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Project number:	FV387
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Date project completed (or expected completion date):	31 October, 2011

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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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GROWER SUMMARY

Headline

This project investigates the potential for extending the season of UK leeks by 3-4 weeks which would significantly reduce the dependence on leek imports during May and June.

Background and expected deliverables

The season for UK leeks starts at the end of June with transplant plants produced under glass. These plants are then transplanted outside under crop covers. The season then runs through until late April/early May in the following year. The crops for the latest part of the season are direct field drilled in the previous May for harvest up until late April/early May the following year.

The season finishes usually because the old season crop runs to seed (bolts) making it unacceptable for the market.

Figure 1: An example of external bolting in leeks at the field site taken 26th May after harvesting.

In many similar biennial crops such as onions, carrots and parsnips the use of a sprout suppressant reduces bolting and re-growth to allow a longer marketing season. The use of these sprout suppressants also offers improvements in quality and shelf life for late season

produce. The use of such materials has not been investigated in leeks previously and hence this study was proposed by the British Leek Growers Association.

Summary of the project and main conclusions

The application of Fazor (maleic hydrazide 60%) gave a highly significant reduction in bolting for late leek production under these conditions. When it was applied in the autumn, although it reduced bolting very well, it also produced short, fat, soft leeks with a poor shelf life, which were unacceptable. When applied at the latest timing in mid-April it failed to control bolting. The March application however gave a significant reduction in bolting whilst showing few negative effects. There does appear to be a window somewhere between January and April, which should offer the best compromise between these two situations. Further research is needed to optimize the timing within this window.

The other two products tested: Canopy (mepiquat chloride 30% & prohexadione-calcium 5%) and Sunorgpro (metconazole 9%) didn't show any significant benefits to leek production.

Further work is required to pin point more accurately the best application timing between January and April, the rate of use also needs to be confirmed. Following confirmation of the timing window and rate, it will be necessary to investigate how different varieties react to the application of maleic hydrazide. We also need to know how the technique can be integrated with cold storage to further extend the UK season of production. The use of maleic hydrazide is likely to exceed the current Maximum Residue Level (MRL) for leeks as the use is not an approved use. Once the timing and rates have been confirmed therefore, residue studies will be required to submit data to allow an increase of the MRL, to comparable levels with other crops where the active is in approved use. Following this increase in MRL an application for an off-label approval could be submitted.

Financial benefits

Using this technique could extend the leek season by up to four weeks, potentially allowing year long supply of British leeks to consumers when used with the correct storage. Given that the total value of leek production in the UK is currently worth £35,000,000 this could add a further £2,500,000 worth of production value to this figure.

Action points for growers

There are no action points for growers at present as further work is required to refine the timing of application. Maleic hydrazide is not currently approved for UK use in leeks.

SCIENCE SECTION

Introduction

Currently the UK supplies home grown leeks from around the 1st July until the end of April the following year, with cold storage increasing the length of supply by a few weeks into May.

The main factor which stops field harvesting in late April/early May is the development of the seed head within the plant – bolting. If bolting could be reduced or controlled, UK leeks could be marketed for an extra 3-4 weeks, reducing dependence on imports and increasing UK late season production. Previous studies have looked into the effects of temperature, day length and transplanting on leek bolting (Weibe, 1994; Wurr, *et al*, 1999) but none so far have looked into the effects of applying growth regulators to reduce and delay the occurrence of bolting.

The total value of UK leek production is around £35,000,000 (source Defra hort. Stats 2009). Extending home production by 4 weeks could add £2-2.5 million gross output for UK leek growers and expand production from 1,800ha to 2,000ha.

In addition to season extension, the quality of late produced leeks could be improved as the use of growth regulators improves shelf life and keeping quality. This characteristic is already in commercial use on onions, carrots, parsnips and potatoes.

Growth regulators are currently used in UK onions to reduce sprouting, improve quality and shelf life, increasing the season of production. The same is also true of carrots and parsnips, increasing the season and improving product quality. Retailers have become mostly accepting of the use of growth regulators when used in a measured, limited time period and in a careful and responsible way.

The current range of crops, in which there is commercial use of growth regulators, do so to retain dormancy. The timing of application of growth regulators is therefore clearly at the point just before the onset of dormancy. Leeks are physiologically quite different from onions or carrots in that they are never truly physiologically dormant under UK growing conditions as they are field harvested green throughout the Winter and therefore the

potential timing for the use of sprouting regulators under UK conditions is unclear and requires detailed investigation.

Maleic Hydrazide (Fazor) is currently used in onions, carrots, parsnips and potatoes and is the obvious choice of product to test, however mepiquat chloride is quoted as being used on onion, leek and garlic in the US to control re-growth and Trinexapac-ethyl was also worthy of evaluation.

Materials and methods

Experimental design

The trial was carried out at field HH40, Hollyhouse farm, Manea, Cambridgeshire (OS grid reference: TL 456875). The soil in this field is an organic loam. The crop was direct drilled using natural seed and a precision commercial air drill on the 7th May 2010.
The experiment comprised of four treatments applied at four different timings, so 16 treatments in total. This gave seventeen plots per replicate, including an untreated control. There were three replicates to the experiment, giving a total of fifty one plots. Each plot measured 2m by 6m.The variety used was Harston F1, known for its bolting susceptibility.

Treatments

The treatments were two rates of maleic hydrazide (60%w/w) as the product Fazor at 8.0kg/ha or 4.0kg/ha product respectively as well as one each of mepiquat chloride (30%) & prohexadione-calcium (5%) as Canopy 1.5l/ha and metconazole (9%) as Sunorgpro 0.8l/ha (see Table 1). Treatments were due to be applied at four timings, one in mid-November and one in mid-December, one in mid-March and one in mid-April (see tables below). The treatments were applied with a precision 2M Azo plot sprayer. The December application timing however was delayed as the crop was frozen at that time and so this treatment was applied in early January when the crop had thawed.

Table 1: The treatments used in the trial

Treatments		Hectare rates		Water l/ha
	Product	**Rate**	**unit**	
1	Fazor 8.0 T1	8000	gm	400
2	Fazor 4.0 T1	4000	gm	400
3	Canopy T1	1500	ml	400
4	Sunorgpro T1	800	ml	400
5	Fazor 8.0 T2	8000	gm	400
6	Fazor 4.0 T2	4000	gm	400
7	Canopy T2	1500	ml	400
8	Sunorgpro T2	800	ml	400
9	Fazor 8.0 T3	8000	gm	400
10	Fazor 4.0 T3	4000	gm	400
11	Canopy T3	1500	ml	400
12	Sunorgpro T3	800	ml	400
13	Fazor 8.0 T4	8000	gm	400
14	Fazor 4.0 T4	4000	ml	400
15	Canopy T4	1500	ml	400
16	Sunorgpro T4	800	ml	400
17	Untreated	0		400

Table 2: Treatment application details

Treatment	Date & Time	Operator	Temp °C	Wind	Cloud cover
T1	19/11/2010 1530 – 1615	P Hammond	6	Speed – 2 Direction- NE	100% foggy
T2	06/01/2011 1345 - 1445	P Hammond	4	Speed – 4 Direction - NW	100%
T3	14/03/2011 1030 - 1115	P Hammond	10	Speed – 11 Direction - SW	70%
T4	15/04/2-11 0915 - -945	P Hammond	13	Speed – 8 Direction – NE	0%

Assessments

The crop was harvested on the 3rd May 2011; a couple of days after the surrounding field crop was harvested, when assessments on yield, quality at harvest and bolting were carried out. Before harvest the mean plant height for each plot was measured. For the yield assessments four meter lengths of each of the two centre rows of each plot were hand lifted and loose leek specification trimmed to 30cm length by professional leek harvesters provided by Allpress Farms Ltd. The leeks were weighed and counted by Precision Agronomy staff, to obtain the gross yield and average leek plant weight. Samples from each plot of 35 leeks per plot, 105 leek plants per treatment, were sent to NIAB, Cambridge for shelf-life testing where they were put into the shelf life room at 4°C. The samples were kept in plastic bags and then put in crates which were wrapped and covered in plastic to keep the humidity up around the leeks.

Samples were assessed by NIAB staff after 7 days. The following measures were recorded: count of leeks which had telescoped (converted to a percentage), sum of telescoping length in cm (converted to per plant), count of leeks with re-growth of roots, count of soft leeks (converted to a percentage), 1-9 score of overall sample for softness (1=soft, 9 =firm), count of leeks rotten at base (converted to a percentage) and count of leeks obviously bolted (converted to a percentage).

Samples were re-bagged and covered to maintain humidity levels and returned into cold storage for a further 7 days. The following measures were recorded 14 days after harvest:

- count of leeks which had telescoped (converted to a percentage),

- sum of telescoping length in cm (converted to per plant),
- count of leeks with re-growth of roots,
- count of soft leeks (converted to a percentage) and
- a 1-9 score of overall sample for softness (1=soft, 9 =firm).

The leeks were then cut in half along their length and assessed as following: a count of leeks bolted, where the flower stem was greater than 30cm (converted to a percentage), sum of bolt lengths less than 30cm (added to the sum of those less than 30cm and converted to a length per plant).

Residue Testing

A sub-sample of six treated leeks from each of the final timing of treatments made in April – i.e. the most recent applications, were taken in final trimmed form and sent to Eclipse at Chatteris for pesticide residue testing.

Results

There were highly significant differences in the length of the bolt length at the point of harvest. Fazor at 4kg and Fazor at 8kg had significantly shorter bolt lengths ($P<0.001$, see Fig. 1) than the untreated control. There was a significant interaction between the time of application and the treatments which was most obvious in the Fazor treatments.

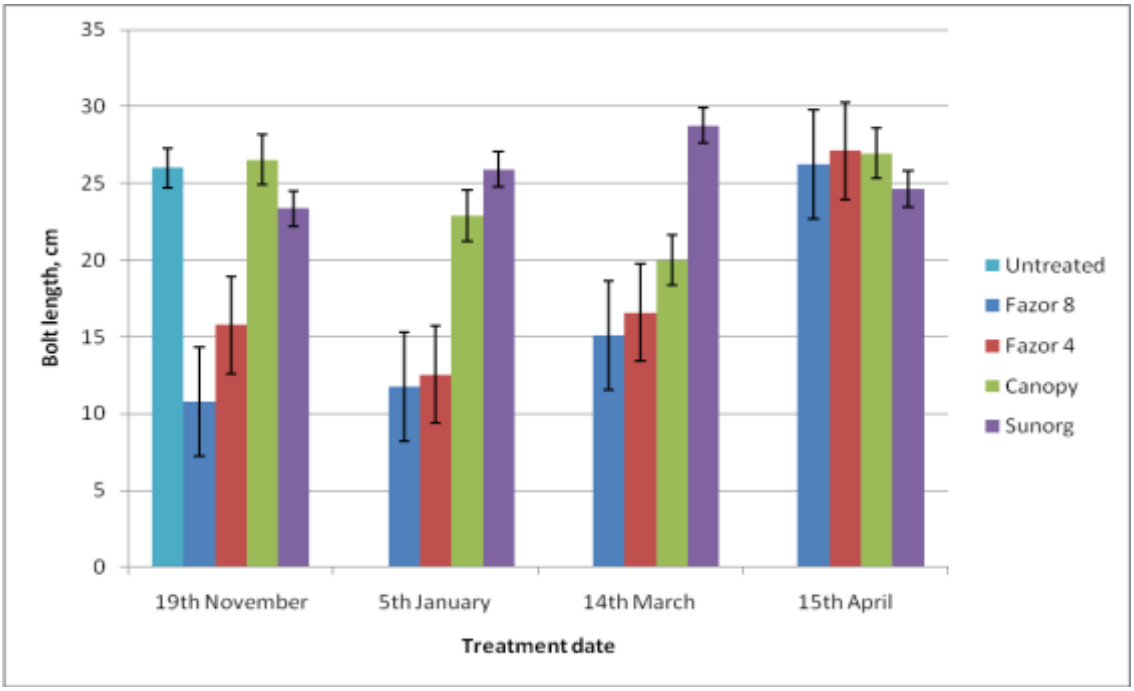

Figure 1: The length of bolting after each treatment.

There was a highly significant difference between treatments ($P<0.001$), the date at which the treatment was applied ($P<0.001$) and the interaction between date and treatment ($P<0.001$).

There were significant differences in plant height between the treatments when the interaction between treatment and timing was considered (see fig. 2 and table 1 below). The two Fazor treatments applied in November gave significantly shorter plant heights than the other treatments ($P<0.001$) as did these two treatments when applied in January ($P<0.05$). These plant heights were also significantly smaller than the control plots ($P<0.01$).

There were also significant differences in the plant heights at harvest (see Fig 2 and Table 3). The applications of Fazor 8 and Fazor 4 in November and January gave significantly shorter leeks than the other treatments and the untreated control, being up to 25cm shorter in some cases.

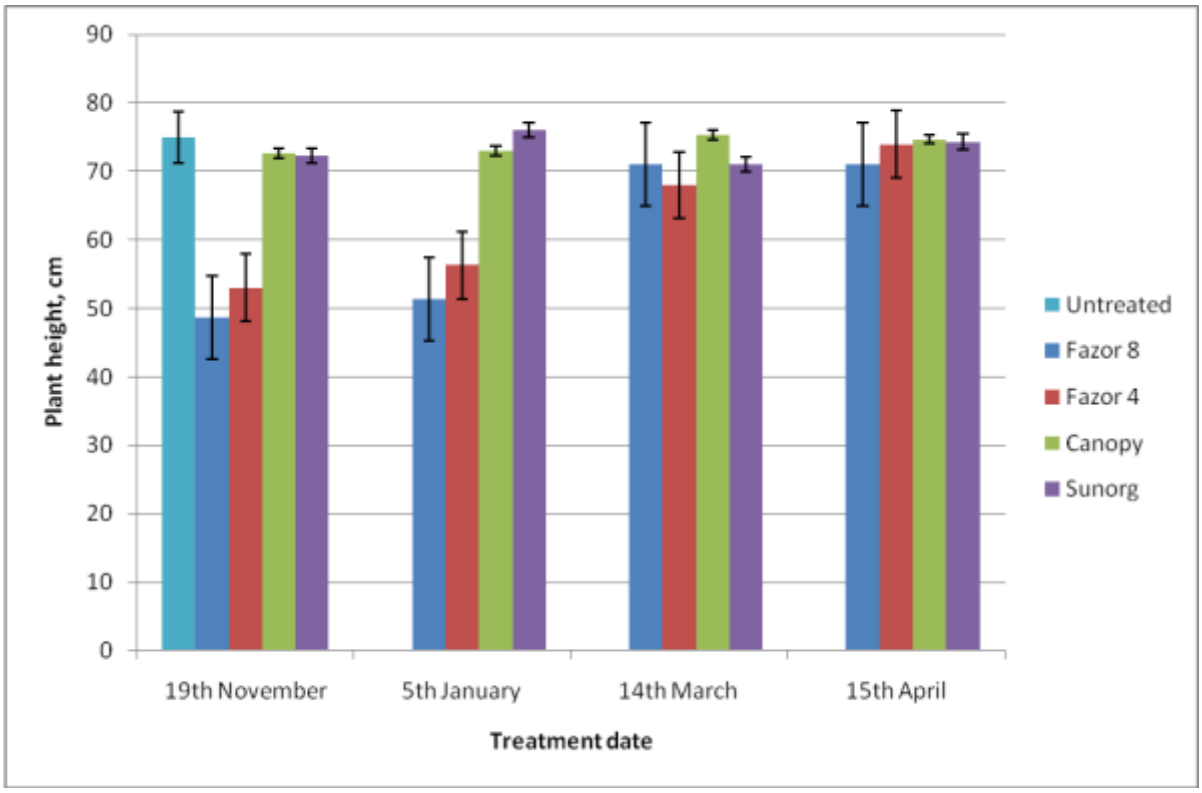

Figure 2: The plant height at harvest for each of the treatments.

Within treatment application timing one (Nov) Fazor 8 and Fazor 4 gave significantly shorter plants than the control (P<0.001) and they were also shorter than the other treatments – Canopy and Sunorgpro - within this timing application (P<0.01). Within treatment application timing two (Jan) both Fazor treatments again gave significantly shorter plant lengths than the control (P<0.001) and the other treatments – Canopy and Sunorgpro – applied at this time (P<0.01).

Table 3: The plant heights for each of the treatments

	Height (cm)							
	Fazor 8	**Fazor 4**	**Canopy**	**Sunorg**	**Fazor 8**	**Fazor 4**	**Canopy**	**Sunorg**
		19th November				**5th January**		
Rep	T1	T2	T3	T4	T5	T6	T7	T8
1	48	46	75	70	48	55	68	80
2	48	56	75	72	58	54	74	68
3	50	57	68	75	48	60	77	80
Mean	49	53	73	72	51	56	73	76

Table 3 (continued): The plant heights for each of the treatments

Fazor 8	Fazor 4	Canopy	Sunorg	Fazor 8	Fazor 4	Canopy	Sunorg	Control	
14th March				15th -April					
T9	T10	T11	T12	T13	T14	T15	T16	T17	**Mean**
70	69	70	76	68	74	72	73	76	67
73	62	76	75	75	73	76	74	75	68
70	73	80	62	70	75	76	76	74	69
71	68	75	71	71	74	75	74	75	68

Table 4, below, shows the 7 day shelf life assessment means. The most obvious deteriorations in leek quality after shelf-life testing were the tendencies to telescope and for leeks to go soft. There was little or no sign of re-growth at the roots. The November and January Fazor 4 and Fazor 8 treatments caused distortion of the leeks into an oval shaft and produced soft leeks. Table 4 shows the assessment means after 7 days of shelf-life storage.

There were significant differences in the amount of telescoping per leek. The earlier the application the less telescoping there was. Fazor 4 and Fazor 8 had the least amount of telescoping. Correspondingly the Fazor 4 and 8 treatments were more effective at earlier timings.

There were significant differences in the percentage of plants which had bolted between treatments. Sunorg had significantly more bolters than the other treatments including the untreated; however, this was non-destructive and therefore not as definitive as the later assessment at 14 days. Fazor applications, especially the earlier ones, had significantly less bolting.

There were also significant differences in the softness of plants (on a 1-9 scale, where 1 is soft and 9 is firm) when considering the interactions between treatments and date of application. Canopy treatments resulted in more soft leeks from the later application dates. The Fazor 4 and Fazor 8 treatments gave fewer soft leeks at the later treatments (see Fig.3)

Table 4: Seven day shelf-life assessment means

Treatment	% telescoped per plot	telescoping/ plant cm	re-growth	% of soft leeks	softness 1-9 (1=soft)	% rots at base	% bolters
T1	16	0.1	0	47	5.0	25	0
T2	69	0.7	1	65	4.3	35	0
T3	100	2.0	0	32	6.8	15	7
T4	100	1.7	0	56	6.0	16	1
T5	25	0.1	0	47	5.0	23	0
T6	47	0.4	0	61	4.3	23	0
T7	100	1.9	1	53	6.0	7	1
T8	100	2.1	0	58	5.5	28	7
T9	91	0.5	3	39	6.7	19	0
T10	80	0.6	0	53	6.2	19	0
T11	100	2.1	0	56	5.7	17	4
T12	97	1.7	0	63	5.7	7	27
T13	95	1.4	0	44	6.5	9	0
T14	100	1.5	0	44	6.5	19	10
T15	100	1.6	0	57	5.7	11	5
T16	100	2.1	0	55	5.7	23	27
T17	100	1.9	0	47	6.3	4	3

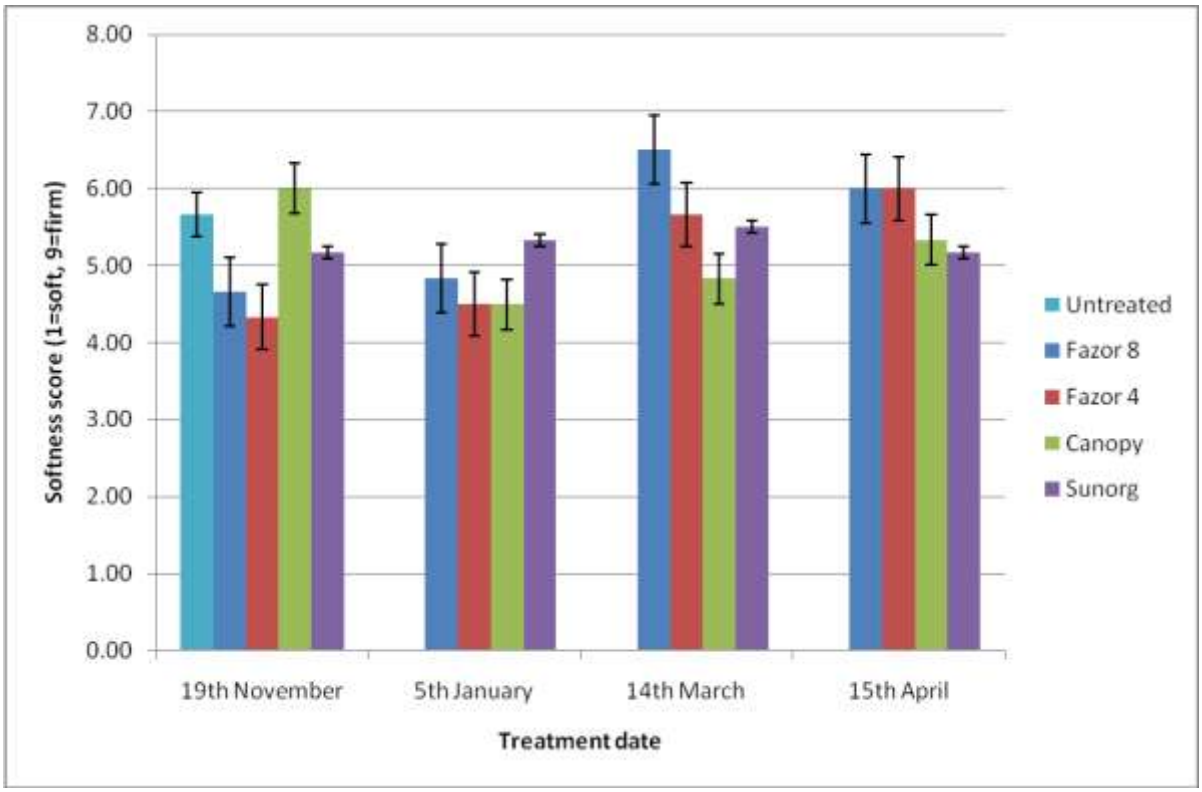

Figure 3: The softness scores for each treatment after the first round of shelf life testing (1=soft, 9=firm).

There was a significant difference when the interaction between the treatment and the date applied was compared ($P<0.01$).

Table 5, below, shows the assessment means after 14 days of shelf-life storage. At 14 days after harvest the amount of telescoping had increased from that at 7 days. There were signs of roots starting to re-grow and the majority of samples had become softer. Destructive assessment gave a fuller picture of bolting.

There were still significant differences in the amount of telescoping per leek. The earlier applications showed less telescoping than the later applications. Fazor at 4kg and Fazor at 8kg had the least amount of telescoping. Correspondingly the Fazor at 4kg and 8kg treatments were more effective at controlling telescoping at earlier timings. The interactions between date and treatment were more significant at the later assessment.

The significant differences in softness had disappeared as the length of storage overtook the effect of treatment and treatment timing. The trends shown earlier (shown above in Table 4) still hold true.

Table 5: Fourteen day shelf-life assessment means

Treatment	% telescopers per plot	telescoping/plant cm	regrowth	% of soft leeks	softness 1-9 (1=soft)	% internal bolters	mean bolt length
T1	65	0.4	12	68	4.7	45	0
T2	89	1.1	1	67	4.3	48	2
T3	100	3.6	7	45	6.0	100	24
T4	100	3.2	4	73	5.2	100	24
T5	69	0.5	4	67	4.8	75	8
T6	87	1.1	9	76	4.5	73	3
T7	100	3.2	7	84	4.5	100	25
T8	100	3.9	3	69	5.3	100	24
T9	97	1.1	8	52	6.5	100	6
T10	96	0.9	8	56	5.7	97	6
T11	100	3.3	5	71	4.8	100	25
T12	100	3.4	3	56	5.5	100	26
T13	100	2.5	0	59	6.0	100	23
T14	100	2.4	4	60	6.0	100	23
T15	100	2.9	1	61	5.3	100	22
T16	100	3.8	7	69	5.2	100	26
T17	100	3.4	13	63	5.7	100	27

The results for the residue testing are shown in Table 6 below. The higher rate of maleic hydrazide (Fazor 8.0kg/ha) produced a residue of 2.0, the lower rate of maleic hydrazide (Fazor 4.0kg/ha) produced a residue of 1.8. Both these results show a level of residue in excess of the current Maximum Residue Level (MRL) of 0.2.

Canopy produced a residue of mepiquat of 0.35, which is also in excess of the MRL which is set at 0.05 Limit of Determination (LOD). Sunorgpro produced no detectable residues of metconazole at the rates applied.

Table 6: The results of the residue testing for each of the active ingredients

Compound	Source of Sample	MRL	Result
Maleic Hydrazide	T13 - Fazor 8.0	0.2	2
Maleic Hydrazide	T14 - Fazor 4.0	0.2	1.8
Mepiquat	T15 - Canopy	0.05	0.35
Metconazole	T16 - Sunorgpro	0.02	ND<0.05

The yield results are given in Table 7 below. There was also no significant effect of the plant growth regulators on either total yield of the crop or individual weight per plant at harvest, so none of the applications caused a significant yield reduction over the untreated control.

Table 7: The yields from each of the treatments

Treatment	Date applied	Treatment number	Replicate	Yield kg/ha	Mean weight per leek kg
Fazor 8	19th November	T1	R1	54350	0.22
			R2	36850	0.21
			R3	55550	0.23
Fazor 4	19th November	T2	R1	49250	0.26
			R2	45550	0.22
			R3	52650	0.24
Canopy	19th November	T3	R1	52450	0.22
			R2	46850	0.21
			R3	51950	0.24
Sunorg	19th November	T4	R1	53350	0.22
			R2	53500	0.21
			R3	42950	0.26
Fazor 8	5th January	T5	R1	56450	0.23
			R2	56250	0.24
			R3	46900	0.17
Fazor 4	5th January	T6	R1	58650	0.23
			R2	46750	0.23
			R3	57350	0.23

Canopy	5th January	T7	R1	46175	0.25
			R2	52550	0.21
			R3	60800	0.25
Sunorg	5th January	T8	R1	51650	0.23
			R2	44250	0.20
			R3	52500	0.22
Fazor 8	14th March	T9	R1	53450	0.24
			R2	53450	0.24
			R3	56950	0.24
Fazor 4	14th March	T10	R1	56500	0.26
			R2	46850	0.24
			R3	56950	0.25
Canopy	14th March	T11	R1	45400	0.22
			R2	51200	0.23
			R3	49150	0.23
Sunorg	14th March	T12	R1	47650	0.23
			R2	46600	0.24
			R3	52050	0.24
Fazor 8	15th April	T13	R1	43850	0.23
			R2	52650	0.22
			R3	51800	0.26
Fazor 4	15th April	T14	R1	44950	0.23
			R2	51400	0.24
			R3	53800	0.18
Canopy	15th April	T15	R1	42750	0.24
			R2	46400	0.27
			R3	54550	0.21
Sunorg	15th April	T16	R1	45050	0.21
			R2	48700	0.21
			R3	54350	0.22
Control		T17	R1	44300	0.25
			R2	51750	0.24
			R3	50950	0.22

Discussion

Fazor at 4kg and Fazor at 8kg gave the best control of bolting (see Figure 1). The control of bolting was best at earlier timings. This is, perhaps, not surprising as this treatment is commercially used on other closely related crops such as onions, garlic and shallots to control bolting. However, there is a danger of a too early application causing the plants to become short and soft.

The two Fazor treatments, therefore, gave the greatest control at earlier applications, which shows real promise for technique. The earlier applications of the Fazor at 4kg and 8kg were also more effective at controlling telescoping during shelf-life testing. This, however, came at a cost. The softness, length and shape of the leeks after these earlier treatments are commercially unacceptable - the early November and January treatments producing much softer and fatter leeks. These leeks were also significantly shorter and fatter than their untreated counterparts as compared to leeks treated at a later date with Fazor or any leek treated with either of the other two treatments – Sunorgpro and Canopy. With the earlier treatments showing greater control of bolting it therefore appears there is a trade off between the control of both bolting and telescoping and the quality of the finished product. The period between January and April, specifically, is where this trade off appears to occur. It, therefore, makes it crucial that further research is carried out with regards to the timing of the application within this window to accurately determine where this tipping point lies and at what point the application gives the greatest compromise between control of bolting and the commercial acceptability and height of the plant stem.

Given that both the treatments of Fazor showed good results in terms of bolting control the dose required to exact this response is debateable and requires further investigation. The maximum recommended application rate for other crops which use Fazor commercially are between the two values tested in this investigation. In potatoes this value is 5kg/ha and for onions it is 4kg/ha. In carrots and parsnips the maximum recommended application rate is 8kg/ha, in which it is used as a specific off-label approval (SOLA).

Conclusions

The application of Fazor gives a highly significant reduction in bolting for late leek production under UK conditions. However, when applied too early it produces short, fat, soft leeks that have a poor shelf life. When applied too late, it fails to stop bolting. There is a window of application, yet to be closely defined, between January and April which will produce the best result. This timing requires further validation and confirmation. Neither of the other products tested, Canopy or Sunorgpro show significant benefits to leek production to merit further evaluation. Further trials with Fazor are required to refine the timing of application of maleic hydrazide and to look at integration of this with varieties of differing maturity and bolt susceptibility. The use of good storage varieties combined with cold storage and successful bolt suppression could potentially allow a significantly increase the UK leek season and see growers able to produce UK leeks for 12 months of the year.

Knowledge and technology transfer

This is a one year project; the results will be presented to the UK Leek Growers Association and their 2011-12 winter meeting.

Glossary

Bolting – The appearance of a flower stalk in the centre of the plant, this particularly occurs with biennial plants such as Alliums in the second season of growth.

Softness – A good quality leek should have a firm straight shank, a soft or flabby shank is unacceptable

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APPENDICES

PA - HDC FV387 Leek PGR's Allpress Farms Hollyhouse 40

Trial plan and application details.

Plot Layout

11	2	7	1	16	8	4	14	17	6	9	3	15	5	10	12	13
9	7	5	11	17	13	15	12	3	14	16	2	6	1	4	8	10
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Treatment List

Treatments		Hectare rates		Water l/ha
	Product	Rate	unit	
1	Fazor 8.0	8000	gm	400
	T1			
2	Fazor 4.0	4000	gm	400
	T1			
3	Canopy	1500	ml	400
	T1			
4	Sunorgpro	800	ml	400
	T1			
5	Fazor 8.0	8000	gm	400
	T2			
6	Fazor 4.0	4000	gm	400
	T2			
7	Canopy	1500	ml	400
	T2			
8	Sunorgpro	800	ml	400
	T2			
9	Fazor 8.0	8000	gm	400
	T3			
10	Fazor 4.0	4000	gm	400
	T3			
11	Canopy	1500	ml	400
	T3			
12	Sunorgpro	800	ml	400
	T3			
13	Fazor 8.0	8000	gm	400
	T4			
14	Fazor 4.0	4000	ml	400
	T4			
15	Canopy	1500	ml	400
	T4			
16	Sunorgpro	800	ml	400
	T4			
17	Untreated	0		400

An example of external bolting in leeks at the field site taken 26th May after harvesting.

A photograph to demonstrate soft and rotten leek.

A photograph to demonstrate the range of internal bolting from low at the bottom to fully bolted at the top.