Project Title	Asparagus: Further investigation into the benefits of photo selective plastics
Project number:	FV 321
Project leader:	Mark Huey (replaced by Cathryn Lambourne, June 2007)
Report:	Final report, March 2008
Key staff:	Mark Huey Stacy Lambourne Cathryn Lambourne Iwona Burdon Deborah Liddell
Location of project:	Stockbridge Technology Centre
Project coordinator:	Peter Knight, Holly Cottage, 24 Damgate Lane, Martham, Gt. Yarmouth, Norfolk NR29 4PZ
Date project commenced:	March 2007
Date completion due:	March 2008
Key words:	Asparagus, Gijnlim, Jersey Giant, Photoselective plastic, Spanish tunnels, UVO, UVT, Solatrol, Luminance, yield, spear emergence.

The results and conclusions in this report are based on a series of experiments 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.

Report authorised by:

Cathryn Lambourne
Project Manager
Stockbridge Technology Centre Ltd

Signature .... Date ....

Dr G M McPherson
Science Director
Stockbridge Technology Centre Ltd

Signature .... Date ....

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Grower Summary

Headline

- The asparagus crowns established more quickly under protection than in field plots. Harvests after 1 year instead of 2 being realistic with some varieties.

- Growing asparagus under polythene covers can produce harvestable Class 1 spears approximately 9-11 days earlier than conventionally grown field crops.

- Increased yields were observed in protected crops relative to an equivalent outdoor cropped area, harvested at STC during 2006 (CP 19) and 2007 (FV 321).

- Whilst there were demonstrable differences between protected and non-protected crops were observed, there appeared to be few clear differences between the different plastics under investigation

- There was a significant improvement in the number of class 1 spears, mean spear weight and spear diameter in crops grown under protection compared to the equivalent outdoor cropped areas.

- Fern height, strength, disease resistance and root development all appeared to be improved in the crops grown under protection.

- The choice of variety may be important when growing asparagus under protection and varieties bred for use in warmer climates are likely to show greater benefits than those bred for cooler climate production.

Background and expected deliverables

The retail value of asparagus in the UK is approximately £50 million per annum. Approximately 35% of this is home grown, being produced over a relatively short season, often a maximum of 10 weeks. Following a high profile PR campaign in 2004 the industry successfully increased its market penetration and the average annual consumption has increased from approximately 80g to around 120g per person in the UK over the last 5 years. There is currently 1400ha of asparagus being produced in the UK, by approximately 200 businesses, often using production systems that have changed very little over many years. In an expanding and competitive market-place, the industry needs to understand whether alternative, cultural techniques can improve yield and quality yet still provide a viable economic return.

The agronomic benefits of growing a large range of crops under particular photoselective claddings was demonstrated in the HDC funded project CP 19 at Stockbridge Technology Centre. Asparagus crowns of two asparagus varieties; Gijnlim and Jersey Giant, established under the various plastics as part of CP 19, showed distinct differences in the fern growth and cropping times compared to an unprotected crop growing beside the Spanish tunnels used in this investigation. Asparagus crops in the UK are traditionally field grown, however in recent years an increasing percentage of UK asparagus has been raised under protection to lengthen the harvest times for this short season crop. The aim of this 1 year project was to follow-up the interesting and positive data gathered in CP 19 and to provide further data on which, if any, of the plastic claddings produced the greatest agronomic benefits in this crop.

Five claddings were used in this study with an outdoor cropped area included for comparison. The claddings evaluated were; Standard, UV-opaque, UV-transparent, Solatrol (able to absorb far-red light) and Luminance which has light diffusing properties. The claddings were used to cover Haygrove multi-span Spanish style tunnels with open sides between March and October each year.

Plate 1. View of Spanish style Haygrove tunnels at STC

The module raised asparagus crowns were planted in 2004 (Batch 1, whilst Batch 2 were planted in 2005), and were cropped for the first time in 2006 (the final year of CP 19). A number of economically beneficial attributes were observed on the protected crops compared to the outdoor crop during the initial studies in CP 19. The aim of this additional year of work in the current project (FV 321) was to validate the promising results from 2006. Also, to ensure optimisation of irrigation on the crop, 'EnviroSCAN' sensors were installed which provided weekly updates from Peter White regarding water usage and requirements. Regular Brix testing on the crop also provided information on any changes in carbohydrate reserves in the crop via the 'AspireUK' software package.

Summary of the project and main conclusions

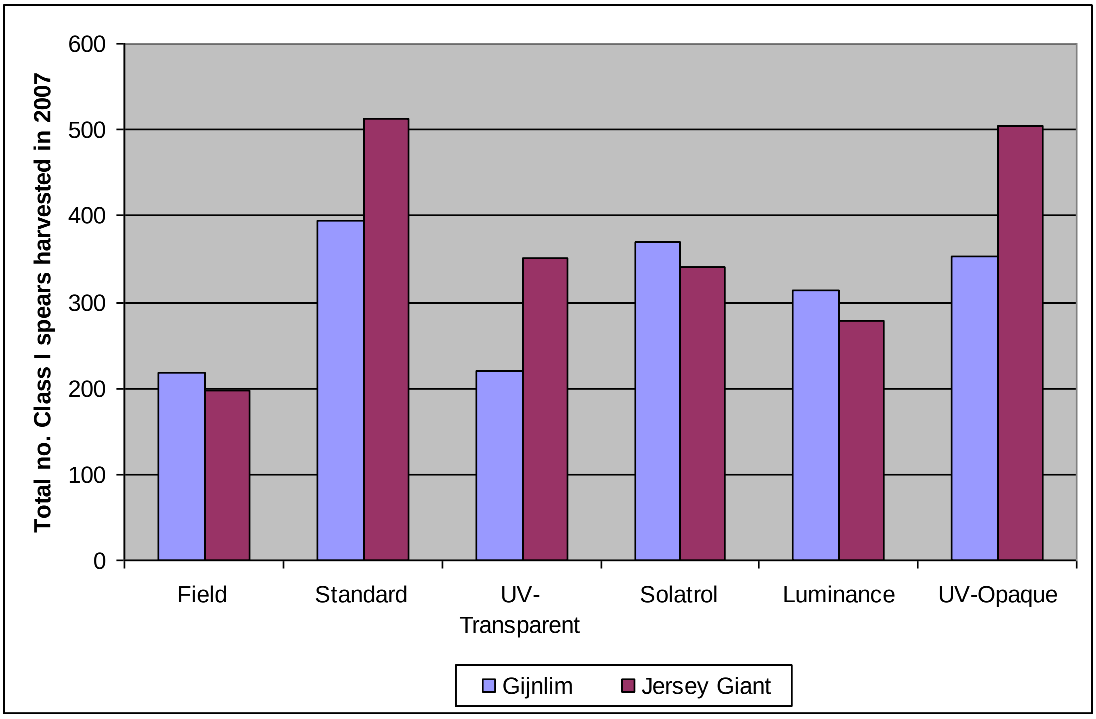
Module raised plants of Gijnlim and Jersey Giant asparagus were received at STC in 2003. They were potted-up over the winter and planted at 2 different planting dates which were labeled as Batch 1 and Batch 2, data included in this study all relates to the Batch 1 crop which established better. Planted in 2004, the crowns were allowed to establish prior to the first crop being harvested in 2006. As different parameters were measured on the crop under CP 19, this report focuses solely on the data generated under FV 321 during the period March 2007 to March 2008.

Data was collected on yield, spear emergence dates, class of spears, fern establishment, nutritional analysis of ferns, pest and disease incidence and severity and the incidence of secondary fern growth. Samples of roots were also tested on 3 occasions during the growing season to measure the carbohydrate content of the roots to gain feed-data back via the 'AspireUK' software. At the end of the investigation excavations around the crowns allowed us to determine the approximate root mass.

Although the Batch 1 (planted in 2004) crop was not harvested until 2006, examination of the protected crops by an independent agronomist (Peter Knight) during 2005 indicated that harvesting in 2005 would have been economically worthwhile. Such a reduction in the time for crown establishment could have important financial benefits for growers in the UK.

Improvement in overall yield (all classes) was seen on all the crops grown under protection, irrespective of the cladding material, and this was particularly evident in the cv. Jersey Giant which was originally bred for warmer climates.

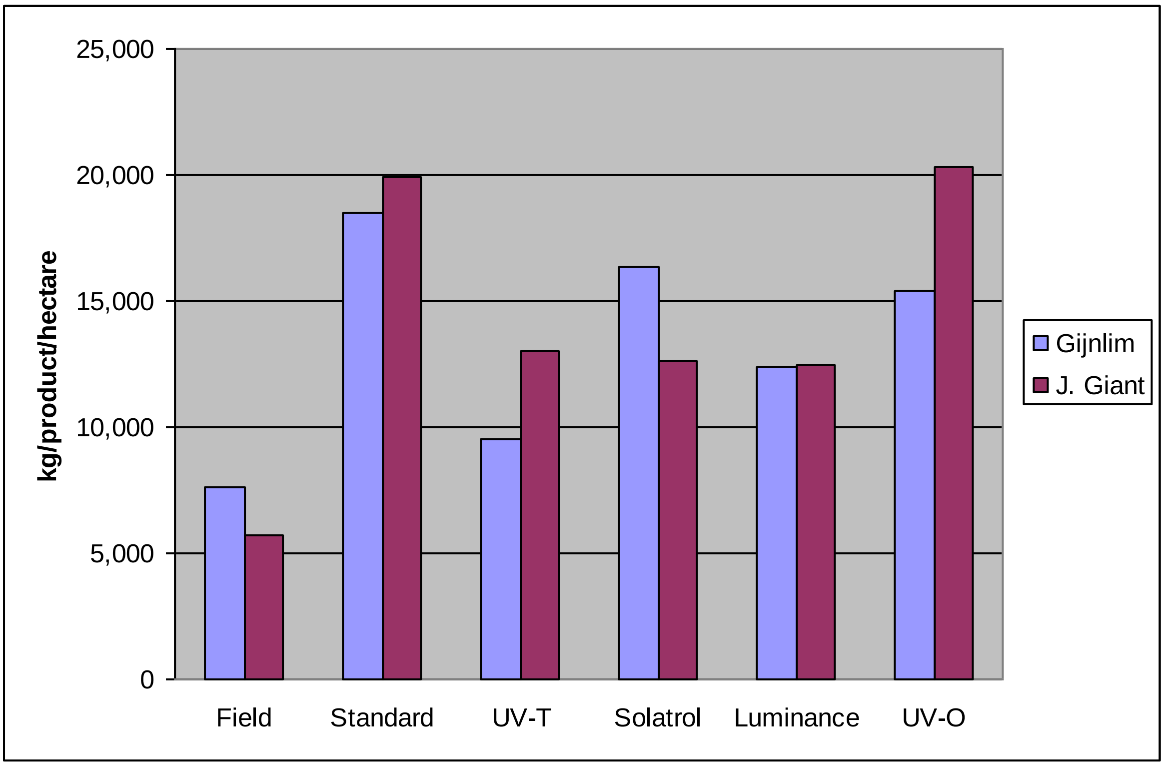
Chart 1. A comparison of the total number of Class 1 spears harvested in 2007



Note: Data shown is based on Batch 1 harvests in 2007 with spears collected from 16 crowns/plot

Spear harvest weight and girth were recorded on a weekly basis during the harvest period. This data has been used to estimate the projected yield in kilograms of product (Class 1 spears) per hectare (Chart 2).

Chart 2. Estimated yield of Class 1 spears over the season in kg/product/ha



Data shown is based on Batch 1 harvests in 2007

This data clearly demonstrates the potential for improving the financial benefits of this crop by growing under some form of protective cover. It should also be borne in mind that the Haygrove tunnels used in this investigation were in the Spanish style e.g. had open sides and ends. There may be the potential for greater improvements to yield in tunnels with a more 'closed' structure. However, it should also be noted that the figures shown, even in the outdoor cropped areas, also demonstrate a large increase on standard commercial production (P. Knight pers comm.). The most likely explanation for this discrepancy is that that the experimental plots were relatively small and have less competition for root space, light and water compared to a fully cropped field environment. Extrapolation of yield data therefore tends to over estimate potential yield and, as such, the data in chart 2 must be treated with some caution. However, it does hopefully put the relative yield increases in context.

Pest and disease pressure was low across the whole trial area including the outdoor cropped areas and in the tunnels during 2007. Low levels of asparagus beetle were seen, but were kept under control by predatory spiders. No crop protection products were applied to the crops during 2007. Fern stem bases were strong and healthy with little or no incidence of *Stemphylium*, *Botrytis* or *Fusarium* infections on the tunnel crops (Plates 2 & 3) whilst slightly higher levels of *Stemphylium* particularly were observed on the outdoor area. This factor may well be significant in years when environmental conditions are more conducive to disease development on outdoor crops resulting in the reduction of pesticide applications to protected crops.

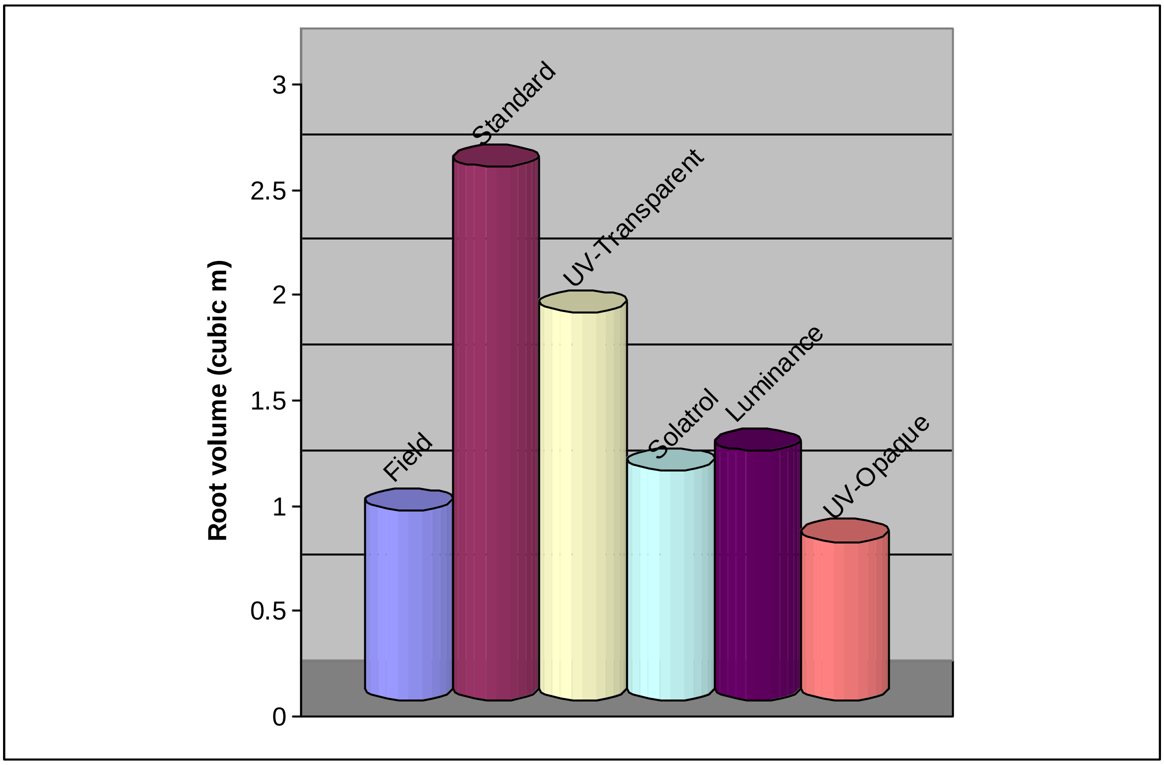
Plates 2 & 3. Comparison of fern base on the field and Luminance crop

Fern nutrient analyses carried out in August, September and October showed little variance across the sample dates and plots suggesting that the various crops were managing to get sufficient levels of nutrition. There is a suggestion that the higher levels of Magnesium, Calcium and Boron in the crops grown under protection indicate that the improved environment and general health have aided uptake.

Brix% testing on the roots of the Gijnlim Batch 1 was carried out on 3 occasions; at the end of harvest, 6 weeks after the end of harvest and at fern senescence. The values were fed into the AspireUK software to provide some indications of the carbohydrate content of the roots in each plot. Overall the carbohydrate content of the roots was similar across all plots irrespective of location i.e. protected or outdoors. However, in the samples collected 6 weeks following the end of harvest the roots collected from the Solatrol tunnel were showing 'unusually high' carbohydrate (CHO) levels. A range of possible reasons for this were provided by AspireUK. The most likely cause was that 'the spear harvest in this treatment was too short and it could potentially have been extended without harming the crop'. Samples collected in November (at fern senescence) gave CHO values falling into 3 bands. CHO in roots from UV-Transparent, Solatrol, Field and UV-Opaque tunnels were below the desirable levels for a healthy crop. The possible cause for this may be that 'the reading may have been taken too early before the crop had completely senesced, and root-recharge was incomplete'. It was certainly true that the crops under protection were still showing a lot of green fern at the sampling date. The sample from the Standard tunnel showed 'satisfactory' CHO content, while the Luminance roots were 'full of CHO' ... suggesting that ..'a good harvest could be anticipated next year'.

Investigation of the approximate root mass indicated that the root mass was larger in the majority of samples taken from the crops under protection than that recorded in the field cropped area. This could have impacts on yield in the following year, particularly when the information is linked to the carbohydrate content (Brix %). The data suggests that greater reserves of CHO will be stored in the roots of protected crops; hence elevated yields being possible.

Chart 3. Calculated root mass of a Gijnlim crown at each site.



Financial benefits

FV 321 has provided data which supports a whole range of potential financial benefits for the asparagus industry. These include extension of the season which impacts on increased yield, increased numbers of Class 1 spears, increased average spear weight and increased average number of spears/crown over the season. Ferns established 7-10 days earlier on the protected crops and stayed green for longer at the end of the season, only senescing when the plastic covers were removed at the end on November. This may well impact on the ability of the crowns to store carbohydrate and 'fill the tank' ready for the following season.

Measurements of root mass demonstrated that root development and extension in the protected crops was considerably larger than in the field plots and this along with the calculated carbohydrate content values generated by AspireUK suggest that protected crops may store high levels of carbohydrate which could be expected to translate into higher yields in subsequent years.

Crops grown under plastic covers will undoubtedly benefit from improved irrigation control and complete leaf dryness both of which are likely to reduce disease pressure in the crop. This in turn should result in a reduction in pesticide applications.

Action points for growers

- Consider the potential benefits of season extension and yield enhancement for asparagus production under protection.
- Data collected during 2007 (and previously in 2006 CP 19) suggests that the benefits of growing asparagus under protection are as good, or better, when standard polythene is used as compared with the alternative cladding materials which offer particular wavelength factors.
- Choice of varieties may be important if growing under protection. It may be possible to utilize this information to extend harvest times at either, or both, ends of the traditional harvesting period.
- The use of EnviroSCAN, or similar, irrigation advice can be beneficial for cost effective water management
- The recommendations provided by AspireUK can provide sound crop management advice when used over successive seasons.
- Production under plastics should have the added advantage of reducing pest and disease incidence, thereby minimizing the need for crop protection products, thus helping environmental protection more broadly.

Science Section

Introduction

Spanish-style Haygrove tunnels were erected at STC in 2002/3 and covered with a range of different (5) plastics with specific light filtering properties. The plastics used were; standard, UV-opaque, UV-transparent, Solatrol (absorbs far-red light) and Luminance (light diffusing properties). The plastics remained in place between March and November in each year of the project. An adjacent outdoor cropped area was used for comparison purposes. The structures were originally erected as part of the HDC funded project CP 19 which studied the impact of the differing light transmissions on plant growth, pests, disease, and flavour amongst other parameters on a large range of horticultural crops ranging from herbs to brassica propagation to cut flower production. As part of this project plots of 2 cultivars of Asparagus (Gijnlim and Jersey Giant) were established to investigate any potential benefits from growing under plastic generally, but, more specifically, also under the specialised plastics listed above. As with other crops, the outside cropped areas provided a direct comparison.

HDC project CP 19 was finalised in 2006 at which time only 1 year of harvest data had been collected on the asparagus plots. An additional year of funding by the industry through HDC allowed the collection of further data under FV 321. This additional year was extremely valuable, allowing further validation and generation of data to support the preliminary findings in CP 19.

It is important to remember that the data collected is based on measurements recorded on spears harvested from 2 relatively short rows of asparagus e.g. not a full field capacity planting and that extrapolation that have been used should be treated with caution.

Materials and Methods

The plastic covers were replaced on the Haygrove structures in March 2007, using polythene stored from the previous year. Each plot was originally planted with 16 module raised plants in two batches. Batch 1 was planted in 2004 and Batch 2 in 2005.
Trickle tape irrigation was used in all plots. EnviroSCAN sensors were already in position in the middle of the Batch 1 row of plants in each plot having been installed in 2006 by

Peter White. These sensors were solar powered and the data collected could be remotely accessed by Peter White to enable interrogation and interpretation and thus provide us with weekly updates on the water requirements and usage of the crop.

The crops were monitored closely throughout the season and data was collected on the date of 1st spear emergence, the class, number and weight and diameter of spears harvested. During the harvesting period spears were cut daily and records of the number and diameter of spears under each Class rating was made

e.g. Class 1, 2 and 3

Spear base diameter of	0 - 8mm,
	8-12mm
	12-16mm
	16-20mm
	20+mm

Plate 2. Class 1 spears were relatively straight with tight heads with no defects

Plate 3. Class 2 spears were less straight and had looser or slightly blown heads

Plate 4. Class 3 spears were often distorted, spindly or had loose 'blown' heads

A weekly detailed assessment was made which recorded the weight of each harvested spear along with the class and spear thickness at the base and the mid-point.

The date of fern establishment was also recorded. Once the ferns had established regular monthly samples of fern tips were sent for full nutrient analysis to allow comparison of growth effects in the crops under the different plastics and the field site. The fern samples were collected on the 6th August, the 10th September and the 11th October. The fern tips were taken from the same height in the crops to ensure that they were of the same maturity.

Brix % Testing

Samples of roots were also collected from each plot at 3 key times during the season; these were:-

i. at the end of harvest
ii. 6 weeks after the end of harvest
iii. at fern senescence.

The root samples were subjected to Brix% testing using a standard methodology (full method shown in Appendix 3).

The results collected from the Brix% testing were fed into the *AspireUK* software. This program estimates root system carbohydrate content by assessing measurements of the Brix% of sap solution extracted from storage roots sampled from the crop.

Root carbohydrate content is variable within a crop, so ideally 20 to 40 root samples are needed on each measurement occasion to obtain a reliable estimate of carbohydrate content.

Brix% of sap is measured using a refractometer with a range from 0 to 32%. Values higher than 32 seldom occur and, to guard against errors, *AspireUK* will not accept values above 32.

The system was developed in New Zealand during the late 1990s and has been adapted for UK asparagus production systems by Dr Kim Green of ADAS in a project supported by British asparagus growers through the HDC (HDC Project FV 271). The system and the science behind it were described in papers presented at the 10th International Asparagus Symposium at Niigata, Japan in September 2001 and at the 11th International Asparagus Symposium at Horst, The Netherlands in June 2005.

Registered member growers can feed Brix% values into the program via a secure log-in area and use the interactive delivery system to:

- Decide when to stop harvesting based on the carbohydrate content of the roots.
- Evaluate the effect of extended harvests on carbohydrate reserves.
- Identify root carbohydrate recharge during the summer and autumn.
- Assess the effects of management inputs on carbohydrate recharge during fern growth.
- Determine if pest or disease outbreaks are influencing carbohydrate replenishment.

(See www.aspireUK .org for more information)

The crops were also monitored for the incidence and severity of pests and disease during the trial period. At the end of fern senescence the dead ferns were removed and excavations within the plots were carried out to help estimate the total crown volume. This was done by digging trenches with a mini-digger to determine the horizontal spread and vertical depth of the root system (Figure 1). This was carried out on one Gijnlim crown in Batch 1 under each cladding and in the outdoor plot.

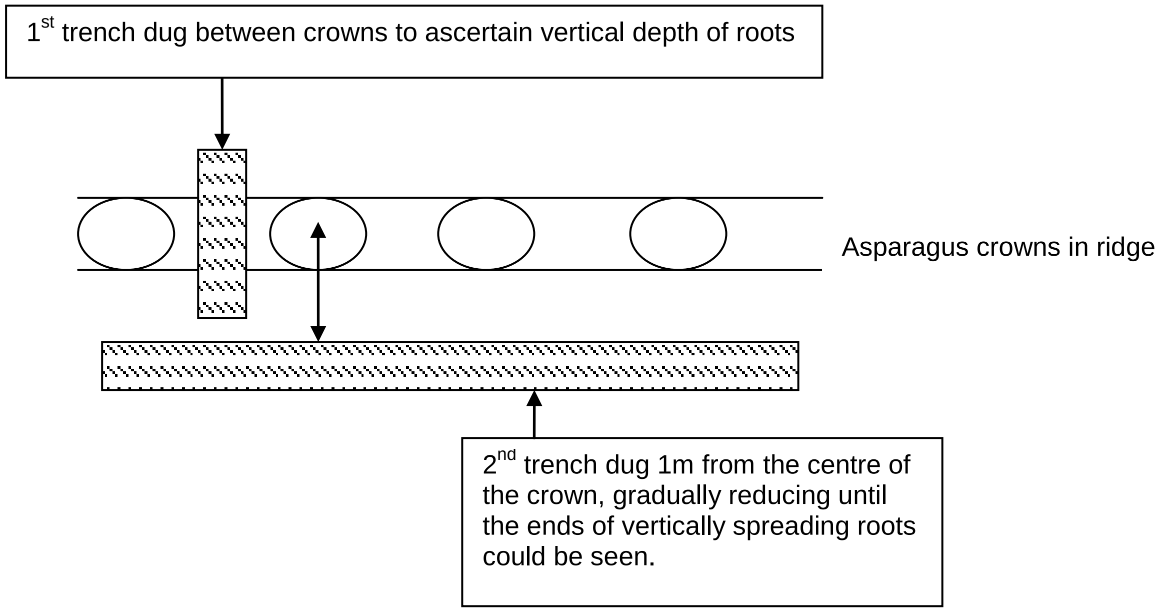


Figure 1. Diagram showing excavations carried out to determine crown volume.

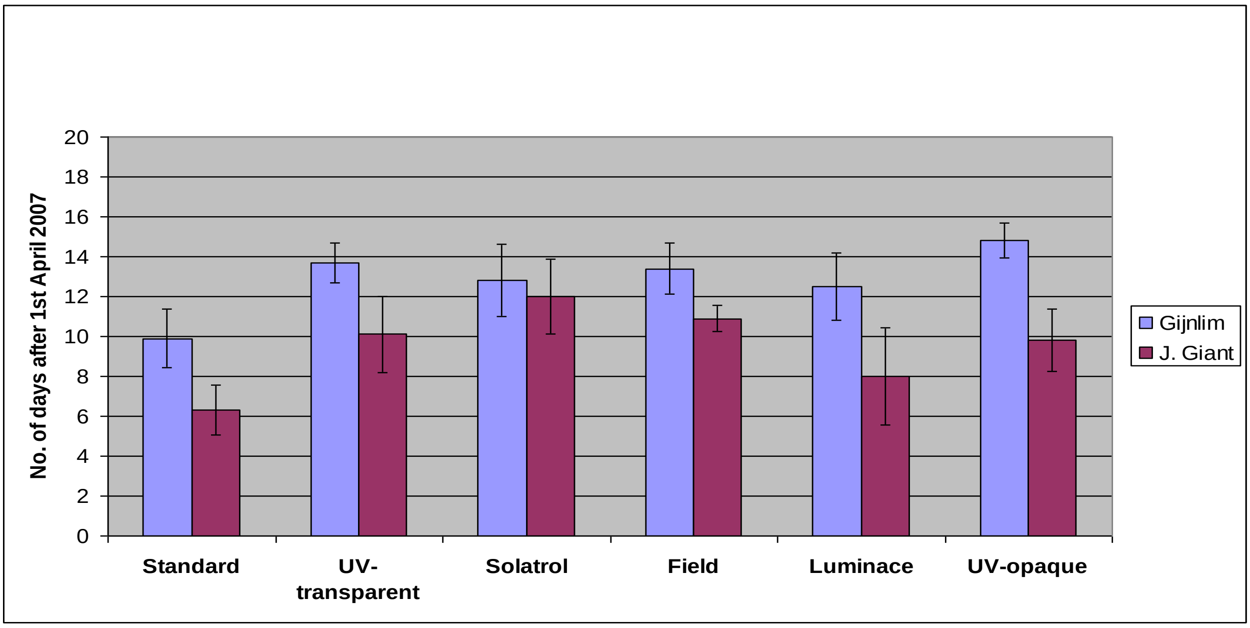
Results and Discussion

Yield

Emergence

One potential benefit of producing asparagus under polythene covers would be to produce harvestable spears slightly ahead of the typical season starting in mid-April. Spear emergence at STC in 2007 was recorded to provide information in this aspect. The mean data is shown in Chart 4 (average of 10 crowns per plot) with full raw data sets showing actual date of emergence in Appendix 2.

Chart 4. The mean number of days to 1st spear emergence after 1st April 2007.



Data shown is taken from the Batch 1 planting only

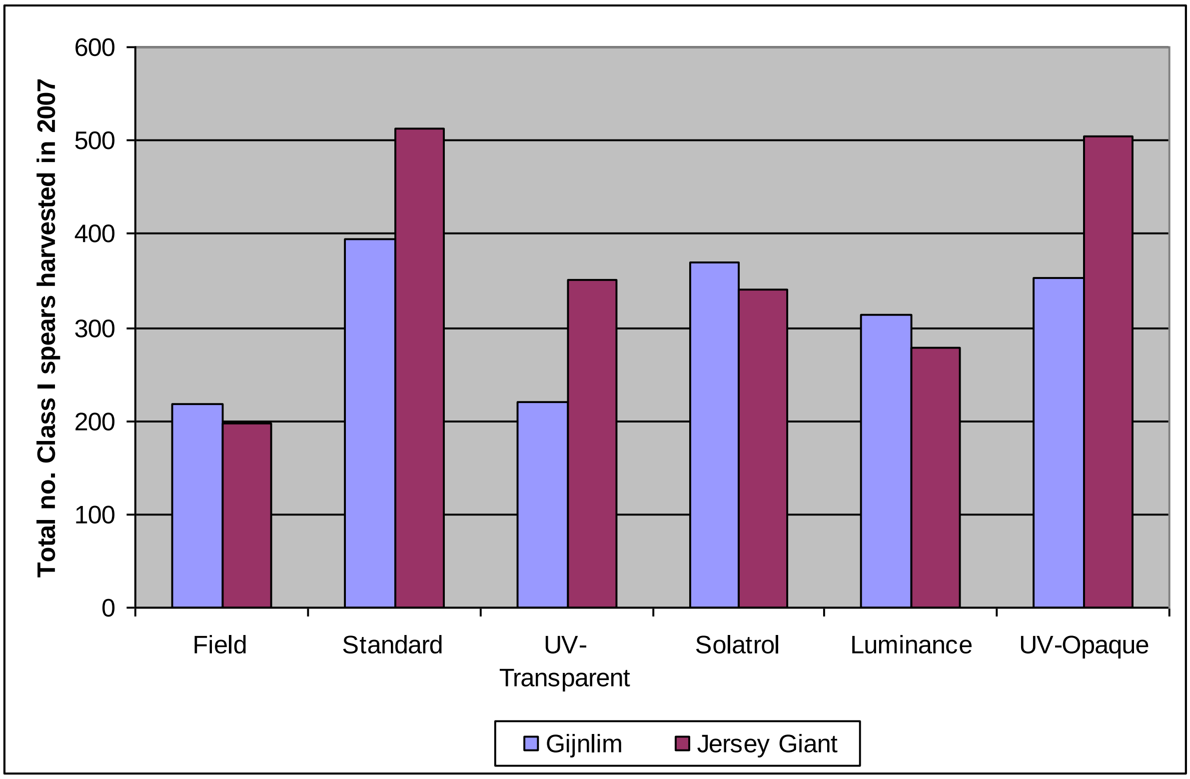
The collected data shows that in all cases J. Giant spear emergence was ahead of the Gijnlim variety both under protection and in the field plot and this is linked to the genetic traits of the two varieties. Under the majority of the plastic covers J. Giant spears appeared earlier than the field plot, although the only statistically significant difference was between the standard polythene and the field plot. The early spear production effect was less apparent in the Gijnlim although, once again, the Standard polythene crop was significantly earlier than the field crop.

The final harvest on the plots was carried out on the 15th June 2007. This resulted in a 10 week harvest period in the majority of the protected plots.

Spear Quality

The number of spears in each class was recorded for each harvest. Chart 5 shows the total number of Class 1 spears harvested in 2007, the data for the remaining classes is shown in Appendix 2.

Chart 5. The total number of Class 1 spears harvested at STC in 2007.



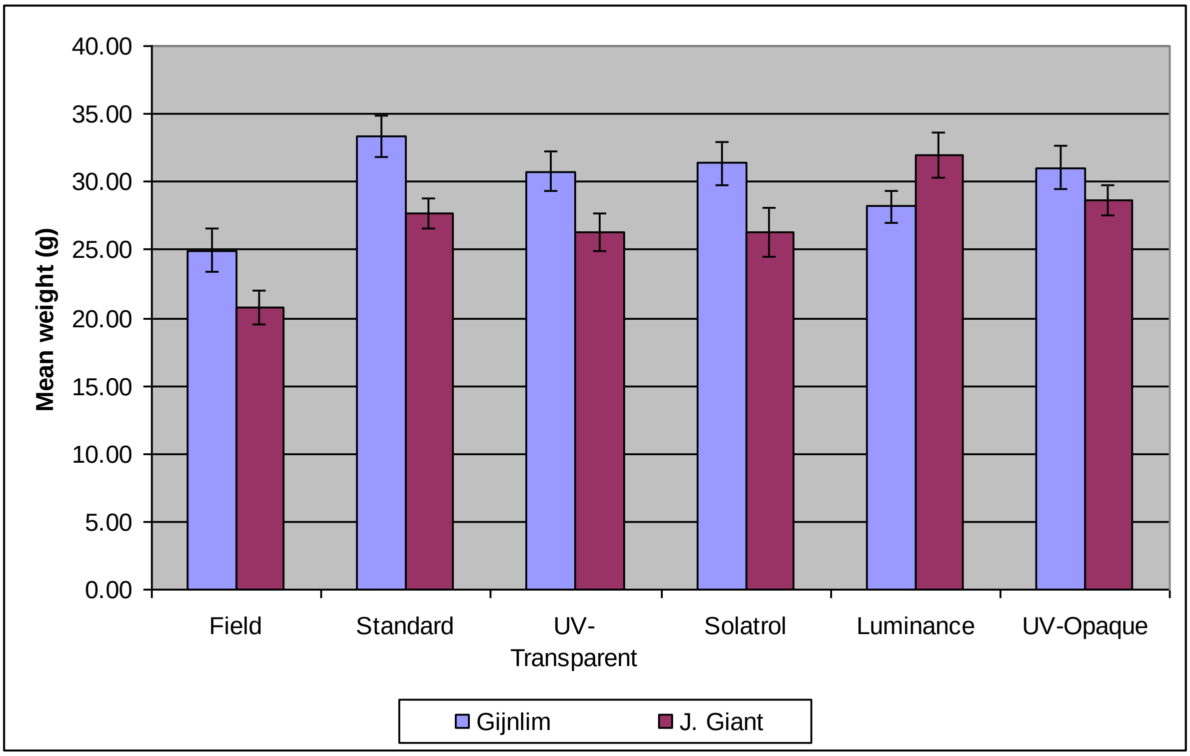
Data shown is taken from the Batch 1 planting only

The number of Class 1 spears of both varieties increased during 2007 when the crops were grown under plastic covers compared to the field plot. This effect was evident most clearly in the J. Giant crop, again a factor of the crop genetics. The highest numbers of Class 1 spears were harvested in the Standard and UV Opaque plots.

On one day of each week during the harvest period a more detailed yield assessment was carried out where the weight of each spear harvested and the spear diameter at the mid-point and base were recorded. The average spear weight for Class 1 spears is shown in Chart 6 with the full data sets shown in Appendix 2.

The mean spear weight was significantly higher in all the protected plots for both varieties compared to the field plot. Under the majority of the plastics Gijnlim spears were marginally heavier than the J. Giant spears, although this was not the case under the Luminance cover. On average the Gijnlim crop grown under protection was approximately 20% heavier than the same variety in the field, whilst the J. Giant were on average 25% heavier when grown under protection. This would equate to a substantial cost benefit over the season.

Chart 6. Mean spear weight of Class 1 spears collected weekly in 2007



Using the mean spear weight and the total number of Class 1 spears harvested an estimate of yield of product/ha (Table 1) can be made using the following calculation.

<u>Total no. of Class 1 spears</u>
No. of crowns/plot X Mean Spear Weight X Normal Commercial Planting (22,500 crowns/ha)[1]

Table 1. Estimated yield of product per hectare of Class 1 spears at STC in 2007

Variety	Estimated yield (kg) product/hectare					
	Field	**Standard**	**UV-T**	**Solatrol**	**Luminance**	**UV-O**
Gijnlim	7,623	18,506	9,563	16,322	12,412	15,375
J. Giant	5,740	19,908	12,981	12,589	12,494	20,320

All values are based on Class 1 spears harvested from the Batch 1 planting.

The yield estimations presented in Table 1 are significantly higher than those seen generally in commercial production. However, it must be considered that the yield

[1] Information supplied by Peter Knight

recorded was based on spears harvested from 2 short rows of crowns only i.e. without the competition of row on row production as would be normal in a field crop.

The daily distribution of Class 1 spears is shown in Charts 7-12 for Gijnlim and 13-18 for Jersey Giant. The same scale has been used on the y-axis to give a clear visual indication of the no. of spears harvested in each plot.

Charts 7-12 - The mean number of Class 1 spears on cv. Gijnlim harvested in each treatment.

Chart 7

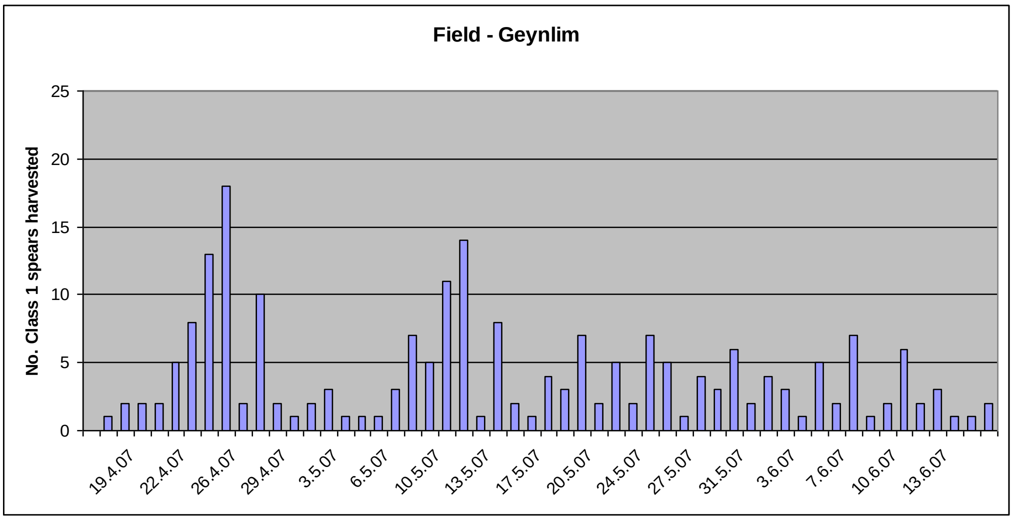


Chart 8

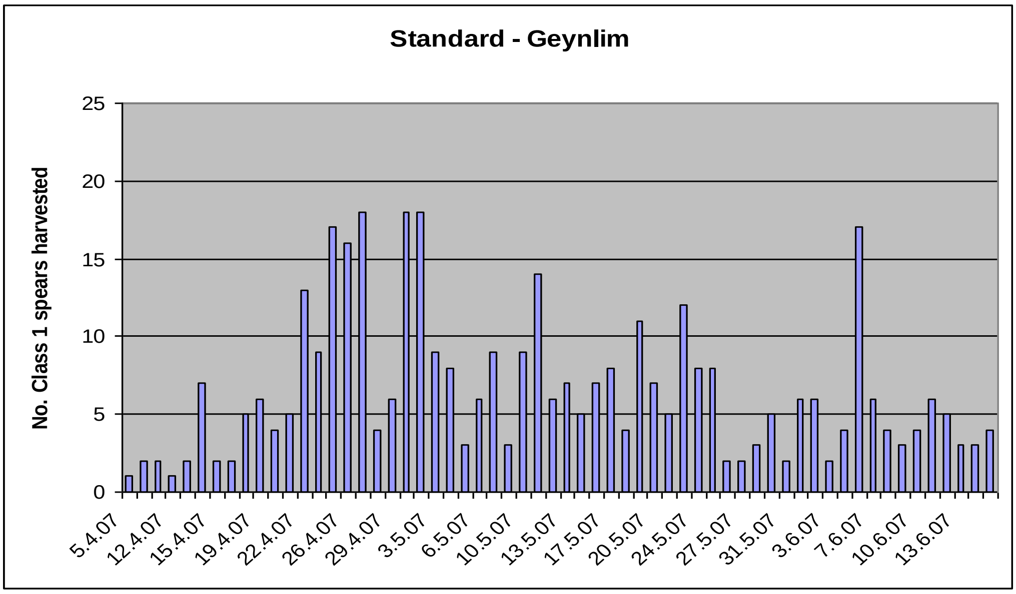


Chart 9

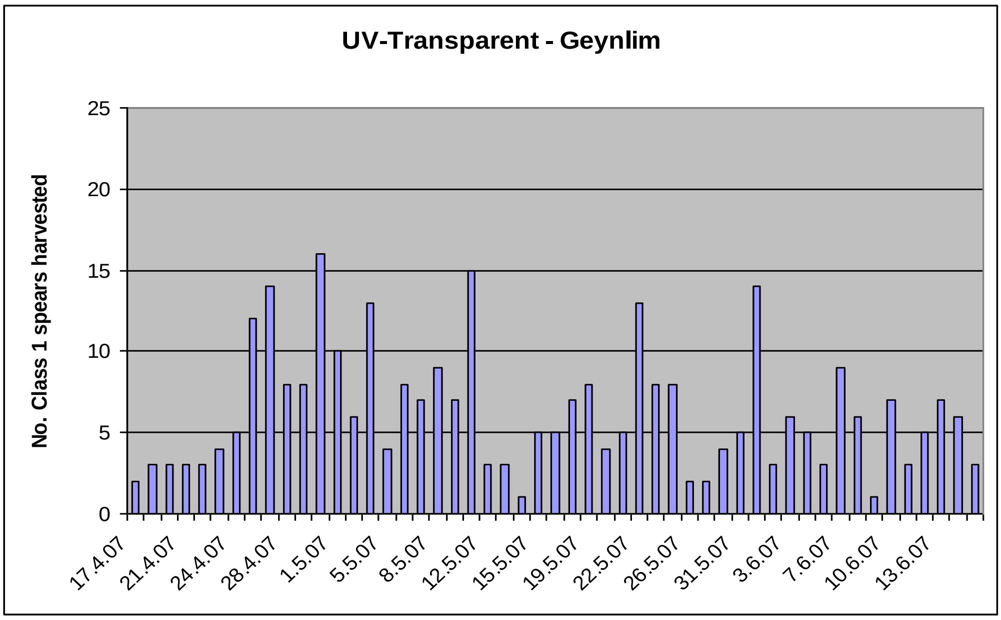


Chart 10

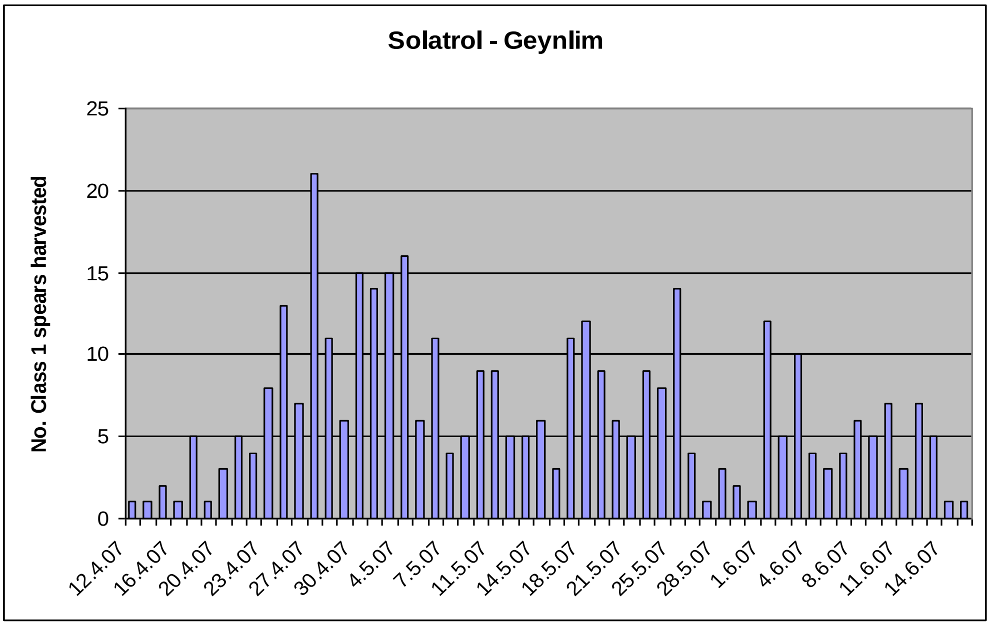


Chart 11

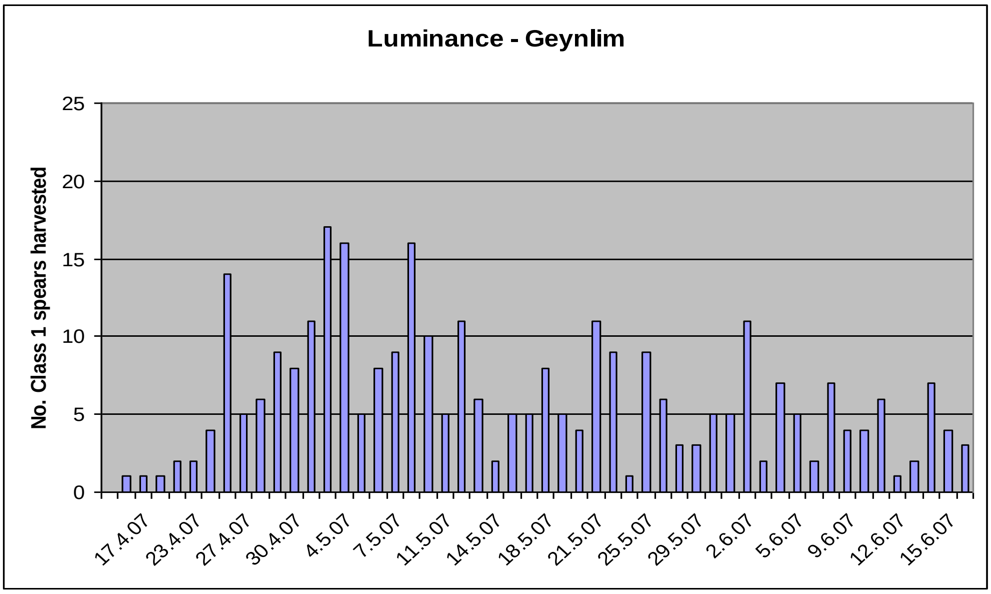
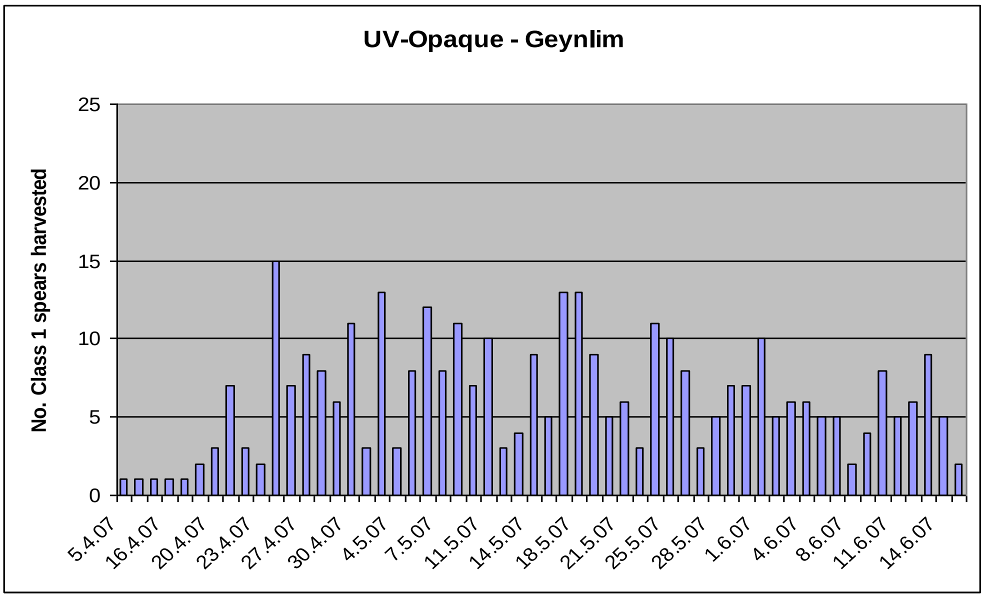


Chart 12



Charts 10-15 - The mean number of Class 1 spears on cv. Jersey Giant harvested in each treatment.

Chart 13

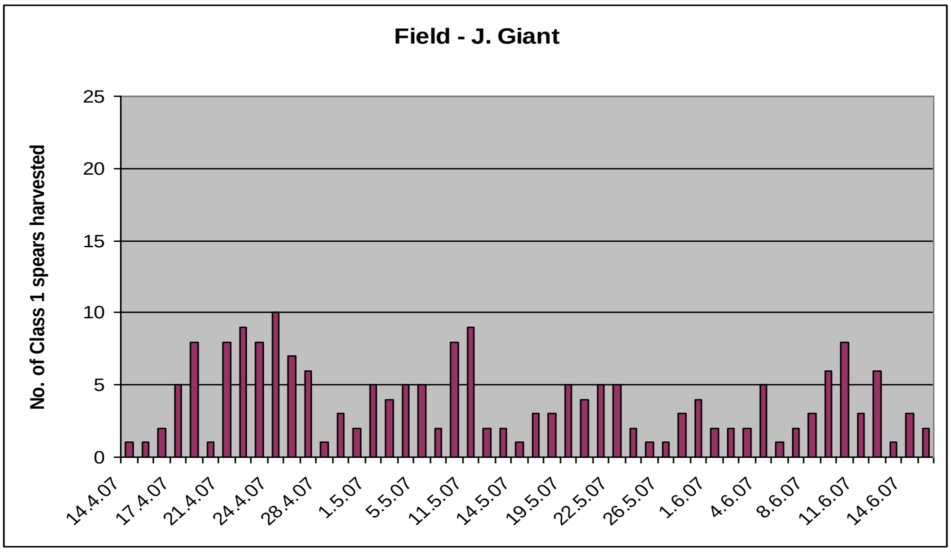


Chart 14

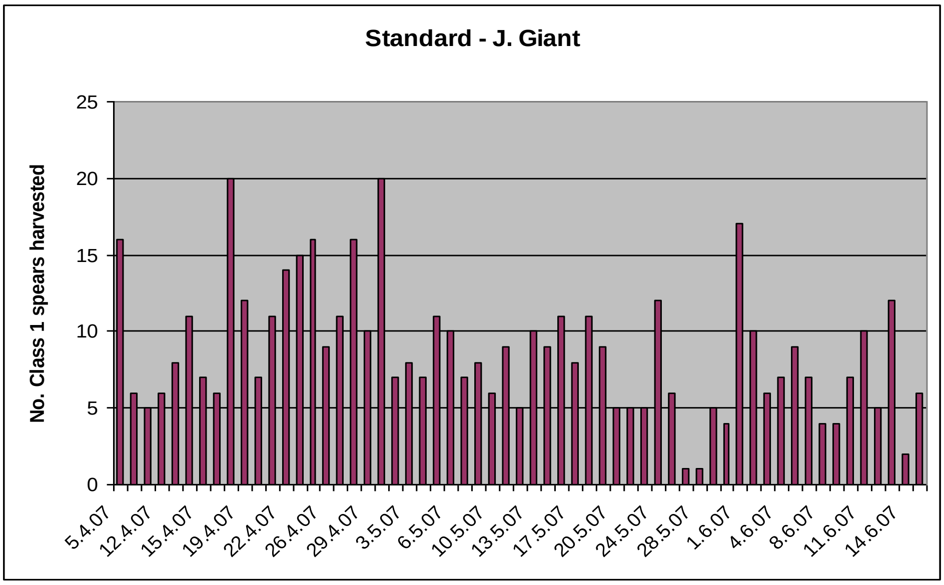


Chart 15

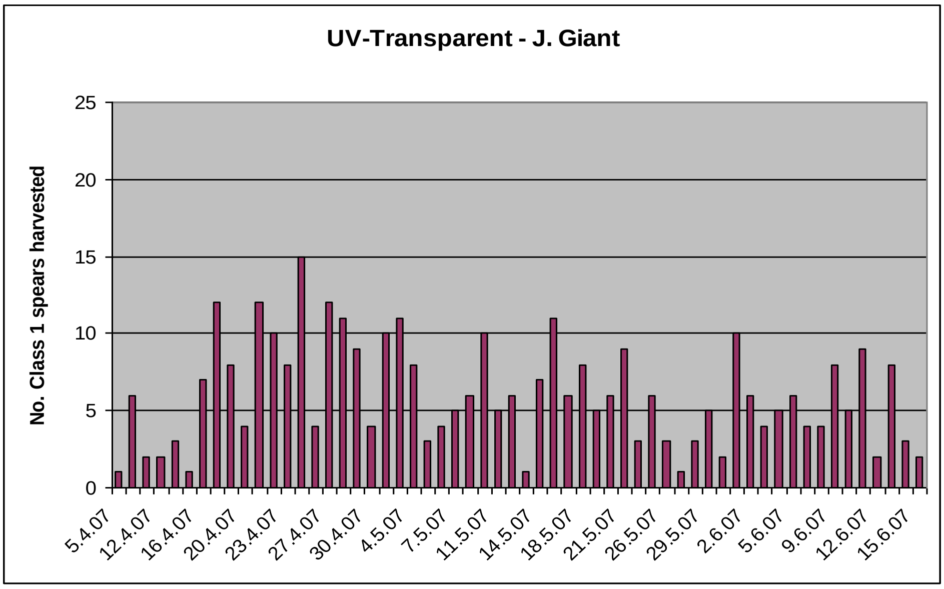

UV-Transparent - J. Giant
No. Class 1 spears harvested
0
5
10
15
20
25
5.4.07
12.4.07
16.4.07
20.4.07
23.4.07
27.4.07
30.4.07
4.5.07
7.5.07
11.5.07
14.5.07
18.5.07
21.5.07
26.5.07
29.5.07
2.6.07
5.6.07
9.6.07
12.6.07
15.6.07

Chart 16

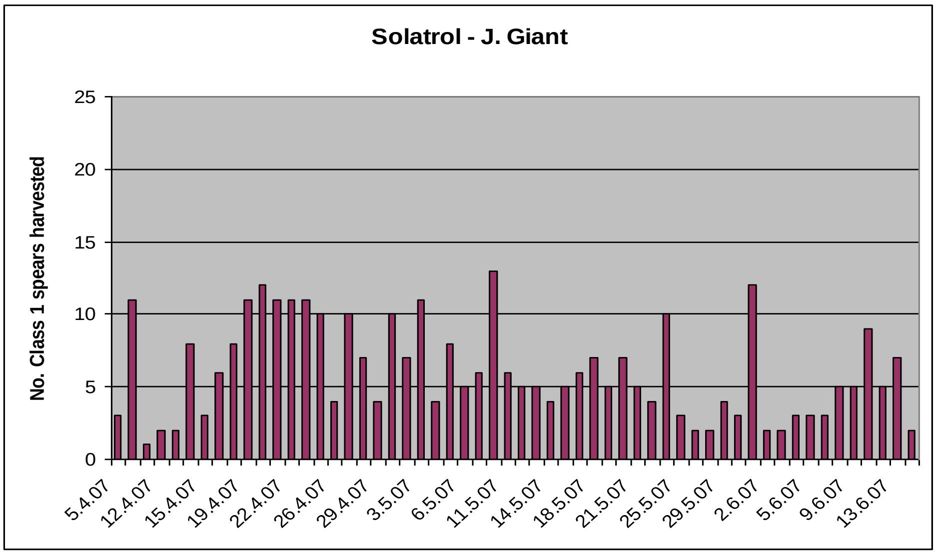


Chart 17

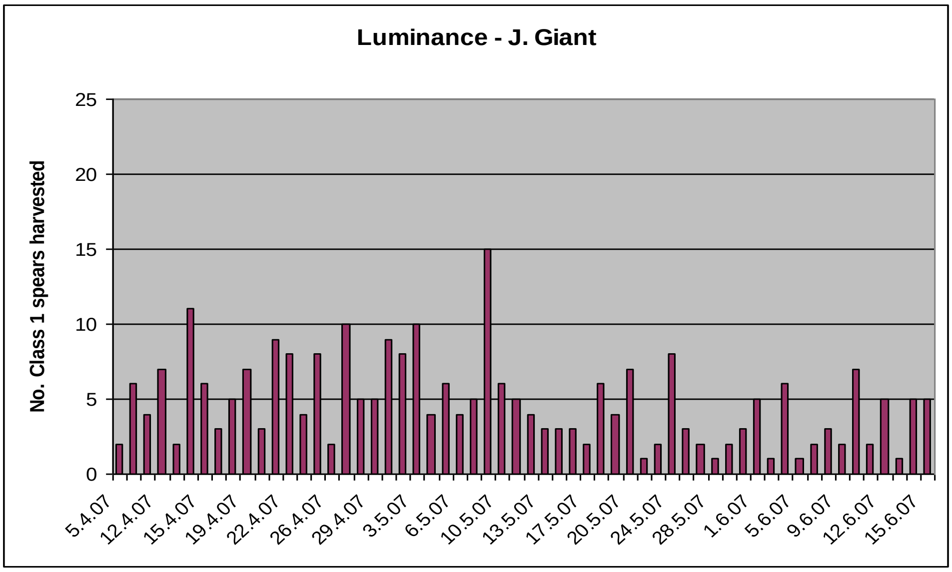
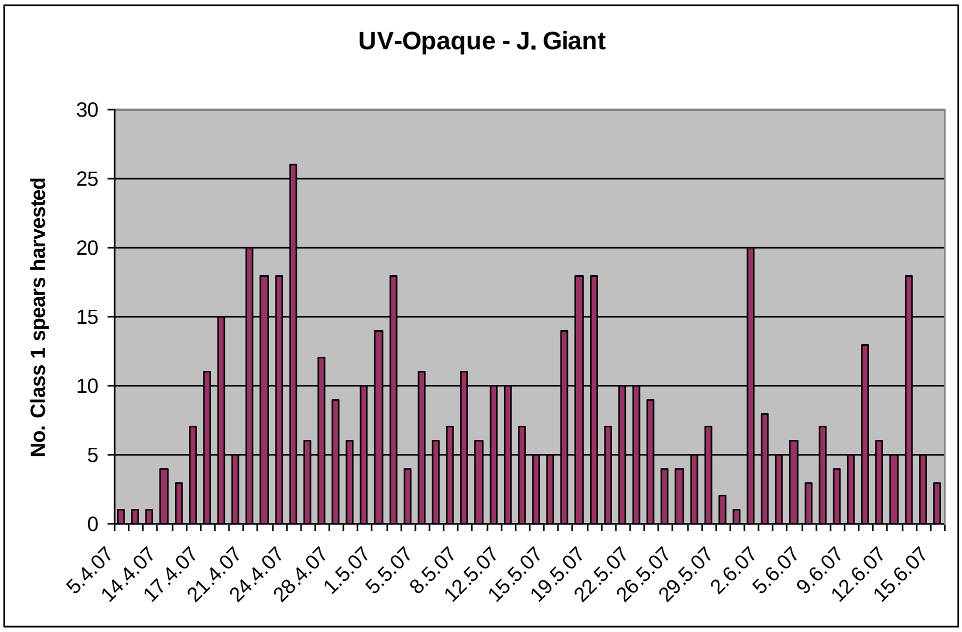
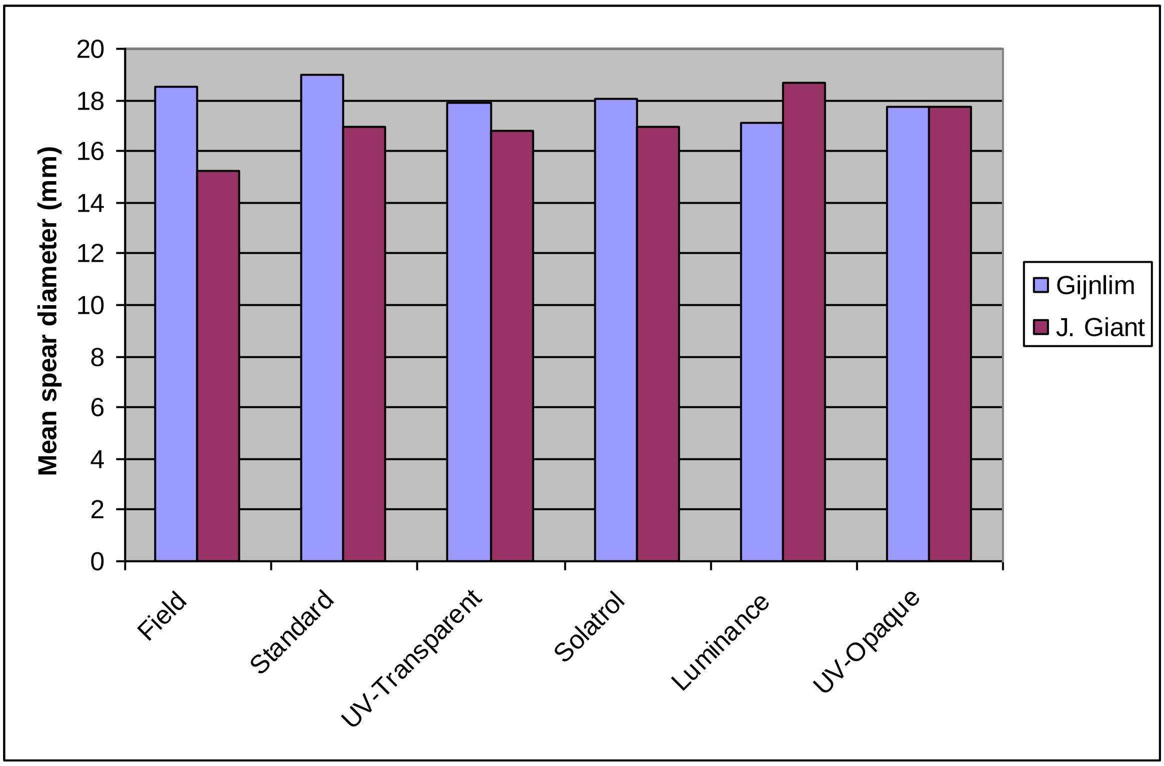


Chart 18



The charts suggest that the higher numbers of Class 1 spears were harvested during April in 2007. In the field plot both varieties show 2-3 peaks of Class 1 spear production early on in the season, and these were possibly triggered by optimum weather conditions. However, under the plastic covers the no. of Class 1 spears produced is greater, as has already been seen, but is also more evenly distributed throughout the main production period or season. This aspect could prove beneficial to growers enabling them to fill their retail orders with more consistency over the season. The J. Giant variety performed particularly well under the standard and UV-opaque plastics producing high numbers of class 1 spears right through the growing period.

Chart 19. Mean spear diameter measured at the base on Class 1 spears collected weekly in 2007



Spear diameter measured at the base (Chart 19) was also increased on the spears produced under the plastic covers compared to the outdoor field cropped in cv. J. Giant. This effect was not seen with the Gijnlim crop.

Crop Irrigation

The crops were irrigated using trickle tape irrigation linked to a bore-hole. A five probe EnviroSCAN was installed in four covered crops and one outdoor crop. Peter White was able to access the data remotely and send weekly reports regarding water uptake and usage. These were used to determine the frequency and duration of irrigation events on the crop during the season.

Fern nutrition

A record of the date of fern establishment was made (Table 2). The data shows that fern establishment occurred more quickly in the protected plots in comparison with the field plot where ferns established between 7 and 11 days later.

Table 2. Date of whole plot fern establishment at STC in 2007

Site	Variety	Date of fern establishment (whole plot)
Field	Gijnlim	20.7.08
	J. Giant	20.7.08
Standard	Gijnlim	10.7.08
	J. Giant	10.7.08
UV-Transparent	Gijnlim	11.7.08
	J. Giant	10.7.08
Solatrol	Gijnlim	10.7.08
	J. Giant	11.7.08
Luminance	Gijnlim	10.7.08
	J. Giant	10.7.08
UV-Opaque	Gijnlim	9.7.08
	J. Giant	9.7.08

The number of remaining shoots that emerged for fern production from each crown was recorded on the 16th August 2007 (Chart 20), along with the height from the soil to the first branch on 20 random ferns/plot (Chart 21).

The data in chart 5 shows that on average more ferns were produced/crown in the plots under protection with the highest numbers being produced in the crops under the standard and UV-opaque plastics.

The measurements of fern height to the 1st branch are fairly similar across all the sites with little difference seen between the field and protected plots, with the exception of the crops growing under the Solatrol plastic. These plants showed a marked increase in height and this is potentially an effect of the light far-red absorbing qualities of this plastic.

It was not possible to measure the overall fern height in the crops, though the digital images captured (plates 5 & 6) give some idea of the general increase in height observed in the protected crops compared to the field crop.

Chart 20. The mean no. of ferns produced/crown at STC during 2007

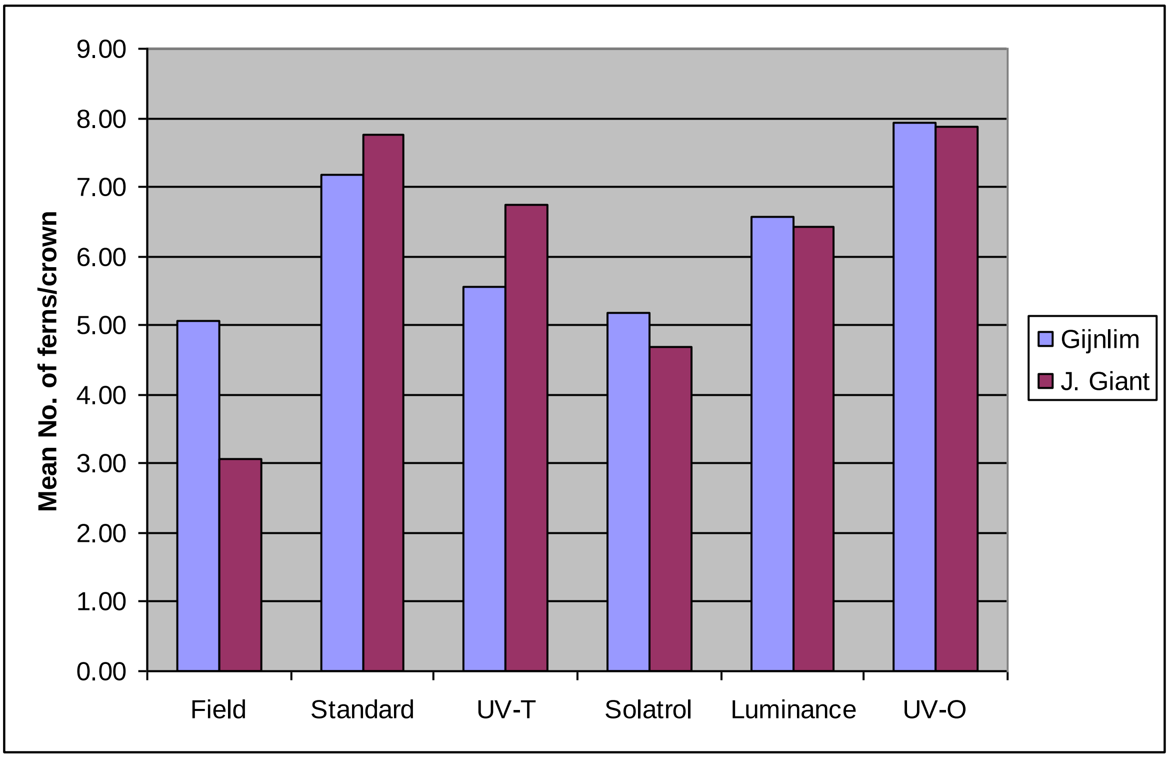


Chart 21. The mean height (cm) of the ferns from soil level to the 1st branch

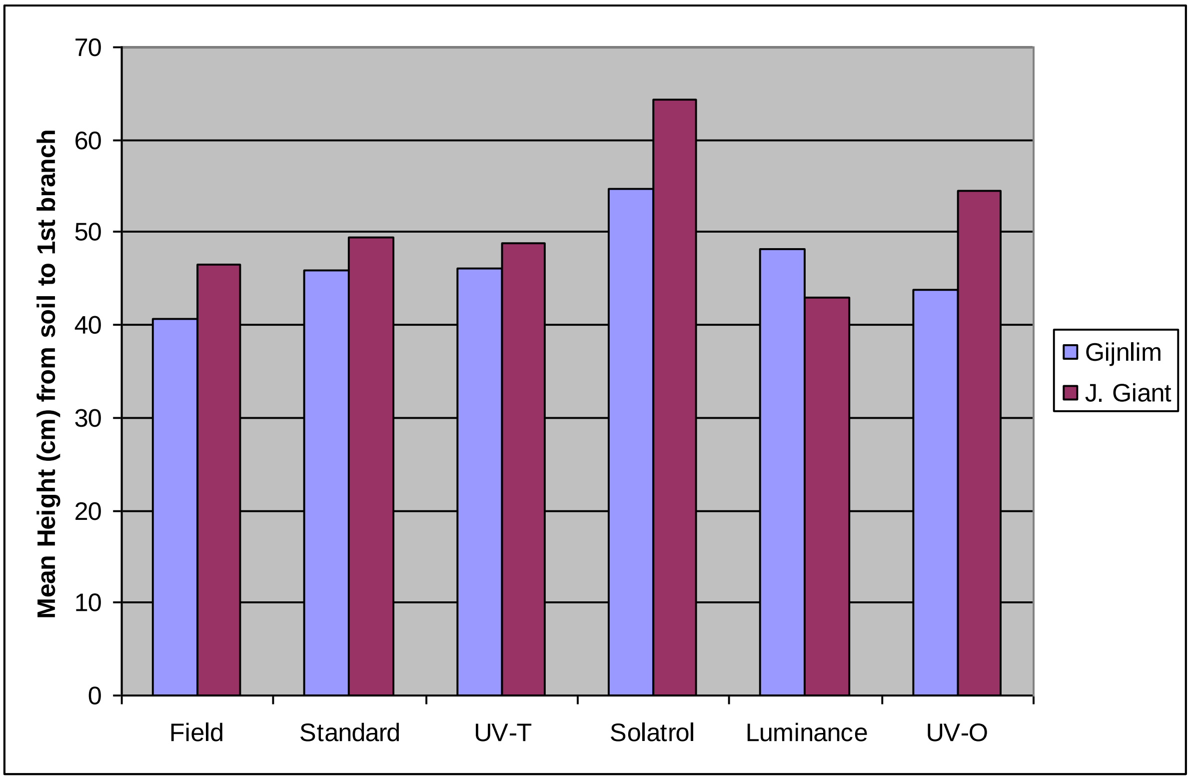


Plate 5. Gijnlim under Luminance plastic (Batch 1 on right, Batch 2 on left) Peter Knight for height comparison in the centre (taken 13th Aug 2008)

Plate 6. Gijnlim in the Field plot on the same date

Samples of fern tips were collected from each variety (Batch 1) on 3 occasions post harvest. The data has been tabulated and is shown overleaf (Tables 3, 4 and 5).

> These comprehensive results show little variance and generally the crops have managed to get sufficient levels of nutrition. There are no significant variances between open and protected cropping in the levels of major or minor elements that have been extracted, however when comparing the levels of Magnesium, Calcium and Boron the protected crops show generally higher levels than the field in the results from September to October, indicating that their improved environment/health has aided uptake, leading to "the good get better".
>
> Comment from Peter Knight, Independent consultant.

Table 3. Fern nutrient analysis - 6th August 2007

Tunnel	Standard		UV transparent		UV Opaque		Solatrol		Luminance		Outdoor	
Variety / Element	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant
Nitrogen %	4.03	3.84	4.34	4.16	4.72	3.64	4.18	4.45	4.18	4.46	4.24	4.12
Phosphorus %	0.33	0.39	0.26	0.29	0.29	0.38	0.33	0.40	0.34	0.36	0.46	0.42
Potassium %	2.91	2.68	2.88	2.69	3.20	3.10	3.57	2.63	3.04	2.44	2.85	2.81
Magnesium %	0.28	0.30	0.36	0.30	0.32	0.32	0.25	0.26	0.27	0.28	0.26	0.23
Calcium %	0.75	1.15	0.91	0.85	0.90	0.94	0.67	0.92	0.67	0.96	0.75	0.69
Manganese %	31	56	31	41	27	38	26	70	21	62	79	75
Copper (mg/kg)	8.5	15.3	5.9	7.6	7.0	10.6	7.9	11.8	7.6	10.7	11.6	10.0
Sodium %	0.02	0.05	0.01	0.03	0.01	0.02	0.01	0.03	0.01	0.03	0.02	0.02
Iron (mg/kg)	394.2	706.5	154.1	715.8	148.7	406.5	192.9	1000.3	235.7	1136.1	542.5	449.9
Zinc (mg/kg)	25.6	43.1	18.1	27.7	18.5	37.8	24.4	41.4	35.1	39.8	40.4	38.4
Molybdenum (mg/kg)	0.86	1.14	0.71	0.86	0.52	0.96	0.56	1.56	0.56	1.21	1.20	1.94
Boron (mg/kg)	38.8	35.0	47.3	45.1	46.4	33.5	36.8	48.3	35.1	45.9	43.1	72.4
Sulphur %	0.22	0.54	0.68	0.61	0.75	0.55	0.66	0.55	0.39	0.57	0.52	0.54
N:S ratio	18.7:1	7.1:1	6.4:1	6.9:1	6.3:1	6.6:1	6.3:1	8.1:1	10.7:1	7.8:1	8.2:1	7.6:1

Table 4. Fern nutrient analysis - 10th September 2007

Tunnel	Standard		UV transparent		UV Opaque		Solatrol		Luminance		Outdoor	
Variety / Element	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant
Nitrogen %	3.25	2.98	3.29	2.88	3.50	3.19	3.08	2.94	3.09	3.12	2.68	2.00
Phosphorus %	0.26	0.25	0.27	0.24	0.26	0.26	0.26	0.25	0.26	0.25	0.31	0.31
Potassium %	3.29	2.97	2.75	2.81	3.04	3.18	4.13	3.99	3.21	2.98	2.83	3.66
Magnesium %	0.39	0.34	0.50	0.37	0.44	0.51	0.36	0.38	0.49	0.40	0.21	0.30
Calcium %	1.36	1.11	1.44	1.16	1.39	1.60	1.29	1.03	1.39	1.28	0.83	1.19
Manganese %	30	22	35	25	27	23	40	36	23	24	82	92
Copper (mg/kg)	6.8	7.2	6.1	6.6	6.1	6.7	6.9	6.0	6.7	7.3	3.1	8.4
Sodium %	0.03	0.12	0.03	0.10	0.03	0.03	0.04	0.06	0.04	0.06	0.16	0.66
Iron (mg/kg)	325.0	335.1	441.0	437.0	254.0	283.6	569.8	548.9	391.0	382.2	1671.1	1640.7
Zinc (mg/kg)	13.9	15.6	13.6	15.6	12.5	13.3	13.4	14.3	13.5	14.7	19.8	26.7
Molybdenum (mg/kg)	0.91	1.08	0.74	0.85	0.43	0.65	0.60	0.88	0.53	0.54	1.03	1.30
Boron (mg/kg)	108.8	93.7	120.1	110.1	108.3	105.9	106.9	123.6	100.5	118.8	65.3	71.3
Sulphur %	0.56	0.56	0.64	0.60	0.63	0.70	0.55	0.65	0.54	0.58	0.40	0.27
N:S ratio	5.8:1	5.3:1	5.1:1	4.8:1	5.6:1	4.6:1	5.6:1	4.6:1	5.7:1	5.3:1	6.7:1	7.5:1

Table 5. Fern nutrient analysis – 11th October 2007

Tunnel	Standard		UV transparent		UV Opaque		Solatrol		Luminance		Outdoor	
Variety / Element	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant	Gijnlim	J. Giant
Nitrogen %	3.31	3.15	3.25	3.10	3.57	3.34	3.24	3.35	3.73	3.45	2.98	3.49
Phosphorus %	0.26	0.19	0.20	0.18	0.24	0.21	0.19	0.20	0.21	0.19	0.28	0.33
Potassium %	1.91	1.63	1.91	1.96	2.25	2.05	2.86	2.54	1.98	1.99	2.36	2.64
Magnesium %	0.34	0.38	0.42	0.38	0.37	0.45	0.35	0.37	0.41	0.38	0.21	0.18
Calcium %	1.70	1.62	1.72	1.57	1.78	1.84	1.65	1.60	1.74	1.49	1.08	0.88
Manganese %	42	19	33	21	28	18	38	28	25	18	88	48
Copper (mg/kg)	8.5	8.9	8.3	6.5	7.7	9.9	6.2	5.9	6.4	6.2	6.6	6.7
Sodium %	No analysis provided											
Iron (mg/kg)	378.2	234.6	303.1	253.1	222.5	157.8	175.6	147.0	333.4	158.1	203.1	153.4
Zinc (mg/kg)	26.5	15.1	14.7	13.4	26.2	20.0	11.7	12.7	16.8	13.4	20.3	20.1
Molybdenum (mg/kg)	1.08	1.17	0.78	0.73	0.58	0.81	0.55	1.02	0.85	0.61	1.04	1.63
Boron (mg/kg)	101.6	124.9	113.8	127.0	106.7	114.0	112.0	145.7	103.8	130.4	83.3	78.3
Sulphur %	0.74	0.68	0.88	0.84	0.86	0.91	0.80	0.87	0.82	0.77	0.56	0.76
N:S ratio	4.5:1	4.6:1	3.7:1	3.7:1	4.1:1	3.7:1	4.0:1	3.9:1	4.6:1	4.5:1	5.3:1	4.6:1

Pest and Disease

The incidence of pests and disease in the crops during 2007 was relatively low overall. Asparagus beetle was observed in the crop during early August (Plates 7 & 8). However, we also found evidence of the presence of a predatory spider in the crops. The levels of the beetle were monitored over the remainder of the season.

Plate 7 & 8. Asparagus beetle larvae and adult

Visual assessments of the infestation levels showed there to be no difference in the numbers of beetles or larvae present between the plastic tunnels and the field plot. Numbers did not increase dramatically and it was not deemed necessary to apply any crop protection products to control the beetles.

A disease assessment carried out on the 23rd October 2007 recorded the number of stems on which there was evidence of *Botrytis*, *Stemphylium* or *Fusarium* infections (Table 5). Disease levels overall were very low.

Table 6. Incidence of stem infections on 23rd October 2007

Site	Variety	No. of stems/plot showing infection		
		Botrytis	***Stemphylium***	***Fusarium***
Field	Gijnlim	0	1	3
	J. Giant	0	0	3
Standard	Gijnlim	0	1	0
	J. Giant	0	0	0
UV-Transparent	Gijnlim	0	1	0
	J. Giant	0	0	0
Solatrol	Gijnlim	0	2	0
	J. Giant	0	0	0

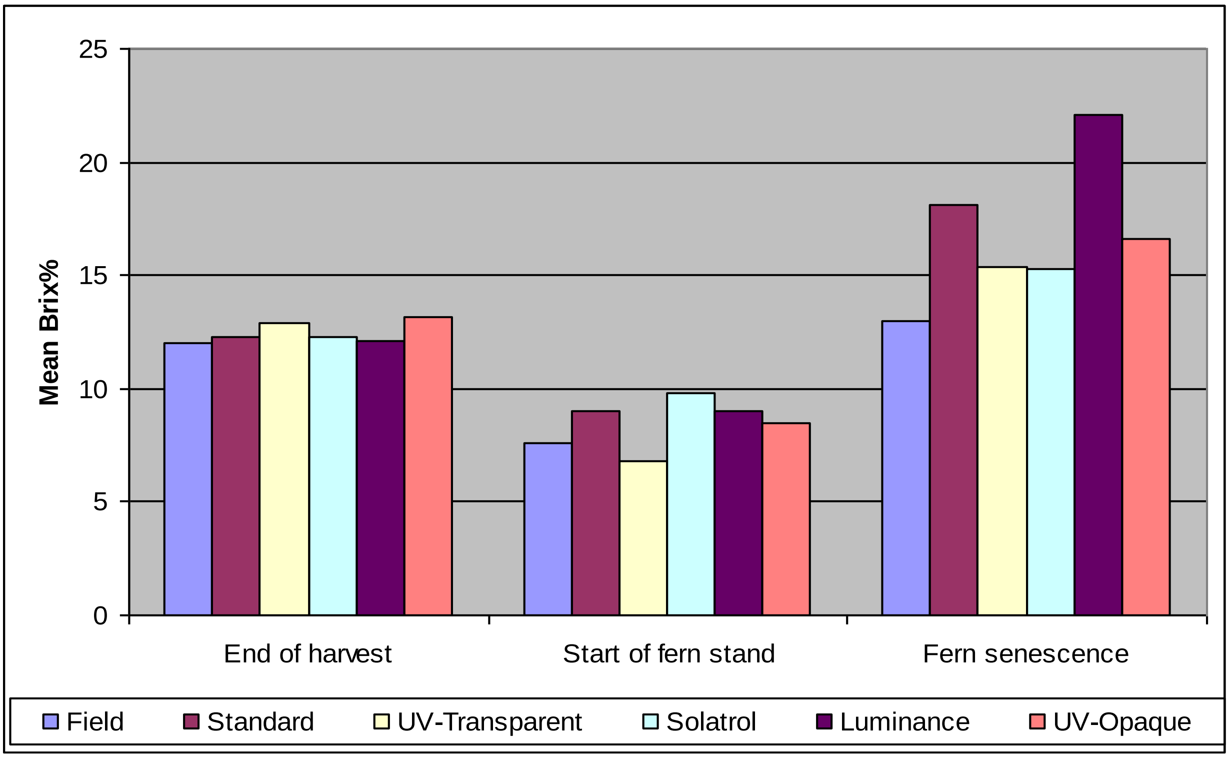
Luminance	Gijnlim	0	0	0
	J. Giant	0	0	0
UV-Opaque	Gijnlim	0	1	0
	J. Giant	0	2	0

The strong and healthy stem and fern material of the protected crops may well result in potential financial benefits in terms of reductions in pesticide usage on the crops. However, it is important to bear in mind that this data was collected over one season only, and disease pressure may vary in subsequent years.

Brix% testing results.

Samples of roots were collected at the end of harvest, the start of fern stand and at fern senescence and were tested using the method described in the Materials & Methods section. The data was input into the AspireUK package to provide information on the carbohydrate content of the roots at the stated crop timings. The Brix% values are shown in Chart 7 below, however these values are converted into mg/g of carbohydrate (CHO) in the AspireUK software. It is also important to note that the Aspire software provides crop management information to growers based on 20 collected values. Due to the relatively small plots only 5 values/plot were collected from the Gijnlim, Batch 1 crop at STC and therefore the output data and recommendations must should be treated with caution.

Chart 22. Brix% values for Gijnlim roots tested during 2007



A summary of the AspireUK recommendations based on the collected Brix% values is provided below.

End of Harvest:

- Brix% readings from all of the treatments fell within the same CHO band.

- The ***AspireUK*** output stated that root CHO was 'optimum' for the time of year.

- The recommendation was that harvesting could be continued until CHO reached 320 mg/g.

6 weeks after harvest end:

- Brix% readings from the different treatments were split between two CHO bands.

- For the standard, transparent, field, luminance and UV-opaque treatments, CHO content was 'normal' for the end of fern establishment, and was unlikely to be limiting fern growth.

- CHO levels for the Solatrol treatment were marginally higher than for the other treatments and were classified in a higher CHO band. The data was considered 'unusually high' for the time of year. Possible reasons were that i) the CHO measurement was done too late, when CHO content had already started to recover, ii) the spear harvest was too short and could have been extended without harming the crop, and iii) fern establishment had been poor, and the available CHO was not used.

Dormancy (fern senescence):

- Brix% readings from the different treatments were split between three CHO bands.

- For the transparent, Solatrol, field and UV-opaque treatments, ***AspireUK*** stated that root CHO contents were below the desirable levels of a healthy crop by the end of the season. Values in this range, especially at the low end (e.g. the field treatment), indicate poor replenishment of CHO reserves in the roots during fern growth. This can be caused by factors such as harvest ending too late, poor fern establishment, fern growth flushes later in the season, and premature fern loss or needle drop caused by disease, insect pests, weed competition, damage by wind or hail, or too much or too little, water. **Alternatively, readings may have been taken too early before the crop had completely senesced, and root re-charge was complete.** The recommendation was to be flexible about when to stop harvesting in following years, and be prepared to stop earlier than usual – although this advice is not relevant for this trial.

- For the standard treatment, root CHO content was 'satisfactory', but not as high as it could be by the end of the season. Values in this range, especially at the low end (as for this treatment), indicate good but incomplete replenishment of CHO reserves in the roots during fern growth.

- For the Luminance treatment, the root system was full of CHO, as it should be by the end of the season. The high CHO content means that a good harvest would be likely next year, especially if the crop has a large root system.

Some interesting recommendations and observations were made which demonstrated (based on the limited data supplied and in only one season) that CHO content differences were seen under the different plastic films which may well have impacted on subsequent crop yields had it been a straight-forward commercial crop.

Conclusions

The data collected during the final year of CP 19 and in FV 321 during 2007 has shown definitively that there are potential economic advantages to raising asparagus crops under protection. The studies demonstrated that the crowns established earlier under the plastic tunnels than their field counterparts. Yield in terms of the number, mean spear weight, and weight of produce/ha were all significantly higher in the crops grown under plastic, whilst spear emergence was approximately 1 week earlier than in the field crop leading to harvest extension. Although the incidence of pests and diseases were low in 2007, the ferns were stronger, taller, healthier and established earlier in the protected crops. It would be expected that the ability to keep the ferns dry would potentially impact on fern and crown health resulting in more uniform cropping and crown longevity. The controlled irrigation by drip tape in the protected plots ensured that the crop could be managed more efficiently and this led to the production of a more consistent and reliable harvest than a conventionally grown field crop.

Although a range of plastics with differing light diffusing properties were used in the 2 investigations the data collected showed consistently that growing asparagus under any form of protection produced significant benefits over field produced crops. Interestingly the greatest benefits in terms of yield and crop health were observed in the crops grown under the standard polythene material, whilst some of the other plastics appeared to be imposing very slight limitations on spear yield and fern establishment. This is useful information for growers as they should not find it necessary to buy more expensive 'smart' plastics to enjoy the benefits of harvest extension and yield improvement.

Measurements of the nutrient content of the fern tips, the carbohydrate content of the roots (Brix%) and the root mass all provided additional supporting data for the potential benefits that are available when asparagus is produced under protection. Healthy ferns will photosynthesise well and store more carbohydrate in a large root system enabling them to produce a greater number of heavier Class 1 spears in the following season.

Both of the asparagus varieties grown under protection at STC showed improvements in all aspects of their growth compared to the field grown plants. However, the cv. Jersey Giant y grown under protection showed the greatest improvement over the field plots of the same variety and this is undoubtedly due to its in-bred characteristics and suitability for growing in warmer soils. This suggests that the choice of variety is important when growing under plastic (or glass) and may also be used to extend the harvest season. Long term trials would be required to establish the effect of driven production on the life of different varieties.

At STC Spanish style Haygrove tunnels were employed during this investigation, having open sides and ends. It is unclear whether further benefits may result from growing asparagus under even greater level of protection with end walls and partially vented side walls or similar.

Technology transfer

The potential financial benefits of producing asparagus under protection have been clearly demonstrated during this and the previous study (CP 19). It is hoped that many of the UK asparagus growers will now consider this method of production.

Article produced for the HDC News Publication – February 2008.

Presentation to AGA Annual conference in March 2008.

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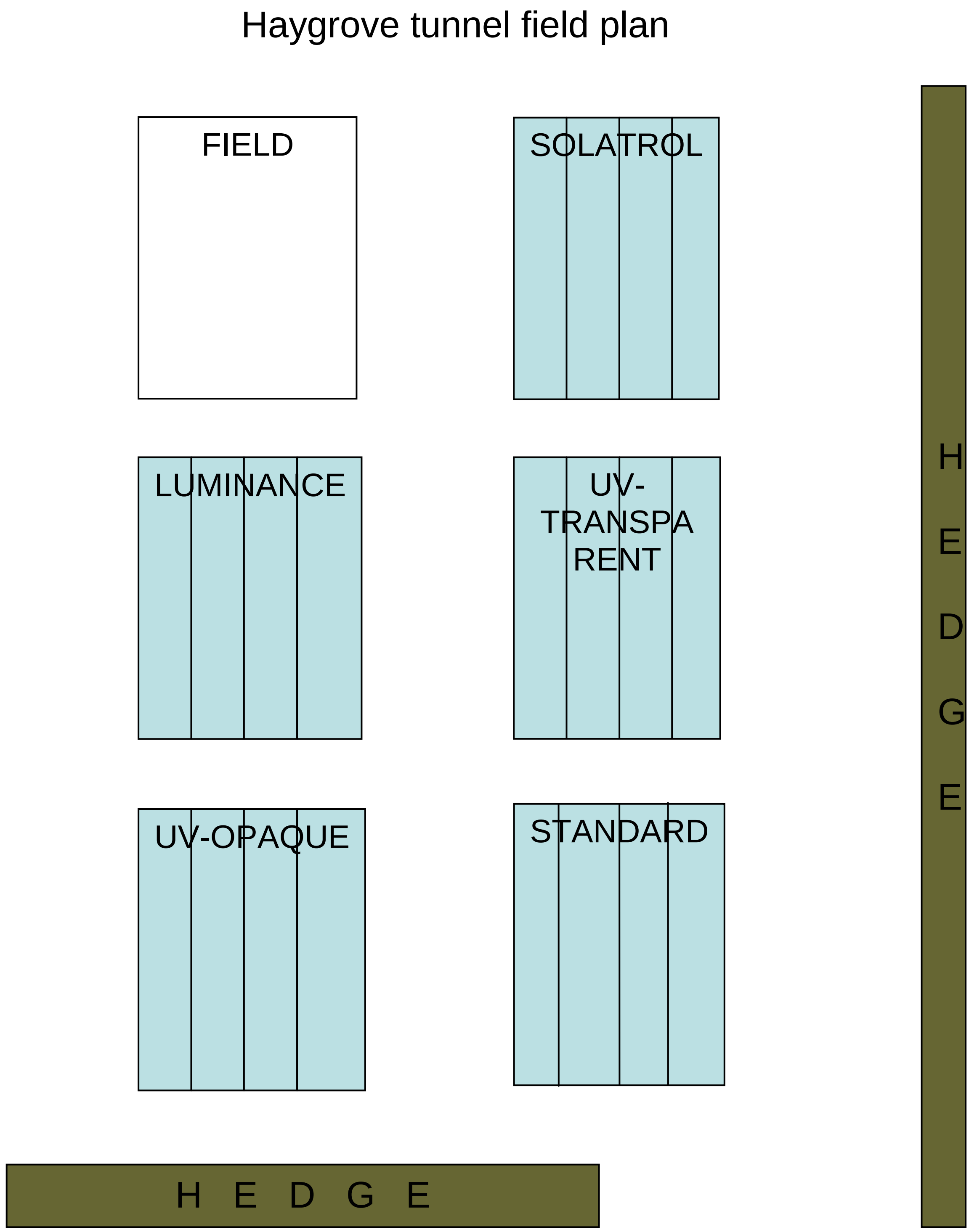
Kim Green (ADAS) for AspireUK recommendations

Appendices

Appendix 1 – Field Plan



Appendix 2 – Raw Data Sets for 2007

Table 1. Date to 1st spear emergence for 10 crowns per plot – Gijnlim

<u>Emergence</u>

Date of first spear emergence – Gijnlim

Crown No.	1	2	3	4	5	6	7	8	9	10
Standard	17.4.07	15.4.07	4.4.07	8.4.07	4.4.07	11.4.07	12.4.07	13.4.07	10.4.07	5.4.07
UV-transparent	12.4.07	19.4.07	10.4.07	12.4.07	10.4.07	16.4.07	15.4.07	15.4.07	11.4.07	17.4.07
Solatrol	7.4.07	16.4.07	8.4.07	24.4.07	15.4.07	9.4.07	6.4.07	18.4.07	15.4.07	10.4.07
Field	11.4.07	10.4.07	22.4.07	17.4.07	11.4.07	10.4.07	17.4.07	13.4.07	11.4.07	12.4.07
Luminance	11.4.07	16.4.07	11.4.07	8.4.07	22.4.07	17.4.07	12.4.07	3.4.07	16.4.07	9.4.07
UV-opaque	12.4.07	16.4.07	11.4.07	15.4.07	16.4.07	11.4.07	18.4.07	19.4.07	16.4.07	14.4.07

Table 2. Date to 1st spear emergence for 10 crowns per plot – Jersey Giant

Date of first spear emergence – Jersey Giant

Crown No.	1	2	3	4	5	6	7	8	9	10
Standard	5.4.07	2.4.07	6.4.07	7.4.07	15.4.07	8.4.07	3.4.07	2.4.07	5.4.07	10.4.07
UV-transparent		17.4.07	9.4.07	4.4.07	3.4.07	12.4.07	3.4.07	15.4.07	11.4.07	17.4.07
Solatrol	7.4.07	16.4.07	8.4.07	24.4.07	15.4.07	9.4.07	6.4.07	7.4.07	17.4.07	11.4.07
Field	11.4.07	15.4.07	12.4.07	12.4.07	10.4.07	8.4.07	8.4.07	10.4.07	11.4.07	12.4.07
Luminance	2.4.07	2.4.07	3.4.07	3.4.07	3.4.07	8.4.07	10.4.07	26.4.07	16.4.07	7.4.07
UV-opaque	15.4.07	12.4.07	9.4.07	9.4.07	9.4.07	2.4.07	2.4.07	15.4.07	16.4.07	9.4.07

Spear Quality

Table 3. The total number of spears of each class of Batch 1 crowns harvested at STC during the 2007 season

Site	Variety	Number of harvested spears																	
		Class 1						Class 2						Class 3					
		spear base diameter (mm)						spear base diameter (mm)						spear base diameter (mm)					
		0-8	8-12	12-16	16-20	>20	TOTAL	*0-8*	8 - 12	12 -16	16-20	>20	TOTAL	*0-8*	8 - 12	12 -16	16-20	>20	TOTAL
Field	*GIJNLIM*	0	48	74	63	32	**217**	0	27	26	37	9	**99**	62	24	23	26	19	**154**
	JERSEY GIANT	0	53	73	58	13	**197**	0	13	27	27	15	**82**	52	12	21	12	9	**106**
Luminance	*GIJNLIM*	0	25	78	116	94	**313**	0	13	19	22	35	**89**	92	20	4	11	14	**141**
	JERSEY GIANT	0	50	73	77	78	**278**	0	10	10	16	34	**70**	66	13	9	17	36	**141**
Solatrol	*GIJNLIM*	0	44	100	157	69	**370**	0	8	10	17	7	**42**	59	5	9	8	4	**85**
	JERSEY GIANT	0	84	96	99	61	**340**	0	5	5	5	8	**23**	52	6	9	10	3	**80**
Standard	*GIJNLIM*	0	62	80	124	128	**394**	0	18	15	26	35	**94**	110	9	6	13	27	**165**
	JERSEY GIANT	0	91	156	177	88	**512**	0	16	20	16	14	**66**	91	21	16	18	17	**163**
UV-Opaque	*GIJNLIM*	0	31	86	125	110	**352**	0	11	16	20	35	**82**	91	8	10	12	33	**154**
	JERSEY GIANT	0	65	147	184	108	**504**	0	6	17	15	23	**61**	102	7	7	13	16	**145**
UV-Transparent	*GIJNLIM*	0	34	69	38	80	**221**	0	11	11	22	28	**72**	68	7	7	5	10	**97**
	JERSEY GIANT	0	52	111	115	73	**351**	0	15	23	21	19	**78**	64	8	7	11	24	**114**

Table 4. Mean spear weight and diameter of Batch 1 spears in 2007 – Gijnlim

Site	Class 1			Class 2			Class 3		
	Mean spear weight (g)	Mean spear Diam at base (mm)	Mean spear Diam at mid-point (mm)	Mean spear weight (g)	Mean spear Diam at base (mm)	Mean spear Diam at mid-point (mm)	Mean spear weight (g)	Mean spear Diam at base (mm)	Mean spear Diam at mid-point (mm)
Field	24.98	18.53	12.63	18.76	13.67	10.78	16.89	12.03	9.35
Luminance	28.20	17.09	13.44	30.44	17.22	13.15	16.60	11.84	9.36
Solatrol	31.37	18.04	14.27	26.34	15.72	12.58	14.64	10.17	7.96
Standard	33.40	18.98	14.97	27.45	16.62	13.39	22.70	12.85	10.10
UV-Opaque	31.06	17.71	14.04	31.92	17.83	14.32	15.17	10.79	8.50
UV-Transparent	30.77	17.87	14.00	34.26	18.90	14.85	7.82	7.43	5.82

Table 5. Mean spear weight and diameter of Batch 1 spears in 2007 - Jersey Giant

Site	Class 1			Class 2			Class 3		
	Mean spear weight (g)	Mean spear Diam at base (mm)	Mean spear Diam at mid-point (mm)	Mean spear weight (g)	Mean spear Diam at base (mm)	Mean spear Diam at mid-point (mm)	Mean spear weight (g)	Mean spear Diam at base (mm)	Mean spear Diam at mid-point (mm)
Field	20.72	15.23	11.52	18.16	14.65	10.66	12.22	10.61	8.22
Luminance	31.96	18.69	14.41	38.19	20.67	16.00	30.63	16.95	13.62
Solatrol	26.33	16.92	13.02	22.71	15.18	12.53	12.66	10.20	8.05
Standard	27.65	16.98	13.24	21.77	15.26	11.72	9.33	8.94	6.88
UV-Opaque	28.67	17.74	13.45	27.92	18.02	13.50	17.54	11.67	8.82
UV-Transparent	26.30	16.79	12.95	42.70	22.90	17.14	17.97	11.41	8.99

Appendix 3 Brix % Methodology

1) Collect samples from 20-40 random locations in the crop. The locations should accurately represent the crop as a whole. Avoid seedlings, outside rows and ends of rows.
2) Take roots from a typical plant at each sampling location. Use a spade to make a vertical cut about 30 cm deep into the soil, through the roots, just outside the crown area. Then make a second vertical cut, parallel to the first one, about 15-20 cm further away from the crown.
3) Lift and remove the severed roots from between the two cuts. Discard any hollow asparagus roots or roots from other plants such as weeds. About ten 15 cm root pieces are needed for each sample.
4) Seal the roots in a plastic bag and store return to the laboratory.

How to prepare root samples for Brix% measurements:

1) Keep the 20-40 samples separate from each other throughout the procedure.
2) Remove all soil by washing the roots in cold or lukewarm (not hot) water as soon as possible after collection.
3) Drain excess water by laying the roots on paper for a short time.
4) Rinse the plastic bag, and then place the roots back in it.
5) Freeze the roots in the bags. It is difficult to extract solution from the roots if they are not frozen first. Sap is released when the cell walls break down as the roots thaw.

How to measure Brix%:

Equipment required:

- Refractometer (0-32% Brix, preferably temperature-adjusted, e.g. Atago ATC-1).
- 20-40 small plastic specimen jars.
- heavy duty garlic crusher.
- teaspoon.
- box of tissues.
- scissors.
- bucket of clean water.
- newspaper.

Procedure:

1. Take ten root samples from the freezer and lay them out to thaw on newspaper. They need to be thawed completely and free of surface moisture, but do not let them dry out excessively. If necessary, pat them dry with tissue paper once they are thawed.

2. When the first ten samples have thawed, take the next ten out and allow them to

thaw while working on the first lot. If all samples are thawed at once some may dehydrate and give an incorrect result.

3. Check that the refractometer reads zero with a few drops of clean water. If not, give it time to reach room temperature (ideally about 20°C). It may be necessary to adjust it to zero (see the refractometer manual).

4. Cut the roots into 1-2 cm lengths with scissors.

5. Place the pieces in the garlic crusher and squeeze the solution into a specimen jar.

6. Swirl the solution around until it is mixed thoroughly.

7. Use the teaspoon to place about three drops onto the prism surface of the refractometer.

8. Close the cover over the juice, avoiding bubble formation

9. Read the Brix% on the refractometer scale and record the result.

10. Wipe the prism surface clean with tissues between samples. The refractometer cannot be immersed in water.

11. Dispose of the crushed roots and wipe garlic crusher dry with a tissue after each sample. Any water left on the equipment will affect subsequent readings.