# FINAL REPORT

# Understanding the fundamental role of ethylene in potato storage

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# 1. Summary

Ethylene is used as a sprout suppressant with 4% of the total Great Britain tonnage treated in 2008 (Garthwaite *et al.* 2010). The main appeal to the potato industry is the absence of a deposited residue. However, there is limited understanding of how ethylene works and its use is currently limited to low temperature, pre-pack potato storage.

The aim of this study was to broaden the understanding of the application of ethylene as a sprout suppressant. A range of cultivars and application timings were tested and periodically assessed for sugars and plant growth regulators at Cranfield University and physical sprouting at Sutton Bridge Crop Storage Research (formerly Sutton Bridge Experimental Unit).

Crops were divided into two experimental stores, one with no added ethylene and the other with ethylene supplied at 10 ppm. There were four treatments: two were full term storage under the regimes in these stores. The other treatments were reciprocal swaps between the two stores, triggered by 10% sprout eye movement in the untreated crop.

Ethylene reduced sprouting in all varieties. Excellent sprout inhibition was observed in Russet Burbank and Sylvana, both relatively long dormant varieties, and good sprout inhibition in Desiree, Estima, Fianna and Maris Piper. The least inhibition was observed in the very short dormant *Solanum phureja* cultivar, Mayan Gold. Although sprout inhibition appeared more pronounced in long dormant cultivars there were exceptions, notably Marfona, which is long dormant but in which sprouting was only weakly inhibited by ethylene.

Previous studies have found that ethylene reduces the dormant period of a potato. However, in this study, no correlation was discerned between ethylene use and observed dormancy in any variety.

After 30 weeks' storage, there was little difference in sprout length between 'full term ethylene treatment' and 'treatment since dormancy break'. This suggested that

initiating ethylene treatment at dormancy break, as measured by 10% eye movement, was as effective as treating with ethylene throughout the storage period. However, in the long dormant varieties, Marfona, Russet Burbank and Sylvana, there was a reduction in the incidence of sprouting in ethylene treatments at transfer, indicating that ethylene apparently increases the duration before dormancy break in these cultivars.

This study provides baseline data to guide the further exploitation of ethylene in the GB potato industry. These findings need to be analysed in conjunction with the biochemical data from Cranfield University to more fully understand the effects of ethylene on potatoes.

# 2. Introduction

The use of ethylene as a sprout suppressant is gaining ground in the UK. The main appeal to the potato industry is the absence of a deposited residue. This adds value to a crop and may become a requirement of consumers in the future. However, there is limited understanding of how ethylene works and its use is currently limited to low temperature pre-pack potato storage. Improved understanding may facilitate wider application, for example sprout control in warmer stored processing crops.

The aim of this three year study was to broaden the understanding of the application of ethylene as a sprout suppressant. A range of cultivars, and application timings were tested and periodically assessed for sugars and plant growth regulators at Cranfield University (CU) and physical sprouting at Sutton Bridge Crop Storage Research (SBCSR).

The initial storage trial studied ten cultivars (Desiree, Estima, Fianna, King Edward, Marfona, Maris Piper, Mayan Gold, Russet Burbank, Saturna and Sylvana). In the second year four cultivars (Estima, Marfona, Russet Burbank and Saturna) were used with an expanded treatment range including 1-methyl cyclopropene (1-MCP) applications. Technical limitations in the quantity of crop that could be treated necessitated a reduction in the scope of the Sutton Bridge component of the study, achieved by reducing replication from 4 to 3 trays and assessing only the same treatments as were carried out in the first year. For the third and final year CU essentially replicated the second year treatment regime with two cultivars, Estima and Marfona, SBCSR replicated the second year experiment with all four varieties. This report covers the SBCSR storage and sprouting assessment components of the study and is intended as an aid for interpreting the extensive biochemical data generated by CU.

# 3. Material and methods

## *3.1 Methods*

### Treatments and experimental design

Crops were divided into two experimental stores, one with no supplied ethylene and the other with ethylene supplied at 10 ppm. There were four treatments. Two were full term storage in these stores. The other treatments were reciprocal transfers between the two stores, triggered by a 10% sprout eye movement in the untreated crop. The treatments were referred to as *Ethylene, Untreated, Ethylene→untreated* and *Untreated→ethylene*. The experimental design was an unreplicated comparison of treatments with variation measured by four in-store replicates.

### Controlled environment store set up and control

Two 12-tonne Controlled Environment Rooms were set at a target temperature of 6.0 C (tolerance ± 0.5 °C) and 95% RH (tolerance ± 5%), see Appendices; Figures 5 and 6 (2008/09), Figs. 40 and 41(2009/10), Figs. 55 and 56 (2010/11) provide the trial period store control data. The rooms were identically configured to constantly recirculate air. Air was discharged by overhead throw from the conditioning duct and then drawn back into a return at the bottom of the store for refrigeration or heating as necessary. Humidification method, however, differed between stores. The untreated store was fitted with a Humimax HM2 2000 *[Munters Ltd]* fan assisted humidification cell, whereas the treated store had a conventional compressed air atomiser. No chlorpropham (CIPC) sprout suppressant had ever been used in these stores.

The trayed crop was stacked onto trolley-racks. One shelf was allocated to each cultivar/treatment combination at random but this order was replicated in both stores. Trays were stacked randomly within shelves.

Ethylene was monitored and controlled by an EMU2 TS Ethylene Management Unit *[BioFresh Ltd]* which sampled and measured the concentration of ethylene gas in store air using a Polytron *[Dräger]* electro-chemical sensor calibrated specifically for ethylene. Sampled air was drawn through a narrow bore tube from the opening of the store's air return duct. This unit drove an external control mechanism with solenoid valves to control the introduction of ethylene, from a pressurised cylinder, with reference to a configurable set-point. An integral data logger recorded the ethylene concentration and was downloaded at weekly intervals see Appendices, Figure 4 for 2008/09, Fig 39 for 2009/10, and Fig 54 for 2010/11. Real-time ethylene readings were checked manually each day.

To minimise the risk of ethylene contamination from treated to untreated crops a second untreated store was employed on each transfer occasion. In this store, any ethylene associated with the *Ethylene→untreated* material was allowed to dissipate for a minimum of 24 hours before moving to the designated untreated store.

**Eye movement and sprouting assessments**

The trigger for reciprocal transfer between the stores was when 10% of the untreated tubers of a sample demonstrated white sprout tissue development. This sprout movement was monitored in whole trays at approximately weekly intervals and, where possible, a tray was assessed only once to minimise handling stress.

Within 24 hours of intake, four 25 tuber samples from each crop were taken for pre-treatment sprout assessment. Thereafter sprouting assessments were carried out on sub-samples of 25 tubers from the selected trays on each of four occasions: after 28 days of ethylene treatment, at the time of 10% eye movement transfer, transfer plus 28 days and full term storage (30 weeks). The length of the longest sprout on each tuber was measured and also the number of sprouting sites. When a large number of sprouting assessments were due, the allocated trays were moved to a 3.0 C cold store, which effectively halted sprout development until assessments were possible.

If the threshold for transfer had not been achieved by the 28 day sampling occasion, the treatments designated for transfer were not assessed as, by definition, there was no difference from the continuous treatments. For the same reason, any crop that achieved the transfer threshold before ethylene treatment began, was not assessed for any transfer treatment or related sampling occasion. Sampling occasions and dates are shown in Figure 10 for 2008/09, Fig 13 for 2009/10 and Fig 15 for 2010/11.

### Relative dormancy assessment

Immediately after sprouting assessment the four 25 tuber intake samples for individual cultivars were pooled and stored in paper-sacks at 15 °C and 95% RH. At approximately weekly intervals, tubers were transferred to an alternate paper-sack and any tuber with a sprout of 3 mm or longer was counted and discarded. This process continued until all tubers had sprouted.

### 1-Methyl Cyclopropene and control treatment *2009-10* and *2010-2011*

Some CU treatments required treatment with 1-methyl cyclopropene (1-MCP) [Rohm & Haas]. The application of this chemical took place at 6.0 °C in 0.5 $m^3$ sealed chambers, with internal circulation, for 24 hours. As a control, all tubers were similarly sealed, either with or without 1-MCP, in chambers prior to other storage treatment regimes. Because of limited availability of sealed chambers at Sutton Bridge it was necessary for this component of the trial to begin a day later than the CU trial.

## *3.2 Year 1 materials and methods (2008/09)*

### Crop, loading and temperature pull-down

Ten cultivars were selected to represent a range of physiological dormancy characteristics (see Appendices, Table 7). The crops were loaded into the treatment stores in two batches of five depending on their availability. The first batch was delivered on the 24th August 2008 and comprised Desiree, Maris Piper, King Edward, Estima and Marfona [supplied by *Solanum*]. The second batch arrived later, and over several days. Mayan Gold 6th October 2008 and Sylvana 7th October 2008 *[Greenvale AP],* Russet Burbank 8th October 2008 *[McCain Foods]*, Saturna 9th October 2008 *[G H Chennells]* and Fianna 10th October 2008 *[H Prins].*

As soon as possible, potatoes were passed over a grading line to remove soil, rots, damage, green and undersize tubers (< 45 mm) and loaded into 10 kg (capacity) plastic trays. Once in trays, crops underwent a controlled pull-down regime of 0.5 °C per day, at ambient relative humidity (RH), to a holding temperature of 6.0 °C. This was to minimise temperature stress and allow time for skin healing after handling. The second batch of crops went into a holding store at 10 °C on arrival, to synchronise the start of their pull-down.

Treatment of the two batches started on 15th and 23rd October 2008 respectively.

## *3.3 Year 2 materials and methods (2009/10)*

**Treatments and experimental design**

**Crop, loading and temperature pull-down**

Four commonly grown cultivars were selected to represent a range of ethylene responses and physiological dormancy characteristics (see Appendices, Table 7) agreed at the project meeting 18 August 2009. Estima was supplied on 16th October 2009 *[source: Elveden Farms]*, Saturna on 21st October 2009 *[R.S. Cockerill]* and Marfona on 22nd October 2009 *[C. Wright & Son].* Russet Burbank *[Greenvale AP]* was delivered on 3rd November 2009.

As soon as possible, potatoes were hand graded to remove soil, rots, damage, green and undersize tubers (< 45 mm) and loaded into 10 kg (capacity) plastic trays. Once in trays, crops underwent a controlled pull-down regime of 0.5 C per day, at ambient relative humidity (RH), to a holding temperature of 6.0 C. This was to minimise temperature stress and allow time for skin healing after handling. However, due to the late arrival of Russet Burbank the temperature of this crop was pulled down at an accelerated rate of 1.0 C per day in order to meet the start of the experiment. Treatment started on 11th November 2009.

## *3.4 Year 3 materials and methods (2010/11)*

### Crop, loading and temperature pull-down

For added replication, CU decided to repeat the previous experiments concentrating on Estima and Marfona only. Later a second batch, comprising Russet Burbank and Saturna, were also sourced for sprouting assessment only by SBSCR. The physiological dormancy characteristics of the four varieties are shown Appendices, Table 7. Intake of Estima and Marfona was on 12$^{th}$ October 2010 *[C. Wright & Son],* Russet Burbank *[Greenvale AP]* arrived on 26$^{th}$ October 2010 and Saturna on 1$^{st}$ November 2010 *[R.S. Cockerill].*

As soon as possible, potatoes were hand graded to remove soil, rots, damage, green and undersize tubers (< 45 mm) and loaded into 10 kg (capacity) plastic trays. Once in trays, crops underwent a controlled pull-down regime of 0.5 C per day, at ambient relative humidity (RH), to a holding temperature of 6.0 C. This was to minimise temperature stress and allow time for skin healing. Treatment started on 30$^{th}$ October 2010 and then on 18$^{th}$ November 2010 for the second batch.

# 4. Results

## *4.1 Year 1 Results (2008/09)*

### Ethylene concentration and control in store

The recorded ethylene readings for both ethylene treated and untreated rooms are shown in Appendices Figure 4. Data were not automatically recorded for a sum total of 23 out of 210 experimental days (Appendices Table 8), but were manually recorded every day (results available but not shown). The control of ethylene in the ethylene treated store was relatively stable apart from an interruption to the gas supply over the weekend of the 8$^{th}$ and 9$^{th}$ November 2008. The ethylene reading was less stable in the untreated store; the maximum reading was 6 ppm on 31$^{st}$ December 2008. However, all independent verification gave very low ethylene levels, peaking at 0.2 ppm (Appendices, Table 9).

### Dormancy

None of the cultivars were sprouting at intake. However, King Edward, a very short dormancy cultivar grown in the UK, had already passed the 10% sprout movement threshold as ethylene treatments began. Consequently, only the full-term *Ethylene* and *Untreated* treatments were continued as any swap at this stage would simply reproduce existing treatments.

The relative dormancy (50% 3mm sprout growth at 15°C) results are shown in Figure 1. They demonstrate a broad range of dormancies from short (e.g. Mayan Gold and King Edward) to long (e.g. Russet Burbank and Sylvana). When compared with the treatment transfer date (10% eye movement at 6°C), the rank of dormancies although broadly similar showed some notable disagreements (Table 1). Fianna in particular was more dormant at 6°C storage and Sylvana and Desiree less so. In this study, the transfer date is a more directly relevant measure of dormancy.

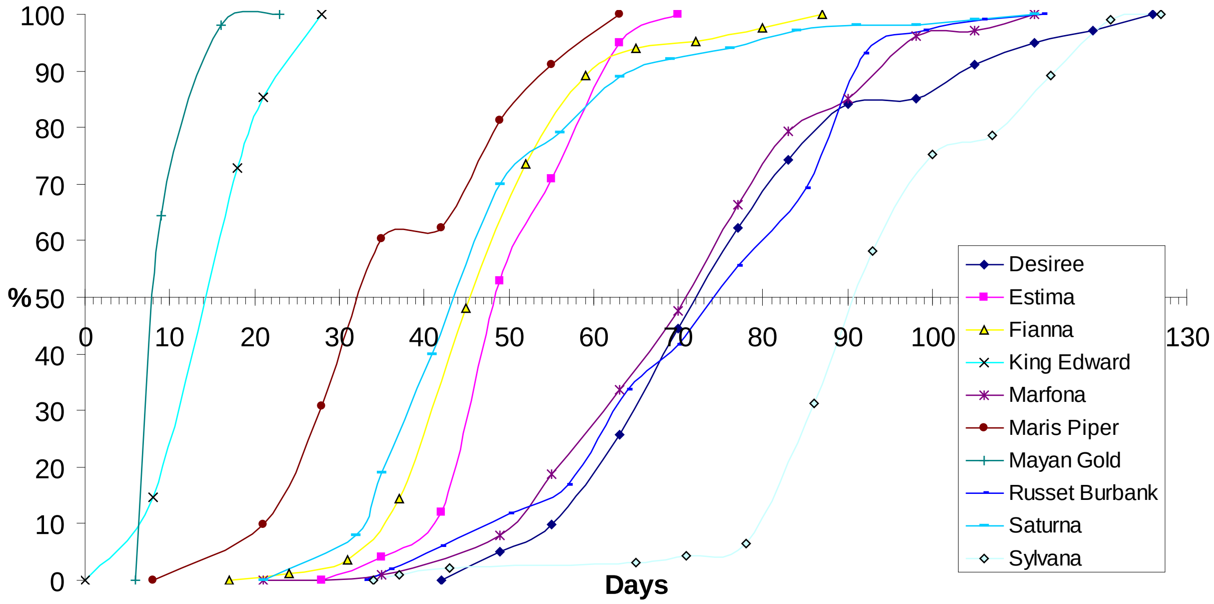


**Figure 1. Dormancy break at 15 °C for the potato varieties used in the study (tubers sprouting 3 mm or more).**

## Sprouting

Ethylene reduced sprouting in all varieties. Table 2 shows the actual mean longest spout length after 30 weeks of storage both with and without ethylene. Exceptional sprout inhibition was achieved in Russet Burbank and Sylvana, both relatively long dormant varieties. The least inhibition was achieved in the very short dormancy variety Mayan Gold. Although sprout inhibition appeared generally better in long dormant cultivars there were major exceptions; most notably Marfona, which was long dormant and weakly suppressed.

Generally, there was little difference in longest sprout length between treatments before the final assessment at week 30 because the earlier assessments were made before, at and shortly after dormancy break. The sprout inhibition due to ethylene then became very apparent, but there was little difference between *Untreated* and *Ethylene→untreated*. Similarly there was little difference between *Ethylene* and *Untreated→ethylene.* Histograms of means of sprouting for all cultivars, treatments and assessment occasions are shown in Appendix 8.1.2, Figures 7 - 36.

**Table 1. Rank comparison of relative dormancy period against transfer day.**

| Dormancy<br>Days at 15 °C for 50% of plants to show sprouts ≥ 3mm | Variety rank<br>(NIAB dormancy rating in brackets) | Variety rank | Eye Movement<br>Days at 6°C for 10% of plants to show eye movement = transfer day |
|---|---|---|---|
| 8 | Mayan Gold (4) | King Edward | Missed |
| 14 | King Edward (6) | Mayan Gold | 6 |
| 35 | Maris Piper (5) | Maris Piper | 14 |
| 43 | Saturna (-) | Saturna | 15 |
| 45 | Fianna (8) | Desiree | 51 |
| 48 | Estima (5) | Estima | 64 |
| 71 | Marfona (5) | Sylvana | 84 |
| 72 | Desiree (4) | Marfona | 92 |
| 74 | Russet Burbank (-) | Fianna | 97 |
| 91 | Sylvana (-) | Russet Burbank | 97 |

**Table 2. Effect of ethylene on mean longest sprout length, after 30 weeks of storage at 6ºC, and dormancy period.**

| Cultivar | Mean longest sprout length (mm) after 30 weeks of storage | | Dormancy (days until 10% incidence of eye movement) |
|---|---|---|---|
| | Ethylene | Untreated | |
| Sylvana | 0.8 | 18.2 | 84 |
| Russet Burbank | 1.0 | 13.5 | 97 |
| Estima | 2.6 | 16.3 | 64 |
| Fianna | 3.3 | 14.4 | 97 |
| Desiree | 3.9 | 24.3 | 51 |
| King Edward | 6.3 | 14.0 | Missed |
| Saturna | 6.7 | 13.3 | 15 |
| Maris Piper | 7.1 | 25.4 | 14 |
| Marfona | 11.1 | 21.4 | 92 |
| Mayan Gold | 23.8 | 30.8 | 6 |

The length of the longest sprout on a tuber is the most practical measure of sprouting but is relatively insensitive at low sprout incidences. Total sprout incidence is more sensitive. However, after dormancy break, 100% incidence is rapidly approached. The incidence data show that there was little sprouting at 28 days where this preceded dormancy break. At transfer, the longer dormant varieties, for example Marfona, Russet Burbank and Sylvana, had more than 20% lower incidence of sprouting in the two ethylene treatments.

The number of sprouting sites increases markedly between dormancy break (transfer) and 28 days later except for the short dormancy varieties such as Saturna and Mayan Gold. The difference between treatments gave patterns broadly similar to the longest sprout data where at ‘transfer + 28 days’, *Untreated* and *Ethylene→untreated* showed similar but more sprout sites than *Ethylene* and *Untreated→ethylene.* However, by 30 weeks the differences between treatments had become negligible except for the long dormant varieties Fianna, Russet Burbank and Sylvana.

**Sprout vigour**

The sprout growth of some of the short dormant cultivars (e.g. Mayan Gold and King Edward) subjectively appeared more vigorous than the longer dormant varieties (e.g. Russet Burbank) and also more vigorous close to break of dormancy. Sprout “vigour” was approximately estimated in two ways by subtracting the sprout length at transfer from length at either ‘transfer + 28 days’ or ‘30 weeks’ to give a rate of growth. The latter was plotted per 28 day month for comparison; see Appendix 8.1.3 for figures and description. As might be expected, the post-transfer untreated treatments were generally more vigorous than those in ethylene, where a difference had had time to develop. Appendix 8.1.3 Figure 37 showed that vigour in the first 28 days ranged up to approximately 3 mm of growth but that the rate of growth per 28 days up to 30 weeks ranged higher, up to 5 mm (Appendix 8.1.3, Figure 38).

## *4.2 Year 2 Results (2009/10)*

Originally this study was to include Mayan Gold as a short dormant cultivar. However, the growing conditions this season were unusually hot and dry which promoted sprouting in the field. All available Mayan Gold was found to be sprouting in the field beyond the 10% eye movement threshold and was subsequently dropped from the study. Crops of Estima and Marfona sourced in September 2009 had to be replaced due to unacceptable levels of sprouting. All crops had some level of sprouting at harvest and it was especially difficult to find Estima with a low level of sprouting. Any tubers found with long sprouts, and often associated root growth, were discarded before the trial started. The lack of sprouting in this trial may have resulted from the season's unusual field conditions or the necessity to select the least sprouting crops or both.

All Russet Burbank is grown under contract to *McCain Foods,* whose policy this season was for it to be sprayed in field with maleic hydrazide (MH), a sprout inhibiting treatment used to prevent volunteers growing in the following crop. This would confound a sprout inhibition study. The only MH untreated Russet Burbank available were crops destined for seed. The top size fraction of a crop, too big for sale as seed, was used in this study. The crop was grown in Scotland and not subject to the conditions that caused field sprouting. However, at 15 C, the crop broke dormancy much more rapidly than expected and this might be due to the agronomy techniques used to ensure vigorous seed growth. Nevertheless, the early break of dormancy was less pronounced at 6 C, with 10% eye movement occurring at 75 days (97 last season).

**Ethylene concentration and control in store**

Ethylene levels were only recorded in the treated room and are shown in Appendix 8.2.1 Figure 39. Data were not automatically recorded for a total of 17 out of 198 experimental days (Appendix 8.2.1, Table 11), but were manually recorded every day (results not shown). The control of ethylene in the ethylene treated store was relatively stable apart from an interruption to the gas supply on 10th May 2010. Independent verification of the untreated room found no ethylene with one exception on 15th May 2010 at 0.647 ppm. The ethylene treated room usually had levels close to the target of 10 ppm except on 23rd November 2009 when the level was almost double (Appendix 8.2.1, Table 12).

## Dormancy

None of the dormancy sub-samples was sprouting at intake. The relative dormancy on arrival at SBCSR (50% 3mm sprout growth at 15°C) is shown in Figure 2. It is noteworthy that the rate of break of dormancy of the varieties was similar for all varieties except Estima, which was distinctly more prolonged. Also, the normally long dormant Russet Burbank was unusually quick to break dormancy at 26 days compared with 74 days last season. The rank did not agree with that of transfer date (10% eye movement at 6°C), see Table 3.

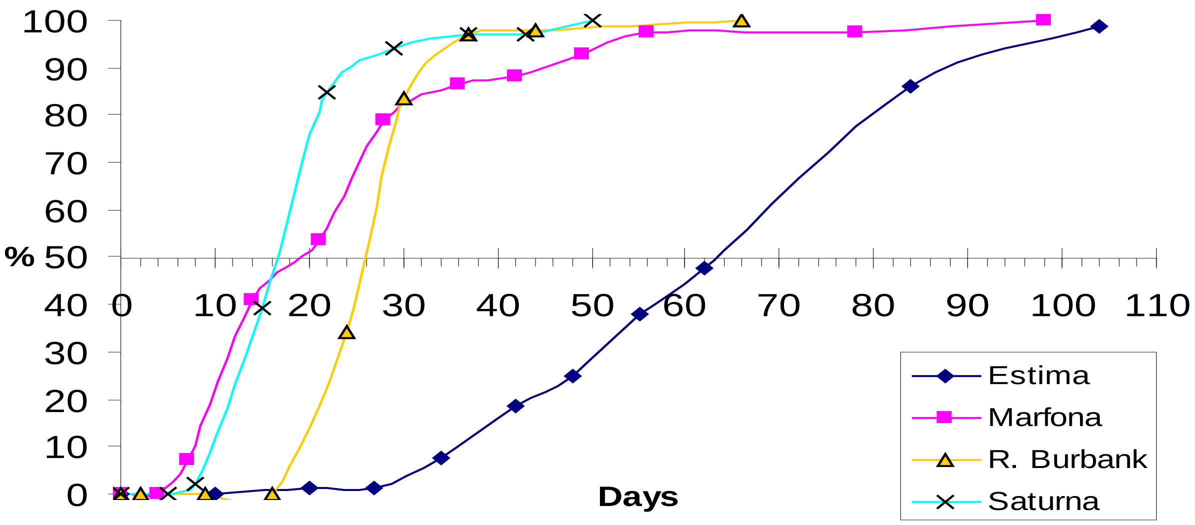


**Figure 2. Dormancy break at 15 C (tubers sprouting 3 mm or more).**

## Sprouting

Unfortunately, the overall level of sprouting in this experiment was very low compared with the previous season. In fact, a direct comparison of sprout length after storage between continuous ethylene and the untreated crops revealed either very small or no differences and in the case of Marfona (known to be less responsive to ethylene) sprout length was greater in ethylene (Table 4). Histograms of means of sprouting for all cultivars, treatments and assessment occasions are shown in Appendix 8.2.2. Figures 42-53.

**Table 3. Rank comparison of relative dormancy period against transfer day**

| Dormancy<br>Days at 15 C for 50% of plants to show sprouts ≥ 3mm | Variety rank<br>(NIAB dormancy rating in brackets) | Variety rank | Eye movement<br>Days at 6 C for 10% of plants to show eye movement = transfer day |
|---|---|---|---|
| 16 | Saturna (-) | Saturna | 18 |
| 19 | Marfona (5) | Marfona | 18 |
| 26 | Russet Burbank (-) | Estima | 36 |
| 63 | Estima (5) | Russet Burbank | 75 |

**Table 4. Effect of ethylene on mean longest sprout length, after 30 weeks of storage at 6 ºC, and dormancy period**

| Cultivar | Mean longest sprout length (mm) after 30 weeks of storage | | Dormancy (days until 10% incidence of eye movement) |
|---|---|---|---|
| | Ethylene | Untreated | |
| Russet Burbank | 1.2 | 1.3 | 75 |
| Estima | 1.2 | 1.7 | 36 |
| Saturna | 3.5 | 4.0 | 18 |
| Marfona | 4.8 | 3.9 | 18 |

The length of the longest sprout on a tuber is the most practical measure of sprouting, but is relatively insensitive at low sprout incidences. Total sprout incidence is more sensitive. However, after dormancy break, 100% incidence is approached rapidly. The incidence data show that, at transfer, ethylene only inhibited sprouting in Estima (students t test $P<0.05$) and Russet Burbank ($P<0.05$).

The number of sprouting sites did not significantly differ due to ethylene treatment.

## *4.3 Year 3 Results (2010/11)*

### Ethylene concentration and control in store

Ethylene levels were automatically recorded in the treated room only (Appendix 8.3.1 Figure 54) and also manually recorded every day (results not shown). Data were not available for a total of 5 out of 234 experimental days (Appendix 8.3.1 Table 14). The control of ethylene in the ethylene treated store was stable apart from a slight upward sensor drift in November which requiring sensor replacement, and several incidences of freezing hardware in abnormally cold weather. Store atmosphere samples collected by CU on 7th January 2011 were analysed by gas chromatography to independently verify ethylene concentrations in the treatment stores. No ethylene was found in the untreated store and 9.433 ppm in the treated.

### Dormancy

No tubers were sprouting at intake. The relative dormancy, estimated as days for 50% of tubers to achieve 3mm sprout growth at 15°C, is shown in Figure 3. Saturna was least dormant with 50% of tubers sprouting at 19 days. The other cultivars were all similar to each other, long dormant, with Russet Burbank demonstrating the longest dormant. The rank broadly agreed with that of transfer date (10% eye movement at 6°C), see Table 5.

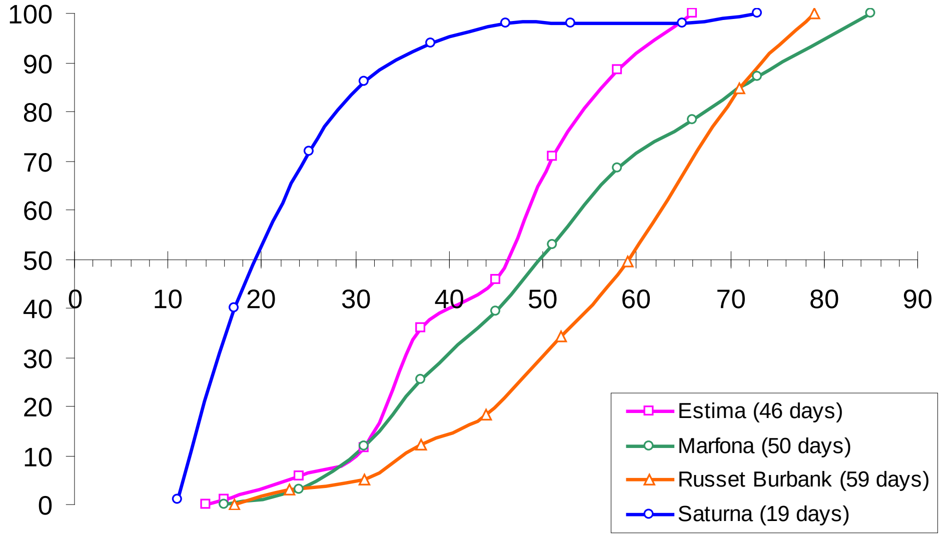


**Figure 3. Dormancy break at 15 C (tubers sprouting 3 mm or more).**

**Sprouting**

The trends in the sprouting data were very consistent between cultivars. For the mean length of longest sprout there was no significant difference due to ethylene treatment at time of transfer. At full term the *Untreated* and *Ethylene→untreated* crops were not significantly different from each other in sprouting incidence or sprout length and similarly both *Untreated→ethylene* and *Ethylene* were not significantly different from each other. However, the latter treatments always demonstrated significantly reduced sprout length (P>0.05) compared with the former. In Table 6 cultivars are ranked in order of greatest suppression in sprout length due to ethylene after full term storage. It is notable that although Estima demonstrated the greatest difference between treatments, it nevertheless had the longest mean sprout length in ethylene of all the cultivars. Histograms of means of sprouting for all cultivars, treatments and assessment occasions are shown in Appendix 8.3.2., Figures 57-68.

**Table 5. Rank comparison of relative dormancy period against transfer day**

| **Dormancy**<br>Days at 15 C for 50% of plants to show sprouts ≥ 3mm | **Variety rank**<br>(NIAB dormancy rating in brackets) | | **Variety rank** | **Eye movement**<br>Days at 6 C for 10% of plants to show eye movement = transfer day |
|---|---|---|---|---|
| 19 | Saturna (-) | ●——● | Saturna | 60 |
| 46 | Estima (5) | ●——● | Estima | 72 |
| 50 | Marfona (5) | ●——● | Marfona | 83 |
| 59 | Russet Burbank (-) | ●——● | Russet Burbank | 83 |

**Table 6. Effect of ethylene on mean longest sprout length, after 30 weeks of storage at 6 ºC, and dormancy period**

| Cultivar | Mean longest sprout length (mm) after 30 weeks of storage | | Dormancy (days until 10% incidence of eye movement) |
|---|---|---|---|
| | Ethylene | Untreated | |
| Russet Burbank | 1.4 | 29.0 | 83 |
| Saturna | 5. 0 | 25.2 | 60 |
| Estima | 1.7 | 14.3 | 72 |
| Marfona | 2.6 | 12.0 | 83 |

The length of the longest sprout on a tuber is the most practical measure of sprouting, but is relatively insensitive at low sprout incidences. Total sprout incidence is more sensitive but, after dormancy break, 100% incidence is approached rapidly. The data show that, at transfer, ethylene inhibited sprouting incidence and there were significant differences in sprout length of Estima, Marfona and Saturna ($P<0.05$). The number of sprouting sites did not significantly differ due to ethylene treatment.

# 5. General discussion

**Ethylene control in store**

Prange *et al*. (2005) suggested that continuous exposure to ethylene over 23-33 weeks at 4 µL $L^{-1}$ (4 ppm) was an effective method of sprout control in potatoes. Subsequently a rate of 10 ppm ethylene has become established as the industry standard, with refinements such as gradual introduction (ramping) of gas to avoid potential problems related to the increase in respiration induced by ethylene. In these trials, the target ethylene concentration in store was 10 ppm (unramped) and this concentration was achieved for essentially all of the storage period (See Appendices Figures 4, 39 and 54; daily manual recording data, not shown). Ethylene was occasionally detected in the untreated store with potential sources being exhaust products from propane-powered forklift use, potato production (<0.1 µL $kg^{-1}$ $h^{-1}$ at 20ºC; Knee *et al*., 1985) or positive feedback after transfer to the untreated store, despite a period of 'degassing' (Saltveit, 1999). Overall, the control of 10 ppm ethylene within the store was acceptable and the ethylene concentration in the untreated store was always either nil or significantly less than that required to exert an effect according to Prange *et al*. (2005).

**Effects of ethylene**

There is enough evidence in this study to make some broad generalisations. At transfer there was usually a greater incidence of sprouting in the *Untreated* than *Ethylene*. Furthermore, where there is enough sprouting to demonstrate a difference at full term storage, *untreated* and *ethylene→untreated* potatoes tended to show no significant difference and had longer sprouts than the *untreated→ethylene* and *ethylene* regimes*.* The latter treatments also tended to show no significant difference. This pattern was seen in Desiree, Estima, Fianna, Marfona, Maris Piper, Russet Burbank, Saturna and Sylvana. No other trends were evident except that the number of sprouting sites was little affected by any treatment.

**Dormancy**

A comparison of relative dormancies is shown by cultivar for the four varieties common to all seasons in the study Appendix 8.4 Figures 69-72. Season to season, there was a wide variation in the time taken for 50% of tubers to show 3mm sprouts. Generally, the 2008/09 season had the longest dormancy periods and 2009/10 the shortest, but one crop that appeared different was Estima in 2009/10. Its dormancy period was much longer than expected and the rate of dormancy break slower than in other seasons. The reason for this difference is unknown. Conversely, Russet Burbank broke dormancy in 2009/10 at a faster rate than in the other seasons of the trial, although a possible reason is that it was grown as a seed crop in Scotland. This dormancy information should be considered in conjunction with the biochemical data generated by CU.

**Dormancy break**

Rylski *et al* (1974) suggested that ethylene reduces the true dormant period compared with control tubers stored in air so ethylene breaks dormancy, but suppresses sprout elongation, a conclusion supported by others, for example Pruski *et al*. (2006). There was little or no evidence to support this conclusion in this study. Dormancy break is measured in terms of sprouting and it might be expected that an increase in eye activity would be observed in the presence of ethylene. However, there was only one observed incidence of increased sprouting by ethylene treatment at the time of transfer, all other cases ethylene appeared to reduce the sprouting incidence. This is possibly because the break of dormancy happens at or near to the onset of treatment and continuous ethylene may rapidly suppress sprout elongation.

In 2008/09 Maris Piper at transfer had a greater incidence of sprouting under ethylene, but this coincided with a particularly short time to achieve 10% sprouting (14 days). Thus a dormancy breaking effect may have overcome a sprout suppressing affect. However, there does not appear to be any lasting effect in the longer term as *Ethylene→untreated* did not sprout more than *Untreated.*

**Timing of ethylene application**

The two commercial suppliers of ethylene treatment in UK potato stores recommend different ethylene initiation timings with *BioFresh* recommending that ethylene is enabled early in storage (before dormancy break) and *Restrain* recommending that it should be enabled at dormancy break. Even though differences in sprouting can be detected before transfer, the insignificant difference in sprout length between *Ethylene* and *Untreated→ethylene*, at full term storage, would suggest that beginning ethylene treatment at dormancy break (as measured by 10% eye movement) is no less effective than treating with ethylene throughout the storage period. In the case of Russet Burbank this has amounted to more than three months expensive treatment for no beneficial effect.

## 6. Summary conclusions

- **Ethylene is an effective agent for sprout control, having an effect on all varieties tested in this trial.**
- **It is particularly effective for some varieties but these results confirm that there is significant variation in response of different potato varieties to ethylene.**
- **The results support the previous finding that application of ethylene suppresses sprout elongation.**
- **The results do not provide evidence to support the previous finding that exogenous ethylene encourages dormancy break.**
- **The application of ethylene is as effective at the break of dormancy as application at the start of storage, but crops must be monitored closely to identify dormancy break.**

**Future work for consideration:**

- Investigate timing of ethylene application.
- Test ethylene effect on dormancy break for this selection of potato varieties.
- Establish how the removal of all ethylene affects tubers, e.g. use of an ethylene scrubber to influence dormancy break.
- Determine whether varietal responses to ethylene can be broadly associated with shared characteristics (e.g. dormancy, determinacy, vigour etc.)
- Does ethylene break dormancy in all varieties?

# 7. References

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Saltveit, M.E., 1999. Effect of ethylene on quality of fresh fruits and vegetables. Postharvest Biology and Technology **15**: 279-292.

# 8. Appendices

## *8.1.1 Year 1 Data 2008/2009*

### Table 7. Dormancy ratings for the potato varieties used in the trial

| Cultivar | Dormancy- The European Cultivated Potato Database |
|---|---|
| Desiree | Medium [**1**]<br>Medium to long [**2**, **3**, **5**] |
| Estima | Medium to long [**1**]<br>Long [**2**, **5**] |
| Fianna | - |
| King Edward | Medium [**2**]<br>Medium to long [**1**] |
| Marfona | Medium to long [**1**]<br>Long [**2**, **5**] |
| Maris Piper | Medium [**1**]<br>Medium to long [**2**] |
| Mayan Gold | - |
| Russet Burbank | Long to very long [**4**] |
| Saturna | Medium [**1**]<br>Long to very long [**2**, **5**] |
| Sylvana | - |
| Source | **1**. Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Germany<br>**2**. SASA, UK<br>**3**. Pannon University , Hungary<br>**4.** HZPC B.V., Nederlands<br>**5**. Nederlands Potato Consultative Foundation, Netherlands |

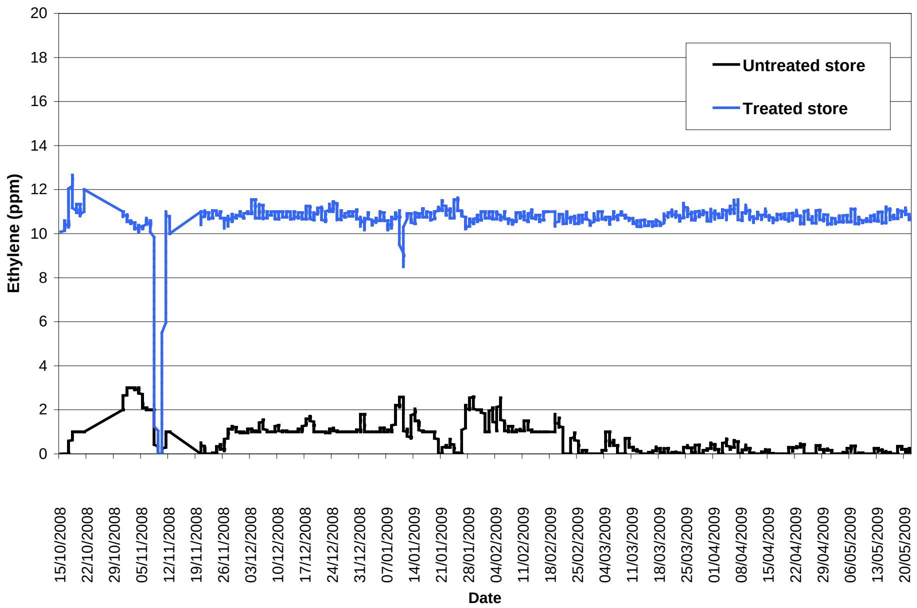



**Figure 4. Rolling 24 hour average of hourly ethylene reading**

**Table 8. Time periods for when automatically recorded data was unavailable**

| Ethylene logger data missing from | to | Number of days data not recorded |
|---|---|---|
| 20/10/2008 | 31/10/2008 | 11 |
| 11/11/2008 | 20/11/2008 | 9 |
| 16/02/2009 | 19/02/2009 | 3 |

**Table 9. Independent measurement of ethylene in treatment stores**

| Sampling date | Untreated store, Ethylene (ppm) | Ethylene treated store, Ethylene (ppm) |
|---|---|---|
| 9th October 2008 | 0* | - |
| 21st October 2008 | 0* | 10* |
| 28th October 2008 | 0.11 | 13 |
| 7th November 2008 | 0 | 13 |
| 12th November 2008 | 0 | 10.6 |
| 18th December 2008 | 0.2 | - |
| 2nd January 2009 | 0.13 | - |
| 15th January 2009 | 0.12 | 10.8 |
| 28th January 2009 | 0.14 | 8.9 |
| 10th February 2009 | 0.097 | 11.13 |
| 24th February 2009 | 0 | 8.77 |

All measurements provided by Cranfield University using gas chromatography except * where a GasTec 172L ethylene detector tube was used (detection limit 0.05 ppm).

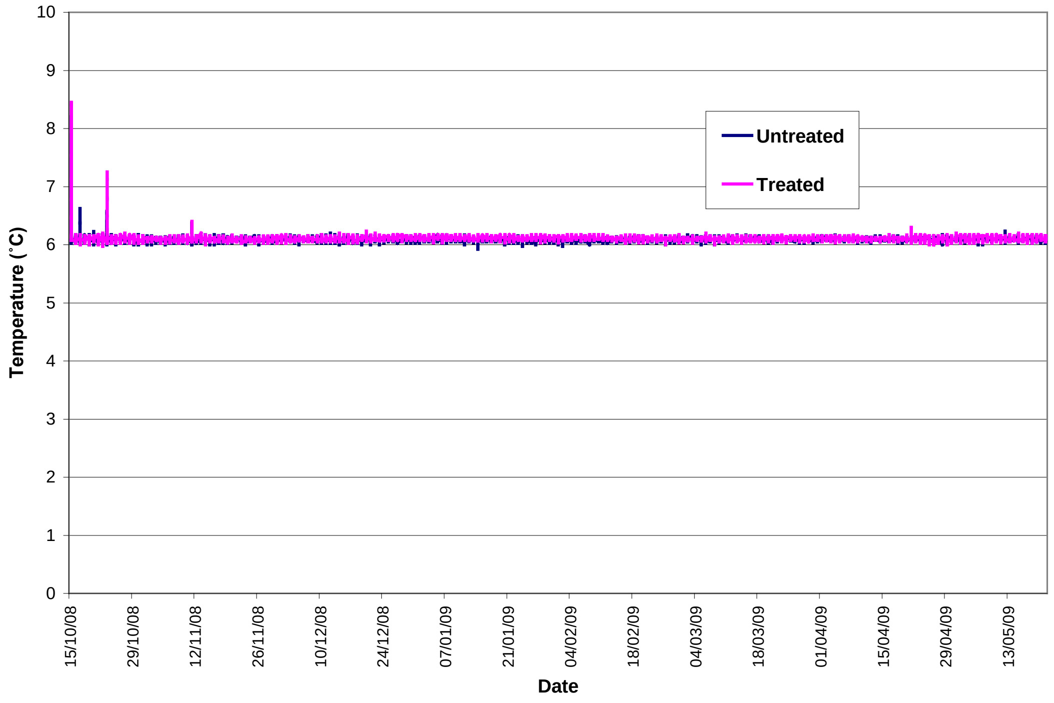



**Figure 5. Store temperature for the trial period.**

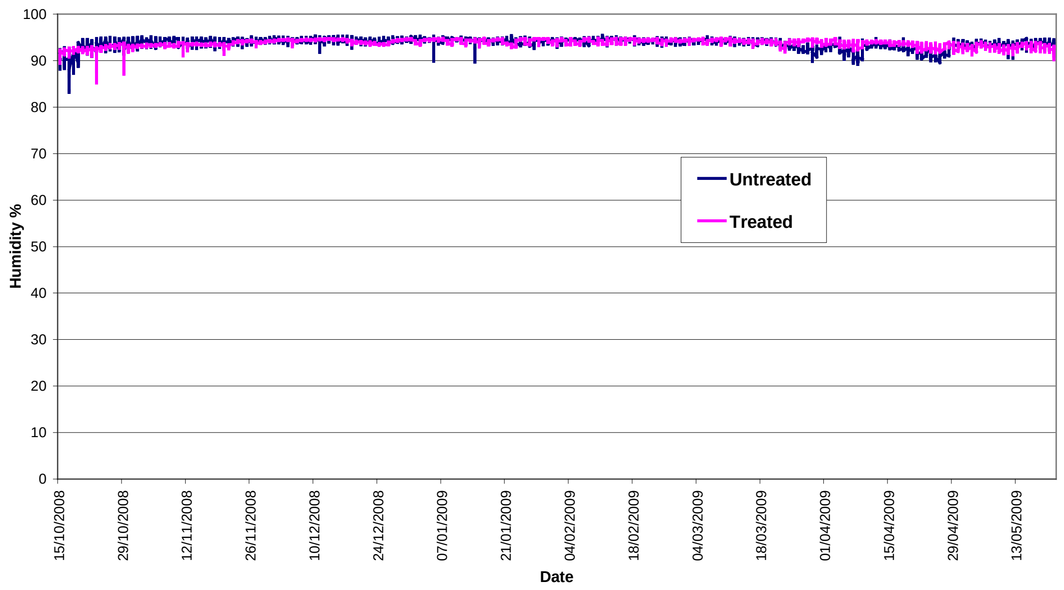



**Figure 6. Store relative humidity for the trial period.**

**Table 10. Sampling dates and occasions for sprouting assessments**

| Variety | 28 days in ethylene | Transfer | 28 days after Transfer | 30 weeks |
|---|---|---|---|---|
| Desiree | 12/11/2008 | 05/12/2008 | 02/01/2009 | 13/05/2009 |
| Estima | 12/11/2008 | 18/12/2008 | 15/01/2009 | 13/05/2009 |
| Fianna | 20/11/2008 | 28/01/2009 | 25/02/2009 | 21/05/2009 |
| King Edward | 12/11/2008 | Missed | Missed | 13/05/2009 |
| Marfona | 12/11/2008 | 15/01/2009 | 12/02/2009 | 13/05/2009 |
| Maris Piper | 12/11/2008 | 29/10/2008 | 26/11/2008 | 13/05/2009 |
| Mayan Gold | 20/11/2008 | 29/10/2008 | 26/11/2008 | 21/05/2009 |
| Russet Burbank | 20/11/2008 | 28/01/2009 | 25/02/2009 | 21/05/2009 |
| Saturna | 20/11/2008 | 07/11/2008 | 05/12/2008 | 21/05/2009 |
| Sylvana | 20/11/2008 | 15/01/2009 | 12/02/2009 | 21/05/2009 |

### 8.1.2 Sprouting 2008/09 by cultivar

Error bars showing +/- 1 sd.

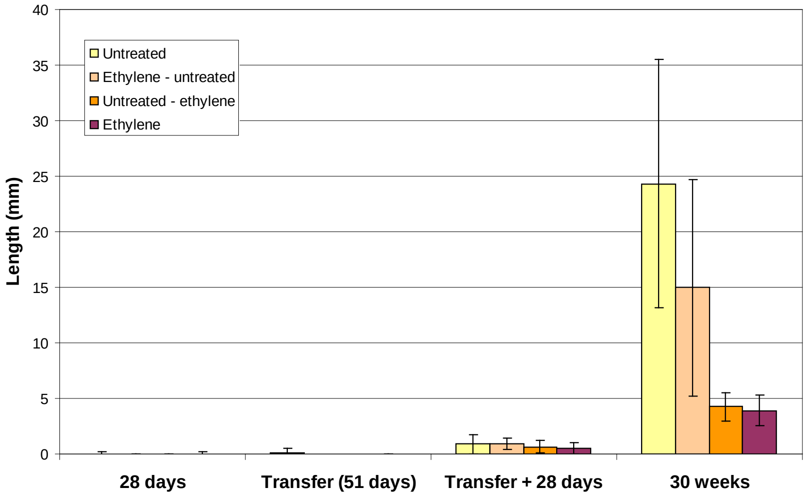



**Figure 7. Desiree mean longest sprout**

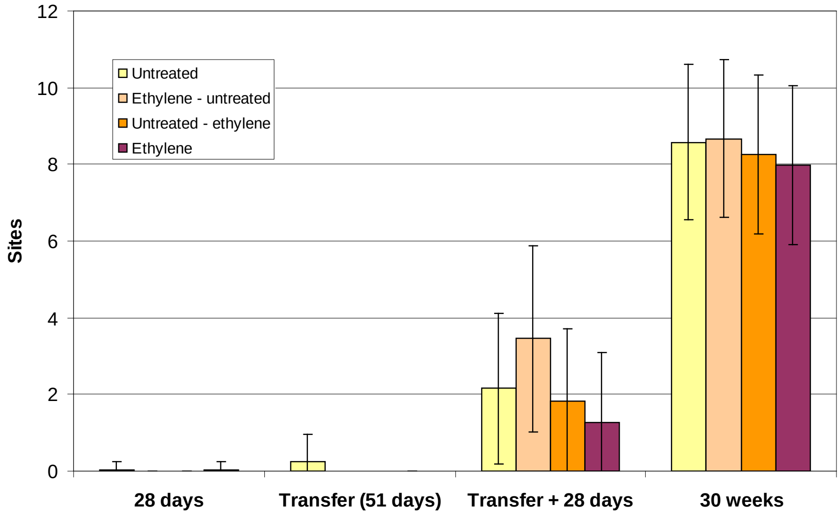
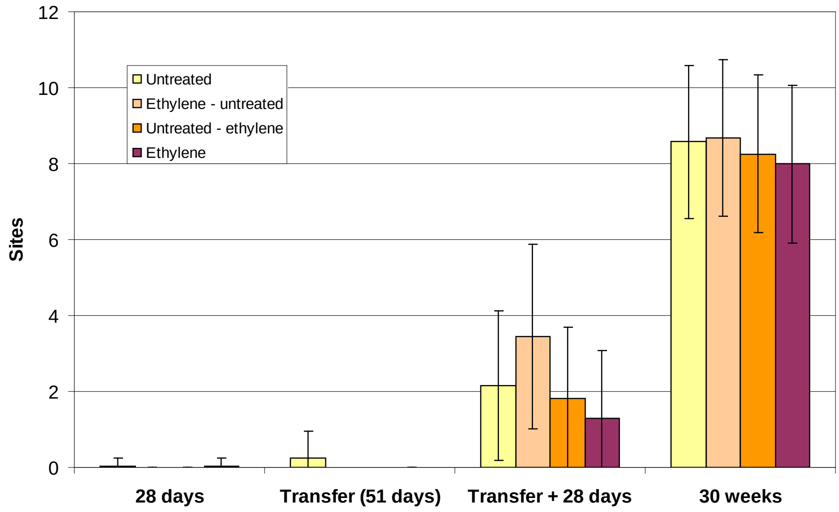
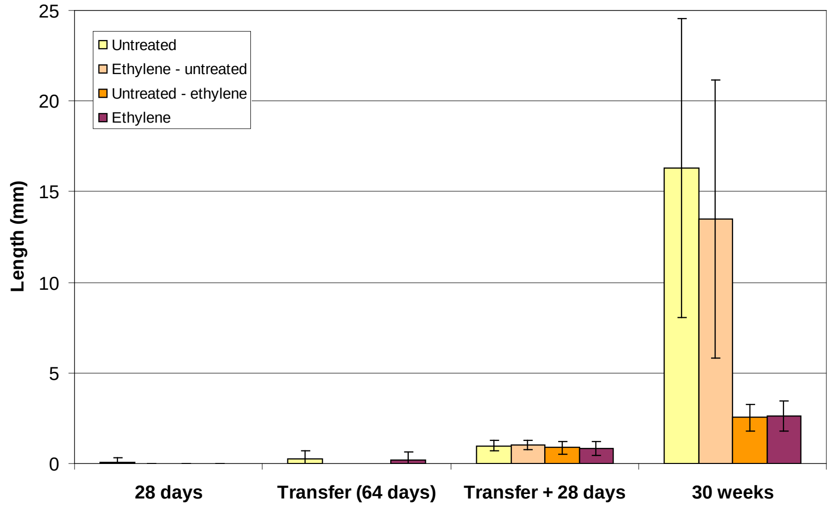


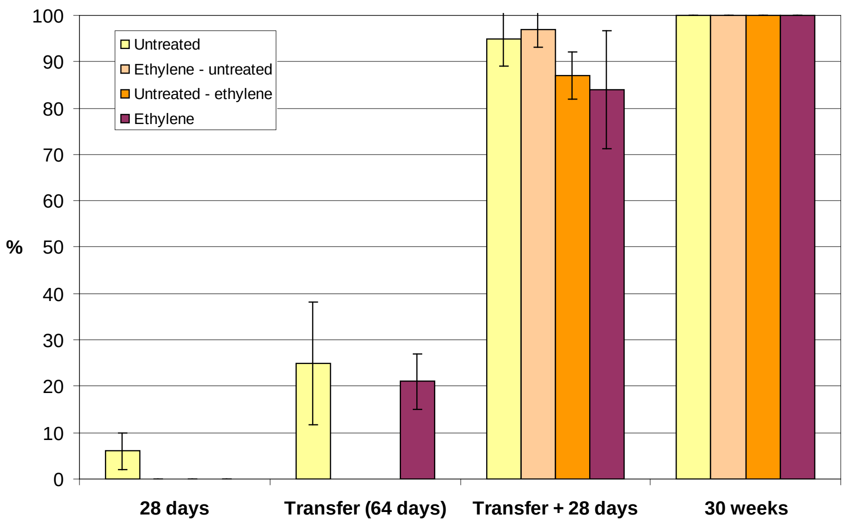

**Figure 8. Desiree incidence of sprouting**




## Figure 9. Desiree mean sprouting sites




## Figure 10. Estima mean longest sprout




## Figure 11. Estima incidence of sprouting

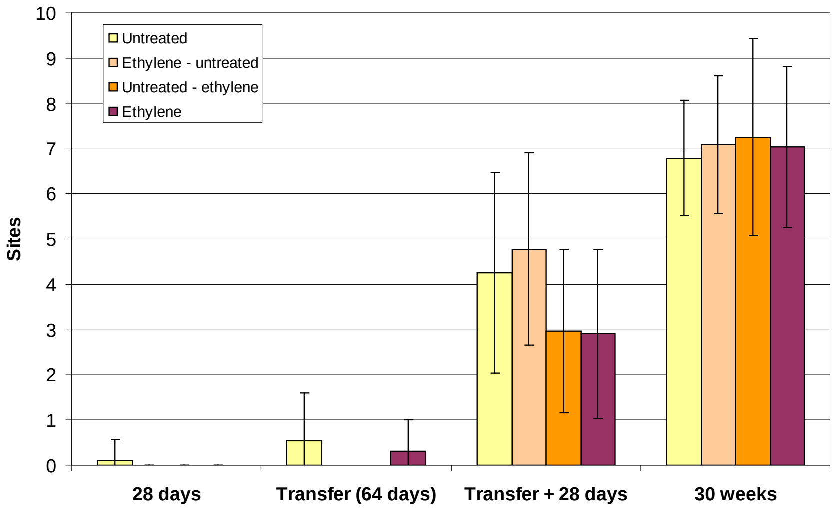



**Figure 12. Estima mean sprouting sites**

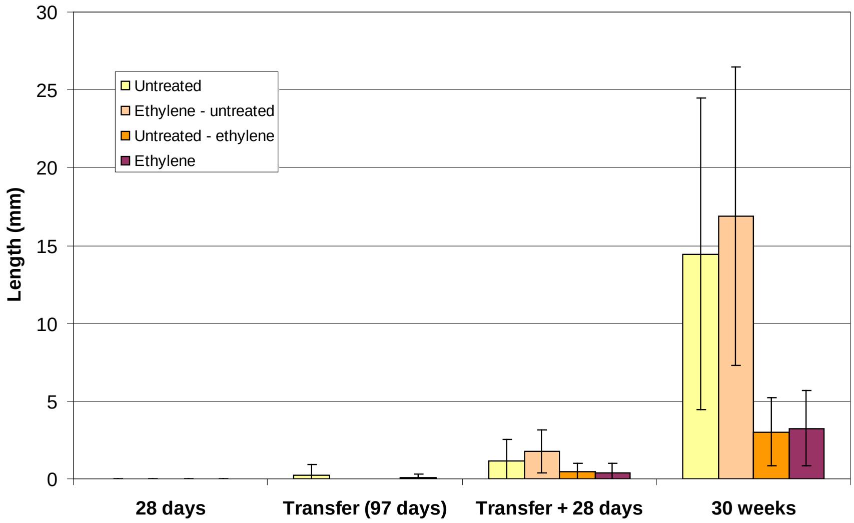



**Figure 13. Fianna mean longest sprout**

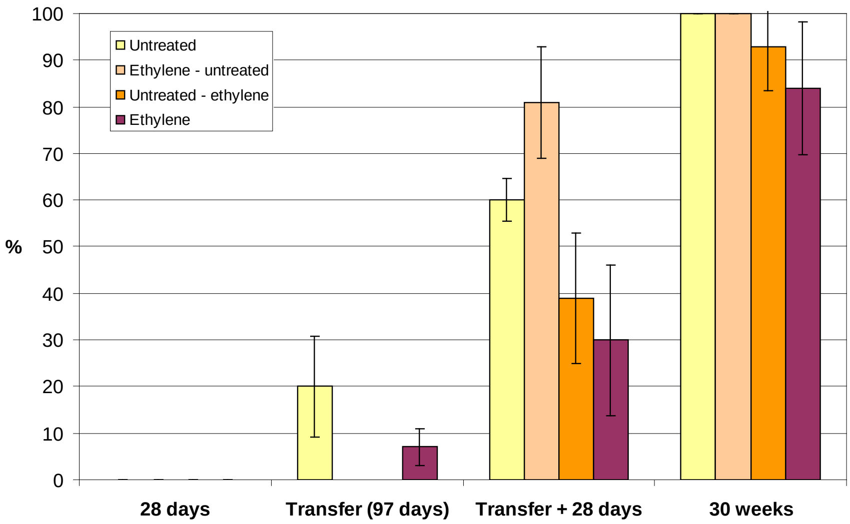



**Figure 14. Fianna incidence of sprouting**

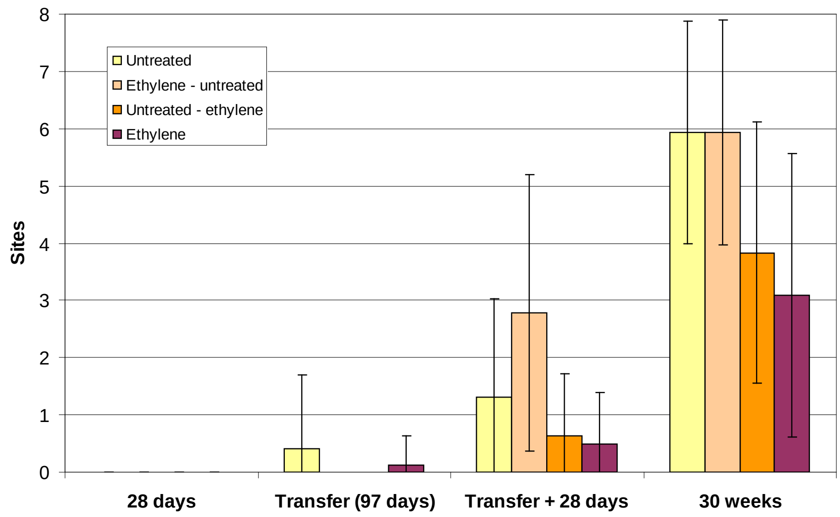



**Figure 15. Fianna mean sprouting sites**

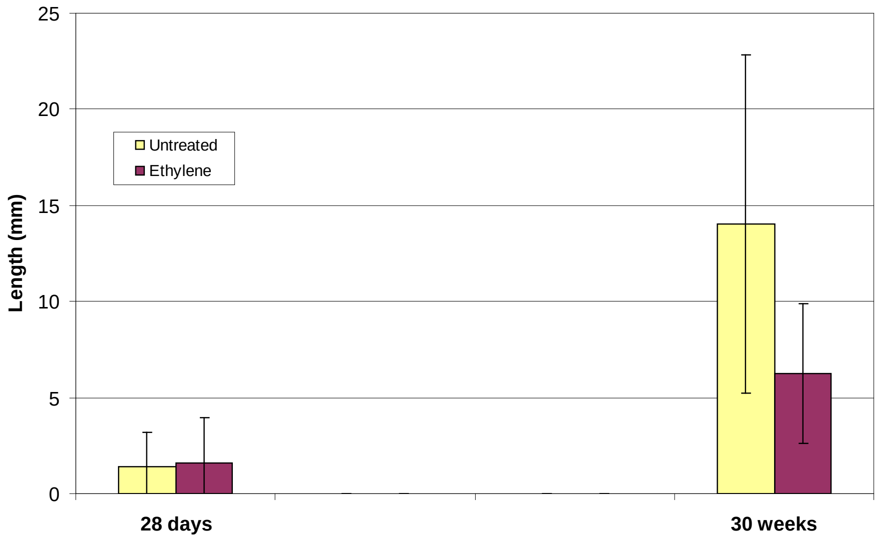



**Figure 16. King Edward mean longest sprout**

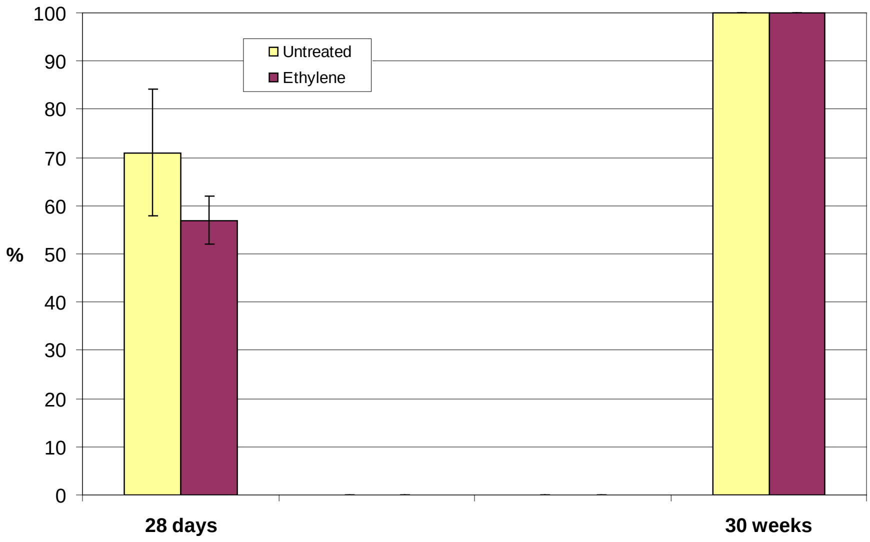



**Figure 17. King Edward incidence of sprouting**

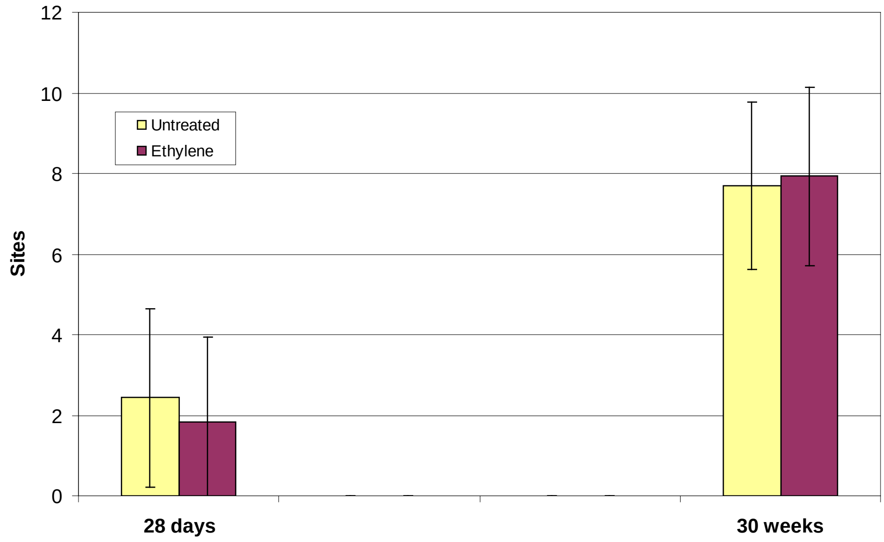



**Figure 18. King Edward mean sprouting sites**

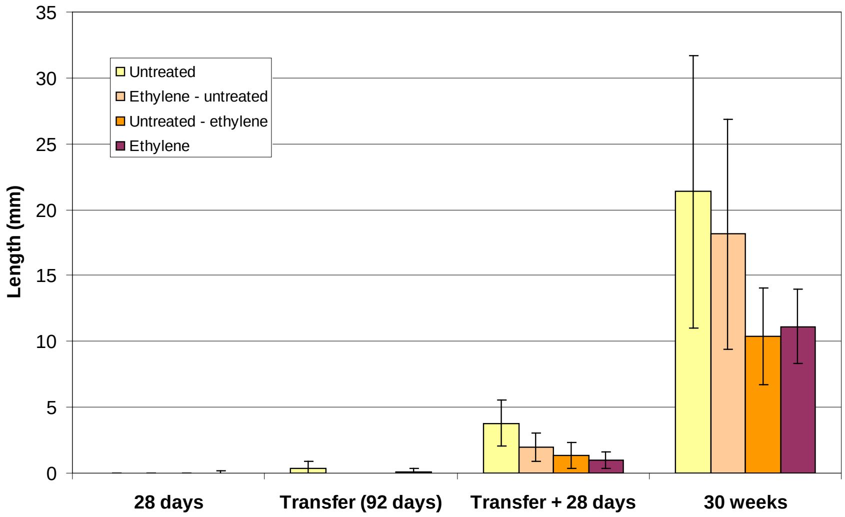



**Figure 19. Marfona mean longest sprout**

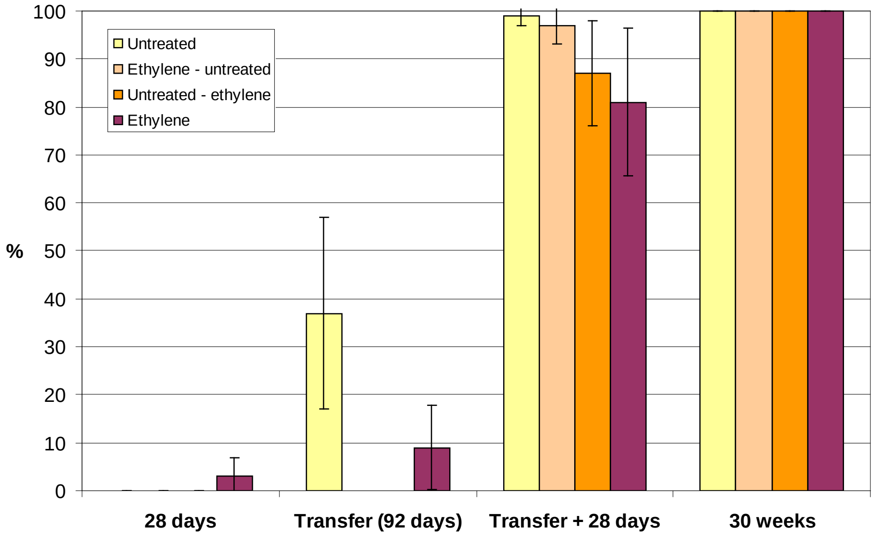



**Figure 20. Marfona incidence of sprouting**

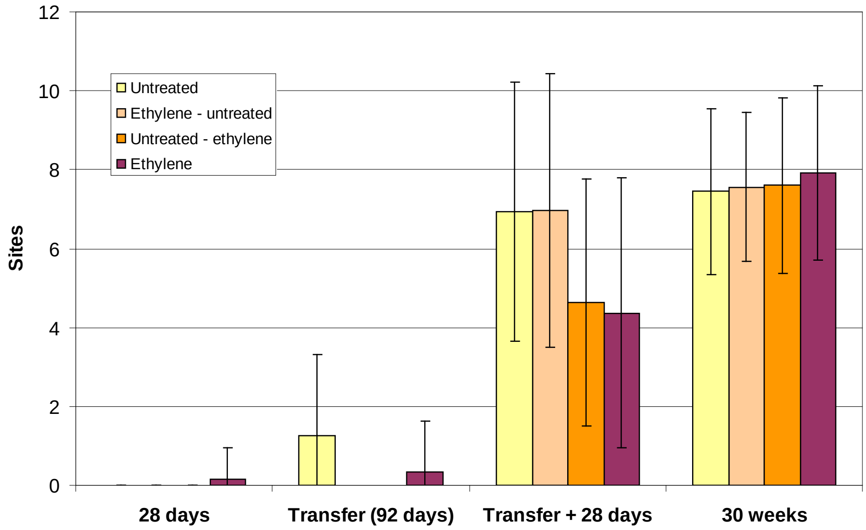
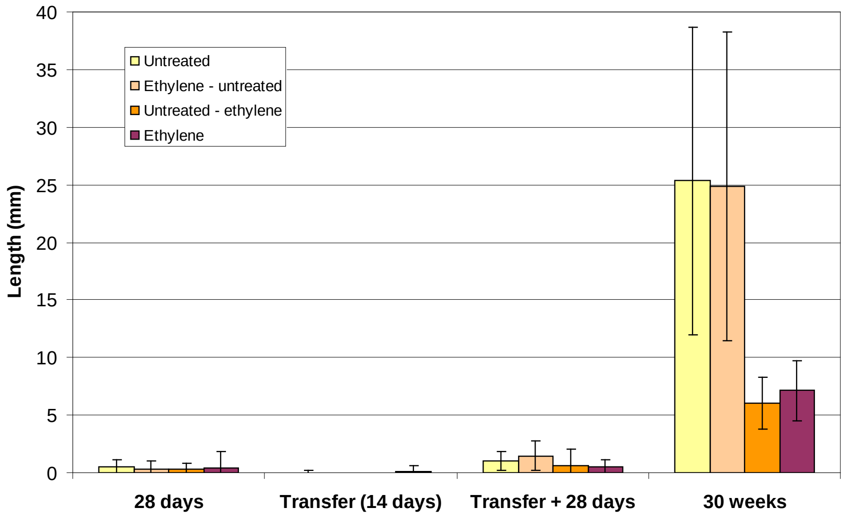
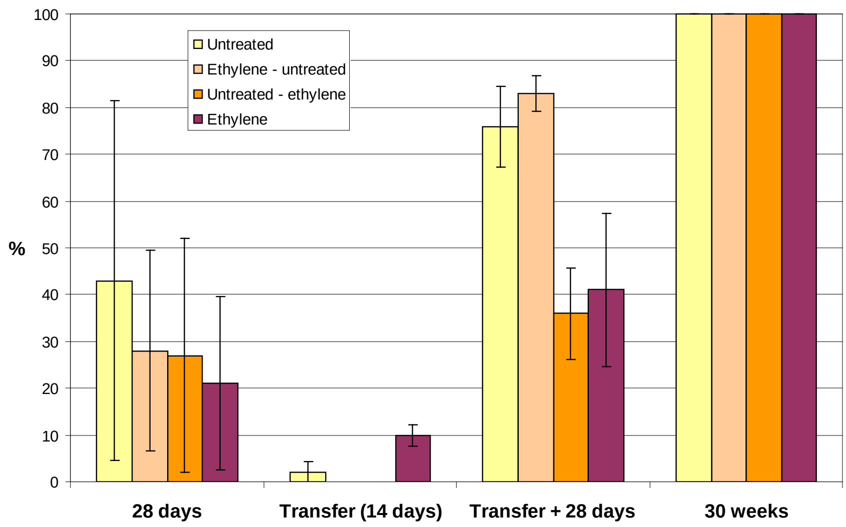


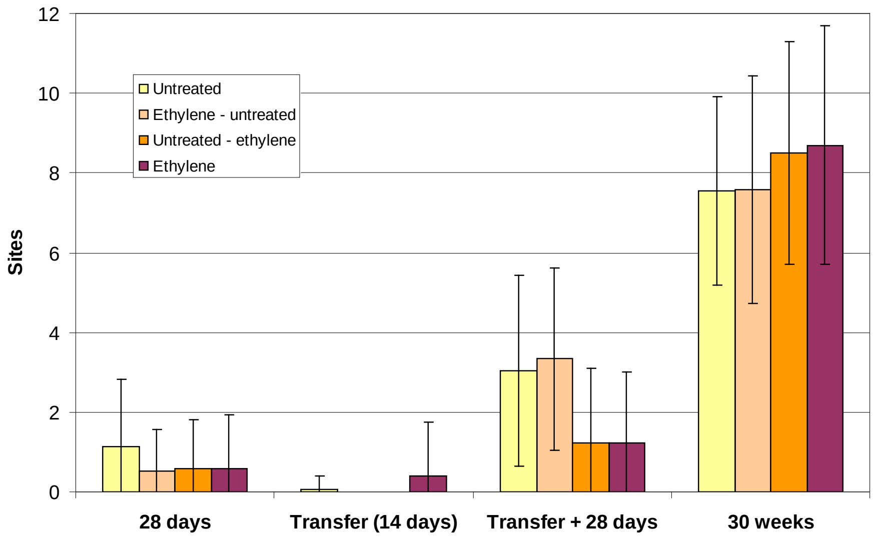

**Figure 21. Marfona mean sprouting sites**




## Figure 22. Maris Piper mean longest sprout




## Figure 23. Maris Piper incidence of sprouting




## Figure 24. Maris Piper mean sprouting sites

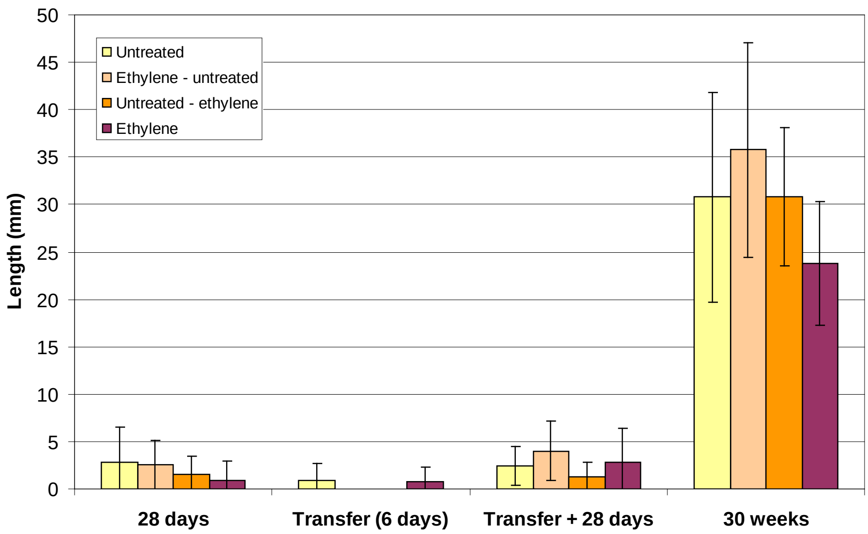



**Figure 25. Mayan Gold mean longest sprout**

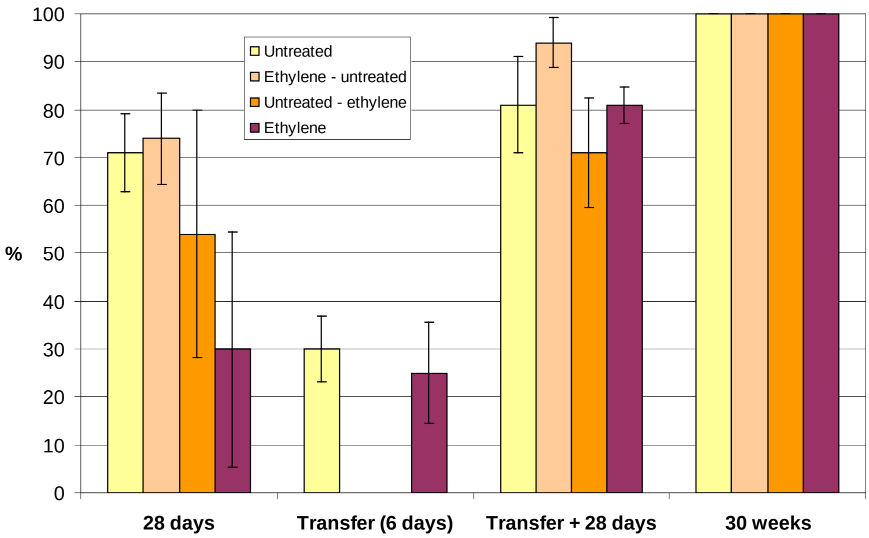
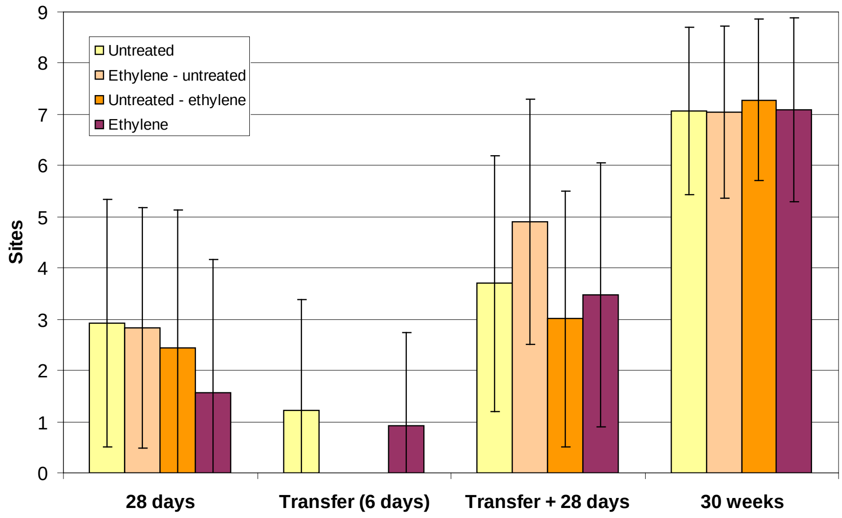
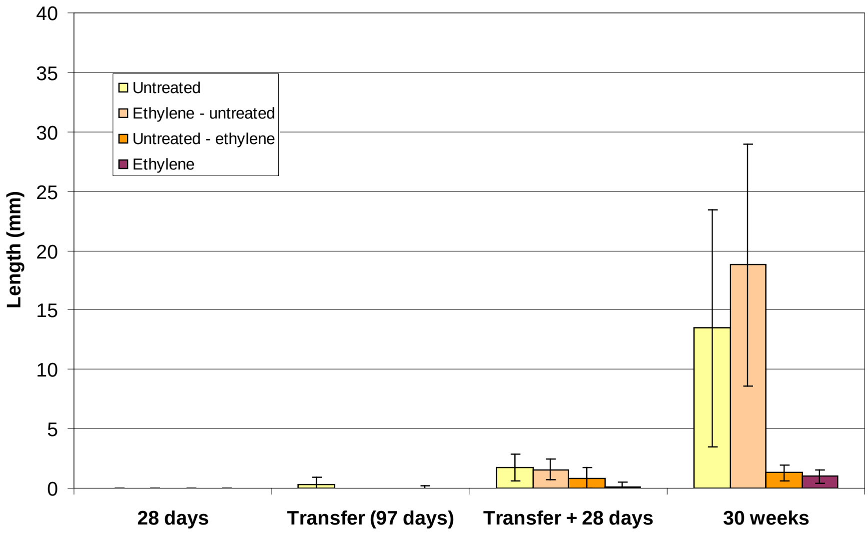



**Figure 26. Mayan Gold incidence of sprouting**




## Figure 27. Mayan Gold mean sprouting sites




## Figure 28. Russet Burbank mean longest sprout

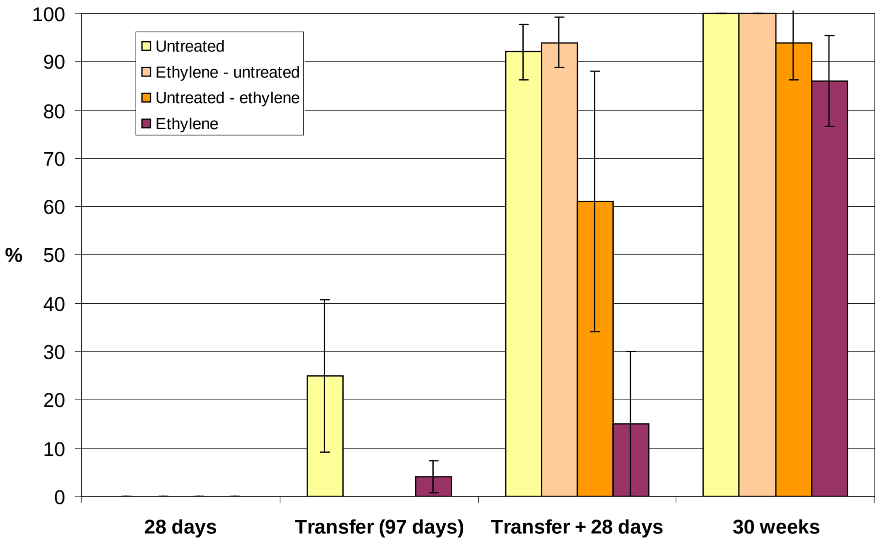


**Figure 29. Russet Burbank incidence of sprouting**

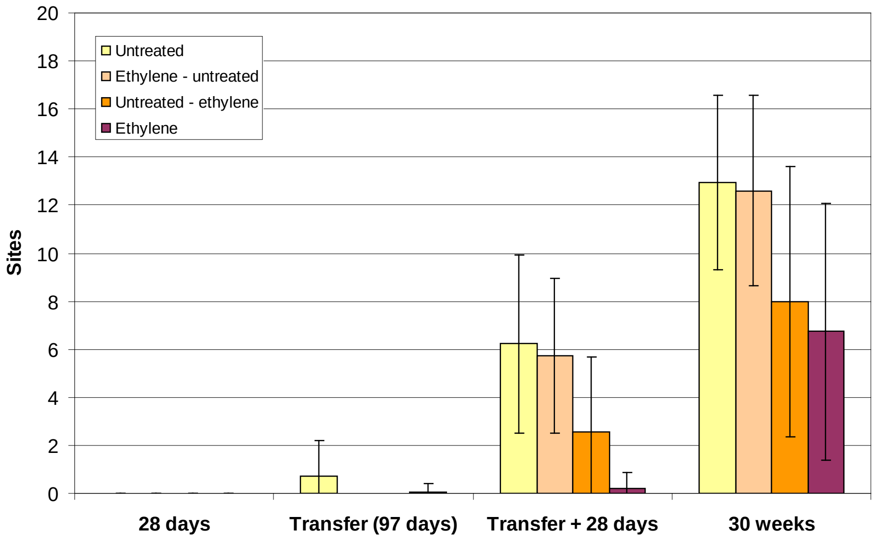



**Figure 30. Russet Burbank mean sprouting sites**

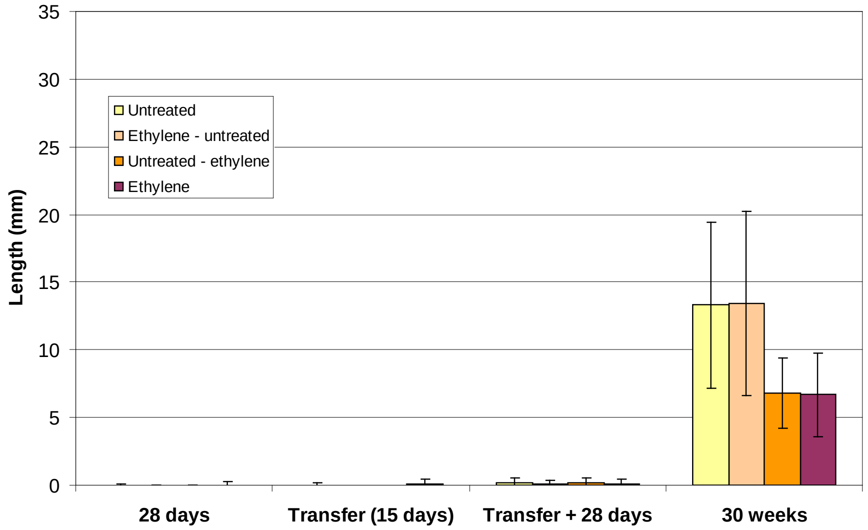



**Figure 31. Saturna mean longest sprout**

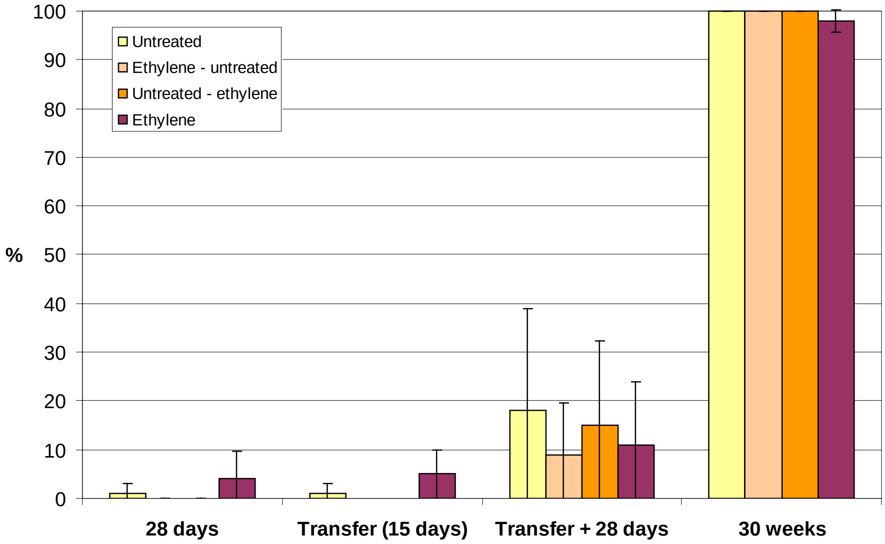



**Figure 32. Saturna incidence of sprouting**

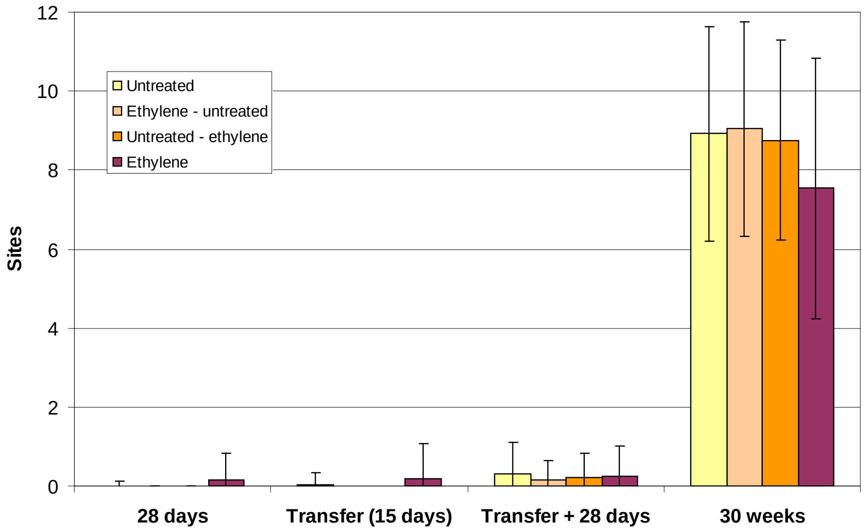



**Figure 33. Saturna mean sprouting sites**

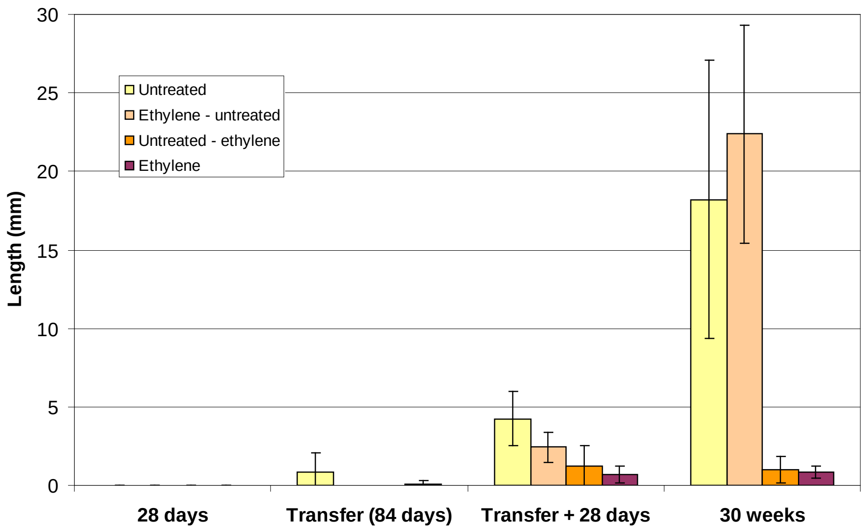


Figure 34. Sylvana mean longest sprout

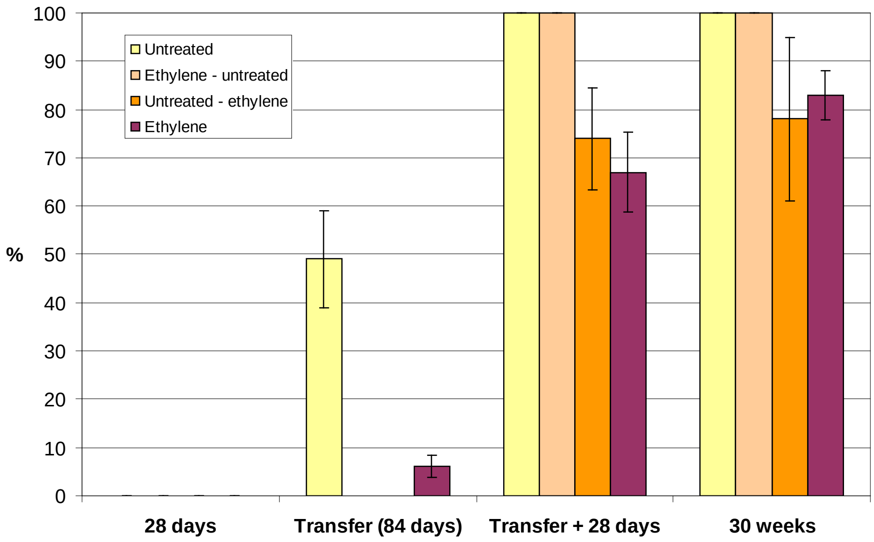



Figure 35. Sylvana incidence of sprouting

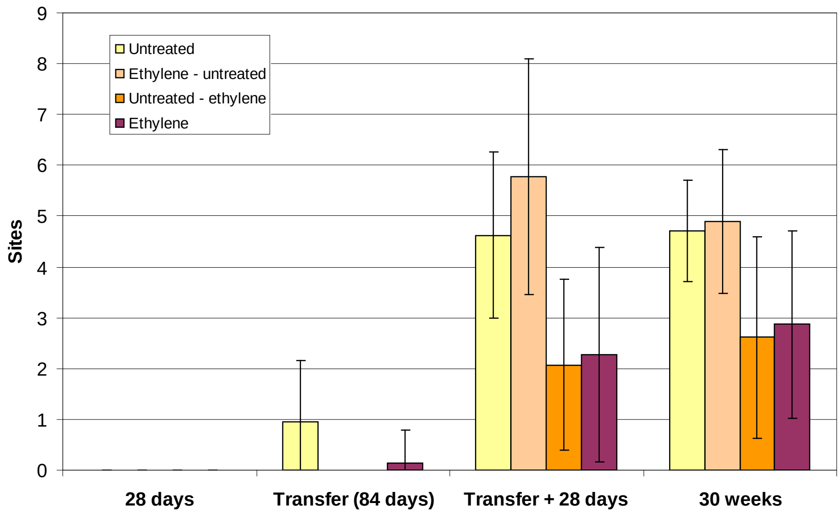



Figure 36. Sylvana mean sprouting sites

### 8.1.3 Vigour 2008/09

Figure 37 shows mean longest sprout growth over 28 days for all cultivars and treatments. During this period Desiree, Estima and Saturna had low vigour whereas most other cultivars showed greater vigour in the treatments without ethylene. *Untreated* Marfona and Sylvana appeared to have relatively high vigour at 3mm growth. *Ethylene→untreated* Fianna and Mayan Gold had more vigour than *Untreated*.

Figure 38 gives mean longest sprout growth in the period between 'transfer' and '30 weeks' per month (28 day month for comparison). Samples treated without ethylene were more vigorous than samples treated with ethylene, except for Mayan Gold in which all treatments were vigorous. On the whole there was little difference between the no ethylene treatments except for Desiree in which *Untreated* was more vigorous and for Russet Burbank and Sylvana which were more vigorous in *Ethylene→untreated* than in *Untreated*.

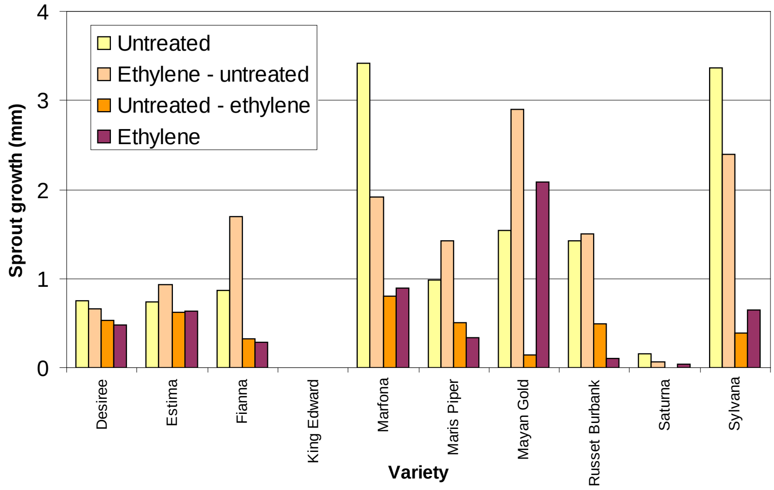



**Figure 37. Sprout length difference from transfer to 28 days later**

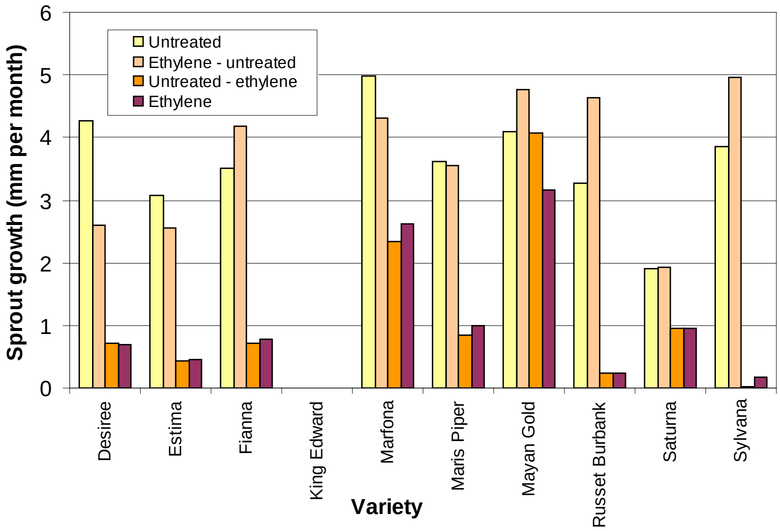



**Figure 38. Sprout length difference from transfer to completion**

### *8.2.1 Year 2 Data 2009/10*

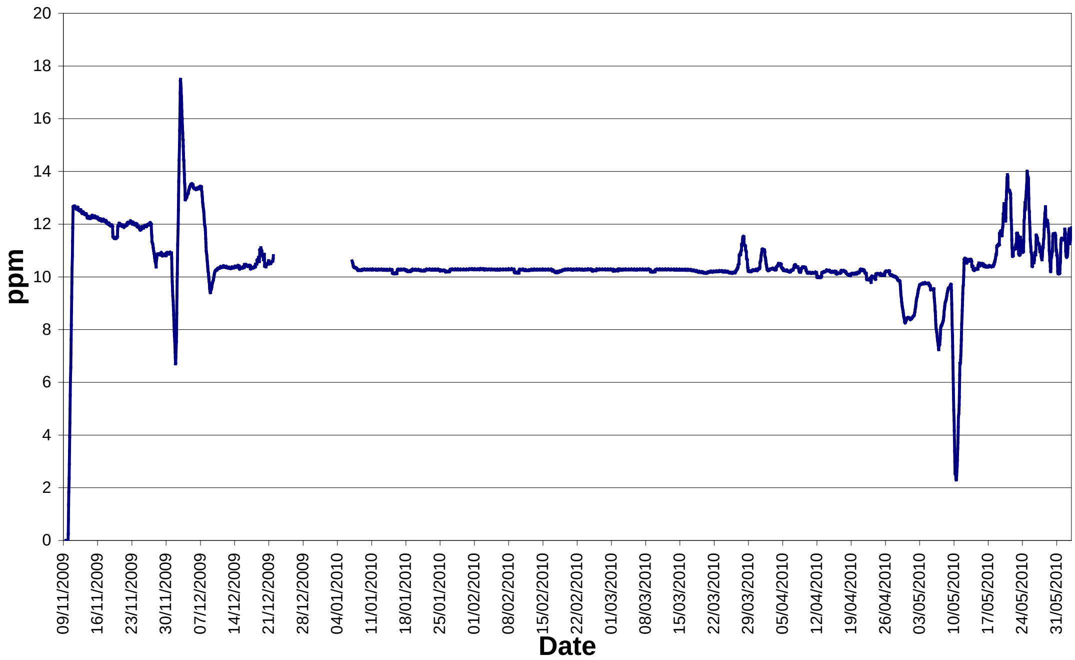



**Figure 39. Rolling 24 hour average of hourly ethylene reading**

**Table 11. Time periods for when automatically recorded data was unavailable**

| Ethylene logger data missing from | to | Time data not recorded | Reason |
|---|---|---|---|
| 21st December 2009 | 7th January 2010 | 17 days | Logger failure |
| 25th February 2009 | 25th February 2009 | 4 hours | Power cut |

**Table 12. Independent measurement of Ethylene concentrations in treatment stores**

| Sampling date | Untreated store, Ethylene (ppm) | Ethylene treated store, Ethylene (ppm) |
|---|---|---|
| 23rd November 2009 | 0 | 19.854 |
| 15th December 2009 | 0 | 10.821 |
| 25th January 2010 | 0 | 8.935 |
| 17th May 2008 | 0.647 | 9.437 |

All measurements provided by Cranfield University using gas chromatography

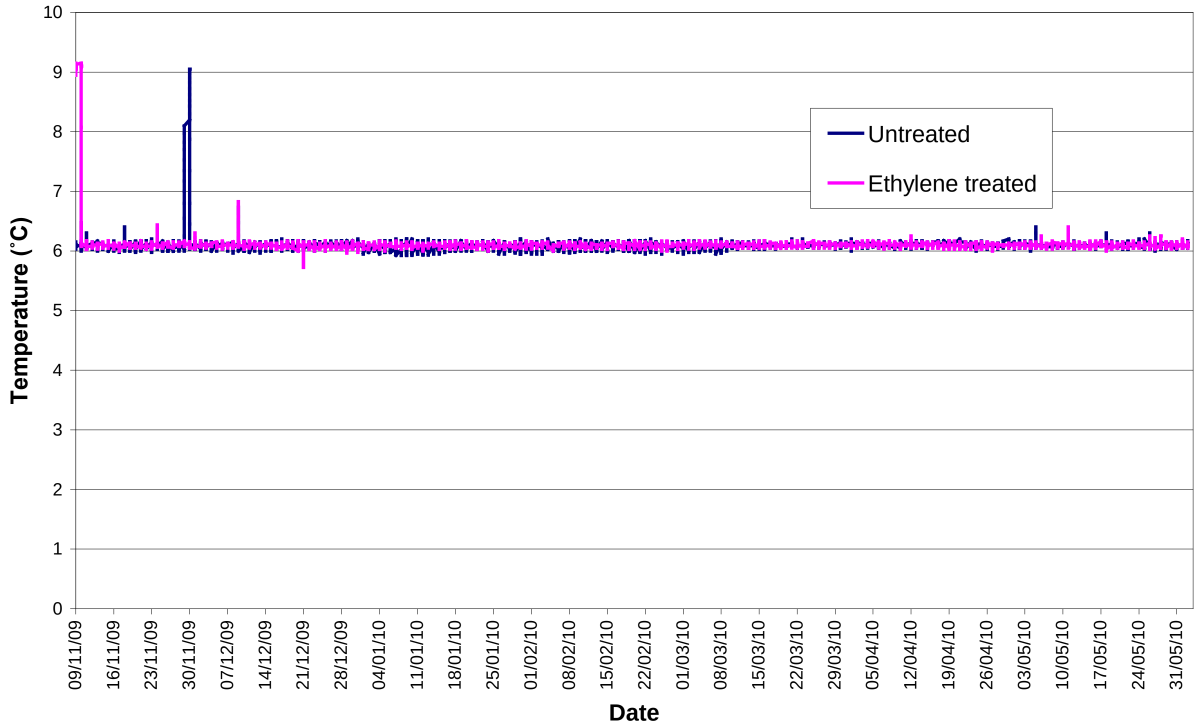



**Figure 40. Store temperature for the trial period.**

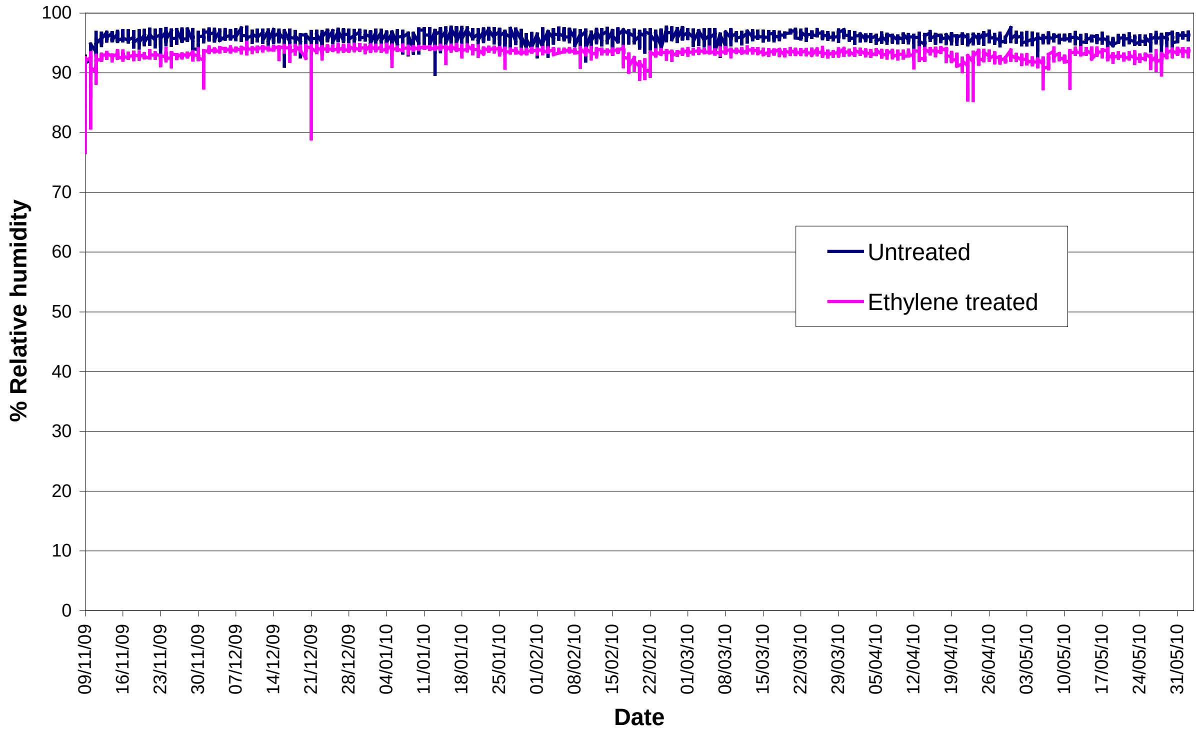



**Figure 41. Store humidity for the trial period.**

**Table 13. Sampling dates and occasions for start of sprouting assessments**

| Variety | Transfer | 28 weeks |
|---|---|---|
| Estima | 17/12/2009 | 27/05/2010 |
| Marfona | 29/11/2009 | 27/05/2010 |
| Russet Burbank | 25/01/2010 | 27/05/2010 |
| Saturna | 29/11/2009 | 27/05/2010 |

Treatments began on 11$^{th}$ November 2009

### 8.2.2 Sprouting 2009/10

Error bars show +/- 1 SD.

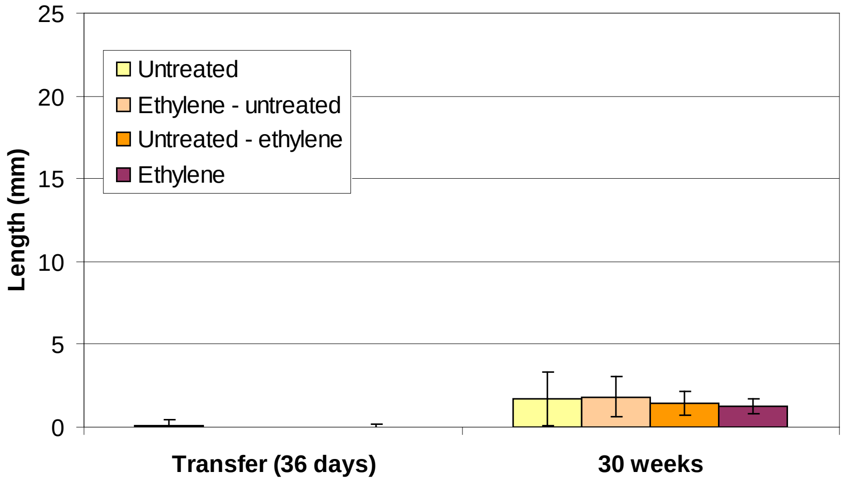



**Figure 42. Estima mean longest sprout**

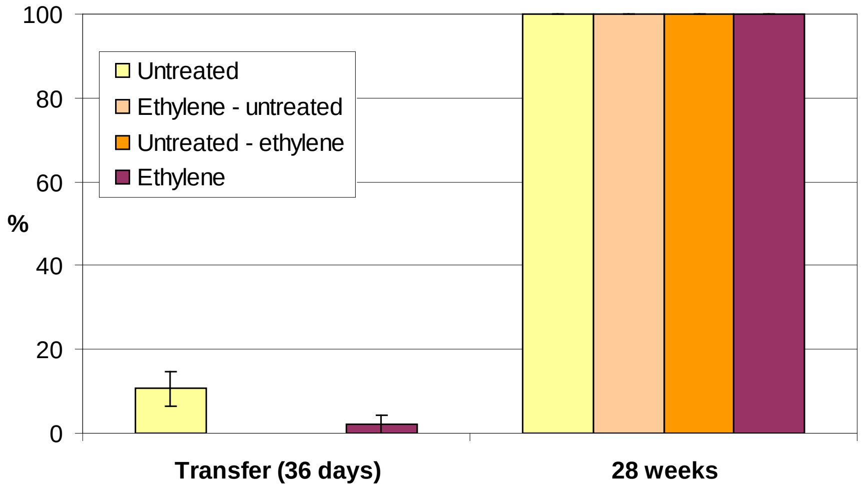



**Figure 43. Estima incidence of sprouting**

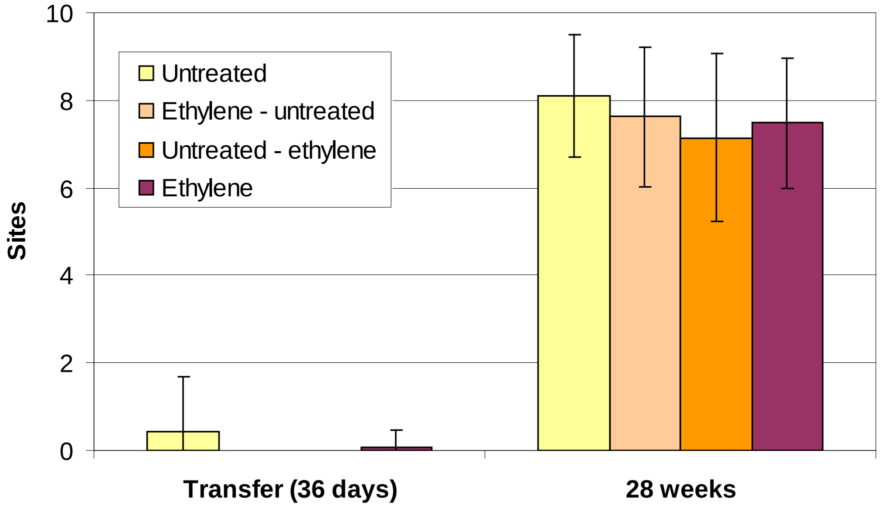



**Figure 44. Estima mean sprouting sites**

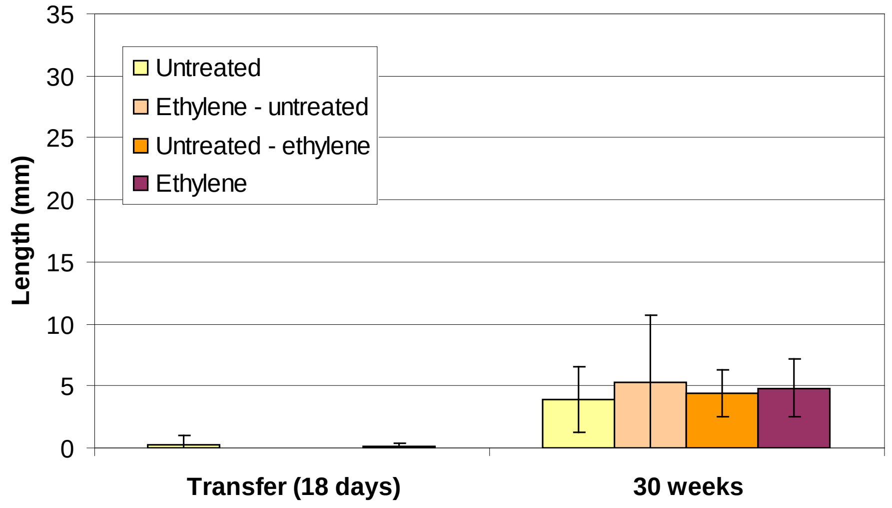



**Figure 45. Marfona mean longest sprout**

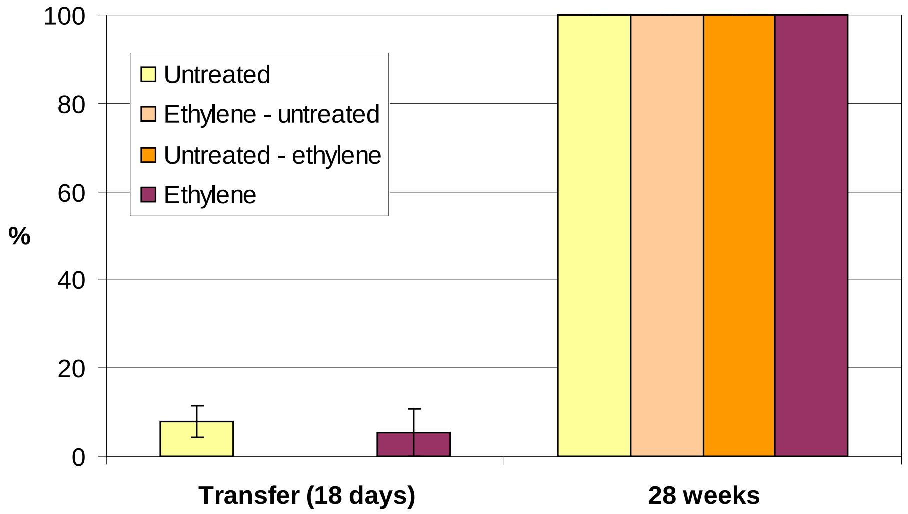



**Figure 46. Marfona incidence of sprouting**

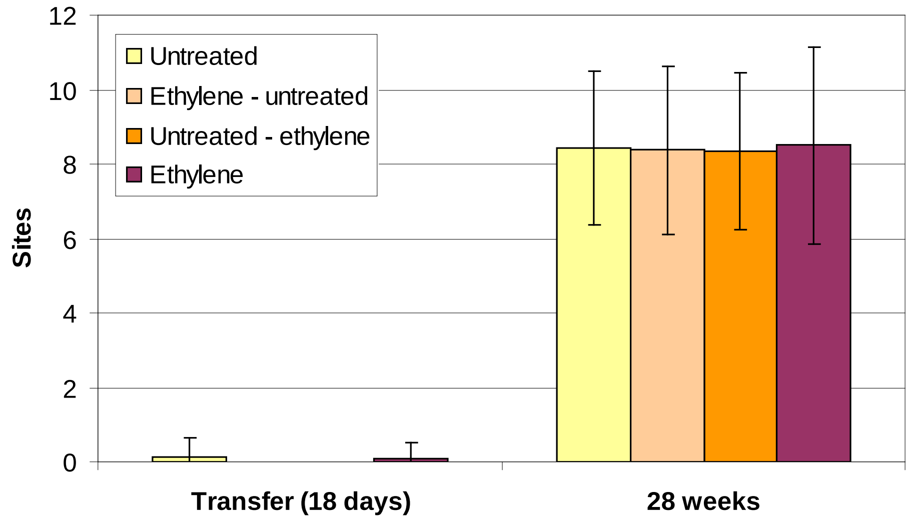



**Figure 47. Marfona mean sprouting sites**

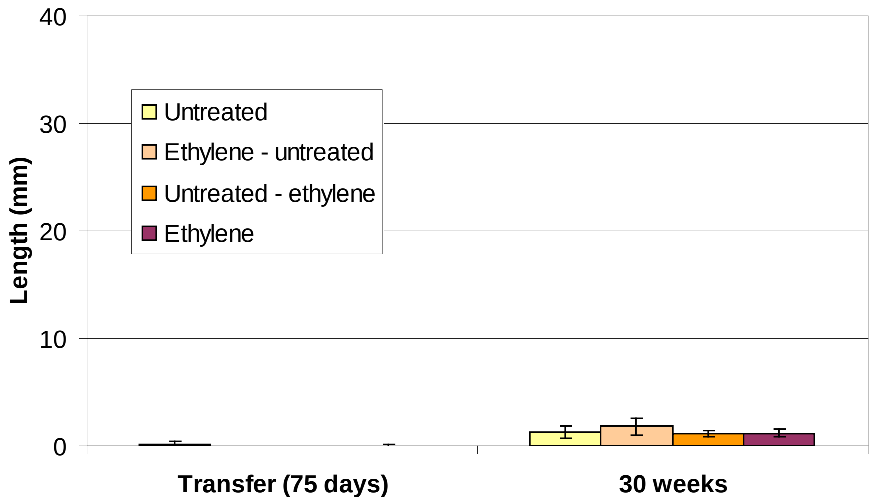



**Figure 48. Russet Burbank mean longest sprout**

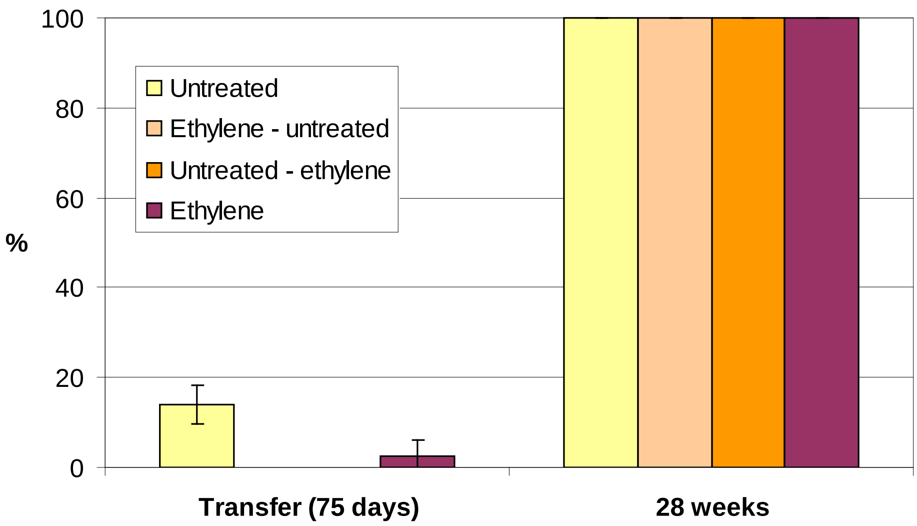



**Figure 49. Russet Burbank incidence of sprouting**

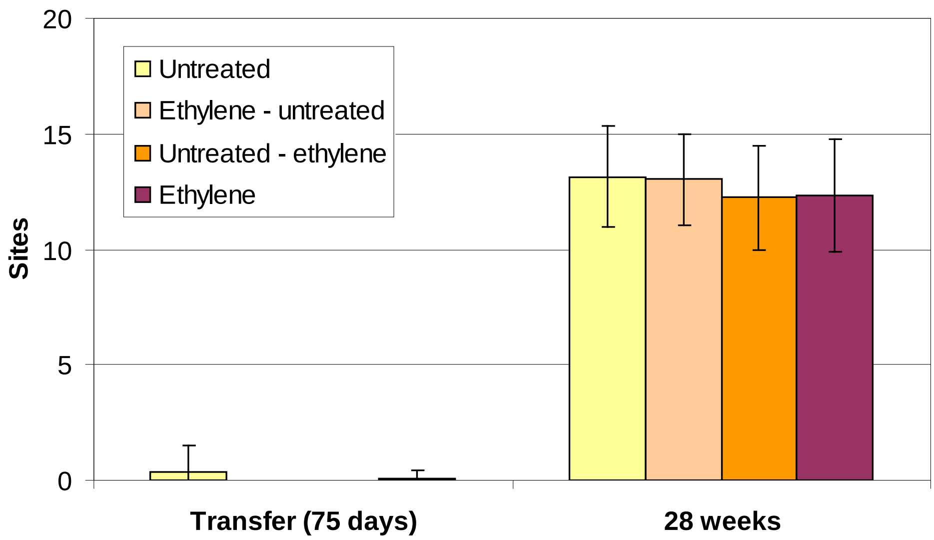



**Figure 50. Russet Burbank mean sprouting sites**

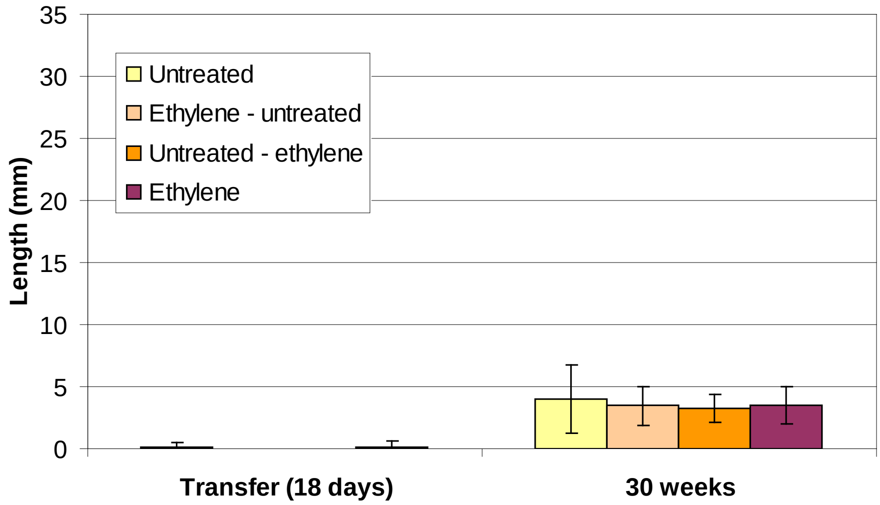



**Figure 51. Saturna mean longest sprout**

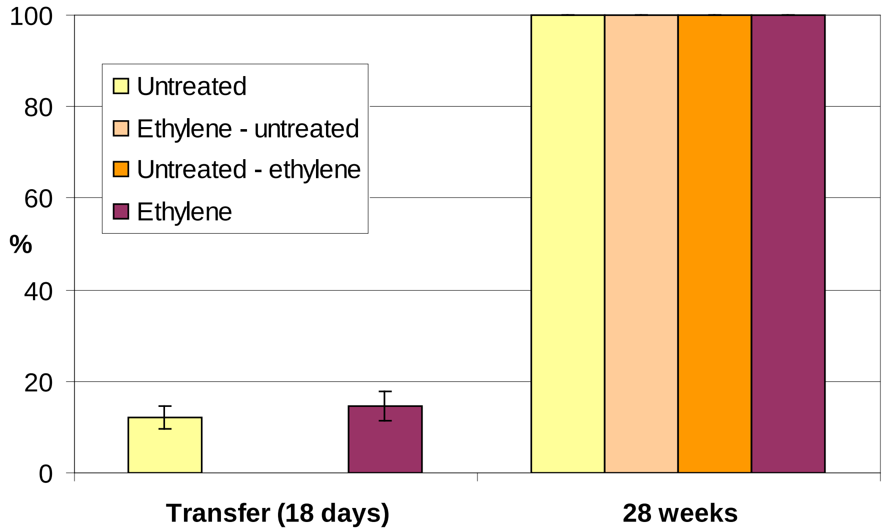



**Figure 52. Saturna incidence of sprouting**

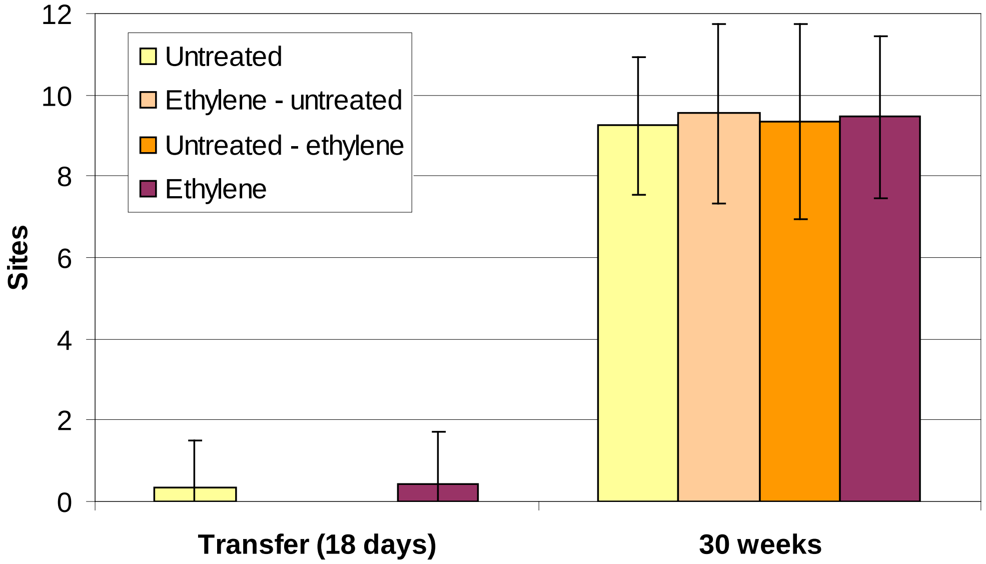



**Figure 53. Saturna mean sprouting sites**

### *8.3.1 Year 3 Data 2010/11*

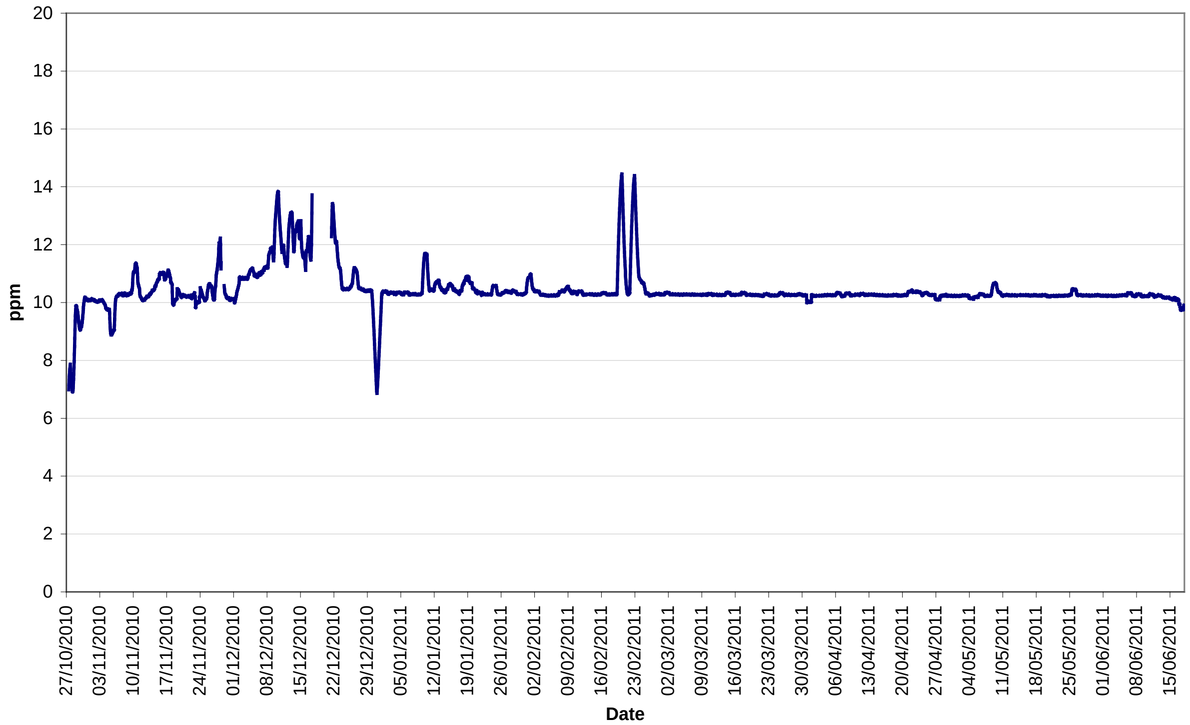



**Figure 54. Rolling 24 hour average of hourly ethylene reading**

**Table 14. Time periods for when accurate automatically recorded data was unavailable**

| Ethylene logger data missing from | to | Time data not recorded | Reason |
|---|---|---|---|
| 28th November 2010 | 29th November 2010 | 1 day | Frozen vent filter |
| 17th November 2010 | 21st November 2010 | 4 days | Sensor replacement |

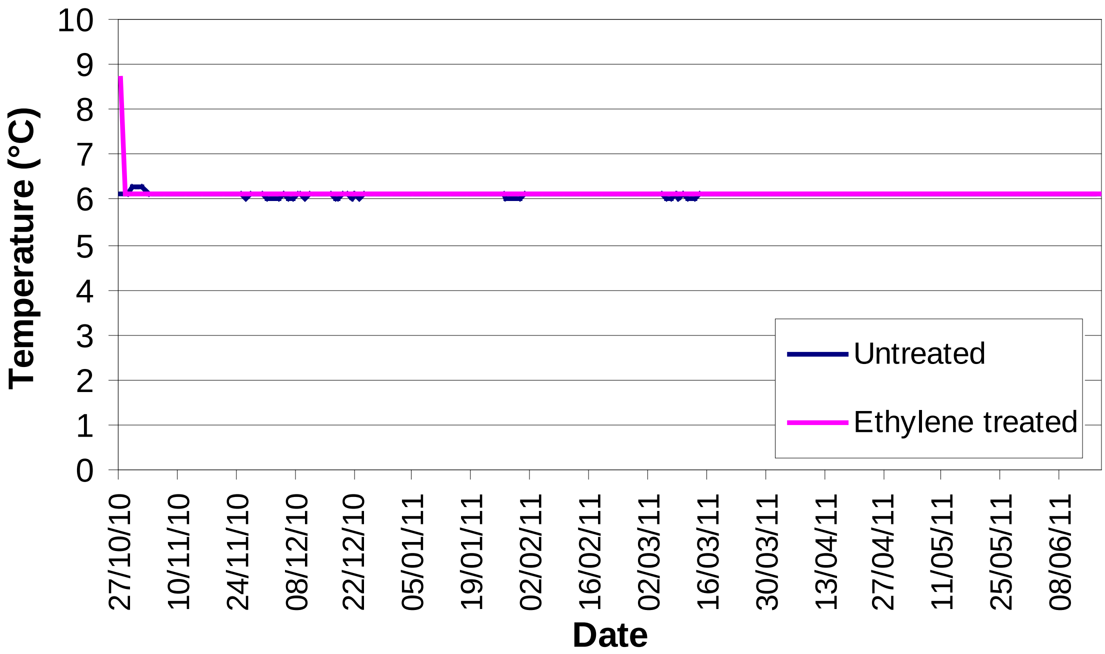



**Figure 55. Store temperature for the trial period.**

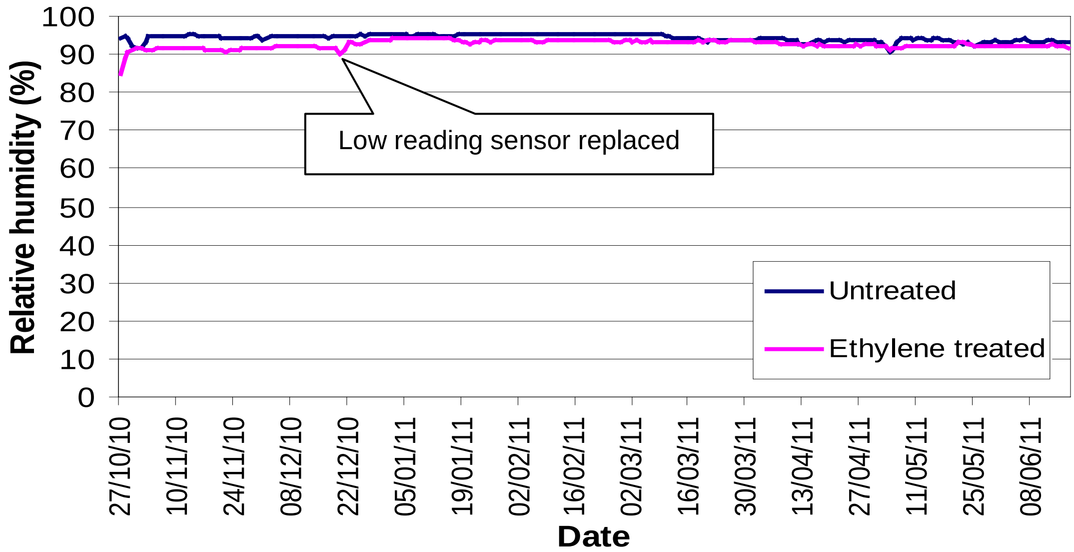



**Figure 56. Store humidity for the trial period.**

**Table 15. Sampling dates and occasions for start of sprouting assessments**

| Variety | Transfer | 28 weeks |
| --- | --- | --- |
| Estima | 17/12/2009 | 27/05/2010 |
| Marfona | 29/11/2009 | 27/05/2010 |
| Russet Burbank | 25/01/2010 | 27/05/2010 |
| Saturna | 29/11/2009 | 27/05/2010 |

Treatments began on 11th November 2009

### 8.3.2 Sprouting 2010/11

Error bars show +/- 1 SD.

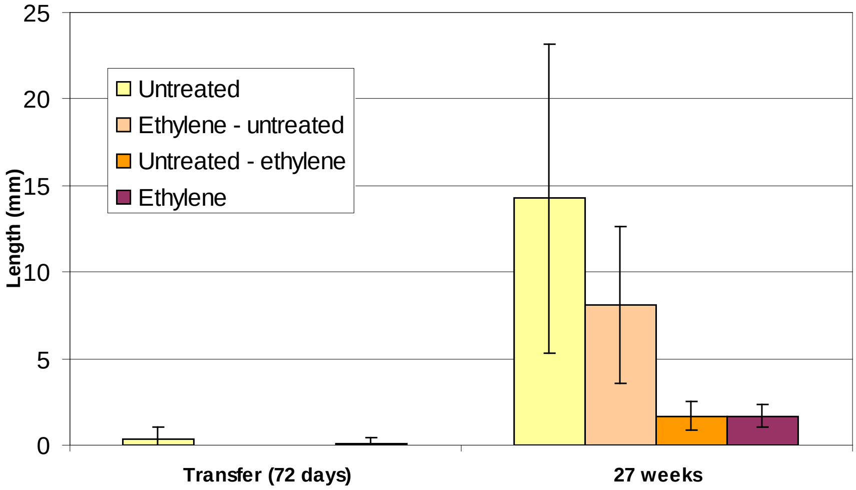



**Figure 57. Estima mean longest sprout**

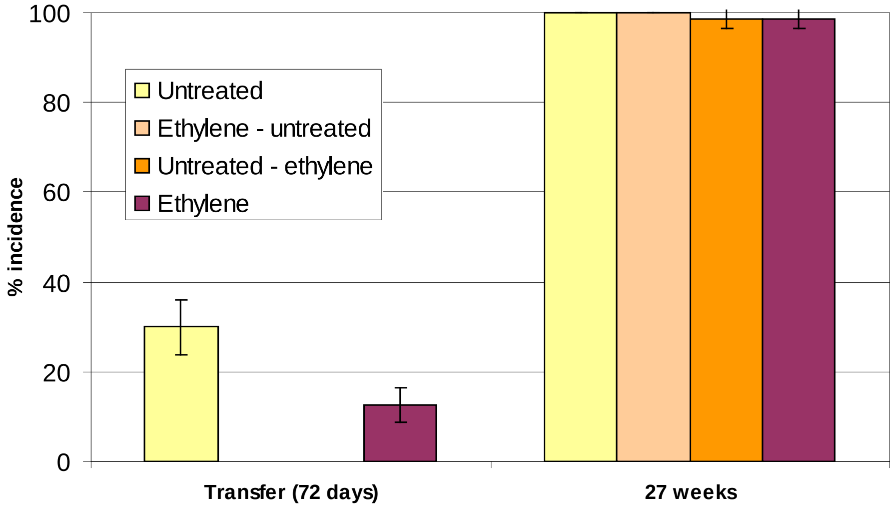



**Figure 58. Estima incidence of sprouting**

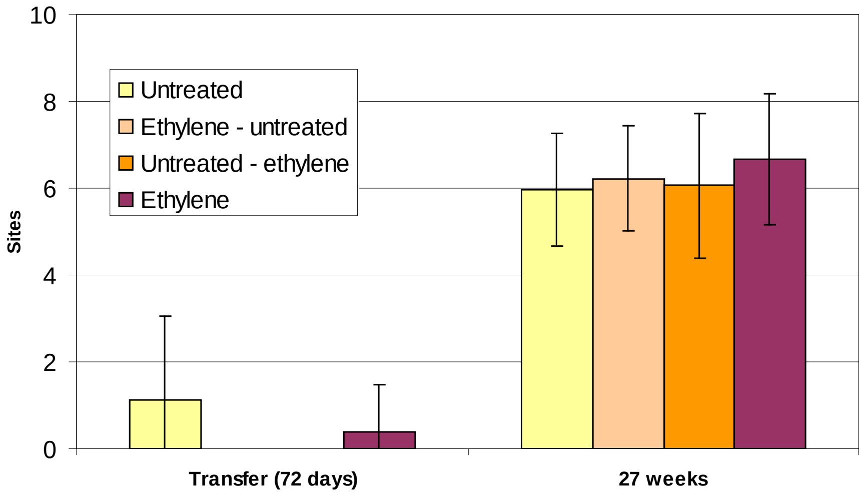



**Figure 59. Estima mean sprouting sites**

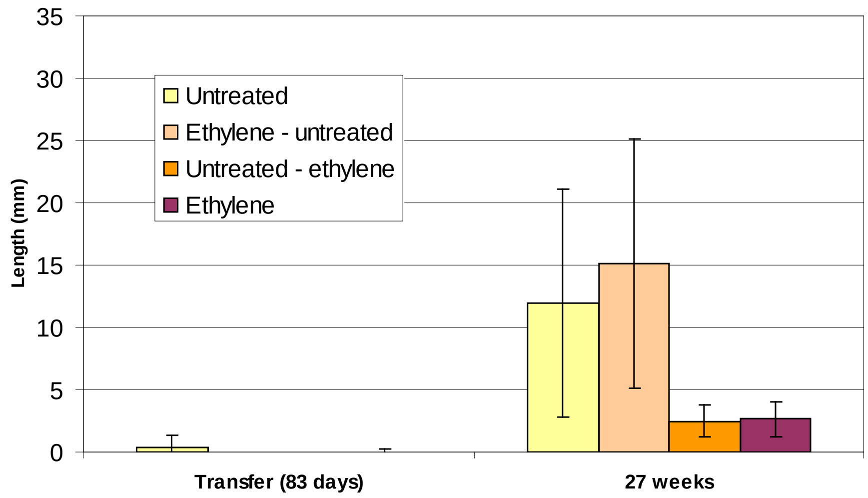



**Figure 60. Marfona mean longest sprout**

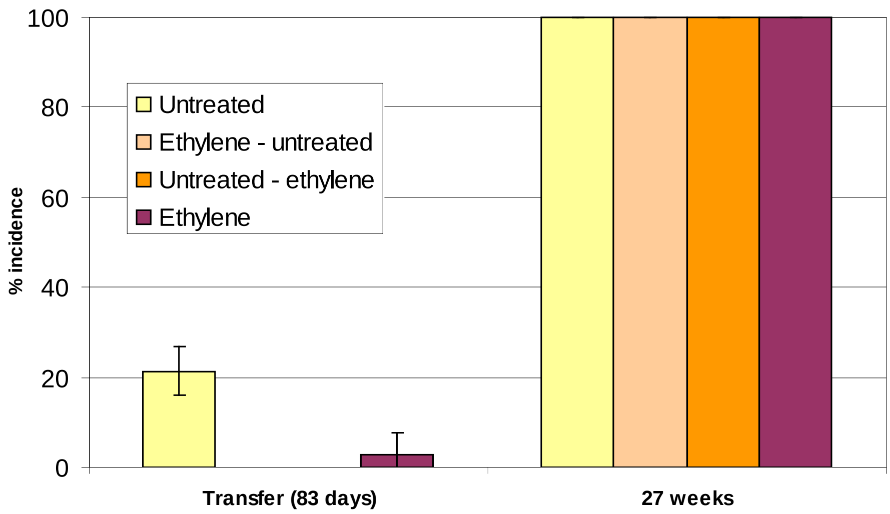



**Figure 61. Marfona incidence of sprouting**

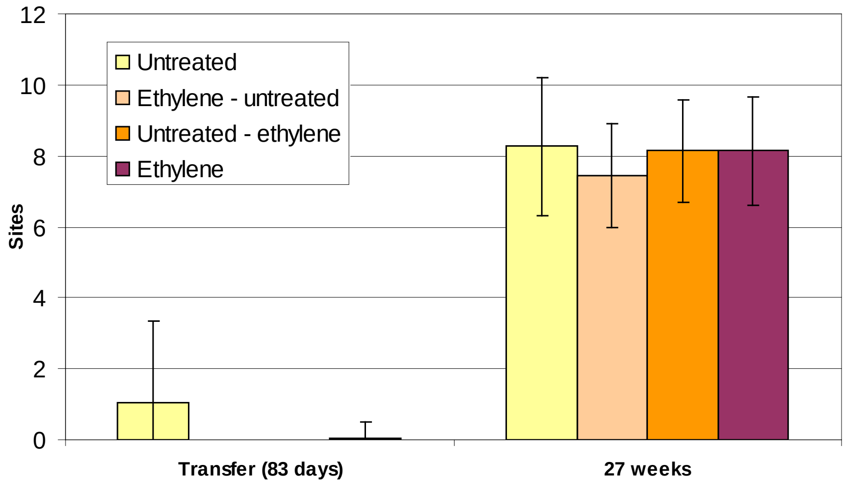



**Figure 62. Marfona mean sprouting sites**

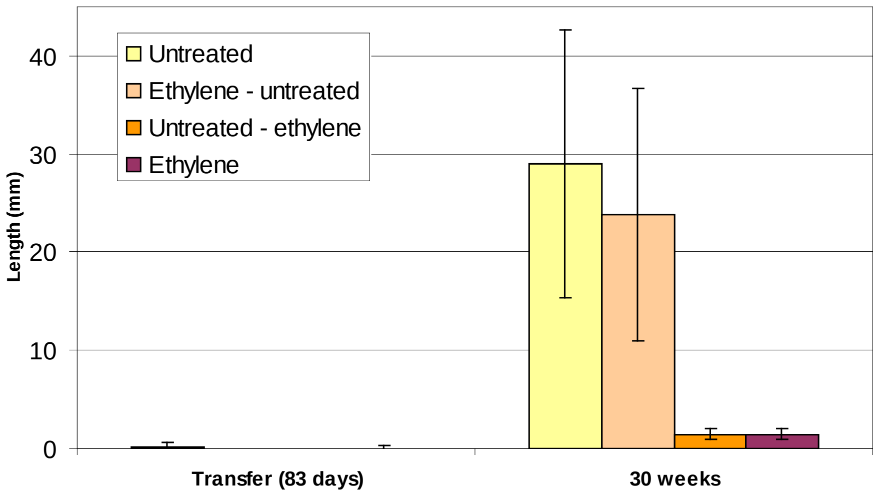



**Figure 63. Russet Burbank mean longest sprout**

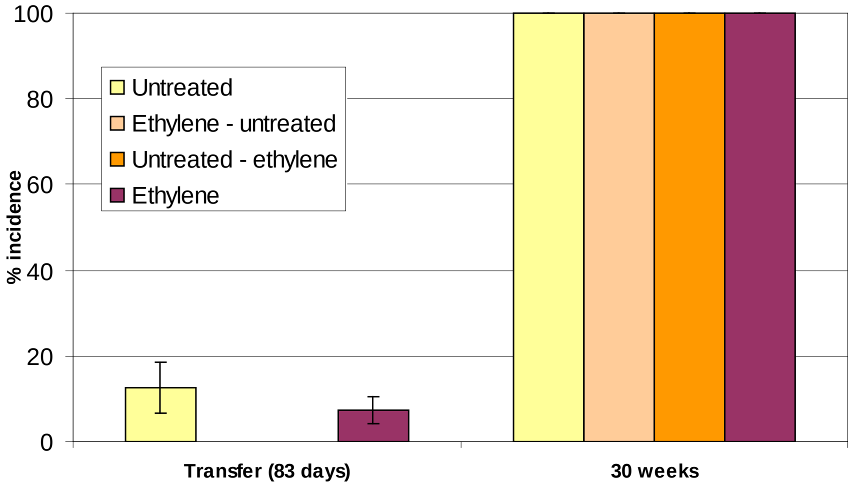



**Figure 64. Russet Burbank incidence of sprouting**

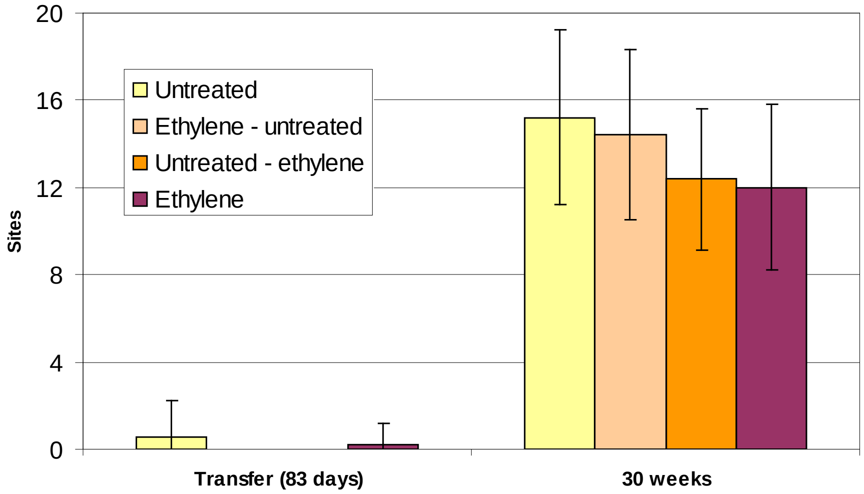



**Figure 65. Russet Burbank mean sprouting sites**

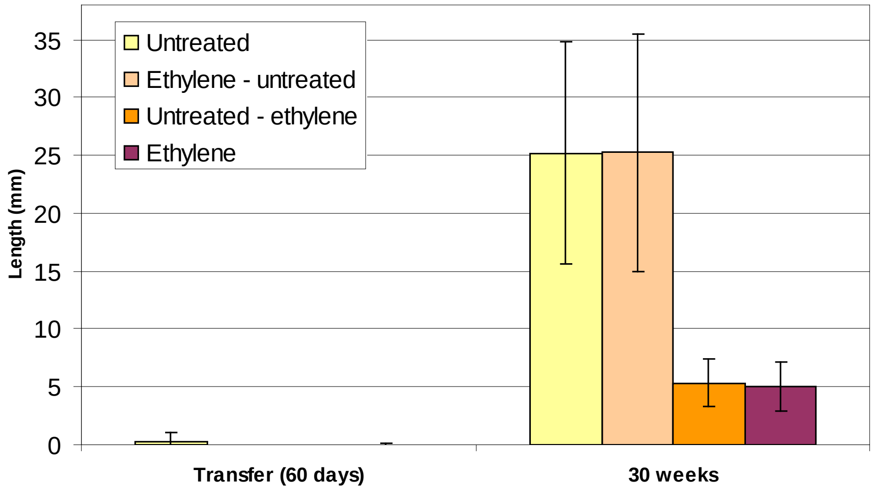



**Figure 66. Saturna mean longest sprout**

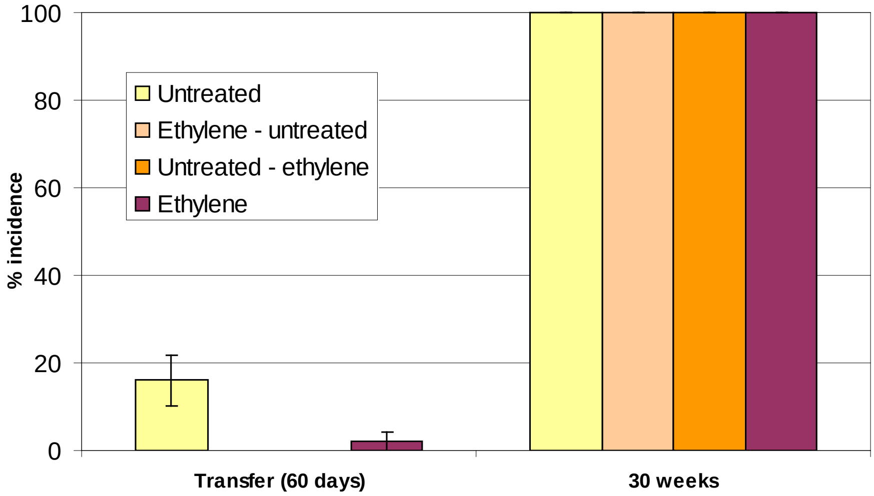



**Figure 67. Saturna incidence of sprouting**

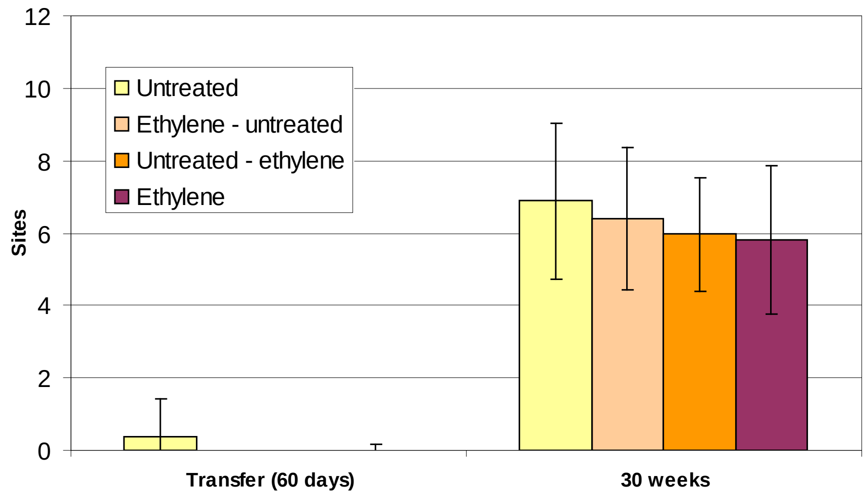



**Figure 68. Saturna mean sprouting sites**

## *8.4 Comparison of relative dormancy in three seasons by cultivar*

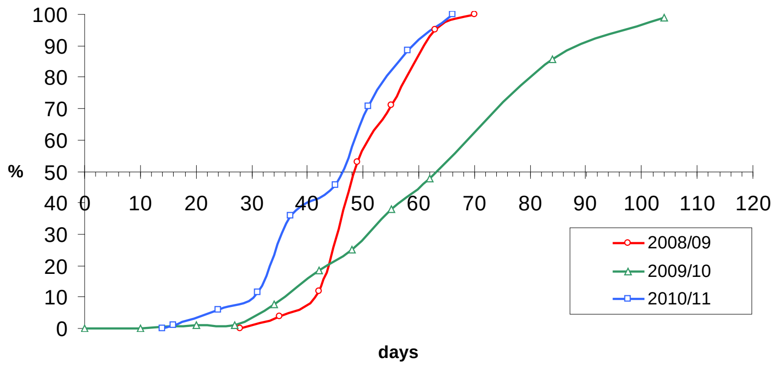



**Figure 69. Estima dormancy break at 15 C (for three seasons)**

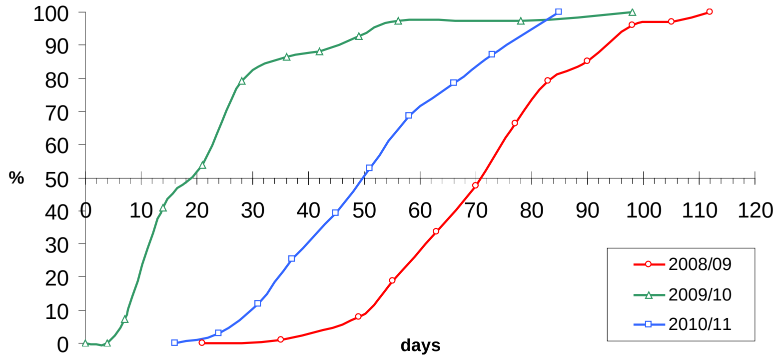
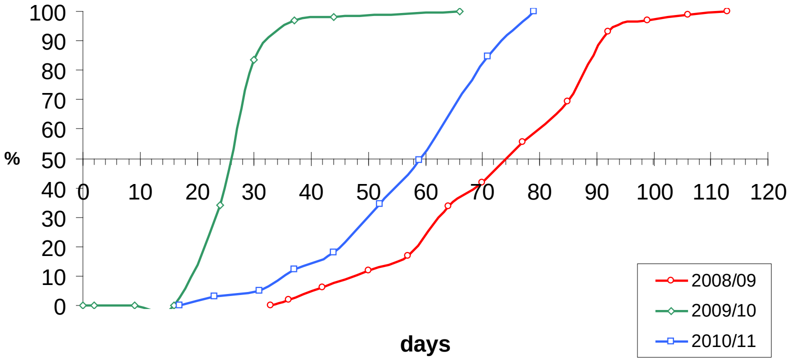
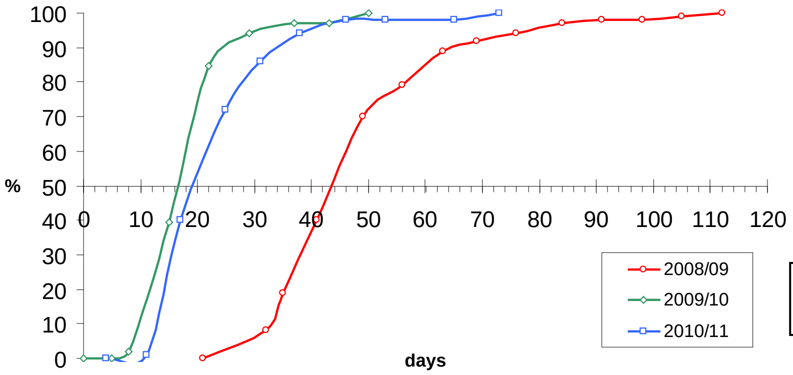



**Figure 70. Marfona dormancy break at 15 C (for three seasons)**




N.B. 2010/11 Russet Burbank
not used by Cranfield University

**Figure 71. Russet Burbank dormancy break at 15 C (for three seasons)**




N.B. 2010/11 Saturna
not used by Cranfield University

**Figure 72. Saturna dormancy break at 15 C (for three seasons)**