Project title:	Impact of irrigation practices on Rijnsburger bulb onion husbandry, quality and storability - II
Project number:	FV 326a
Project leader:	Dr. Tim Lacey, Vegetable Consultancy Services (Developments) Ltd.
Report:	Annual report, Year 2
Previous report:	None
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Date project commenced:	18th March 2010 (contract signed 27th April 2010)
Date project completed (or expected completion date):	30th September 2013

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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The authors would like to acknowledge the invaluable assistance of RL Long Farms Ltd. in accommodating the open-field trial within their commercial onion land. Thanks also to Wroot Water and Pessl Instruments for their assistance in the technical aspects of trial operation.

GROWER SUMMARY

Headline

Irrigating with “little and often” up to bulb initiation increases bulb onion canopy growth, biomass and yield.

Background

An estimated 85% of dry bulb onion crops in the UK are irrigated, following a drive in the industry for production on light soils to improve quality and aid crop management. However, there are concerns that existing irrigation practices may be compromising crop yield, quality and storability. Furthermore, there is little scientific evidence to support current practices, either for crop production or to justify irrigation water use and demonstrate efficiency for abstraction licence renewal in the future.

This project builds on findings from a 1-year HDC trial FV 326 (2007-8), which strongly indicated that irrigation practices had a significant impact on crop performance. However, due to inherent limitations of FV 326, further, large-scale field-based trials were required to fully evaluate the impact of irrigation regimes, particularly on crop quality and storability. This follow-on project proposes to address these issues by extending the original study to one commercial-scale field trial plus one rain-shelter trial over a period of 3 seasons.

Ultimately, this project will lead to the identification of optimum irrigation practices in the form of “best-practice” guidelines to help growers maximise marketable percentages and increase the storage period of bulb onions. Furthermore, the findings will assist growers at abstraction licence renewal and may show benefits for nutrient and weed management.

This report summarises the available data for year 2 of the trial (2011 season) and also presents the storage data from 2010. Note that all other data from 2010 (gathered prior to January 2011) was reported in the year 1 report.

Summary of the results and main conclusions

A description of the irrigation regimes applied at the rain-shelter site and the open-field commercial site is given in Table 1. Treatment A represents typical field practice for bulb onion irrigation. Both sites were on sandy loam near Bury St Edmunds.

Note that the open-field site received frequent light rain and occasional heavy showers from early to mid-June through to harvest. Consequently, few irrigation events were scheduled on this site, and little differences between treatments were observed. Therefore, most data observations relate to the rain-shelter site only in this summary.

Table 1: Irrigation regimes investigated in 2011. Note, "FO" refers to canopy fall over.

Trt	Name	Irrigation from start of season to bulb initiation	Irrigation from bulb initiation to egg stage	Stop irrigation at	Stop
A	**Typical, end season stress**	c25mm every 7 days	c25mm every 7 days	c25mm every 14 days	50% FO
B	**Typical with mid+end season stress**	c25mm every 7days	c25mm every 14 days	c25mm every 14 days	50% FO
C	**Typical with early+end season stress**	c25mm every 14 days	c25mm every 7 days	c25mm every 14 days	50% FO
D	**Less more often, no stress**	c15mm every 4 days	c15mm every 4 days	c15mm every 4 days	50% FO
E	**Less more often, end season stress**	c15mm every 4 days	c15mm every 4 days	c25mm every 14 days	50% FO
F	**Less more often, mid+end season stress**	c15mm every 4 days	c25mm every 14 days	c25mm every 14 days	50% FO
G	**Less more often, early+end season stress**	c25mm every 14 days	c15mm every 4 days	c25mm every 14 days	50% FO
H	**Stress all season**	c25mm every 14 days	c25mm every 14 days	c25mm every 14 days	50% FO

At the rain-shelter site, crop growth and vigour was significantly influenced by the irrigation regime applied (see Figure 1). Irrigation regimes that applied "less more often" achieved a larger canopy with greater biomass quicker than regimes that applied less water or with less frequent irrigations. In particular, regimes that did not cause water stress early in the season (up to bulb initiation) promoted the greatest canopy growth – but also tended to result in a slightly higher proportion of bolting plants (up to 1%).

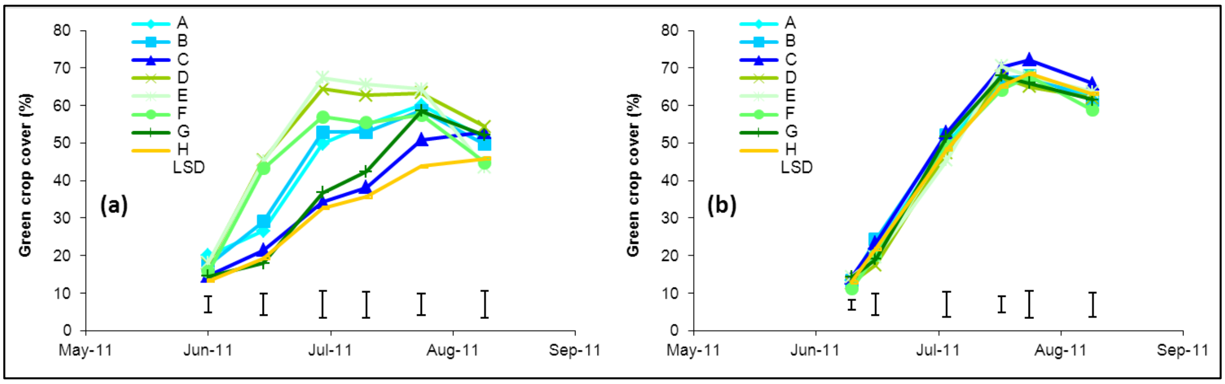

Figure 1: Crop canopy growth as % green cover at rain-shelter site (a) and open-field site (b). Error bars show least significant difference (LSD).

The differences in crop canopy translated almost directly into significant differences in green crop yield (see Figure 2). Water stress early in the season (up to bulb initiation) significantly reduced green yields in both “typical” and “less more often” regimes by 20% and 30% respectively. Irrigating through to 50% fall-over produced a further yield increase of 18% over a regime with the standard practice of imposing water stress at the end of the season. “Little and often” regimes tended to result in greater green yields when compared to equivalent “typical” regimes.

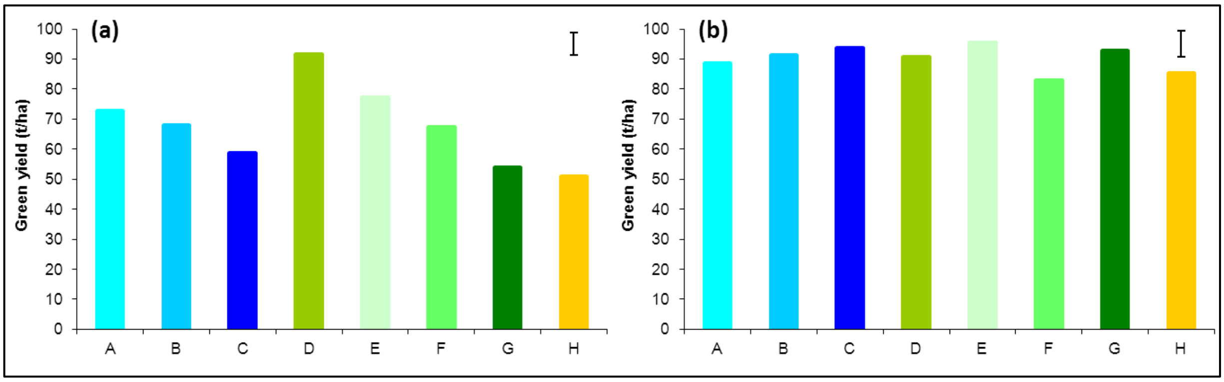

Figure 2: Crop green yield at rain-shelter site (a) and open-field site (b). Error bars show LSD.

Preliminary work shows a strong and direct correlation between total water (irrigation + rainfall) received by an onion crop and green yield, resulting in a yield increase of approximately 0.25-0.3 tonnes/ha per mm up to a total of around 300mm of water. Beyond this point, yields tend to plateau. However, there are variations in this relationship that reflect the timing of water application.

Onions harvested for green yield in 2011 are currently in storage under commercial conditions to be assessed for quality and marketability (including size, skin finish, shape, doubles, disease, regrowth and dry matter content) in March/April 2012.

Storage data from 2010 closely reflected the green yield reported in January 2011. Size grading indicated that the irrigation regimes which promoted the greatest crop growth and green yield tended to have a greater proportion of larger bulbs and fewer smaller bulbs Contrary to expectations, quality assessments indicated that there were few differences in storage diseases, dry matter, regrowth and other defects resulting from the irrigation treatments applied during the season.

Observations at the rain-shelter site indicate that overhead irrigation assists in onion Thrips control: Thrips damage decreased more or less in proportion to the amount and frequency of irrigation applied. There was little indication of an effect of irrigation regime on crop foliar diseases (downy mildew, leaf blight, leaf spot and bacterial infections).

Measurement of soil ammonium N and nitrate N through the season gave some slight indication that irrigation regimes which applied water earlier and/or had more frequent irrigations may retain less N in the soil than current practice or “stress” irrigation. However, the data was characteristically variable and did not provide conclusive evidence of this.

Weed pressure was generally higher where irrigation regimes kept the soil surface moist (i.e. more frequent irrigations), but the effect of rainfall, grower intervention and timing of water application are likely to be more important than the irrigation regime in managing the weed burden.

In summary, the second year of trials has provided some excellent data to support the 2010 data from FV 326a and previous FV 326 findings (despite the poor weather on the open-field site). Onions respond well to water, with more frequent applications of smaller amounts tending to drive canopy development, crop vigour and biomass more than typical applications of c25mm every 7-10 days. In particular, early season irrigation (prior to bulb initiation) appears to be key to driving crop development, although some caution needs to be applied to prevent excess canopy developing too early, thus increasing the bolting risk. Increased canopy development largely translates into greater yield, although late application of water also tends to increase yields, most likely due to direct water uptake by the bulb. At the time of this report, crop quality and storability from 2011 have not been assessed. Although indications from 2010 storage assessments were that different irrigation regimes did not affect storability, this is largely contrary to commercial experience.

Financial benefits

Currently, no indication of financial benefits can be given until all data from the 3-year trial has been collected and analysed.

Action points for growers

At this stage of the project, it is not advised that growers make any extensive changes to their irrigation regimes based on the information contained in this report: further data is required on crop quality and marketability to support any changes in irrigation practice.

However, given the potential for significant shortages of water for irrigation in 2012, it may be wise for growers to consider prioritising irrigating their onions in the early season to promote canopy at least up to the point of bulb initiation – bearing in mind the potential for increased bolting risk in excessively forward crops.

SCIENCE SECTION

Introduction

Cured and stored Rijnsburger dry bulb onions (*Allium cepa*) form a significant proportion of the UK vegetable sector. An estimated 85% of the crop is irrigated.

There are concerns that existing irrigation practices may be compromising crop yield, quality and storability. Furthermore, there is little scientific evidence to support current practices, either with respect to agronomic aims or to justify irrigation water use and demonstrate efficiency for abstraction licence renewal in the future.

To this end, project FV 326a was established to continue the successful FV 326 onion irrigation trial of 2007/8. FV 326 was a 1-year trial that demonstrated significant differences in crop production as a result of differing irrigation regimes under rain-shelter conditions. However, due to inherent limitations, further, large-scale field-based trials were required to fully evaluate the impact of irrigation regimes, particularly on crop quality and storability. This follow-on project proposes to address these issues by extending the original study to one commercial-scale field trial plus one rain-shelter trial over a period of 3 seasons.

Project FV 326a proposes to investigate a range of irrigation regimes (based on FV326 and industry consultation) in each of the 3 years of the work for their impact on bulb onion crop growth, yield, quality and storability and for the secondary impacts on nitrate leaching and weed flushes. Ultimately, the trial results will lead to the identification of optimum irrigation practices in the form of “best-practice” guidelines to help growers maximise marketable percentages and increase the storage period of bulb onions, thereby increasing profitability. Furthermore, the findings will assist growers at abstraction licence renewal and may potentially show benefits for nutrient and weed management.

Year 1 of FV 326a (2010) demonstrated that different irrigation regimes resulted in significant differences in crop growth and yield. “Little and often” type regimes tended to drive greatest canopy growth, thus promoting yield. Late applied water also tended to bulk up yields. However, contrary to expectations, little difference in disease levels and overall storability was noted between treatments.

This report summarises the trials carried out in Year 2 of the project (2011/12 – referred to as 2011 season in this report) and reports available data from this work. Note that not all data for this year is currently available, since harvested bulb onions are being stored until

March/April for assessment of crop quality and storability attributes. This report also summarises post-storage size grading and quality data from the 2010 trial.

Materials and methods

Experimental design and layout

The project again comprised two parallel experiments in Year 2: at one site, a bulb onion crop was grown under artificial rain-shelters and exposed to a range of differing irrigation regimes; at a second site, the same irrigation regimes were applied on a site located within a commercial onion field. The rain-shelter site was hosted by Broom's Barn Research Centre (near Bury St Edmunds, Suffolk) and the open-field site was hosted by RL & JP Long (also near Bury St Edmunds) (See Figure 3) For the purposes of this report, the sites will be referred to as "rain-shelter" and "open-field" respectively.

Details of each site are presented in Table 2.

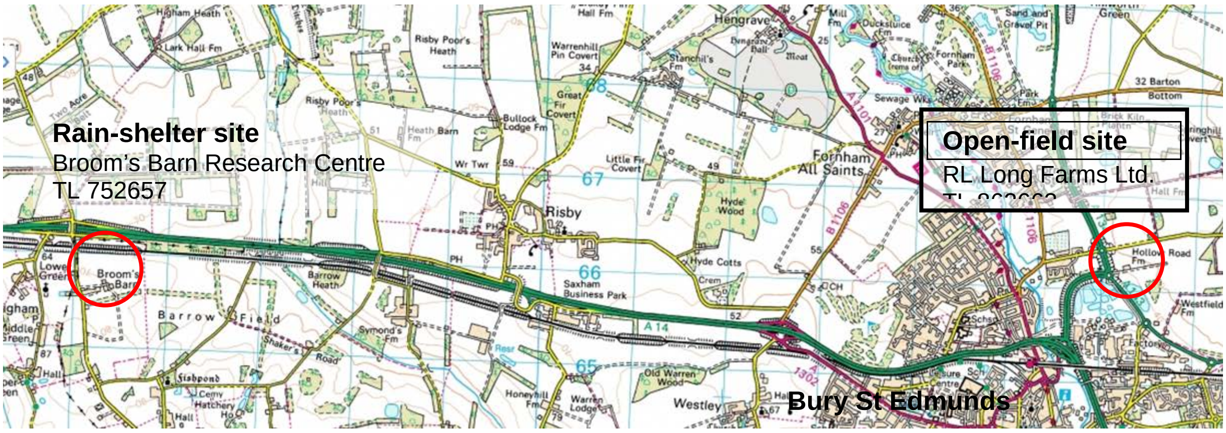

Figure 3. Field site locations 2011

Table 2. Details of rain-shelter and open-field sites

	Rain-shelter	**Open-field**
Soil type	Sandy loam	Sandy loam
Onion variety	Arthur	Arthur
Drilling date	21st March	3rd March
Target density	52 plants per m^2	48 plants per m^2
Wheel centres	1.83m	1.83m
Plot size	1 bed by 8m	3 beds by 10m
No. of sprinklers per plot	8	16
Replicates	3	3
Irrigation treatments	8	8
Date of wetting to field capacity (FC)	28th April	17th May
Harvest date	30th August	14th September
Crop husbandry	As field crops (except water)	As rest of field (except water)

Each site had three replicate blocks of eight differing irrigation regimes, as described in Table 3. These irrigation regimes were chosen based on results from FV 326 and industry advice. Treatment A represents typical field practice on light mineral soils.

Plot layout at each site is presented in Figure 4 and Figure 5 whilst Figure 6 and Figure 7 illustrate the two sites.

Table 3. Irrigation regimes

Trt	Name	L May to Initiation (E July)		Initiation (E July) to egg stage (E Aug)		Egg stage (E Aug) to stop (50% FO)		Stop
		Trigger	Target App^n	Trigger	Target App^n	Trigger	Target App^n	
A	Typical, end season stress	50% AWC	Return to FC	50% AWC	Return to FC	75% AWC	50% of AWC	50% FO
B	Typical with mid+end season stress	50% AWC	Return to FC	75% AWC	50% of AWC	75% AWC	50% of AWC	50% FO
C	Typical with early+end season stress	75% AWC	50% of AWC	50% AWC	Return to FC	75% AWC	50% of AWC	50% FO
D	Less more often, no stress	25% AWC	Return to FC	25% AWC	Return to FC	25% AWC	Return to FC	50% FO
E	Less more often, end season stress	25% AWC	Return to FC	25% AWC	Return to FC	75% AWC	50% of AWC	50% FO
F	Less more often, mid+end season stress	25% AWC	Return to FC	75% AWC	50% of AWC	75% AWC	50% of AWC	50% FO
G	Less more often, early+end season stress	75% AWC	50% of AWC	25% AWC	Return to FC	75% AWC	50% of AWC	50% FO
H	Stress all season	75% AWC	50% of AWC	75% AWC	50% of AWC	75% AWC	50% of AWC	50% FO

AWC = Available Water Content within rooting zone (assumed to be 30cm)
FC = Field Capacity within rooting zone (assumed to be 30cm)
FO =canopyfall-over

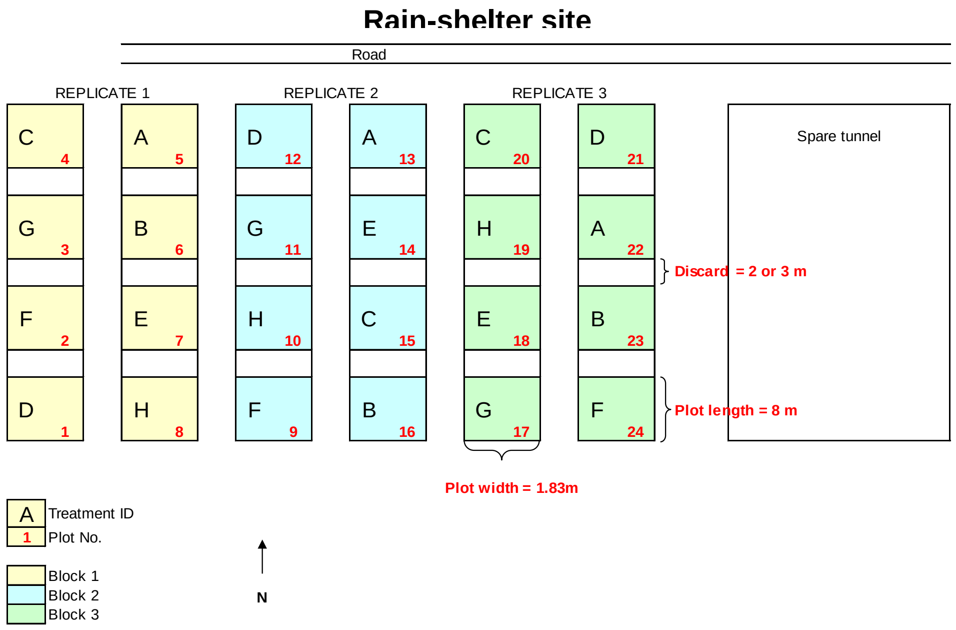

Figure 4. Plot layout at rain-shelter site

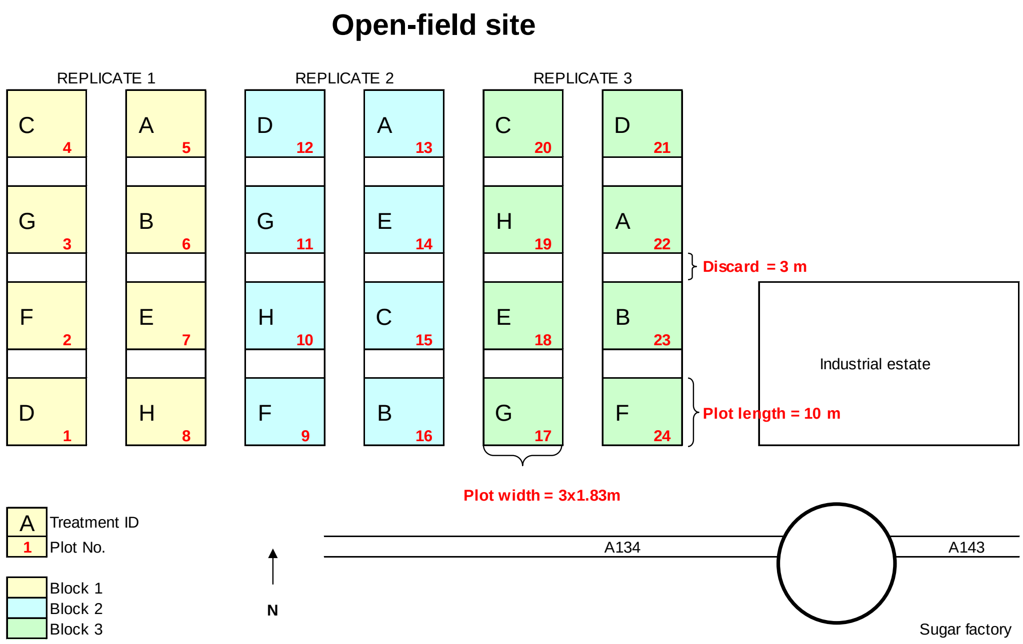

Figure 5. Plot layout at open-field site.

Figure 6. Rain-shelter site (replicate 1) on 17th June 2011.

Figure 7. Open-field site (replicate 1) on7th July 2011

Weather / soil moisture monitoring and irrigation scheduling

Irrigation events were scheduled using calculations of soil moisture deficit based on data from soil moisture sensors in each plot (3 x Decagon 10HS sensors per plot at 10, 20 and 30cm depths). All sensors were connected to an iMetos weather station, with all data (including weather data at each site) downloading to a secure web-site. Both sites were brought to field capacity near the start of the season in order to allow accurate determination of soil moisture deficit. At each irrigation event, 4 rain gauges were placed in each plot to verify the amount of irrigation applied.

Crop performance

The impact of irrigation regimes on crop performance was evaluated using a number of parameters as detailed below.

Crop establishment was measured using 3 randomly placed replicate counts of bulbs harvested from a 1 m section of bed.

Crop canopy growth was measured approximately weekly through the season using a spectral ratio meter (Skye Spectrosense 2) to determine % green cover at a specific point in each plot. Crop vigour was assessed visually at approximately fortnightly intervals (on a scale of 0= dead to 10= extremely vigorous). At approximately 4-week intervals, crop biomass was assessed by weighing a sub-sample of 10 randomly selected plants per plot.

As the crop neared maturity, fall-over progression was noted (as % fall-over and % senescence). At harvest (30thAugust at rain-shelter site and 14th September at open-field site) 3 randomly placed replicate samples of 1 m x 1 bed were hand harvested (with tops removed), counted for population data, netted and weighted to assess green bulb yield. All samples were then placed in a commercial onion store for further assessments after curing and storage (size grading, disease and physiological defects, dry matter). 2010 samples were assessed between the 18th and 26th April 2011. From each plot at the rain-shelter site only, a random sub-sample of 2 bulbs were taken and amalgamated by treatment to a single sample for analysis of quality and storability bio-markers by Cranfield University. Note that it had originally been intended to analyse a sample from each plot from both sites for these markers, but the extremely high cost of analysis proved prohibitive.

Observations at both trial sites indicated that there may have been some differences in the proportion of plants "bolting" (prematurely flowering) between treatments. Consequently, although it was not originally programmed for assessment, counts of the number of bolting plants per plot were made prior to harvest. Counts were converted into a % bolting using the average plant population counts from each plot.

Post-storage assessments will take place after long-term storage (approximately April 2012). All netted samples will be assessed for dried bulb yield, bulb size, bulb quality (including skin quality, bulb morphology, disease etc.) and marketable yield. In addition, a sub-sample of bulbs will be tested for dry matter content.

Crop pest and disease

Crop pest and disease incidence and severity was visually assessed for: onion Thrips (*Thrips tabaci*); downy mildew (*Peronospora destructor*); leaf blight (*Botrytis squamosa*); leaf blotch (*Cladosporium allii* / *C. allii-cepae*); secondary bacterial infection on foliage, and; bacterial rots in bulbs. Note that crop pest and disease data were not subjected to statistical analysis since this was intended as a solely observational part of the experiment. Observations were made on a scale of 0= no infection/infestation to 10= extreme infection/infestation.

Soil nitrate leaching

The impact of irrigation regimes on nitrate leaching from the soil was evaluated by assessment of soil mineral nitrogen (as nitrate and ammonium) at the start (immediately prior to commencing irrigation), middle and end of the season. Multiple samples were taken from each plot at 0-30cm and 30-60cm and amalgamated to a single sample for each depth. The rain-shelter site was sampled on the 13th May (start), 21st July (mid) and 31st August (end). The open-field site was sampled on the 25th May, 14th July and 14th September. Samples were kept cool and sent for analysis at Anglian Soil Analysis Ltd.

Weed response

Weed response to irrigation regimes was monitored by visual assessment of weed levels prior to harvest (on a scale of 0= no weeds to 10= extreme weed pressure). Data were recorded on 23rd August at the rain-shelter site and 14th September at the open-field site.

Irrigation efficiency, cost-benefit and identifying optimal irrigation regimes

Data collected from trials to date will be used in combination with crop quality information after storage to calculate the irrigation efficiency of the tested regimes and to conduct a cost-benefit analysis in the final report. This information will assist in identifying an optimal irrigation regime for bulb onions, ultimately helping to justify water use and demonstrate efficient irrigation to the Environment Agency for irrigation licence renewal in the future.

Statistical analysis

All data were subject to statistical analysis by the biometric department at Rothamsted Research. Analysis of variance (ANOVA) was used to determine differences between treatments using transformed data where necessary. Where required, repeat measures ANOVA was used. All results are reported at a significance level of p=0.05.

Results

Weather / soil moisture monitoring and irrigation scheduling - 2011

A summary of weather conditions during the growing season at the rain-shelter site (including comparison between inside and outside the rain-shelters) and open-field site are presented in Figure 8 and Figure 9.

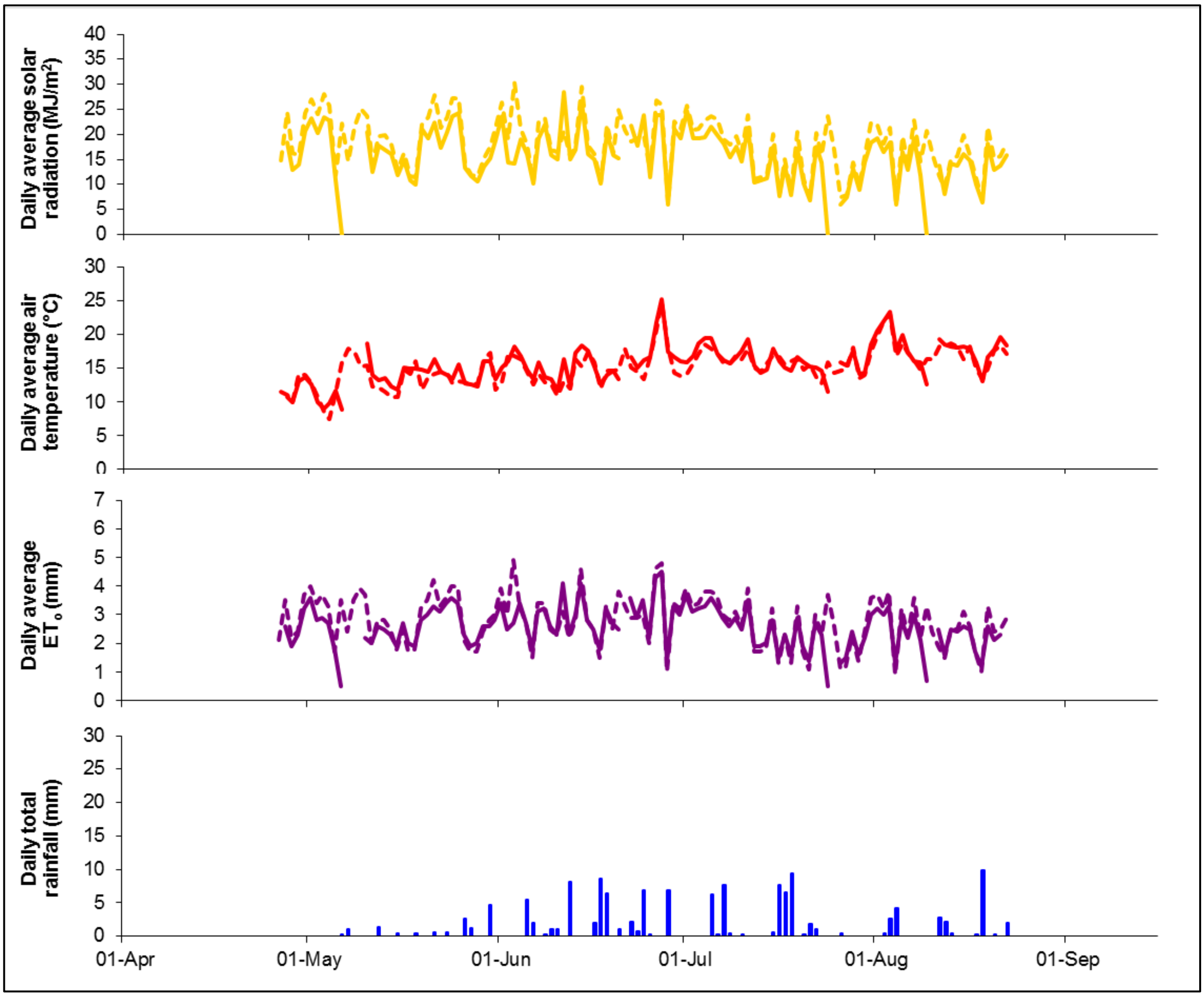

Figure 8. Weather at rain-shelter site during growing season.Solid line represents data within rain-shelter, dashed line outside rain-shelter. NB rainfall outside rain-shelter.

In general, the season started similarly to 2010, being relatively bright, warm and dry. However, the dry period lasted longer in 2011, with drought conditions persisting up until early-mid June. From this point onwards, overcast and damp but mild conditions prevailed, with frequent light showers and occasional heavy downpours (e.g. as on 28th June at the open-field site). These conditions severely limited the requirement to irrigate at the open-field site. As with 2010, solar radiation and wind-speeds were lower within the rain-shelter at Broom's Barn than outside, but the average daily temperature was similar or often higher in the rain-shelter. Consequently, reference evapotranspiration (ET_0) within the rain-shelters was slightly less (7-8%) when compared to outside.

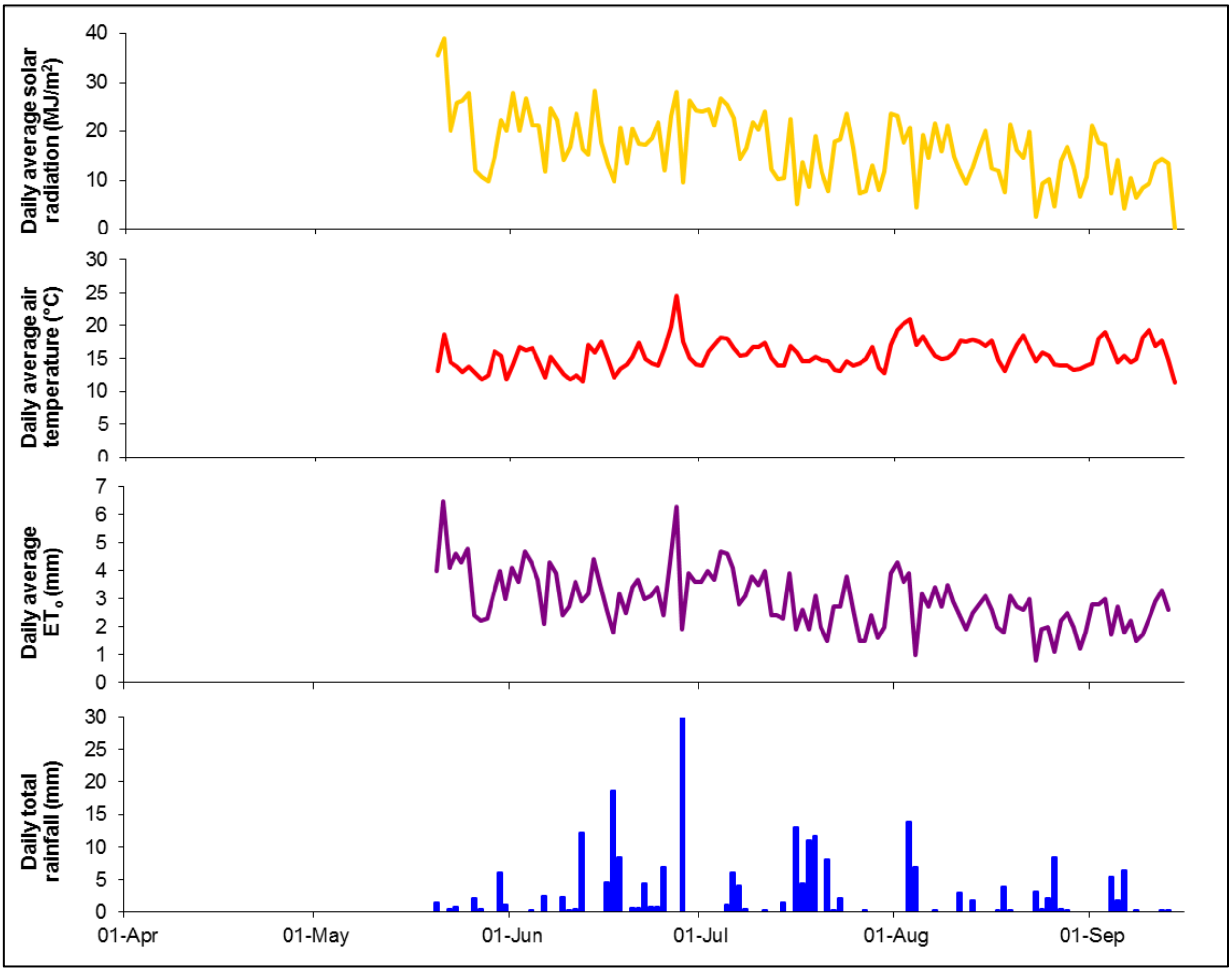

Figure 9. Weather at open-field site during growing season.

A summary of soil moisture deficit (SMD) in the root zone and irrigation applications through the season for each treatment is presented in Figure 10 (rain-shelter site) and Figure 11 (open-field site). Root zone was defined as the top 20cm of soil up until the point where significant quantities of water started to be removed from the 30cm profile, at which point the root zone was defined as the top 30cm for the remainder of the season.

Permanent wilting point at the rain-shelter site was assumed to be reached when soil moisture deficits reached 20%, 30% and 50% of AWC in the 0-10cm, 10-20cm and 20-30cm profiles as indicated by the non-irrigated control, H, during 2010 trials. On the slightly heavier soil at the open-field site, permanent wilting point was assumed to be reached when soil moisture deficits reached 20%, 25% and 35% of AWC in the 0-10cm, 10-20cm and 20-

30cm profiles as indicated by the non-irrigated control, H, during 2010 trials. This gave an average available water content (AWC) of 39mm at the rain-shelter site and 45mm at the open-field site within the 30cm rooting zone. Irrigation applications were applied as per Table 3 based on the required quantity of water to bring the soil to the target level (either field capacity or approximately 50% of AWC, depending on regime) plus an additional approximately 2-4mm to account for evaporative losses from the soil surface.

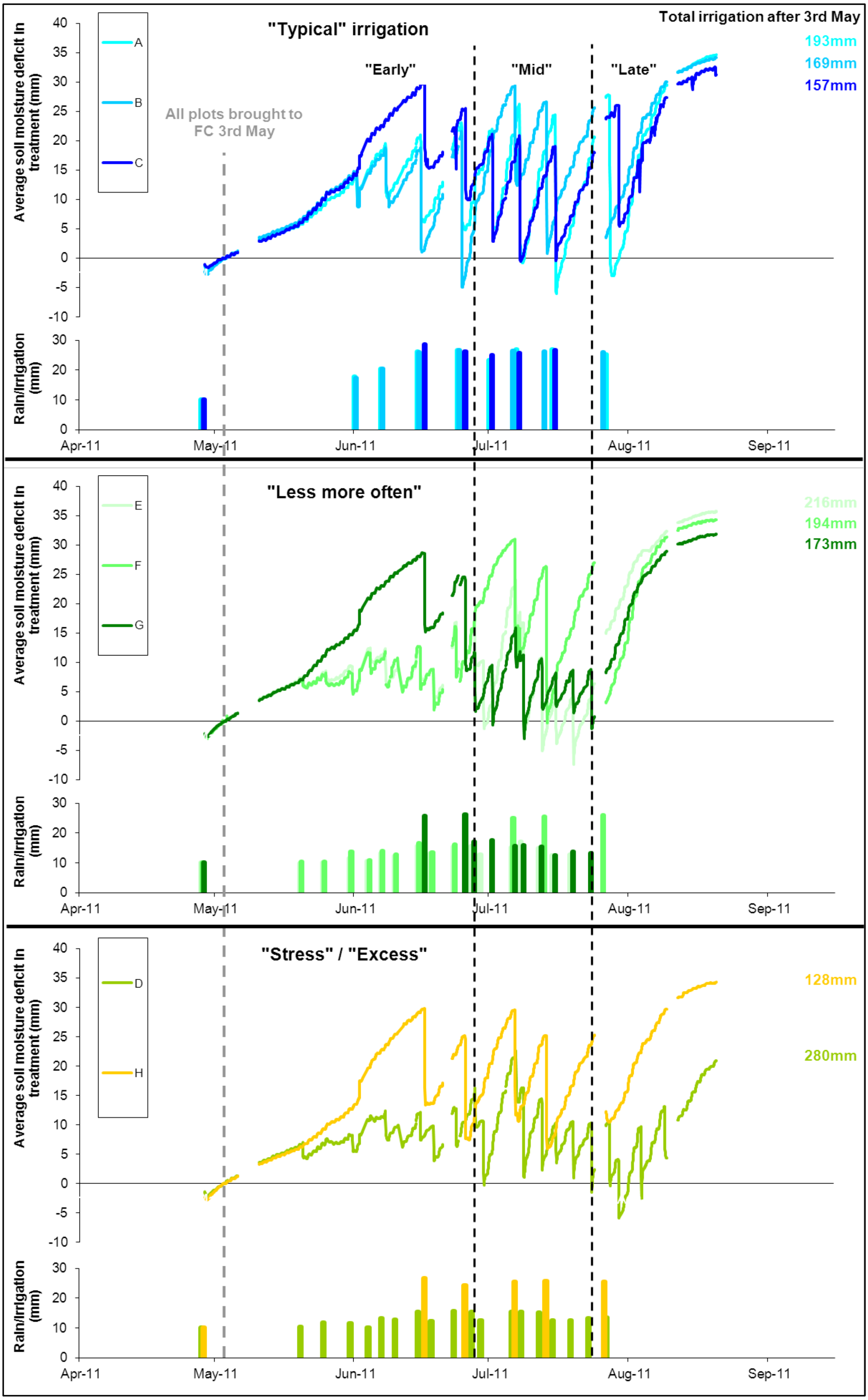

Figure 10. Soil moisture deficit in root zone and irrigation applications at rain-shelter site.

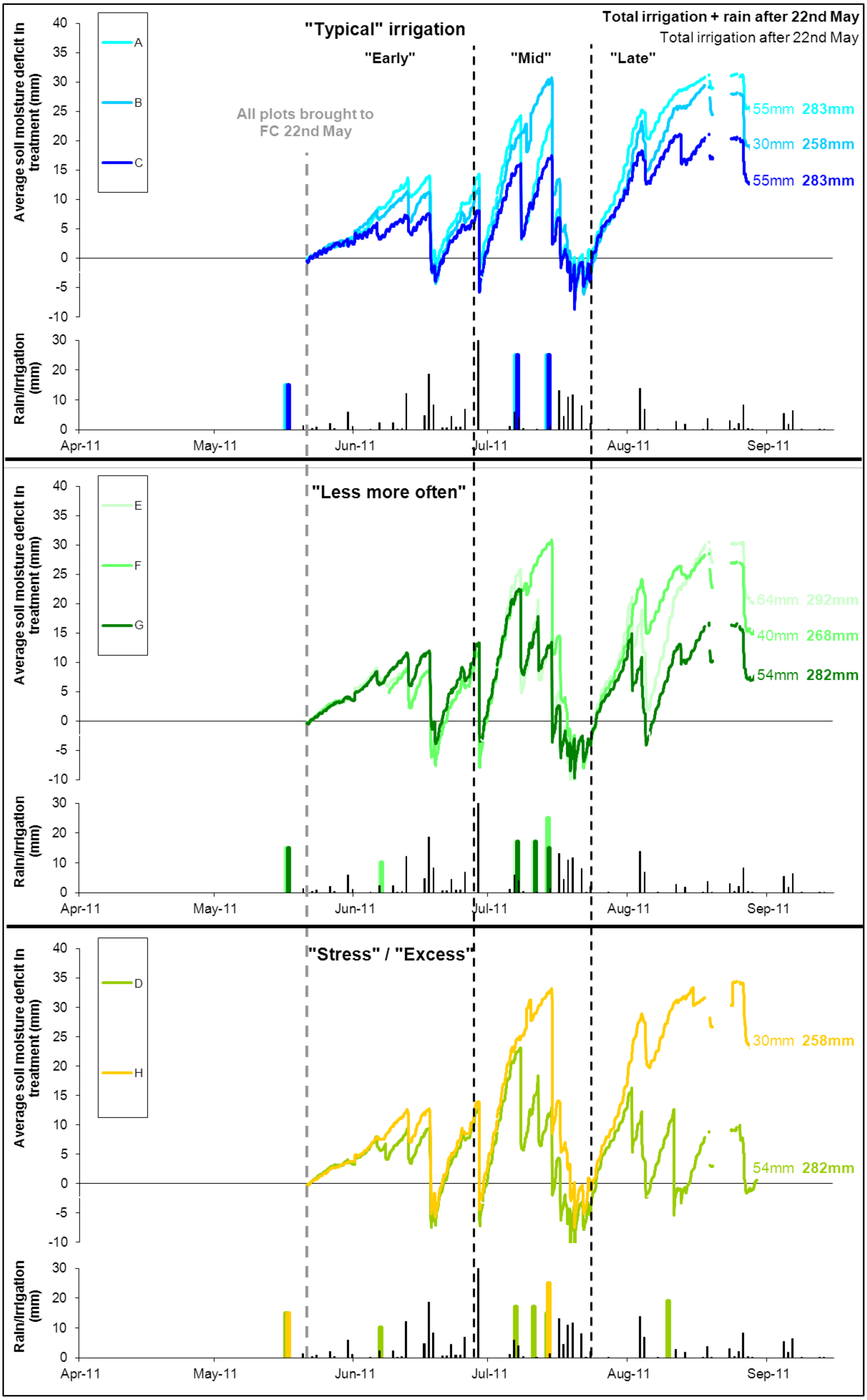

Figure 11 Soil moisture deficit in root zone and rain / irrigation at open-field site.

Table 4 summarises the number of irrigations and depth of irrigation applied to each treatment after initial wetting to field capacity. In general, irrigation regimes based on the "typical" field irrigation (A, B and C) were similar to field applications made by growers in 2011, being around 25mm every 7-10 days during the main crop canopy building phase and the start of bulbing. During a typical season, growers would generally expect to apply between 100 and 150mm in 4-6 x 25mm applications.

Regimes based on a "less more often" principle (D, E, F and G) generally had around 12-15mm applied every 3-4 days and a resulted in greater total application than the "typical" type treatments. The "stress" periods within both "typical" and "less more often" regimes generally had around 25-30mm applied every 10-14 days.

It should be noted that the wetter period from early-mid June significantly reduced irrigation requirements in the open-field trial site in 2011. Consequently, few irrigation applications were made during the season, and it is likely that little useful data will be generated from this year at the open-field site.

Table 4. Summary of irrigation events applied to each treatment

Trt	Name	Rain-shelter			Open-field		
		Total number	Total depth	Average depth	Total number	Total depth	Average depth
A	**Typical, end season stress**	8	193mm	24.1mm	2	55mm	27.5mm
B	**Typical with mid+end season stress**	7	169mm	24.2mm	1	30mm	30.0mm
C	**Typical with early+end season stress**	6	157mm	26.2mm	2	55mm	27.5mm
D	**Less more often, no stress**	21	280mm	13.3mm	5	83mm	16.6mm
E	**Less more often, end season stress**	17	216mm	12.7mm	4	64mm	16.0mm
F	**Less more often, mid+end season stress**	12	194mm	16.2mm	2	40mm	20.0mm
G	**Less more often, early+end season stress**	10	173mm	17.3mm	3	54mm	18.0mm
H	**Stress all season**	5	128mm	25.5mm	1	30mm	30.0mm

Crop performance - 2011

Note that, wherever possible a convention has been adopted such that graphs of results from the rain-shelter site appear on the left, and the open-field site on the right.

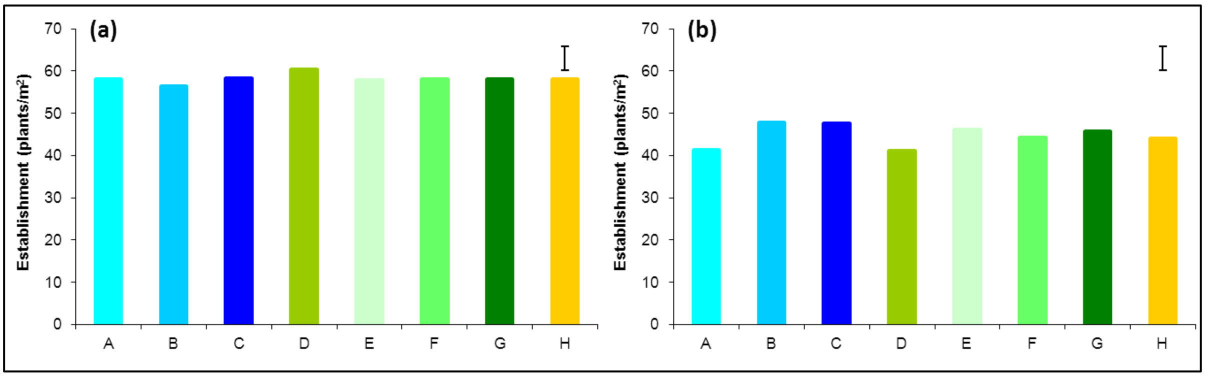

Figure 12. Crop population at harvest at rain-shelter site (a) and open-field site (b). Error bars show least significant difference (LSD).

Crop establishment

Crop population at the time of harvest is presented in Figure 12. No significant differences in population were observed between treatments. Populations at the rain-shelter site were around 11% higher than the target of 52 plants/m^2, largely due to good soil conditions at drilling. At the open-field site, populations were on average 6% lower thanthe targetof 48 plants/m^2, largely due to the dry conditions after drilling and some rabbit damage.

Canopy growth

Canopy growth as percentage green cover measured by spectral ratio meter is presented in Figure 13. In general, crop growth followed typical patterns for onion crops, with relatively slow development to mid-June, followed by rapid canopy expansion, peaking in late July (early July under rain-shelters) before starting to mature and senesce. Crop canopy growth reached a peak earlier in 2011 than 2010, perhaps reflecting the different climatic conditions. Significant differences in canopy growth were observed between treatments in the rain-shelter trial at most measurements (except the first measurement). There were no significant differences in crop canopy cover at the open-field site.

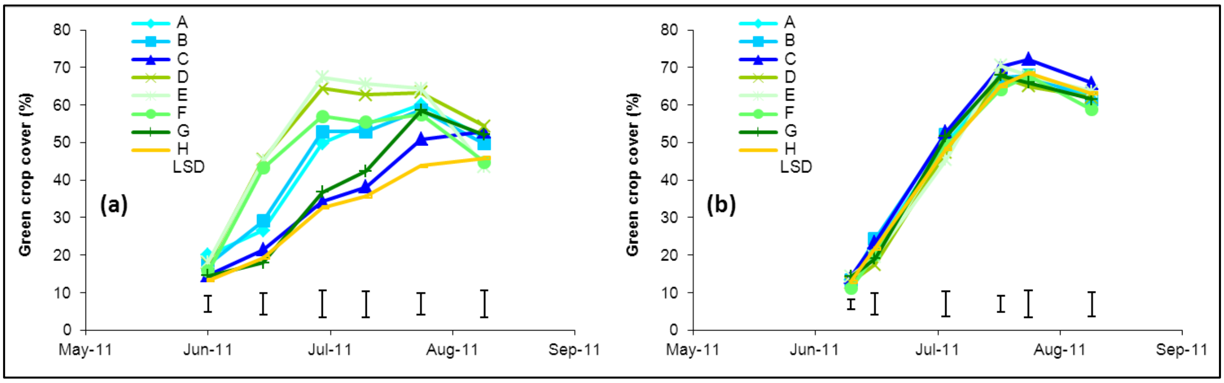

Figure 13. Crop canopy growth as % green cover at rain-shelter site (a) and open-field site (b). Error bars show LSD.

At the rain-shelter site, "less more often" treatments generated significantly greater canopy growth in the early and mid parts of the season when compared to equivalent "typical" irrigation regimes (D, E,F and G compared to A, B and C). Regimes that stressed crop growth early in the season suffered from significantly slower canopy growth and achieved smaller canopies overall (compare C to A and B or G to E and F). Applying more water later in the season did not allow these crops to catch up with those that had not been stressed up to the point of bulb initiation.

Vigour

Visual assessment of crop vigour is presented in Figure 14. Crop vigour follows a similar pattern to canopy cover, with significant differences between treatments being observed at the rain-shelter site from the period of rapid canopy expansion but no significant differences being observed at the open-field site. "Less more often" treatments tended to result in more vigorous early crop growth and water stress in the early part of the season tended to significantly reduce crop vigour during the critical development phase. The stress treatment H showed significantly less vigour than most full irrigation regimes, particularly as the season progressed.

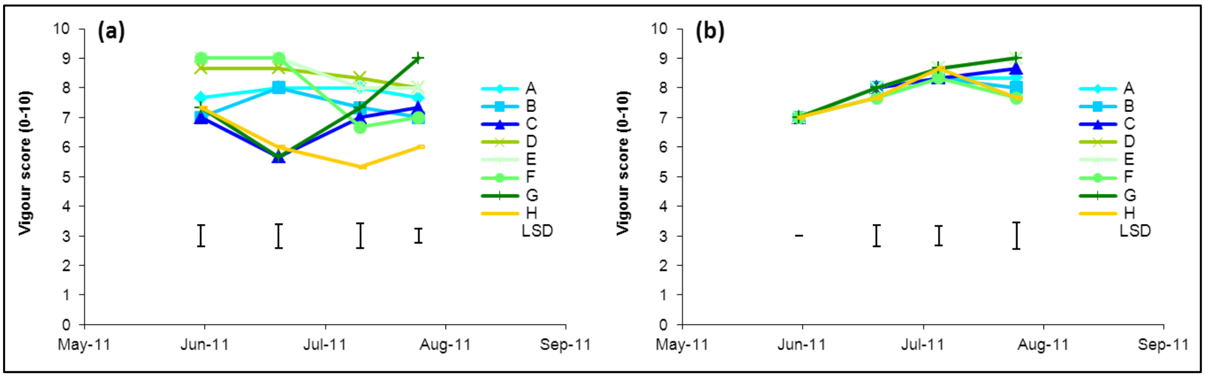

Figure 14. Crop vigour assessment at rain-shelter site (a) and open-field site (b). Error bars show LSD.

Biomass

Plant biomass is presented in Figure 15. There were significant differences in plant biomass between treatments at all sample intervals at the rain-shelter site. At the open-field site, there were significant differences only at the June and July measurements. Plant biomass response to the irrigation regimes followed a similar pattern to crop canopy growth and vigour score. In general, “little-and-often” regimes promoted more rapid and greater biomass accumulation. Water stress, particularly in the early season, significantly slowed and reduced biomass accumulation (regimes C, G and H).

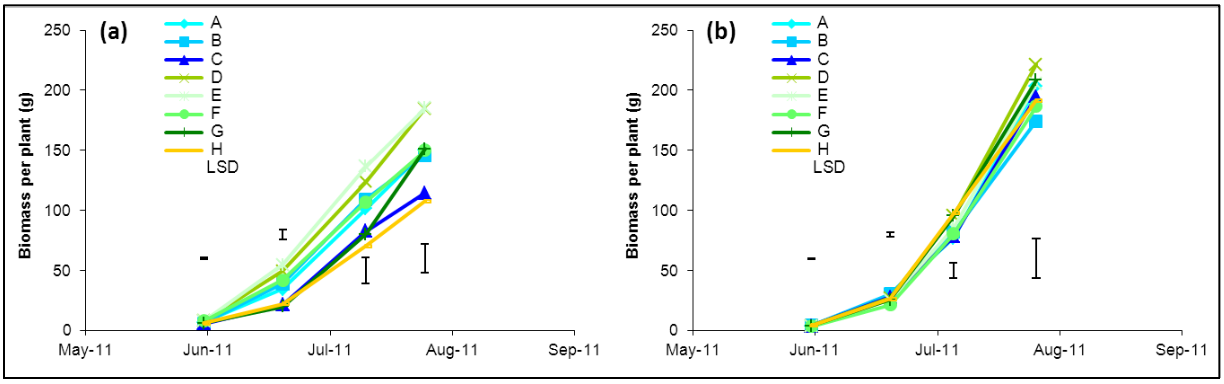

Figure 15. Crop biomass per plant at rain-shelter site (a) and open-field site (b). Error bars show LSD.

Fall-over and senescence

Crop fall-over progression and senescence are presented in Figure 16 and Figure 17. Crop fall-over was much earlier at the rain-shelter site than the open-field site. This was partly because the crop matured earlier under the rain-shelters, but also because the prolonged wet period during August and early September stimulated a widespread switch from bulb production back towards foliage production in the field. At the rain-shelter site, the fall-over progression was significantly slower in regime C than most other regimes. However, there were no significant differences between the majority of irrigation regimes, either relating to the frequency of application or the timing of period of water stress. Surprisingly, both the excess (D) and stress (H) regimes followed the same fall-over progression curve, with both being later to fall over than most other irrigation regimes. There were no significant differences in fall-over progression between treatments at the open-field site.

As with fall-over, crop senescence was later at the open-field site than under the rain-shelter. Note that the open-field site was harvested with the majority of the crop showing a relatively low degree of senescence due to commercial harvesting requirements in the surrounding field. Under rain-shelters, senescence progressed significantly more rapidly in the crop with the quicker fall-over progression – e.g. treatments C,D and H fell over significantly later than most other treatments, and senesced significantly later as a result. At the open-field site, no significant differences in senescence were observed between treatments.

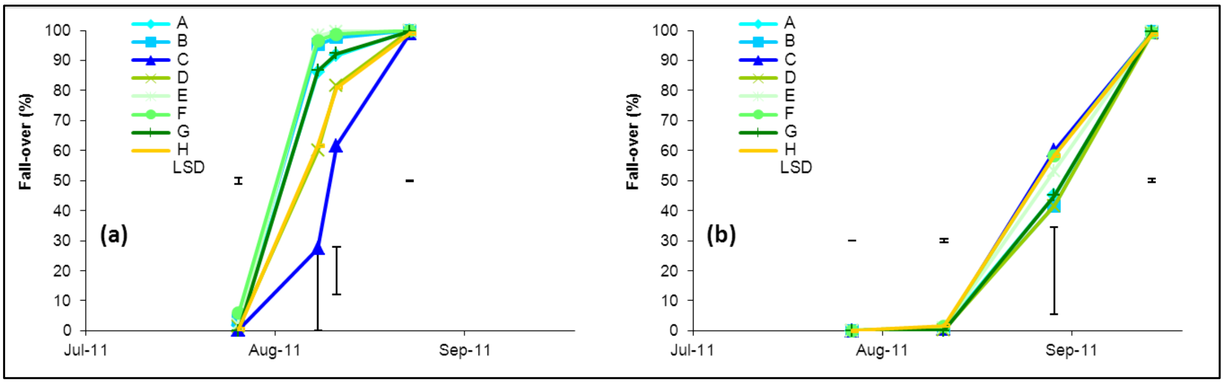

Figure 16. Crop fall-over progression at rain-shelter site (a) and open-field site (b). Error bars show LSD.

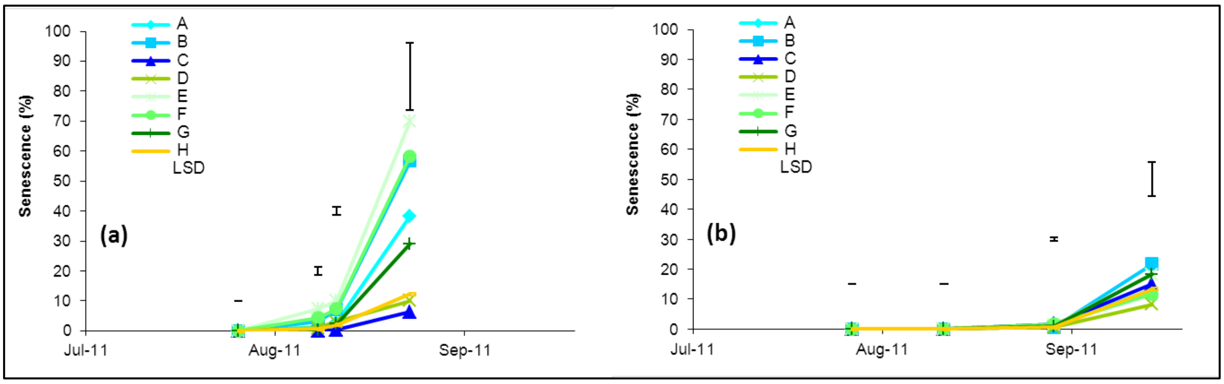

Figure 17. Crop senescence at rain-shelter site (a) and open-field site (b). Error bars show LSD.

Bolting

Crop % bolting is presented in Figure 18. There were significant differences in the level of bolting between treatments at both sites. At the rain-shelter site, all the treatments with early season water stress had no bolting plants present prior to harvest, but increasing water inputs in the early and mid- parts of the season significantly increased bolting. The same pattern was not so evident on the open-field site, with only treatment E and G showing significantly higher bolting than other treatments.

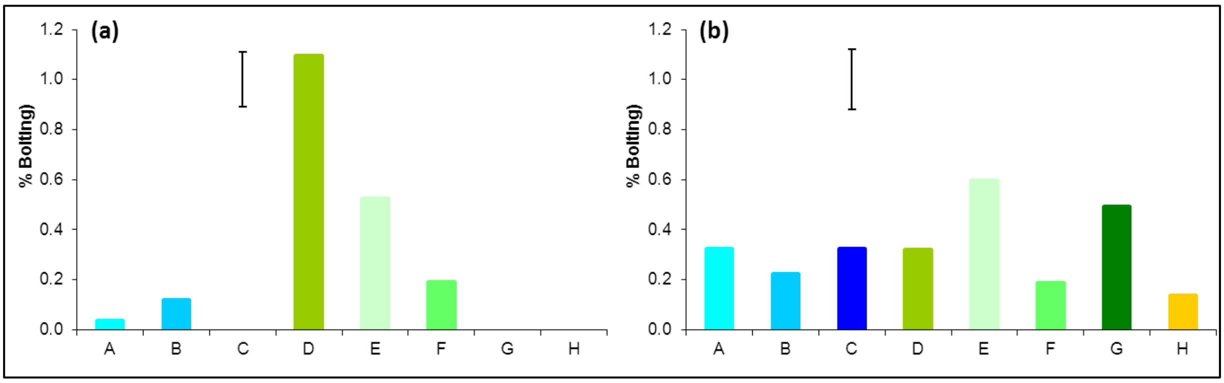

Figure 18. Crop % bolting prior to harvest at rain-shelter site (a) and open-field site (b). Error bars show LSD.

Green yield

Green yield is presented in Figure 19. Yields at both sites were quite typical for a dry year (at the rain-shelter site) and a wet end to the season (open-field site), and were similar to 2010 yields at both sites. Note that hand-harvesting tends to result in an estimated 10-15% greater yield than mechanical harvesting.

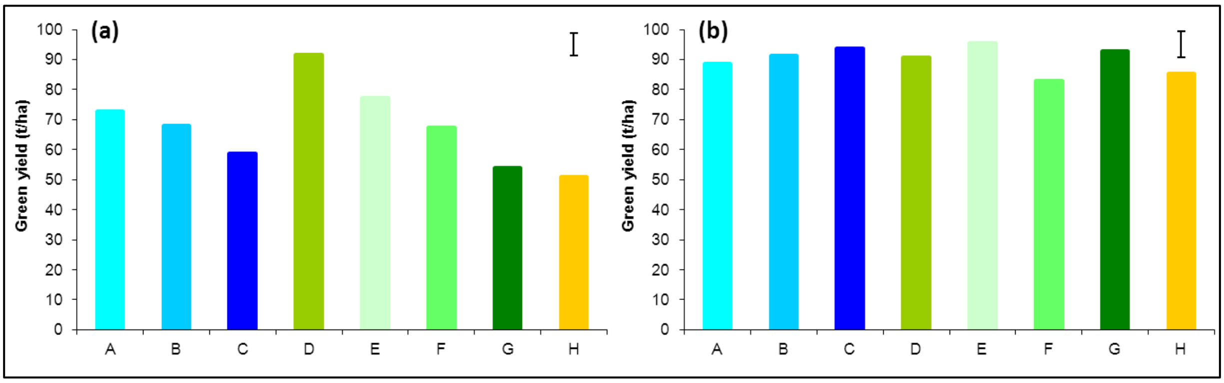

Figure 19. Crop green yield at rain-shelter site (a) and open-field site (b). Error bars show LSD.

At the rain-shelter site, there were significant differences in green yield between many treatments. Treatments without added water stress (i.e. only being subject to increased stress at the end of the season, from egg-stage bulbing: A and E) generally had significantly higher yields than those with additional water-stress periods. In particular, water stress early in the season (up to bulb initiation) significantly reduced green yields in both “typical” and “less more often” regimes by 20% and 30% respectively (C compared to A and G compared to D). Irrigating through to 50% fall-over produced a significant yield increase of 18% from a regime with end of season stress (D compared to E). In addition, irrigating “little and often” tended to produce slightly higher yields than a comparable “typical” regime – although these differences were not significant. The “stress” regime, H yielded 30% lower than the “typical” industry standard irrigation regime, A. There were no significant differences in green yield at the open-field site.

Crop storability and quality

All samples are currently in storage under commercial onion cold-storage conditions, and will be assessed for quality and marketability in March/April 2012.

Quality and storability biomarkers

Crop quality and storability biomarkers are currently being analysed at the laboratory: therefore no data can be presented here.

Crop storage – 2010

Crop storability and quality – 2010 trial data

This section presents post-storage data from the **2010 trial**. Figure 19 presents post-storage size-graded yields. There were significant differences in yields within each size grade category at both sites – primarily between the stressed (G) and non-irrigated (H) treatments and the main irrigation regimes (ABCDEF). In general, irrigating “little more often” and irrigating closer to harvest tended to produce higher yields of larger sized bulbs and lower yields of smaller sized bulbs. Conversely, more restricted irrigation tended to limit larger sized bulbs and promoted smaller bulbs.

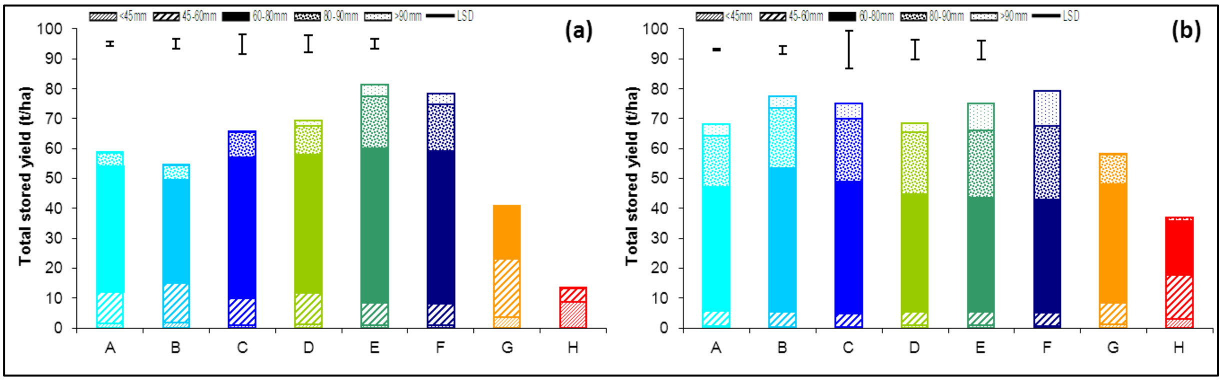

Figure 20. Crop post-storage size-graded yield at rain-shelter site (a) and open-field site (b). Error bars show LSD within size-grade category.

Figure 21 presents post-storage crop dry matter content. Dry matter content was typical for onion crops, but did not differ significantly between irrigation treatments. However, there were some indications at the rain-shelter site that the "little more often" type regimes tended to reduce dry matter compared to more typical irrigation.

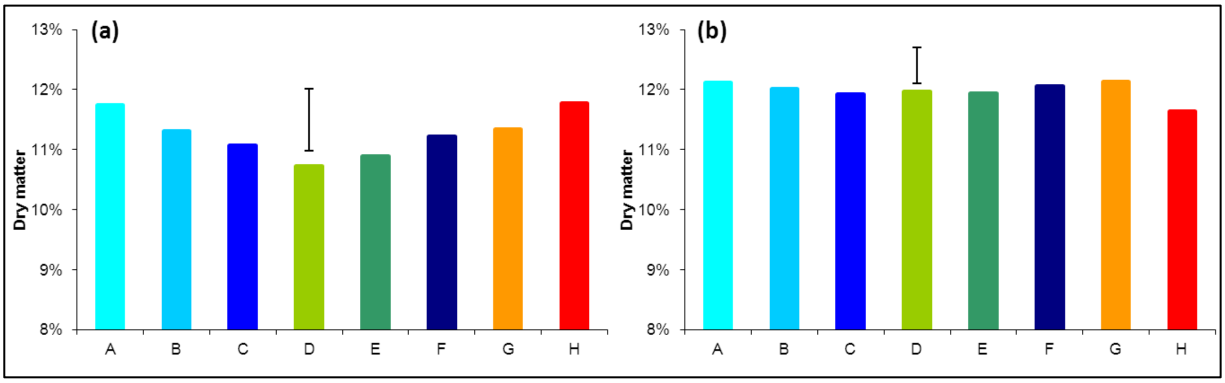

Figure 21. Crop dry matter content at rain-shelter site (a) and open-field site (b). Error bars show LSD.

Figure 22 presents post-storage disease assessment data. Note that samples were assessed at the very end of commercial cold-storage and that the open-field site was assessed first, with the rain-shelter site following afterwards. Consequently, there was some increased development of Penicillium type moulds on the rain-shelter site samples during this period between the end of cold-storage and assessment which may have affected results. At both sites, there were no significant differences in disease levels between irrigation treatments, with the exception of bacterial rots and Penicillium at the rain-shelter site. It is thought that the Penicillium levels were artificially high in these samples, and that consequently, the differences between treatments may not be meaningful. Bacterial rots were significantly higher in the non-irrigated treatment, but did not differ significantly between other treatments. There were some indications that Fusarium levels may have been higher in treatments that applied the greatest quantity and frequency of water, but this was not statistically significant.

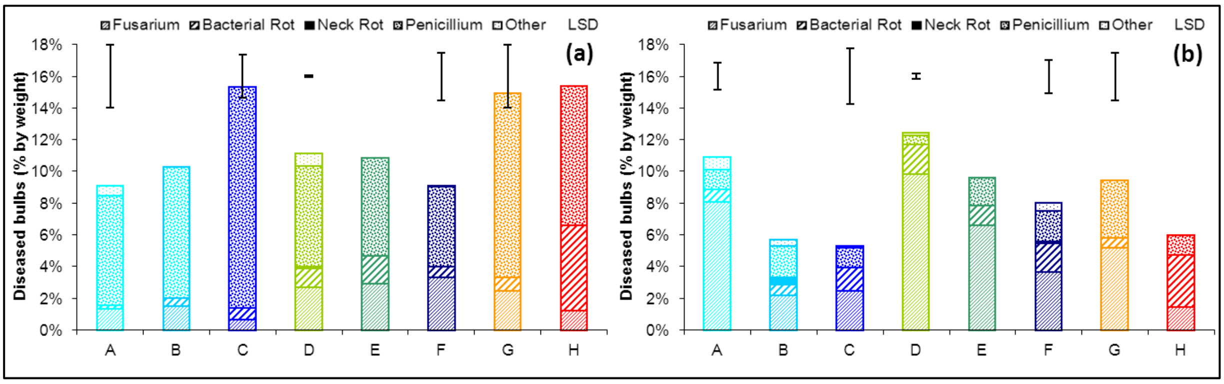

Figure 22. Crop post-storage disease assessment at rain-shelter site (a) and open-field site (b). Error bars show LSD within disease category.

There were no significant differences in the proportion of bulbs with double centres, the proportion of bulbs with internal die-back symptoms or in internal re-growth levels, skin finish or shape (except the non-irrigated treatments which tended to have a more elongated shape). Consequently, this data is not displayed here.

Quality and storability biomarkers – 2010 trial data

Crop quality and storability biomarker datahave been received and analysed, however, it is suggested that they are best presented in the final report rather than in this annual report.

Crop pest and disease - 2011

The results for Thrips (*Thrips tabaci*) observations are presented in Figure 23. There were significant differences in Thrips damage at the rain-shelter site, but no damage was noted at the open-field site. Treatments that received the greatest frequency and quantity of water showed the lowest Thrips damage and those with the least frequency and quantity of water showed the greatest damage.

The results for downy mildew (*Peronospora destructor*) incidence and severity are presented in Figure 24. At both sites, little downy mildew was observed, largely due to the dry conditions experienced under protection in the rain-shelter and the efficacy of commercial fungicide programmes at the open-field site. At the rain-shelter site, occasional downy mildew was noted in some plots, but this largely dried back under low humidity conditions by harvest. In field crops, the dry period until the mid-June resulted in low downy mildew pressure, which then increased during the wet period in July/August. This is reflected in the open-field site data, with downy mildew levels generally being low, but increasing slightly during late August/September.

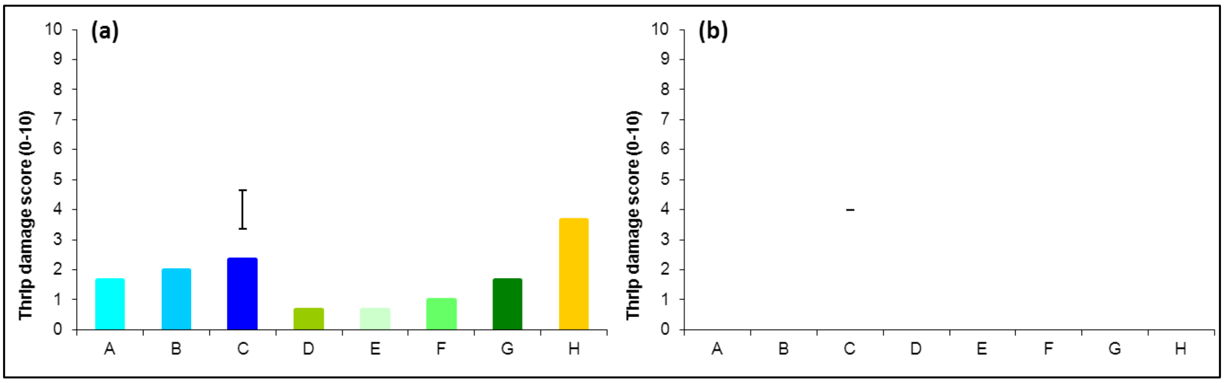

Figure 23. Thrips incidence and severity score at rain-shelter site (a) and open-field site (b). Error bars show LSD.

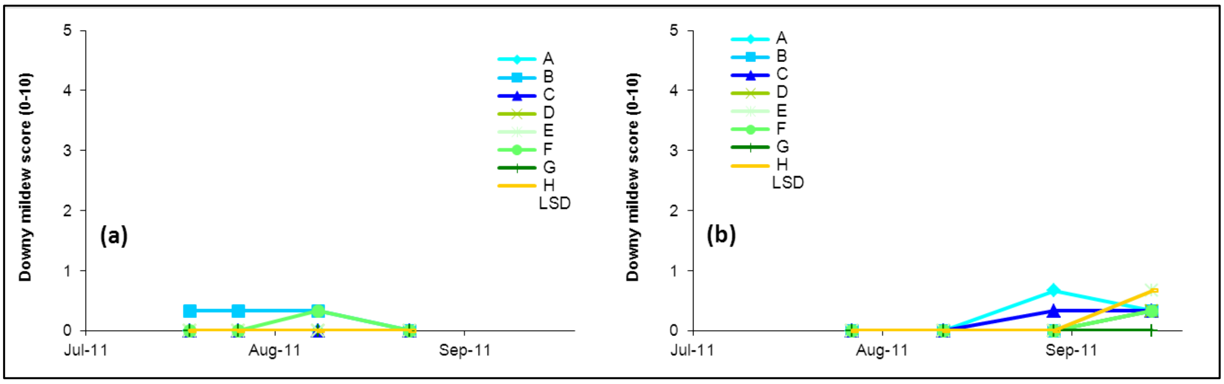

Figure 24. Downy mildew incidence and severity score at rain-shelter site (a) and open-field site (b).

Results for leaf blight (*Botrytis squamosa*), leaf blotch (*Cladosporium allii* / *C. allii-cepae*), secondary bacterial infection and bacterial rots are not presented here. All were present at relatively low levels from late July onwards, generally greater at the open-field site, and increasing through to harvest. In most cases, levels of these diseases were marginally higher in irrigation treatments that had more frequent irrigations that continued later in the season, however this was not conclusive.

Soil nitrate leaching - 2011

Soil ammonium N and soil nitrate N in the 0-30cm and 30-60cm profiles are presented in Figure 26 to Figure 28. Characteristic of soil nutrient measurements, data from both sites were very variable, with typically a two-fold variation seen between replicates, but up to 10-fold in some cases.

Although the variability in observed data resulted in few statistically significant differences between treatments in ammonium or nitrate levels within the 0-30cm or 30-60cm profile at either site, there were some apparent trends. Irrigation regimes with the greatest quantity and frequency of water (especially early to mid-season) generally tended to have lower levels of ammonium and nitrate N in the 0-30cm and 30-60cm profiles than regimes with less water. This may suggest that some leaching may have occurred, but may also reflect the greater crop growth observed in the "wetter" treatments than in more stressed regimes.

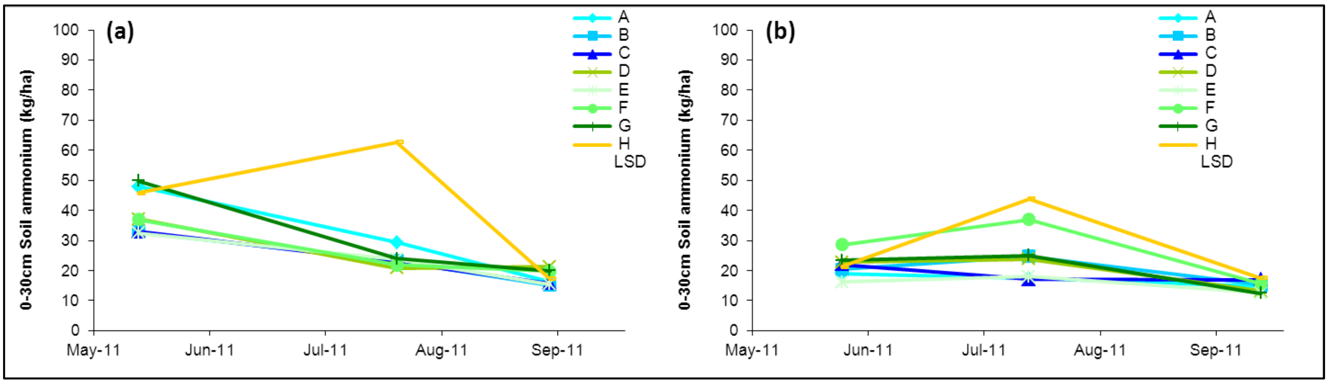

Figure 25. Soil ammonium N in 0-30cm profile at rain-shelter site (a) and open-field site (b).

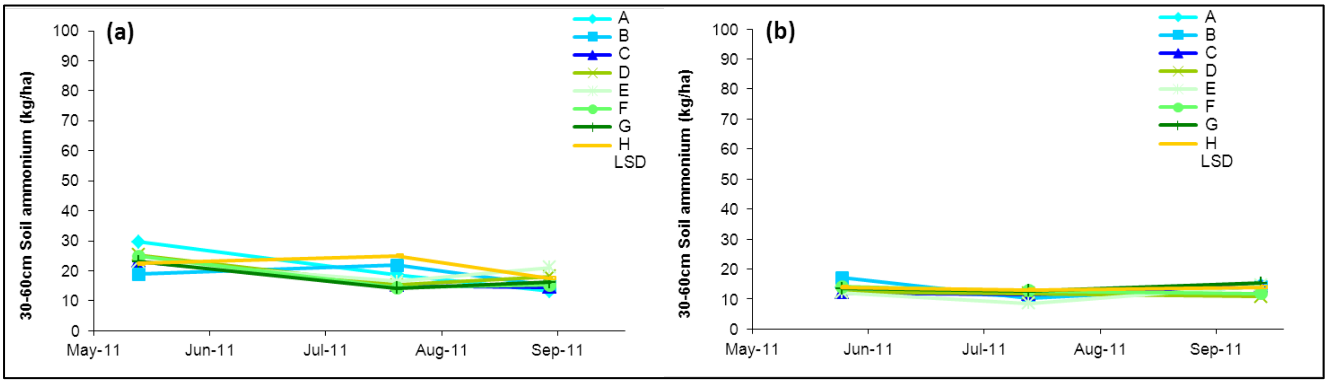

Figure 26. Soil ammonium N in 30-60cm profile at rain-shelter site (a) and open-field site (b).

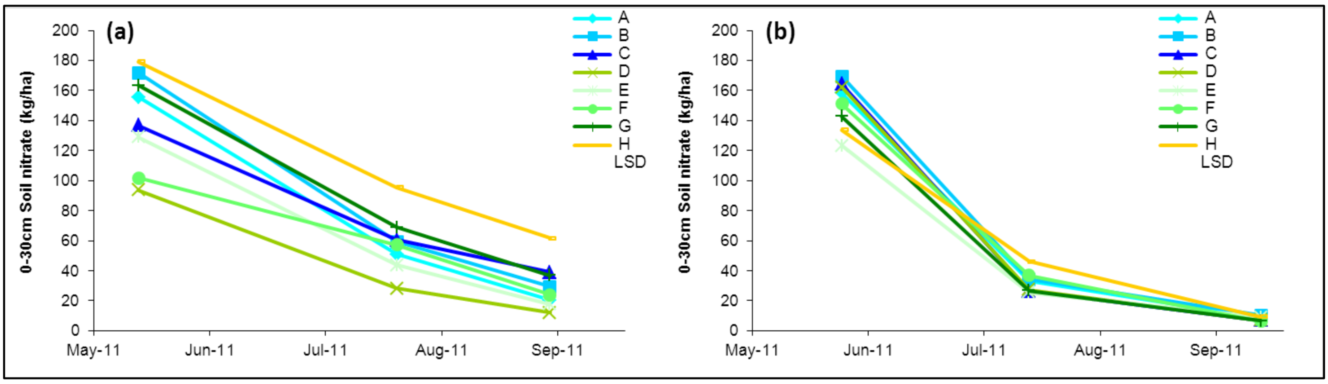

Figure 27. Soil nitrate N in 0-30cm profile at rain-shelter site (a) and open-field site (b).

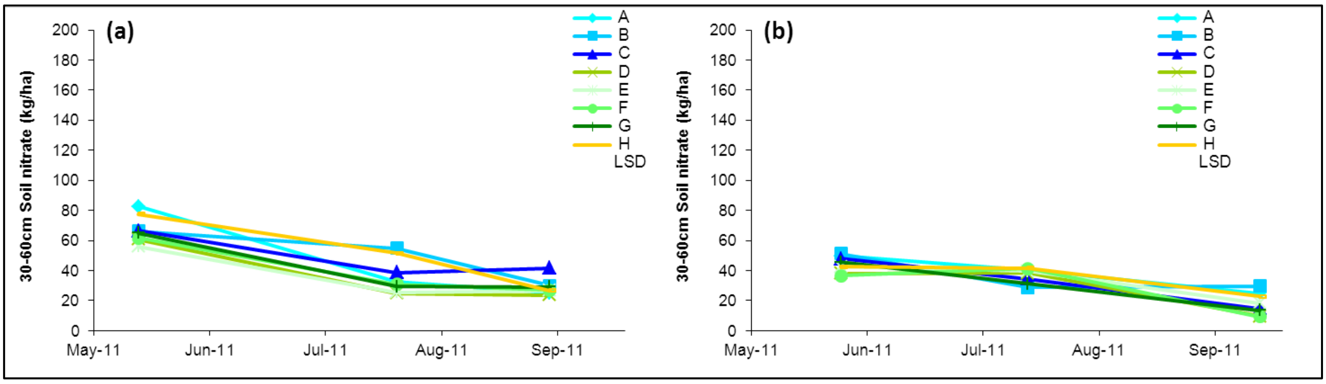

Figure 28. Soil nitrate N in 30-60cm profile at rain-shelter site (a) and open-field site (b).

Weed response - 2011

Weed scores at harvest are presented in Figure 29. In the rain-shelter, there were clear differences in weed pressure as a result of the irrigation regime applied. The majority of weeds in the rain-shelters were fat hen, nightshade, pansy, speedwell, chickweed, groundsel and sow thistle. Regimes with frequent applications in early and mid-season tended to have a higher weed pressure than those which received less frequent irrigation. The lowest weed pressure was observed in treatments with water stress in early and mid-season. There were no observed differences in weed levels at the open-field site, largely due to effective herbicide programmes.

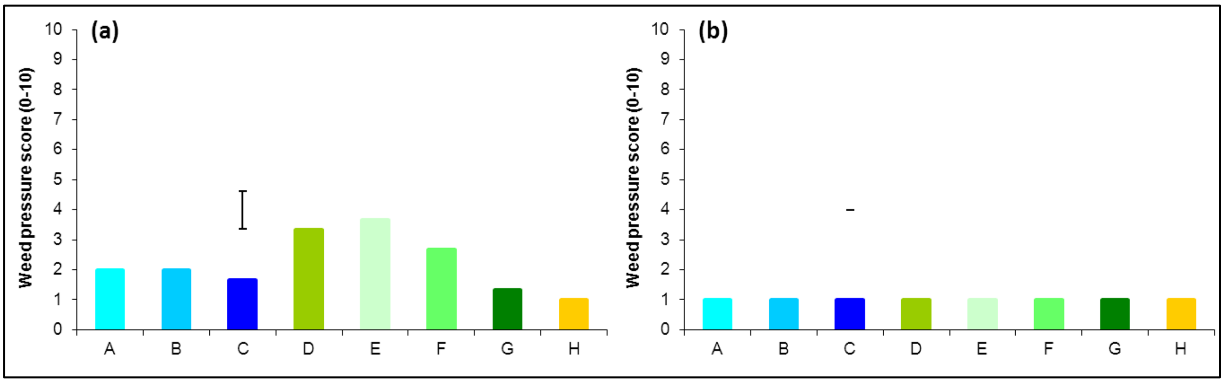

Figure 29. Weed score at harvest at rain-shelter site (a) and open-field site (b).

Irrigation efficiency, cost-benefit and identifying optimal irrigation regimes – 2011

Although the evaluations of irrigation efficiency, cost-benefit and optimal irrigation regimes are best reserved until sufficient data has been accumulated later in the project, some preliminary results are presented in Figure 30, also including 2010 data. These graphs indicate a very strong and direct correlation between total water received by the crop and green yield at the rain-shelter site. However, the open-field site indicated very different response to water between 2010 and 2011 – perhaps due to other climatic influences. Indications from the data to date are that onion crop yield increases by between 0.25 and 0.3 t/ha for every mm of irrigation and/or rainfall received by the crop up to around 300mm total, where the response appears to plateau. Note that although a linear regression has been applied to some of these data, it is understood that the relationship is not likely to be linear; rather it will plateau or peak at high water input levels. This relationship could be further refined by removing the proportion of water at each rainfall/irrigation event that is estimated to be lost as evaporation from the soil surface. This may well result in a closer alignment between data from the two sites.

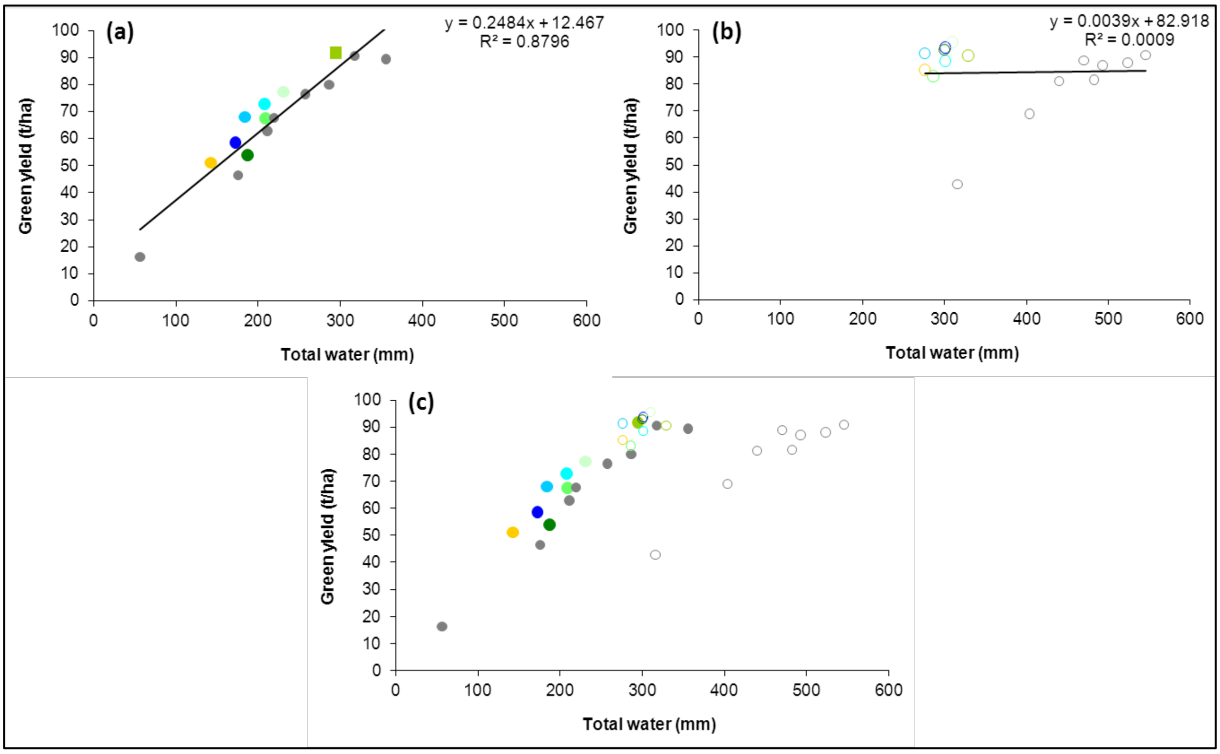

Figure 30. Correlation between total water received by crop and green yield at the rain-shelter site (a), open-field site (b), and all data from both sites together (c).

Discussion

Firstly, it should be noted that the open-field site received an unusually large number of rainfall events (most small, but some heavier showers) during the majority of the main part of the growing season from early June until harvest. Consequently, few irrigation treatments could be applied to this site and, as a result, there are few if any significant differences in crop performance, pests, disease and weeds in the data from this site. However, the data from the rain-shelters once again provided some very useful information. The majority of the discussion will therefore focus on the rain-shelter site unless specified.

Irrigation regime did not affect crop establishment at either site in this trial due to crops inevitably requiring to be established before differential irrigation regimes could commence.

As with 2010, the irrigation regime applied to plots had a profound effect on crop growth (whether measured as % green crop cover, visual assessment of crop vigour or plant biomass). Irrigation regimes that applied less water more often tended to drive crop canopy cover development and increased crop vigour and biomass over more typical regimes of c25mm every 7-10 days. In particular, it was apparent that irrigation regimes which induced water stress in the crop early in the season (prior to bulb initiation) significantly reduced both the rate of crop development and the total canopy or biomass achieved.

In turn, this increased canopy development translated almost directly into increased crop green yield, following relatively well understood principles of resource partitioning to storage tissues. There were also clear signs from the rain-shelter site that not deliberately inducing water stress late in the season (only up to 50% fall-over in this trial) increased green yields over the typical practice. This was supported by observations of the yield increase that the abnormally wet period near harvest had on both the open-field site and field crops in general this year. Although a similar situation occurred in 2010, storage data from last season did not indicate significant differences in crop storage potential as a result of late water applications – somewhat contrary to commercial experience.

Significant differences in the proportion of plants bolting (prematurely flowering) were noted at both sites, generally with those treatments which had promoted increased early canopy growth (i.e. “less more often” regimes) tending to have a greater proportion of bolting plants than more typical regimes. It is thought that this increased bolting may relate to the crop being more advanced than usual around the time that the appropriate day-length trigger causes the switch of resources from leaf to bulb production. Consequently, the plants may believe they are in the second year of their biennial cycle and therefore produce flowers. It is worth noting that although the percentage of bolting plants that were observed was relatively low, bolting to 0.5-1% in a field situation is sufficiently visually striking to cause concern to growers.

Currently all 2011 harvest samples are in storage under typical commercial conditions. They will be assessed for crop quality and marketability in March/April. Analysis of 2010 samples indicated that irrigation regimes which applied the greatest amount or frequency of irrigation through the season tended to promote larger bulbs and fewer small bulbs. There did not appear to be any significant increase in storage diseases as a result of irrigation regimes that applied more water, more frequent water or later water – again contrary to commercial experience.

There were strong indications that more frequent irrigation reduced Thrips damage under the rain-shelter. These results reflect accepted knowledge that overhead irrigation is an effective control agent for onion Thrips.

As with 2010 season, disease levels were generally quite low at both sites, and there were no apparent differences in disease expression as a result of irrigation regime.

Soil ammonium N and nitrate N levels were characteristically variable and there were few significant differences between the irrigated regimes. However, there were some indications that regimes with less water may have retained a greater proportion of soil ammonium and nitrate than those that applied more water and/or with more frequent irrigations. This may suggest some leaching through the profile, or it may reflect the greater crop growth in these plots.

Weed pressure appeared to be generally higher under those irrigation regimes that applied water more frequently and in the early to mid-season.

These data discussed here address objectives 1 and 2 of the project, although further data has yet to be gathered from the 2011 season trials (primarily storage data). Objectives 3 and 4 are long-term goals of the project, and will require data from all 3 years of trials to complete.

Conclusions

The 2011 season trials have continued to provide very useful data to project FV 326a. Eight irrigation regimes were investigated for their impact on onion crops both under rain-shelters and in a commercial open-field site. Strong differences were observed between irrigation treatments under the rain-shelter. Differences between treatments were much smaller at the open-field site, largely due to the abnormally wet period from mid-June until harvest.

In general, as found in 2010, onions respond well to water, with more frequent applications of smaller amounts tending to drive canopy development and crop vigour more than typical applications of c25mm every 7-10 days. The most critical period for driving this canopy growth appears to be early in the season (prior to bulb initiation). This increased canopy development largely translates into greater yield. However, late application of water also tends to increase yields, most likely due to direct water uptake by the bulb.

Analysis of 2010 storage data showed little significant effects of irrigation regime on storability of onion bulbs (contrary to field experience), but backed up previous yield data with size-grading information. 2011 crop samples are currently in cold-storage for analysis in April/May 2012.

Because the project is still in progress, the authors are reluctant to advise significant changes to irrigation practices based on the data generated to date. However, given the potential for significant shortages of water for irrigation in 2012, it may be wise for growers to consider prioritising irrigating their onions in the early season to promote canopy at least up to the point of bulb initiation – bearing in mind the potential for increased bolting in excessively forward crops.

Knowledge and Technology Transfer

A review article was written for the HDC News in June 2011, giving information on the trial and summarising storage results from the 2010 trials. A field day was held to coincide with the annual open day at Broom's Barn Research Centre on 28th June 2011. It is anticipated that a further article will be written for the HDC News and another field day will be held at Broom's Barn Research Centre in 2012.

Data from the irrigation trial has been shared with the LINK project HL0196 "Developing precision irrigation for field-scale vegetable production, linking in-field moisture sensing, wireless networks and variable rate application technology". This data will assist the project to validate onion growth and water response models. Meetings with the project co-ordinators are planned for 2012 to share further data between the LINK project and FV 326a.