Project title:	Improving Quality and Extending the Season for Late UK Leeks
Project number:	FV 387b
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Previous report:	None
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Location of project:	Precision Agronomy, Mepal, ELY, Cambs
Industry Representative:	Patrick Allpress, Allpress Farms, Hollyhouse Farm, Horseway, Chatteris, Cambs
Date project commenced:	21st March 2014
Date project completed (or expected completion date):	30th November 2015

DISCLAIMER

[The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.]

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.

[Name]

[Position]

[Organisation]

Signature .... Date ....

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[Name]

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GROWER SUMMARY

Headline

Maliec Hydrazide applied as the product Fazor, gave a highly significant reduction of bolting in late leeks produced under UK conditions. This application technique has the potential to extend the production season of UK by 3-4 weeks, significantly reducing the dependence on leek imports, mainly from Spain, during May and June. There were no significant effects on stem extension with the applications of gibberellins to short stemmed winter hardy leek types.

Background

The earlier project FV 387 examined the use of three different growth regulators on leeks applied during the autumn or in the spring. This project concluded that only maleic hydrazide was useful in reducing bolting and that spring applications were the most promising for reducing bolting without adverse crop effects when compared with autumn applications. In FV 387a maleic hydrazide was further evaluated using spring applications and showed great potential to reduce bolting in over-wintering leeks; however difficulties in the possible registration of maleic hydrazide for leeks led to this project being amended to include a single year's work on gibberellins. Year 2 of FV 387a therefore included work on the effect of gibberellins on the growth, bolting and quality of UK late leeks, whilst also further examining the effects of maleic hydrazide. The results of gibberellin use were interesting and some treatments increased stem length, but because of variability within the plots there were inconsistencies and the results were not statistically significant. The Leek Growers' Association asked for more work to be done over two years to further evaluate the effects of gibberellins on stem extension in the shorter bold hardy winter leek types, whilst keeping a watching brief on the possible development of maleic hydrazide. This is a two year project extension looking at increased numbers of timings and more replicates over two seasons to investigate whether the stem extension effects can be proved more conclusively. Gibberellins are currently approved for use in two stem vegetables; rhubarb and celery to promote stem extension, but not in leeks.

Summary

Fazor (maleic hydrazide) showed excellent promise for extending the season of UK leeks. This can be achieved by a reduction in bolting, the main cause of the loss of quality at the end of the UK leek season. In addition to reducing bolting Fazor has other beneficial effects on leek quality, reducing softness and telescoping, both of which are important quality defects at the end of the UK season. There does, however, need to be caution in the use of this product, should it become approved, as application too early can cause leeks to become too short and fat, and application too late after bolting has occurred does not have any beneficial effects. The effects of gibberellins on the increase of shank length were inconclusive, with some variable results with interesting trends but no significant increase proven from year one of the trial.

Financial Benefits

Currently the UK supplies home grown leeks from around the 1st July until the end of April. Cold storage can increase the length of supply by a few weeks into May.

Leek production in the post-Christmas period between January and May is unreliable because of the effects of severe frosty weather damaging leeks, and the fact that the most frost tolerant varieties tend to have shorter stems which are lower yielding and less favoured by the market. Longer stemmed varieties tend to be more frost susceptible, as well as being quicker to bolt.

Improving the quality and reliability of late leeks would reduce imports and allow more leeks to be grown in the UK.

Using this technique could extend the leek season by up to four weeks, potentially allowing yearlong 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 £30,400,000 this could add a further £2.0-3.0 million worth of production value to this figure.

Action Points

The earlier study FV387a confirmed that the best application window for maleic hydrazide on leeks is during March, as spring re-growth resumes after the winter dormant period. The effects on bolting reduction were proven on two different varieties and over three seasons of work.

The use of gibberellins to increase stem length in winter hardy leeks remains inconclusive and further work in the spring of 2015 is required to confirm any possible benefits. Neither maleic hydrazide nor gibberellins are currently approved for use on leeks.

SCIENCE SECTION

Introduction

Currently the UK supplies home grown leeks from early July until the end of April in 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 potentially be marketed for an extra 3-4 weeks, reducing dependence 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 to date, none have looked into the effects of applying growth regulators to reduce and delay the occurrence of bolting and none have looked at the effects of gibberellins on increasing the stem length of the more winter hardy leek types.

The total value of UK leek production is around £30,400,000 (source Defra hort. Stats 2013). Extending domestic production by 4 weeks could add £2.0-3.0 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 potentially be improved as the use of growth regulators have been shown to improve shelf life and storage quality when applied to other field crops (e.g. 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.

In the earlier project FV 387 three products were tested maleic hydrazide, mepiquat chloride and Trinexapac-ethyl. The first project demonstrated that maleic hydrazide was the best active tested, with regards to reducing bolting; however, timing was crucial, with spring applications performing better than autumn. This follow on project was therefore design to refine the timing of the spring application, test the rate of application and investigate whether the technique could be integrated with storage and different varieties to provide the maximum benefit. Due to uncertainty regarding whether maleic hydrazide will be registered for use in the UK the project objectives in year two were amended to include some work on the application of gibberellins. Gibberellins promote stem extension, therefore we investigated whether they could be applied to winter hardy short stemmed leek varieties with a view to increasing stem length and making those leek varieties more attractive for the UK market. Short stemmed variety types have better winter hardiness than longer stemmed type and therefore could meet the project objective of season extension for UK leeks.

Materials and methods

Methods

Two commercial crops of leeks both of variety Triton F1 were chosen for the experiments. The variety Triton F1 was chosen as it is one of the most winter hardy and reliable leek varieties, but is also one of the shorter types and can usually only be harvested once there has been a considerable amount of spring re-growth, giving it a very short harvest window. Being able to achieve a longer stem length would open the harvest window considerably and give more reliable cropping at the end of the season.

Site One

Location: Nightlayer Leek Co Ltd, Fairview Farm, Cottenham, Cambs.

OS reference: TL 48083 71920.

Field Name: Fairview 1

Soil type: Organic loam

Drilling Date: May 7th 2013, variety Triton, seed rate 320,000/ha

Site Two

Location: Allpress Farms, Hollyhouse Farm, Horseway, Chatteris, Cambs.

OS reference: TL 46064 86916.

Field Name: Hollyhouse 58

Soil type: Peaty loam

Drilling Date: May 10th 2013, variety Triton, seed rate 333,000/ha

A standard commercial crop protection programme for weeds, pest and disease control was applied at each site and fertiliser was applied according to soil analysis. No irrigation was applied at either site.

At each site 9.7% a.i gibberellins as 0.35kg/ha product "Smartgrass" (gibberellins/GA3) was applied at each of the four timings, starting week 12, 14, 16 and week 18. So treatments were, gibberellin applied at each timing, plus three gibberellin treatments applied twice at two different timings weeks 12+14, weeks 14+16 and weeks 16+18. There were two treatments containing Fazor at 4.0kg/ha product (maleic hydrazide 60%) each plus or minus a gibberellin treatment to test possible interactions. This resulted in 9 treatments including untreated controls to give 10 plots in total with three replicates within a fully randomised block design, i.e. 30 plots repeated on two sites to provide a good data set for statistical analysis. Applications were carried out by Peter Hammond of Precision Agronomy using an Azo precision plot sprayer with a 2m boom. Plot size was 2m by 6m, a water application volume of 400l/ha was used at each time.

Treatment List

Table 1: Treatments & Rates Applied

Treatments		Hectare rates	
	Product	**Rate ml/gm/ha**	**Water l/ha**
1	GA3 wk12	350	400
2	GA3 wk 12 & wk 14	350	400
3	GA3 wk14	350	400
4	GA 3 wk 14 & wk 16	350	400
5	GA3 wk 16	350	400
6	GA 3 wk 16 & wk 18	350	400
7	GA3 wk 12, 14, 16, & 18	350	400
8	GA3 wk 12 + Fazor wk 12	350 4000	400
9	Fazor wk 12	4000	400
10	Untreated		

Table 2: Application Timing Site One, Fairview Farm.

	T1	**T2**	**T3**	**T4**
Operator	P Hammond	P Hammond	P Hammond	P Hammond
Date	17/03/2014	31/03/2014	15/04/2014	28/04/2014
Time	1150 – 1224	1000-1010	1000-1010	0915-0920
Temp (°C)	12	13	7	10
Wind Speed (mph)	12	7	6	2
Wind direction	E	NW	SW	S
Cloud cover	60%	Mist/haze	60%	100%

Table 3: Application Timings Site Two, Hollyhouse Farm.

	T1	*T2*	*T3*	*T4*
Operator	P Hammond	P Hammond	P Hammond	*Not applied due to crop destruction*
Date	17/03/2014	31/03/2014	15/04/2014	
Time	1330 - 1400	1115-1125	1100-1115	
Temp (°C)	13	13	9	
Wind Speed (mph)	13	7	7	
Wind direction	E	NW	SW	
Cloud cover	60%	75% High & wispy	40%	

Harvest Assessment – Hollyhouse site

Unfortunately when we came to do the harvest assessments at the Hollyhouse site the trial plots had been mistakenly destroyed by cultivation just hours before. This was despite the plots being well marked. This was apparently due to a communication error. There is therefore no harvest data for this site. This trial site will be repeated in the spring of 2015 to replace the lost data.

Harvest Assessments (Fairview site only)

The plots were harvested at the normal crop maturity time for the surrounding commercial crop. The two centre rows of each plot were lifted by experienced leek harvest workers, the leeks were bulk weighed and counted to give mean leek weight and yield. 25 leeks from each plot were measured for length from base plate to first V (leaf break point), giving 75 measurements per treatment. The same amount of leeks per plot were then cut open and measured for bolting length. There were no visible differences in flag quality at harvest between the treated and untreated leeks.

Statistical analyses

The effects of treatment on plant height and bolt length were analysed using a generalised linear mixed model (GLMM) with a gamma distribution and a log link function. For both models treatment nested within replicate was used as a random factor. Yield data were analysed by taking the average plant weight per bag for each plot in each site. These data were then analysed using a GLMM with a negative binomial distribution and a log link function. In all models, non-significant terms were removed in a step-wise manner to give minimum adequate models. Post-hoc pairwise comparisons of treatments used the sequential Bonferroni method to control for multiple comparisons. All statistics were performed in SPSS (v.21 SPSS Inc., Chicago, IL, U.S.A.).

Results

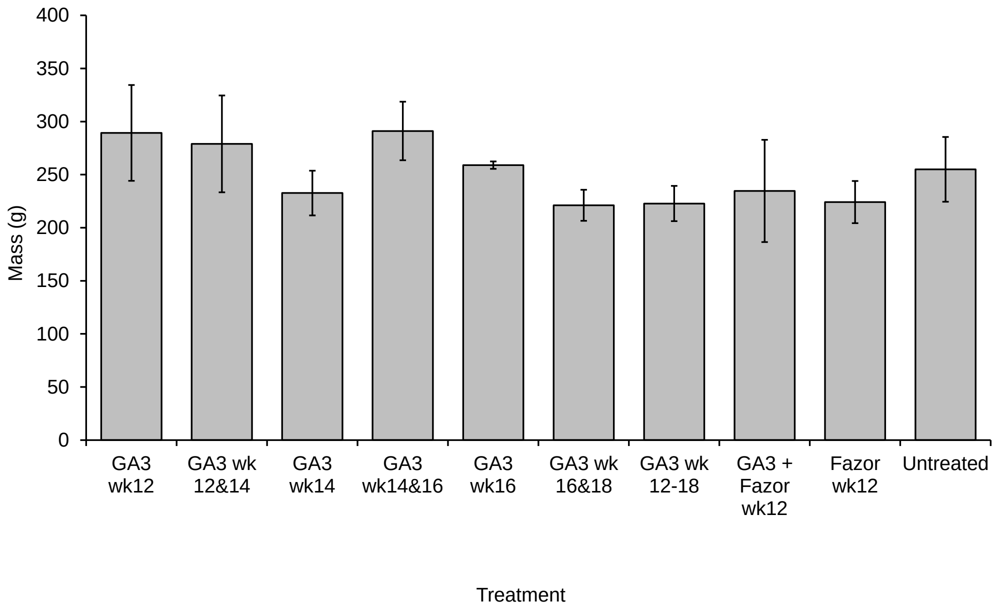

Figure 1: Mean individual leek weight +- standard error

Yield data were analysed by taking the average plant weight per bag for each plot in each site. These data were then analysed using a GLMM with a negative binomial distribution and a log link function. In all models, non-significant terms were removed in a step-wise manner to give minimum adequate models. None of the treatments showed a significant effect on gross yield or individual leek weight.

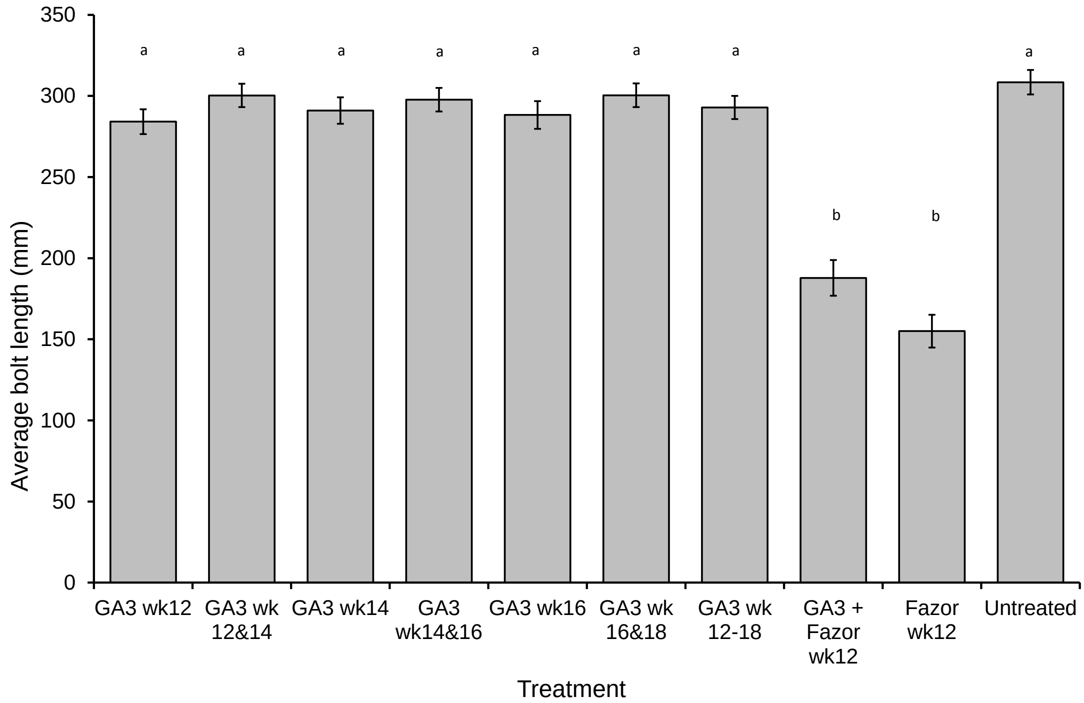

Figure 2: The mean ± standard error of bolt length per plant for each of the 10 treatments. Letters above each bar represent significant pairwise comparisons. Treatment showed a significant relationship with bolt length ($F_{9,\ 738} = 9.56$, $P<0.001$; figure 2). All treatments showed significantly longer bolt lengths than treatments 8 and 9 (8: GA3 + Fazor application at week 12, 9: Fazor only application at week 12); ($P < 0.003$ for all pairwise comparisons). Fazor was therefore very effective in reducing the amount of bolting, when applied on its own or with a gibberellin treatment.

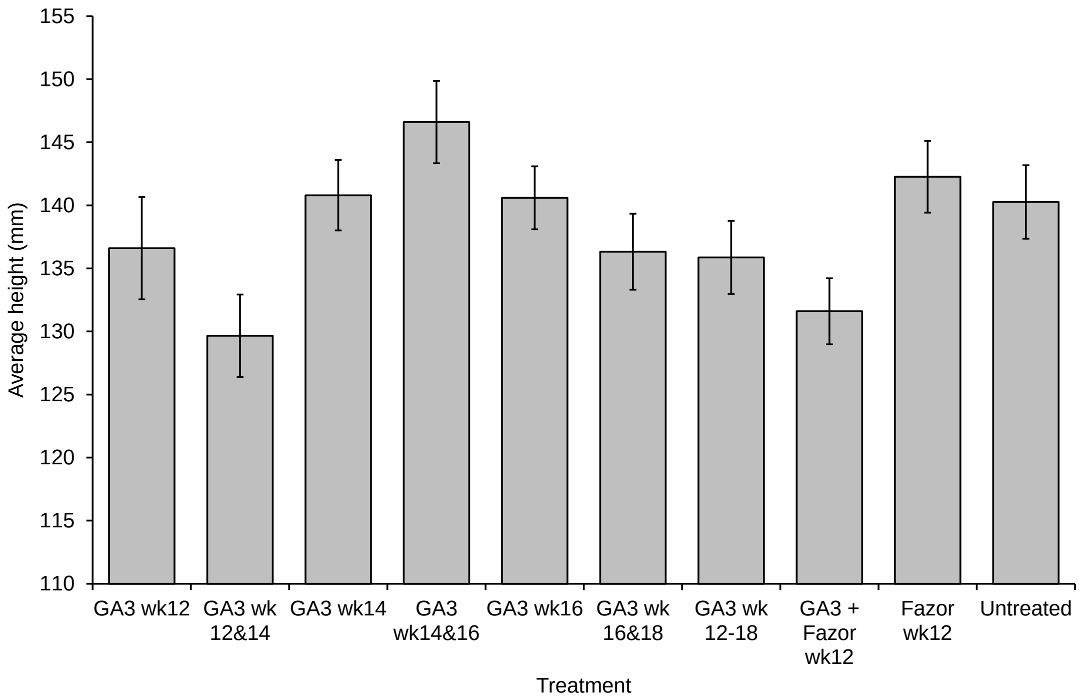

Figure 3: Plant height as length from base plate to first V. There was no significant effect of treatment on plant height ($F_{9,\ 711}$ = 0.001, P = 1.00; figure 3). Although treatments on week14+16 produced the longest leek this result was not statistically significant.

Discussion

With regards to yield it is somewhat encouraging that there were no differences in yield between the treatments as this means none of the treatments had a negative effect on the crop. This would be expected for both maleic hydrazide and gibberellins treatment.

Looking at the results for bolting the applications of Fazor in 12 week gave a significant reduction in bolting. The winter and spring of 2014 were especially mild with few frosts recorded and the warm spring weather meant that many commercial leek crops were running to seed (bolting) very quickly, any technique to slow down bolting would increase the harvest window and would have meant that more leeks would have made a marketable grade. In fact many crops were lost to bolting and had to be destroyed.

There was a concern that gibberellins would make bolting happen more quickly but this did not appear to be the case in this trial as the bolt length in the treated plots was very consistent at between 250-300mm where Fazor had not been applied. Where Fazor was applied together with gibberellins, as in treatment 8, there was still a significant bolt reduction. There was also therefore no negative interaction between maleic hydrazide and gibberellins.

With regards to plant stem length measured as the length between the base plate and first V, there were no differences between treatments, there was quite a large variation in plant length as is typical with this type of leek. One of the biggest effects determining plant height in leek is population density and closeness to the neighbouring plant. It is felt that in this case the small variations in plant spacing from neighbouring plants probably had a greater effect on the final plant height than any of the treatments; it is very difficult to get long runs of consistent plant density in commercial crops of this variety. As the lost 2014 Allpress Triton site trial will be repeated in 2015, it would seem sensible to choose a replacement site with a different variety that maybe would react slightly differently and would maybe have a more consistent population.

Conclusions

As this is an annual report from the first year of a two year project and one of the first year sites was lost, then caution needs to be taken in drawing any firm conclusions. However, it would appear that Fazor gives a significant reduction in bolting of leeks, whilst having no effect on yield or plant height. It would appear gibberellins do not affect yield or bolting and that, in this trial at least, not the plant height. Further work is planned in 2015 on different sites, in a different season and on at least one other variety to further confirm these results.

Knowledge and Technology Transfer

The project results were discussed at the Leek Growers Association meeting on 14th November 2014. Further technology transfer is not planned until after the second year trials are completed.

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

Telescoping

Re-growth of the leaf sheath tops after trimming causing the tops of the leek to form a pyramid shape rather than be flat.

References

The use of fazor in potatoes: Dow Agrosciences (2009)
http://www.dowagro.com/uk/media/potato/20090819.htm <date accessed: 14-07-2011>

Dow AgroSciences Fazor label.
http://msdssearch.dow.com/PublishedLiteratureDAS/dh_04fd/0901b803804fd696.pdf?filepath=/uk/pdfs/noreg/011-01286.pdf&fromPage=GetDoc <date accessed:14-07-2011>

Weibe, J.H. (1994) Effects of temperature and daylength on bolting of leek (Allium porrum L.) Scientia Horticulturae 59:177-185

Wurr, D., Fellows, J.R., Hambidge, A.J. & Fuller, M.P (1999) Growth, development and bolting of early leeks in the UK. *The Journal of Horticultural Science & Biotechnology* **74**:140-146.

DEFRA Basic Hort Stats

https://www.gov.uk/government/publications/basic-horticultural-statistics

Appendices

Table 1a: Plot layout (both sites)

5	10	7	9	4	1	3	2	8	6
6	4	8	1	10	2	9	5	7	3
1	2	3	4	5	6	7	8	9	10 (2m × 6m)

Table 2a: Measured length to first V and bolt length (mm) Rep 1

Rep 1	Height (mm)																			
	T1		T2		T3		T4		T5		T6		T7		T8		T9		T10	
plant	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt
1	105	280	105	280	135	350	135	320	150	270	125	320	120	280	135	130	145	250	155	270
2	80	360	100	350	115	350	125	260	140	310	135	300	130	165	120	120	120	120	150	340
3	105	300	100	240	135	200	130	270	140	300	120	300	130	320	125	300	120	175	150	270
4	110	340	115	280	155	240	120	340	170	320	105	240	110	240	125	180	95	130	140	330
5	100	240	125	350	130	340	110	320	125	190	110	190	130	270	100	230	120	140	140	330
6	100	340	90	350	120	250	170	190	145	240	105	200	155	310	110	125	110	130	110	225
7	90	260	70	350	100	350	140	310	110	170	140	270	125	280	175	155	110	220	130	290
8	90	220	100	350	195	350	170	250	120	40	140	340	125	340	160	165	110	260	100	340
9	100	300	120	350	170	350	165	240	120	200	120	320	120	280	110	120	110	80	110	310
10	110	420	95	240	180	120	170	260	130	340	150	330	130	300	155	120	130	50	135	210
11	125	190	90	320	165	320	125	350	125	290	110	210	105	260	105	210	115	180	130	350
12	170	350	80	350	145	260	150	350	145	140	115	260	115	230	120	215	115	250	120	350
13	95	220	100	350	160	350	100	350	140	300	145	290	115	310	150	280	130	160	160	350
14	95	220	125	270	160	90	165	350	140	320	140	350	130	290	100	100	120	145	130	350
15	105	240	110	260	130	350	135	350	125	240	140	350	130	250	120	210	110	310	150	350
16	100	280	115	230	100	350	115	350	110	270	215	350	120	350	145	260	165	350	120	350
17	90	280	125	280	135	350	220	350	155	130	130	350	115	350	110	100	155	170	130	350
18	105	270	105	350	140	350	170	350	160	300	130	350	115	350	150	250	155	90	150	350
19	90	220	115	350	160	350	170	350	125	350	135	350	100	350	145	190	130	270	145	350
20	100	350	125	350	155	350	130	350	165	350	100	350	155	350	145	60	100	60	120	350
21	110	300	90	325	130	210	125	350	105	350	100	350	135	350	125	190	130	140	130	350
22	115	200	155	150	140	350	140	350	155	350	120	350	155	350	135	145	150	50	115	350
23	90	200	120	260	160	280	190	350	155	350	145	350	120	350	110	350	135	70	120	350
24	90	320	85	220	175	180	125	350	165	350	150	350	120	350	145	350	135	20	125	350
25	85	350	120	310	135	330	140	350	150	350	125	350	135	350	145	350	120	80	155	350
Total	2555	7050	2680	7515	3625	7370	3635	8010	3470	6820	3250	7770	3140	7625	3265	4905	3135	3900	3320	8165
Average	102	282	107	301	145	295	145	320	139	273	130	311	126	305	131	196	125	156	133	327

Table 3a: Measured length to first V and bolt length (mm) Rep 2

Rep 2	Height (mm)																			
	T1		T2		T3		T4		T5		T6		T7		T8		T9		T10	
Stick	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt
1	130	300	140	260	140	270	120	230	140	270	140	155	135	260	155	290	140	130	140	220
2	155	190	80	190	120	280	140	190	165	310	175	330	110	275	125	320	140	180	170	270
3	200	290	150	190	175	330	145	220	105	200	145	240	130	170	120	270	190	165	150	190
4	220	250	150	250	175	235	175	340	170	220	125	290	130	300	160	210	150	230	120	300
5	180	250	145	340	130	300	220	180	150	290	235	220	180	180	120	330	140	100	180	220
6	190	215	120	320	120	310	185	330	145	300	180	200	120	120	160	250	160	110	230	300
7	110	300	110	300	150	250	145	240	150	230	140	320	170	310	155	120	165	50	220	245
8	120	195	140	340	140	285	110	120	125	330	185	300	140	250	180	180	185	270	120	170
9	160	220	140	330	145	250	105	245	170	330	130	260	120	210	115	240	130	250	150	165
10	175	260	130	130	145	225	135	200	95	330	130	325	110	170	160	290	145	320	180	290
11	140	310	110	170	130	160	140	310	145	330	155	320	155	220	170	175	180	250	130	26
12	165	310	130	200	145	350	120	350	140	240	140	340	130	280	130	340	145	240	135	300
13	160	260	105	240	150	350	115	350	110	330	140	200	140	330	150	170	150	170	125	330
14	120	320	100	350	110	350	140	350	145	220	125	270	90	230	120	340	155	345	130	220
15	155	250	150	350	160	350	140	350	135	290	140	350	130	340	110	220	130	210	170	110
16	150	350	145	350	120	350	120	350	150	180	100	350	110	320	130	250	145	210	140	350
17	200	350	165	350	125	350	150	350	160	340	120	350	130	350	160	300	145	50	185	350
18	160	350	170	350	120	350	125	350	100	350	130	350	120	350	160	260	220	40	130	350
19	140	350	155	350	175	350	125	350	140	350	140	350	120	350	150	190	160	230	180	350
20	120	350	150	350	150	350	145	350	100	350	150	350	105	350	130	250	195	165	140	350
21	180	350	130	350	170	350	145	350	110	350	120	350	160	350	110	180	210	210	145	350
22	160	350	150	350	195	350	115	350	150	350	150	350	155	350	140	130	110	130	110	350
23	175	350	150	350	105	350	165	350	135	350	135	350	160	350	105	350	170	100	155	350
24	190	350	140	350	135	350	140	350	130	350	110	350	145	350	130	350	145	120	100	350
25	125	350	130	350	125	350	200	350	145	350	175	350	175	350	120	350	140	160	140	350
Total	3980	7420	3385	7460	3555	7795	3565	7505	3410	7540	3615	7620	3370	7115	3465	6355	3945	4435	3775	6856
Average	159	297	135	298	142	312	143	300	136	302	145	305	135	285	139	254	158	177	151	274

Table 4a: Measured length to first V and bolt length (mm) Rep 3

Rep 3	Height (mm)																			
	T1		T2		T3		T4		T5		T6		T7		T8		T9		T10	
Stick	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt	V	Bolt
1	105	300	180	170	145	200	140	250	155	280	80	150	255	220	120	145	150	150	140	325
2	155	330	135	300	155	220	150	230	130	260	120	180	130	300	110	160	145	30	95	330
3	130	200	150	330	105	280	130	345	155	220	120	250	150	260	130	170	155	90	125	265
4	140	220	95	155	130	180	135	200	170	125	130	280	135	330	135	90	140	85	170	230
5	105	300	130	270	155	290	110	250	100	160	180	320	120	305	170	60	190	235	90	280
6	175	100	140	165	145	170	135	230	190	330	125	190	140	170	130	30	165	210	130	340
7	150	210	130	290	120	270	110	230	185	330	135	230	120	260	140	60	145	110	120	300
8	145	225	135	310	140	240	190	260	160	300	155	230	140	320	135	80	140	170	130	210
9	145	265	140	300	125	340	135	240	110	285	160	240	175	310	195	120	120	90	110	280
10	150	190	195	320	130	240	180	200	130	100	180	320	125	290	80	190	130	120	135	300
11	170	110	130	230	180	250	130	300	160	210	100	120	185	190	110	50	145	220	155	350
12	150	220	170	270	145	195	180	230	190	190	120	220	140	160	115	55	130	110	130	350
13	130	280	135	295	135	140	165	180	160	340	120	220	135	240	120	80	165	60	130	350
14	110	180	120	290	125	210	120	200	125	280	130	340	165	210	125	105	150	115	150	350
15	155	210	125	350	100	210	140	290	120	350	150	350	130	250	125	110	135	155	170	350
16	210	350	190	350	110	220	120	245	120	350	105	350	120	260	100	40	145	80	155	350
17	120	350	100	350	210	200	160	250	150	350	135	350	110	350	100	40	130	90	120	350
18	180	350	160	350	120	350	225	230	150	350	130	350	170	350	150	50	160	20	150	350
19	140	350	150	350	170	350	150	350	160	350	140	350	140	350	155	130	150	225	145	350
20	160	350	165	350	140	350	205	350	145	350	160	350	130	350	100	270	155	40	150	350
21	145	350	175	350	115	350	180	350	140	350	100	350	120	350	100	180	130	70	135	350
22	120	350	195	350	145	350	150	350	120	350	120	350	170	350	110	300	110	10	185	350
23	150	350	110	350	100	350	160	350	145	350	145	350	170	350	115	190	110	105	120	350
24	210	350	125	350	110	350	135	350	150	350	160	350	130	350	150	90	150	350	140	350
25	160	350	180	350	125	350	160	350	145	350	160	350	175	350	120	30	145	350	145	350
Total	3710	6840	3660	7545	3380	6655	3795	6810	3665	7260	3360	7140	3680	7225	3140	2825	3590	3290	3425	8110
Average	148	274	146	302	135	266	152	272	147	290	134	286	147	289	126	113	144	132	137	324

Table 5a: Measured length to first V and bolt length (mm) Replicate Means and Standard Errors

Plot	Treatment	V length	Mean	Bolt	mean	std err bolt length	std err plant height
1	GA3 wk12	10245	136.6	21310	284.1333	7.672563341	4.053871467
2	GA3 wk 12&14	9725	129.6666667	22520	300.2667	7.217279898	3.267824763
3	GA3 wk14	10560	140.8	21820	290.9333	8.142145573	2.793235071
4	GA3 wk14&16	10995	146.6	22325	297.6667	7.235630888	3.264332734
5	GA3 wk16	10545	140.6	21620	288.2667	8.523678378	2.50037835
6	GA3 wk 16&18	10225	136.3333333	22530	300.4	7.292325968	3.007997348
7	GA3 wk 12-18	10190	135.8666667	21965	292.8667	7.166723235	2.896679263
8	GA3 + Fazor wk12	9870	131.6	14085	187.8	10.97960435	2.618644172
9	Fazor wk12	10670	142.2666667	11625	155	10.09593621	2.84160425
10	Untreated	10520	140.2666667	23131	308.4133	7.546757393	2.909898195

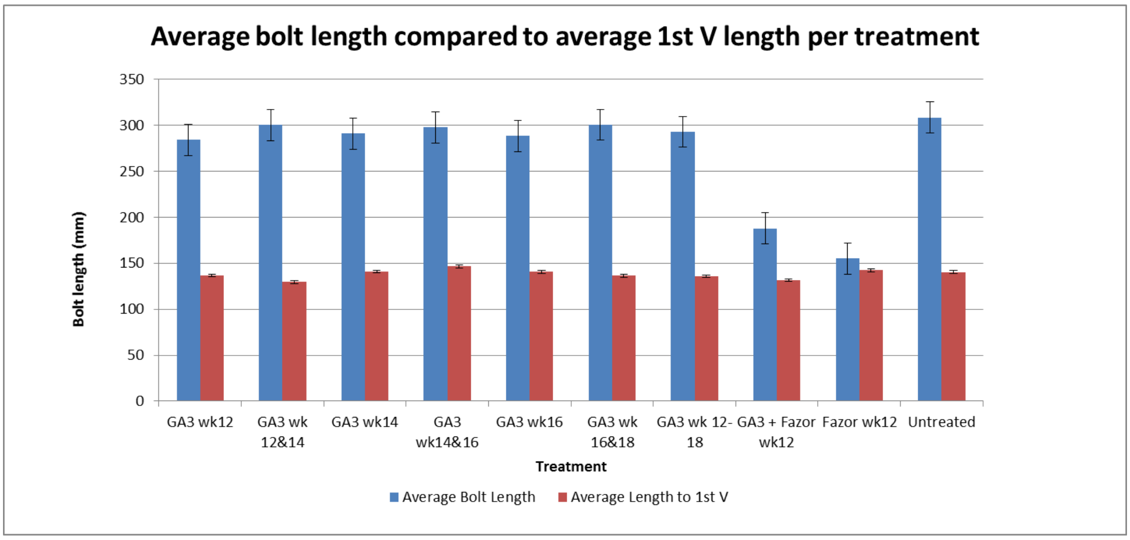

Figure 1a: Average bolt length compared to length to first V.

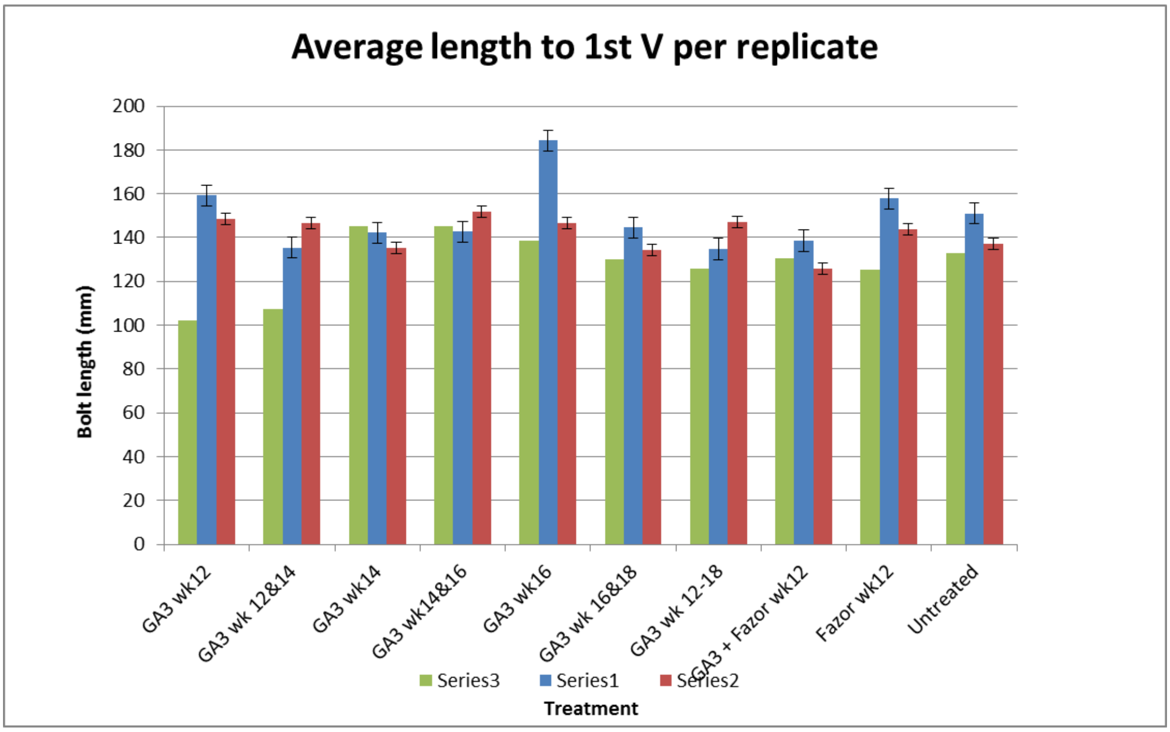

Figure 2a: Plant length to first V by replicate.

Table 6a: Plot weights and mean plant weights per treatment.

Rep 1		Weight (kg)									
		Trt1	Trt2	Trt3	Trt4	Trt5	Trt6	Trt7	Trt8	Trt9	Trt10
	Number	66	59	67	69	73	75	83	95	78	80
	Weight	20.68	22.04	18.99	19.89	19.93	18.39	19.68	21.08	15.56	17.09
	Sling	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total (kg)		19.93	21.29	18.24	19.14	19.18	17.64	18.93	20.33	14.81	16.34
Average		0.30	0.36	0.27	0.28	0.26	0.24	0.23	0.21	0.19	0.20
mean gm		301.9697	360.8475	272.2388	277.3913	262.7397	235.2	228.0723	214	189.8718	204.25
Rep 2		Weight (kg)									
		Trt1	Trt2	Trt3	Trt4	Trt5	Trt6	Trt7	Trt8	Trt9	Trt10
	Number	63	83	81	53	88	72	84	58	83	74
	Weight	23.45	23.39	19.03	19	22.93	17.77	16.86	19.68	19.34	23.68
	Sling	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total (kg)		22.7	22.64	18.28	18.25	22.18	17.02	16.11	18.93	18.59	22.93
Average		0.36	0.27	0.23	0.34	0.25	0.24	0.19	0.33	0.22	0.31
mean gm		360.3175	272.7711	225.679	344.3396	252.0455	236.3889	191.7857	326.3793	223.9759	309.8649
Rep 3		Weight (kg)									
		Trt1	Trt2	Trt3	Trt4	Trt5	Trt6	Trt7	Trt8	Trt9	Trt10
	Number	100	101	94	92	77	89	80	117	89	92
	Weight	21.3	21.28	19.56	23.9	20.93	17.82	20.63	19.88	23.78	23.82
	Sling	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total (kg)		20.55	20.53	18.81	23.15	20.18	17.07	19.88	19.13	23.03	23.07
Average		0.21	0.20	0.20	0.25	0.26	0.19	0.25	0.16	0.26	0.25
mean gm		205.5	203.2673	200.1064	251.6304	262.0779	191.7978	248.5	163.5043	258.764	250.7609

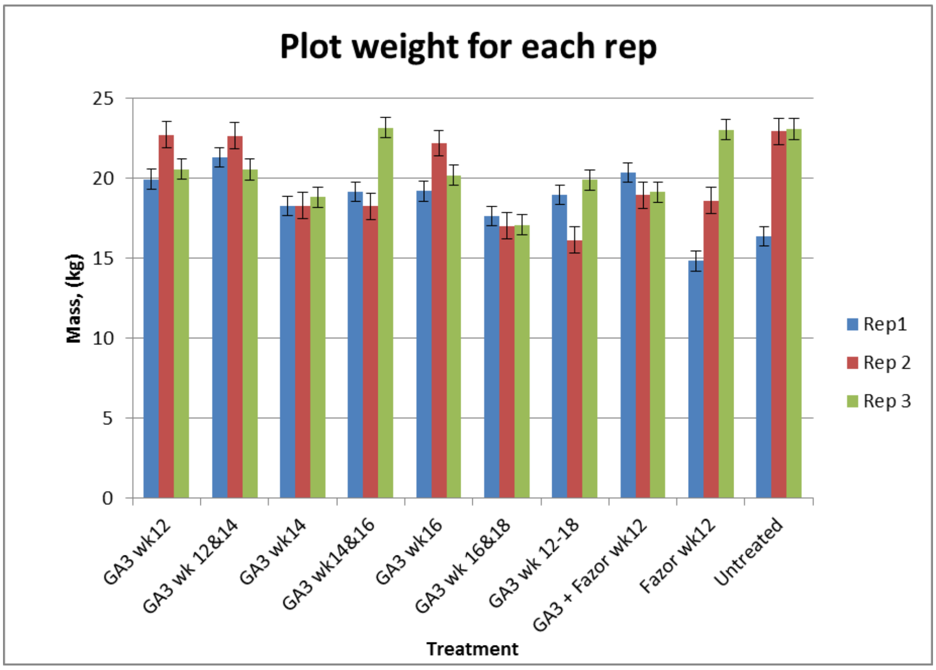

Figure 3a: Plot weights by replicate.

