the use of stored water
- Share real-time information on river flows and forecast changes to help abstractors plan their water use
- Manage water discharges to benefit abstractors downstream who depend on them

Targets for efficient use of irrigation

- Understand crop demand for water
- Maximise the quantity and rate of water extraction from the soil
- Maximise tuber quality (common and powdery scab, lenticel eruption, processing quality, shape and internal defects)
- Minimise losses from irrigation, particularly during early season when SMDs are small (e.g. scab control)
- www.niab.com/NIAB_CUF_Irrigation_Scheduling

Deriving irrigation set points for field-grown 'Elsanta' strawberries (Else *et al*. 2012)



Commercial

Grower test regime

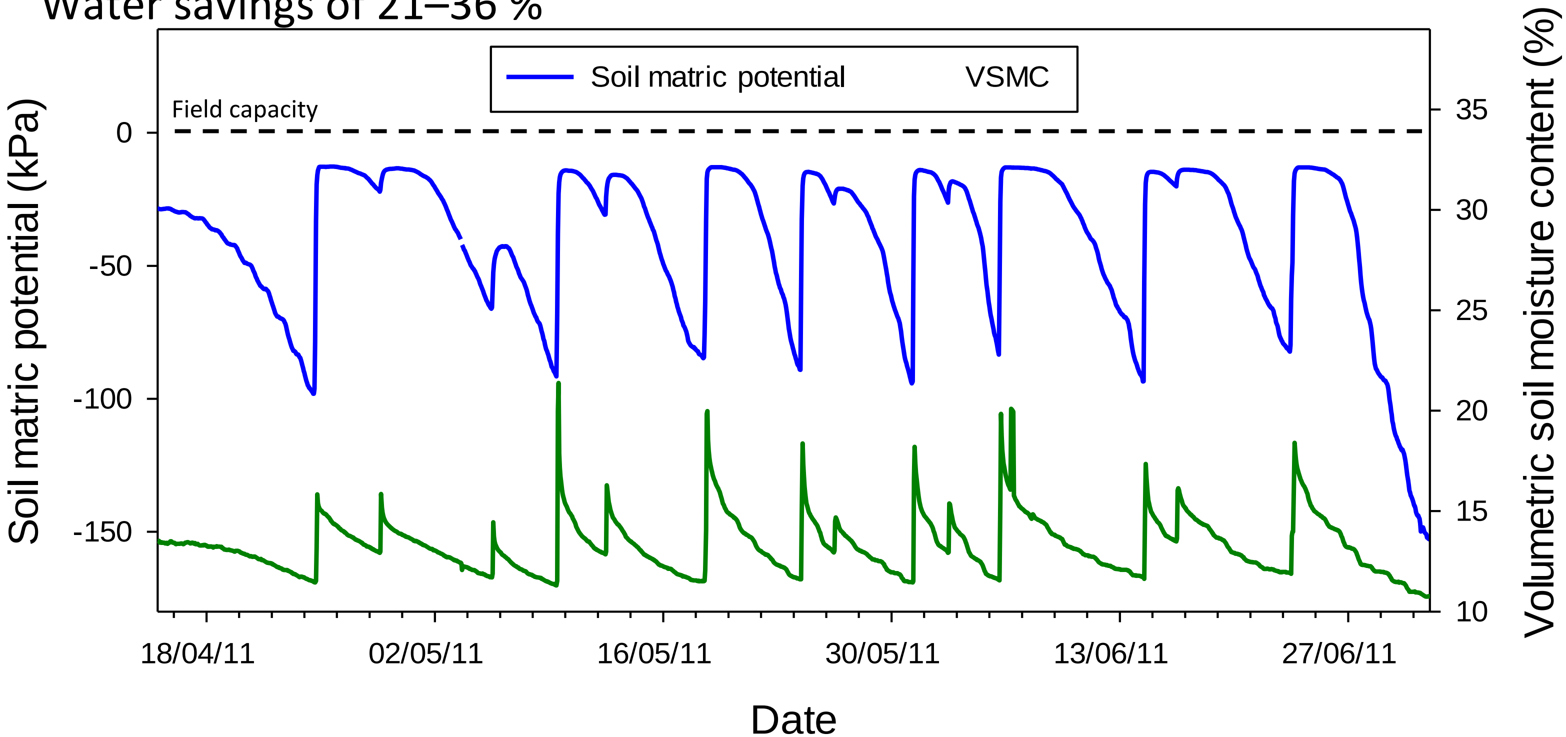
Buffer zone

Mild RDI

Quality and yields reduced…

Higher Class 1 yields under Grower Test Regime

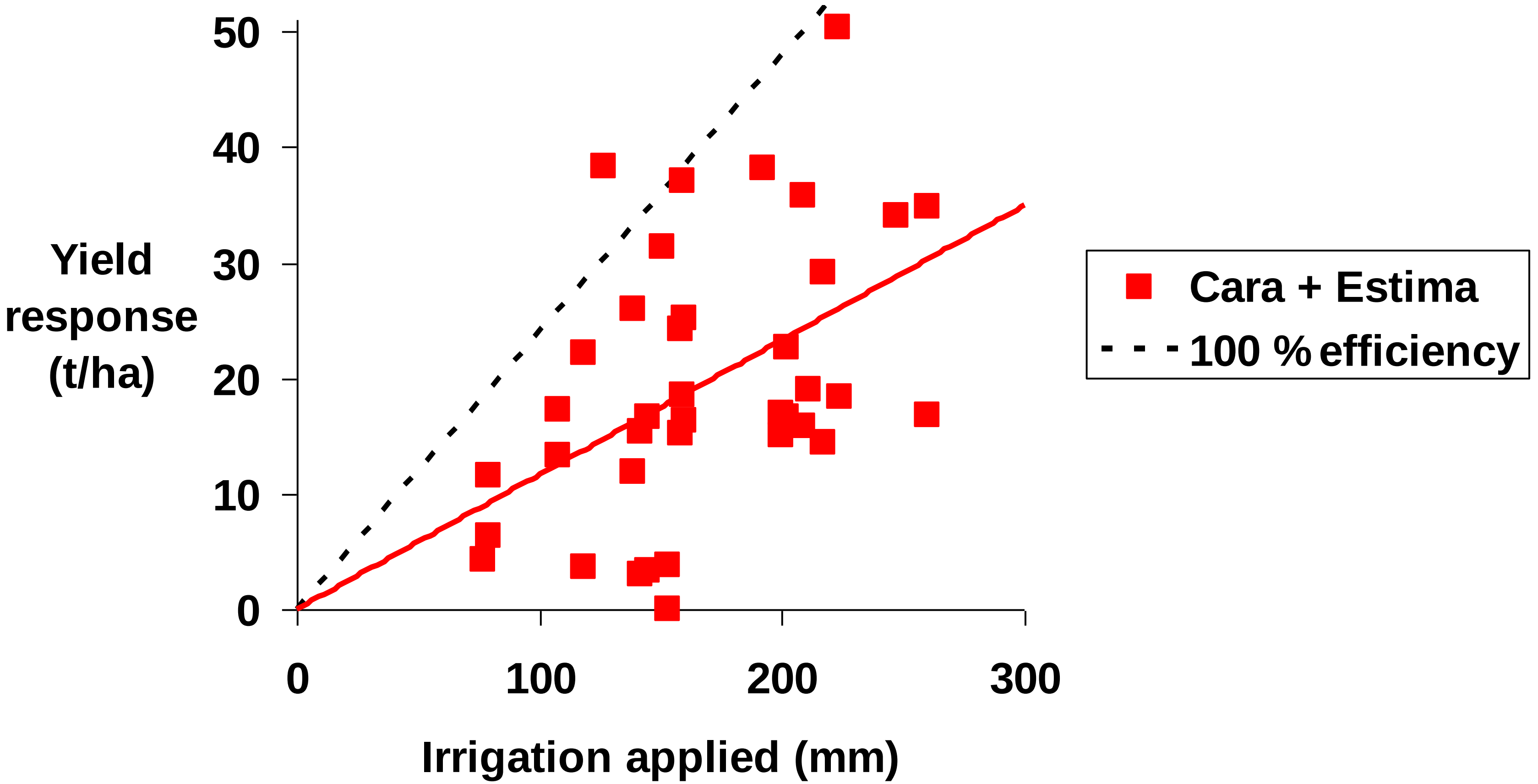
- **100 KPa not 30 KPa refill**
- Water savings of 21–36 %



- Class 1 yields of ~23 t/ha (15 % increase)
- Water productivity = 27 l/kg (**27 % decrease in water per kg**)
- Bigger, firmer, better-flavoured (M&S) berries

LINK collaborative research

Is a **big** improvement possible in irrigation use efficiency?



Source: CUF Reference Crop 1990-2017

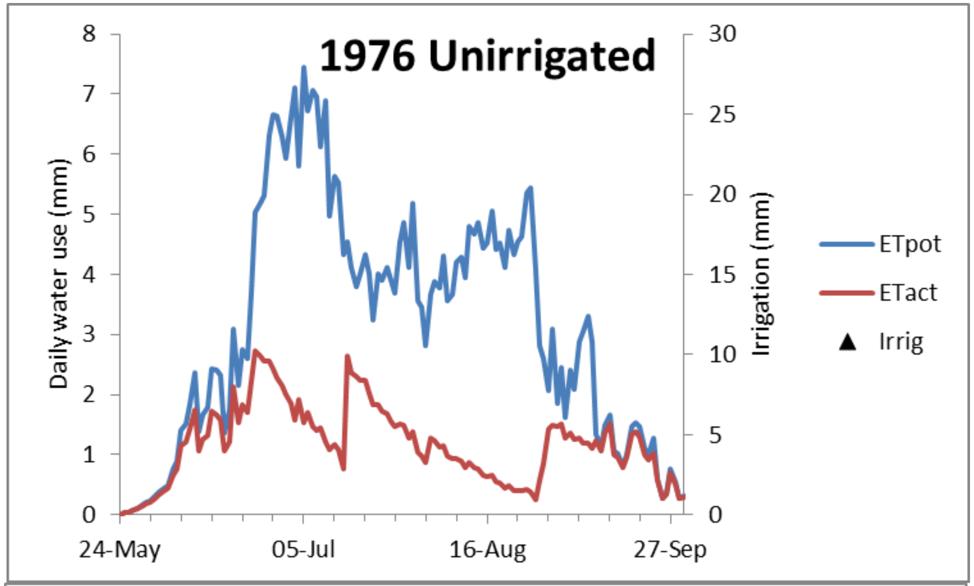
Definitions used in scheduling

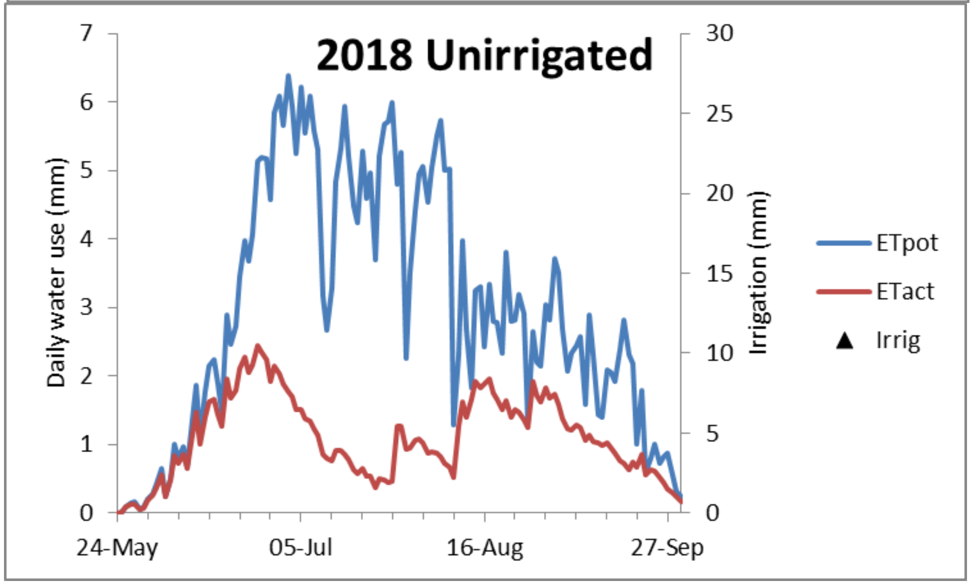
- SMD = soil moisture deficit
- Limiting SMD = SMD when crop water use slows below the potential as the soil is too dry
- Irrigation = amount reaching crop canopy
- Drainage = loss below rooting zone
- Model ET_{pot} = water use by crop with unrestricted water supply
- Model ET_{act} = water use by crop with irrigation schedule being used

Model scenarios

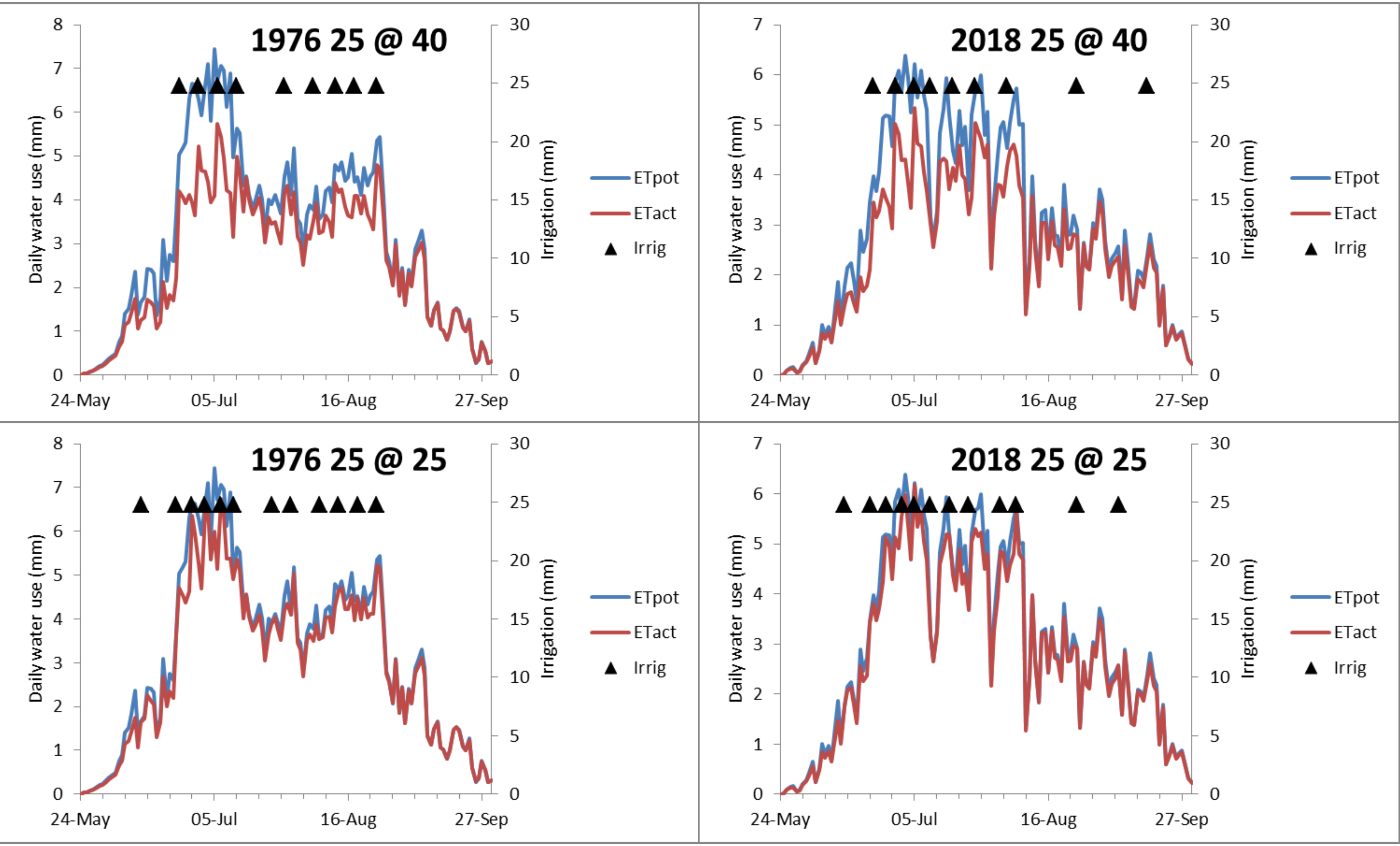
- 1976, (1990), 2018 hot, drought seasons
- ‘Benchmark’ Maris Piper ground cover curve
- Emerged 24 May, commences senescence at end of August, almost dead at end of September
- 6 scenarios
  - Unirrigated
  - 25 mm @ 40 mm SMD
  - 25 mm @ 25 mm SMD
  - 12 mm @ 12 mm SMD
  - 6 mm @ 6 mm SMD
  - Actual experimental practice (and yield check)

Unirrigated

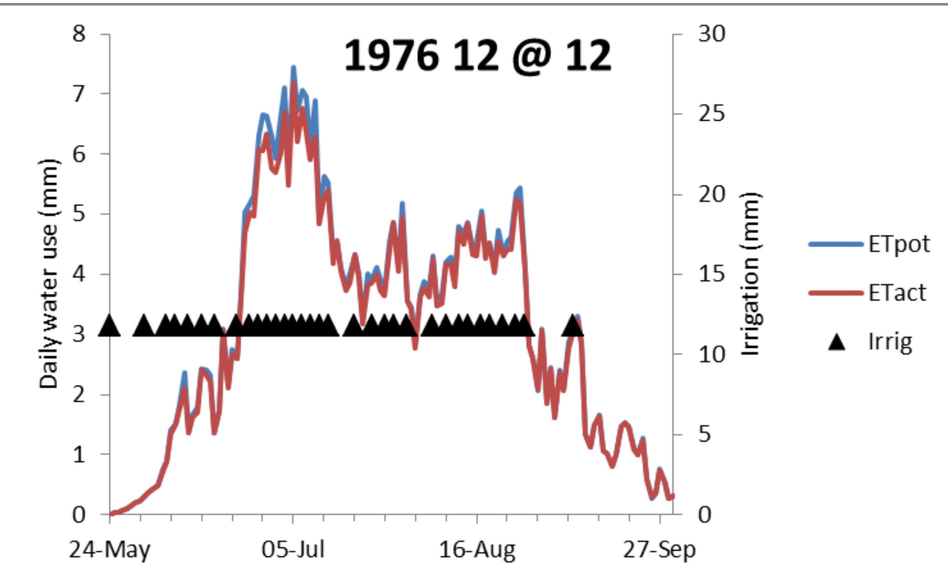


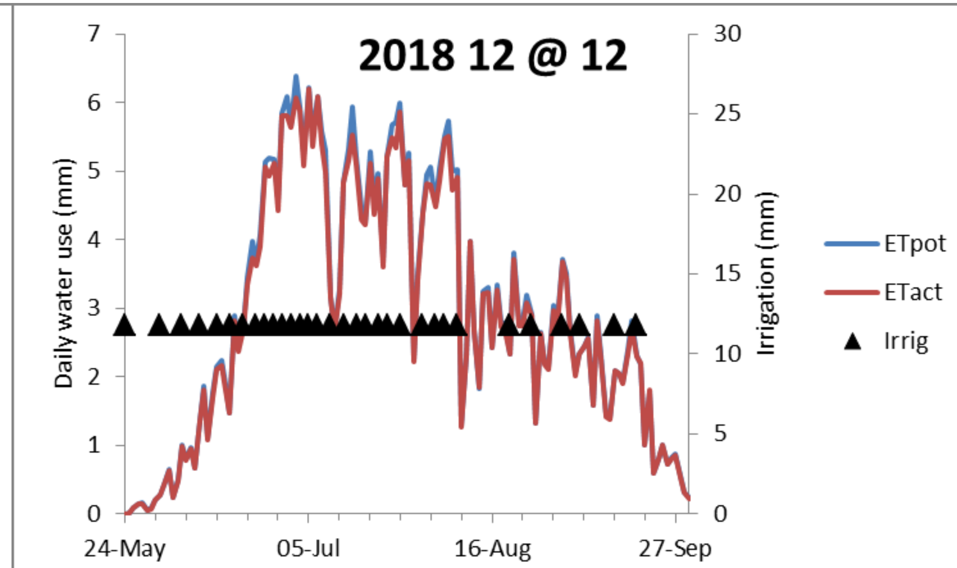


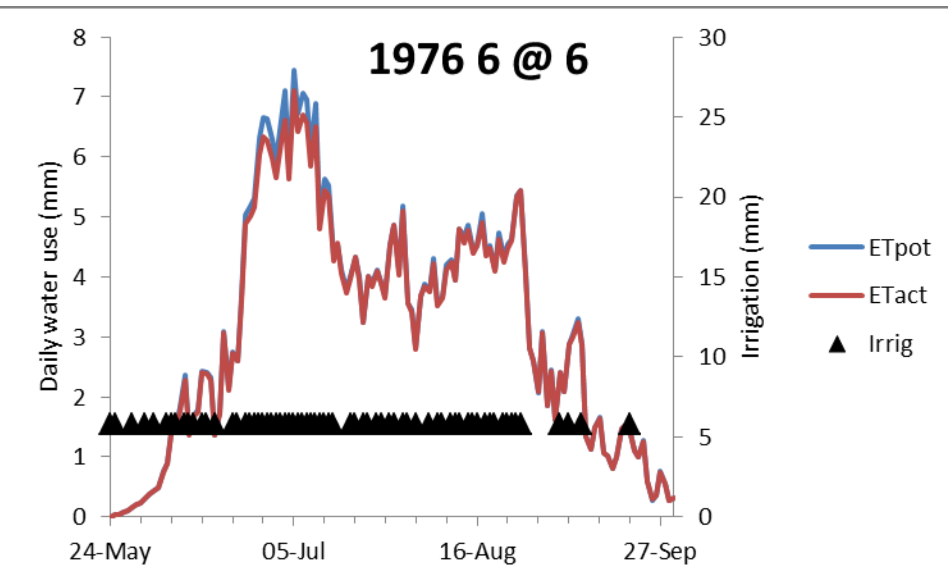
25 mm application

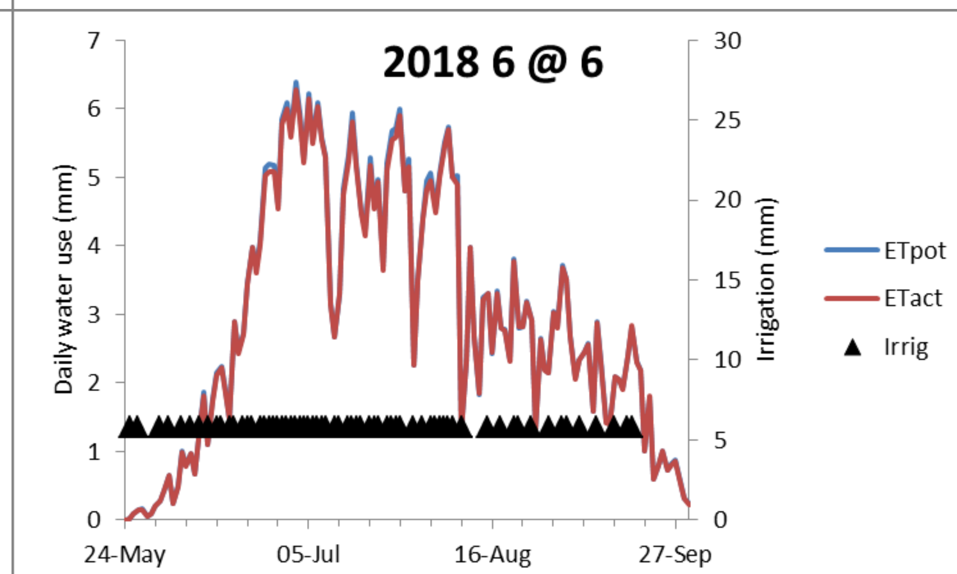


12 or 6 mm application









Summary

	Unirrigated	25@ 40	25 @ 25	12 @ 12	6 @ 6	Actual
Irrigation (mm)						
1976	0	225	300	396	414	-
2018	0	225	300	384	396	316
Irrigation no.						
1976	0	9	12	33	69	-
2018	0	9	12	32	66	16
Yield (t/ha)						
1976	33.5	73.9	83.2	87.1	88.1	-
2018	31.5	70.6	79.5	82.6	83.6	79.9 (79.0)

Do we need the extra frequency as long as we have the capacity (25 mm every 5 days)?

Climate Change Scenarios for 2050

- Rainfall (c.f. 1968-1990) Low vs High emissions
  - Summer 20-40 % drier in SE England
  - Winter +0-15 % (Low) to +5-20 % (High)
  - Pivot point NW Scotland, i.e. SE England greatest change
  - Longer spells of drought
  - More extreme rainfall events (341 mm/day!), but likely to be in the winter not summer

Climate Change Scenarios for 2050

- Evapotranspiration
  - Less cloud cover = increased solar radiation = more ET energy
  - 15-20 % increase in ET
  - Increased demand for irrigation?
- But:
  - CO_2 increase from 350 to 550 ppm
  - Increased growth rate (20-30 %)
  - Reduced stomatal aperture = increased water use efficiency (25-30 %)
  - Balances out so only 20-25 mm more water required per season
  - Can we manage on existing supplies?

The future saviour?

- Tobacco plants with increased Photosystem II Subunit S (PsbS) expression show less stomatal opening in response to light, resulting in a 25 % reduction in water loss per unit CO_2 assimilated under field conditions.
- Since the role of PsbS is universal across higher plants, this manipulation should be effective across all crops.

Glowacka *et al.* (2018)

Application equipment

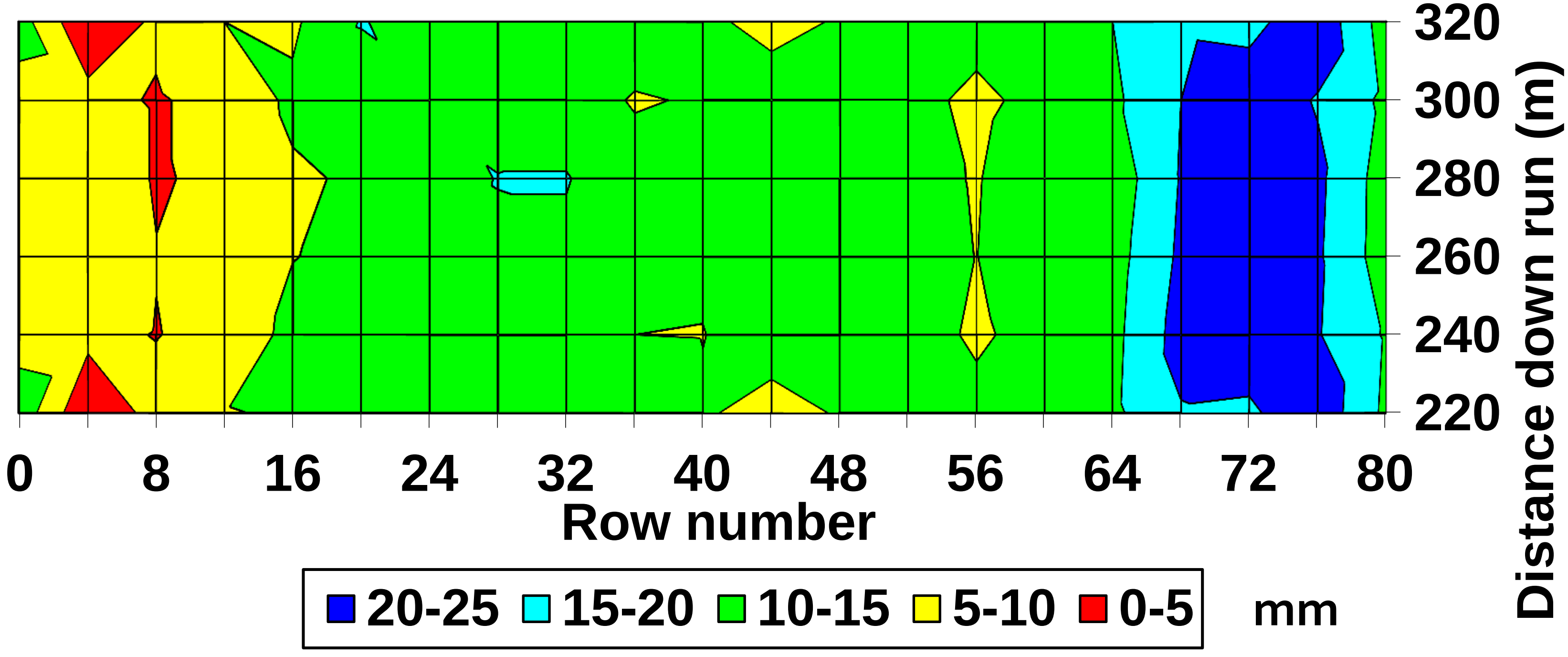
Pressure requirement for typical irrigation systems

• Most pipe systems	12 bar
• Hosereel	5.5-10 bar
• Rainguns	4-5 bar
• Booms	2-4 bar
• Sprinklers	2-4 bar
• Drip	0.5-1 bar

Raingun operation

- Raingun operation – system pressure
- Biggest single problem is often incorrect pressure (i.e. low) at the gun
- Results in:
  - Poor atomisation – many larger drops
  - Poor distribution
  - Higher energy impact on soil / plant
  - Overall shorter throw of water
  - Wind worsens all these factors
- 210° better than 180° as gun lingers on reversal
- Variable or low trajectory (15-25°) guns can provide advantages in windy, exposed conditions

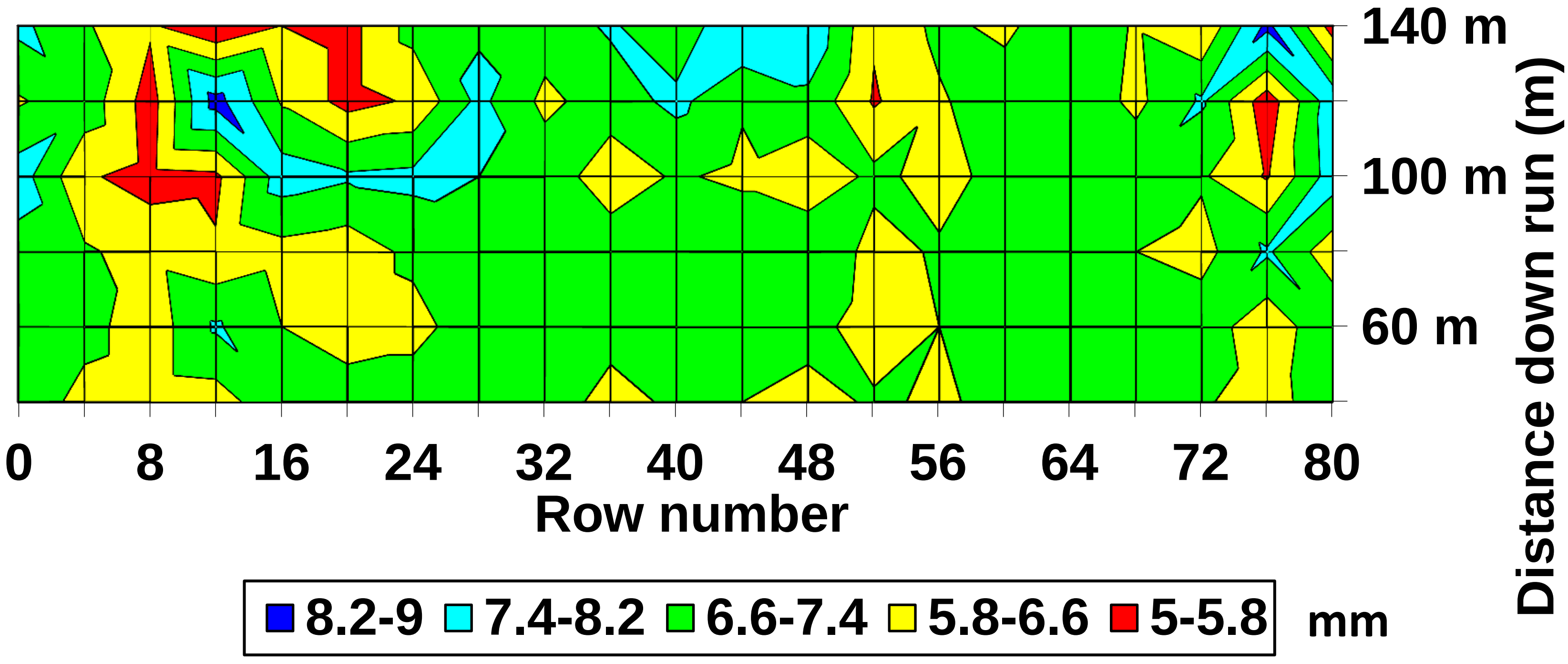
Irrigation distribution pattern of Wright Rain ST350/Nelson gun combination. Three adjacent runs, two day-time, one night-time. Conditions: wind 20 km/hr day, 1 km/hr night. Target application: 12.5 mm. Achieved: 12.5 mm. Coefficient of uniformity: 65 %



Boom operation

- Increasing use on high-value crops
- Uniform droplet size
- Very low crop damage / soil splash
- Application uniformity usually >90 %
- Less prone to wind effects (drift reduces amount uniformly rather than erratically)
- Operate at 2-4 bar
- Higher initial cost
- Slower to move
- Field ‘furniture’ issues
- Not suited to soils with low infiltration rate

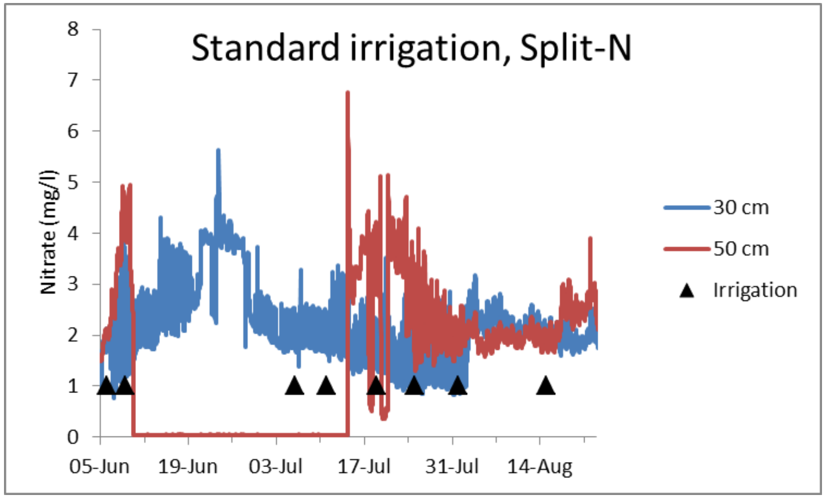
Irrigation distribution pattern of Briggs R50 boom + Ocmis R4/100/450. Two adjacent runs, both day-time. Conditions: wind 25 km/hr. Target application: 8 mm. Achieved: 6.7 mm. Coefficient of uniformity: 87 %

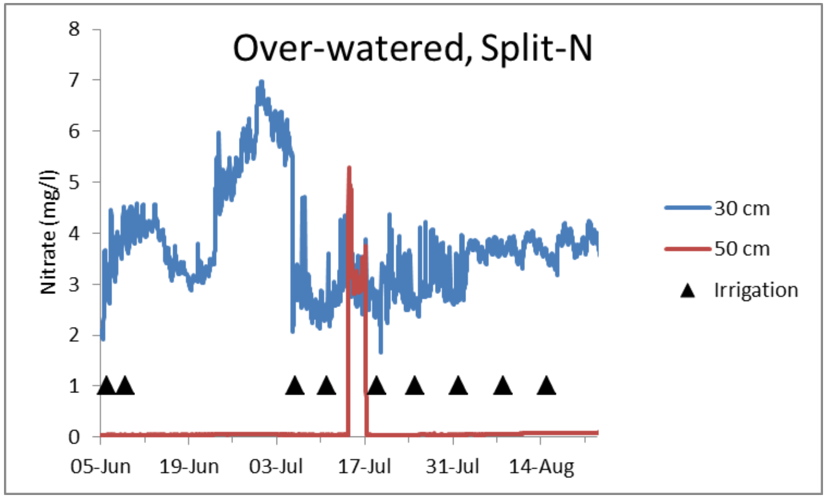


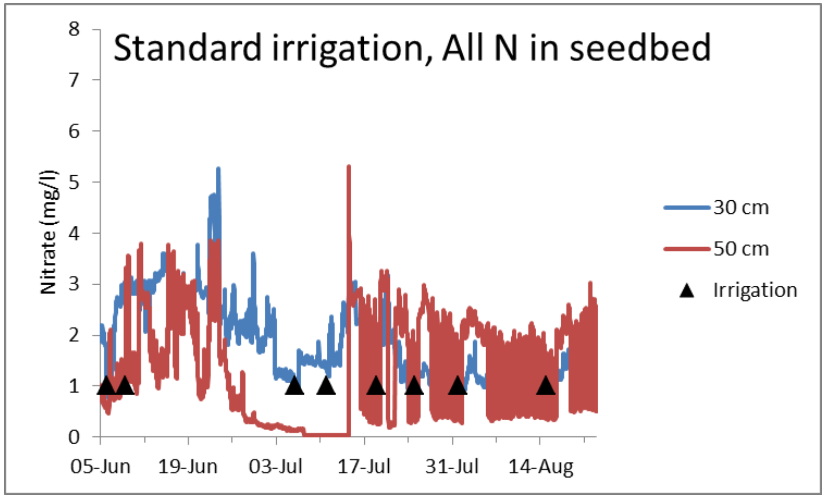
Infiltration rates

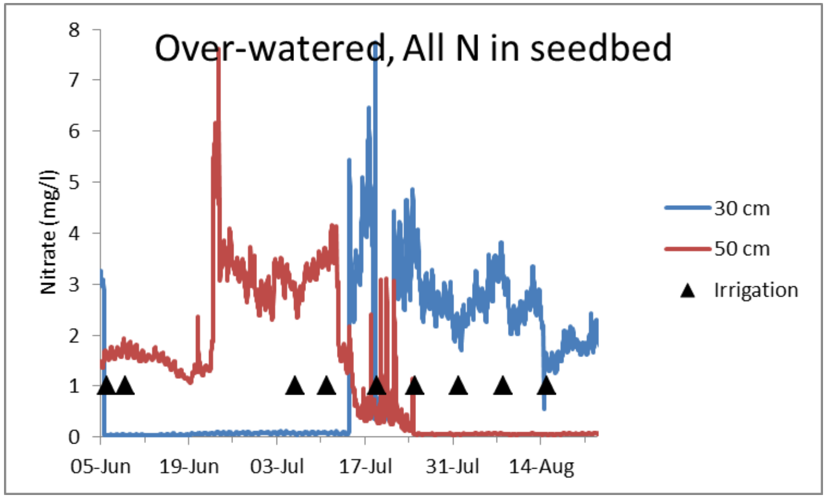
Category	Equilibrium Infiltration Capacity Range (mm/h)	Soil texture
Very high	> 100	Coarse sands, sands, loamy coarse sands and loamy sands
High	20-100	Sandy loams, fine and very fine sandy loams, loamy fine sands and loamy very fine sands
Moderate	5-20	Sandy clay loams, silts loams, silty loams and clay loams
Low	< 5	Clays, silty clays and sandy clays

Are we leaching N: soil NO_3 sensors

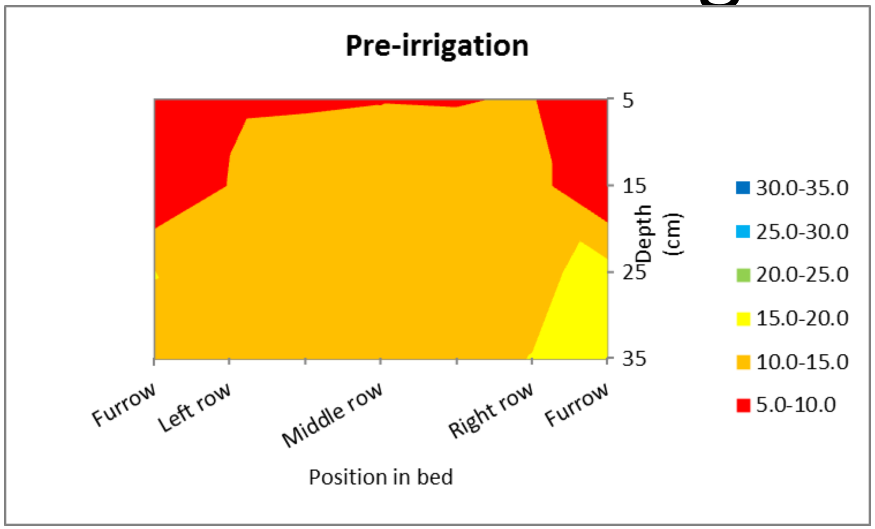


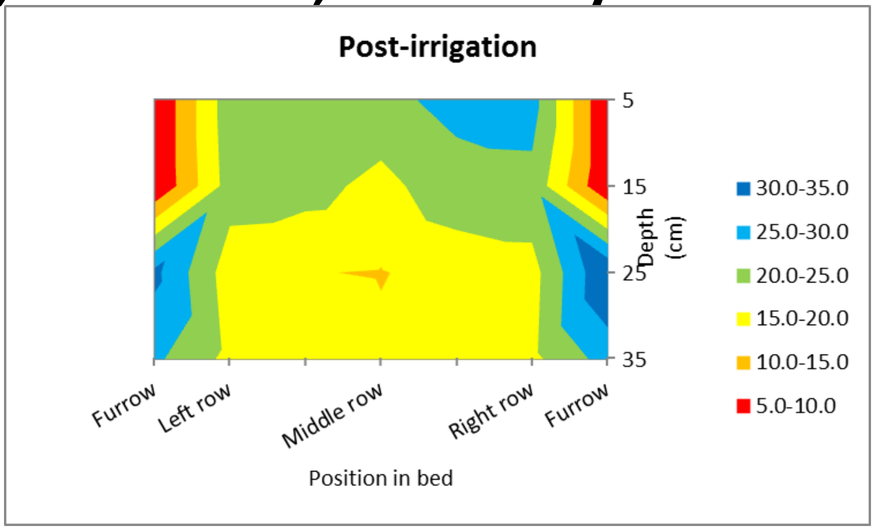


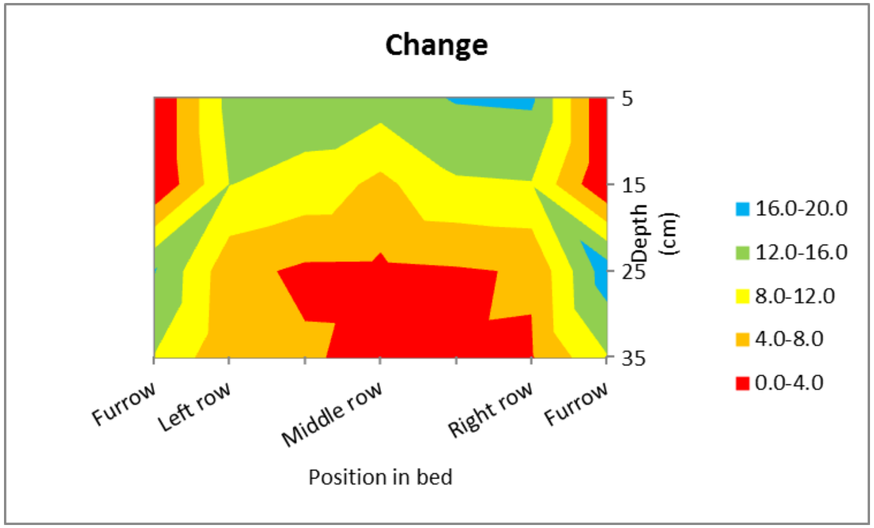




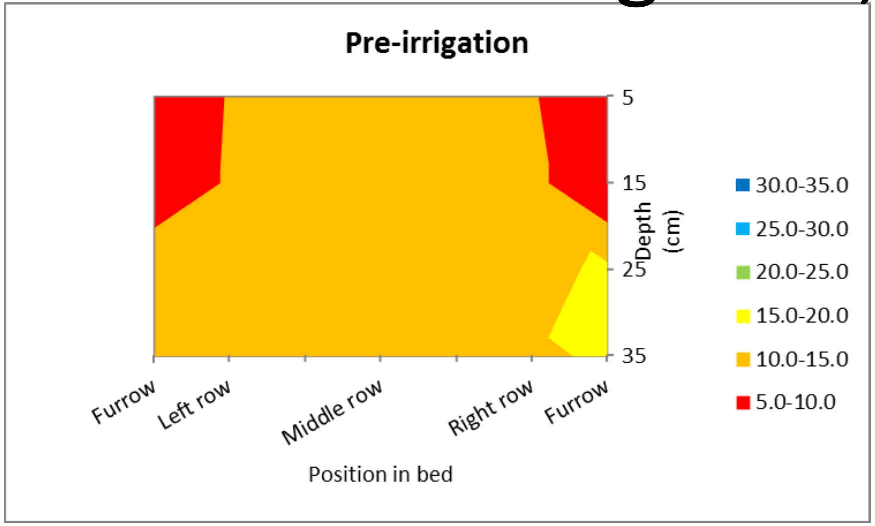
Infiltration across bed after 2 hours: Standard irrigation, 18 mm, 26 July

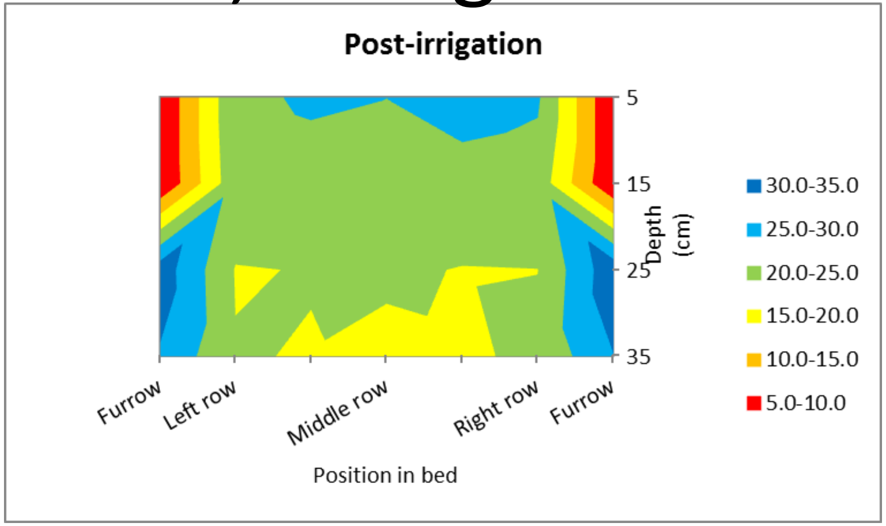


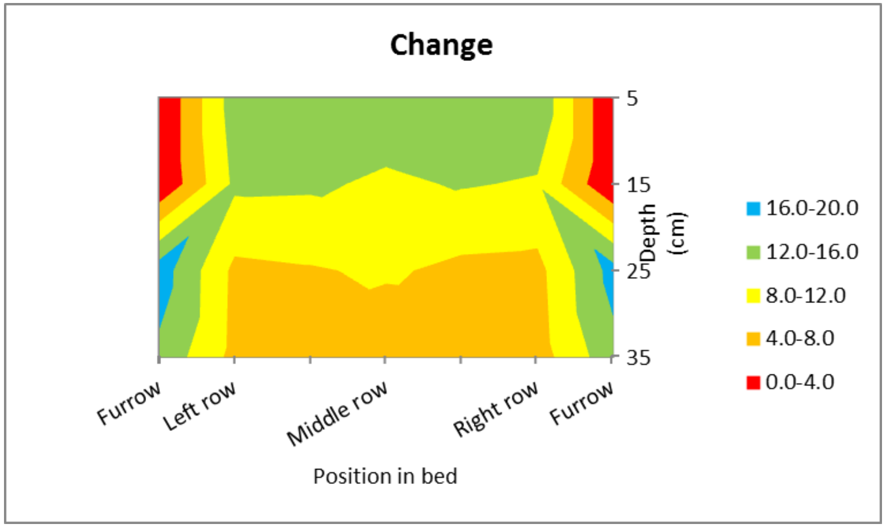




Infiltration across bed after 2 hours: Over-water irrigation, 27 mm, 1 August







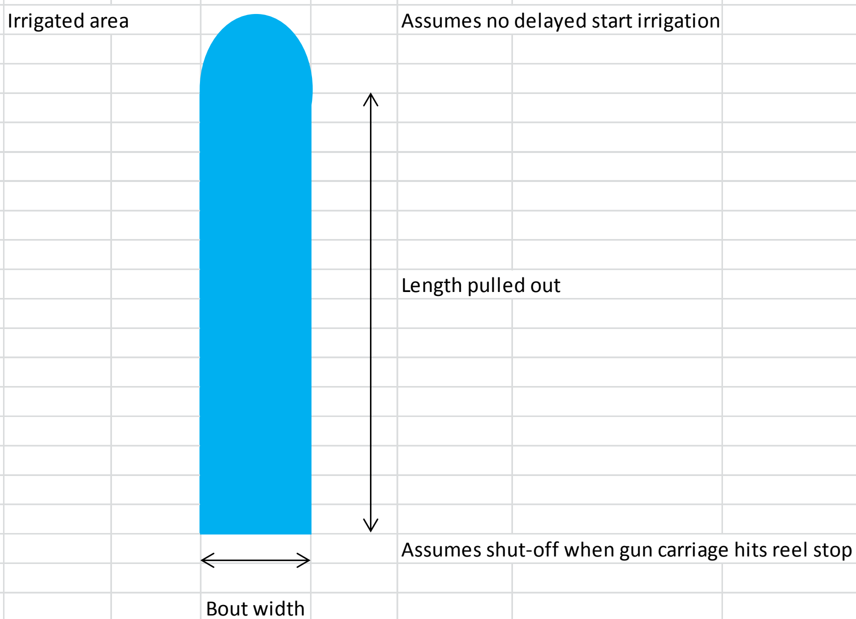
Are growers applying what they think?

Using 81 aerially-irrigated crops each with 3 probe and raingauge sites, analysis of measured irrigation found:

- Overall seasonal total: measured 80 mm vs advised 88 mm
- Under-recoding mostly due to under-dosing and missed events
- Serious over-dosing (+10 mm) at each irrigation on some fields
- Irrigation events that were not advised
- Timing differed by several days in some cases
- On 31 crops the difference between measured and advised was >±20 mm
- On 9 crops the difference was >±30 mm
- Maximum difference -60 mm to +71 mm
- **36 crops were within 10 mm of advised total for season, so 45 % of growers are doing it right!**

Simple flowmeter attached to inlet of hosereel (you know how much but not where)

Grower	Field	Bout (m)	Run no.	Date	Time start	Length pulled out (m)	Wind-in speed (m/h)	Start flowmeter (m3)	Finish flowmeter (m3)	Water used (m3)	Depth (mm)	Pre-Irrigation (min)
GFP	Cley Way	72	1	06-Jun	10:00	465	35	7.00	646.00	639.00	18.0	13.71
GFP	Cley Way	72	2	07-Jun	09:30	465	35	646.00	1303.00	657.00	18.5	13.71
GFP	Cley Way	72	3	08-Jun	08:30	465	35	1303.00	1972.00	669.00	18.8	13.71
GFP	Cley Way	72	4	09-Jun	09:30	465	35	1972.00	2700.00	728.00	20.5	13.71
GFP	Cley Way	48	5	09-Jun	12:16	153	35	2700.00	2941.00	241.00	29.2	13.71
										Average	**18.4**	

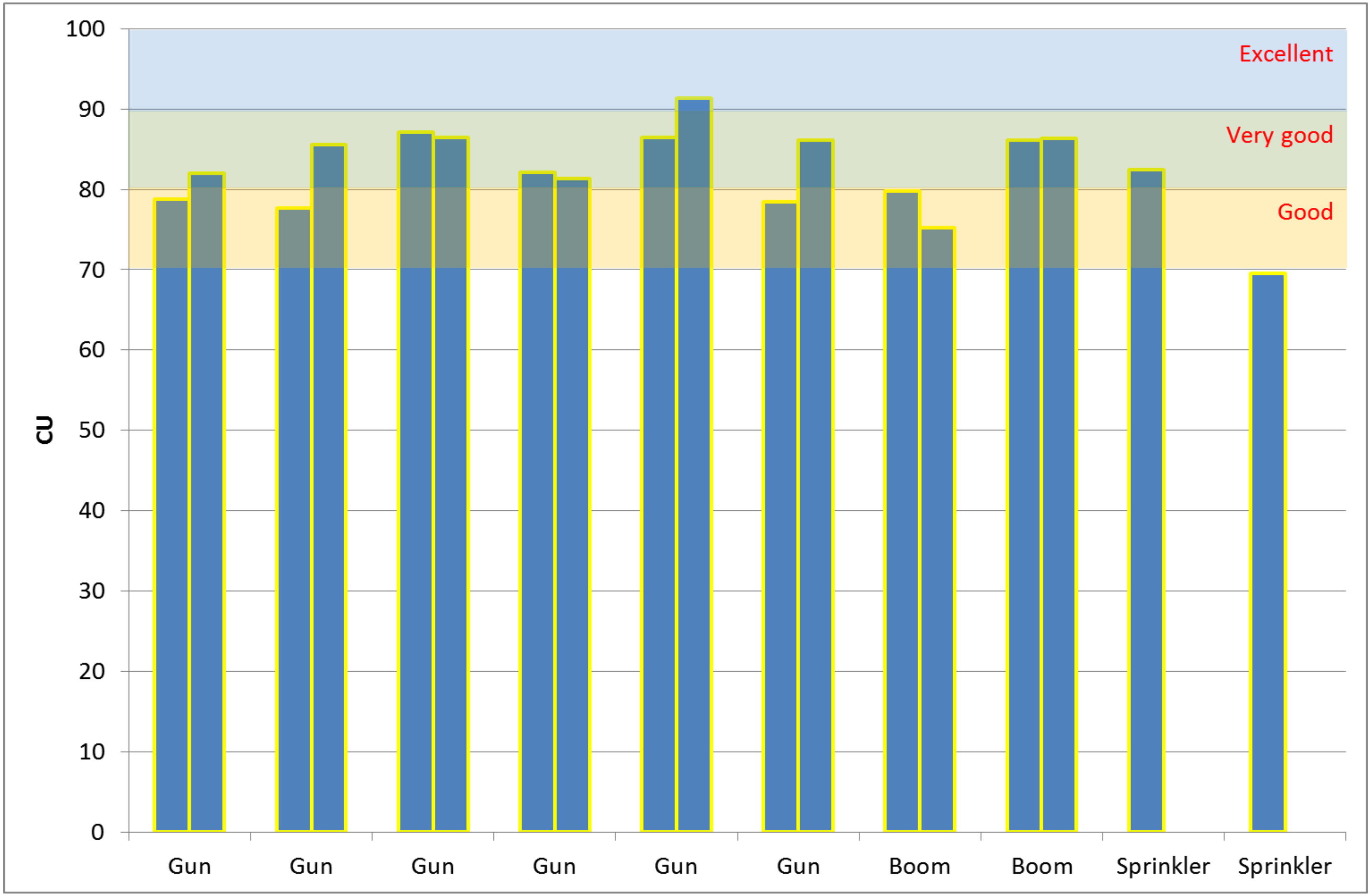


4” meter + connecting pipework, flanges and coupling = £377

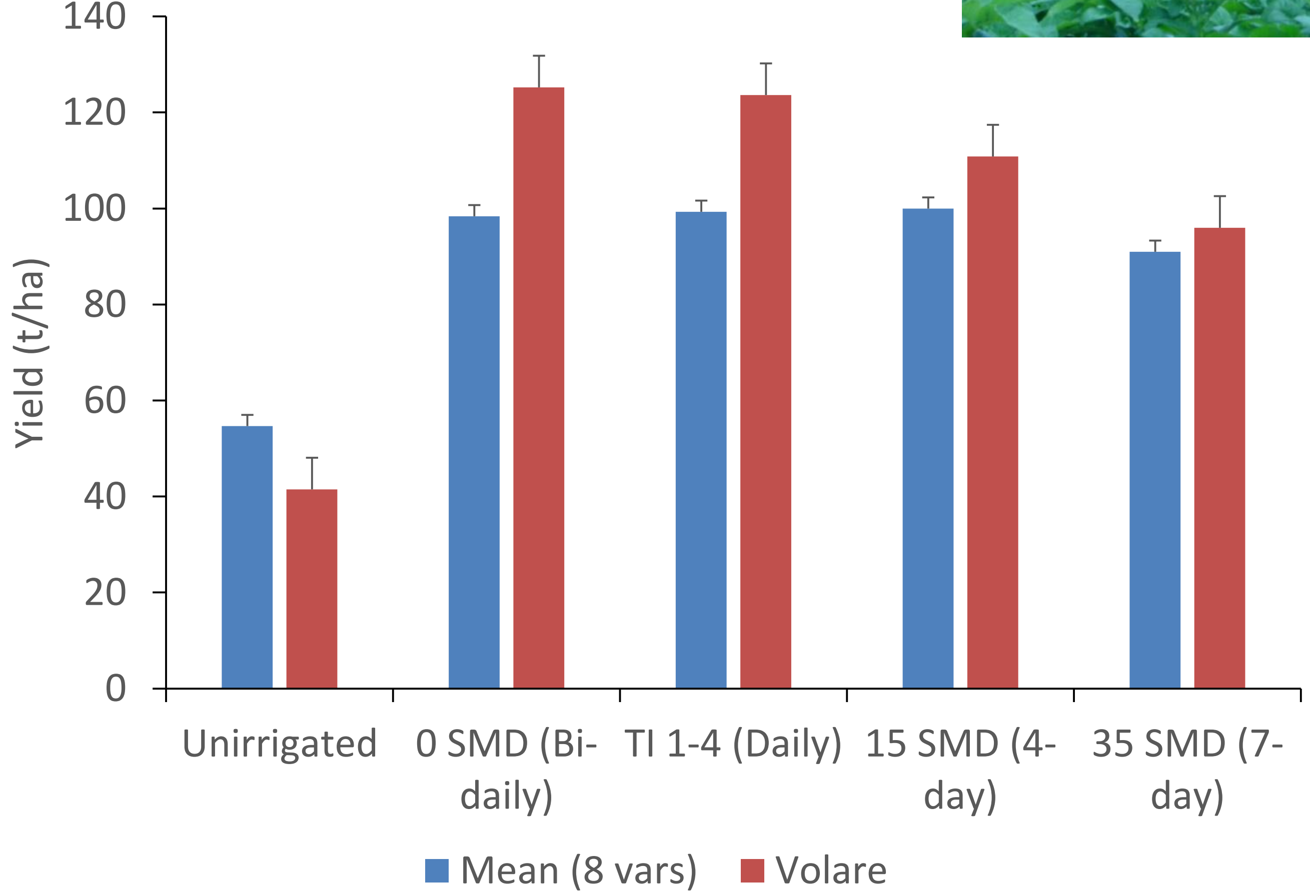
Solid-set sprinkler systems

- New plastic types – 12 m-18 m spacing
- Plastic headers for season-long use
- Low pressure – good uniformity
- Small doses possible (5-10 mm)
- Suits small areas or awkward fields
- Cost can be higher than some systems
- Must be laid out each season

Uniformity – Christiansen coefficient



Sprinkler irrigation

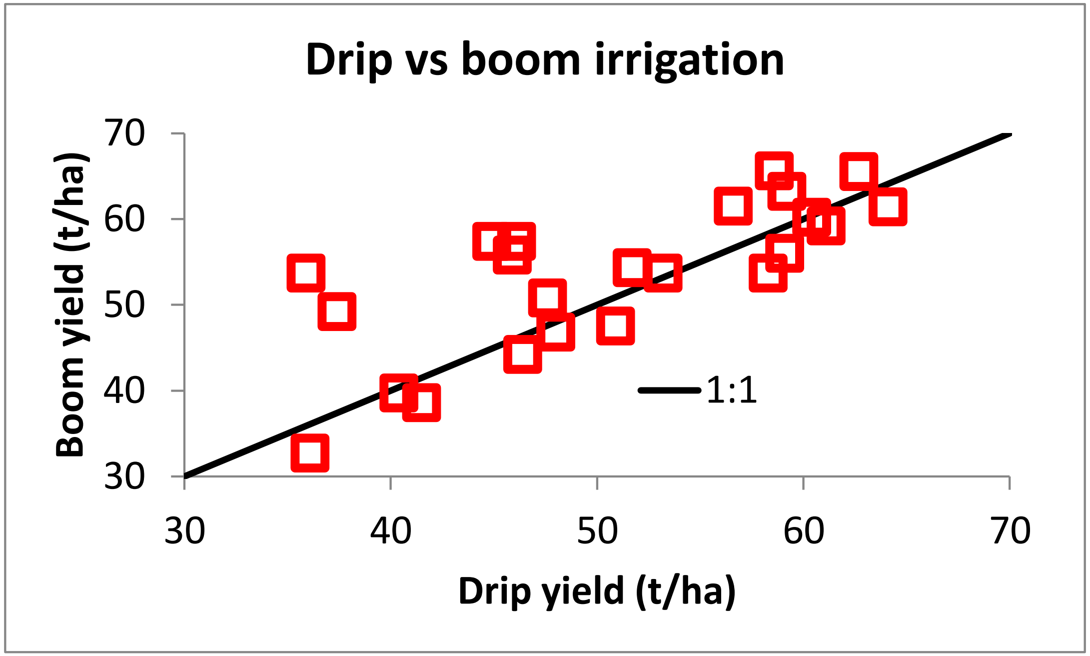


Drip: not really new, but re-emerging

Drip

- Controlled 'uniform' wetting?
- Less evaporation
- Need to match emitter spacing and flow rate to soil profile and texture otherwise localised wetting
- Need to monitor carefully: easy to over-irrigate

Drip: water savings, but at what cost?



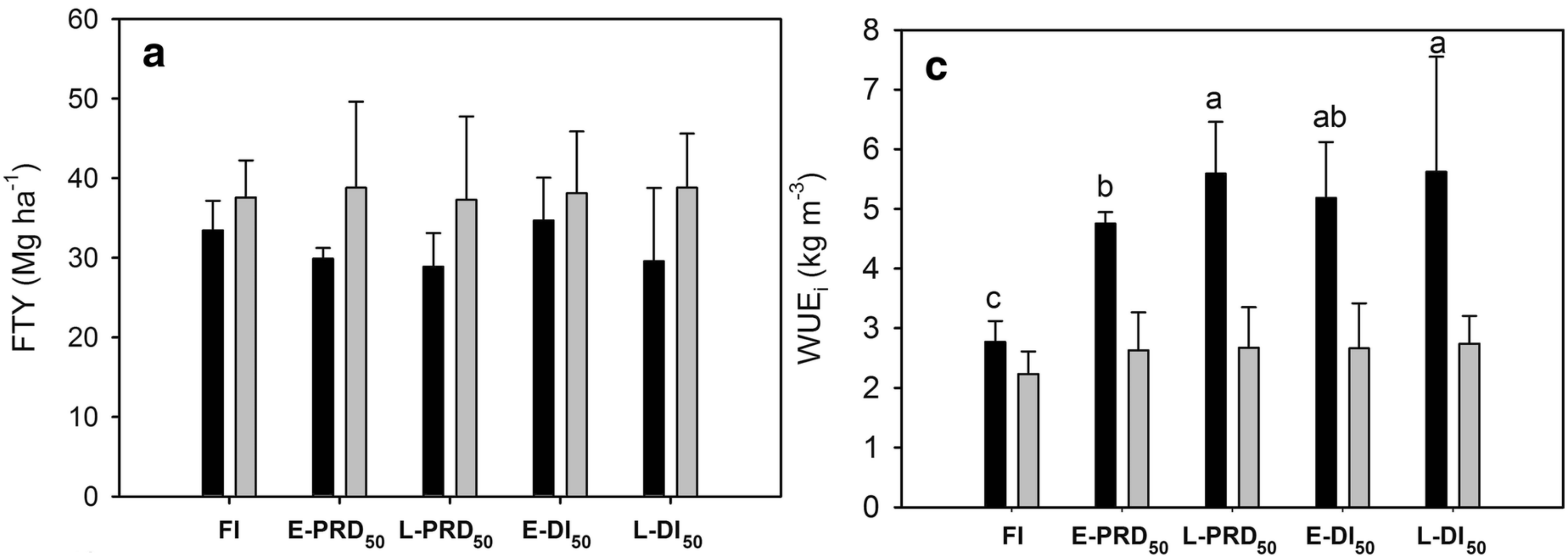
24 crops 2011-2015			
	Yield (t/ha)	Irrigation (mm)	Water saving (%)
Drip	50.7	84	
Overhead	54.2	124	
Diff.	-3.5	-40	33 %

Drip: increased yield or savings in water?

- Both possible
- Single line vs double line per bed
- Survey data: 35 % saving in water with same yield
- 50 % less irrigation: 17 % decrease in yield

Treatment	Yield (t/ha)	Irrigation (mm)	IUE (t/ha/mm)
Unirrigated	37.5	0	
Drip x 1	59.6	73	0.30
Drip x 2	71.9	146	0.24
Boom	70.5	143	0.23

Partial root zone drying: alternate drip lines every 5 days



Qin *et al.* (2018)

Disposable tape within ridges

Drip for common scab

Treatment	Scab (% SA)	Yield (t/ha)	Water scab (mm)	Water total (mm)
Rainfed	3.6	26.1	31	104
Spray 5 mm 4 wks	7.8	63.4	86	327
Allspray 5 mm 4 wks	6.4	68.3	86	329
Spray 5 mm 3 wks	9.6	61.5	65	306
Spray 15 mm @ 18 mm SMD	9.8	61.0	78	320
TTape 5 mm 4 wks	7.7	67.8	87	307
TTape 5 mm 3 wks	9.5	54.3	66	328
TTape Double 5 mm 4 wks	**3.3**	**81.3**	**87**	**307**
TTape 20 cm 5 mm 4 wks	**2.2**	**72.6**	**87**	**328**
TTape Daily 4 wks	4.0	62.3	97	341
TTape 15 mm @ 18 mm SMD	9.7	62.8	78	320
S.E.	0.78	4.51	-	-

Drip: key points

- There is no such thing as a non-draining, pressure compensated tape or drip line
- Slopes and hollows should be avoided
- Block fields to ensure short runs in sloping areas
- Short-duration (1-2 hours) preferred, but needs rapid fill time
- Over-long application 3+ hours leads to problems (poor lateral distribution, deep drainage and water inefficiency)

Costs (20 ha, 10-year depreciation, no pumping system or water costs)

	Headers/ filters etc. (£/year)	Tape/ hose (£/year)	Laying/ removal (£/year)	£/ha/year
Tape	£2364	£8450	£10500	£1066
Hard hose	£2364	£3500	£22000	£1393

Timeliness of tape installation and recovery the key

https://www.youtube.com/watch?v=ufYPmtfKWQA&

Manage wheelings to prevent run-off

Control stone row

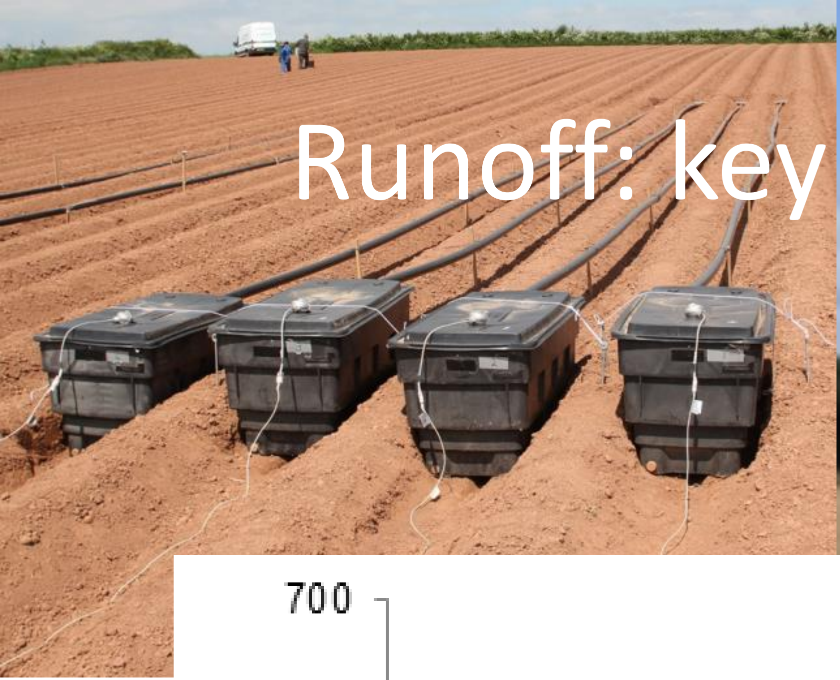
Angled tine

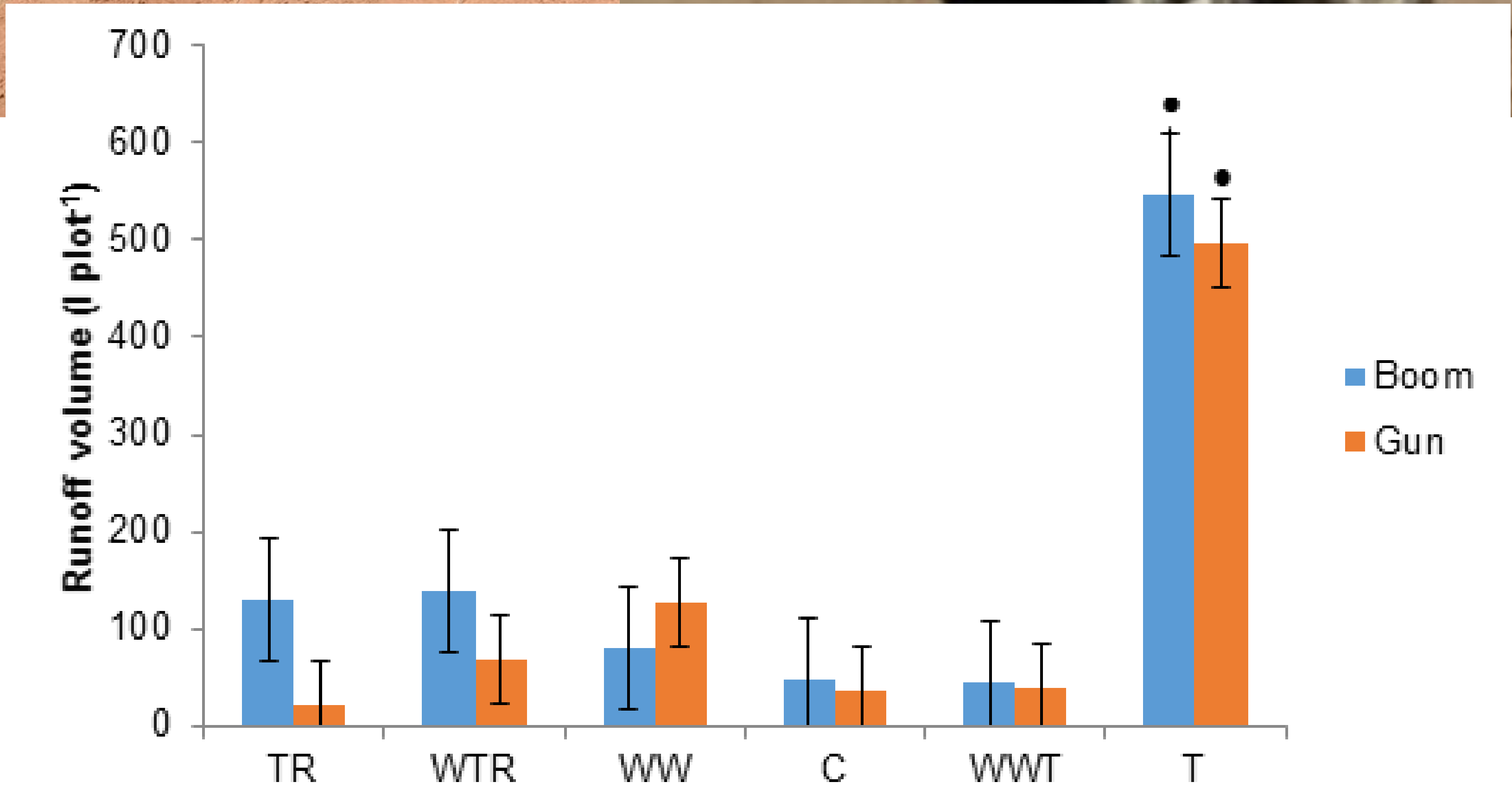
Tied ridger

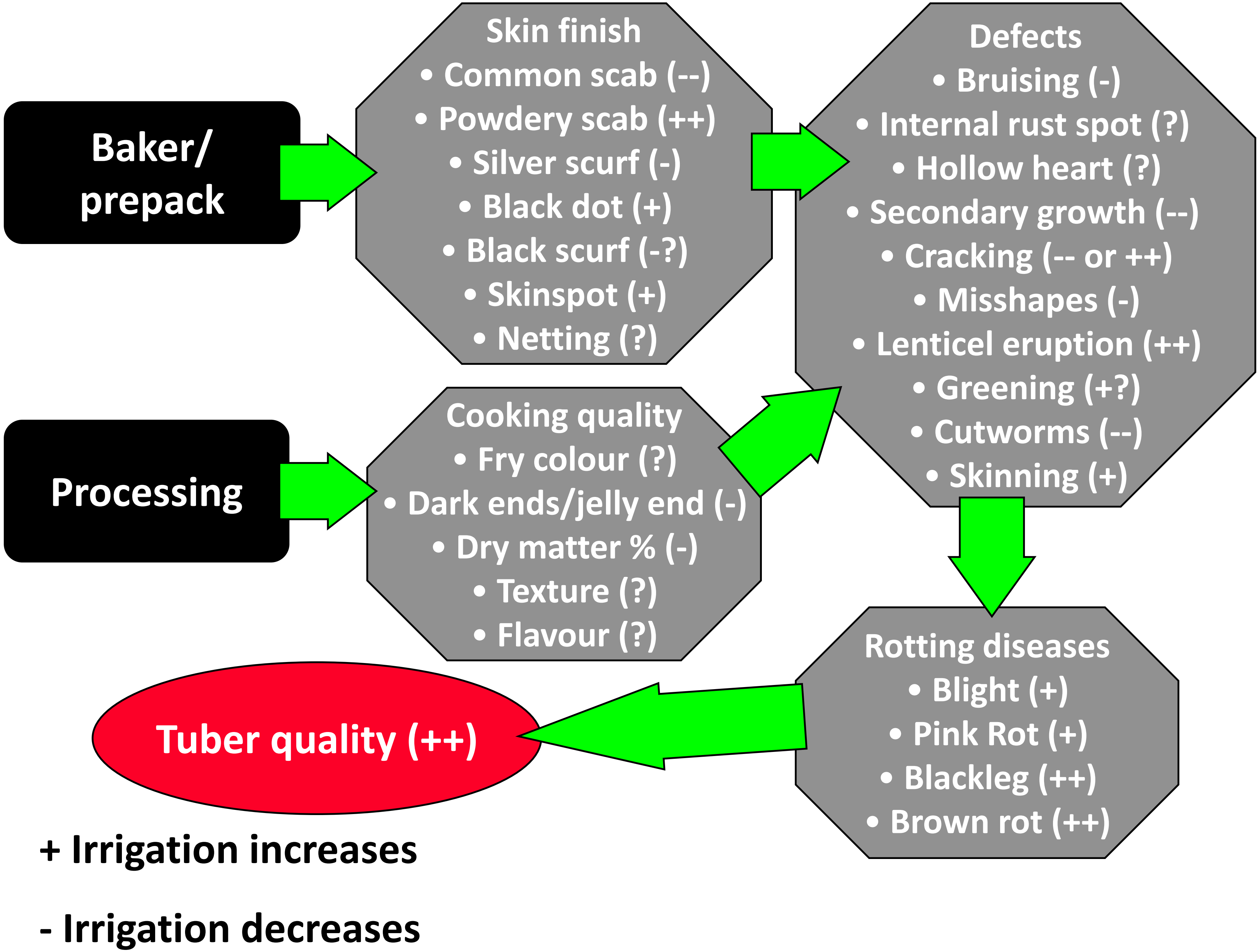
Source: Silgram (2012)




Runoff: key is avoiding traffic






Baker/ prepack
Skin finish
• Common scab (--)
• Powdery scab (++)
• Silver scurf (-)
• Black dot (+)
• Black scurf (-?)
• Skinspot (+)
• Netting (?)
Defects
• Bruising (-)
• Internal rust spot (?)
• Hollow heart (?)
• Secondary growth (--)
• Cracking (-- or ++)
• Misshapes (-)
• Lenticel eruption (++)
• Greening (+?)
• Cutworms (--)
• Skinning (+)
Processing
Cooking quality
• Fry colour (?)
• Dark ends/jelly end (-)
• Dry matter % (-)
• Texture (?)
• Flavour (?)
Rotting diseases
• Blight (+)
• Pink Rot (+)
• Blackleg (++)
• Brown rot (++)
Tuber quality (++)
+ Irrigation increases
- Irrigation decreases

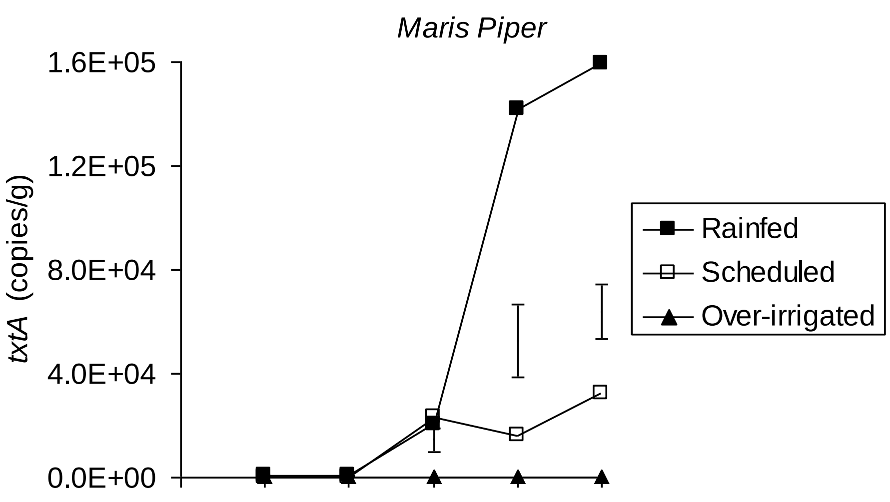
Common scab – *Streptomyces scabiei*
Erumpent or raised corky scab

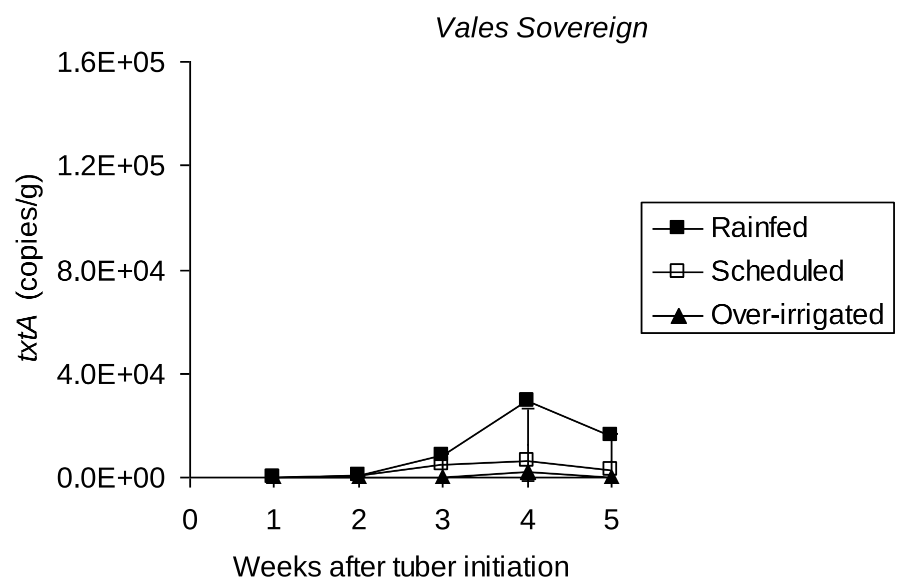
Common scab irrigation

- Soil in ridge needs to remain moist to wet to prevent build-up of pathogenic *Streptomyces*
- Reduction in *Streptomyces* is almost certainly due to a relative shift in other bacterial and fungal populations that act as antonists but situation is unclear what is happening despite 5 years of work at NIAB CUF and FERA
- Key period is weeks 1-3 post tuber initiation
- Over-wet soils will encourage lenticel eruption and turgor-induced cracking

Tuber initiation (TI)

Increase in pathogenic *Streptomyces* populations is greater in dry soils than wet and smaller in more resistant varieties than very susceptible





Common scab irrigation – when to start

- In sensitive varieties, if soil is dry, start irrigation when FIRST plants begin to initiate; 50 % initiation will be 3-5 days behind allowing time to complete field
- With least sensitive varieties, can start at 1 week after initiation
- Ridges may be dry following first irrigation and a repeat application may need to be made within 3-4 days: observe by digging
- Pre-irrigate hydrophobic, capped or cloddy soils 1-2 days before onset of initiation, not 7 days before

Common scab control in different varietal scheduling groups

Notes:
Soil moisture deficit (SMD) for top 25 cm of stone-free ridge profile. This can be calculated by water balance (‘model’), directly measured or converted from soil water tension.

†Excessively cloddy soils may need to be maintained at a smaller SMD.

Values in () are the rankings for common scab resistance in AHDB Potato Variety Database. 1 = most susceptible, 9 = fully resistant.

Varietal scheduling group

1. V. Susceptible	2. Susceptible	3. Intermediate	4. Resistant
Maris Piper(1)	Charlotte (4)	Bute (4)	Electra (8)
Maris Peer (5)	Desiree (4)	Estima (6)	Elfe
	Leontine	Exquisa	Jelly (6)
	Marabel	Flair	Lanorma (7)
	Nectar (4)	Juliette (7)	Orchestra (8)
	Red Fantasy	King Edward (7)	Perline
	Rooster (6)	Melody (7)	Regina
	Safari (4)	Soraya	Vales Sovereign (7)
	Saxon (5)	Sylvana (7)	Volare (5)
	Venezia (3)		
	Vivaldi (5)		

Soil texture	Maximum soil moisture deficit (mm)			
Sand	9.8	12.7	15.6	18.8
Loamy Sand	12.0	15.9	19.3	23.1
Sandy Loam	13.4	17.8	21.5	25.8
Sandy Silt Loam	14.4	19.0	23.0	27.7
Silt Loam	16.3	21.5	26.2	31.4
Clay Loam/Clay†	14.4	19.0	23.1	27.7

Recommendations

1. **Varietal scheduling**. Irrigation regimes for scab should be adapted according to varietal susceptibility (higher allowable SMDs for more resistant varieties).
2. **Delayed start irrigation**. For all varieties other than Maris Piper, delaying start of irrigation until 1 week after initial TI would produce equally good control of scab to commencing irrigation at TI. Delayed-start irrigation timing should be based on initial TI as using the date of 50 % TI in variably-emerging fields could lead to more infection.
3. **Duration of irrigation**. 4 weeks for sensitive, 3 weeks for more resistant. A 6-week period for scab control is sufficient in susceptible salad varieties such as Maris Peer and Charlotte and probably 4-5 weeks in less susceptible varieties such as Regina, Perline or Venezia.
4. **Processing crops.** Where the target is to avoid severe common scab to prevent excessive peeling losses in susceptible varieties, the best time to irrigate is between 1 and 3 weeks after TI, since this coincides with the most rapid phase of pathogen development on tubers. Only irrigating for 2 weeks after TI results in worse common scab than maintaining wet soil for 3 or 4 weeks.
5. **Risk of over-watering.** Over-watering during TI and the scab control phase should be avoided as this increases the incidence of tuber cracking and rotting diseases and reduces nitrogen uptake and promotes early senescence in some varieties.
6. **Soil structural conditions.** Growers should not be producing overly-fine seedbeds as this does not improve control of common scab.

Cracking symptoms
M Piper

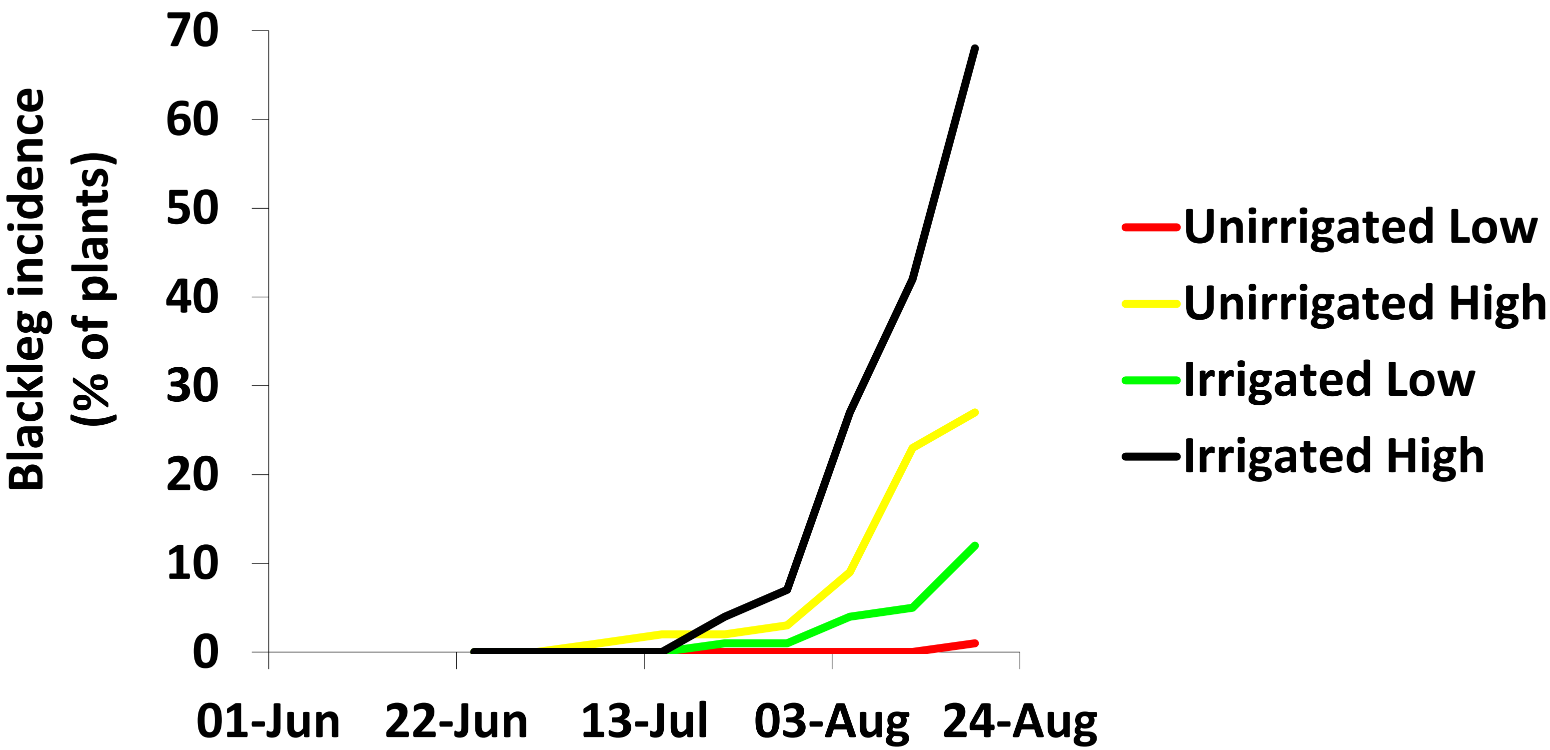
Cracking symptoms
Vales Sovereign

Risk of cracking from over-watering during scab control

	Group	
1. High risk	**2. Moderate risk**	**3. Low risk**
Safari	**Flair**	**Desiree**
Estima	**Jelly**	**Elfe**
Vales Sovereign	**King Edward**	**Exquisa**
Melody	**Maris Peer**	**Marabel**
Orchestra	**Volare**	**Perline**
Nectar		**Regina**
Maris Piper		**Venezia**
Lanorma		**Vivaldi**
Bute		
Sylvana		

Ranked in Group 1 by risk

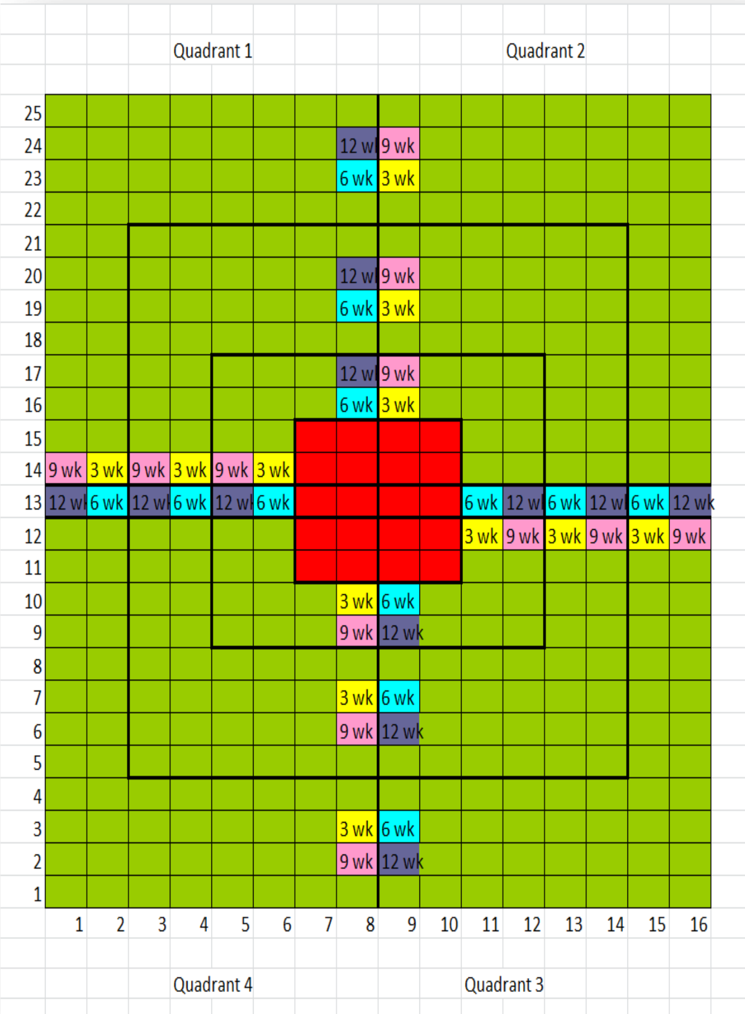
Effect of irrigation regime and seed contamination level on blackleg infection



Source: Firman (2003)

Movement of *P. atrosepticum* within fields

- Tracking the spread of *P. atrosepticum* in the field over 3 years



- Grown from mini-tubers
- No obvious pattern of spread from the marked central zone
- Progeny tuber contamination and <u>blackleg was caused by natural pectobacteria as well as marked strains</u>
- Blackleg appeared with <u>irrigation</u>

The James Hutton Institute

Summary

- Most irrigation in UK is high pressure, high flow
- Changes to licensing will reduce abstraction rates and prevent abstraction in high-risk areas
- Typical, full-season irrigation is 100 mm
- Drought seasons on light soils, 300 mm+
- Climate change will emphasize more frequent irrigation, i.e. pre-installed systems with automation
- Increased interest in drip (and sprinkler), but costly where only used sporadically in wet seasons
- Key is tuber quality in UK

Alternative Irrigation Technology in the United Kingdom

Mark Stalham

Thank you for the invite!