Project title:	Horticultural crops: Demonstration of the potential benefits of modified plastic crop covers
Project number:	CP 19
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Date commenced:	1 January 2003
Duration:	4 years (restructured)

The results and conclusions in this report are based on a series of crop scale observations, crop trials and more detailed field and laboratory-based experiments. The conditions under which the studies were carried out and the results have been reported with detail and 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 the interpretation of the results especially if they are used as the basis for commercial product recommendations.

Authentication

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

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Grower Summary

Headline

The agronomic benefits of four photoselective or 'smart' plastics were determined for a range of crops under UK conditions. The most significant improvements were seen in the quality of lettuce and cauliflower transplants and in stem fresh weights and shelf life in stocks. The results also indicated the taste and smell of herbs may be improved by altering essential oil composition.

Project background and expected deliverables

This project was undertaken to assess the agronomic benefits of four photoselective or 'smart' plastics under UK conditions. The plastics used in the trial were chosen on their ability to alter portions the light spectrum such as UV light (UV opaque and UV transparent) or far-red light (Solatrol). The other 'smart' plastic used in the trial (Luminance) does not affect the light spectrum, but diffuses the light that passes through the plastic. The crops grown under these photoselective films were compared to those grown under a standard plastic and where appropriate outdoor field plots and/or glasshouse facilities.

Each type of plastic can affect the growth of plants in a different and unique manner according to how it manipulates light. In research elsewhere, primarily in Mediterranean climates with high light and temperatures, the use of UV blocking plastic has been shown to reduce pest infestation levels, reduce levels of some diseases and increase growth levels. UV transparent plastic is novel in horticultural use, but has the potential to improve the ability of the plant to withstand physical damage by increasing the thickness of the cell walls, enhance the development of volatiles in a number of crops and affect the colour intensity of foliage and flowers, and may also suppress pest and disease attack. Solatrol, by reducing the proportion of far-red to red light has been shown to reduce the degree of stretching in plants, helping to minimise the use of plant growth regulators. The increase in diffused light levels generated by luminance improves the photosynthetic efficiency of plants leading to increased growth. In addition this plastic can assist in reducing peak temperatures experienced in tunnels during summer by altering the infra-red portion of the light spectrum.

Although there have been small-scale trials with these plastics in the UK, there were no large-scale trials to evaluate these plastics on a semi-commercial scale. This project aimed to provide growers with sufficient information to enable them to accurately judge the economic and agronomic benefits of using these plastics in a commercial situation. In addition to generating information for growers, the project also aimed to undertake some fundamental scientific research to develop a better understanding of the underlying mechanisms, with the intention of aiding the development of new spectral filters with novel or improved characteristics.

The facility at STC was established in 2003 with the assistance of Haygrove Tunnels and BPI Agri. The following five modified plastics were selected because they represented the range of properties exhibited by materials currently available:

- Standard clear horticultural film
- Diffusing standard film (Luminance)
- Red / far red modified film (Solatrol - designed to increase R:FR ratio)
- UV-B transparent film (designed to transmit the full solar UV spectrum)
- UV opaque film

Each was used to cover a 740m^2 tunnel and they were compared to an open field plot.

Summary of the project and main conclusions

- Demonstration of the effects of four spectral filters on a wide range of commercially important crops selected by a consortium of growers compared to a standard plastic and an outdoor field plot.
- Propagation of lettuce and Brassica plants under UV-transparent produced the smallest and most compact plants of all treatments, with leaf thickness increasing by up to 30% compared to conventional glasshouse grown plants
- When lettuce and Brassica plants propagated under UV-transparent plastic were transplanted in the field there were no detrimental effects on establishment or yield compared with glasshouse propagated plants for any planting date.
- Some plantings dates showed an increase in cabbage head weights (8-13%) when propagated under the UV-transparent filter and also in lettuce (2-8%).
- Luminance and UV-opaque plastics increased fresh weights of stocks by up to 17%.
- Results suggest that use of Luminance may assist in the production of late season stocks by maintaining plant quality compared to other plastics.

- Shelf life of flowers was enhanced under Luminance and UV opaque, but further work is required to quantify these benefits.
- Increased coloration of the lollo rosso grown under UV-transparent plastic was seen again in both the triple and double red cultivars used this year, but difference was less pronounced in the triple cultivar. Mean head weights were unaffected.
- Increase in biomass across a range of crops under UV-opaque and luminance noted in 2004 was recorded again in 2005.
- Trial with baby leaf salads showed no consistent effects on biomass, leaf thickness or leaf area.
- Initial work on oil distillation and subsequent testing of pot and drilled coriander indicate plastics can influence essential oil composition
- Initial work carried out on the degree of microbial loading on the baby leaf salads indicated that there was a reduction of microbial loading under some plastics, but additional work will be carried out this year to validate results.

The original project, driven by the Grower Steering Group (GSG) representing a wide range of commodity sectors, began in March 2003 with the overall aim of 'developing, evaluating and implementing technologies to exploit the benefits of modified plastic crop covers in UK horticulture'. Initial results showed marked effects on plant growth regulation, canopy development, time to flowering and colour intensity. The GSG requested that some of these effects be further explored during the 2003 season and the project was extended to allow more detailed scientific studies to underpin the observations. The interest generated by the results was such that the GSG and other grower groups requested that the whole project be restructured from January 2004.

The restructured project was designed by a partnership of scientists, agronomists, product suppliers and potential end-users (GSG) and will run for three years. This report describes the work undertaken in 2005, the second year of the restructured project.

The core activities measure agronomic and physiological changes in a range of plants selected in two groups. The first group consists of container-grown crops propagated under plastics then subsequently transplanted to the field, while the second group consists of annual crops grown to harvest in field soil under the plastics.

The following tasks were completed in accordance with the second year's objectives:

- Continued collation of information produced elsewhere about the effects of modified plastics on plant growth, pest and pathogen incidence and other agronomically significant benefits.
- Selection of key plant species / cultivars in liaison with the GSG.
- Continued monitoring of the degradation and light spectral qualities of the five types of plastic covers.
- Continued evaluation of the potential agronomic and economic benefits of the filters on the selected crops.
- Field 'growing-on' trials with Brassicas, iceberg lettuce and lollo rosso propagated under the various filters.
- Preliminary assessment of the benefits of 'tactical deployment' of plastic filters.
- Preliminary shelf life and taste test trials for baby leaf crops.

Agronomic studies

The overall objective in 2003 was to detect differences in growth and quality of the selected indicator plants and to provide direction for further R&D. The initial results showed marked effects on growth regulation, canopy development, time to flowering, biomass, foliage colour, and yield of essential oils. However, these exact effects varied between plant species and cultivars. All the data were provided in the first Annual Project Report (Project CP 19, HDC, March 2004).

The studies carried out in 2004 repeated some of the work done in the first year and enabled the influence of different growing seasons to be taken into account. There were some modifications based on the experience gained, eg. Strawberries, HONS and some leafy salads (corn salad, chard, pak choi) were removed from the project, while additional bedding plants and asparagus were included. All the data were provided in the second Annual Project Report (Project CP 19, HDC, January 2005).

The work programme in 2005 was a combination of validating the results from previous years, inclusion of new crops (baby leaf salads and annual herbs) and expanding the field trials. The GSG selected the following plants;

- Vegetable propagation (lettuce, cauliflower, cabbage and broccoli).
- Bedding plants (pansy and impatiens).
- Baby leaf salads (rocket, mizuna, spinach and red chard).
- Cut flowers (asters, stocks, pinks, lilies).
- Herbs (pot grown dill, fennel, coriander and basil, plus direct drilled coriander).
- Asparagus.

Meteorological data

Observations were made at STC in accordance with UK Meteorological Centre protocols for the measurement of sunlight, precipitation and temperature. The start to the season in 2005 was colder compared to 2003 and 2004 which affected some trials. Overall it was an ‘average’ year, but with less sunlight than in 2003 and less rain than in August 2004. The tunnels still proved the growing advantages gained from protection, before any added benefits gained from the use of smart plastics were taken into consideration.

Degradation of plastics

All the plastics were replaced in 2005, with a 1m x 1m portion of the original plastic samples attached to wooden frames in the field to monitor the long term degradation of the plastics. The results indicate that apart from some changes in the PAR transmission levels, and an increase in UV light transmission in some plastics, the core attributes of each plastic have remained relatively stable over the three years.

Agronomic results

<u>Propagation of lettuce</u>

Previous work in 2003 and 2004 showed that propagating lettuce plants under Solatrol or UV-transparent produced compact plants that are preferred by the industry. This was due to smaller, thicker walled plant cells. These would possibly increase the ability of the plant to resist physical damage at transplanting, a trait particularly pronounced in UV-transparent propagated plants.

The trials in 2005 attempted to determine if there were any 'carry over' effects of the propagation regime on post-transplanting performance. Plants were grown under Solatrol and UV transparent from seedling emergence for either 1 or 3 weeks, compared to a glasshouse regime and then planted in a replicated field trial. Results are very encouraging, with UV-transparent propagated plants having the same or increased yield (up to 9% increase in head weight) when compared to glasshouse-propagated material. This demonstrated that lettuce could be propagated or hardened off under UV transparent with no detrimental effects on yield or quality.

Propagation of Brassicas

Results from 2004 indicated that plants propagated under Solatrol produced the most compact plants, and little evidence to suggest a carry over effect in crop yield at harvest. The trials in 2005 expanded the field trial component of the project, using broccoli, cabbage and cauliflower, with each crop kept in the different tunnels for period of 2, 4 and 6 weeks, and compared to glasshouse propagated material.

As in previous years, there was an increase in leaf thickness in those plants propagated under UV transparent plastic (up to 30% increase in broccoli) compared to the glasshouse grown plants. When yields were compared, the results were similar to those seen with lettuce, with the UV transparent propagated material having the same or increased yield compared to those grown in the glasshouse. Cabbage plants had increases in head weight of 4-9%, and cauliflower had increases of up to 17% when propagated under UV transparent plastic. The treatments also appeared to influence the cropping period, with some UV treatments increasing the proportion of plants harvested at the first harvest dates.

The results confirm that propagating plants under UV transparent will not affect the yield or quality of cabbage, broccoli or cauliflower. The added leaf thickness exhibited by UV transparent propagated plants may help establishment and reduce transplant shock.

Cut flowers

The severe weather conditions experienced in August 2004 confirmed the significant benefits to be gained from moving production under some form of protection.

However, it was also noted there were additional benefits to be gained from the choice of covering. With the price of cut flowers being determined primarily by the fresh weight of the stem, it was interesting to note that growing plants under UV-opaque or Luminance could substantially increase stem weight in comparison with the standard plastic, especially with stocks. With stem length another important factor, it was quite clear that the growth regulating properties of Solatrol are of limited value in cut flower production. In addition, a late season planting of stocks demonstrated that growing under Luminance might help in maintaining the quality of stocks during high light/temperature conditions, which can adversely affect their growth and quality.

Initial work on shelf life quality of flowers grown under the different plastics suggested there might be some carry over benefits, for plants grown under UV-opaque and Luminance. However, this was a limited assessment, and work will have to be repeated and validated during 2006 before any firm conclusions can be drawn.

Pot and soil grown herbs

The results with perennial herbs in 2004 clearly confirmed the huge increases in biomass gained from growing plants under Luminance. In 2005 the emphasis was changed to assess the impact on the quality of a number of pot grown annual herbs. The potential impact on oil composition in pot and soil grown coriander grown under different plastics and glasshouse or field plots were also assessed.

The impact on biomass and compactness of pot grown herbs was less pronounced than was expected, based on previous experience and feedback from a grower who specialised in the production of pot grown herbs. Further work is required using will be repeated using a larger range of species.

The results from the distillation of essential oils from pot and soil grown coriander indicates that the relative levels of essential oils can be influenced by the choice of plastic, which may in turn affect the taste of the herbs. The work did demonstrate that this is an exceptionally complex area with the character of the oils being potentially influenced by a wide range of factors. To answer all the questions raised by this work would require a more substantial trial than can be justified under CP19, but is a valuable starting point for any such work.

Asparagus

The asparagus that was planted in 2004 is now well established, and the difference in the growth in the ferns under the different plastics has been significant. The ferns under all the plastics stayed greener for a longer period of time than the field grown material, and the size of the ferns varied between the plastics, with the greatest biomass generated under Luminance. It has been proposed that that the combination of increased biomass and greenness (i.e. longer period of photosynthesis) may increase the carbohydrate reserves in the crown. These increased reserves may then influence spear number, thickness or another quality attribute when the plants are cropped for the first time in 2006. There may be other benefits to be gained from using protection due to reduction in disease levels, especially *Stemphylium.*

Baby leaf salads and lollo rosso

This was a new crop to CP19, and developed out of a meeting with Hazeldene Salads who were interested in the potential of the tunnels to improve plant quality. The results of various physical parameters such as leaf thickness were inconclusive, with too much variation in results to confirm any particular effect from the different plastics. However, when samples were sent to Hazeldene Salads for a 'wash test' and an assessment of microbial loadings, there appeared to be reduced microbial loading under some filters. As this was a preliminary test the data is not attached to this report, but was very promising and requires further study.

In 2004 trials clearly demonstrated the effect of the plastics on the colour and taste of lollo rosso lettuce grown in the tunnels, where UV transparent plastic increased the coloration and bitterness of the lettuce and reduced head weight. The UV-opaque and Luminance plastics maximised biomass, but at the expense of the red pigmentation.

In 2005 triple and double red cultivars of lollo rosso were grown, with the triple red cultivar exhibiting less pronounced differences in coloration between the plastic treatments, compared to the double red cultivar.

Bedding plants

From the previous years work it was known that UV-transparent and Solatrol reduced the height of a range of bedding plants. The trial in 2005 aimed to build on this knowledge and assess the interaction between applications of PGRs and the growth of bedding plants under these growth regulating films compared to standard plastic and a glasshouse control.

Unfortunately a period of late frosts and cool growing conditions resulted in the death of the impatiens and no reasonable conclusions could be drawn from the work.

Financial benefits to growers

Potential benefits:
The potential benefits will vary for most plant species and modified plastics, but so far they have included:

- Reduction in use of plant growth regulators on bedding plants.
- Improved quality of crops – stem length, leaf thickness and more compact plants.
- Reduction in wastage due to failure to meet QC standards.
- Improved crop scheduling and extension of the growing season as growers have more control of the growing environment.
- Using plastics to reduce costs of propagation of lettuce and Brassicas without detrimental post planting effects.
- Import substitution by extending production of crops
- Improved pigmentation of foliage and flowers

The potential financial benefits of the factors listed above and economic viability of adopting the new growing systems will be determined at the end of the final year of the project.

Action points for growers:

The Project Management Team and GSG believe that it would be premature to make firm recommendations on the basis of the trials completed so far.

SCIENCE SECTION

SECTION A. GENERAL INTRODUCTION

PROJECT BACKGROUND

The cultivation of crops under simple plastic covered structures is now commonplace in UK horticulture because of its potential to extend growing seasons, control harvests and improve the quality of produce. In recent years advances in technology have allowed the manufacture of novel materials that ‘fine-tune’ the growing environment still further, by manipulating the intensity and wavelength of light reaching the crop.

Each type of plastic can affect the growth of plants in a different and unique manner according to how it manipulates light. In research elsewhere, primarily in Mediterranean climates with high light and temperatures, the use of UV blocking plastic has been shown to reduce pest infestation levels, reduce levels of some diseases and increase growth levels. UV transparent plastic is novel in horticultural use, but has the potential to improve the ability of the plant to withstand physical damage by increasing the thickness of the cell walls, enhance the development of volatiles in a number of crops and affect the colour intensity of foliage and flowers, and may also suppress pest and disease attack. Solatrol, by reducing the proportion of far-red to red light has been shown to reduce the degree of stretching in plants, helping to minimise the use of plant growth regulators. The increase in diffused light levels generated by luminance improves the photosynthetic efficiency of plants leading to increased growth. In addition this plastic can assist in reducing peak temperatures experienced in tunnels during summer by altering the infra-red portion of the light spectrum

Although a limited number of small-scale studies have investigated the potential impacts of spectrally modified plastics on UK crop production, the majority of published research studies come from regions with hotter, sunnier climates which may be hard to extrapolate to UK conditions. Therefore, to date, UK growers have been presented with little objective information about the effects modified plastic covers under UK conditions and using structures approaching the commercial scales.

In contrast, the aim of this long-term, large-scale project is to investigate the costs and benefits to the UK horticultural industry of adopting modern plastic technology, by concentrating on crops that are of specific importance to the UK market. This project will clarify the situation by evaluating plastic covers with a broad range of light manipulating properties, determine their benefits to key UK horticultural crops and rapidly transfer that technology to UK growers. In addition, the proposed research will provide direction for more fundamental scientific studies to determine the underlying mechanisms, with a view to further enhancing the beneficial effects of such filters, and aiding in the development of new spectral filters.

COMMERCIAL OBJECTIVES

The project has been driven by a consortium of growers from a wide range of commodity sectors (led by horticultural consultant, Mr Stuart Coutts) who formed the project's Grower Steering Group. The project also has the support of the leading tunnel and plastic manufacturers. The partnership of applied scientists, agronomists, product suppliers and potential end-users will ensure that the materials are properly evaluated under conditions relevant to commercial crop production and that the results become available to growers as quickly as possible.

Figure 1. Large scale spectral filter trial (Stockbridge Technology Centre, Summer 2003).

SECTION B. MATERIALS AND METHODS

Plant material.

Plants were grown following grower instructions, under five spectral filters (Standard, UV-transparent, Solatrol, Luminance and UV-opaque) provided by BPI Agri (Stockton-on-Tees, UK). Each plastic altered the spectrum of light under the canopy in the way detailed on the following pages. Plants were also grown either in a field plot or in a glasshouse to compare growth to those grown in the tunnels.

Determination of root / shoot fresh and dry weights.

Plants were harvested at the time of first flower (unless otherwise stated) and shoot fresh weights were determined. Dry weights were obtained by weighing the plant material after drying at 75 °C until a constant mass was reached.

Leaf expansion measurements.

In instances where destructive harvests were made determination of leaf area was quantified using an automatic Leaf Area Meter LI-3000 (Li-Cor, Inc., Lincoln, NE, USA).

Leaf thickness.

Leaf thickness was measured at the central region of the lamina, adjacent to the mid-vein, using a 0-25mm micrometer (RS Components, Corby, UK).

Field trials.

On three separate transplant dates, plants were removed from their respective spectral filters and a glasshouse where they had been propagated, and planted out in a random block design.

Shelf life trials.

Winchester Flowers assessed shelf life in cut flowers (Spalding, Lincolnshire).

Statistical analysis.

Multiple Student t-tests were used in all analysis except when calculating daily leaf expansion in lettuce. Because the same leaves were measured throughout the lettuce growth experiment, leaf area data were analysed using two way, repeated measures ANOVA with *post hoc* multiple pairwise comparison using Tukey tests to investigate the effect of treatments on leaf area during development. All analyses were performed using Sigmastat V 2.03 (SPSS Inc.).

SECTION C. RESULTS SECTION

Part 1. THE PERFORMANCE OF THE FILTERS AND METEOROLOGICAL OBSERVATIONS 2003-2005.

Measurement of irradiance

Spectral irradiances within the polytunnels were measured relative to ambient spectral irradiances using two double monochromator spectoradiometers (S9910-PC and SR9910-V7, Macam Photometrics, Livingston, UK). The spectroradiometers were calibrated for wavelength using spectral lines from a mercury arc lamp (LOT Oriel, Leatherhead, UK) and for spectral irradiance against tungsten and deuterium sources (Macam SR903) based on National Physics Laboratory Standards.

The original plastics were first used in 2003, and then in 2005 all of these plastics were replaced. The only exception was the standard plastic which had been replaced in 2004 due to changes in the properties of this plastic during the previous summer, and is therefore one year younger than the other plastics in this test. Samples of the plastics replaced in 2005 were retained, and attached to 1m x 1m frames. These frames were then placed in a field at the same time as the tunnels were re-covered in spring, with the frames set at 45^{o} and facing due south. In autumn, small 10cmx10cm samples were taken and analysed at Lancaster University to determine how the plastics had degraded.

Changes in the transmission properties of five plastics over a two or three year period.

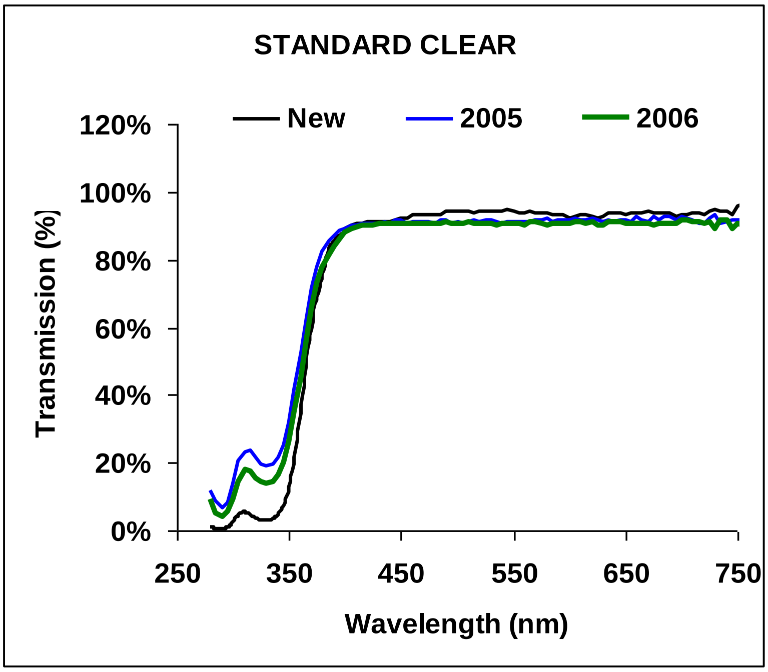


Figure 2. Changes in the transmission properties of standard plastic after two years

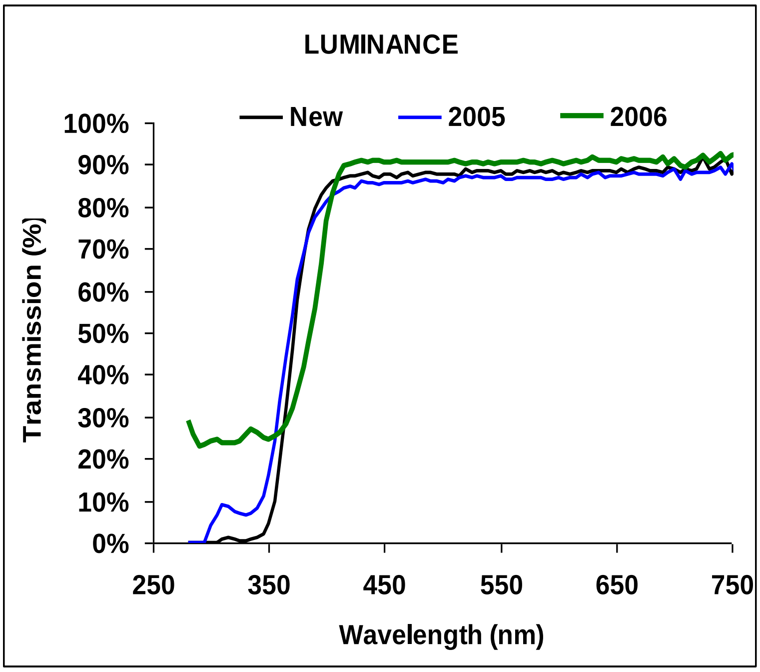


Figure 3. Changes in the transmission properties of Luminance after three years

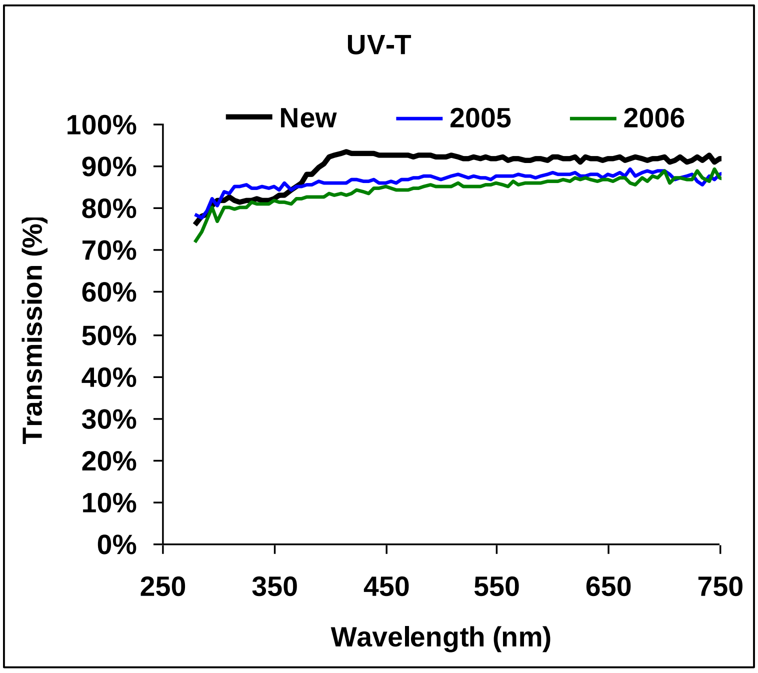


Figure 4. Changes in the transmission properties of UV transparent plastic after three years

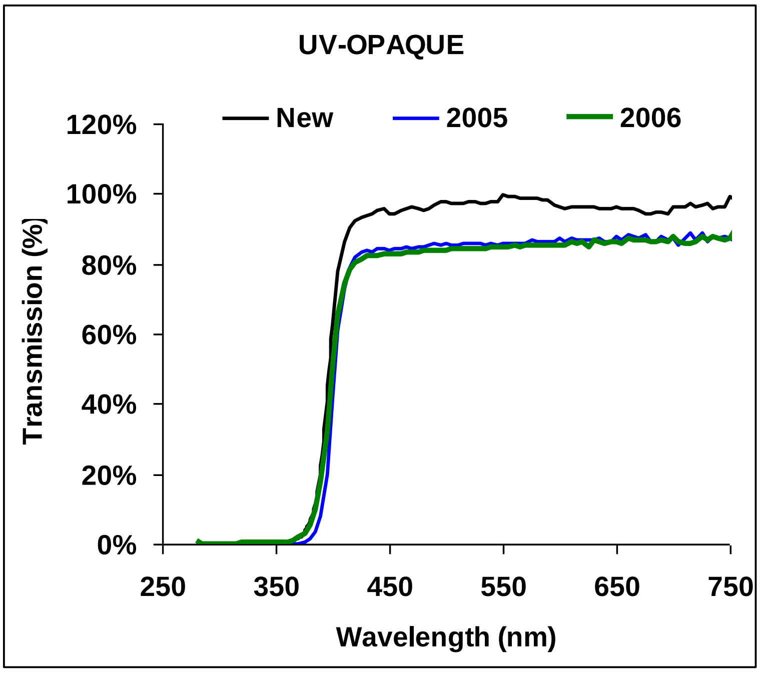


Figure 5. Changes in the transmission properties of UV opaque plastic after three years

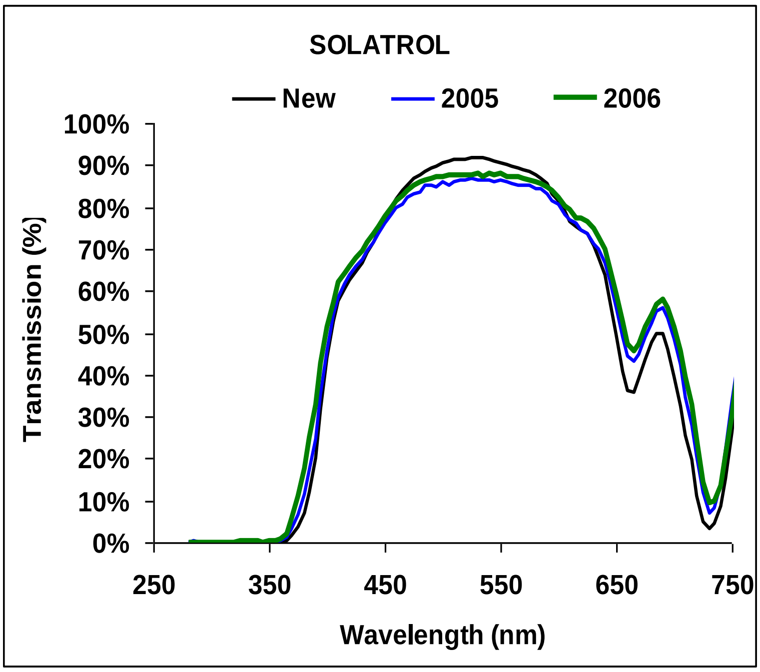


Figure 6. Changes in the transmission properties of Solatrol after three years

The standard plastic was changed in 2004 as it showed a large increase in UV levels, and the film that replaced it continues to show increased UV transmission, but changes have been relatively small. The UV transparent has shown some slight reductions in transmission in the 400-700nm range over the three years, and another reduction was seen again this year. In contrast, the level of UV light transmission has been relatively stable over the three year, and remains the most UV transparent film.

The UV opaque had the greatest fall in overall PAR light transmission levels in the first two years, but has remained relatively stable over the past 12 months and the ability of this plastic to block the UV light has remained stable over the past three years. Solatrol has shown some slight reduction in the 500 – 600nm range, with some increases at longer wavelengths, but overall has been stable over the past 12 months. The basic property of this plastic has not changed, and retains its ability to alter the proportion of red to far-red light penetrating the structure. As with the standard plastic, the Luminance has shown progressive increases in UV transmission over the years, which has been especially marked in the last year. However, it should be noted that the diffusing properties of this film make it harder to obtain precise and repeatable measurements than with the clear films.

The greatest changes that will be seen in a plastic are likely to be due to the location of the plastic on a structure, or the level of sunlight during the summer. Plastic that is facing south is likely to degrade faster and have its characteristics altered the fastest than plastic facing north or in a shaded area. The impact that a bright summer can have on the characteristics of a plastic was seen with the rapid changes in the standard plastic during 2003, which necessitated its removal

Overall the changes in the plastics are relatively minor, with the greatest changes seen in changes in the total PAR transmission levels, but the basic properties of each plastic, such as transmission of UV light, or blocking far-red light have remained stable over the three year period.

Meteorological data from 2003 - 2005


°C

	Hours			mm rainfall			Average temperature		
	2003	2004	2005	2003	2004	2005	2003	2004	2005
March	78	81	45	12	25	24	12	10	10
April	164	95	136	34	74	76	14	13	12
May	177	199	204	59	21	29	17	17	16
June	182	151	142	89	51	41	21	20	20
July	165	160	164	47	47	59	23	21	22
August	173	152	173	6	140	50	23	22	22

Figure 7. Observations were made at Stockbridge Technology Centre in accordance with UK's Meteorological Centres procedures and protocols in measuring a) hours of sunlight, b) precipitation in mm and, c) average temperature in °C

Part 2. PROPAGATED LETTUCES AND BRASSICAS

INTRODUCTION

Horticultural Brassicas (Brussels sprouts, cabbage, broccoli and cauliflower) are grown on approximately 32,500 hectares in the UK (MAFF Basic Horticultural Statistics Census, 2001) and are important crops for a large number of growers. Most of these crops are established from modules grown under protected structures for 6-8 weeks, depending on the time of year, before being machine planted. Similarly, propagation lettuce varieties are normally established under glass structures for a period of approximately 14 days prior to planting out.

The production of module plants has become a specialist business for several companies and there is a need to develop lower cost growing methods whilst not compromising plant quality. Carefully controlled conditions are required to optimise germination and early emergence for the first 1- 2 weeks after sowing Brassicas, and for the entire 14 - 21 day propagation stage for lettuce; from emergence to the planting out stage. For outdoor crops, uniform emergence of drilled crops is known to influence product uniformity at harvest. Therefore, uniform emergence of seeded crops in modules could also be critical to maximise plant establishment and the percentage of plants that are cut at the first harvest.

From the cotyledon stage onwards, Brassica plants must be grown under cooler, ‘tougher’ conditions to ensure that ‘leggy’ growth is avoided and this is achieved by a combination of careful temperature control and by liquid feeding. Plants must not become leggy as this can encourage disease development. Furthermore, if tissue is soft, Brassicas can be damaged by pre-plant drenches applied for cabbage root fly control and also during the planting operation.

Results from both the 2002/ 2003 seasons showed that propagating lettuce under the UV-transparent filter produced plants that were comparable to those propagated under commercial glass. They were ‘short and stocky’, a function of reduced epidermal cell expansion, not cell division, and increased leaf thickness, which preliminary results seemed to indicate was a function of an increase in both the number (and size) of the photosynthesising palisade mesophyll cell layers. Furthermore, these morphological changes may have aided in the plants early adaptation to ambient conditions in field trials, since those plants propagated under the UV-transparent filter produced a 24% increase in fresh weight at time of harvest when compared to plants propagated under the remaining 4 filter treatments. We hypothesised that this may have been, at least in part, a result of an increase in the mechanical strength of the epidermal cell wall and therefore the leaf as a whole, mediated by an increase, relative to the remaining four filters, in the plants exposure to UV radiation under the UV-transparent filter.

It is therefore possible that there is potential to use more ventilated structures with a UV-transparent filter, for raising both Brassica and lettuce plants. This would release glasshouse space for other uses, or increase output if the plants were grown in glasshouses for a shorter period, before being moved out into other cheaper structures.

The aim of the 2003/4 work was to investigate the effects of using the five spectral filters on the growth and development of module raised plants. Iceberg lettuce, cauliflowers and cabbage were used. This year's trial work focused on those filters that have, over the previous two seasons, produced a commercial grade crop: the Standard, UV-transparent and Solatrol filters. Within the filter treatments one lettuce crop batch spent the whole time, from germination to the end of the propagation stage (14 days) under the filter with the remaining treatment batch transferred from glass after 1 week for a period of 7 days. For Brassicas, one crop spent a full 6 weeks under filters before being planted out and the remaining 2 treatments were transferred from glass at 2 and 4 weeks before being planted out at 6 weeks. Appropriate commercial glasshouse produced crops were used as controls in both the lettuce and Brassicas trials.

The purpose of this years work was to further characterise the morphological adaptations of three types of Brassica and two varieties of lettuce under the Standard, UV-transparent (UVT) and Solatrol (SOL) filters, with a Commercial glass control, at the end of the propagation stage. These assessments were followed by commercial field trials of all the propagation crops at Stockbridge Technology Centre at three time points (early, mid and late season) throughout the typical UK growing season.

OBJECTIVES

To identify a filter(s) that produces a plant that is ‘short and stocky’, possesses good mechanical strength and that performs well in the field. This will allow Brassica and lettuce plant propagators to partially, or completely, bypass production under commercial glass and therefore cut production costs while producing a product that performs well through to the harvest stage.

RESULTS

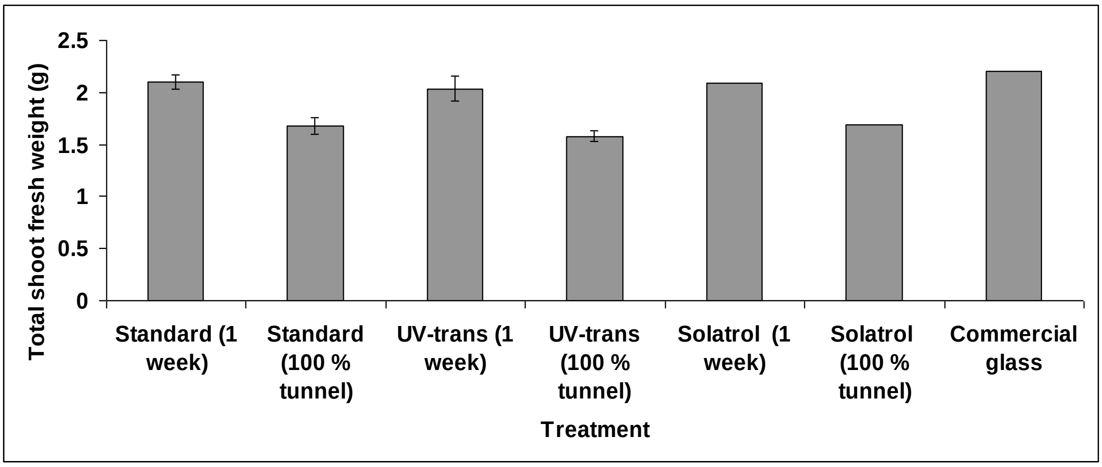
PROPOGATION ICEBERG LETTUCE – MEASUREMENTS TAKEN AT DAY 14

The Commercial treatment significantly increased total shoot fresh weight relative to all filter treatments except Standard (1 week) and Solatrol (1 week) (fig. 1.a.). Of the filter treatments, Solatrol (1 week) increased shoot fresh weight when compared to Standard (100% tunnel) UV-trans (100% tunnel), Solatrol (100% tunnel) only (fig. 1.a). Leaf 2 fresh weight was increased in Commercial when compared to Standard (100% tunnel), UV-trans (100% tunnel) and Solatrol (100% tunnel) only (fig. 1.b). There was no effect of Commercial glass treatment in leaf 2 fresh weight when compared to all filter treatments that spent (1 week) under Commercial glass before transfer to the tunnels (fig. 1.b). Leaf 2 length was significantly increased under Commercial glass when compared to all filter treatments except Solatrol (1 week) (fig. 1.c). Of the filter treatments, UV-trans (100% tunnel) reduced leaf 2 length relative to all remaining treatments (fig.1.c).

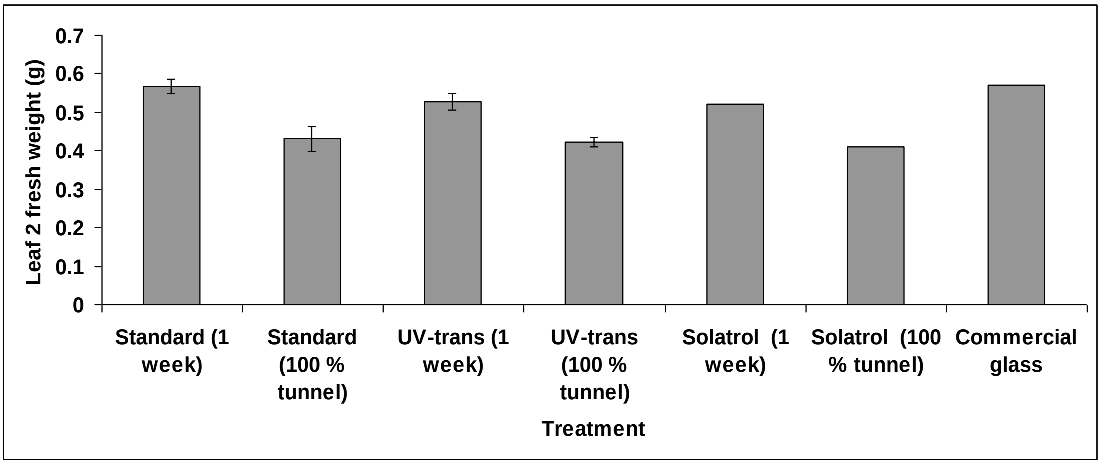
Commercial glass increased total leaf area when compared to all treatments except Standard (1 week) and Solatrol (1 week) (fig. 2.a). Shoot dry weight was significantly increased in Standard (1 week) compared to all UV-trans (100% tunnel) and Solatrol (100%) only (fig. 2.b).

Figure 1. Effect of treatments on (a) total shoot fresh weight (b) leaf 2 fresh weight and (c) leaf 2 length in propagation iceberg lettuce at 14d. Each value is the mean + S.E. of 20 replicates

a)



b)



c)

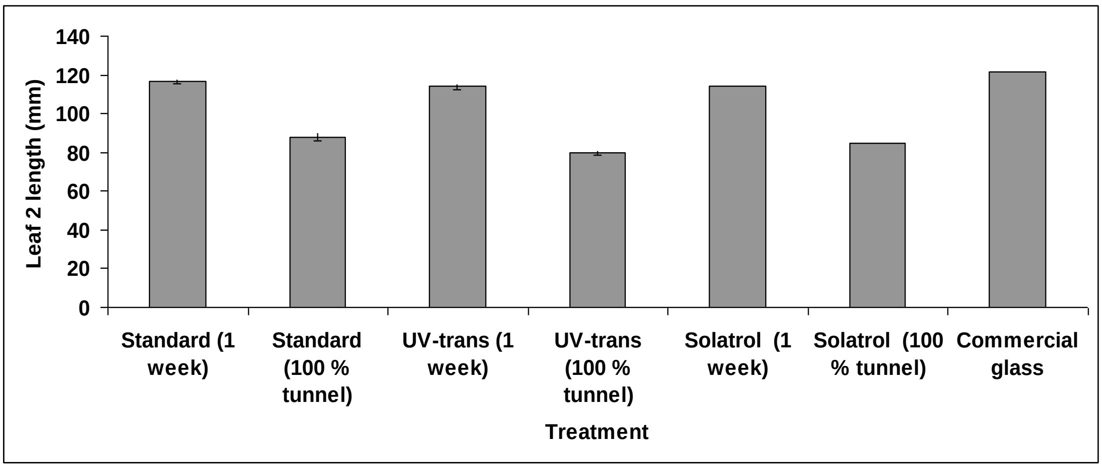
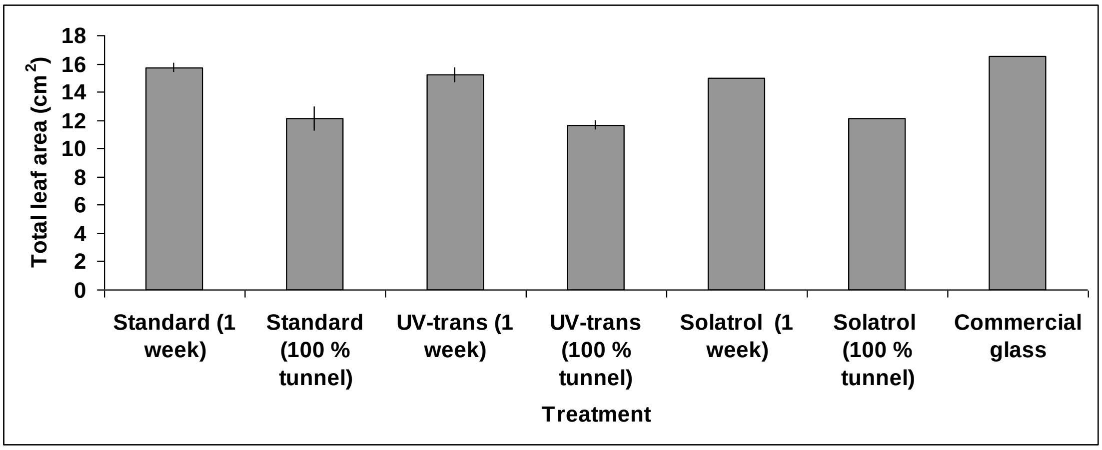
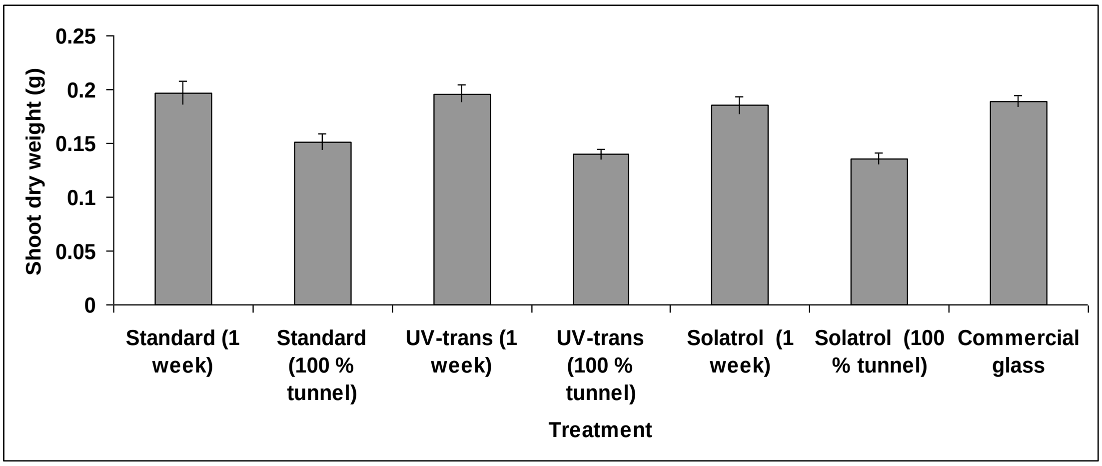


Figure 2. Effect of treatments on (a) total leaf area and (b) shoot dry weight in propagation iceberg lettuce at 14d. Each value is the mean ± S.E. of 20 replicates.

a)



b)



RESULTS

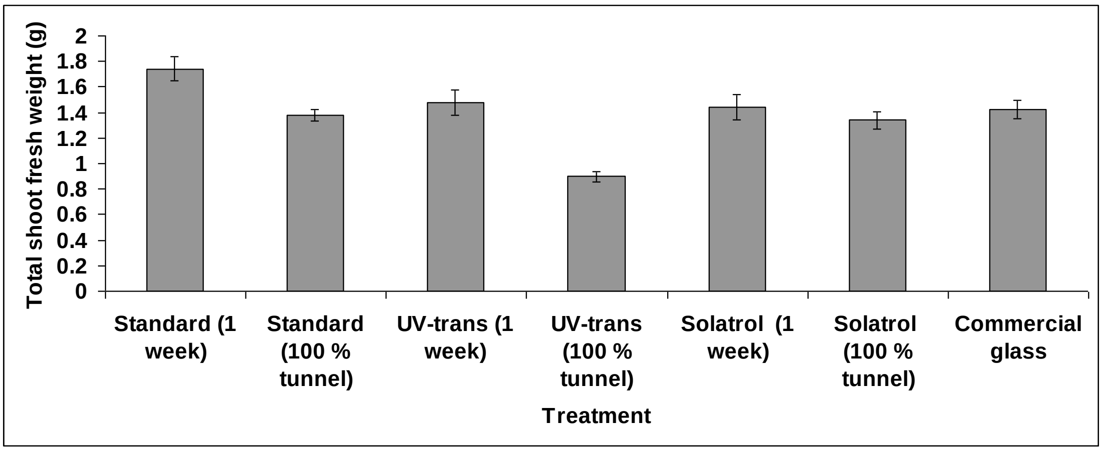
PROPOGATION LOLLO ROSSO LETTUCE – MEASUREMENTS TAKEN AT DAY 14

The Standard (1 week) treatment significantly increased total shoot fresh weight relative to all remaining treatments except UV-trans (1 week) (fig. 3.a.). The Commercial treatment significantly increased shoot fresh weight relative to Standard (100% tunnel) and UV-trans (100% tunnel) and reduced fresh weight compared to Standard (1 week) only (fig. 3.a). Leaf 2 fresh weight was increased in Standard (1 week) when compared to all remaining treatments (fig. 3.b). Commercial glass significantly increased leaf 2 length relative to all remaining treatments except UV trans (1 week) and Standard (1 week), which produced a significant increase in length when compared to all remaining filter treatments and Commercial glass (fig. 3.c). Standard (1 week) significantly increased total leaf area when compared to all remaining treatments (fig. 4.a).

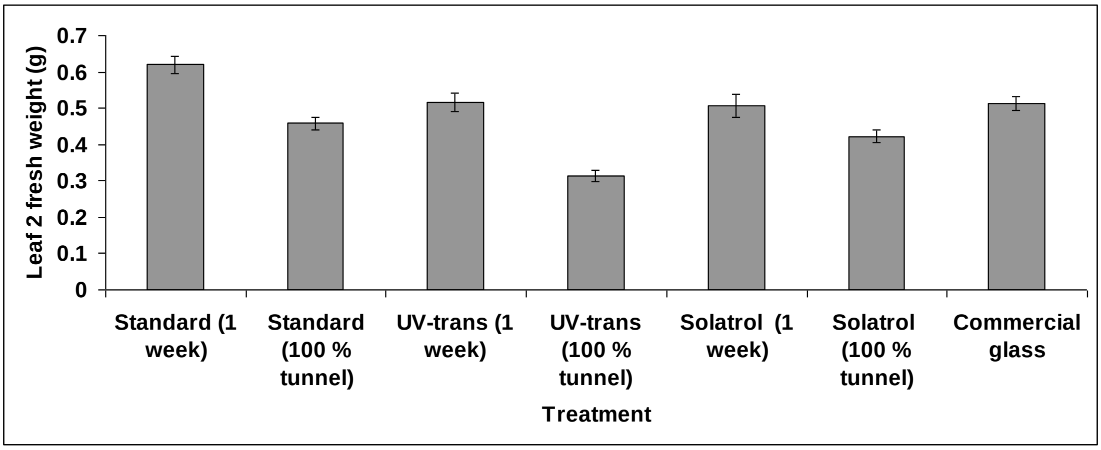
In contrast, UV-trans (100% tunnel) significantly reduced total leaf area relative to all remaining filter treatments and Commercial glass (fig. 4.a). Standard (1 week) significantly increased shoot dry weight compared to all remaining treatments except UV-trans (1 week) and Commercial glass (fig. 4.b). Again, UV-trans (100% tunnel) significantly reduced shoot dry weight when compared to all remaining treatments except Solatrol (1 week) (fig. 4.b).

Figure 3. Effect of treatments on (a) total plant fresh weight (b) leaf 2 fresh weight and (c) leaf 2 length in propagation lollo rosso lettuce at 14d. Each value is the mean + S.E. of 20 replicates

a)



b)



c)

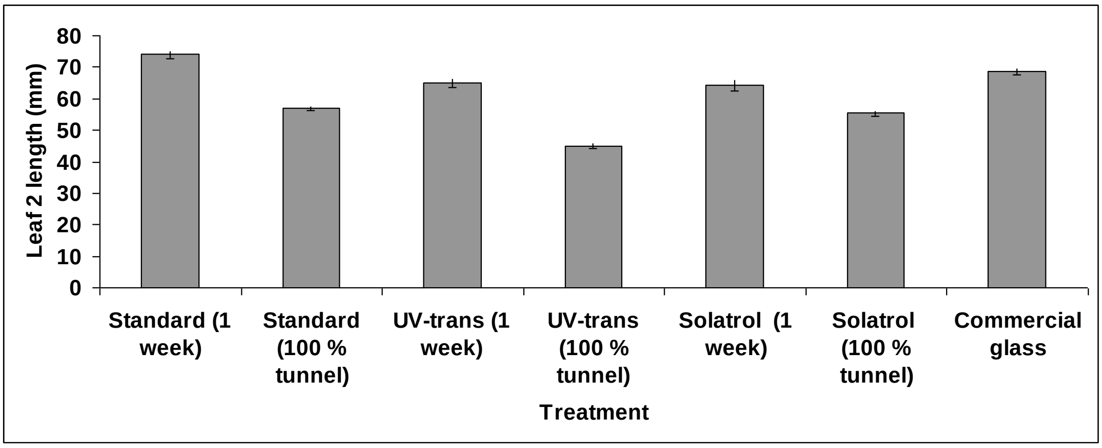
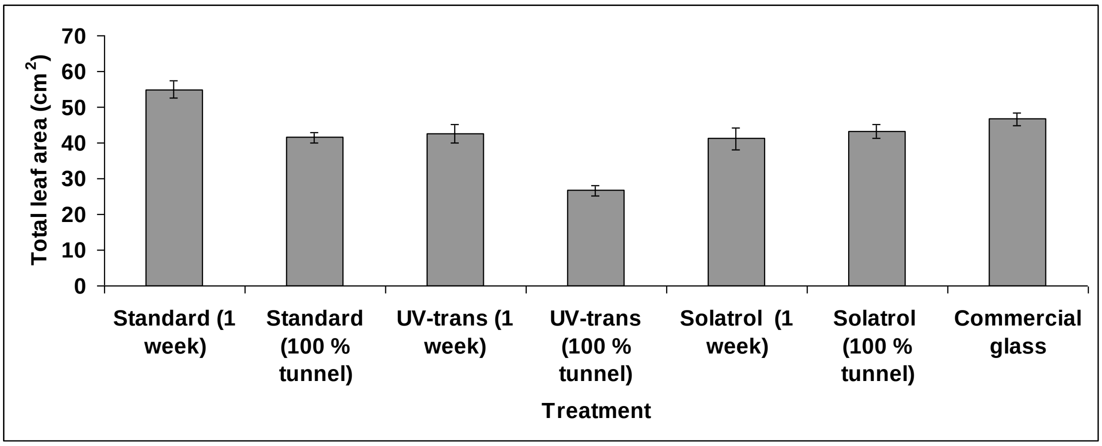
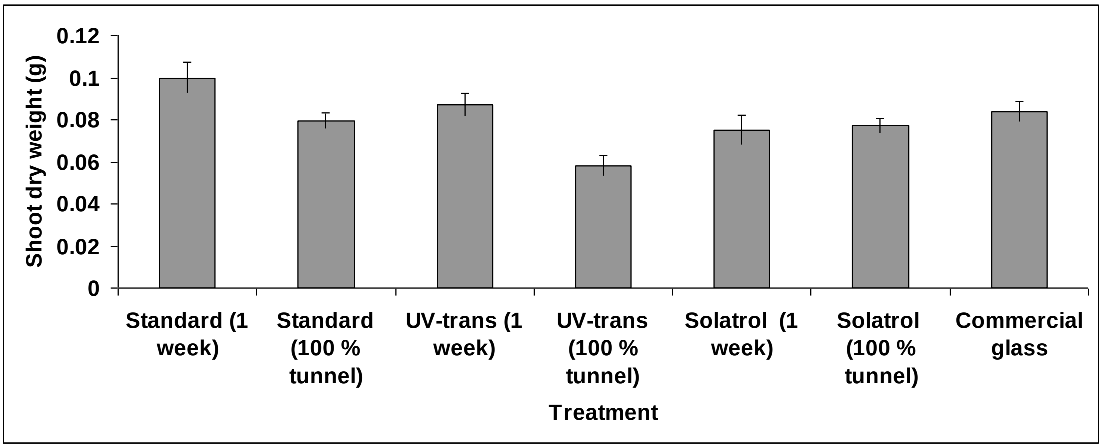


Figure 4. Effect of treatments on (a) total leaf area and (B) shoot dry weight in propagation lollo rosso at 14d. Each value is the mean ± S.E. of 20 replicates.

a)



b)



FIELD TRIALS - ICEBERG LETTUCE

In early-season field trials, there were non-significant increases UV-trans (100% tunnel) fresh weights at time of harvest when compared to Standard (1 week) (5%, P=NS), Standard (100% tunnel) (7 %, P=NS), UV-trans (1 week) (5%, P=NS), Solatrol (1 week) (5%, P=NS) Solatrol (100% tunnel) (9%, P<0.001) and Commercial glass (4%, P=NS) (fig. 5.a).

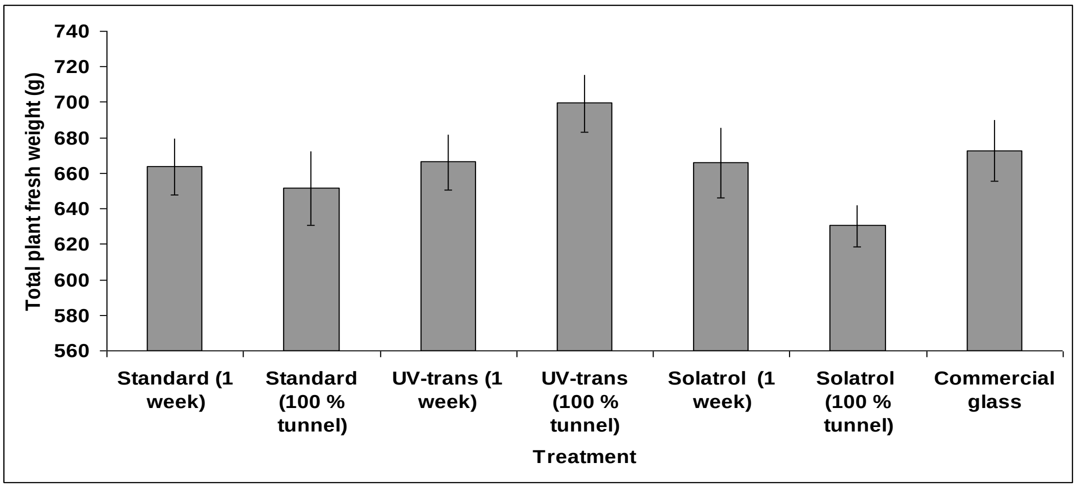
In mid-season field trials, UV-trans (100% tunnel) increased fresh weights at time of harvest when compared to Standard (1 week) (10%, P<0.01), Standard (100% tunnel) (10 %, P<0.01), UV-trans (1 week) (10%, P<0.01), Solatrol (1 week) (8%, P<0.05) Solatrol (100% tunnel) (7%, P=NS) and Commercial glass (10%, P<0.01) (fig. 5.b).

In late-season field trials, UV-trans (1 week) increased fresh weights at time of harvest when compared to Standard (1 week) (9%, P<0.01), Standard (100% tunnel) (6%, P=NS), UV-trans (100% tunnel) (7%, P<0.05), Solatrol (1 week) (6%, P=NS)

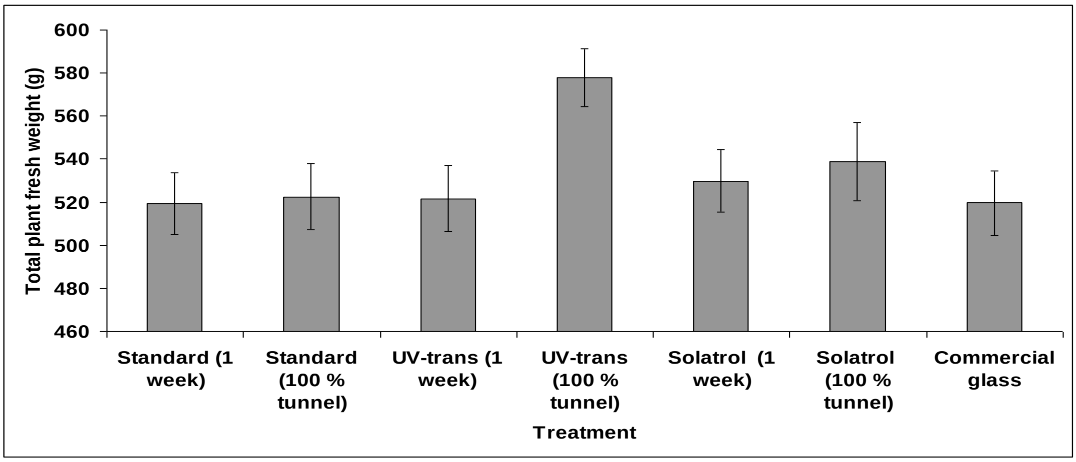
Solatrol (100% tunnel) (2%, P=NS) and Commercial glass (6%, P=NS) (fig. 5.c).

Figure 5. Effect of treatments on head fresh weight Iceberg lettuce in field trials at time of harvest in (a) early, (b) mid and (c) late season plantings. Each value is the mean ± S.E. of 60 replicates.

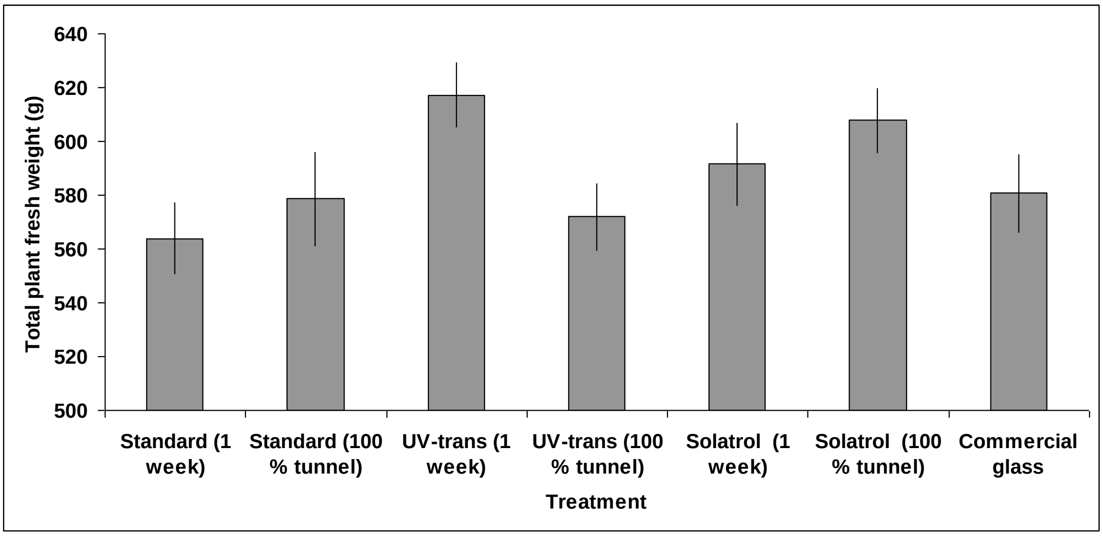
a)



b)



c)



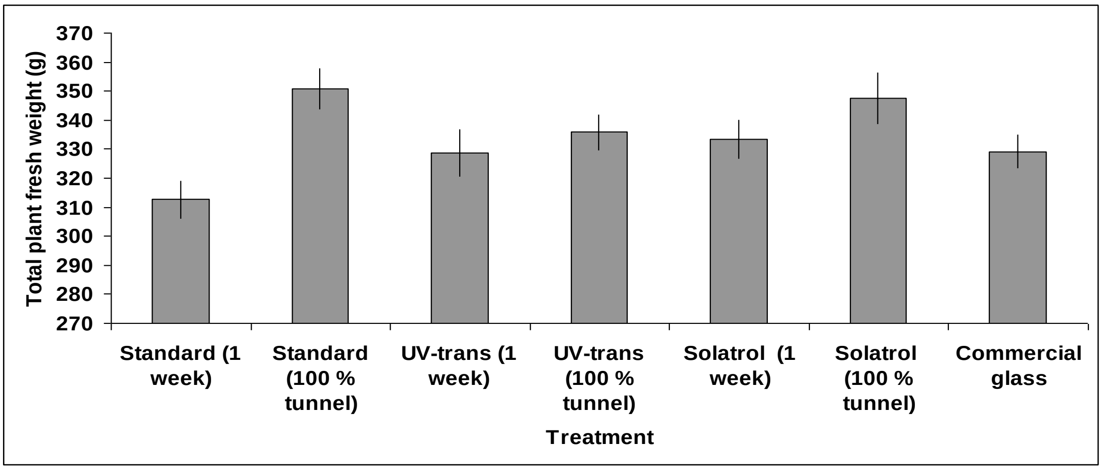
FIELD TRIALS – LOLLO ROSSO LETTUCE

In early-season field trials, Standard (100% tunnel) increased fresh weight at the time of harvest when compared to Standard (1 week) (11%, P<0.01), UV-trans (1 week) (6 %, P=NS), UV-trans (100%) (4 %, P=NS), Solatrol (1 week) (5%, P=NS), Solatrol (100% tunnel) (1%, P=NS) and Commercial glass (6%, P=NS) (fig. 6.a).

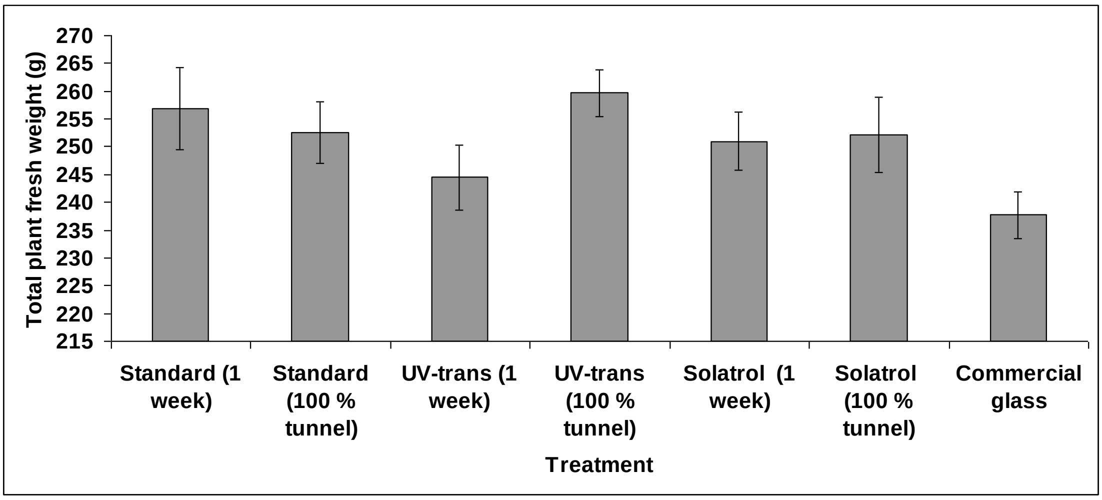
In mid-season field trials, UV-trans (100% tunnel) increased fresh weight at the time of harvest when compared to Standard (1 week) (1%, P=NS), Standard (100% tunnel) (3%, P=NS), UV-trans (1 week) (6%, P<0.05), Solatrol (1 week) (3%, P=NS), Solatrol (100% tunnel) (3%, P=NS) and Commercial glass (8%, P<0.001) (fig. 6.b).

Figure 6. Effect of treatments on head fresh weight lollo rosso lettuce in field trials at time of harvest in (a) early and (b) late season plantings. Each value is the mean <u>+</u> S.E. of 60 replicates.

a)



b)



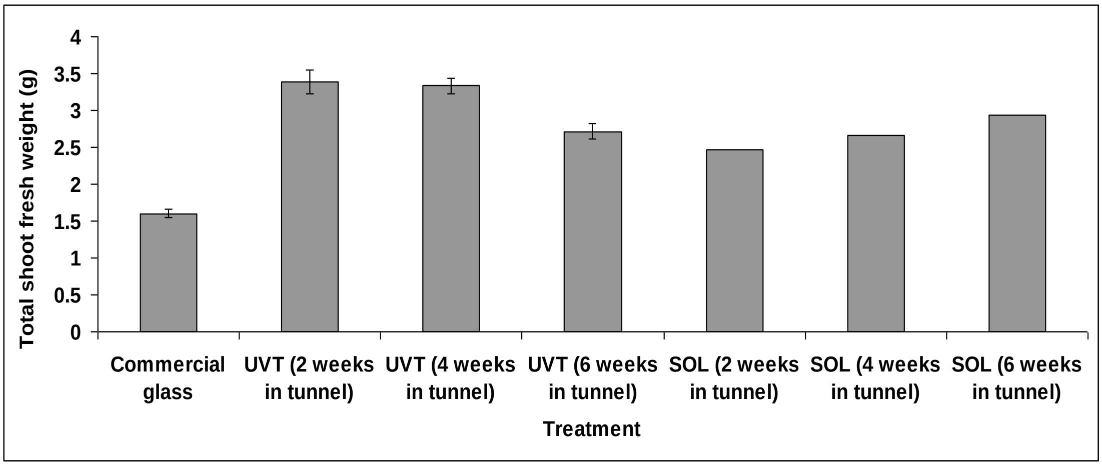
RESULTS

PROPOGATION CABBAGE – MEASUREMENTS TAKEN AT 6 WEEKS

The Commercial glass treatment significantly reduced total shoot fresh weight when compared to all filter treatments (fig. 7.a). The UVT (2 weeks in tunnel) treatment significantly increased total shoot fresh weight relative to all remaining treatments except UVT (4 weeks in tunnel) (fig. 7.a.). Total shoot dry weight was significantly reduced in Commercial when compared to all filter treatments except SOL (6 weeks in tunnel) (fig. 7.b), while UVT (2 weeks in tunnel) and UVT (4 weeks in tunnel) increased shoot dry weight relative to all remaining treatments including Commercial glass (fig. 7 b). The Commercial glass treatment significantly reduced total plant leaf area when compared to all filter treatments (fig. 8.a). Again, UVT (2 weeks in tunnel) and UVT (4 weeks in tunnel) increased leaf area relative to all remaining treatments (fig. 8.a). Commercial glass reduced plant height relative to all filter treatments while UVT (2 weeks in tunnel) increased height when compared to all remaining treatments except SOL (4 weeks in tunnel) (fig. 8.b). UVT (6 weeks in tunnel) produced a significant increase in Leaf 2 thickness when compared to all treatments except SOL (6 weeks in tunnel) (fig. 8.c).

Figure 7. Effect of treatments on (a) total shoot fresh weight and (b) total shoot dry weight in propagation Cabbage at 6 weeks. Each value is the mean + S.E. of 20 replicates.

a)



b)

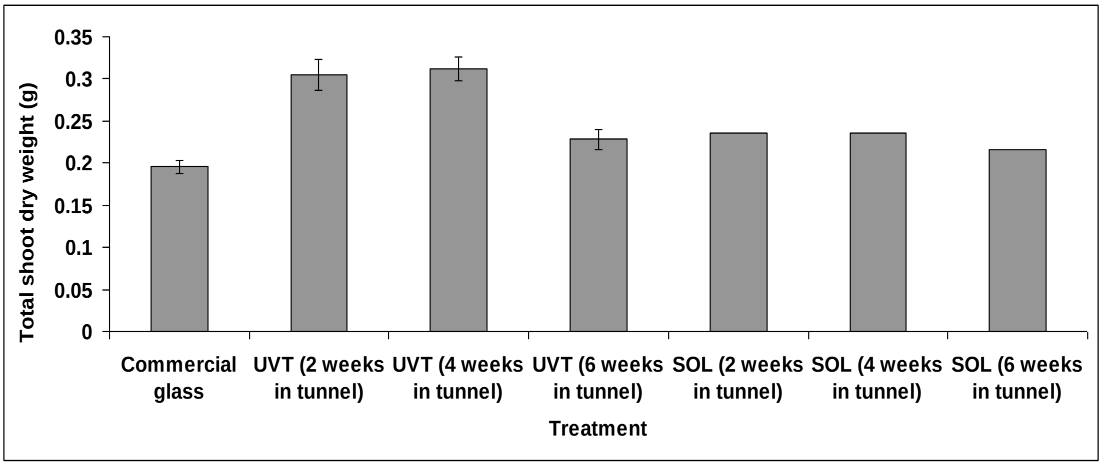
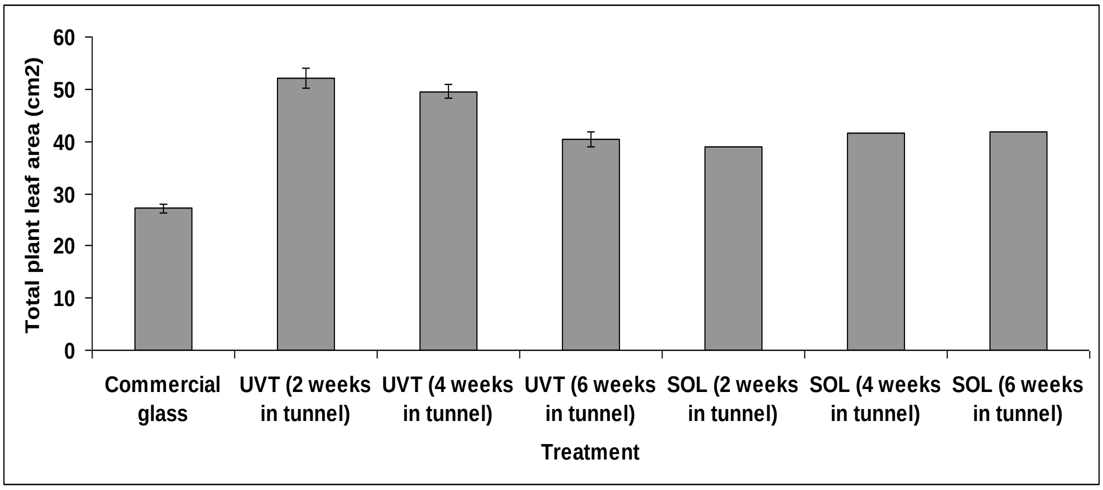
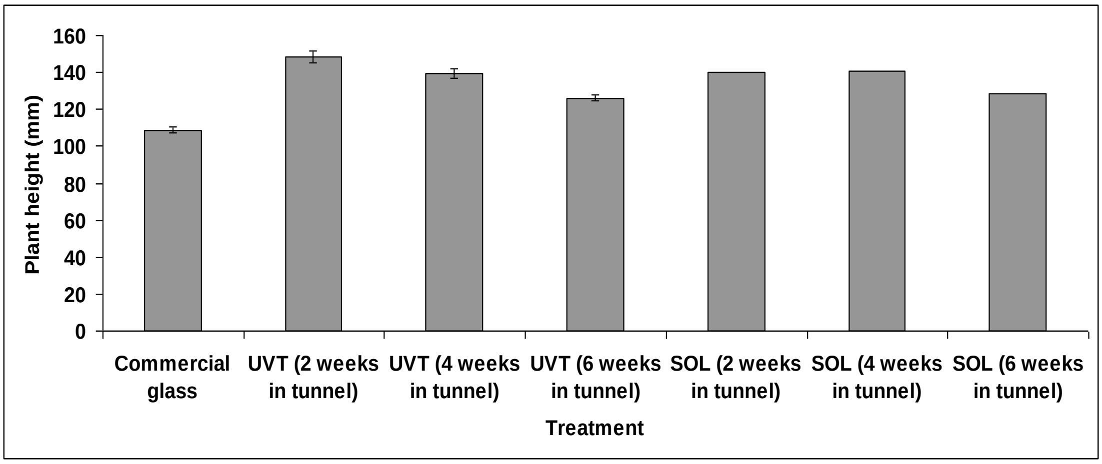


Figure 8. Effect of treatments on (a) total plant leaf area, (b) plant height and (c) leaf 2 thickness in propagation Cabbage at 6 weeks. Each value is the mean + S.E. of 20 replicates.

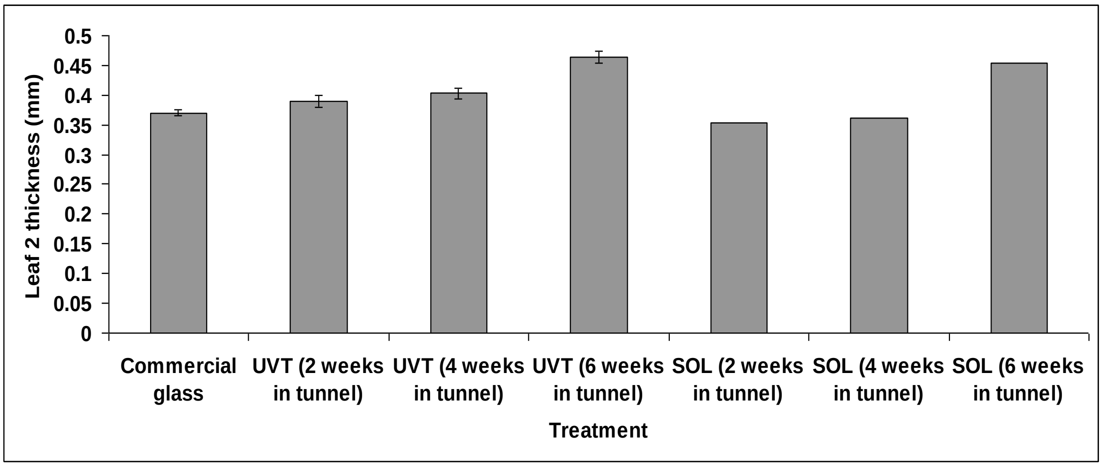
a)



b)



c)

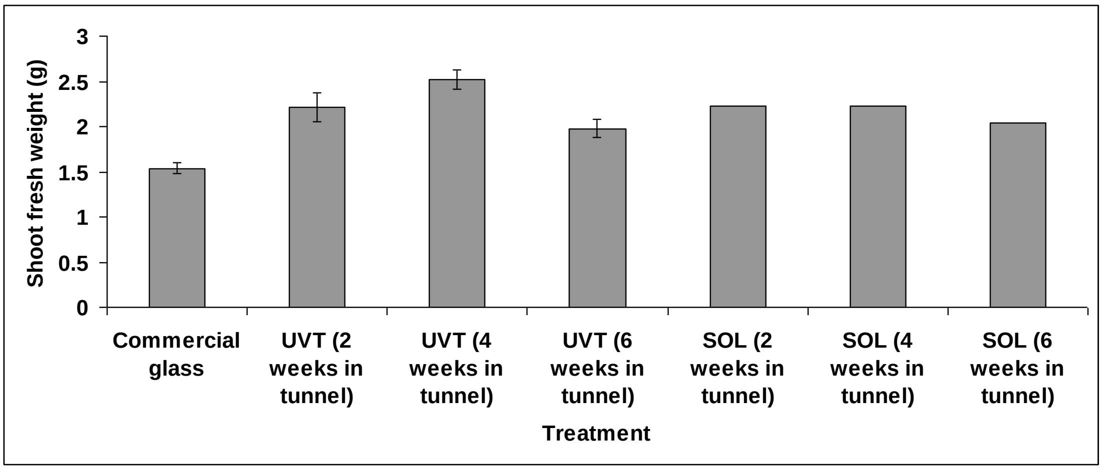


PROPOGATION CAULIFLOWER – MEASUREMENTS TAKEN AT 6 WEEKS

The Commercial glass treatment significantly reduced total shoot fresh weight when compared to all filter treatments (fig. 9.a). The UVT (4 weeks in tunnel) treatment significantly increased total shoot fresh weight relative to all remaining treatments (fig. 9.a). Total shoot dry weight was significantly reduced in UVT (6 weeks in tunnel) when compared to all remaining treatments except SOL (6 weeks in tunnel) (fig. 9. b). The Commercial glass treatment significantly reduced total plant leaf area when compared to all filter treatments expect UVT (6 weeks in tunnel) and SOL (6 weeks in tunnel) (fig. 10.a). Furthermore, Commercial glass reduced plant height relative to all filter treatments except UVT (6 weeks in tunnel) (fig. 10.b). UVT (6 weeks in tunnel) produced a significant increase in Leaf 2 thickness when compared to all treatments (fig. 10.c).

Figure 9. Effect of treatments on (a) total shoot fresh weight and (b) total shoot dry weight in propagation Cauliflower at 6 weeks. Each value is the mean ± S.E. of 20 replicates.

a)



b)

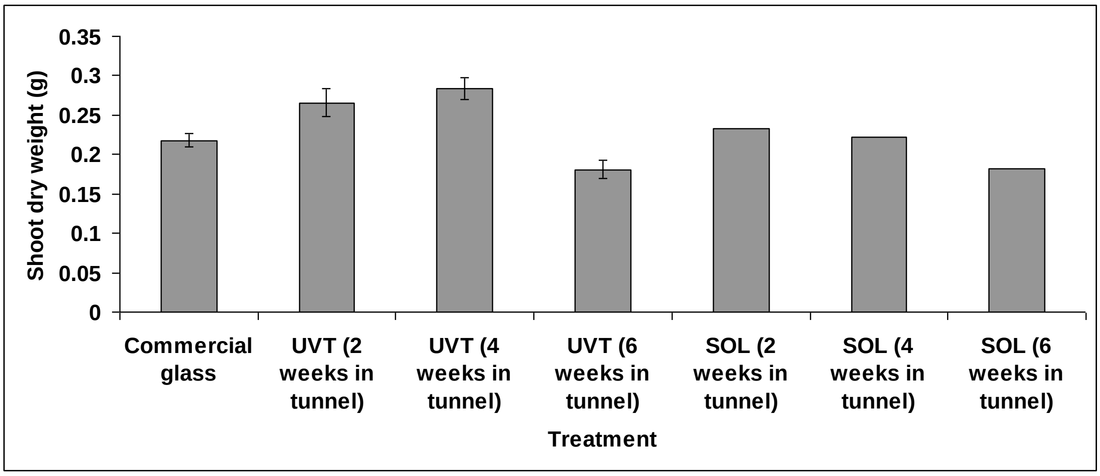
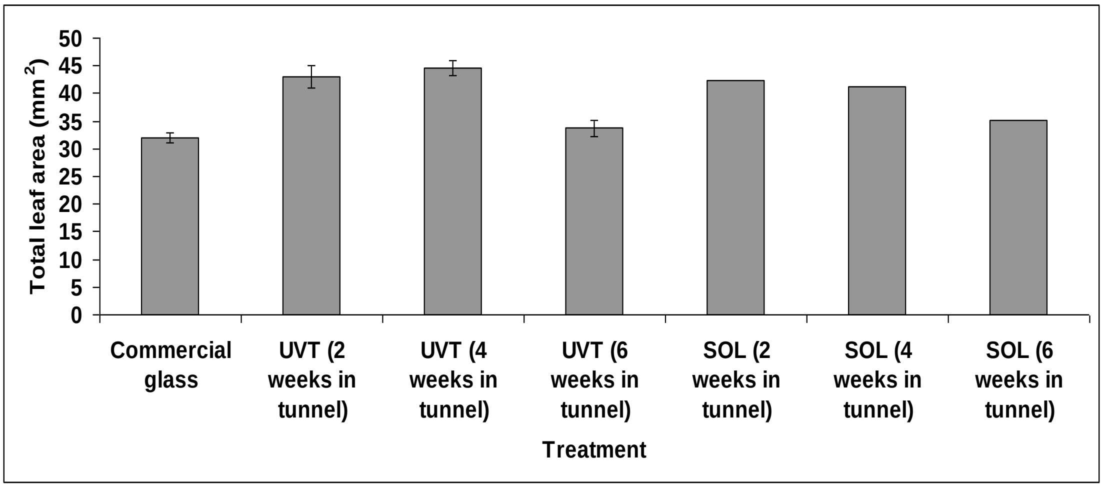
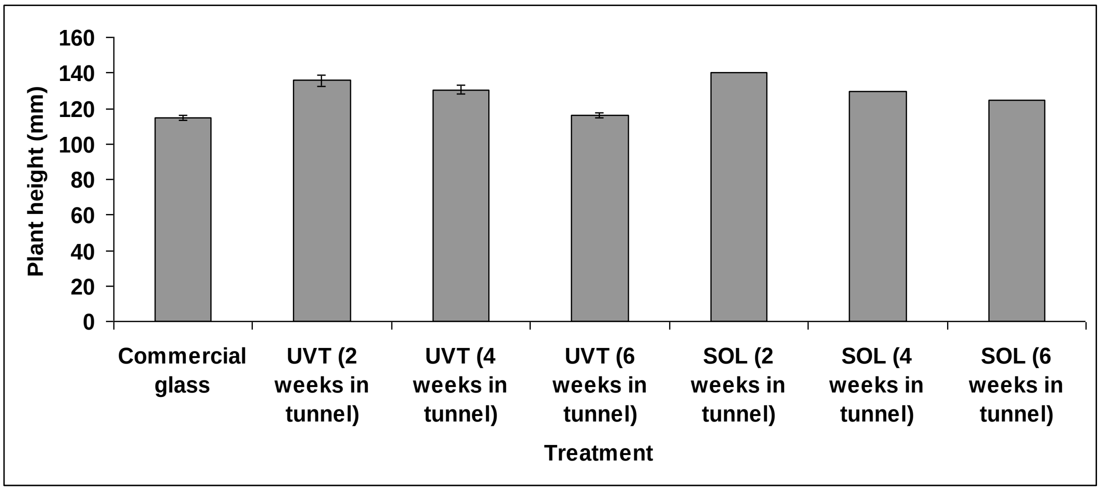


Figure 10. Effect of treatments on (a) total plant leaf area (b) plant height and (c) leaf 2 thickness in propagation Cauliflower at 6 weeks. Each value is the mean ± S.E. of 20 replicates.

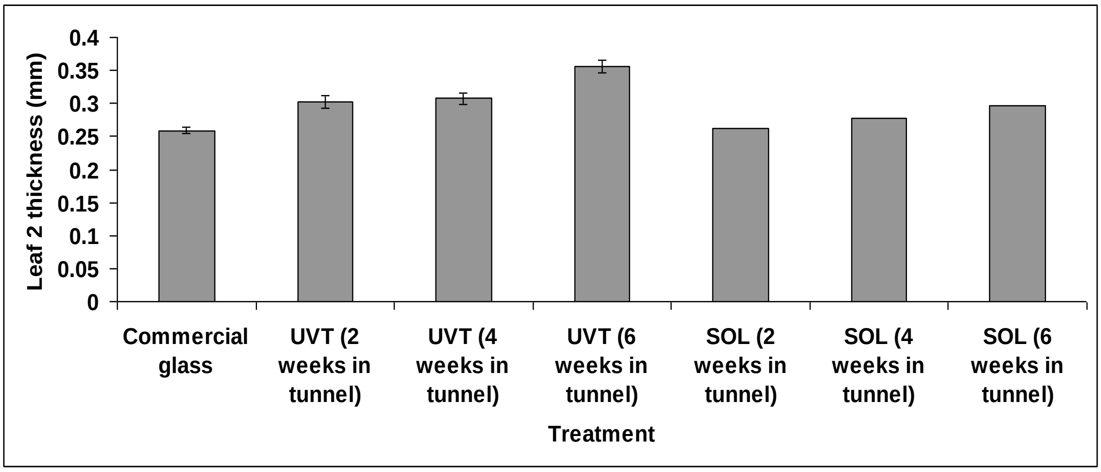
a)



b)



c)



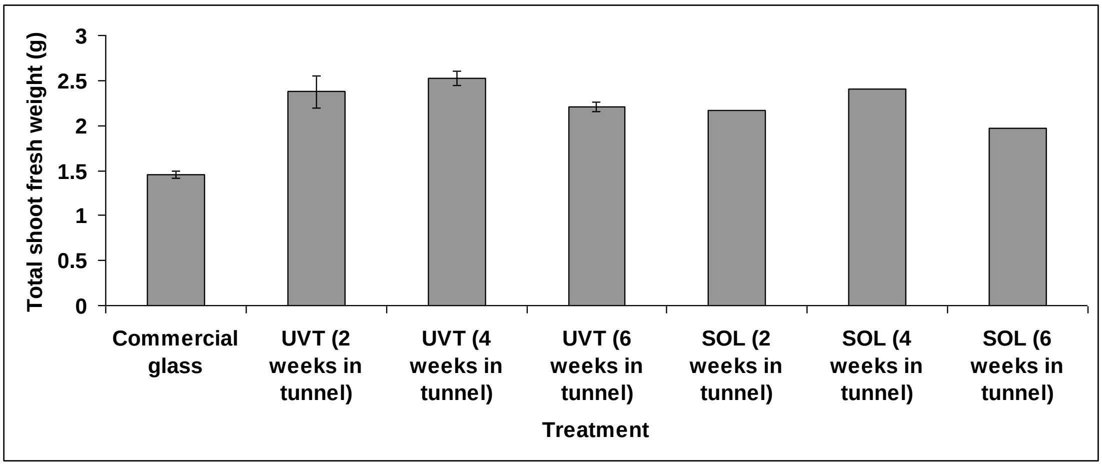
RESULTS

PROPOGATION BROCCOLI – MEASUREMENTS TAKEN AT 6 WEEKS

The Commercial glass treatment significantly reduced total shoot fresh weight when compared to all filter treatments (fig. 11.a). The UVT (4 weeks in tunnel) treatment significantly increased total shoot fresh weight relative to all remaining treatments except UVT (2 weeks in tunnel) and SOL (4 weeks in tunnel) (fig. 11.a.). Total shoot dry weight was significantly reduced in SOL (6 weeks in tunnel) when compared to all remaining treatments including the Commercial glass (fig. 11.b). The Commercial glass treatment significantly reduced total plant leaf area when compared to all filter treatments (fig. 12.a). UVT (2 weeks in tunnel) increased total leaf area relative to all remaining treatments but this was only a significant increase relative to Commercial glass and SOL (6 weeks in tunnel) (fig. 12.a). Commercial glass significantly reduced plant height relative to all remaining treatments except UVT (6 weeks in tunnel) and SOL (6 weeks in tunnel) (fig. 12.b). UVT (6 weeks in tunnel) produced a significant increase in Leaf 2 thickness when compared to all treatments except SOL (6 weeks in tunnel) (fig. 12.c).

Figure 11. Effect of treatments on (a) total shoot fresh weight and (b) total shoot dry weight in propagation Broccoli at 6 weeks. Each value is the mean ± S.E. of 20 replicates.

a)



b)

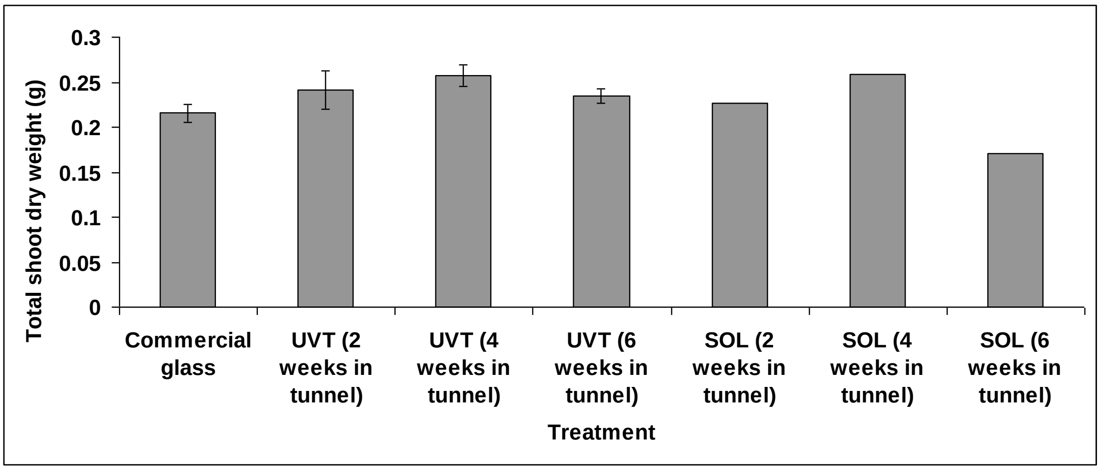
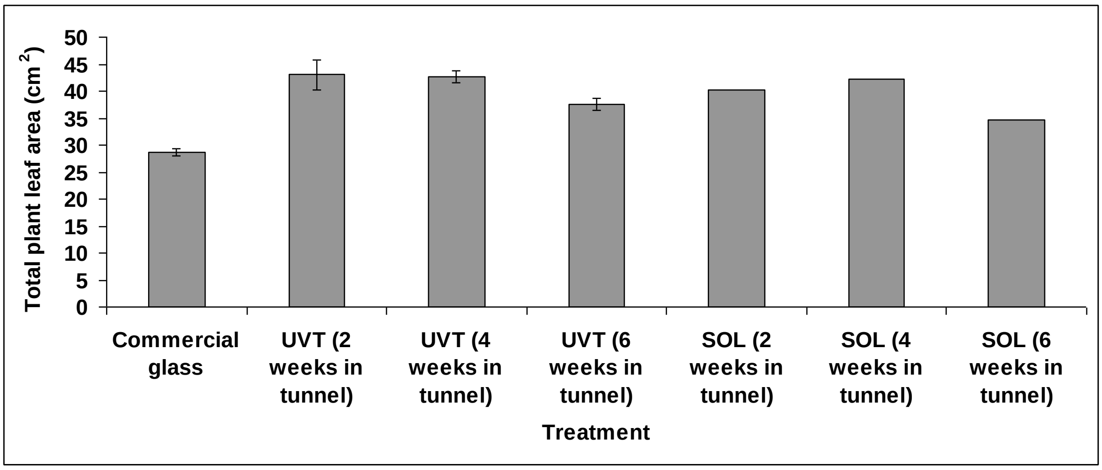
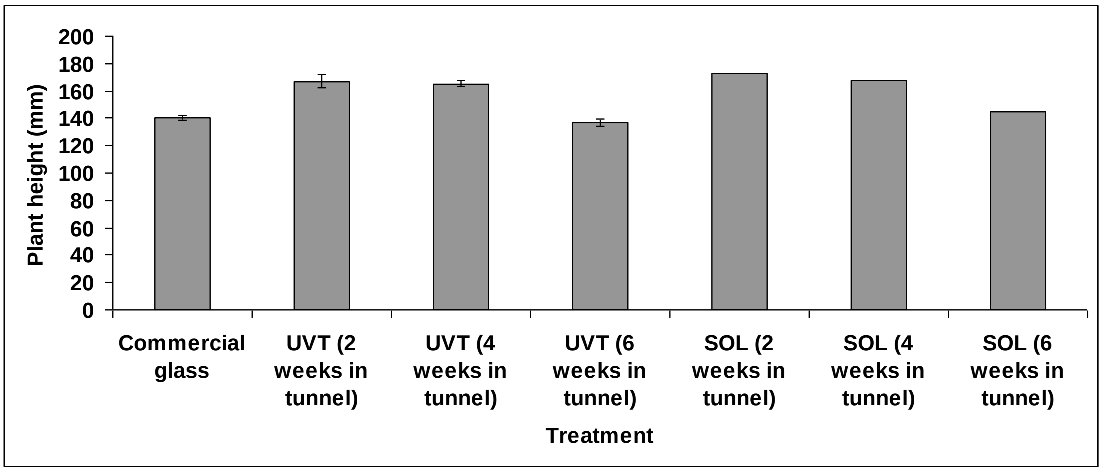


Figure 12. Effect of treatments on (a) total plant leaf area, (b) plant height and (c) leaf 2 thickness in propagation Broccoli at 6 weeks. Each value is the mean ± S.E. of 20 replicates.

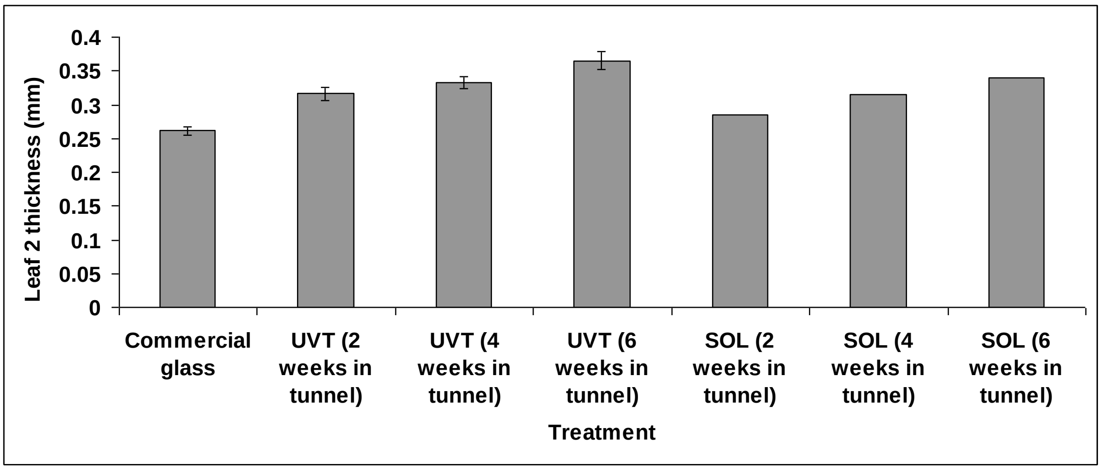
a)



b)



c)



FIELD TRIALS – CABBAGE

In early-season field trials, Commercial reduced harvestable fresh weights at time of harvest when compared to UVT (6 weeks in tunnel) (6%, P=NS), UVT (2 weeks in tunnel) (12%, P<0.01), UVT (4 weeks in tunnel) (8%, P=NS), SOL (6 weeks in tunnel) (15%, P<0.001), SOL (2 weeks in tunnel) (10%, P<0.05), SOL (4 weeks in tunnel) (10%, P<0.05) (fig. 1.a). Of the filter treatments SOL (6 weeks in tunnel) increased fresh weights but this was only significant relative to Commercial glass (15%, P<0.001) and UVT (6 weeks in tunnel) (10%, P<0.05) (fig. 13.a).

In mid-season field trials, Commercial glass reduced harvestable fresh weights when compared to UVT (6 weeks in tunnel) (6%, P=NS), UVT (2 weeks in tunnel) (6%, P=NS), UVT (4 weeks in tunnel) (2%, P=NS), SOL (2 weeks in tunnel) (7%, P=NS), SOL (4 weeks in tunnel) (4%, P=NS), and produced a non-significant increase in fresh weights relative to SOL (6 weeks in tunnel) (2%, P=NS) (fig. 14.a).

In late-season field trials, SOL (2 weeks in tunnel) increased harvestable fresh weights when compared to Commercial glass (12%, P<0.05), UVT (6 weeks in tunnel) (14%, P< 0.01), UVT (2 weeks in tunnel) (3%, P=NS), UVT (4 weeks in tunnel) (7%, P=NS), SOL (6 weeks in tunnel) (13%, P<0.001) and SOL (4 weeks in tunnel) (4%, P=NS) (fig. 2.b). The Commercial treatment reduced harvestable fresh weights relative to all filter treatments but this represented a significant reduction relative to SOL (2 weeks in tunnel) only (fig. 14.b).

Figure 13. Effect of treatments on harvestable fresh weights in early season field plantings in Cabbage. Each value is the mean $\geq$ S.E. of 20 replicates.

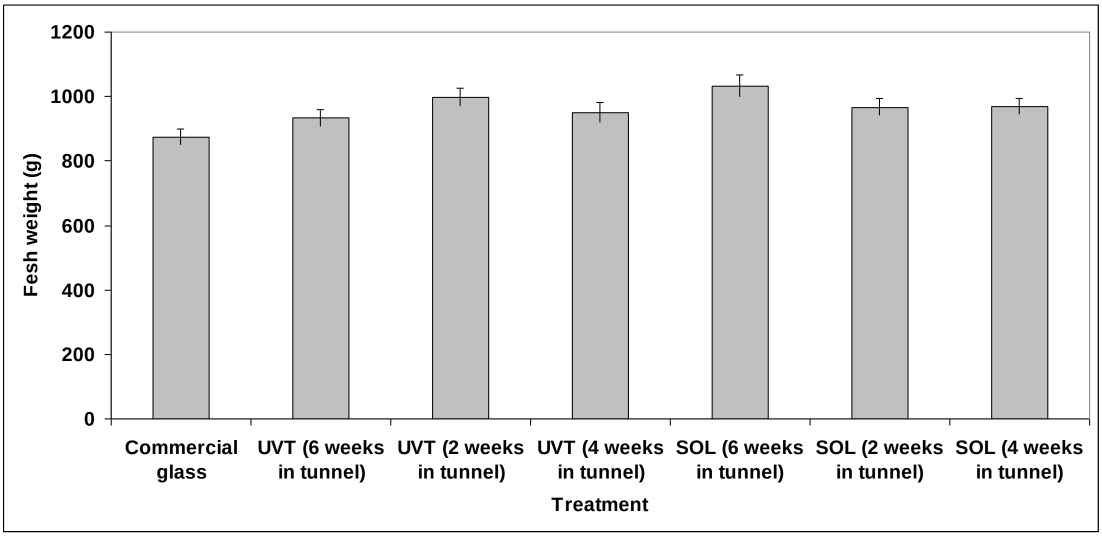
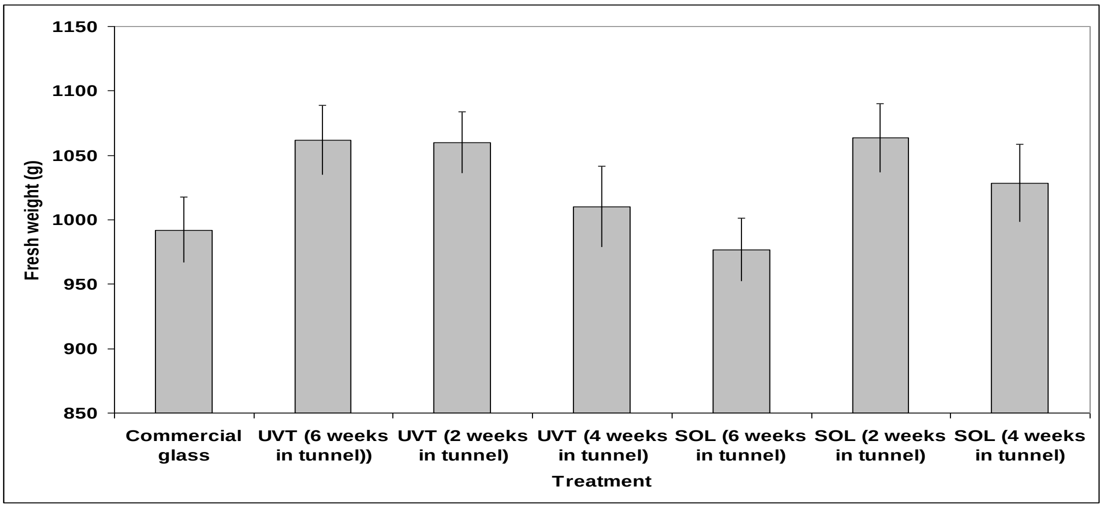
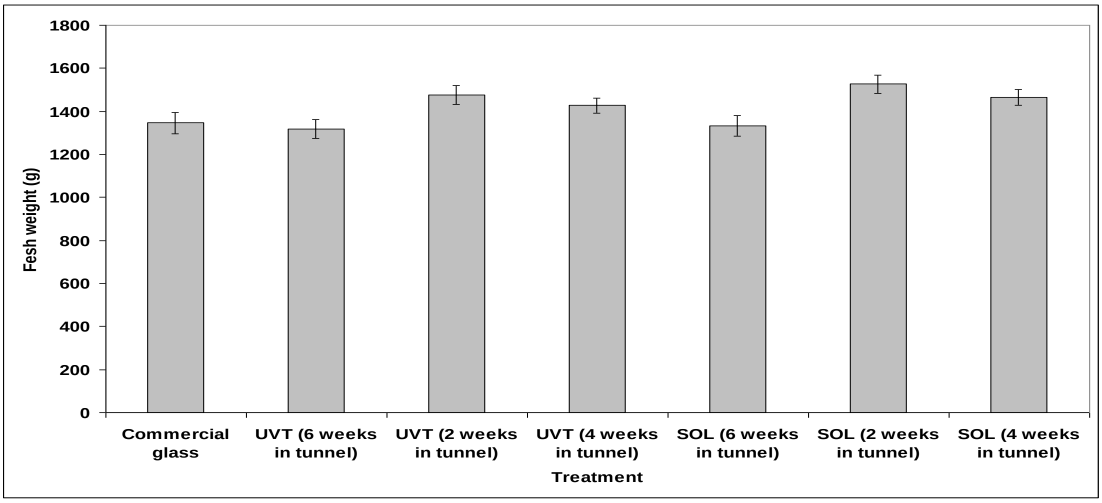


Figure 14. Effect of treatments on harvestable fresh weights in (a) mid and (b) late season field plantings in Cabbage. Each value is the mean > S.E. of 20 replicates.

a)



b)



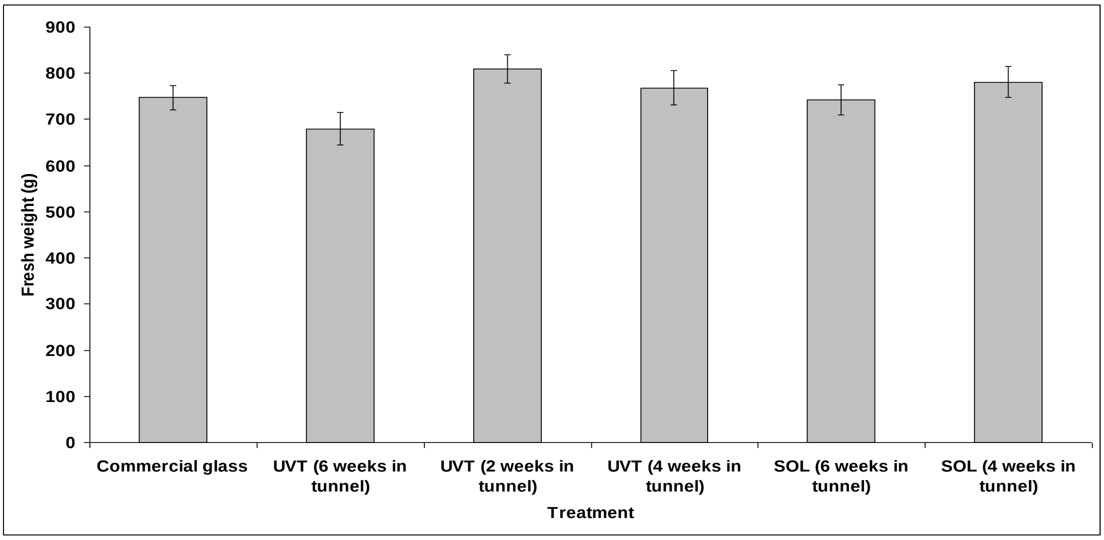
FIELD TRIALS – CAULIFLOWER

In early season field trials, Commercial reduced harvestable fresh weights at time of harvest when compared to UVT (2 weeks in tunnel) (8%, P=NS), UVT (4 weeks in tunnel) (3%, P=NS) and SOL (4 weeks in tunnel) (3%, P=NS) and produced increased fresh weights relative to UVT (6 weeks in tunnel) (9%, P=NS), SOL (6 weeks in tunnel) (<1%, P=NS) and (fig. 15.a).

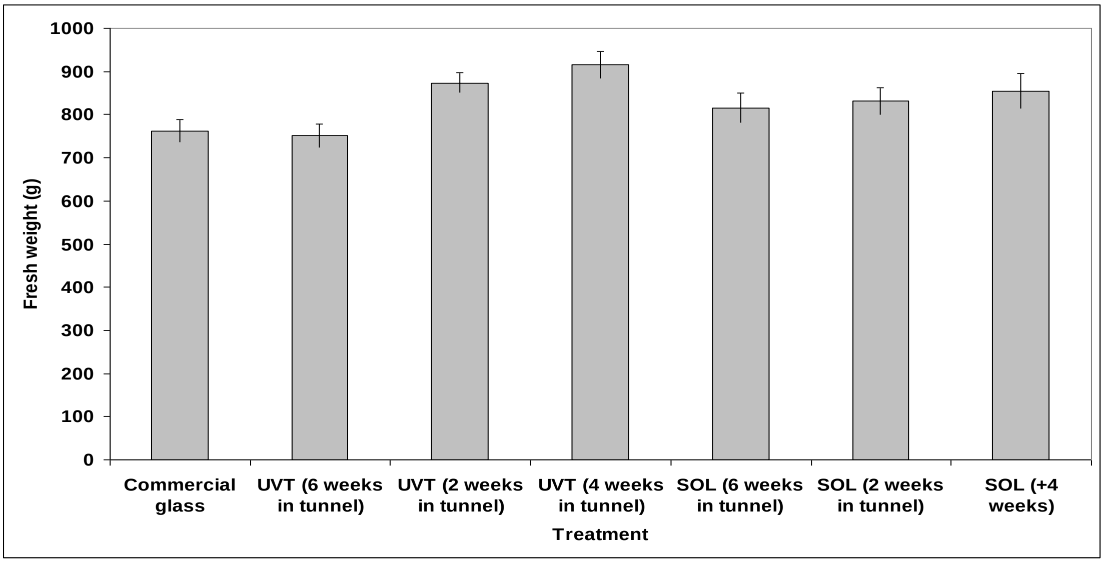
In late season field trials, UVT (4 weeks in tunnel) increased harvestable fresh weights when compared to Commercial glass (17%, P<0.001), UVT (6 weeks in tunnel) (18%, P<0.001), UVT (2 weeks in tunnel) (5%, P=NS), SOL (6 weeks in tunnel) (11%, P<0.05), SOL (2 weeks in tunnel) (9%, P=NS) and SOL (4 weeks in tunnel) (7%, P=NS) (fig.1 b). The Commercial glass treatment significantly reduced fresh weight at harvest relative to UVT (2 weeks in tunnel) (P<0.05) and UVT (4 weeks in tunnel) only (P<0.001) only (fig. 15.b).

Figure 15. Effect of treatments on harvestable fresh weights in (a) early and (b) late season field plantings in Cauliflower. Each value is the mean $\geq$ S.E. of 20 replicates.

a)



b)

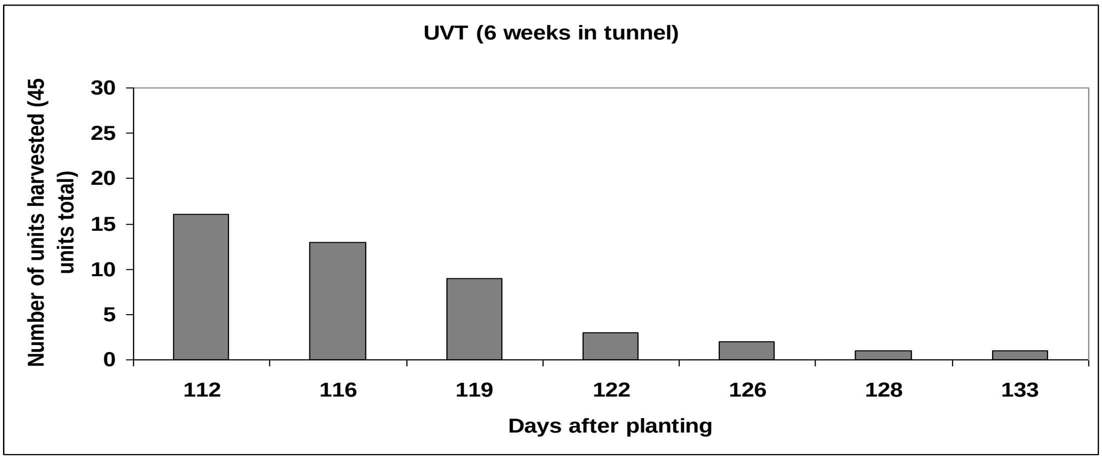


HARVEST DISTRIBUTION IN EARLY SEASON CROPS

Figure 16. Effect of treatments on harvest distribution in a) Commercial glass, UVT (6 weeks in tunnel) and c) UVT (2 weeks in tunnel) in early-season field crops.

a)

b)



c)

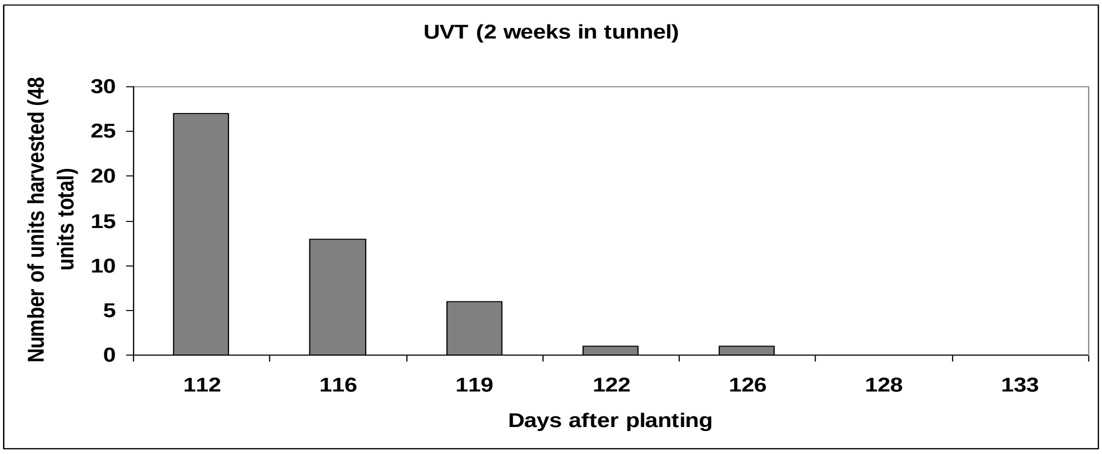
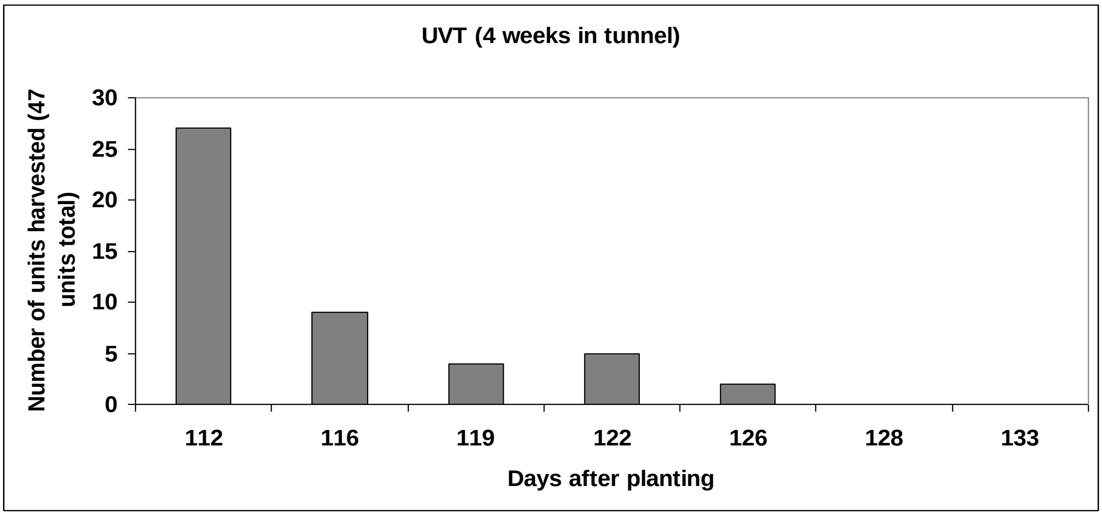
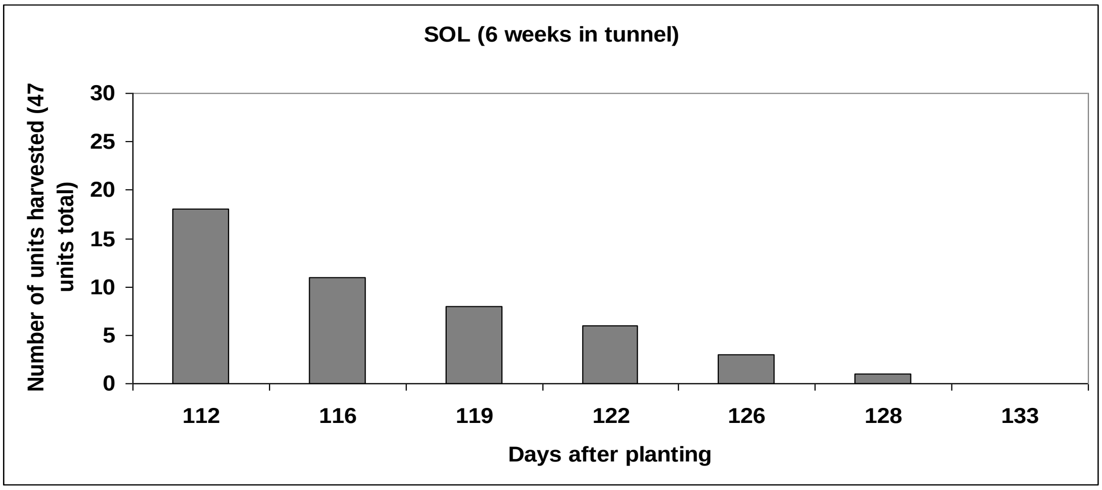


Figure 17. Effect of treatments on harvest distribution in a) UVT (4 weeks in tunnel), SOL (6 weeks in tunnel) and c) SOL (2 weeks in tunnel) in early-season field crops.

a)



b)



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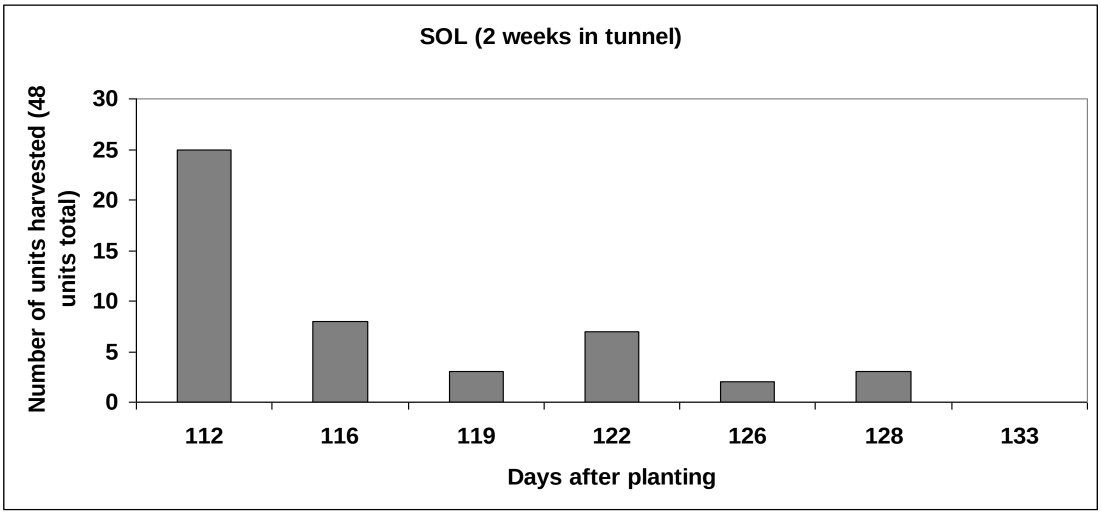
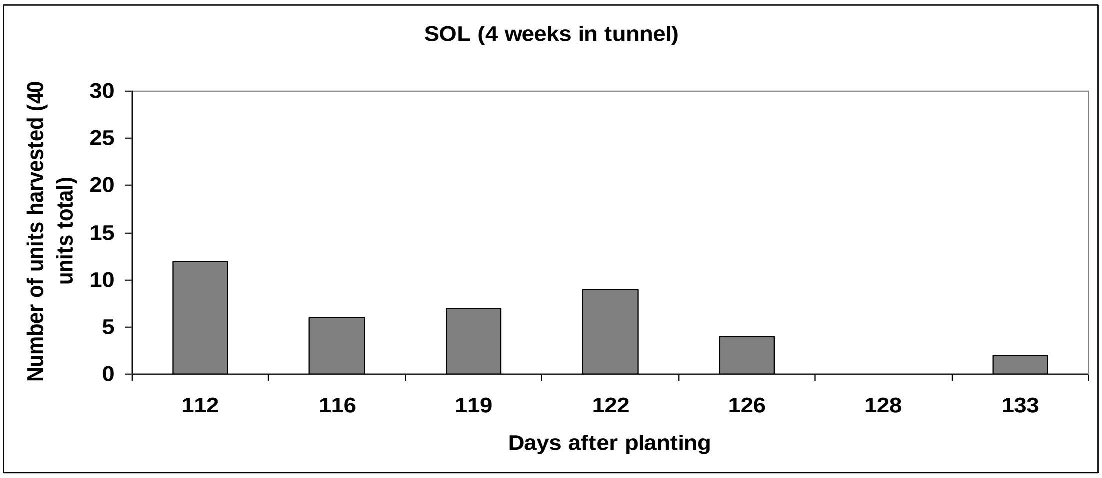


Figure 18. Effect of treatments on harvest distribution in SOL (4 weeks in tunnel) in early season field crops.



HARVEST DISTRIBUTION IN LATE SEASON CROPS

Figure 19. Effect of treatments on harvest distribution in a) Commercial glass and UVT (6 weeks in tunnel) early season field crops.

a)

b)

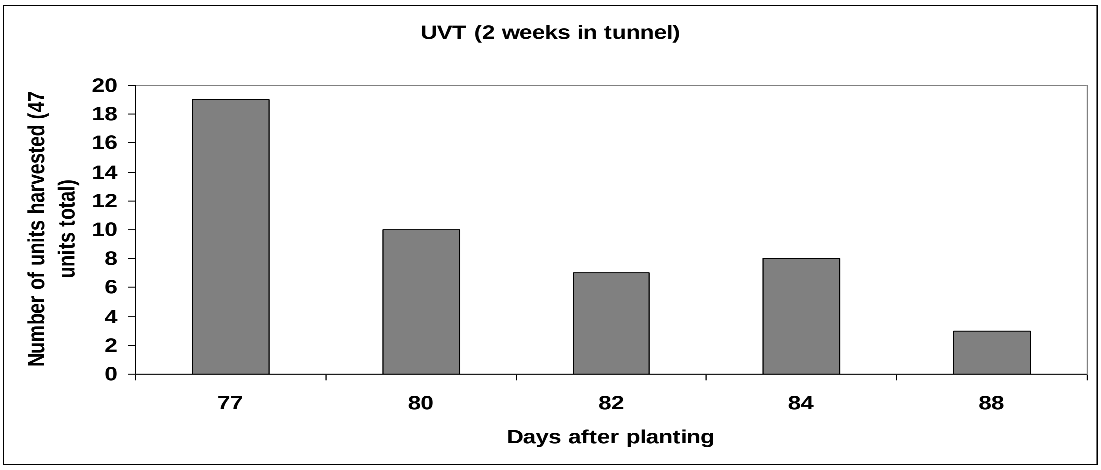
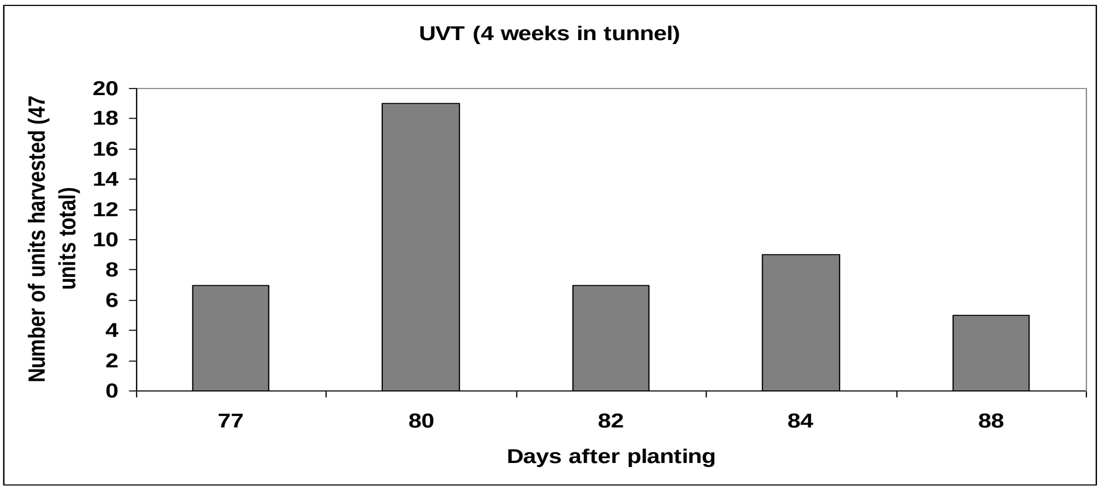
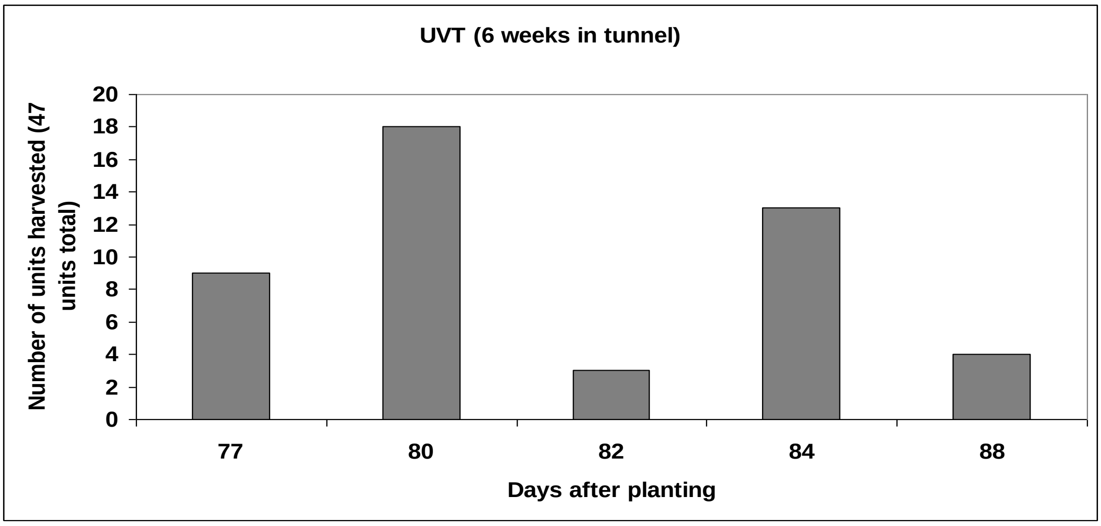


Figure 20. Effect of treatments on harvest distribution in a) UVT (4 weeks in tunnel), b) UVT (6 weeks in tunnel) and SOL (4 weeks in tunnel) late-season crops.

a)



b)



c)

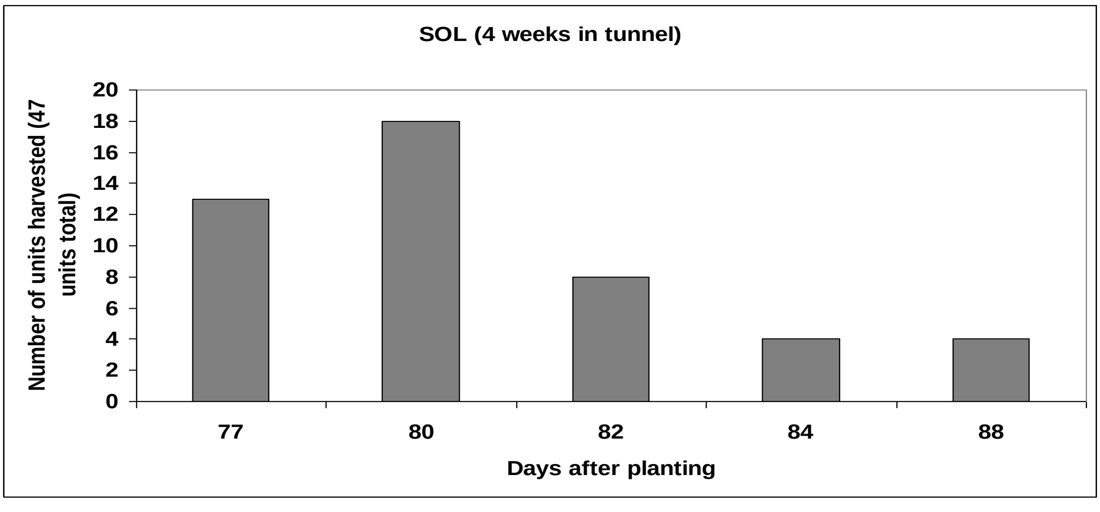
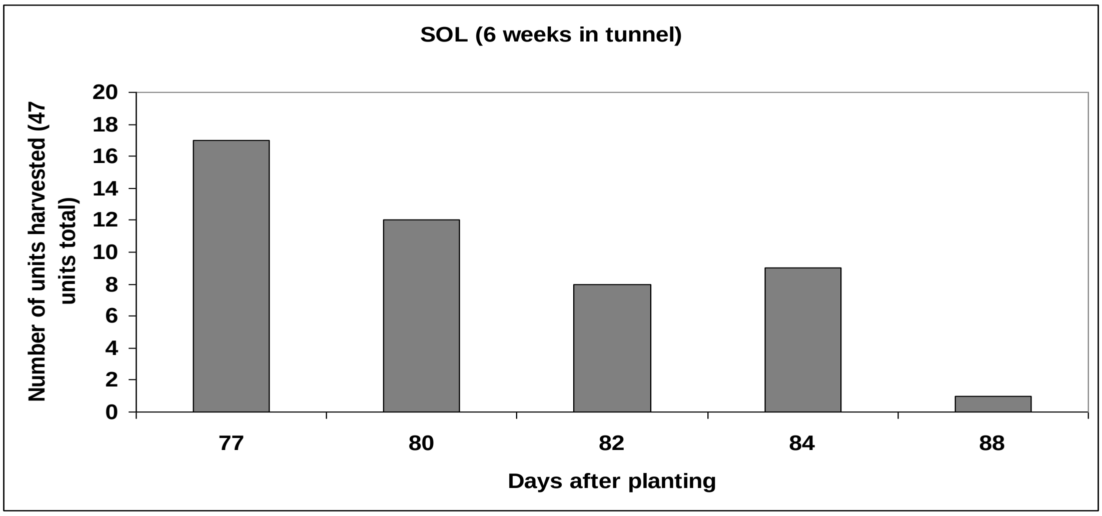


Figure 21. Effect of treatments on harvest distribution in SOL (6 weeks in tunnel) late-season crop.



FIELD TRIAL – BROCOLLI

In a mid season field trial, Commercial reduced harvestable fresh weights when compared to UVT (6 weeks in tunnel) (22%, P<0.001), UVT (2 weeks in tunnel) (16%, P=NS), UVT (4 weeks in tunnel) (12%, P<0.05), SOL (6 weeks in tunnel) (7%, P=NS) SOL (2 weeks in tunnel) (6%, P=NS) and SOL (4 weeks in tunnel) (2%, P=NS) (fig. 22). Of the filter treatments UVT (6 weeks in tunnel) produced significantly increased fresh weights when compared to Commercial (22%, P<0.001), UVT (2 weeks in tunnel) (8%, P<0.05), SOL (6 weeks in tunnel) (16%, P<0.01), SOL (2 weeks in tunnel) (17%, P<0.01) and SOL (4 weeks in tunnel) (20%, P<0.01) but there was no significant effect relative to UVT (2 weeks in tunnel) (8%, P=NS) (fig. 22).

Figure 22. Effect of treatments on harvestable fresh weights in mid-season field plantings in Broccoli. Each value is the mean > S.E. of 20 replicates.

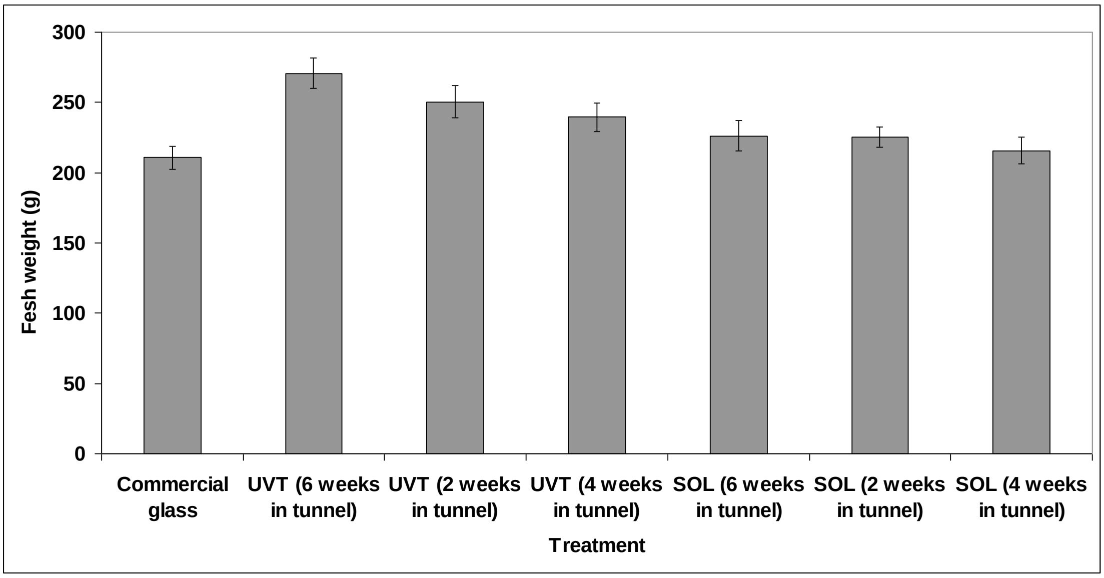
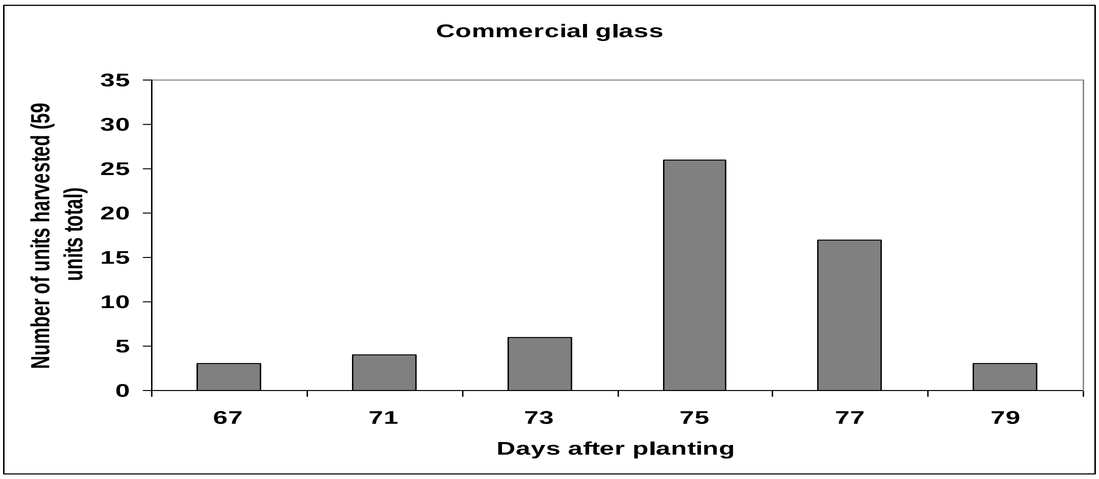
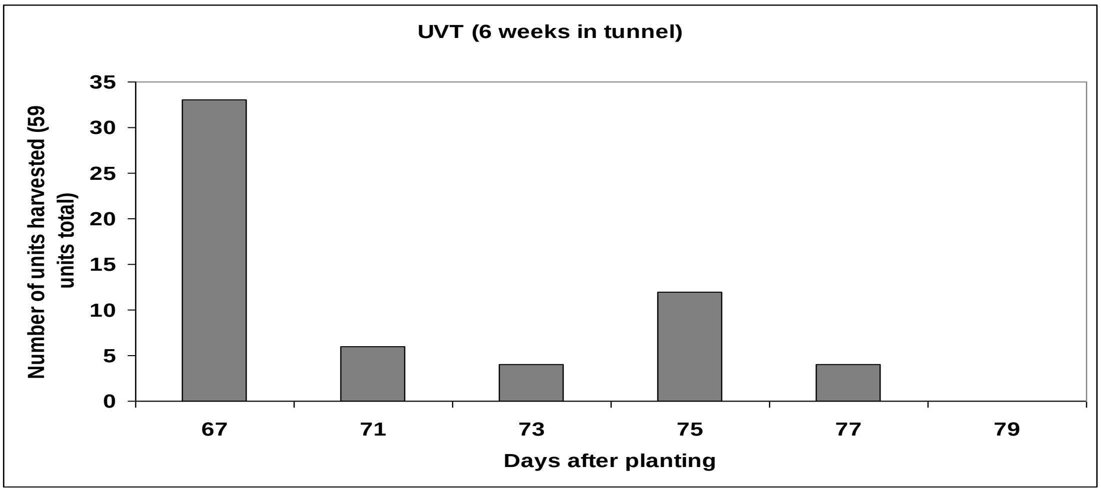


Figure 23. Effect of treatments on harvest distribution in a) Commercial glass, b) UVT (6 weeks in tunnel) and UVT (4 weeks in tunnel) crops.

a)



b)



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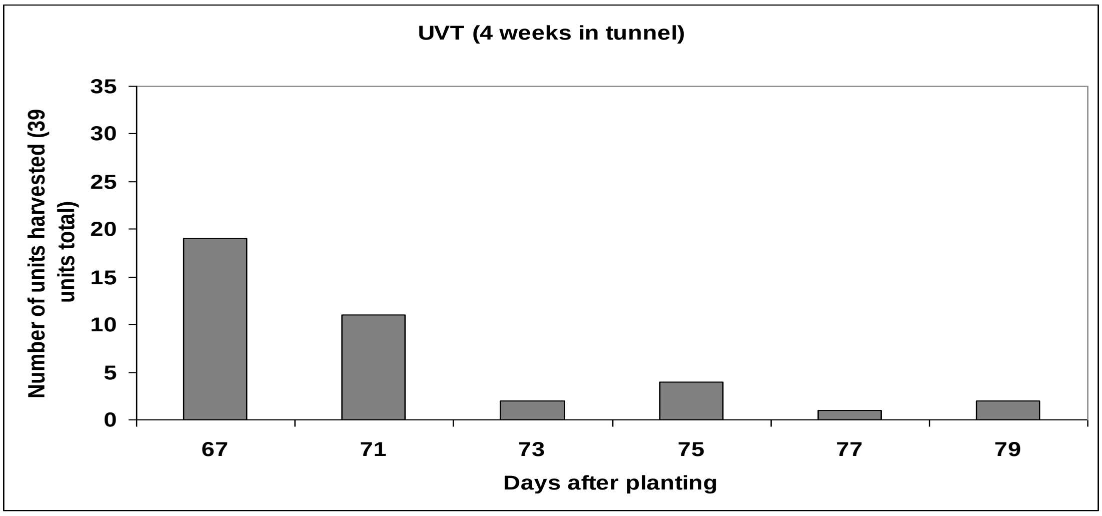
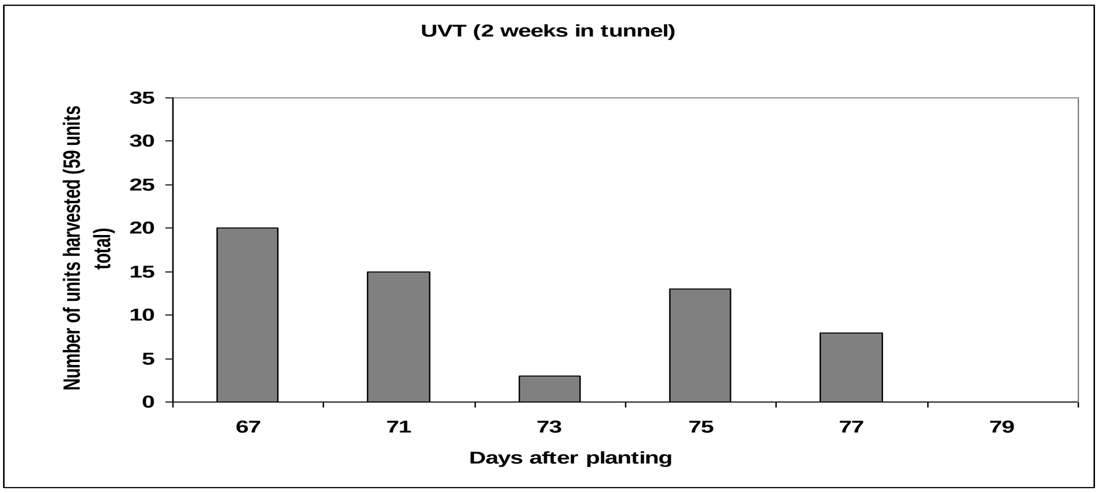
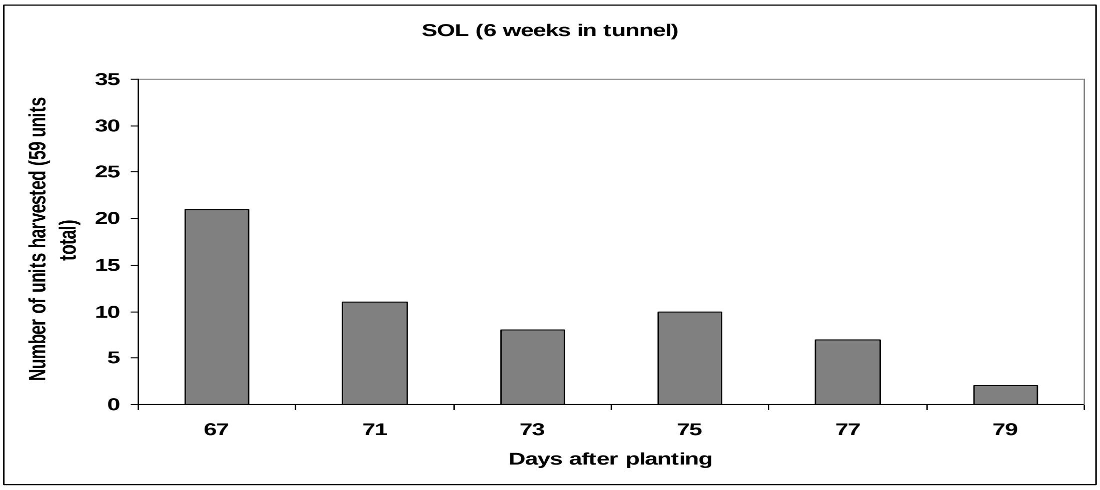


Figure 24. Effect of treatments on harvest distribution in a) UVT (2 weeks in tunnel), b) SOL (6 weeks in tunnel) and c) SOL (2 weeks in tunnel).

a)



b)



c)

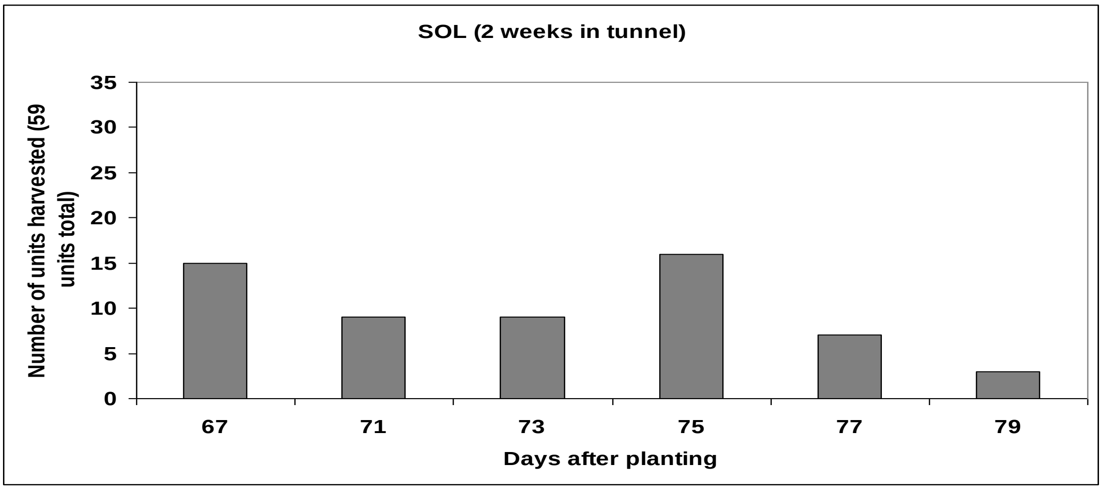
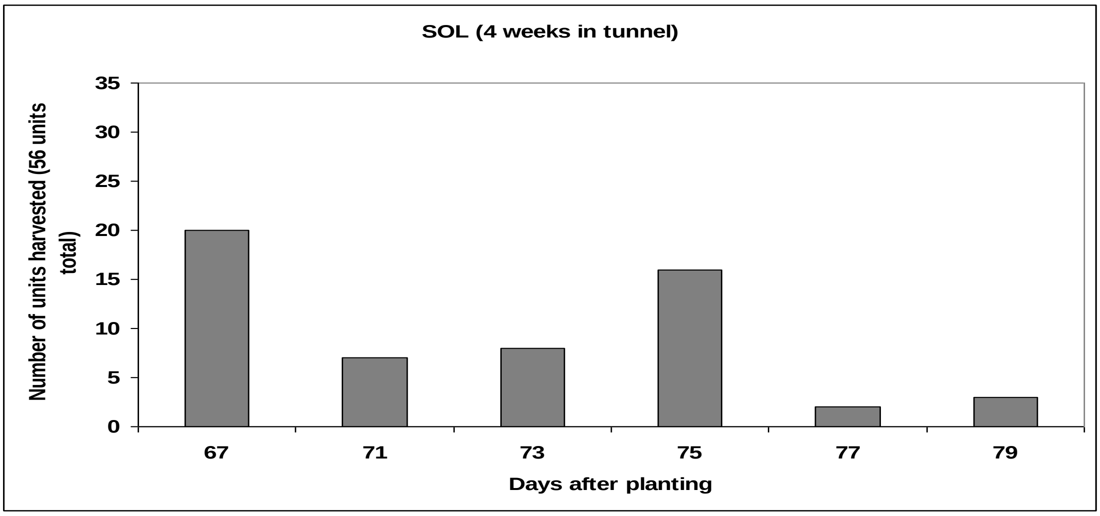


Figure 25. Effect of treatments on harvest distribution in SOL (4weeks in tunnel) crop.



DISCUSSION

We have shown in previous studies that propagating both Brassica and lettuce crops under UV-transparent and Solatrol (R: FR) filters delivers a propagation crop comparable to those produced in a commercial glasshouse environment (CP19 yearly report 2004). Under the UV transparent and Solatrol filters, propagation lettuce crops consistently exhibit reductions in leaf expansion: a function of reduced epidermal cell area and not reductions in cell numbers or changes in carbon fixation (CP19 yearly report 2003). These morphological changes are observed in iceberg lettuce within 4 days of emergence under both the UV transparent and Solatrol filters and these immediate changes have been shown to have long-term, persistent effects on plant development that persist long after the plant has been removed from those altered light regimes. In the three Brassica varieties trialled in the previous two seasons (cabbage, cauliflower and broccoli) morphological changes in the crops were varied. However, Solatrol did tend to produce the shortest, stockiest cabbage plant with a relatively well developed root system and these plants performed well in field trials, generally producing a similar or increased yield at harvest, relative to the commercial glass crop.

What is clear from the current study is that the morphology and development of both propagation lettuce varieties can be reliably and consistently manipulated by exposing the crop to increased UV and R: FR altered light regimes. In iceberg and lollo rosso lettuce total plant fresh weight, leaf 2 fresh / dry weight and leaf 2 length were significantly reduced at the termination of the propagation stage in those crops propagated entirely under the UV-transparent filter (UV-trans 100% tunnel) when compared to the remaining treatments, including the commercial glass control (figs. 1.a. – 1.d. & 2.a. – 2.b). These changes produce the 'short and stocky' characteristics desired by growers. Furthermore, across the three field trials throughout the 2005 season those crops propagated under the UV-transparent filter went on to produce increased fresh weights at point of harvest (see figs. 5.a. – c. & 6.a – b).

In the early and mid-season iceberg lettuce field trials the UV-transparent (100% tunnel) treatment produced a 4 and 9% increase in final harvest fresh weights respectively (figs. 5.a. & 5.b). In the late season field trial the UV-trans (100% tunnel) treatment reduced final yield by 1% compared to the commercial control (fig. 5.c). Similar increases in the harvestable fresh weights of lollo rosso propagated under UV-transparent were observed. In the early season field trial UV-trans (100%) tunnel increased harvest weights by 2% and in the late season trial by 8% over the Commercial glass control (figs. 6.a & 6.b).

Similar results to those observed in the lettuce varieties were seen in the three Brassicas trialled in 2005. In cabbage the commercial glass treatment produced the 'short and stocky' crop desired by growers with shoot fresh / dry weight, total leaf area and plant height all reduced (figs. 7.a – 7.b. & 8.a. – 8.b). Also, the UVT (6 weeks in tunnel) treatment produced a 20% increase in leaf 2 thickness relative to the commercial crop, which might have benefits at transplantation due to increased tissue-mechanical strength (fig. 8.c). Results from propagation cauliflower revealed that UVT (6 weeks in tunnel) produced a crop with morphological characteristics very similar to the commercial glass crop in terms of total leaf area and plant height (figs. 10.a. & 10.b). Furthermore, as with cabbage, cauliflower under UVT (6 weeks in tunnel) produced a 29% increase in leaf 2 thickness (fig. 10.c). Again, in broccoli, the UVT (6 weeks in tunnel) treatment produced a visually comparable propagation crop to the commercial treatment coupled with a 28% increase in leaf thickness (fig. 12.c). This growth regulatory effect in terms of leaf expansion in the UV filter treatment, coupled with increases in leaf thickness in UVT (6 weeks in tunnel) could be of particular importance to the grower because such characteristics aid in the avoidance of disease development and mechanical damage caused by pre-plant drenches. A plant of this type might also be able to withstand stress at planting, possibly leading to faster establishment and increases in final harvestable yield.

Indeed in all three Brassica variety field trials crops propagated under the UV transparent filter produced harvestable fresh weights equal to, or above, those crops propagated under commercial glass. In the three cabbage field trials undertaken in 2005, fresh weights in all the UVT (2, 4 and 6 week) treatments produced fresh weights equivalent to, or above those produced by the commercial glass treatment. The average increase in cabbage fresh weights across the three UV-transparent treatments was 9% in early, 5% in mid and 4% in late season field trials (figs. 13.a & 14.a. – b).

In the two cauliflower field trials the UVT (2 & 4 weeks in tunnel) treatments increased fresh weight at harvest by approximately 8 – 13% and 3 – 17% respectively across the early and late season trials (figs. 15.a. & b). All Solatrol treatments produced fresh weights comparable to the commercial control in both early and late field trials (figs. 15.a. & b). Also, in early season field trials the UVT propagation treatments altered the distribution profile of the harvest with UVT (2 weeks in tunnel) and UVT (4 weeks in tunnel) bringing the majority of the harvest forward by 5 and 2 days respectively (see figs. 16.a. – c. & 17.a). The Solatrol propagation filter treatments also changed the distribution of harvest, reducing times to harvest by approximately 2 - 4 days (figs. 17.b. & c). In the late-season field trial harvest distribution was also significantly affected by treatments.
The spread of harvest was increased in the commercial glass control particularly when compared to UVT (2 weeks in tunnel) and UVT (4 weeks in tunnel) both of which produced a harvest profile with 50% of the crop ready for cutting in the first harvest compared to less than 25% in the commercial treatment (see figs. 19.a. – b. & 20.a). A similar pattern was observed in the broccoli field trial where all three UVT propagation treatments (2, 4 and 6 weeks in tunnel) increased fresh weights at harvest (between 12 - 16%) when compared to the commercial control with the Solatrol treatments producing no significant change in harvestable fresh weights (fig. 22). Furthermore, UVT (6 weeks in tunnel) brought forward time to harvest in 60% of the crop by approximately 8 days when compared to the commercial control (figs 23.a & b).

What is clear from 2005's comprehensive lettuce and Brassica field investigations is that there is strong evidence that plant morphology and development at the propagation stage can be manipulated, particularly using altered UV and R: FR light regimes, for the specific purpose of producing a crop with comparable characteristics to a current commercial product, which when carried through to field trials, produces either no appreciable reduction, or an increase, in harvested yield. Using iceberg lettuce as a model crop the mechanism governing the growth regulatory response in is beginning to be understood.

In 2003 season the immediate effects of the UV-transparent and Solatrol filters were observed as rapid and significant reductions in the expansion rates of leaf two in iceberg lettuce, seven days after the beginning of treatment. Further investigation revealed that this reduction in leaf expansion led to decreased leaf areas at the end of the propagation stage and that this reduction was not a function of reduced carbon fixation, but was attributed to a reduction in epidermal cell area: there was no significant change in epidermal cell number in plants grown under UV-transparent and Solatrol (See CP19 2003). The effect of the filters on cell expansion was also observable using light microscopy where epidermal cells are clearly elongated in plants grown under the Luminance filter (which transmits only % UV and does not alter R: FR) relative to the UV-transparent filter (see below).

Figure 25. Leaf 2 epidermal cells in iceberg lettuce propagated under UV-transparent (at 14d)

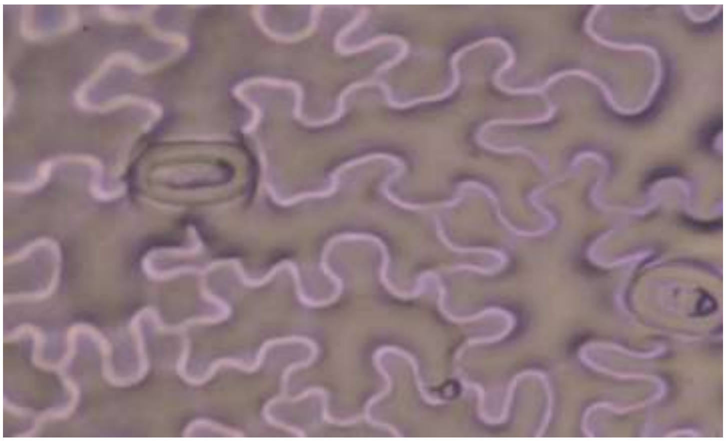
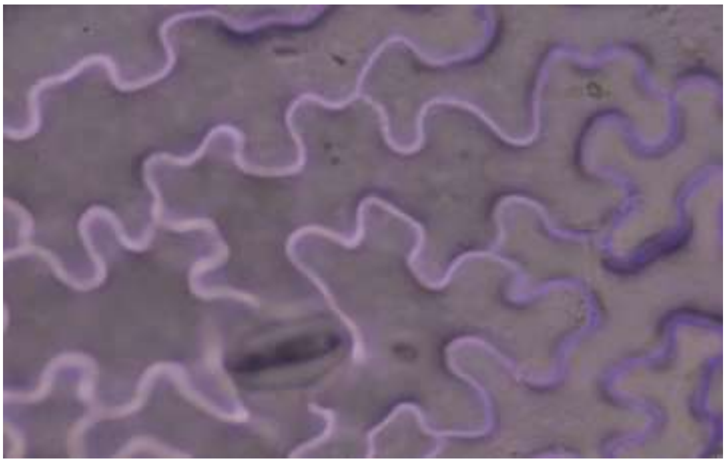


Figure 26. Leaf 2 epidermal cells in iceberg lettuce propagated under Luminance (at 14d)



The regulation of leaf expansion through changes in cell size is complex (Fry 1986). As well as changes in turgor (we have found no evidence of altered water relations in the crops), cell wall extensibility is regulated by several enzymes including xyloglucan endotransglycosylase (XET; for review see Campbell & Braam 1999); expansin (Lee & Kende 2001) and cell wall peroxidises (Hohl, Greiner & Schopfer 1995). The role of cell wall peroxidises in growth processes (Penel et al. 1992) through the control of cell wall plasticity during cell elongation is well documented (Hoson, Wakabayashi & Masuda 1995) with plant growth hormones such as abscisic acid or methyl jasmonate related to an increase in its activity (Tse-Min & Yaw-Huei 1996). These enzymes can increase oxidative cell wall cross-linkages which fix the viscoelatically extended wall structure, leading to the regulation of tissue growth by conferring irreversibility to wall extension (Hohl et al. 1995).

Elevated UVB light have been shown induce increases in the wall thickness of epidermal cells in Quinoa cotyledons, which was associated with lignin deposition and higher activity of the cell wall associated peroxidase (Hilal et al. 2004). We hypothesise that, at least in part, that the observed plant growth regulatory changes observed in both the lettuce and Brassica crops are related to UV induced increases in the activity of cell wall associated peroxidise which is likely to confer increased mechanical strength to the expanding tissue making the crop more resilient to both transplantation and challenge by herbivores and pathogens in the field. Further work will seek to clarify this. In conclusion, propagating crops in a relatively high UV environment, relative to a commercial glasshouse environment, could provide a tool by which growers can manipulate crop development through to harvest using minimal inputs at the propagation stage thereby reducing unit costs and maximising harvestable yield.

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Part 3. CUT FLOWERS

INTRODUCTION

The consumption of cut flowers in the UK remains very buoyant with total imports in 2003 valued at over £550 million and production from UK growers approaching £60 million. This could well be an under estimate as the statistics rely heavily on information from The Netherlands, which may under-estimate direct imports into the UK from Kenya, Colombia and Ecuador etc. Primarily the supermarkets have driven expansion in the cut flower market with growth year on year approaching 15-20%. It is now thought that growth is slowing to approximately 10%. For the purpose of analysis the UK cut flower industry can be divided into two main sectors: the greenhouse protected crops sector and the outdoor / polythene tunnel sector.

According to ministry (DEFRA) returns the greenhouse-protected sector covers an area of 150 Ha. Bulbous crops cover a total area of 4,500 Ha. The majority of the remaining area is either used for the production of chrysanthemums or *Alstroemeria*. Rose production in the UK has declined to zero because of overseas competition, mainly from Kenya. The production of carnations and pinks has declined over the last ten years but now appears to have stabilized. The area of stock being grown under glass has steadily increased over the last five years and is now approaching 25 Ha (Simon Crawford - personal assessment). The expansion of this crop is now limited by the lack of adequate greenhouses and lower cost alternatives are being sought by growers in an attempt to further expand production without raising the price of the product to the consumer.

Outdoor production in the UK is reported to cover a total area of 5,500 Ha. The greater part of this area, 4,500 Ha, is devoted to bulbous crops. Daffodil bulb production, outdoor tulips and gladioli are still major crops in the eastern counties of the country. Lilies have become increasingly popular and area both under protection as well as outdoors has grown significantly during the past five years. The production of seed raised crops is highly fragmented, but a few large growers producing sunflowers, Chinese asters and larkspur are responsible for at least 150 Ha of production. Current outdoor cut flower producers and other farmers and growers seeking to diversify their business into cut flowers are searching for lower cost alternatives to glasshouses and traditional polythene tunnels. A facility that would allow growers to protect their crops from the weather and give a basic level of environmental control in order to ensure ‘on-time’ delivery of crops is essential when serving UK supermarkets with high volume products.

The development of low cost Spanish tunnel systems for strawberries and other soft fruit crops has presented growers with a real option in the search for an adequate solution to their need for a basic level of lower cost environmental control and assured harvesting. Therefore improvement of these systems through technical developments in more sophisticated tunnel designs and plastic coverings for the structures is essential for the progress of these systems in the UK.

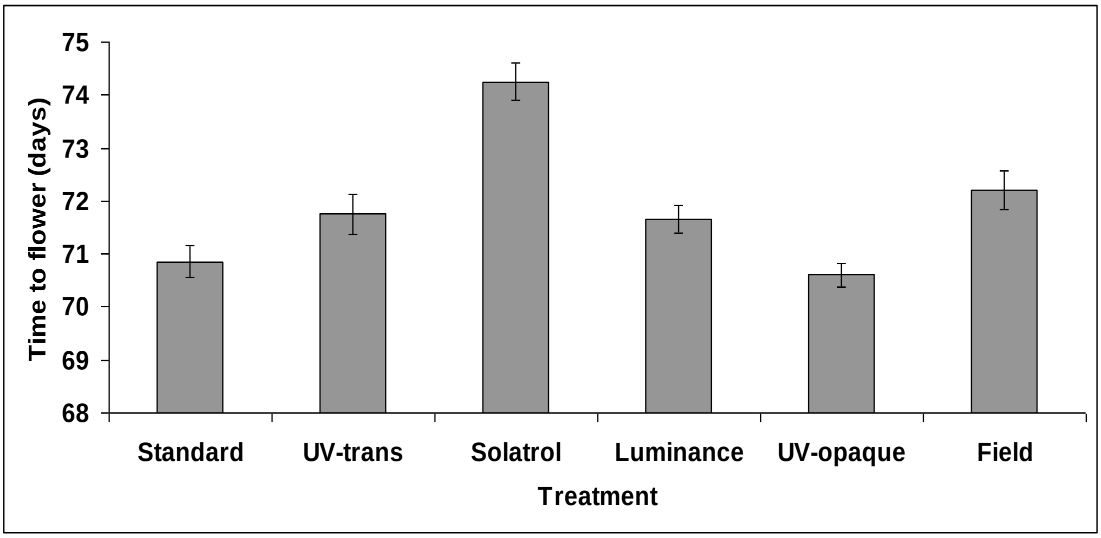
During 2005 a small number of UK flower growers have been pioneering the use of lower cost tunnel structures for growing cut flowers and striving to improve production protocols. The data generated by this project in 2005 will be valuable for refining these production techniques. The quantitative and qualitative data from the 2006 trials will help reconfirm previous year's results and indicate the financial benefits of spectral filters to cut flower growers and possibly through enhanced quality the advantages to flower retailers and consumers.

RESULTS – RED ASTERS

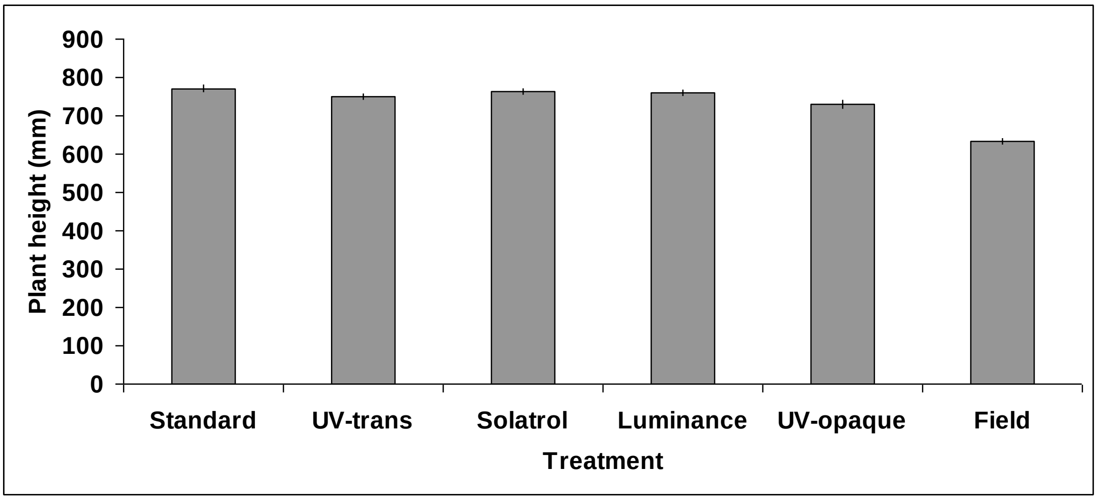
Time to flower was significantly increased in Solatrol when compared to all remaining treatments (fig. 1.a) Time to flower was reduced in UV-opaque relative to Solatrol and Field only (fig. 1.a). Standard significantly increased plant height when compared to UV-opaque and Field only, while height was significantly reduced in Field relative to all filter treatments (1.b). Shoot fresh weight was significantly increased in UV-opaque when compared to all treatments except Standard (1.c). UV-opaque significantly increased primary inflorescence diameter when compared to Standard, UV-transparent, Luminance and Field, although there was no effect relative to Solatrol (fig. 2.a). There was no significant effect of treatments on the number of ancillary inflorescences (fig. 2.b). Stem thickness at the tip was increased in UV-opaque but this only represented a significant increase relative to UV-transparent (2.c). In UV-transparent, tip stem thickness was reduced when compared to all treatments except Luminance (fig. 2.c).

Figure 1. Effect of treatments on (a) time to flower (b) plant height and (c) shoot fresh weight in red asters. Each value is the mean ± S.E. of 20 replicates.

a)



b)



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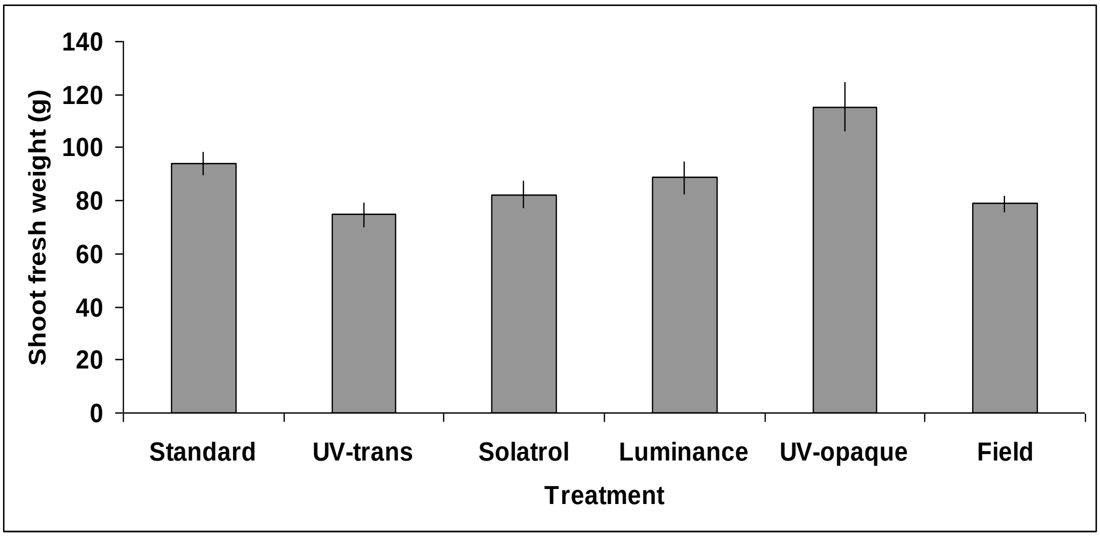
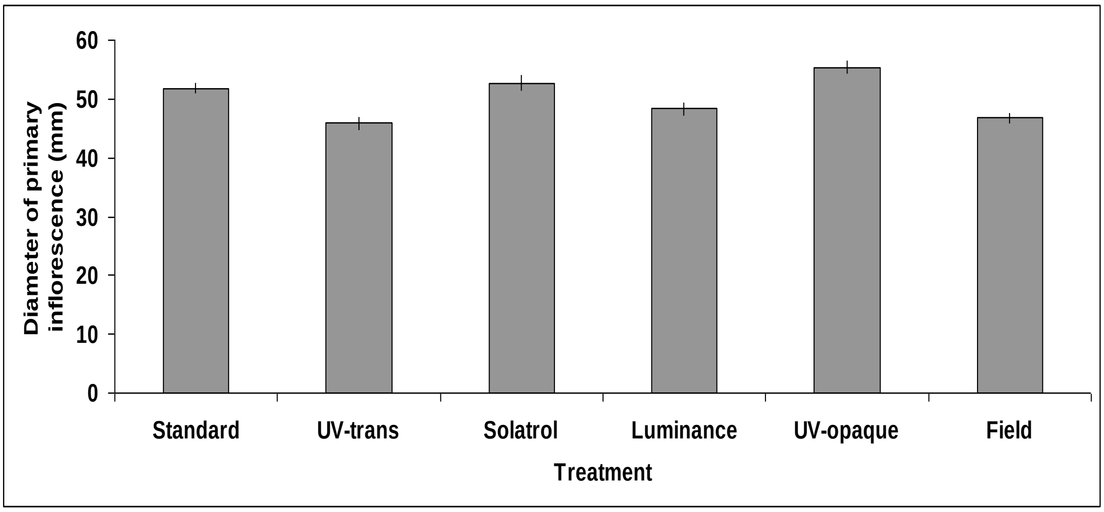
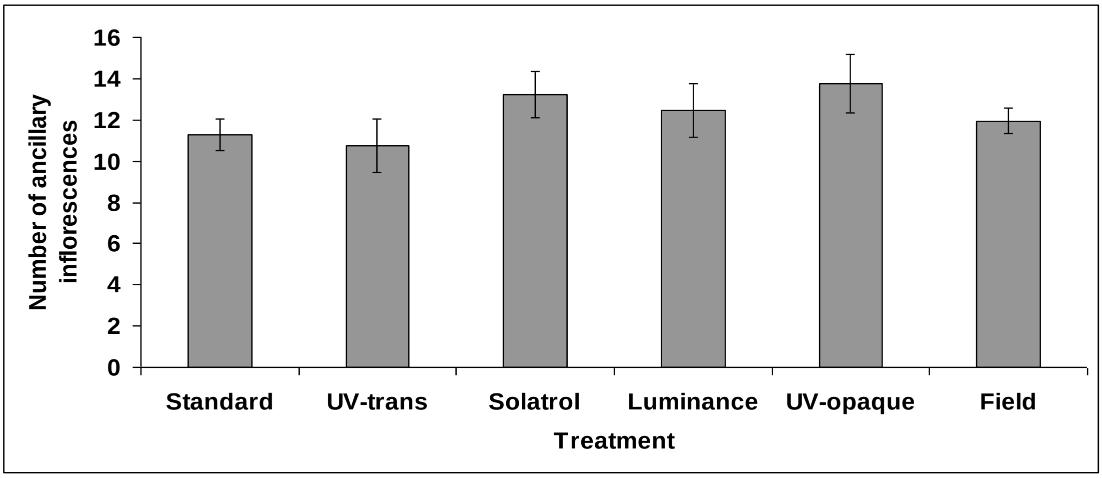


Figure 2. Effect of treatments on (a) diameter of the primary inflorescence (b) number of ancillary inflorescences and (c) stem thickness at the tip in red asters. Each value is the mean ± S.E. of 20 replicates.

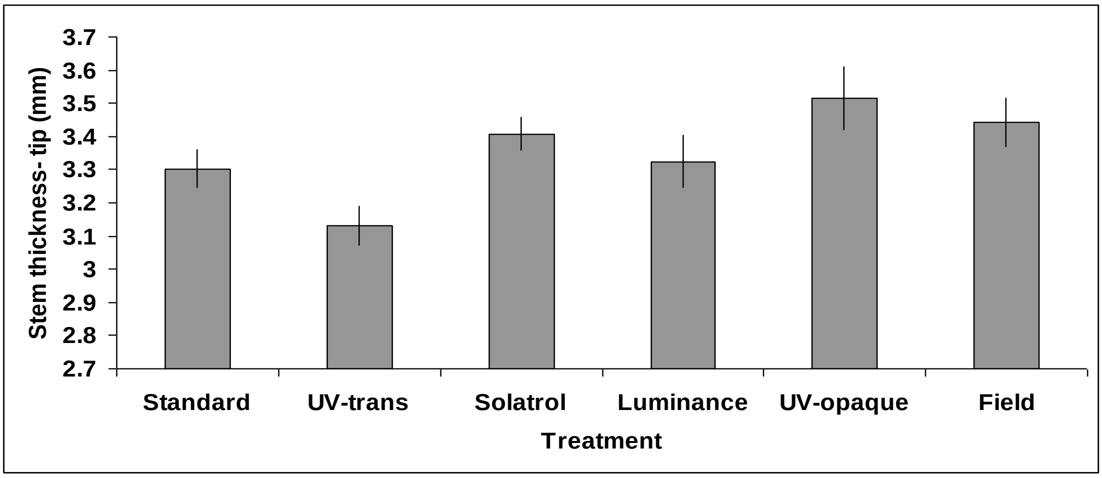
a)



b)



c)

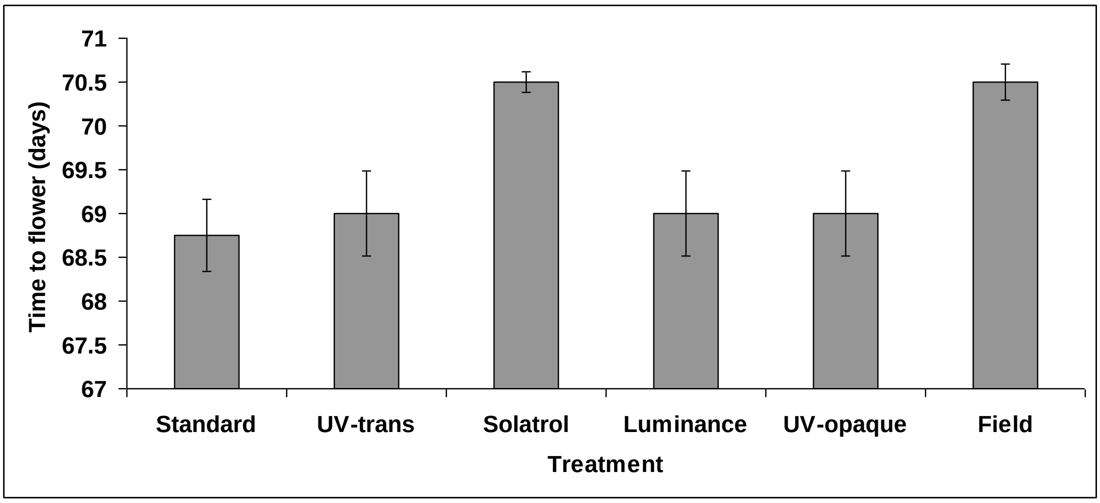


RESULTS – PINK STOCKS

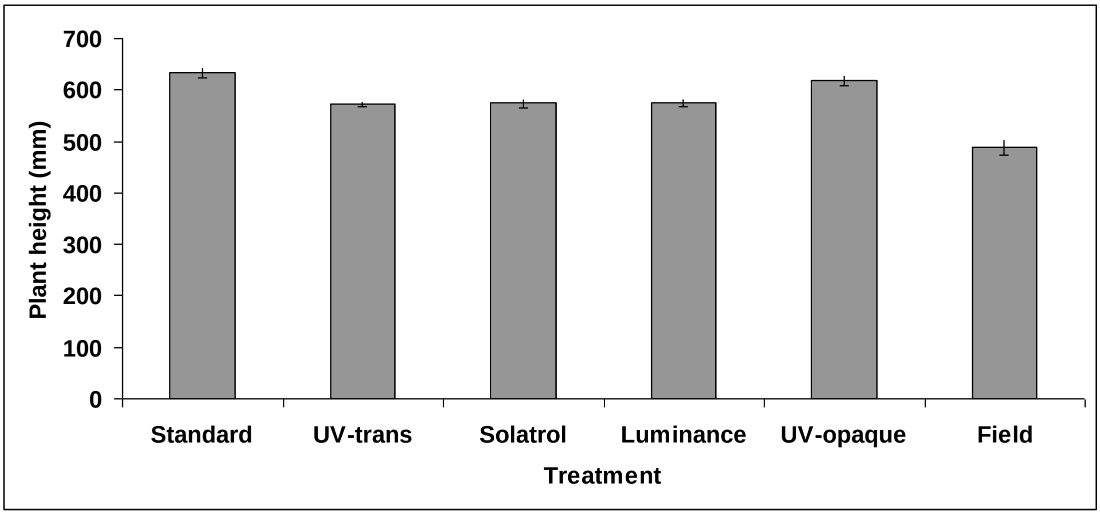
There was a significant increase in the time to flower in both Solatrol and Field when compared to all remaining filter treatments by ~ 2 days (fig. 3.a). There was no significant effect on time to flower in the remaining filter treatments (fig. 3.a). Plant height was significantly reduced in Field plants by ~ 17% when compared to all remaining treatments (fig. 3.b). Of the filter treatments Standard produced the tallest plants and this was a significant increase in plant height relative to all treatments except UV-opaque (fig. 3.b). Shoot fresh weight was significantly reduced in Field plants when compared to all remaining treatments (fig. 3.c). UV-opaque produced the highest fresh weights of all treatments but this was only significant when compared to Luminance and Field (fig. 3.c). The length of the terminal inflorescence was significantly increased in Standard when compared to Luminance and Field only (fig. 4.a). Field plants had significantly reduced inflorescence lengths relative to all filter treatments (fig. 4.a). The total number of individual flowers on the terminal inflorescence was reduced in Field when compared to all treatments. UV-opaque increased flower numbers but this was only significant relative to UV-transparent, Luminance and Field (fig. 4.b). Total leaf area was significantly increased in UV-transparent when compared to Luminance and Field only, and Field reduced total leaf area at the time of harvest relative to all filter treatments (fig. 4.c).

Figure 3. Effect of treatments on (a) time to flower (b) plant height and (c) shoot fresh weight in pink stocks. Each value is the mean ± S.E. of 20 replicates.

a)



b)



c)

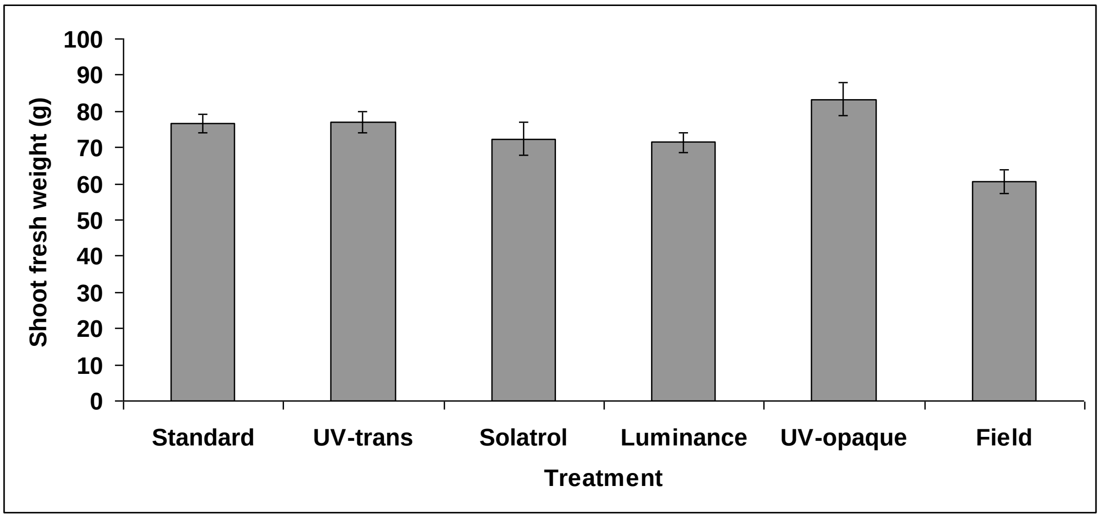
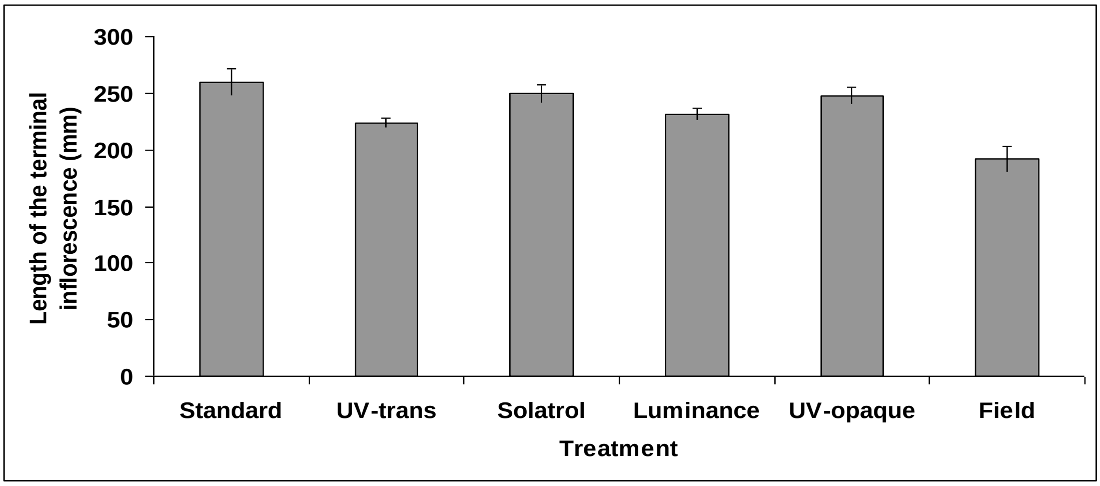
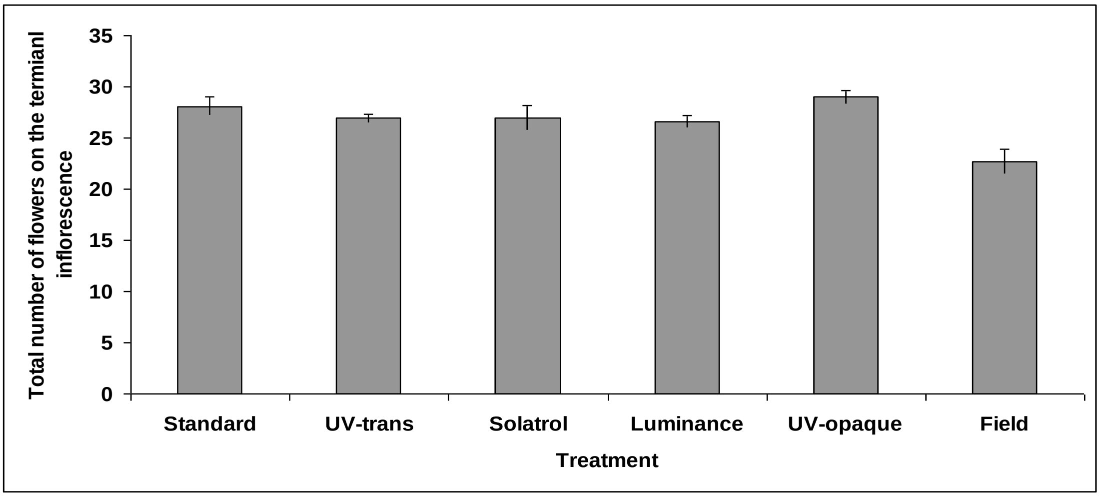


Figure 4. Effect of treatments on (a) inflorescence length (b) total number of inflorescences and (c) total leaf area in pink stocks. Each value is the mean ± S.E. of 20 replicates.

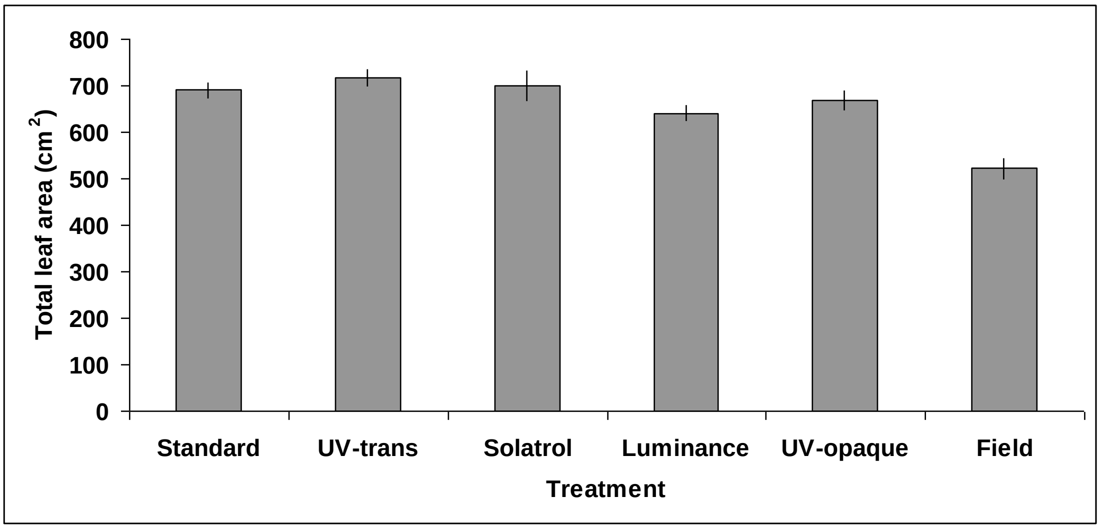
a)



b)



c)

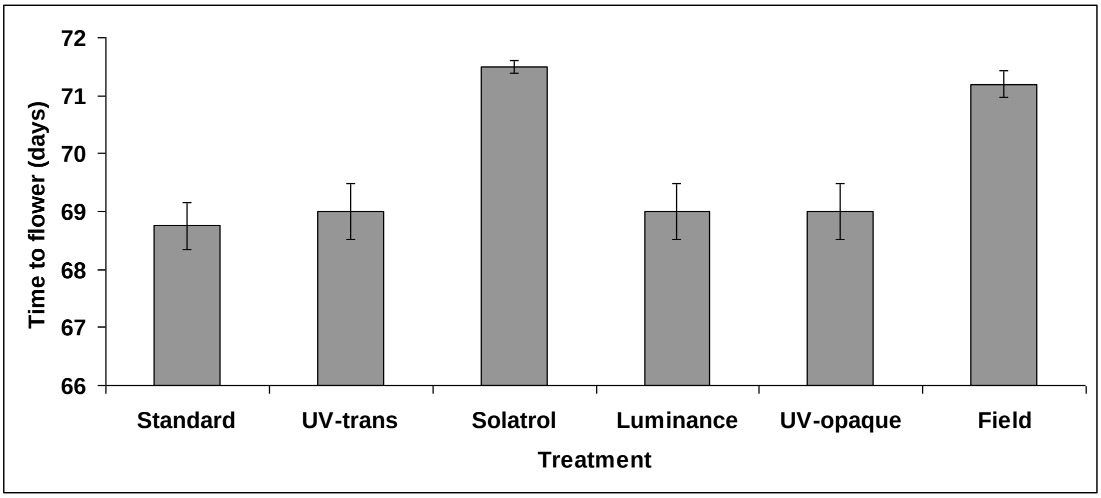


RESULTS – WHITE STOCKS

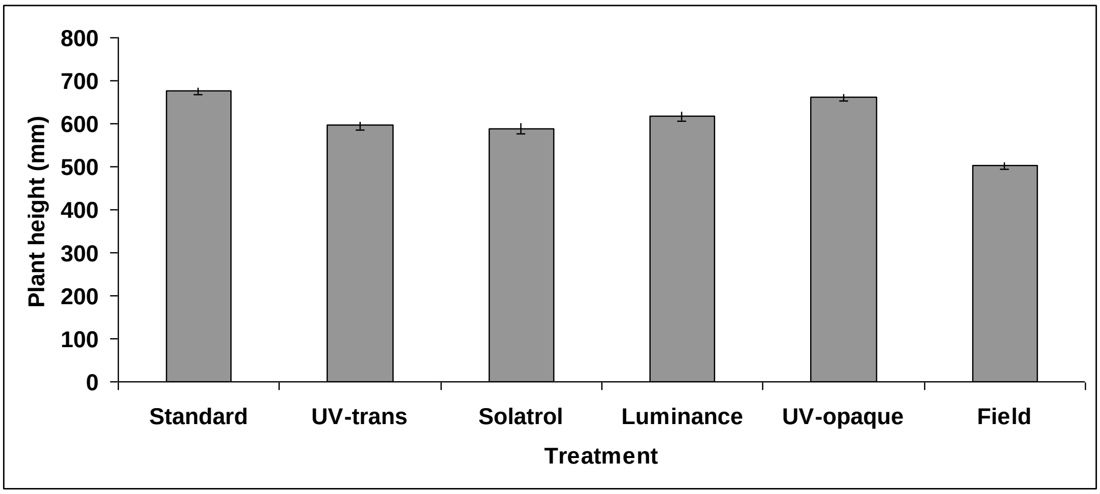
There was a significant increase in the time to flower in both Solatrol and Field when compared to all remaining filter treatments by ~ 2 days (fig. 5.a). There was no significant effect on time to flower in the remaining filter treatments (fig. 5.a). Plant height was significantly reduced in Field plants by ~ 20% when compared to all remaining treatments (fig. 5.b). Of the filter treatments Standard produced the tallest plants and this was a significant increase in plant height relative to all treatments except UV-opaque (fig. 5.b). Shoot fresh weight was significantly reduced in Field plants when compared to all remaining treatments except Solatrol (fig. 5.c). Standard and UV-opaque produced the highest fresh weights of all treatments but this was only significant when compared to UV-transparent and Field (fig. 5.c). The length of the terminal inflorescence was significantly increased in Standard when compared to all remaining treatments except UV-opaque (fig. 6.a). Field plants had significantly reduced inflorescence lengths relative to all filter treatments (fig. 6.a). The total number of individual flowers on the terminal inflorescence was reduced in UV-transparent but this represented a significant reduction relative to Standard only (fig. 6.b). Total leaf area was significantly increased in Standard when compared to Field only (fig. 6.c) Total leaf area at the time of harvest was significantly reduced in Field when compared to all treatments (fig. 6.c).

Figure 5. Effect of treatments on (a) time to flower (b) plant height and (c) shoot fresh weight in white stocks. Each value is the mean ± S.E. of 20 replicates.

a)



b)



c)

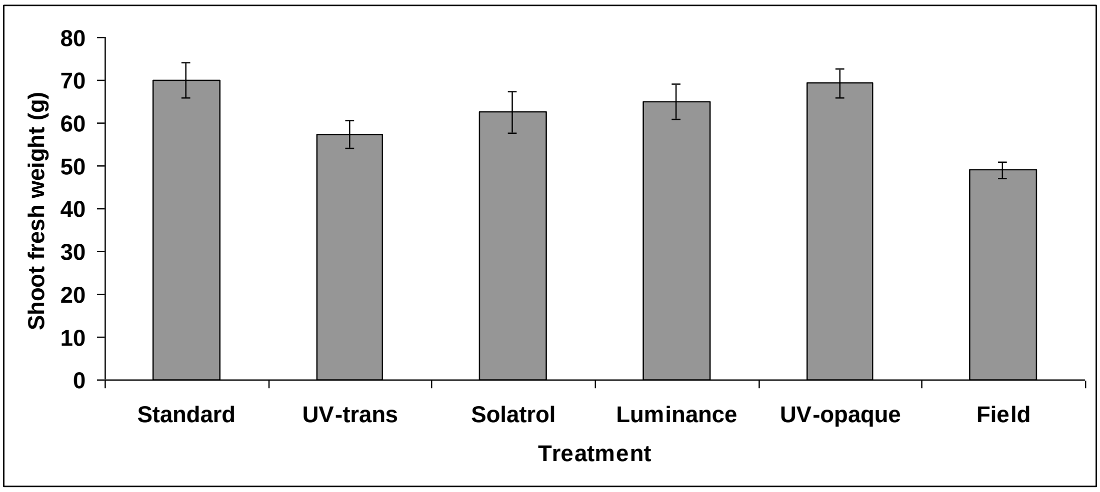
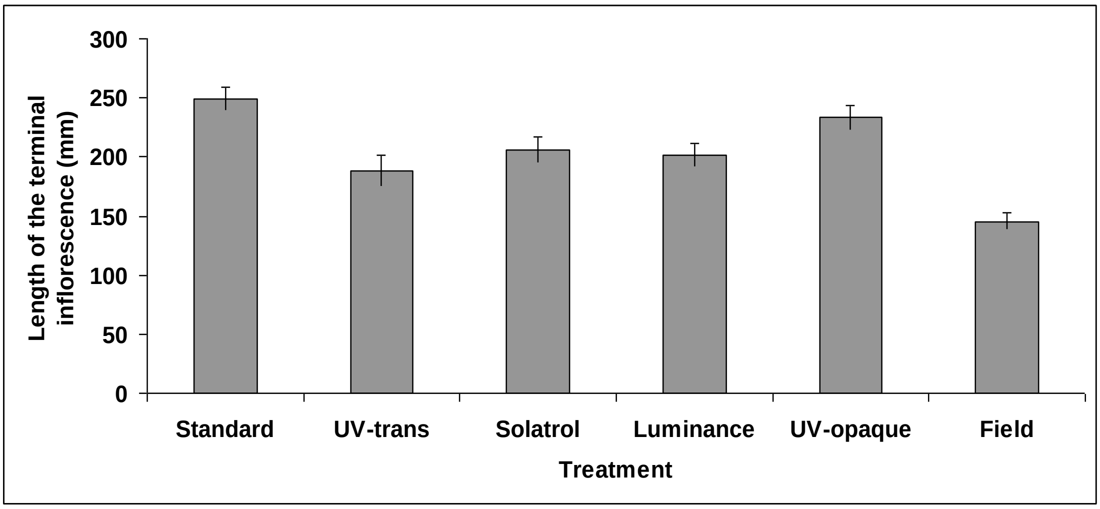
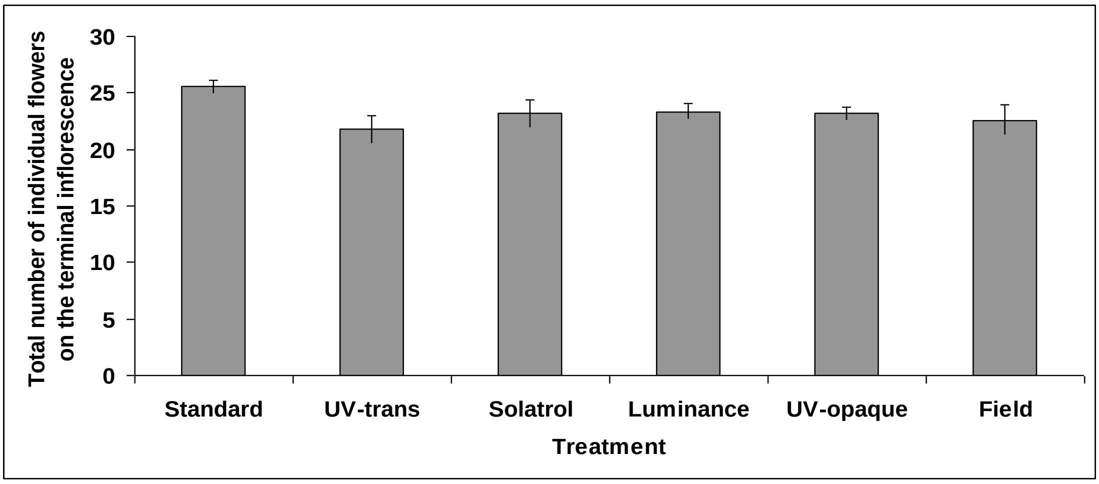


Figure 6. Effect of treatments on (a) inflorescence length (b) total number of inflorescences and (c) total leaf area white stocks. Each value is the mean ± S.E. of 20 replicates.

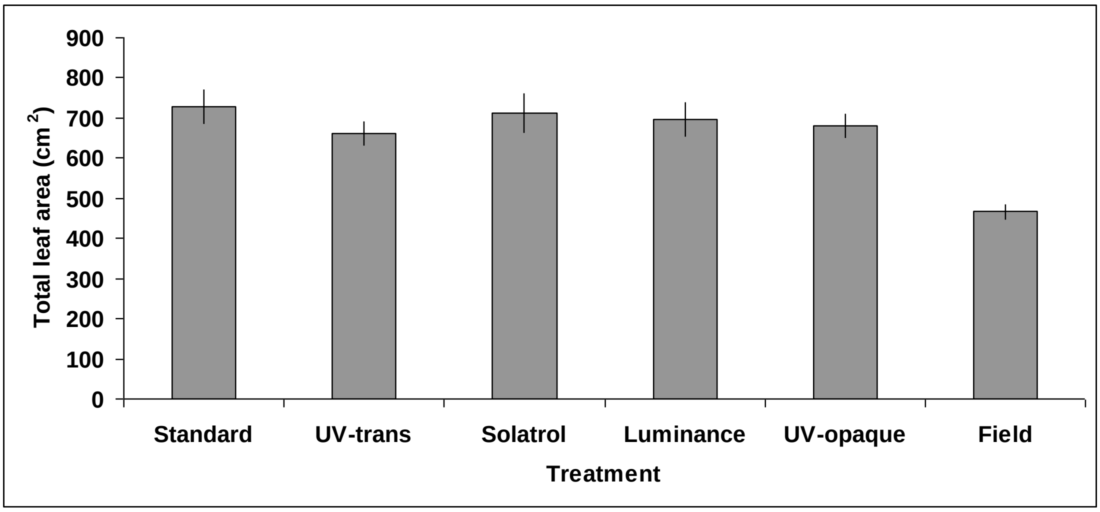
a)



b)



c)

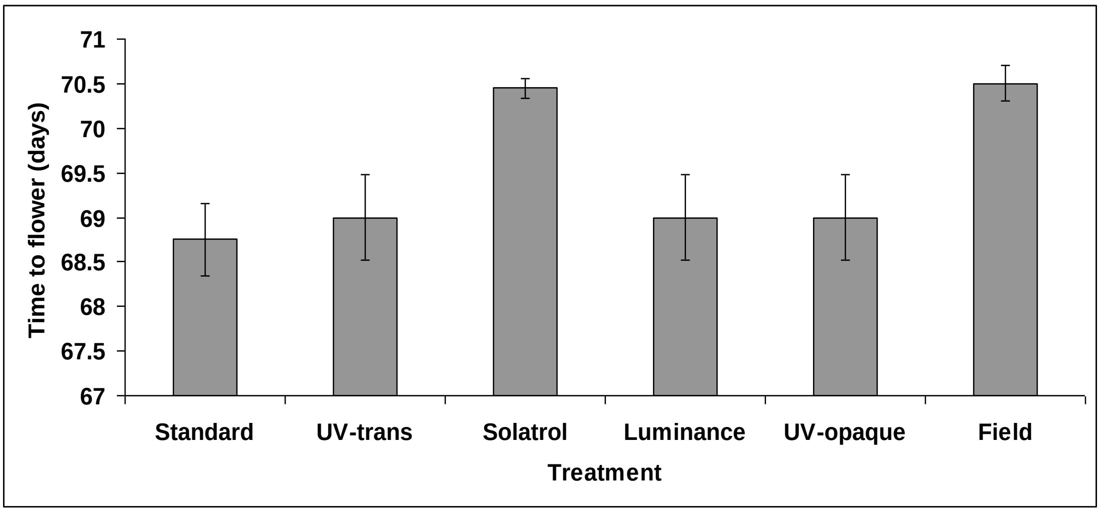


RESULTS – RED STOCKS

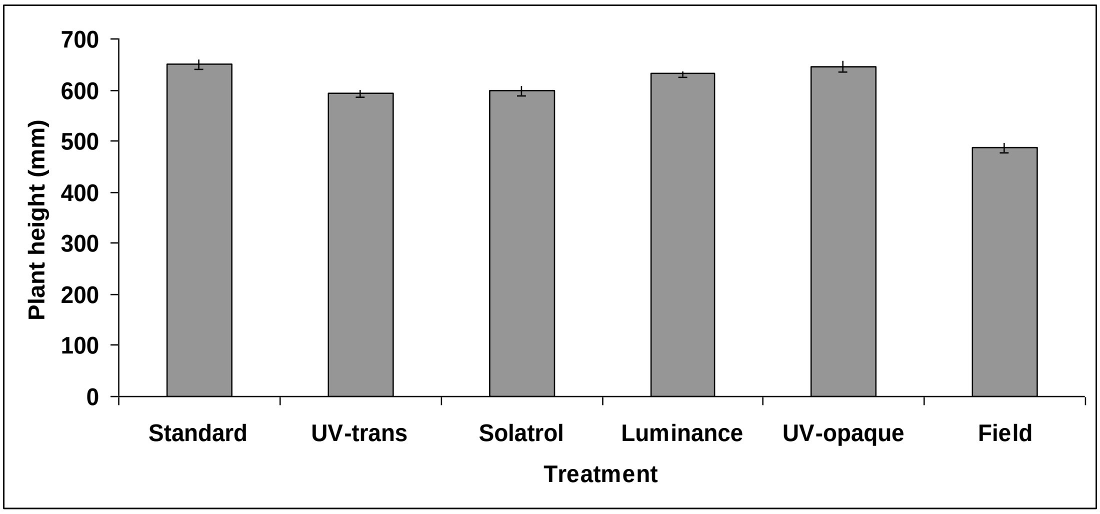
There was a significant increase in the time to flower in both Solatrol and Field when compared to all remaining filter treatments by ~ 2 days (fig. 7.a). There was no significant effect on time to flower in the remaining filter treatments (fig. 7.a). Plant height was significantly reduced in Field plants by ~ 22% when compared to all remaining treatments (fig. 7.b). Of the filter treatments Standard produced the tallest plants and this was a significant increase in plant height relative to all treatments except Luminance and UV-opaque (fig. 7.b). Shoot fresh weight was significantly reduced in Field plants when compared to all remaining treatments (fig. 7.c). UV-opaque produced the highest fresh weights of all treatments but this was only significant when compared to Field (fig. 7.c). The length of the terminal inflorescence was significantly increased in Standard when compared to UV-transparent, Solatrol and Field only (fig. 8.a). Field plants had significantly reduced inflorescence lengths relative to all filter treatments (fig. 8.a). The total number of individual flowers on the terminal inflorescence was reduced in UV-transparent but this did not represent a significant reduction (fig. 8.b). Solatrol produced plants with the greatest number of inflorescences but this was only significant relative to UV-transparent (fig. 8.b). Total leaf area was significantly increased in Luminance when compared to Field only and Field significantly reduced total leaf area when compared to all remaining treatments (fig. 8.c).

Figure 7. Effect of treatments on (a) time to flower (b) plant height and (c) shoot fresh weight in red stocks. Each value is the mean <u>+</u> S.E. of 20 replicates.

a)



b)



c)

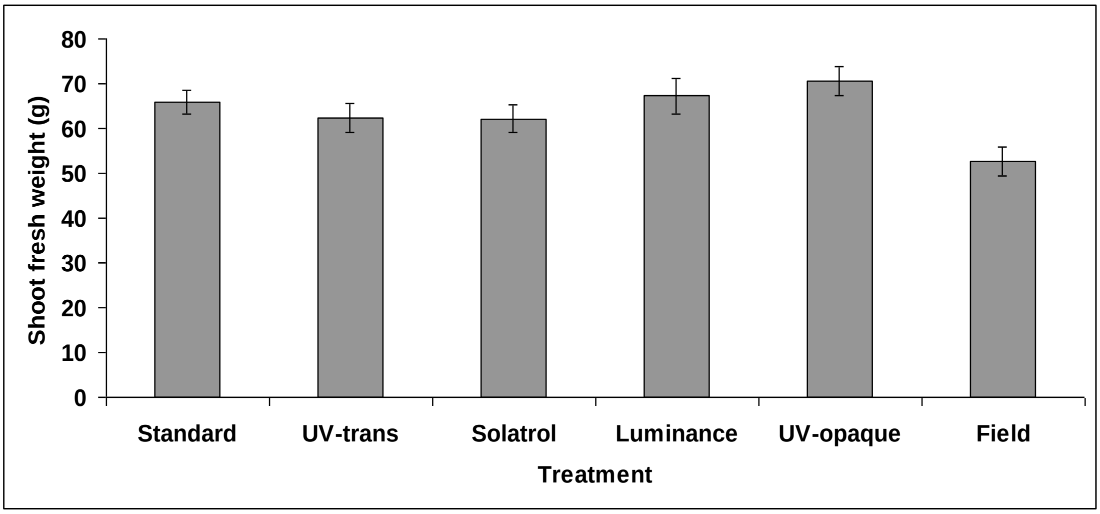
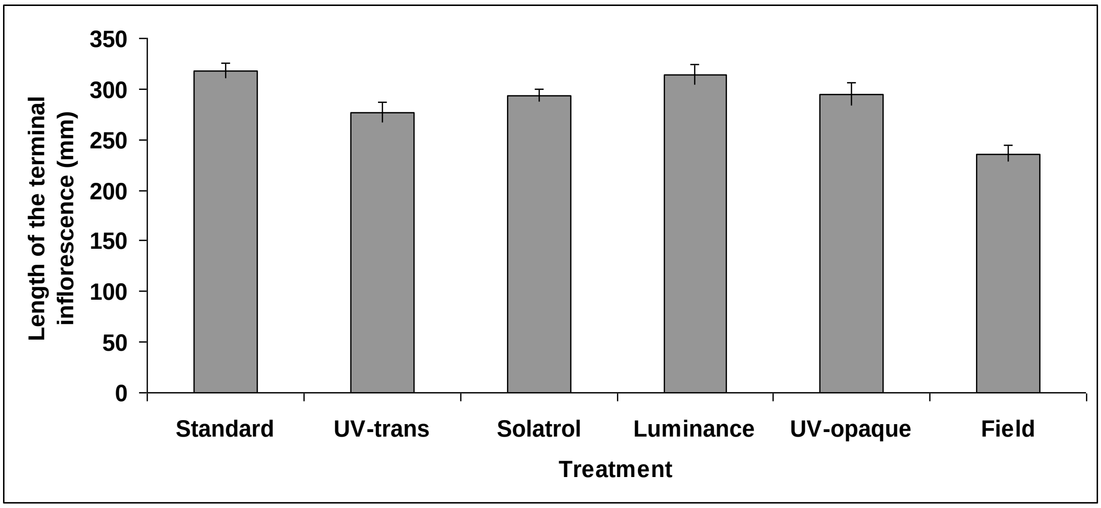
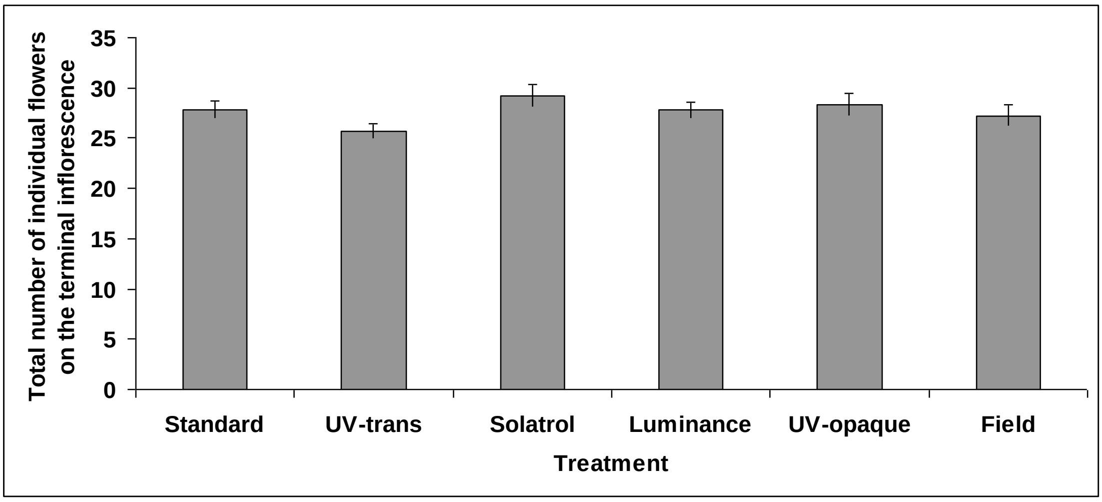


Figure 8. Effect of treatments on (a) inflorescence length (b) total number of inflorescences and (c) total leaf area in red stocks. Each value is the mean ± S.E. of 20 replicates.

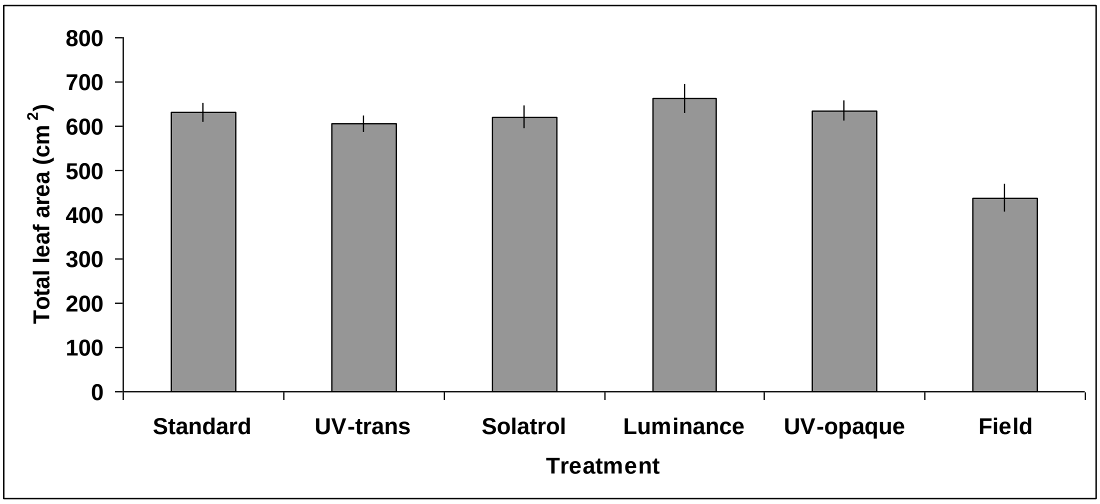
a)



b)



c)

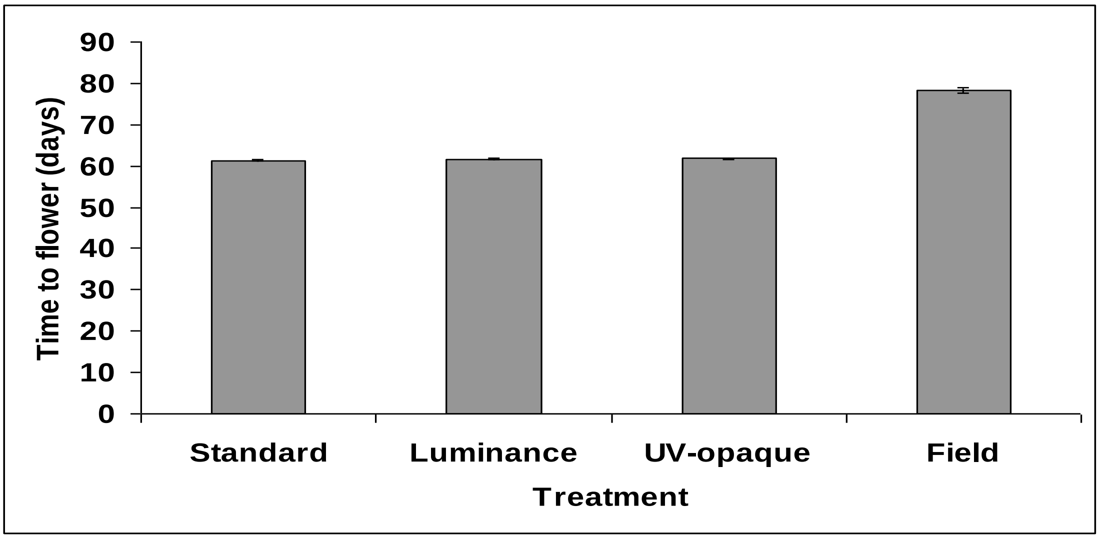


RESULTS – EXTENDED SEASON WHITE STOCKS

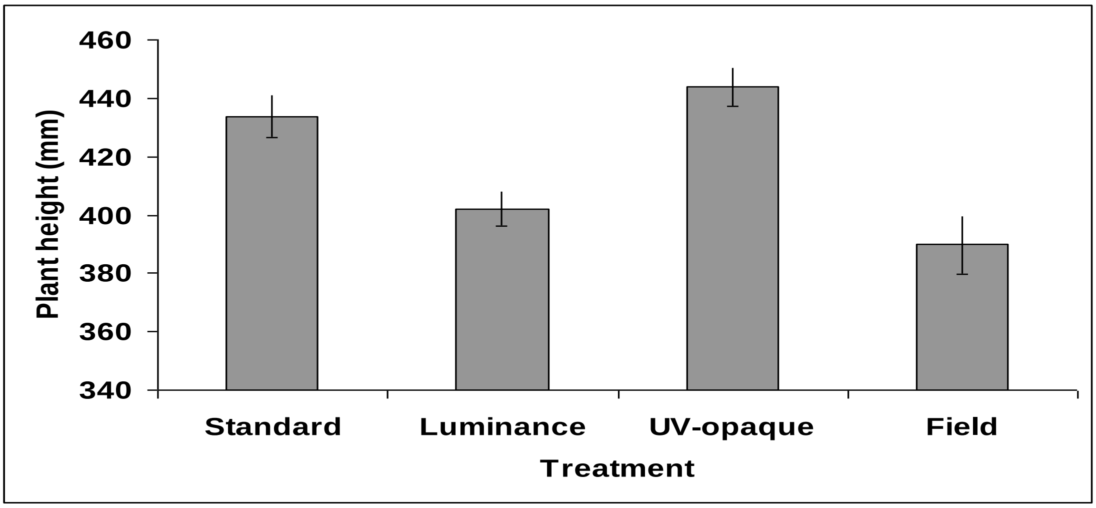
There was a significant increase in the time to flower in Field when compared to all remaining filter treatments by ~ 19 days (fig. 9.a). There was no significant effect on time to flower in the remaining filter treatments (fig. 9.a). Plant height was significantly reduced in Field plants by ~ 9% when compared to all remaining treatments (fig. 9.b). Of the filter treatments UV-opaque produced the tallest plants and this was a significant increase in plant height relative to all treatments except Luminance (fig. 9.b). Shoot fresh weight was significantly reduced in Field plants when compared to all treatments except Luminance (fig. 9.c). Standard produced the highest fresh weights of all treatments but this was only significant when compared to Field (fig. 9.c). The length of the terminal inflorescence was significantly increased in Field when compared to all remaining treatments (fig. 10.a). There was no significant difference in inflorescence lengths in the three filter treatments (fig. 10.a). The total number of individual flowers on the terminal inflorescence was increased in Field UV-transparent compared to all filter treatments (fig. 10.b). There was no significant difference in the number of individual flowers in the three filter treatments (fig. 10.b). Total leaf area was significantly reduced in the Field crop when compared to all filter treatments and there was no significant difference in leaf areas between filter treatments (fig. 10.c).

Figure 9. Effect of treatments on (a) time to flower (b) plant height and (c) shoot fresh weight in white stocks. Each value is the mean + S.E. of 20 replicates.

a)



b)



c)

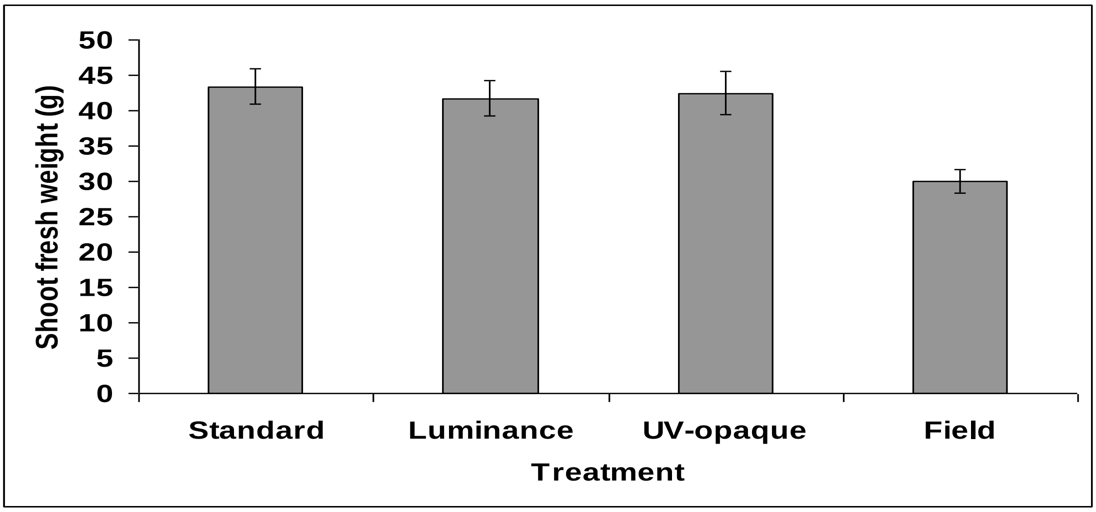
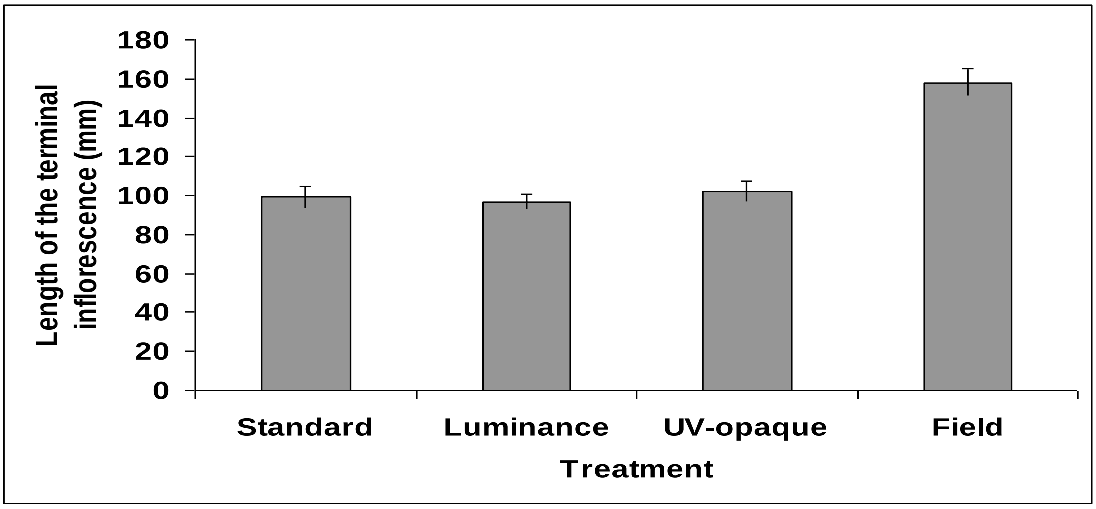
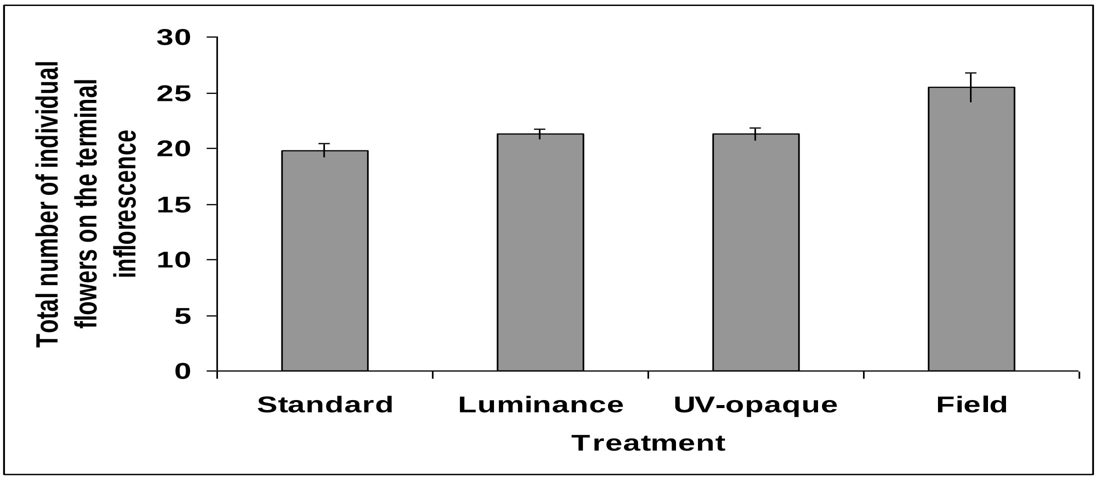


Figure 10. Effect of treatments on (a) length of the terminal inflorescence (b) total number of inflorescences and (c) total leaf area in white stocks. Each value is the mean + S.E. of 20 replicates.

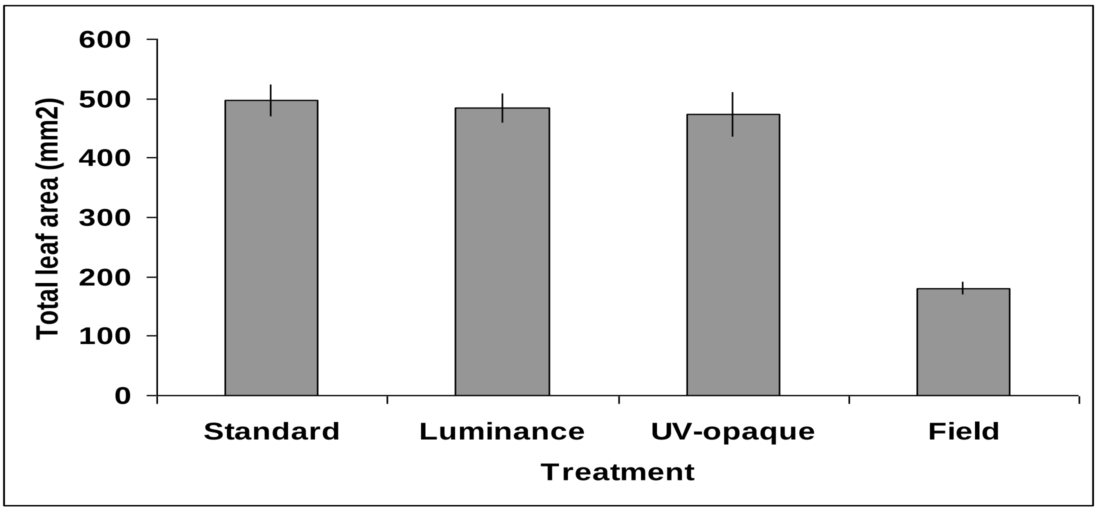
a)



b)



c)

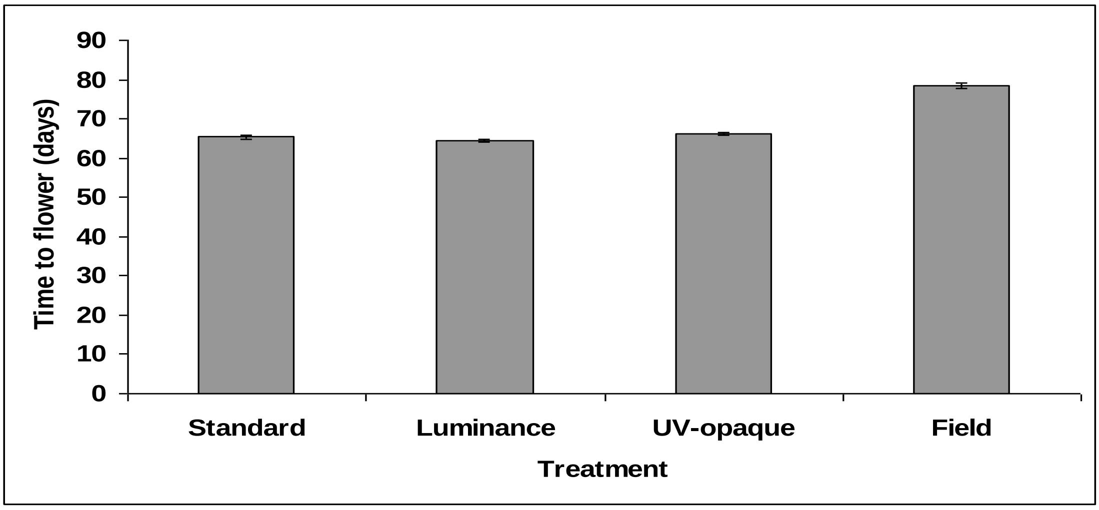


RESULTS – EXTENDED SEASON RED STOCKS

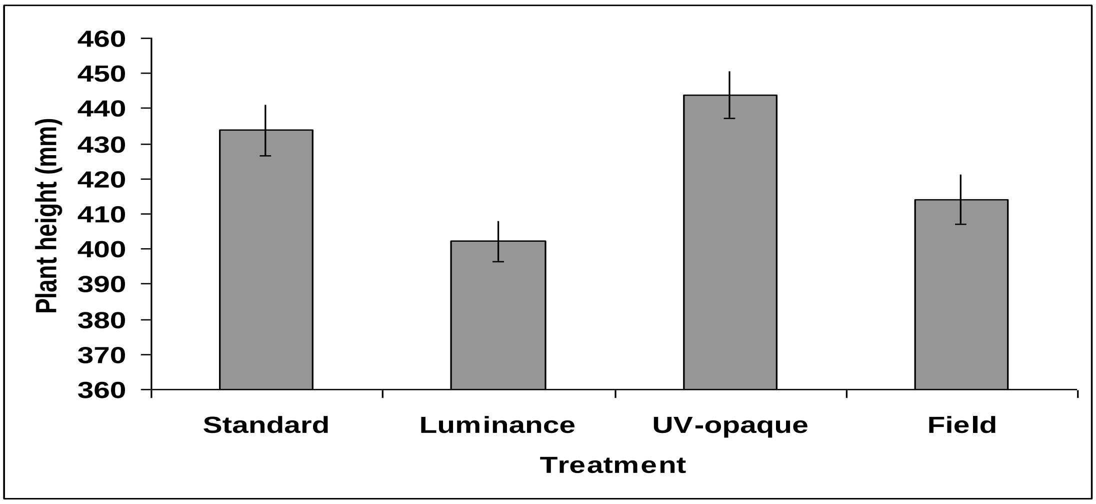
There was a significant increase in the time to flower in Field when compared to all remaining filter treatments by ~ 14 days (fig. 11.a). There was no significant effect on time to flower in the remaining filter treatments (fig. 11.a). Plant height was increased in UV-opaque but this was only significant when compared to Luminance and Field (fig. 11.b). Shoot fresh weight was significantly reduced in Field plants when compared to all treatments (fig. 11.c). Of the filter treatments Standard produced the highest shoot fresh weight but this was not a significant increase (fig. 11.c). The length of the terminal inflorescence was significantly increased in Field when compared to all remaining filter treatments (fig. 12.a). There was no significant difference in inflorescence lengths in the three filter treatments (fig. 12.a). The total number of individual flowers on the terminal inflorescence was increased in Field compared to all filter treatments (fig. 12.b). There was no significant difference in the number of individual flowers in the three filter treatments (fig. 12.b). Total leaf area was significantly reduced in the Field crop when compared to all filter treatments and there was no significant difference in leaf areas between filter treatments (fig. 12.c).

Figure 11. Effect of treatments on (a) time to flower (b) plant height and (c) shoot fresh weight in red Stocks. Each value is the mean ± S.E. of 20 replicates.

a)



b)



c)

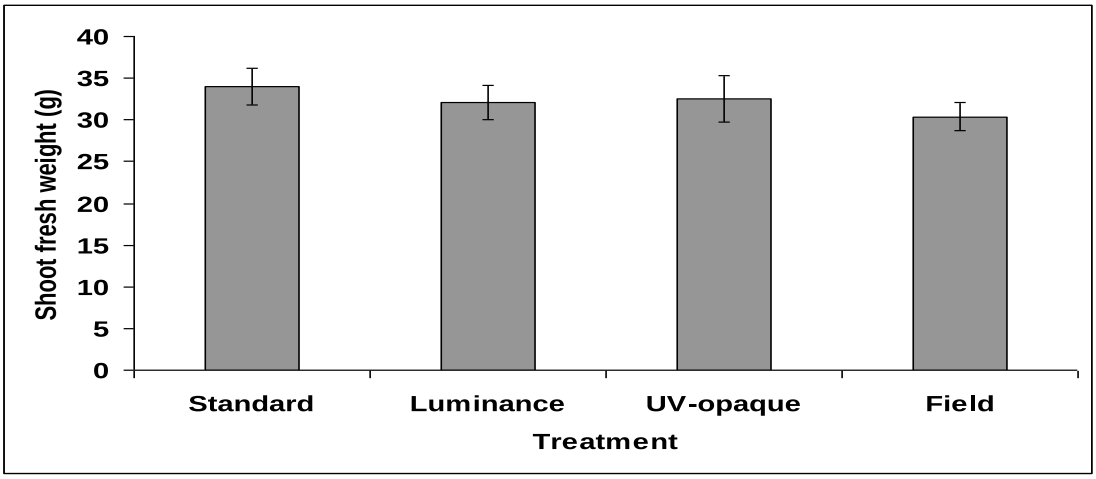
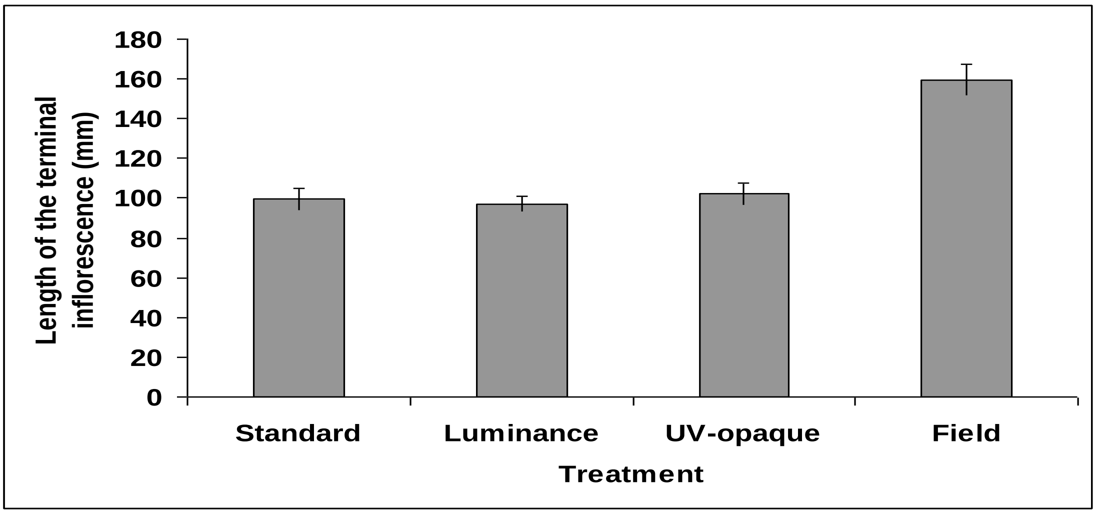
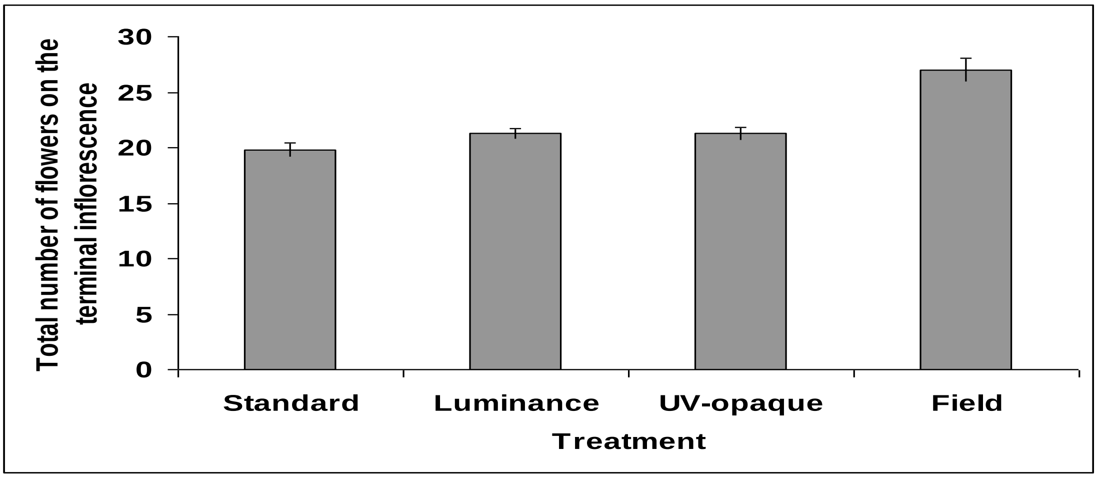


Figure 12. Effect of treatments on (a) length of the terminal inflorescence (b) total number of inflorescences and (c) total leaf area in red Stocks. Each value is the mean + S.E. of 20 replicates.

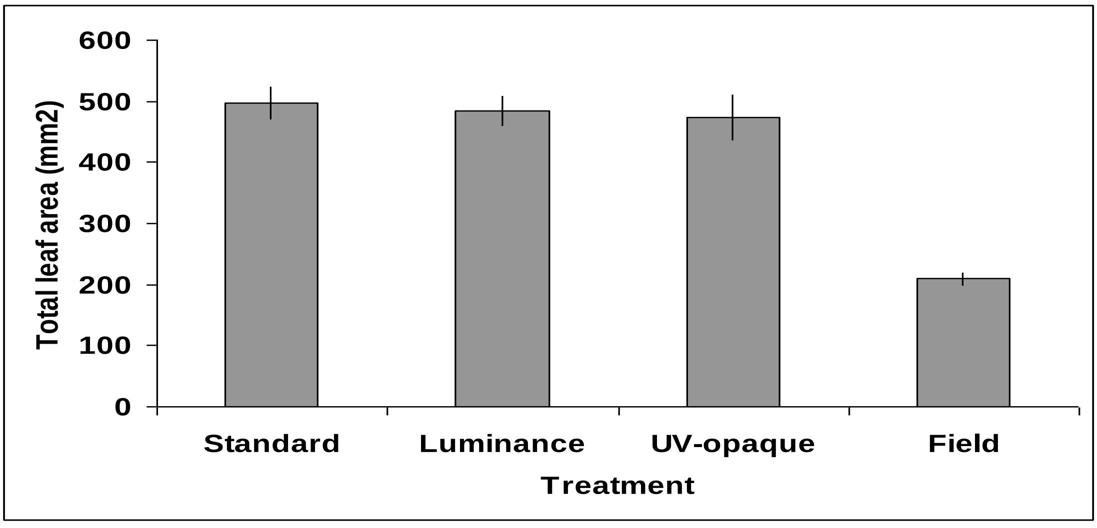
a)



b)



c)

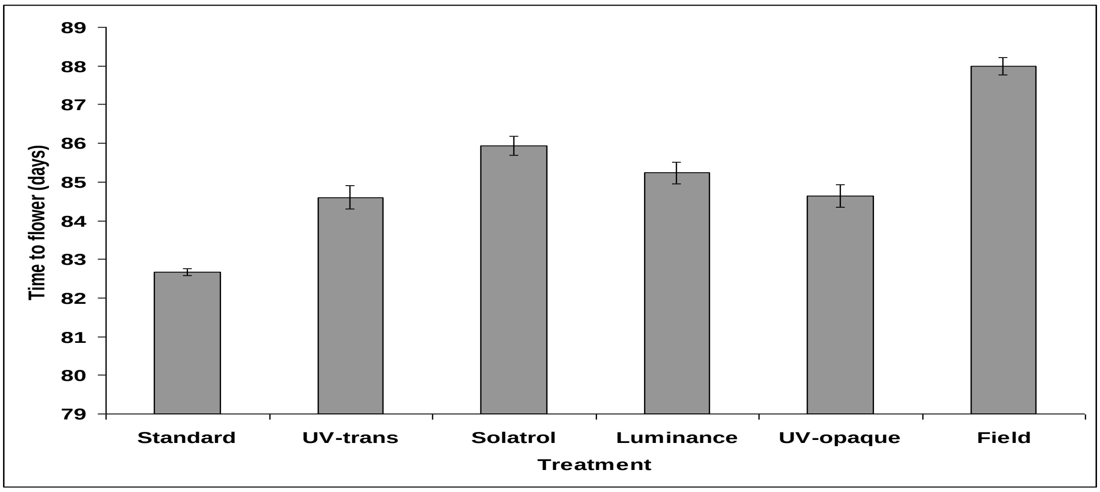


RESULTS – COURIER LILIES

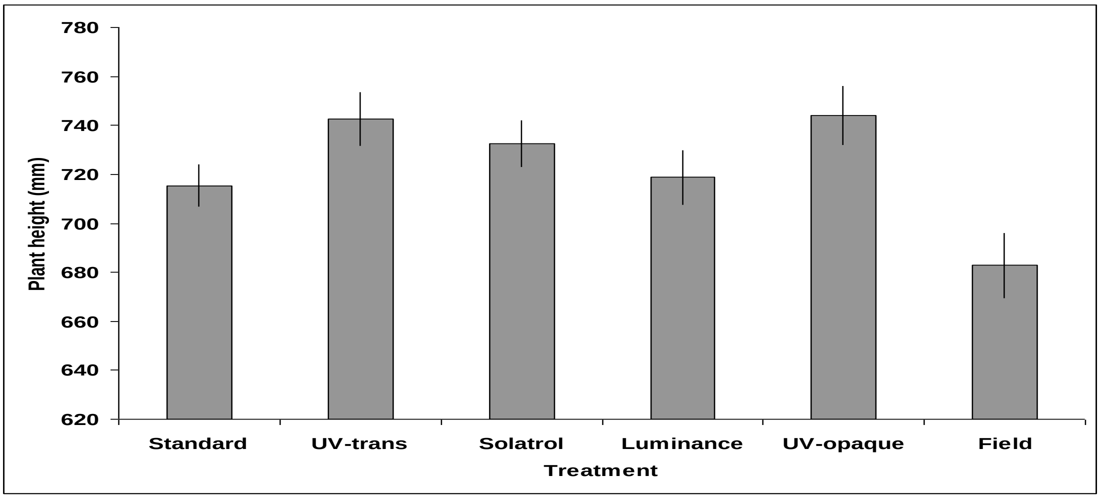
Time to flower was significantly reduced in Standard when compared to all remaining treatments, while Field increased time to flower relative to all filter treatments (fig. 13.a). UV-opaque significantly increased total plant height when compared to Standard and Field only (fig. 13.b). Shoot fresh weight was significantly increased in the Field plants when compared to all treatments except UV-opaque (fig. 13.c). While Solatrol and Luminance produced increased length of the terminal inflorescence this did not represent a significant increase and there was no significant effect on inflorescence length between the remaining treatments (fig. 14.a). Total number of inflorescences was reduced in Luminance when compared to UV-transparent only while UV-opaque increased inflorescence numbers relative to both Standard and Luminance (fig. 14.b). The total fresh weight at harvest of all inflorescences was increased in Field when compared to Standard, Solatrol and Luminance only (fig. 14.c). A reduction in inflorescence fresh weight was recorded in Standard relative to all treatments except Solatrol and Luminance (fig. 14.c).

Figure 13. Effect of treatments on (a) time to flower (b) plant height and (c) shoot fresh weight in Courier Lilies. Each value is the mean + S.E. of 30 replicates.

a)



b)



c)

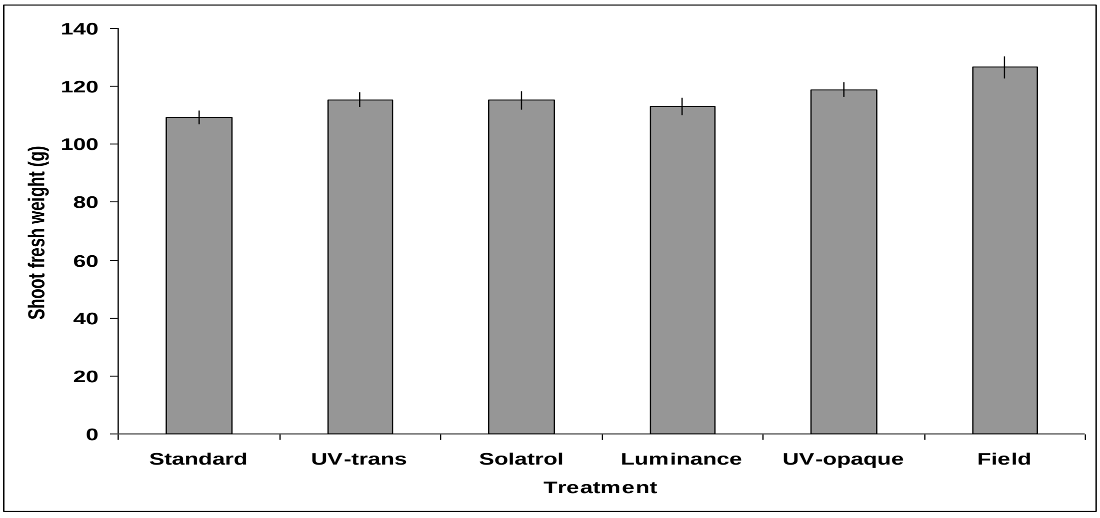
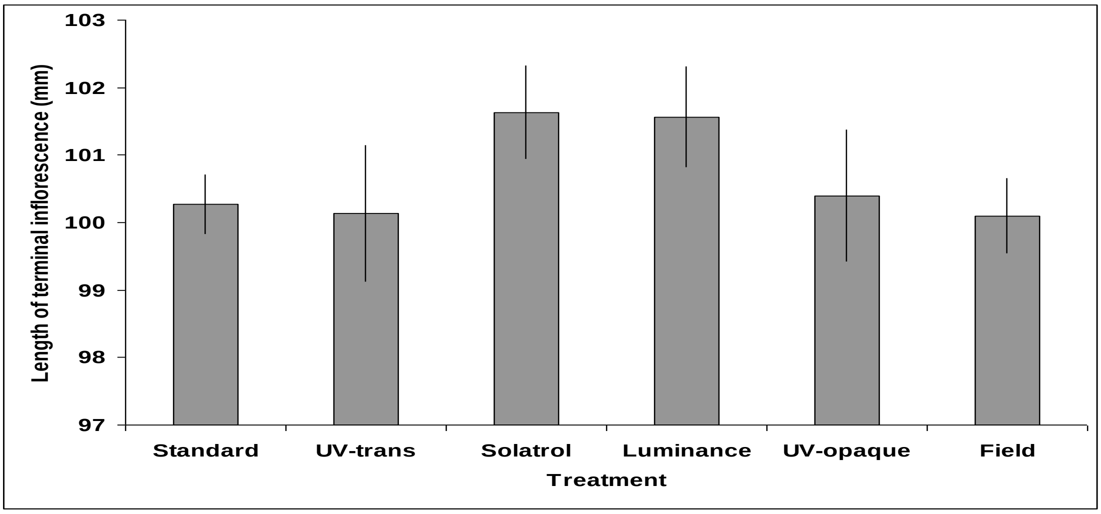
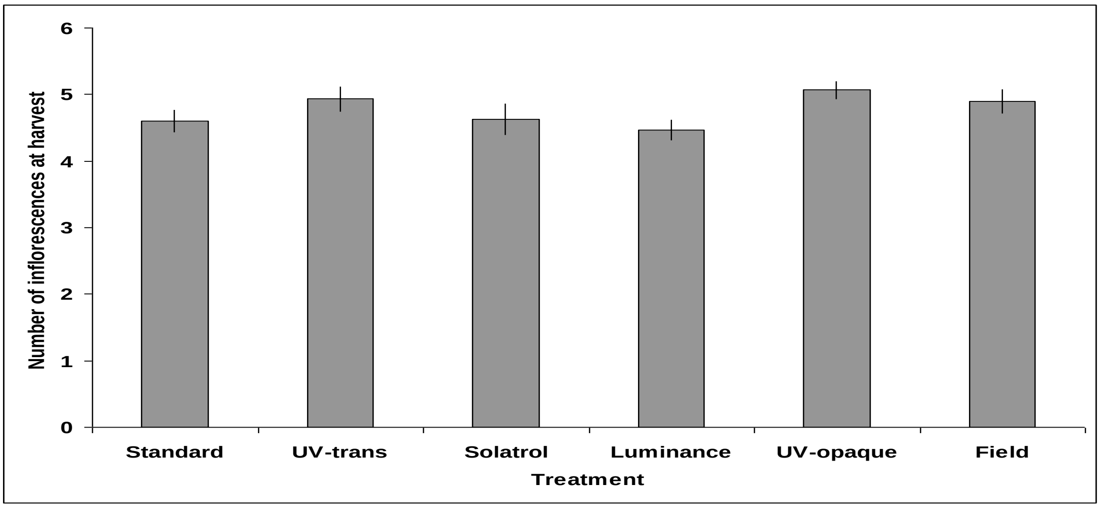


Figure 14. Effect of treatments on (a) length of the terminal inflorescence (b) total number of inflorescences and (c) total weight of inflorescences at harvest in Courier Lilies. Each value is the mean + S.E. of 30 replicates.

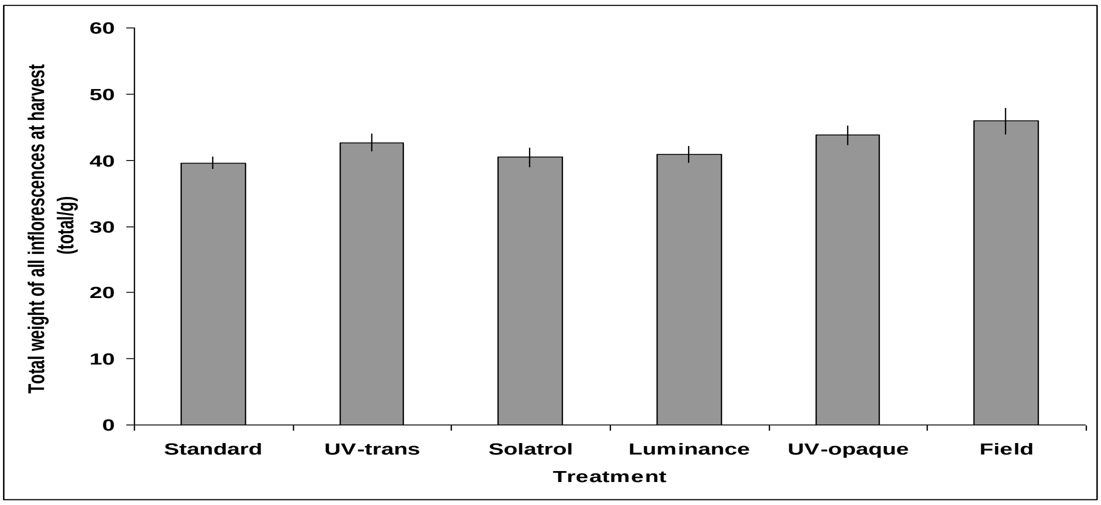
a)



b)



c)

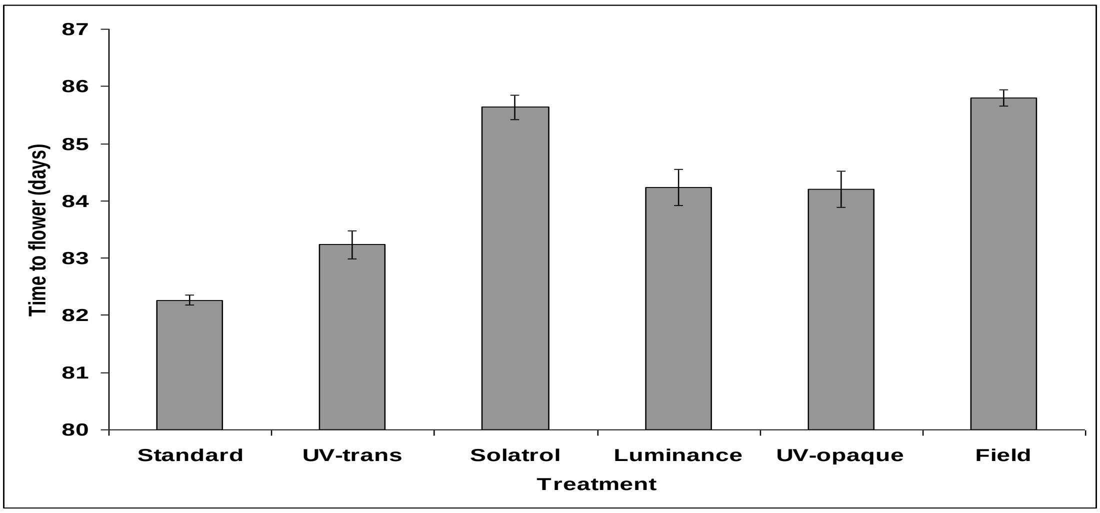


RESULTS – WEINER BLUT LILIES

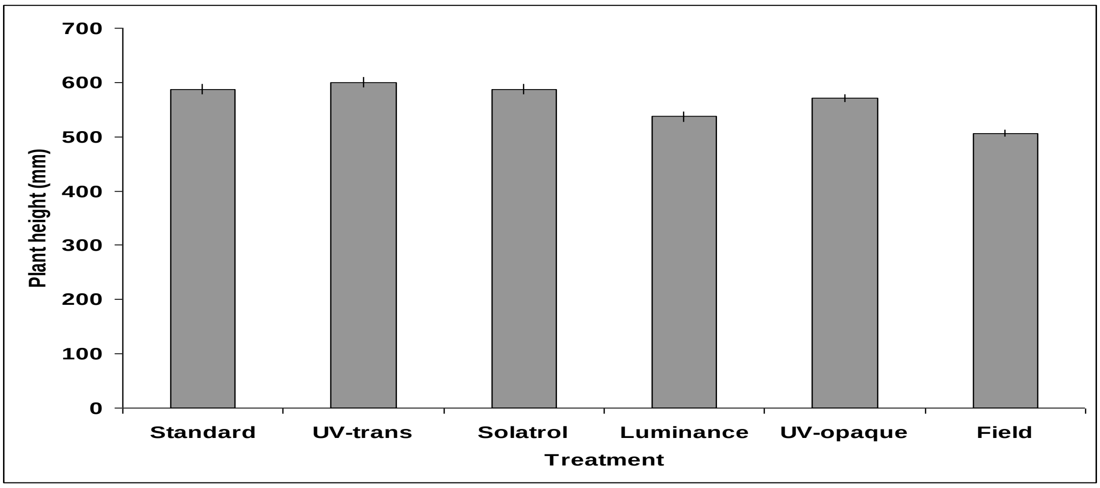
Time to flower was significantly reduced in Standard when compared to all remaining treatments, while Field increased time to flower relative to all filter treatments except Solatrol (fig. 15.a). UV-transparent significantly increased total plant height when compared to Luminance, UV-opaque and Field only (fig. 15.b). UV-transparent significantly increased shoot fresh weight compared to Luminance only (fig. 15.c). In Luminance shoot fresh weight was significantly reduced relative to all remaining treatments (fig. 15.c). Solatrol produced an increase in the length of the terminal inflorescence but this was only significant relative to UV-transparent and Field (fig. 16.a). Total number of inflorescences was increased in UV-opaque when compared to Solatrol and Luminance only (fig. 16.b). The total fresh weight at harvest of all inflorescences was increased in UV-opaque when compared to Luminance only (fig. 16.c). A reduction in inflorescence fresh weight was recorded in Luminance relative to all treatments but this was significant relative only to UV-opaque (fig. 16.c).

Figure 15. Effect of treatments on (a) time to flower (b) plant height and (c) shoot fresh weight in Weiner blut Lilies. Each value is the mean ± S.E. of 30 replicates.

a)



b)



c)

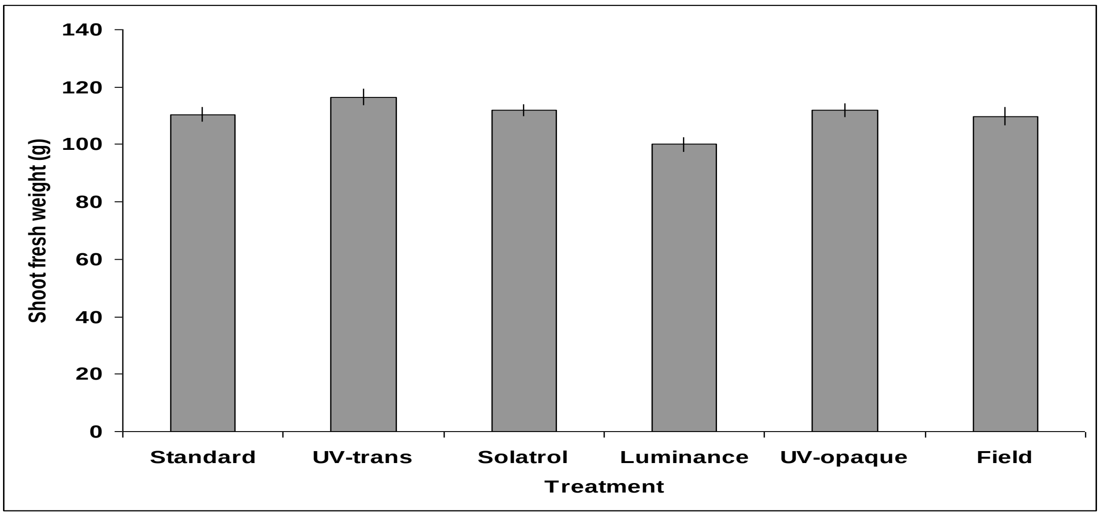
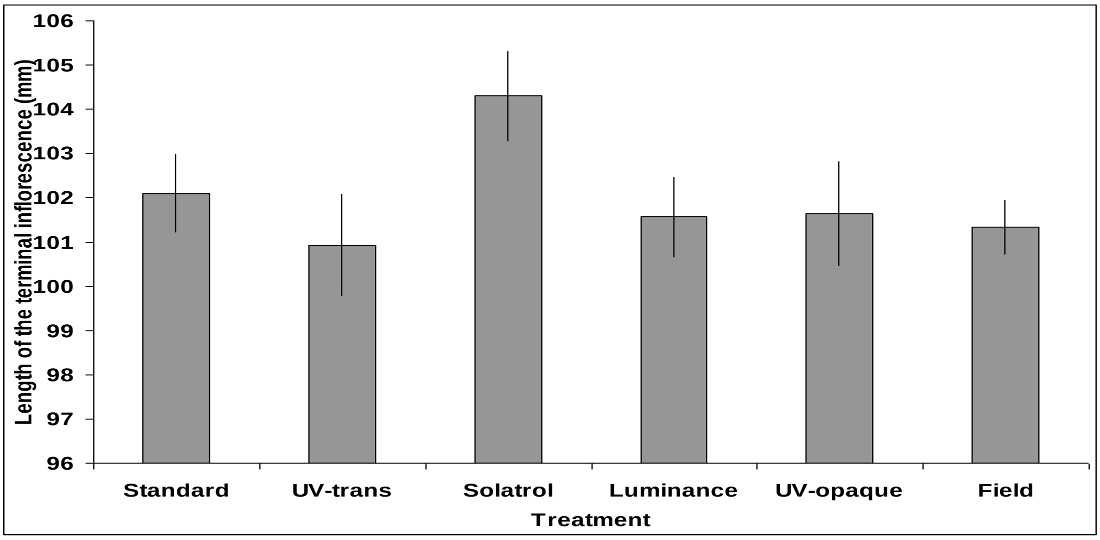
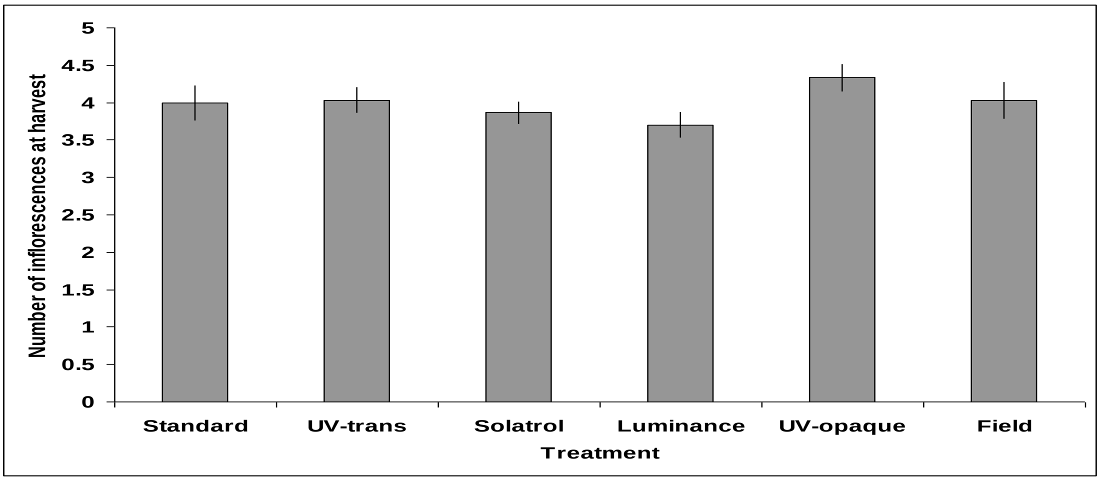


Figure 16. Effect of treatments on (a) length of the terminal inflorescence (b) total number of inflorescences and (c) total weight of inflorescences at harvest in Weiner blut Lilies. Each value is the mean ± S.E. of 30 replicates.

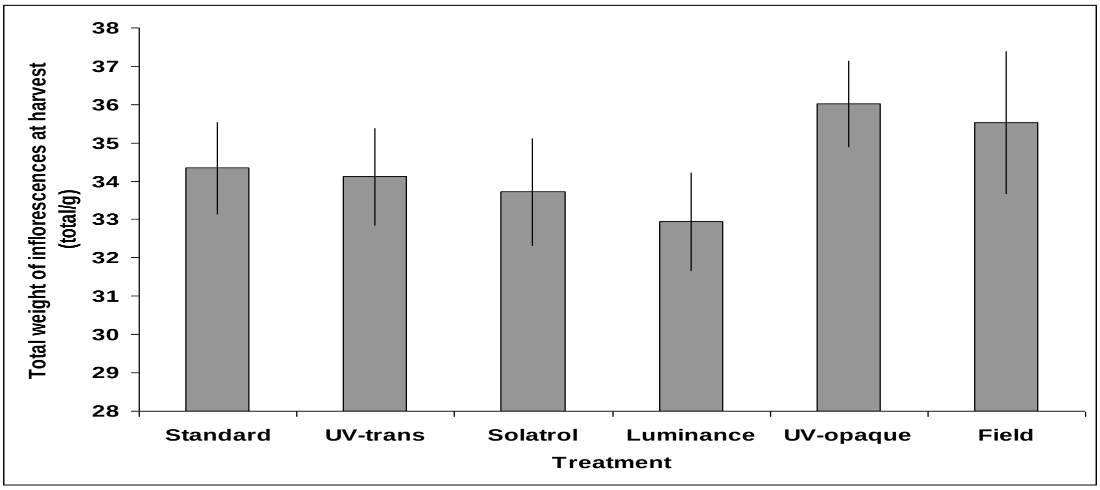
a)



b)



c)

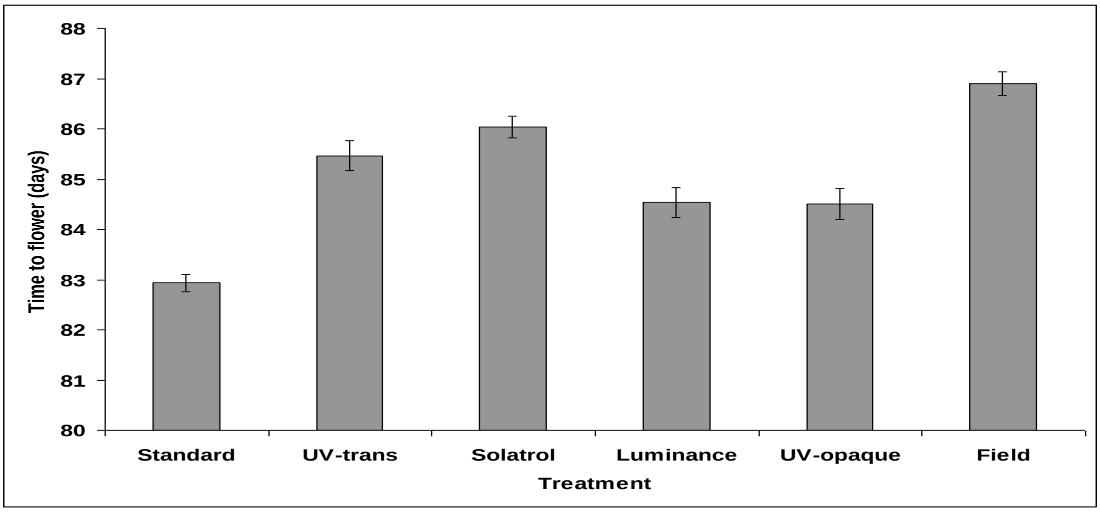


RESULTS – CARIFEO LILIES

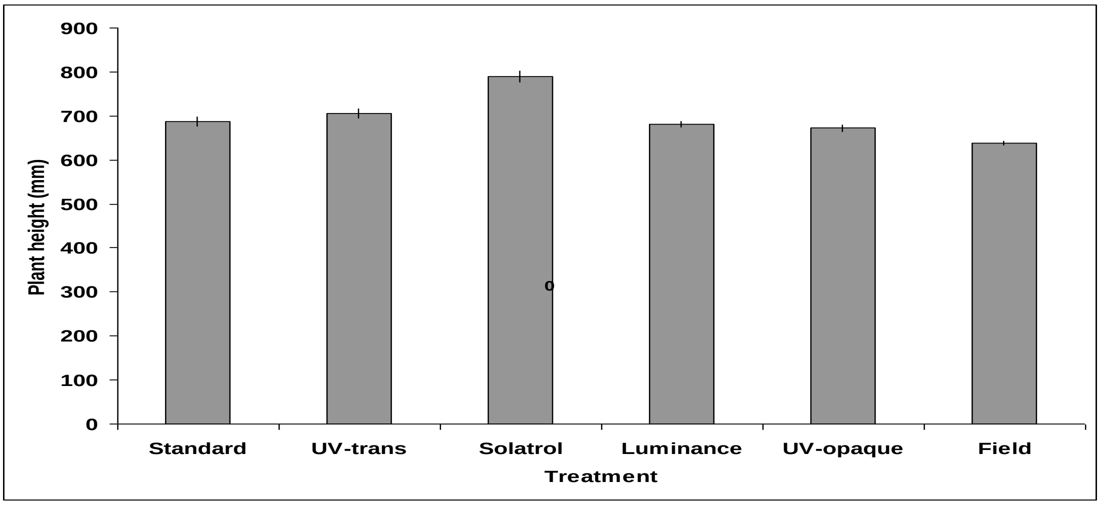
Time to flower was significantly reduced in Standard when compared to all treatments (fig.17.a). In contrast, Field, increased time to flower by ~3 days relative to all filter treatments and this represented a significant increase (fig. 17.a). Solatrol significantly increased total plant height when compared to all treatments except UV-opaque (fig. 17.b). Shoot fresh weight was significantly increased in Solatrol relative to all remaining treatments (fig. 17.c). There was no significant difference in shoot fresh weights between the remaining treatments (fig. 17.c). The only significant effect of treatments on terminal inflorescence length was an increase in UV-transparent relative to both Standard and Field (fig. 18.a). The total fresh weight of all inflorescences at time of harvest was increased in Luminance but this was not significant (fig. 18.b). There was no significant effect on total inflorescence fresh weight per plant at harvest in any of the treatments (fig. 18.c).

Figure 17. Effect of treatments on (a) time to flower (b) plant height and (c) shoot fresh weight in Carifeo Lilies. Each value is the mean ± S.E. of 20 replicates.

a)



b)



c)

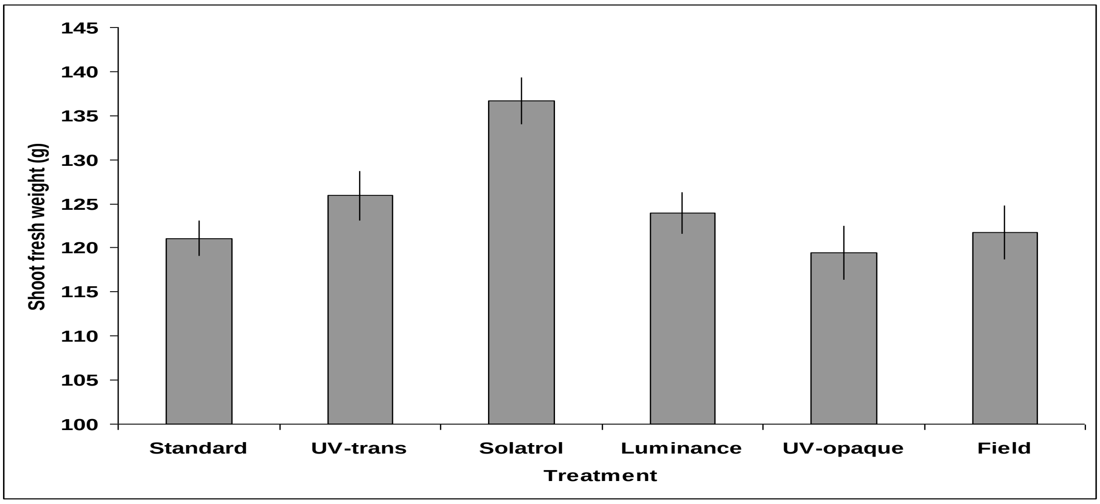
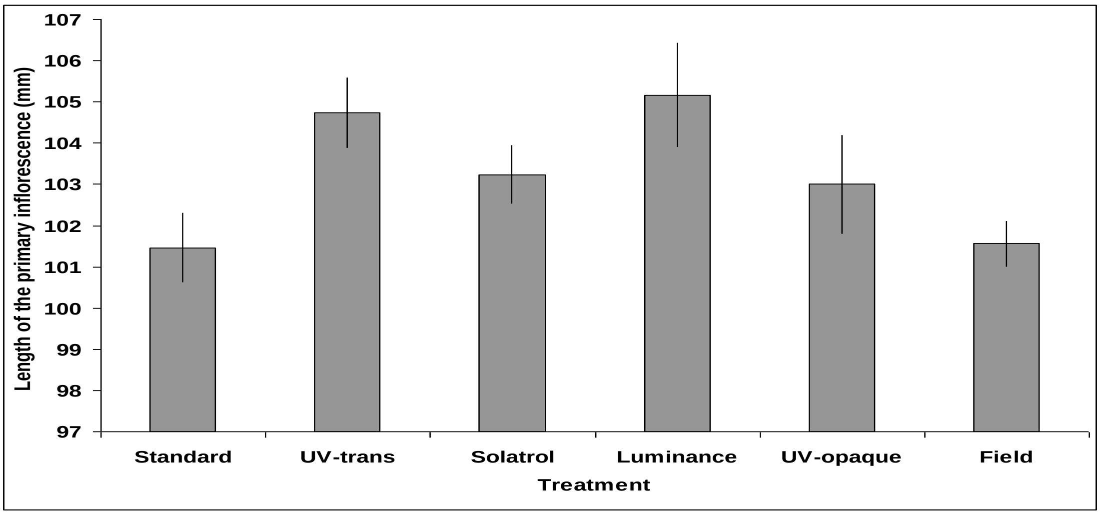
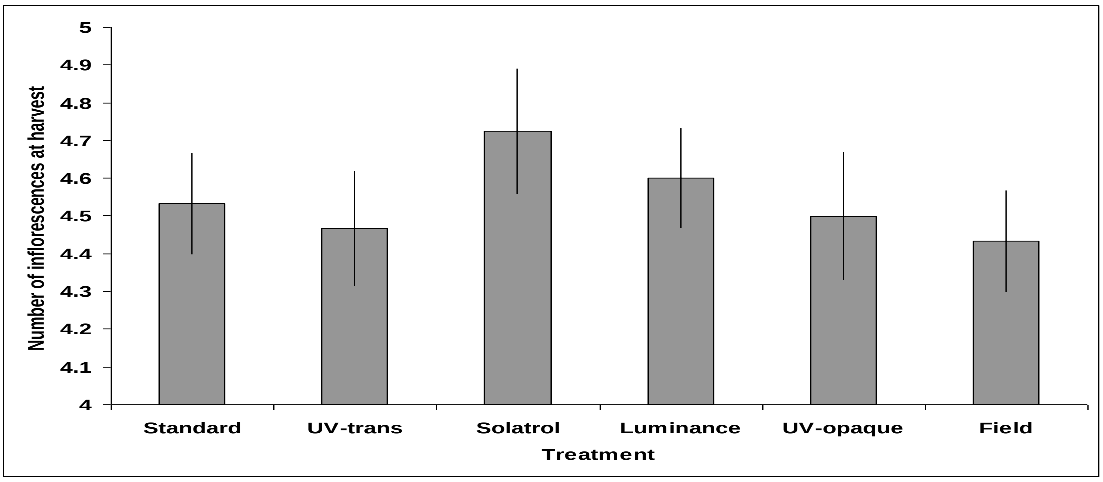


Figure 18. Effect of treatments on (a) length of the terminal inflorescence (b) total number of inflorescences and (c) total weight of inflorescences at harvest in Carifeo Lilies. Each value is the mean <u>+</u> S.E. of 30 replicates.

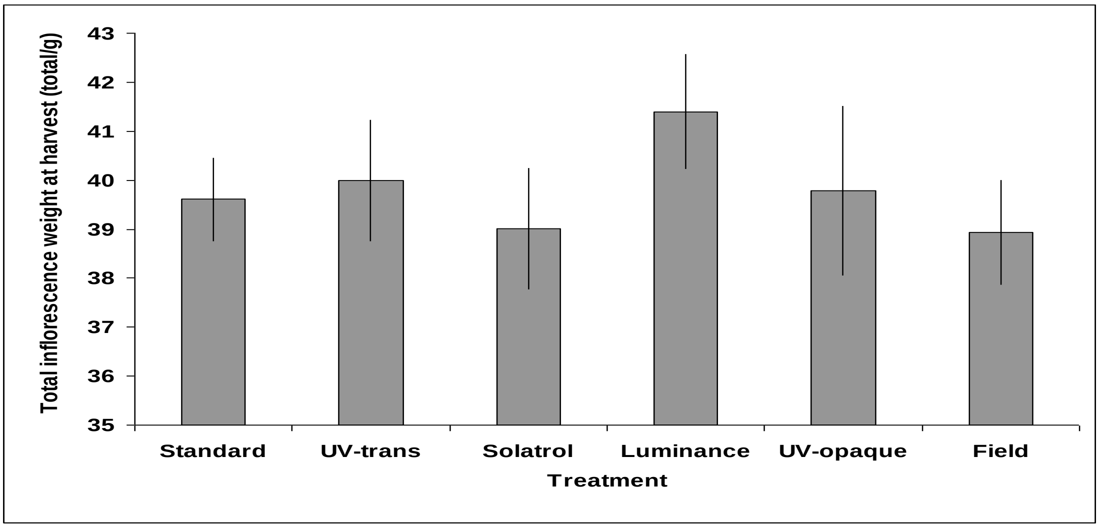
a)



b)



c)



RESULTS – DIANTHUS (LILY THE PINK)

The total number of stems produced per plant was significantly increased in Field when compared to all remaining treatments (fig. 19). Of the filter treatments UV-opaque produced a significant increase in stem numbers relative to UV-transparent, Solatrol and Luminance only (fig. 19). Stem fresh weight was increased in Field by 33% when compared to the remaining filter treatments (fig. 20). This represented a significant increase compared to all treatments (fig. 20). Of the filter treatments Solatrol produced a significant increase in stem fresh weight relative to Standard and UV-opaque only (fig. 20). Stem length was reduced in the Field crop by approximately 12% compared to the remaining filter treatments (fig. 21). This represented a significant reduction in stem length in the Field crop relative to all the remaining filter treatments (fig. 21). Of the filter treatments UV-opaque produced an increase in stem length and this represented a significant increase compared to UV-transparent only (fig. 21).

Figure 19. Effects of treatments on number of individual stems harvested per plant across 3 quadrants within each filter treatment and field plot. Each value is the mean ± S.E. of >48 replicates

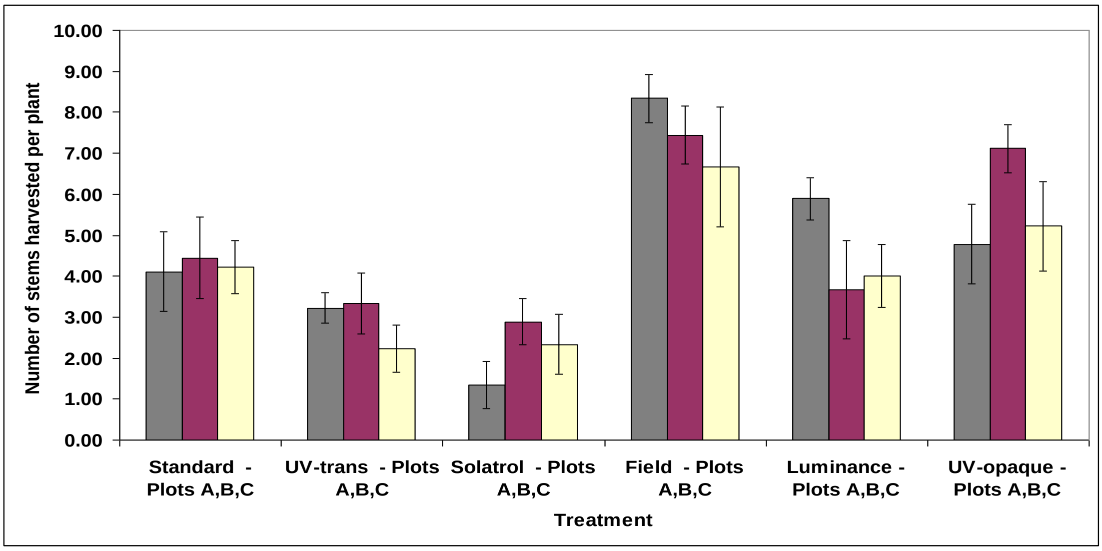


Figure 20. Effects of treatments on stem fresh weight. Each value is the mean ± S.E. of >48 replicates

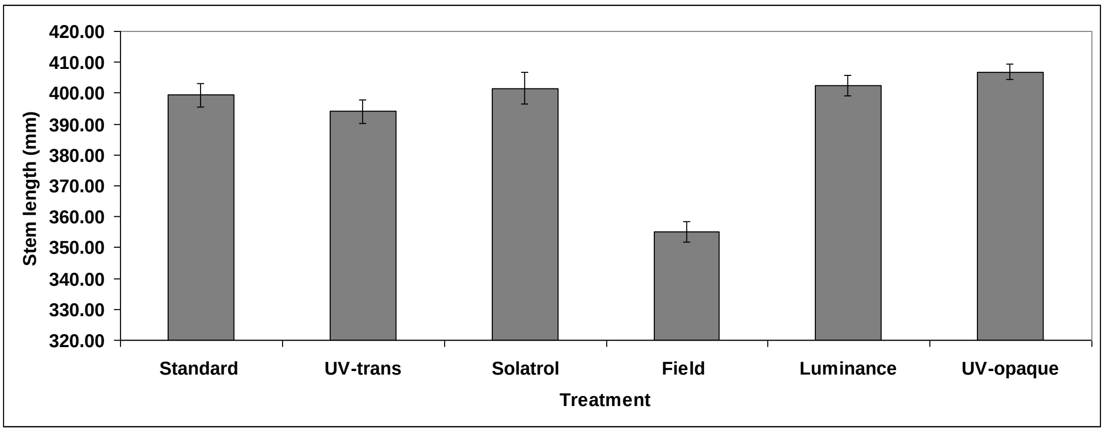
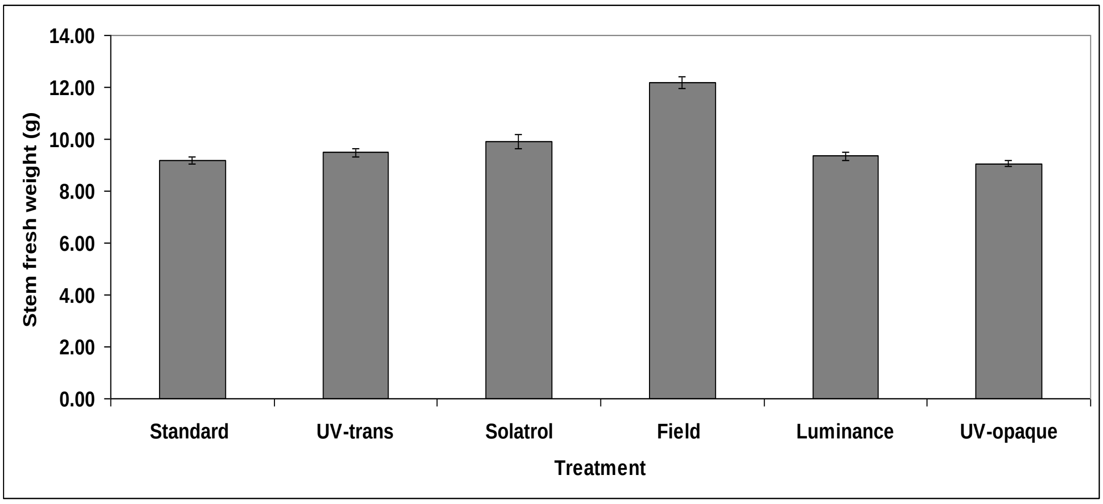


Figure 21. Effects of treatment on stem length. Each value is the mean ± S.E. of >48 replicates



RESULTS – DIANTHUS (DEVON PEARL)

The total number of stems produced per plant was significantly increased in Field when compared to Solatrol and Luminance only (fig. 22). There was no significant difference in stem numbers between filter treatments (fig. 22). Stem fresh weight was increased, on average, by 11% in Field when compared to the remaining filter treatments (fig. 23.a). This represented a significant increase compared to all treatments except Solatrol (fig. 23.a). Of the filter treatments Solatrol produced a significant increase in stem fresh weight relative to Standard, Luminance and UV-opaque only (fig. 23.a). Stem length was reduced in the Field crop by approximately 18% compared to the remaining filter treatments (fig. 23.b). This represented a significant reduction in stem length in the Field crop relative to all the remaining filter treatments (fig. 23.b). Of the filter treatments UV-transparent produced a significant increase in stem length when compared to UV-opaque only (fig. 23.b).

Figure 22. Number of individual stems harvested per plant across 3 quadrats within each filter treatment and field plot in Devon Pearl. Each value is the mean ± S.E. of >72 replicates.

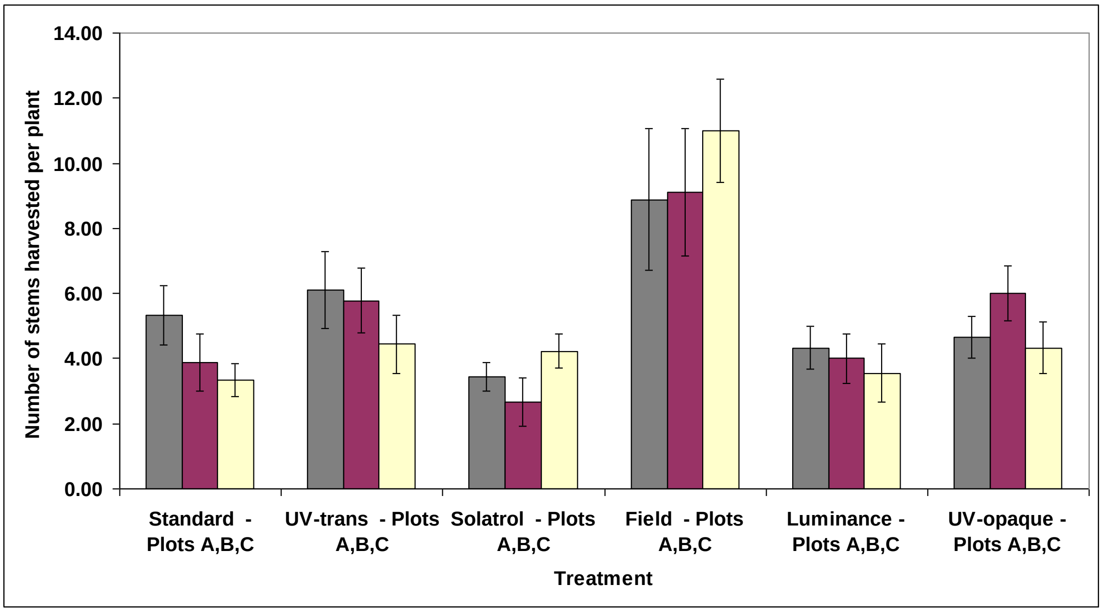
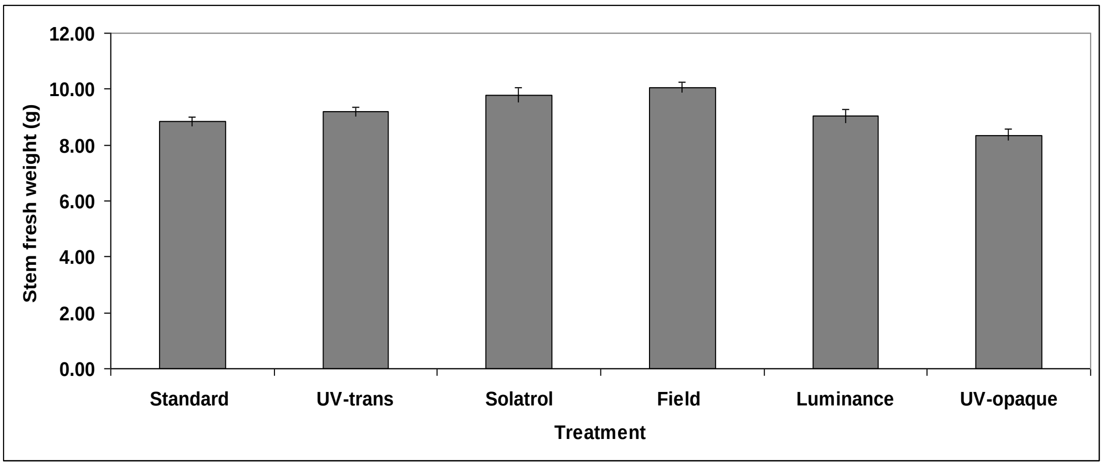
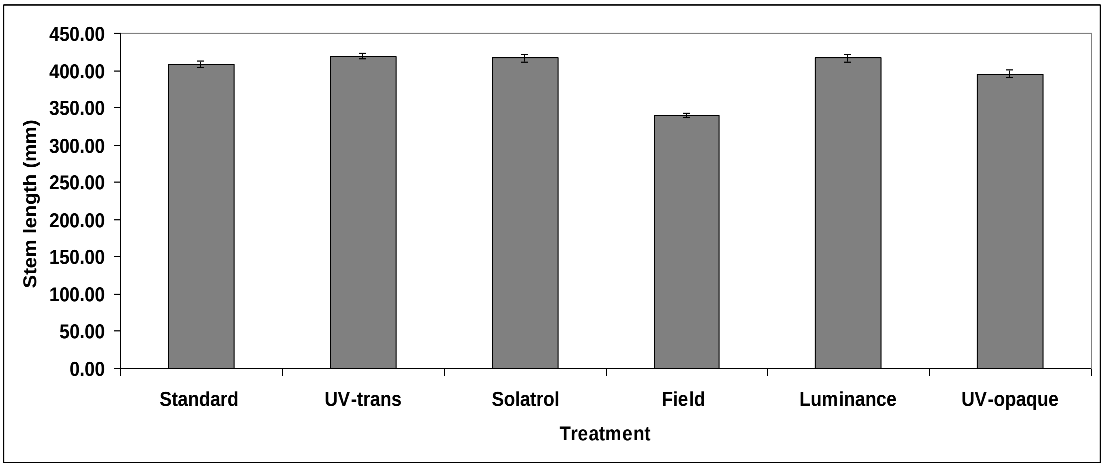


Figure 23. Effects of treatment on a) stem fresh weight and b) stem length. Each value is the mean ± S.E. of >72 replicates.

a)



b)



RESULTS FROM VASE LIFE TRIALS CARRIED OUT BY WINCHESTER GROWERS LTD

Table 1. Vase life tests carried out on 2 separate batches of Stocks (Francesca & Aida rose) by Winchester Growers Ltd.

VARIETY	TREATMENT	VASE LIFE (d) BATCH 1	BATCH 2	MEAN	COMMENTS
White Stocks	Standard	3	3	3	Yellow leaves / short flower life
	UV-transparent	6	8	7	Leaves became mouldy
	Solatrol	4	3	3.5	Short flower life
	Field	3	3	3	Yellow leaves / short flower life
	Luminance	3	8	5.5	Flowers became mouldy
	UV-opaque	3	4	3.5	Yellowing to leaves / short flower life
Red Stocks	Standard	7	7	7	-
	UV-transparent	3	3	3	Yellow leaves / short flower life
	Solatrol	7	6	6.5	Leaves became mouldy
	Field	3	4	3.5	Yellow leaves / short flower life
	Luminance	6	8	7	
	UV-opaque	8	8	8	

Table 2. Vase life tests carried out on 2 separate batches of Lilies (Courier & Wiener Blut) by Winchester Growers Ltd.

VAREITY	TREATMENT	VASE LIFE (DAYS TO 50% DEAD	COMMENTS LEAF QUALITY	FLOWER QAULITY
Courier	Standard	14	Yellowing	Good
	UV-transparent	17	Good	Good
	Solatrol	17	Good	Good
	Field	17	Good	Good
	Luminance	15	Good	Good
	UV-opaque	18	Good	Good
Wiener Blut	Standard	10	Yellowing	Good
	UV-transparent	10	Good	Good
	Solatrol	10	Good	Good
	Field	10	Good	Good
	Luminance	10	Good	Good
	UV-opaque	10	Good	Good

Table 3. Vase life tests carried out on Dianthus (Devon Pearl) by Winchester Growers Ltd.

VAREITY	TREATMENT	VASE LIFE (DAYS TO 50% DEAD	COMMENTS LEAF QUALITY	FLOWER QAULITY
Devon Pearl	Standard	14	Good	Good
	UV-transparent	14	Good	Good
	Solatrol	16	Good	Good
	Field	14	Good	Good
	Luminance	16	Good	Good
	UV-opaque	16	Good	Good

DISCUSSION

Cut flower producers are coming under increasing pressure from large retailers to both diversify their business and to reduce production costs. One possible way of achieving this is by substituting traditional glasshouse production with large-scale plastic protection. Further ‘added value’ could be achieved if the protective filters were shown to alter crop development in such a way as to increase both the quantity and quality of the marketable product. Results from both the first two seasons of this project suggest that the four cut flower varieties trialled here do respond to particular filter treatments in potentially economically beneficial ways.

Results from the 2005 early season batch of asters follow results from previous years work. The Solatrol filter increased time to flower in batch one by approximately 3 days when compared to the remaining treatments (fig. 1.a). In the second batch both Solatrol and Luminance delayed harvest by 1-2 days only (data not presented). In a market where growers supply retailers based on the weight of a fresh ‘bunch’, changes in crop fresh weight induced by the altered growing environment under the filters could be of economic importance. In early season asters the UV-opaque filter increased fresh weight by over 30% relative to the Field grown crop (fig. 1.c) although in the second, late season batch, there was no significant increase in fresh weight under UV-opaque (data not presented).

Modification in aster inflorescence pigmentation and structure have been observed in this seasons crop (fig. 24) and in the previous two seasons across all treatments (see figs. 24-26). Increased pigmentation was consistently observed in the Field and UV-transparent grown crops and visually reduced in UV-opaque (see figs. 24-26 below). Solatrol, over the last three seasons, has produced a smaller flower, which reveals a larger proportion of the underlying sepals (figs. 24-26). Again in the 2005 season we observed a clear effect of certain filters on aster canopy development. In the open plot (Field), canopy development was visually poor and this was a function of reduced total leaf area and development of ancillary stems. However, Solatrol and UV-opaque produced a visually 'deeper' canopy, which could translate into a more marketable product for retailers through customer perception of more attractive foliage and increased plant weight, which helps gives a 'feel' of value.

Figure 24. Inflorescence colouration and structure in Aster in 2005.

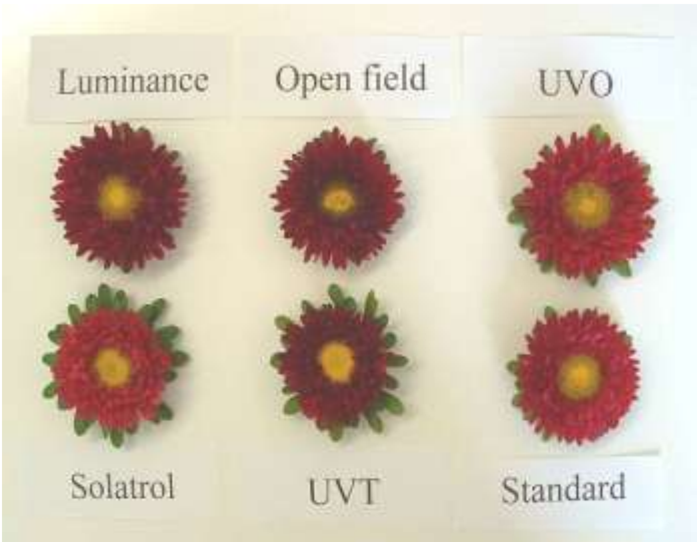


Figure 25. Inflorescence colouration and structure in Aster in 2004.

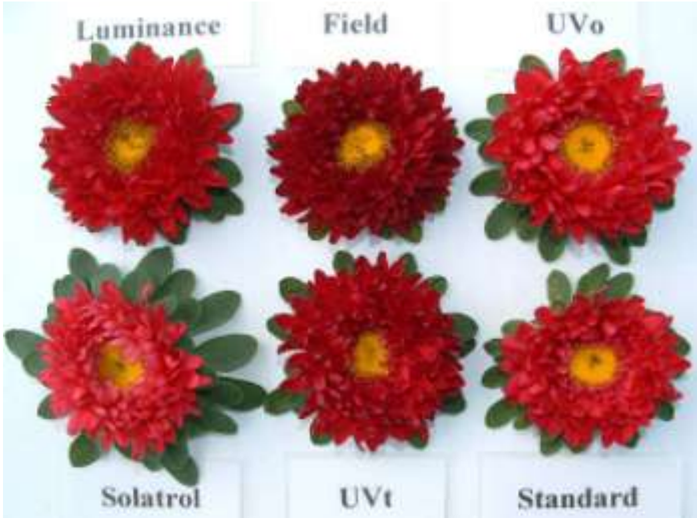


Figure 26. Inflorescence colouration and structure in Aster in 2003.

In the 2005 season we extended the number of varieties of stocks grown to three. We also included an extra 'late' season batch of red and white stocks to determine whether a commercial crop could be grown in the UK starting in mid-July. In the normal season batch the most economically important effect of the filters was the significant and consistent increase in fresh weight in the UV-opaque crop. Across all three varieties in the two normal season crop batches there was between a 5 and 45% increase in harvested fresh weights when compared to the Field crop (see figs. 3.c., 5.c., & 7.c). In the extended season white stocks shoot fresh weight was reduced in Field by approximately 29% when compared to all the remaining filter treatments, including UV-opaque, and between the filters there was no significant difference in fresh weights (fig. 9.c). In contrast to results in white stocks there was no significant effect of treatments on fresh weights in the extended season red stocks (fig. 11.c). Throughout the 2005 season UV-opaque consistently increased shoot fresh weights when compared to Field (fig. 27). This consistent increase in shoot fresh weights, in the normal season crop and in the extended season white stocks could, in conjunction with the protection filters provide from unexpected meteorological events such as those experienced in the summer of 2003, provide sufficient economic impetus for growers to switch production of stocks from field production to the temporary structures covered with a UV-opaque type filter utilised in this trial.

Table 4. Stem fresh weight in open Field and UVO Stock varieties throughout 2005 season.

	Early season crop			Mid season crop			Late season crop		
	Field(g)	UVO(g)	%change	Field(g)	UVO(g)	%change	Field(g)	UVO(g)	% change
Pink stocks	65	76	15%	60	83	17%			
White stocks	46	83	55%	49	69	19%	31	32	3%
Red stocks	66	90	27%	52	70	26%	30	42	29%

As well as changes in plant fresh weight the length and architecture of the terminal inflorescence was altered under the filter treatments. In normal season white and pink Stocks, UV-opaque produced increases in the length of the inflorescence (see figs. 28. & 29). In all three normal season varieties the Luminance filter produced a more marketable inflorescence according to our cut flower consultant; Mr Simon

Crawford. In both the extended season crops, at the stage when the filter treatment crops were harvested, both the Luminance and UV-opaque crop produced visually more marketable inflorescences when compared to the remaining filter treatments and the Field crop was, as expected, unmarketable (see figs. 31 & 32). Further benefit may come from the Luminance filter in terms of the manipulation of crop longevity and vase life. In both red and white stocks preliminary vase life trials carried out on our behalf by Winchester Growers suggest that the life of the crop can be extended under Luminance by 3 ½ and 1 ½ days respectively (table 1). Further work in 2006 will seek to clarify this. In conclusion, results from the past three seasons trials have consistently shown both the Luminance and UV-opaque filters can produce a more marketable stocks crop in terms of recorded changes in plant morphology, economically relevant increases in stem weight and visual marketability.

Figure 28. Inflorescence colouration and structure in white stocks in 2005.

Figure 29. Inflorescence colouration and structure in pink stocks in 2005.

Figure 30. Inflorescence colouration and structure in red stocks in 2005.

EXTENDED SEASON CROP

Figure 31. Inflorescence colouration and structure in extended season white stocks in 2005.

Figure 32. Inflorescence colouration and structure in extended season red stocks in 2005.

Results from lilies, over the past two seasons, have consistently highlighted the benefit of producing the crop under any filter when compared to the open field plot. Time to harvest was significantly increased, by up to 5 days, in the in three varieties of the Field grown crops in 2005 (figs. 13.a, 15.a. & 17.a). Furthermore both plant height and the length of the primary inflorescence were consistently reduced in the Field crop when compared to the majority of the filter treatments (see figs. 13.b, 14.a., 15., 16.a., 17.b. & 18.a). Of the filter treatments the Luminance and UV-opaque filters have potentially produced the most marketable crop due to the their trend in increasing total plant fresh weight (fig. 13.c., 15.c. & 17.c) which, again, provided ‘the feel’ of a more substantial product and the production of a ‘visually’ more appealing crop (see figs. 33-35). In addition to a visually more marketable crop, the UV-opaque filter slightly extended vase life in Courier by a day when compared to the field crop, although there was effect on vase life in Weiner blut (table 2).

Figure 33. Courier Lilies just prior to harvest under Standard filter.

Figure 34. Courier Lilies just prior to harvest under in Open Field plot.

Figure 35. Courier Lilies just prior to harvest under in Luminance filter.

Figure 36. Courier Lilies just prior to harvest under in UV-opaque filter.

This was the first year for dianthus and so the 2006 season will provide the first commercially relevant results. However, results from 2005 do indicate that growing both Lily the Pink and Devon Pearl under filters alter plant development and morphology when compared to a field grown crop. The number of stems produced per plant was significantly increased in the open Field, in both varieties, compared to the majority of the filter treatments (figs. 19 & 22). In both varieties stem fresh weight was also increased in the open Field crop (figs. 20 & 23.a) but stem length was significantly reduced (figs. 21 & 23.b). Also, preliminary results from vase life tests in Devon Pearl indicate that vase life is extended in both Luminance and UV-opaque crops by approximately two days but further work with the commercial crop in 2006 will clarify this position.

In conclusion, results from three seasons of trials incorporating five varieties of cut flowers for UK consumption have not only highlighted the obvious benefits of producing these products under low-cost temporary structures when compared to open field production, but have started to emphasise the divergent benefits of the five main groups of spectral filters openly available on the UK market. Apart from the three lily varieties used over the last two growing seasons, Solatrol, has reliably delayed flowering and plant growth regulation in all varieties. However, due to the high relative cost of Solatrol when compared to other commercially available filters it is unlikely that this film will be economically viable for UK cut flower producers for the purpose of PGR. The UV-transparent filter has consistently provided a limited level of growth regulation when compared to the majority of the more UV blocking filters and produced more intense foliar and flower pigmentation across a number of varieties. Both the UV-opaque and Luminance filters have produced consistent and potentially economically important increases in stem weight; this has been especially apparent in stocks, and to a lesser extent asters, under UV-opaque.

Given the relative low cost of this filter and the potential economic benefits of increasing bunch weights for supermarket consumption, coupled with the possibility of producing a late season crop as reported here, the UV-opaque filter may represent a viable alternative method to field or glasshouse production for stock and aster growers in UK production. Furthermore, both the Luminance and UV-opaque filters have consistently been picked out as producing the most marketable crop by our consultant Mr Simon Crawford and for this reason it is our intention to produce crops in the 2006 season for more consumer satisfaction and shelf life testing in collaboration with a number of project partners.

ACKNOWLEDGEMENTS

The authors wish to thank Tim Crossman and Simon Crawford for helpful discussions and helpful insights into cut flower production and into the condition of the cut flower market.

Part 4. LEAFY SALADS

INTRODCUTION

The market for salads is still growing and highly competitive. The multiple retailers see this market as particularly innovative and an opportunity to differentiate themselves from other retailers. The traditional market for whole head lettuce products is probably at best static. The demand for bagged salad products as customers move more towards ready to eat products (RTE) has been rising at a very high rate.

Bagged salad packs contain a mix of leaves of various species to provide different colours, textures and tastes. The first packs were based on lettuce prepared from whole heads and as a result they had multiple cut surfaces. These were at risk of rapid breakdown despite using modified atmosphere packaging. This reduced shelf life and could influence customer purchasing decisions.

Over the past 6 years salad crops have started to be grown specifically for the bagged salad market as more exciting and exotic products are developed including herbs and oriental salad leaves. These crops have been drilled at high density, harvested mechanically and then mixed with different species to produce the range of products now on the supermarket shelves.

It is extremely important that salad leaves remain intact and in good condition during post harvest processing and this factor has limited the choice of species that might be suitable for use. Soft foliage would not cope with the washing and mixing process and might deteriorate more rapidly during shelf life. The use of protected structures could provide a more uniform growing environment and reduce the risk of hail or wind damage to the tender leaves. Their beneficial effects might be further enhanced if the materials selected for covering these structures altered the physical parameters of the leaves for example by decreasing cell size, increasing cell or leaf thickness, reducing stem length or reducing nitrate levels at harvest. In this first years trial of leafy salads for bagged salad consumption we have focused upon the effects of the filters on basic morphological changes. These experiments were carried out on three separate crops throughout a typical UK season and an extended season crop meant to bridge the gap between the end of UK production and the start of southern European production.

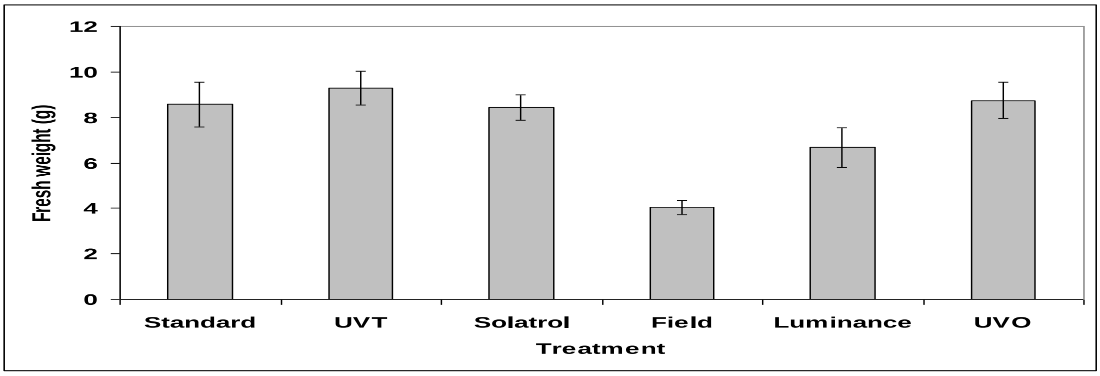
RESULTS

ROCKET FOR BAG SALADS – MEASUREMENTS TAKEN AT THE COMMERCIAL MARKETABLE STAGE

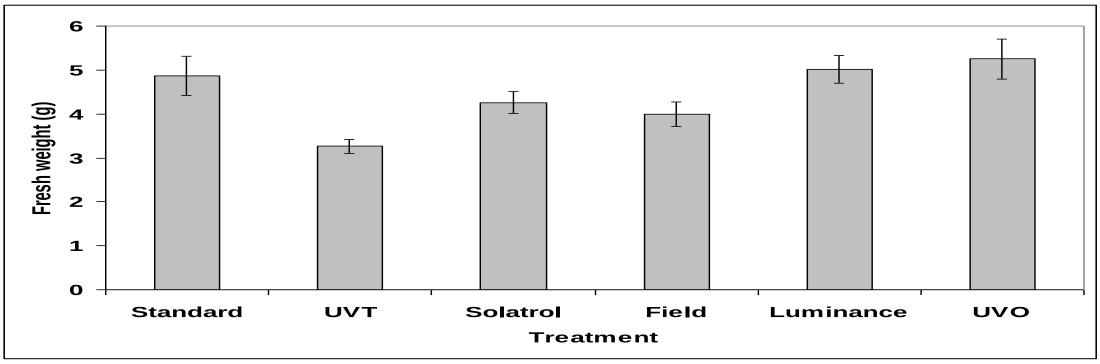
Across the season, in all 4 batches, there was a significant reduction in plant fresh weight in Field crops when compared to the majority of the filter treatments (fig. 1.a. - 1.d). In batch 1, fresh weight was significantly reduced in Field when compared to all filter treatments (fig. 1.a). In batch 2, the reduction was only significant when compared to Luminance and UV-opaque and fresh weight was actually significantly increased in Field relative to UV-transparent (fig.1.b). In batches 3 and 4 fresh weight was again significantly reduced in Field when compared to a number of filter treatments; most predominantly the Standard and UV-transparent (figs. 1.c.-1.d). In all but batch 2 the UV-transparent filter produced a crop with consistently increased fresh weights (figs. 1.a.-1.d). There was no consistent effect of treatments on plant dry weight across the 4 crop batches (figs. 2.a - 2.d). However, Solatrol and Field did have a tendency to produce reduced dry weights throughout the season (figs. 2.a - 2.d). Total leaf area at harvest was significantly increased in Standard and UV-transparent in batches 1 and 3 when compared to the remaining 4 treatments (fig. 3.a. & 3.c). The Field crop produced significant reductions in total leaf area when compared to Standard in batches 1 through to 3 (fig. 3.a. - 3.c). In batch 4 UV-transparent significantly increased total leaf area when compared to all remaining treatments except UV-opaque (fig. 3.d). Plant height was significantly increased in Standard when compared to Solatrol and Field in all four batches (fig. 4.a. - 4.d). Field consistently reduced plant height in all 4 season batches when compared the majority of the remaining treatments, but this was only a significant reduction relative to Standard and UV-opaque (fig. 4.a. - 4.d). There was no consistent effect of treatments on leaf thickness across the 4 crop batches (fig. 5.a. – 5.d). In batches 1 and 2 only leaf thickness was significantly increased in Field when compared to all remaining treatments except UV-transparent (fig. 5.a. – 5.b). In batches 3 and 4 leaf thickness was reduced in Field relative to Standard in batch 3 and UV-transparent and Solatrol in batch 4 (fig. 5.c. – 5.d).

Figure 1. Effect of treatments on shoot fresh weight in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Rocket for bagged salads.

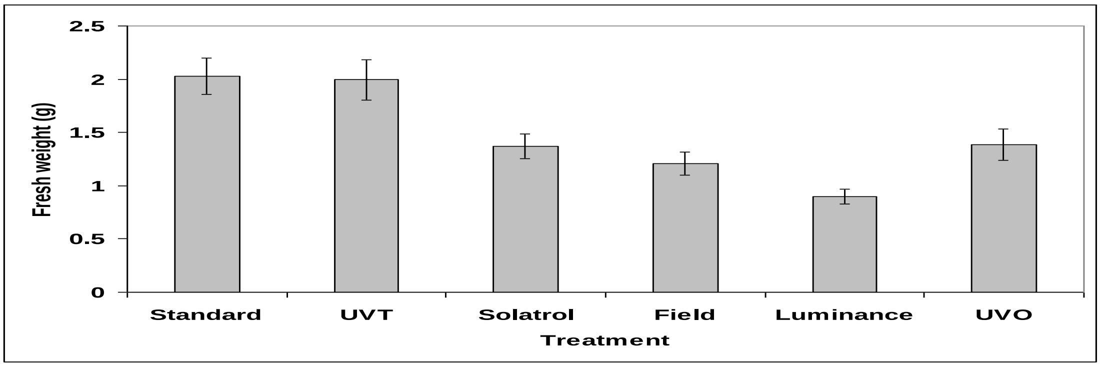
a)



b)



c)



d)

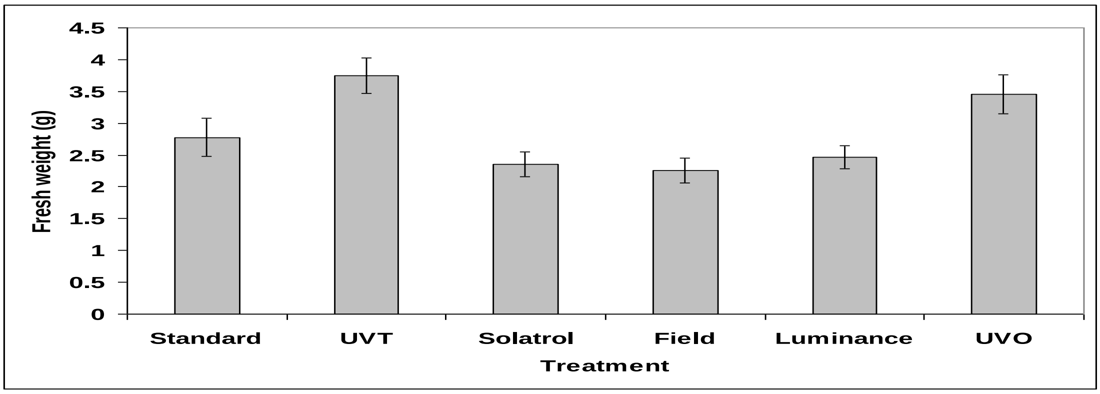
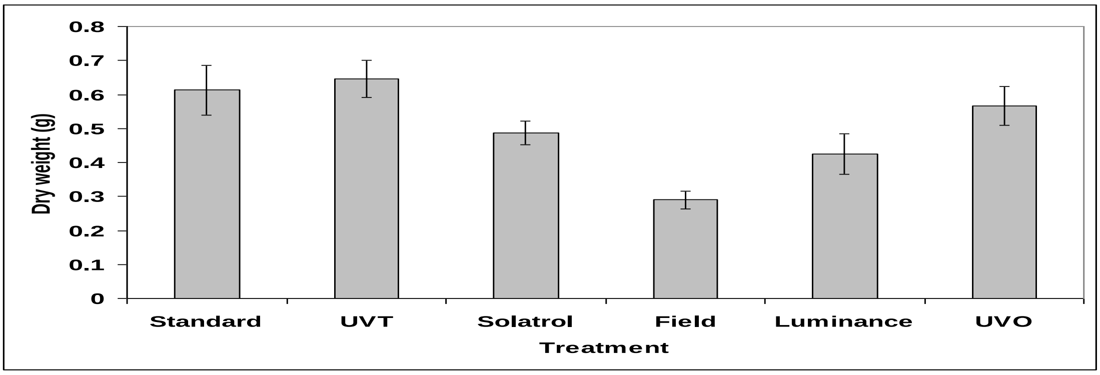


Figure 2. Effect of treatments on dry weight in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Rocket for bagged salads.

a)



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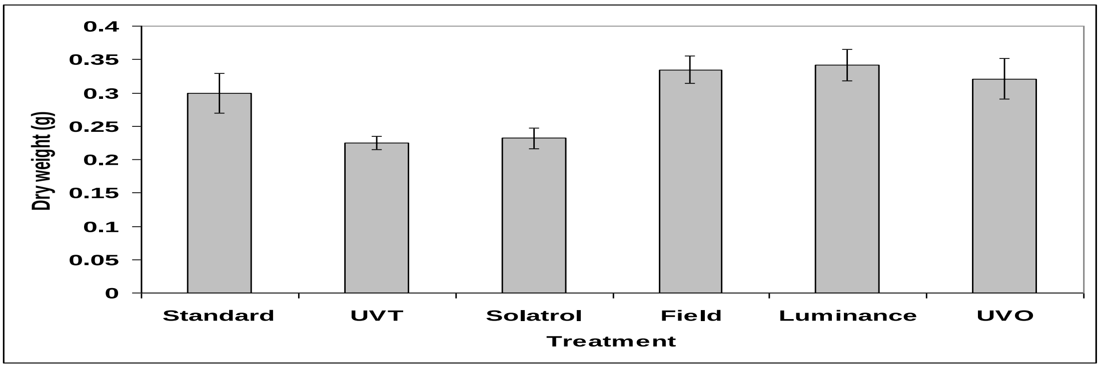

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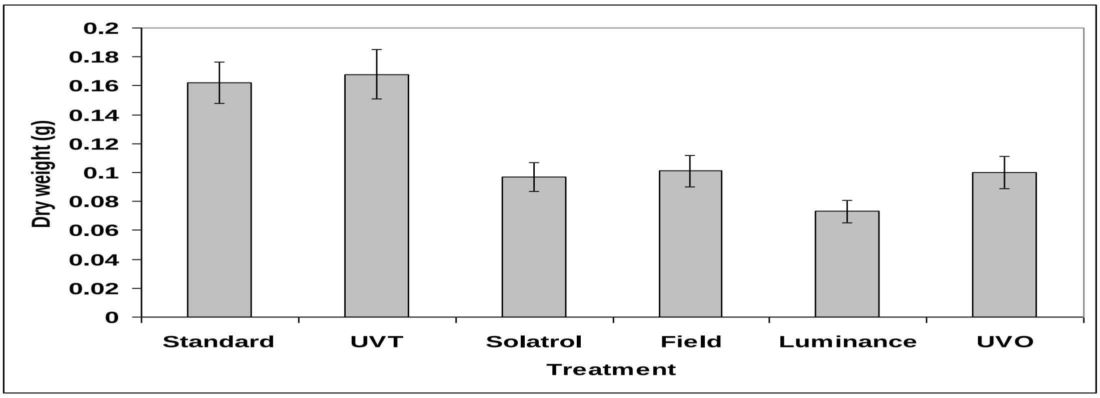

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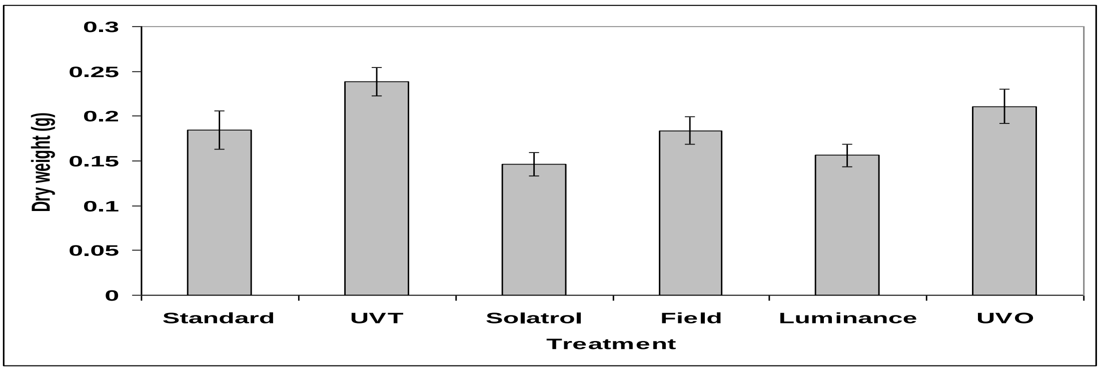
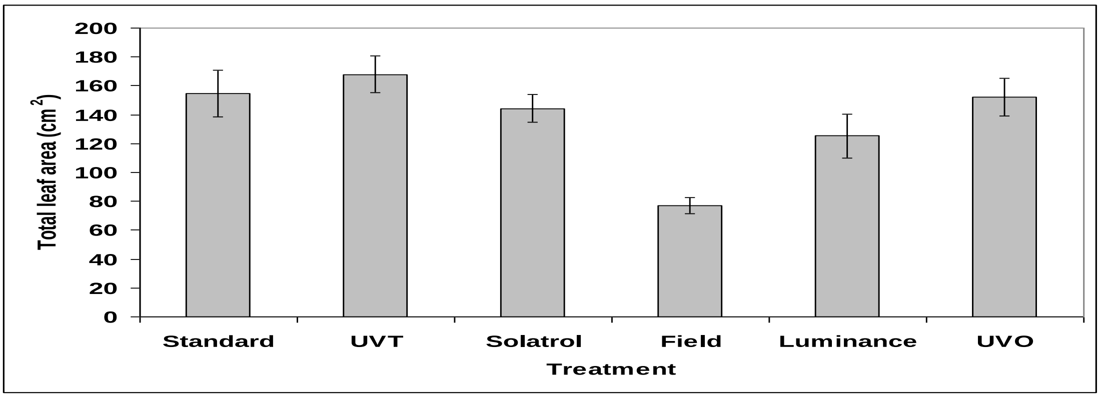
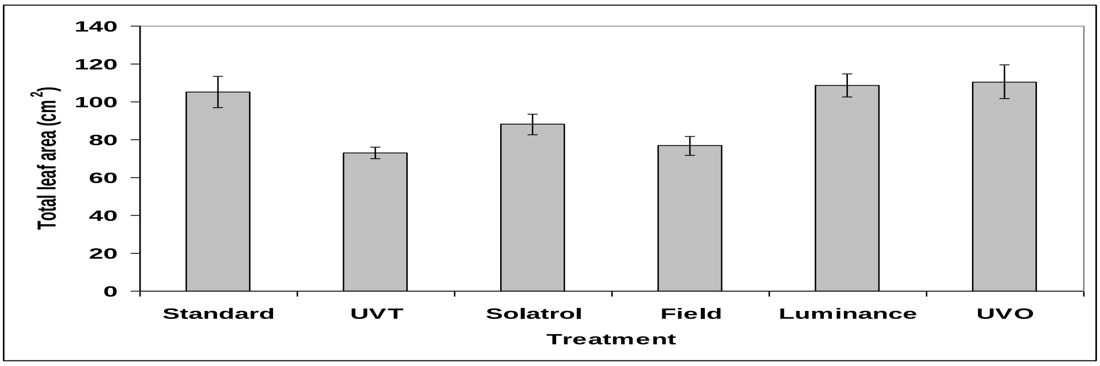


Figure 3. Effect of treatments on total leaf area in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Rocket for bagged salads.

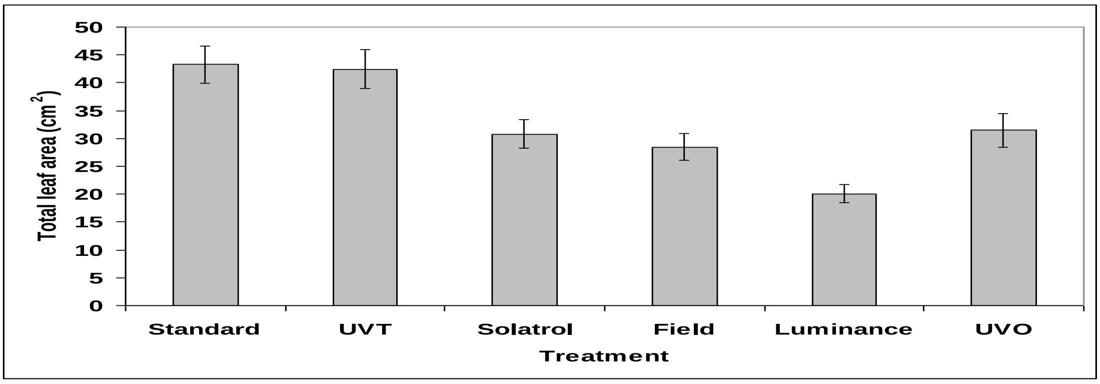
a)



b)



c)



d)

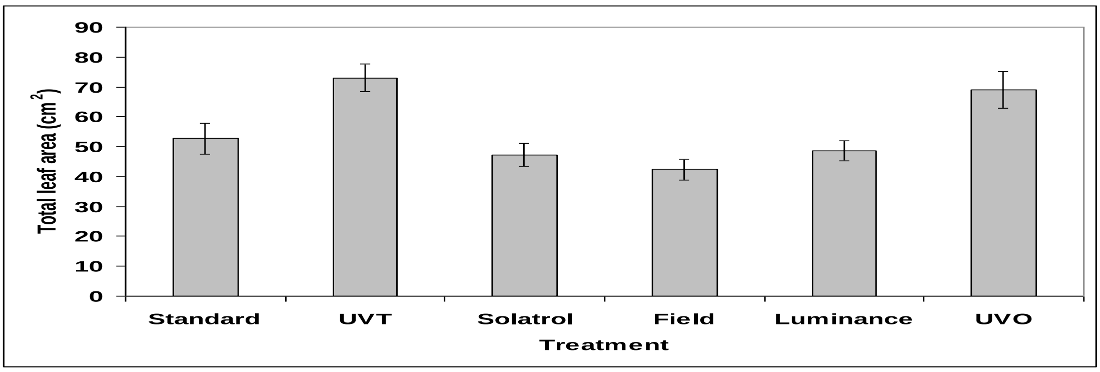
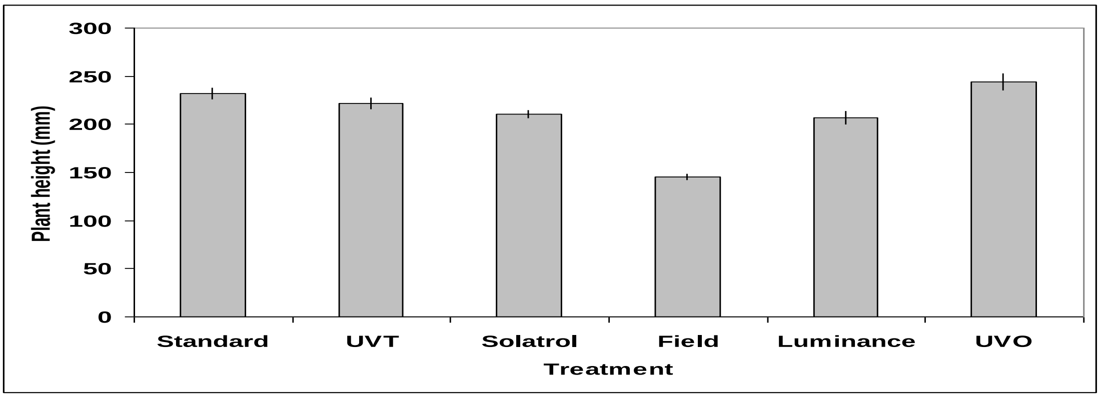


Figure 4. Effect of treatments on plant height in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Rocket for bagged salads.

a)



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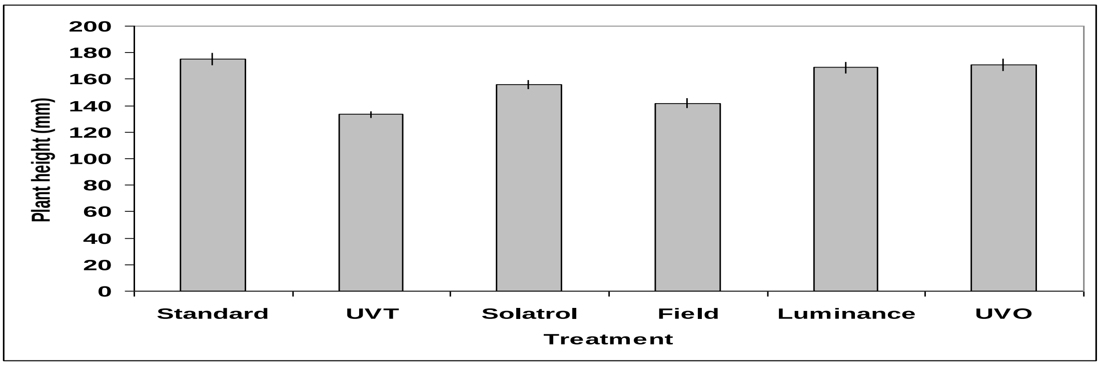

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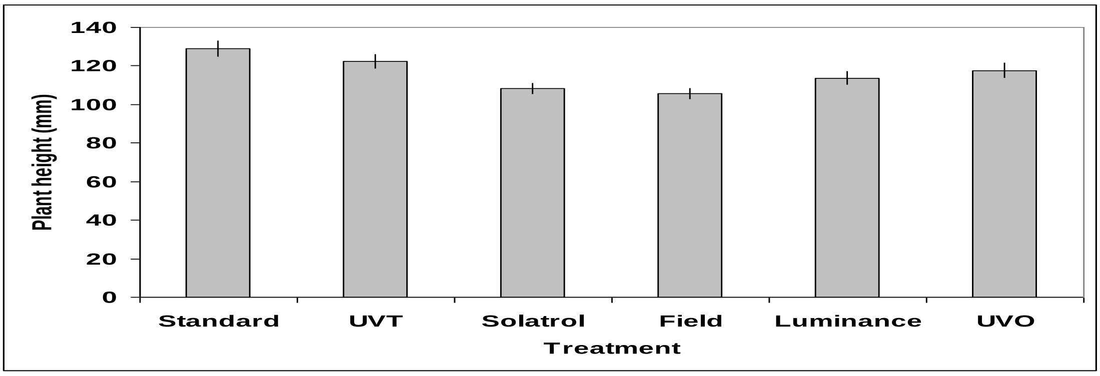


d)

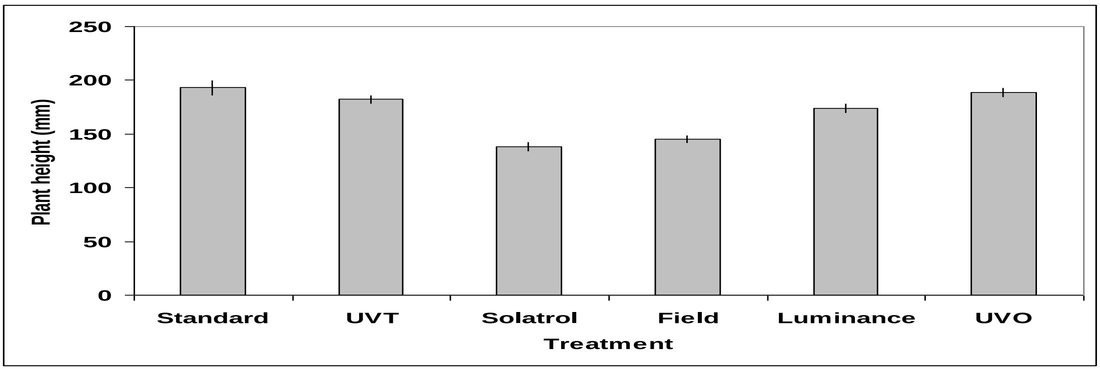
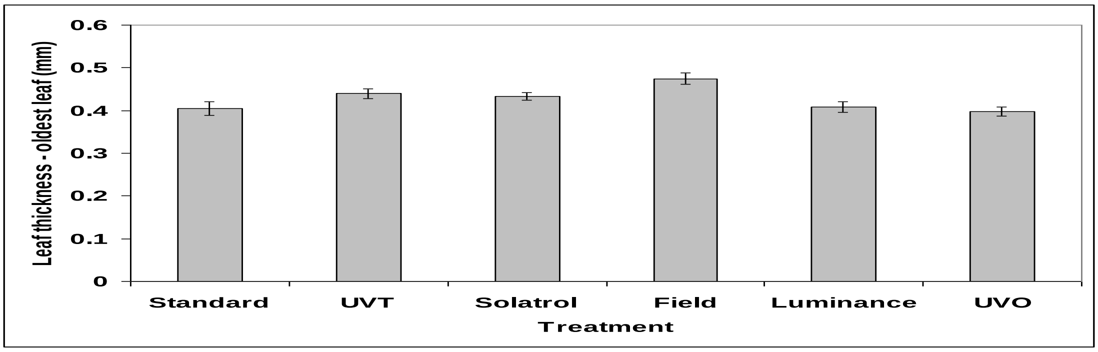
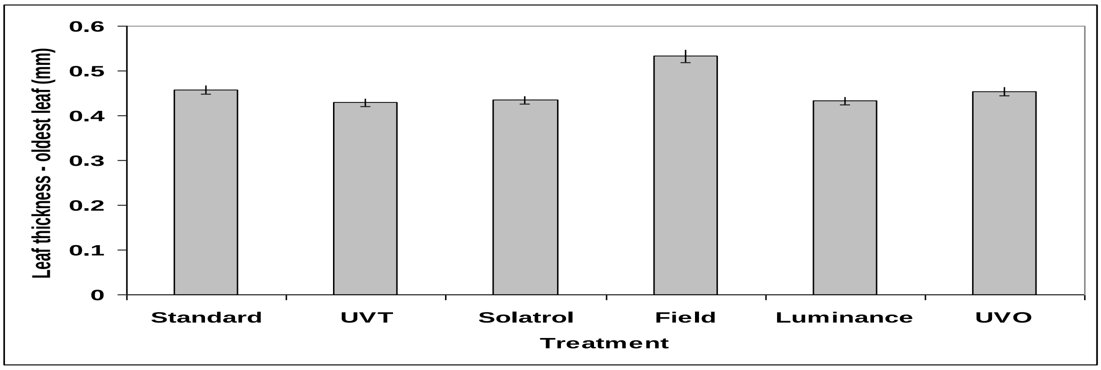


Figure 5. Effect of treatments on plant height in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Rocket for bagged salads.

a)



b)



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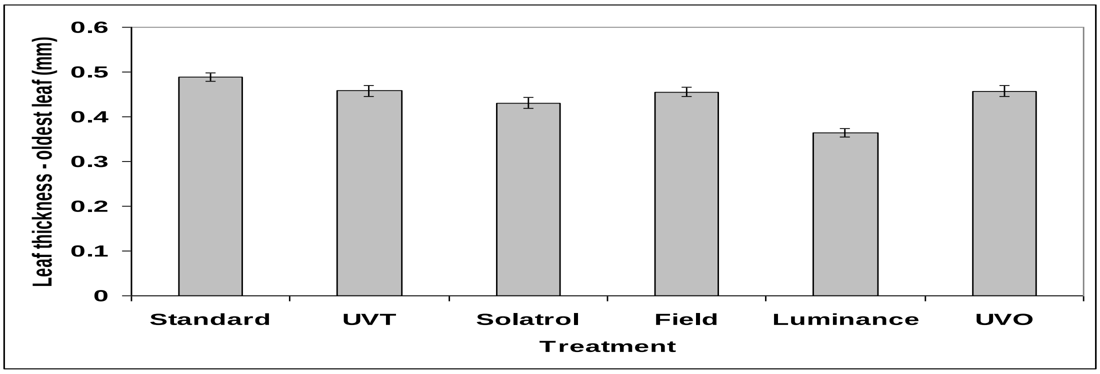
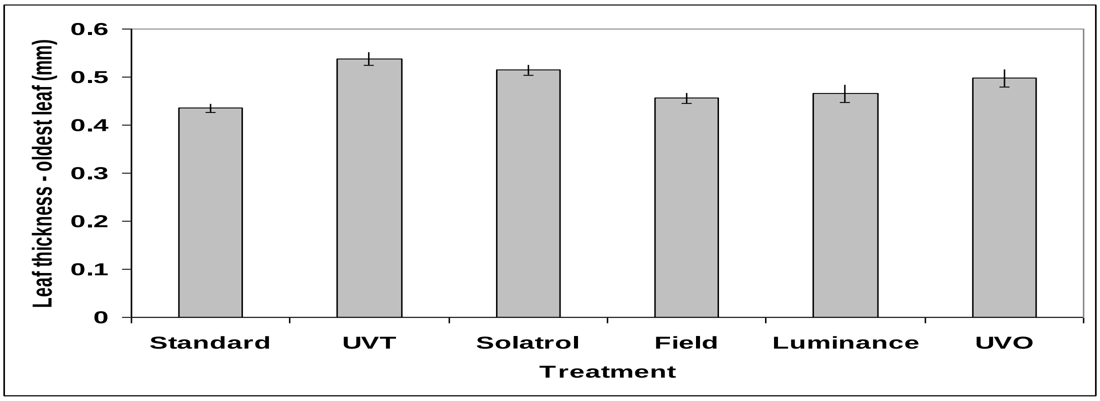


d)

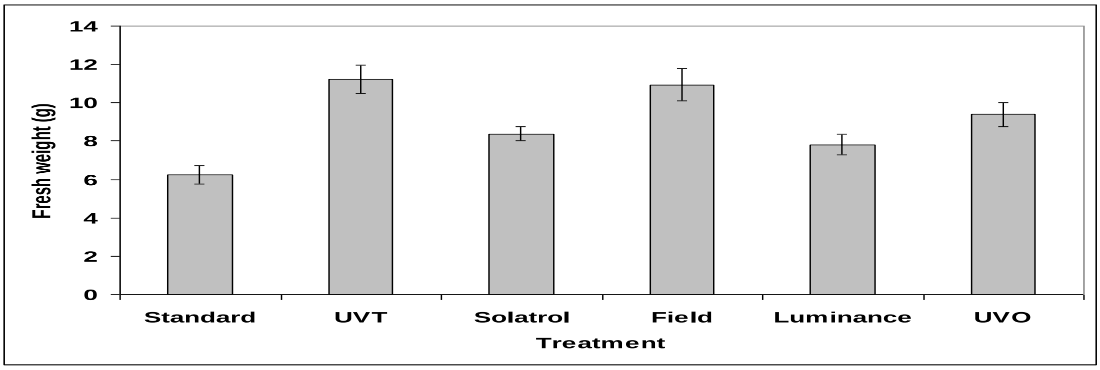


SPINACH FOR BAG SALADS – MEASUREMENTS TAKEN AT THE COMMERCIAL MARKETABLE STAGE

There was no consistent pattern in plant fresh weights across all 4 season batches (fig. 6.a. – 6.d). In batches 2 and 4 Standard significantly increased fresh weights when compared to UV-transparent, Field and Luminance treatments (fig. 6.b & 6.d). However, in batch 1 Standard produced significant reductions in fresh weight relative to all remaining treatments including the open Field (fig. 6.a). In batch 3 there was no significant difference in fresh weights between Standard and the remaining treatments (fig. 6.c). Plant dry weights were increased in Standard in batches 2, 3 and 4 when compared to the majority of the remaining treatments, but Standard significantly reduced dry weights in batch 1 when compared to all remaining treatments (figs. 7.b. – 7.d). There was no consistent effect of treatments on leaf area at the time of harvest (figs. 8.a. – 8.d). In batches 1 and 3 Field produced significant increases in leaf area when compared to Solatrol and Luminance (figs. 8.a. & 8.c). In batches 2 and 4 leaf area was reduced Field when compared to all remaining treatments but this was only significant relative to Standard, Solatrol and Luminance in batch 2 and Standard and UV-opaque in batch 4 (figs. 8.b. & 8.d). Plant height was reduced in Field in batches 1, 2 and 4 (figs. 9.a., 9.b. & 9.d). In batch 1 this was a significant reduction compared to UV-transparent, Luminance and UV-opaque (fig. 9.a). In batches 2 and 4 this reduction in Field crop height was significant when compared to all remaining treatments (figs. 9.b. & 9.d). Leaf thickness was significantly increased in Field when compared to all remaining treatments in batches 1, 2 and 4 (figs. 10.a, 10.b, & 10.d). In batch 3 Field significantly increased leaf thickness when compared to UV-transparent, Solatrol and Luminance only (fig. 10.c).

Figure 6. Effect of treatments on shoot fresh weight in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Spinach for bagged salads.

a)



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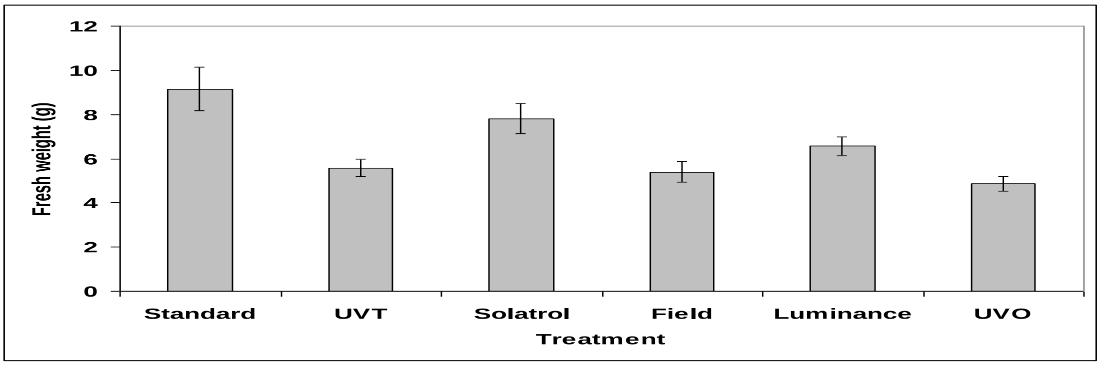

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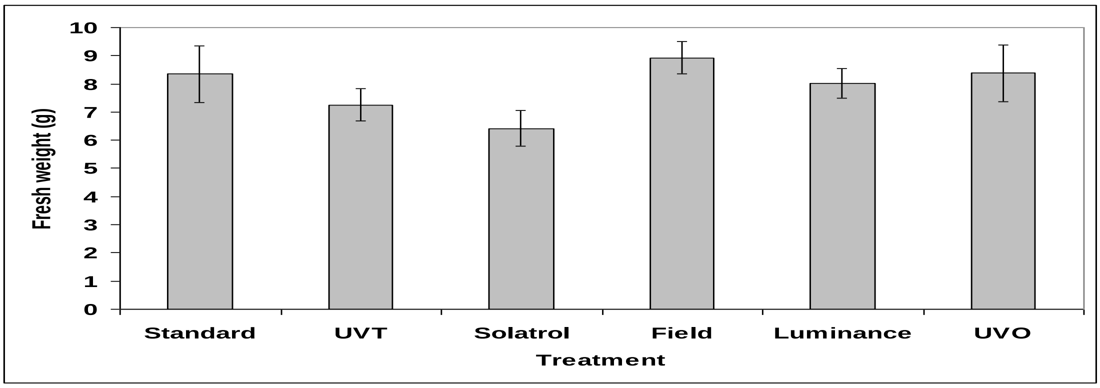


d)

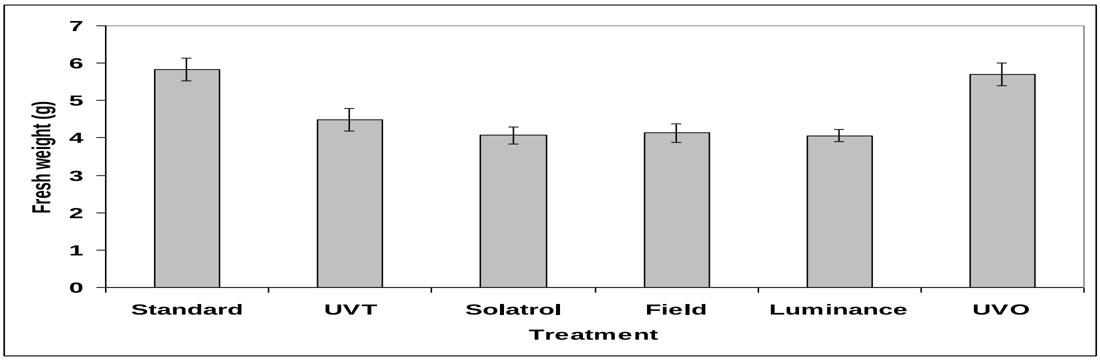
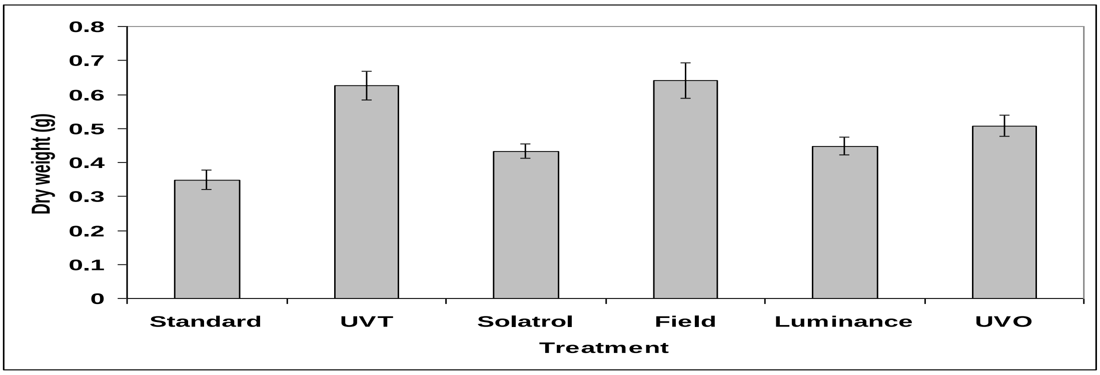
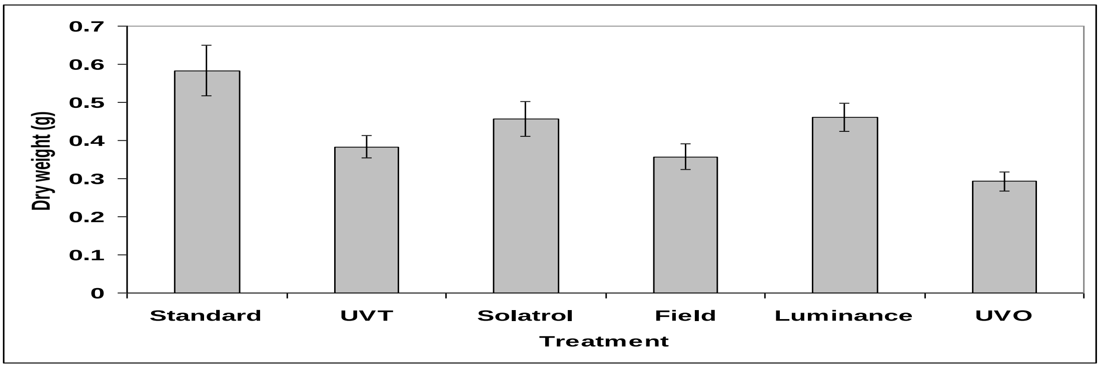


Figure 7. Effect of treatments on shoot dry weight in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Spinach for bagged salads.

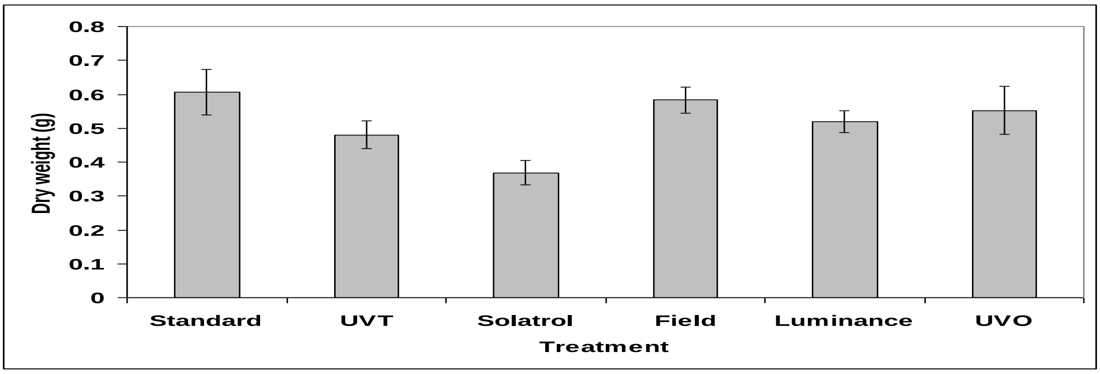
a)



b)



c)



d)

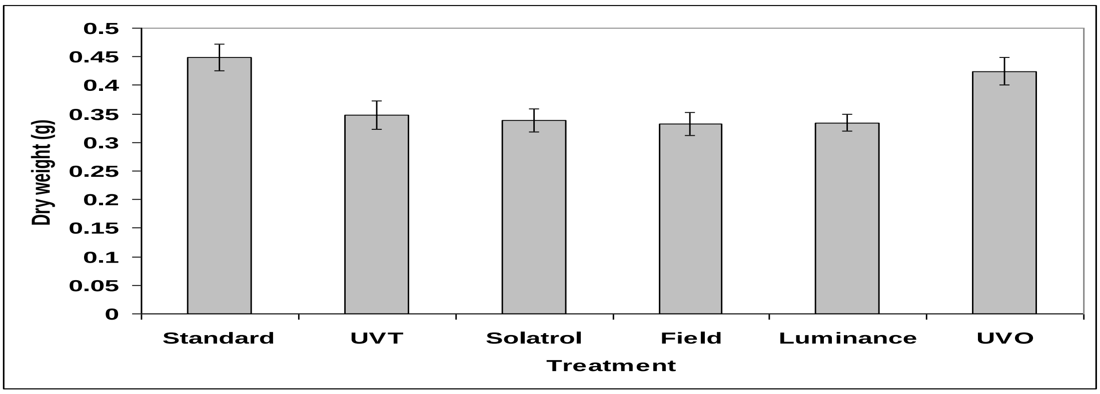
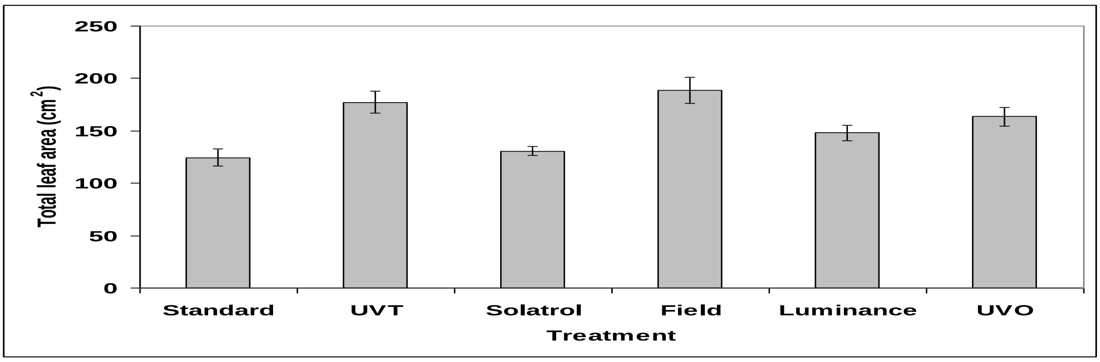
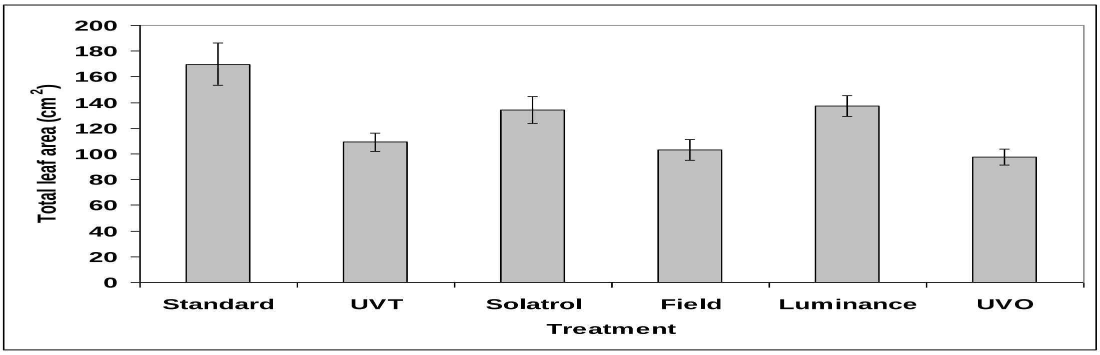


Figure 8. Effect of treatments on total leaf area in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Spinach for bagged salads.

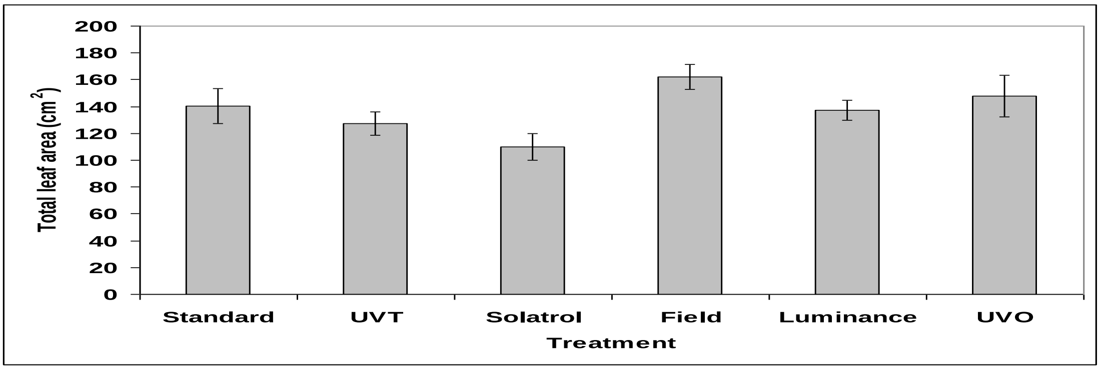
a)



b)



c)



d)

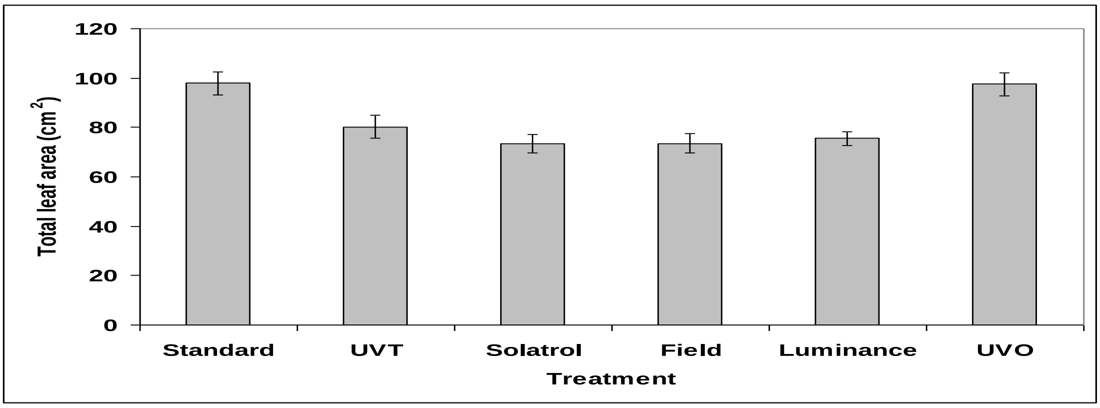
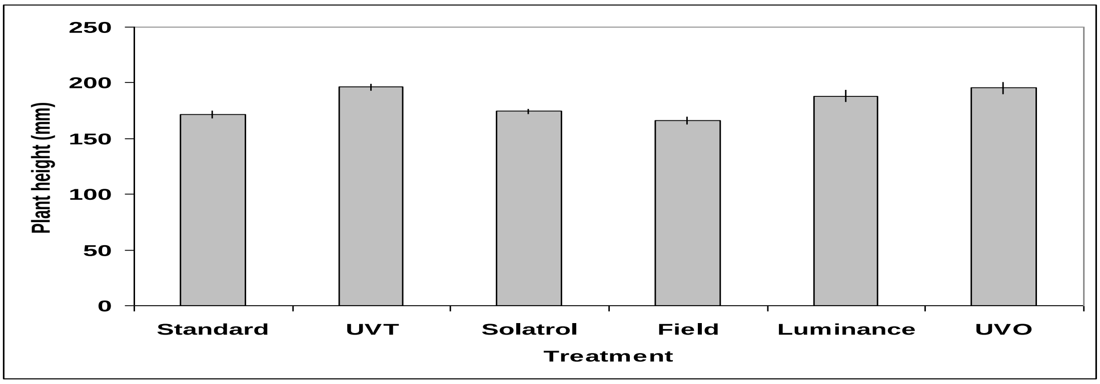
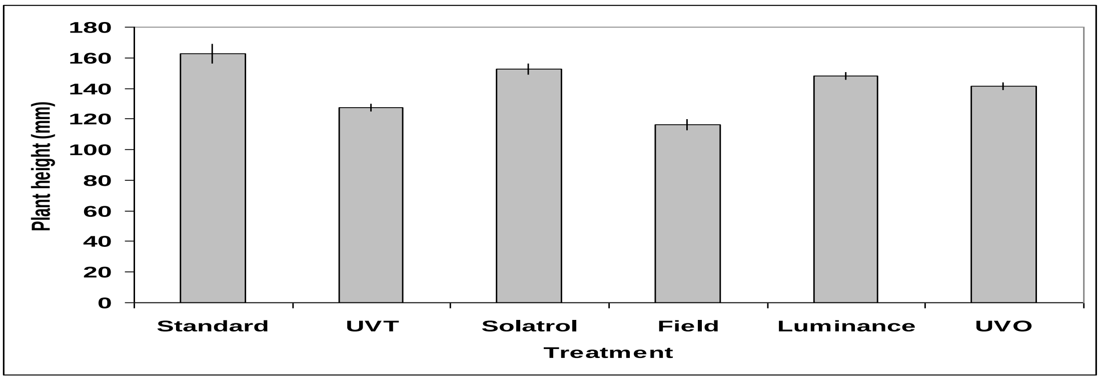


Figure 9. Effect of treatments on plant height in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Spinach for bagged salads.

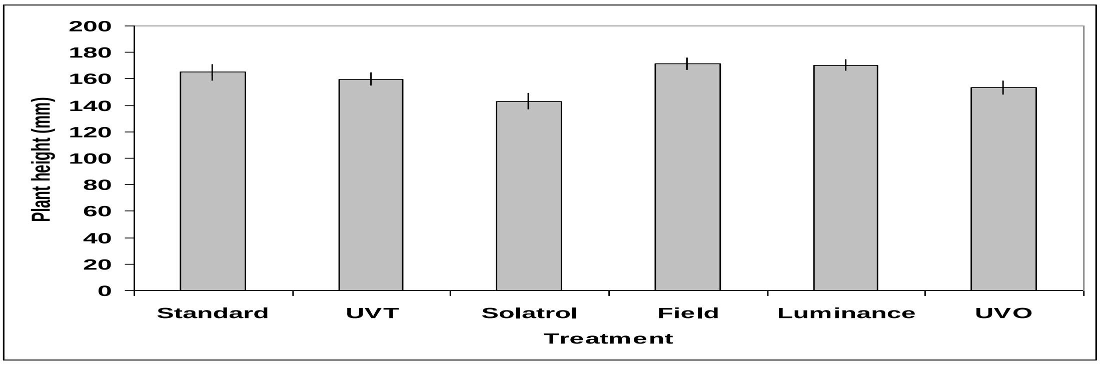
a)



b)



c)



d)

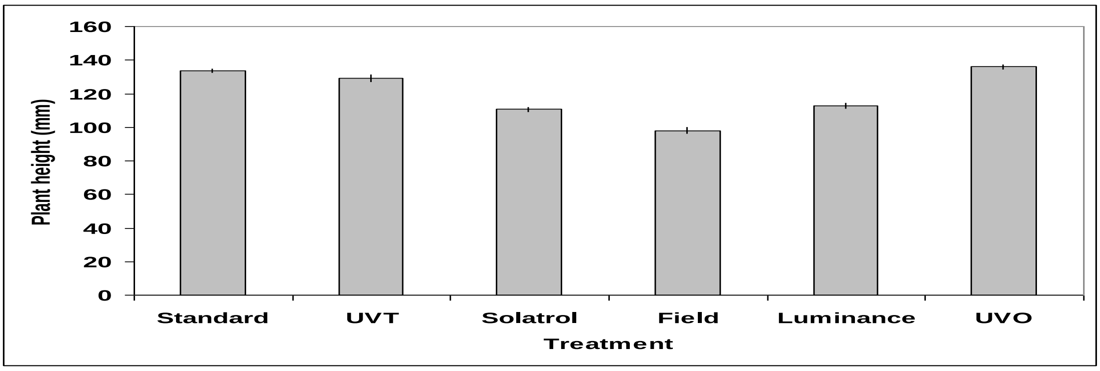
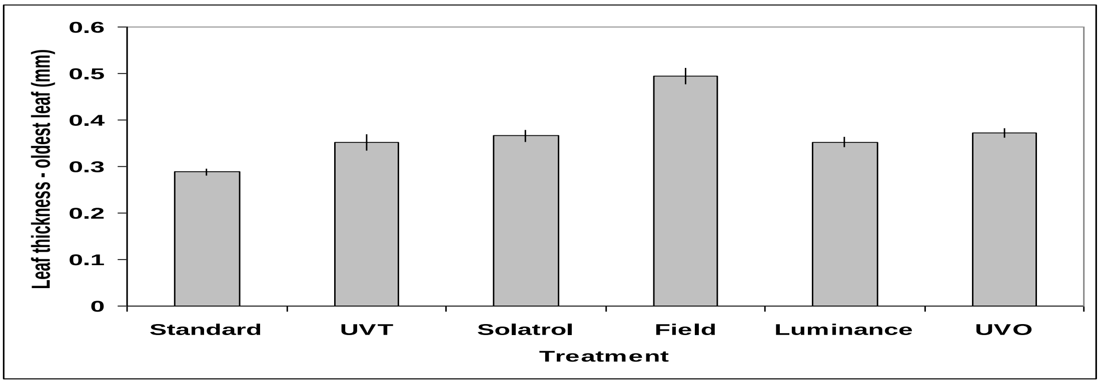
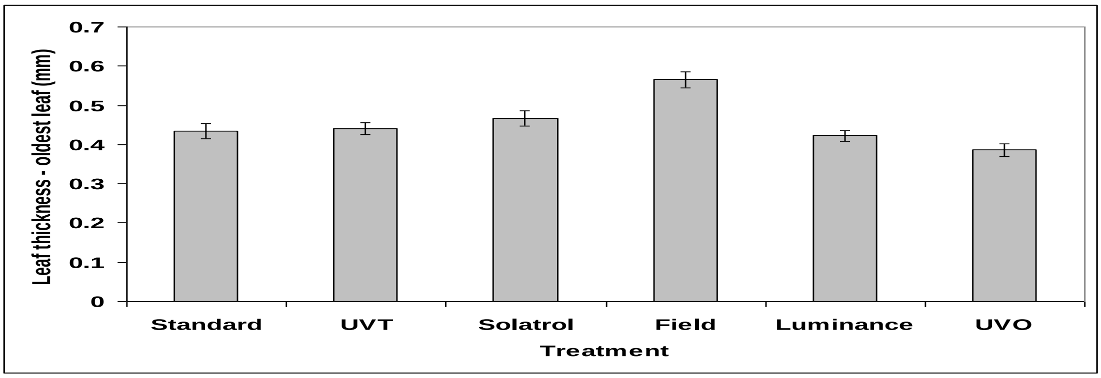


Figure 10. Effect of treatments on plant height in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Spinach for bagged salads.

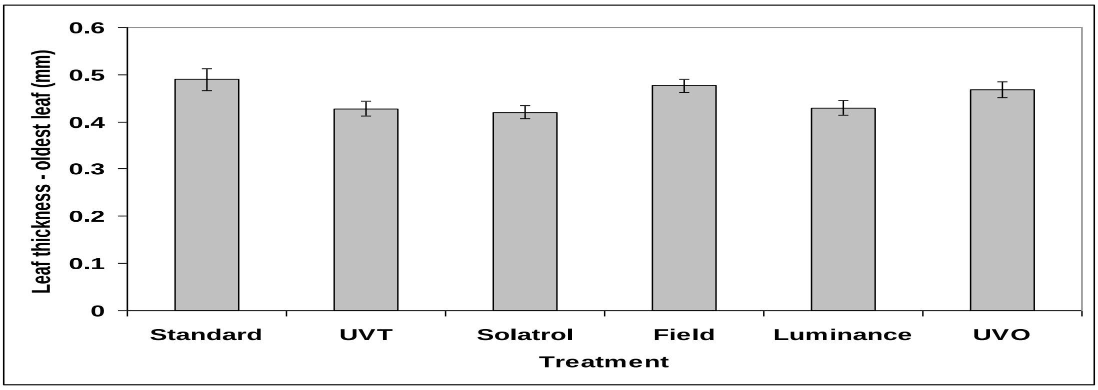
a)



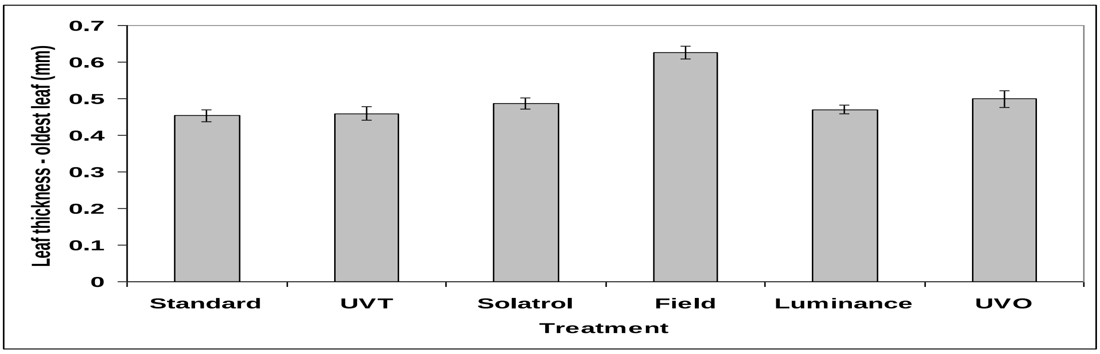
b)



c)



d)

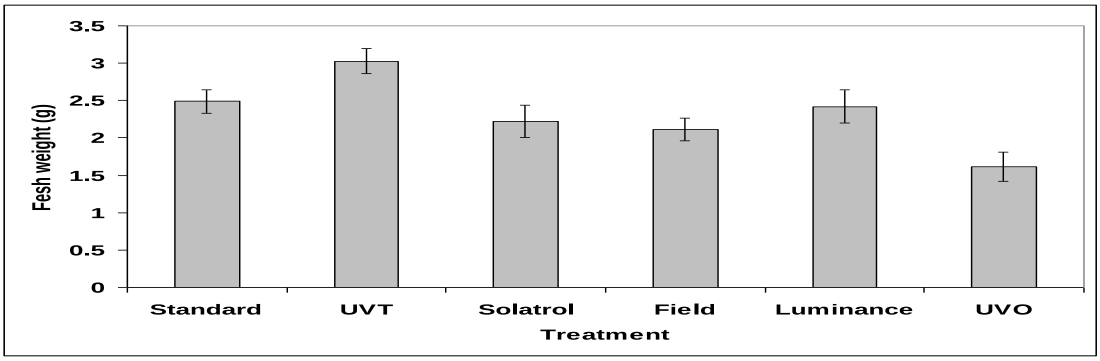


RED CHARD FOR BAG SALADS – MEASUREMENTS TAKEN AT THE COMMERCIAL MARKETABLE STAGE

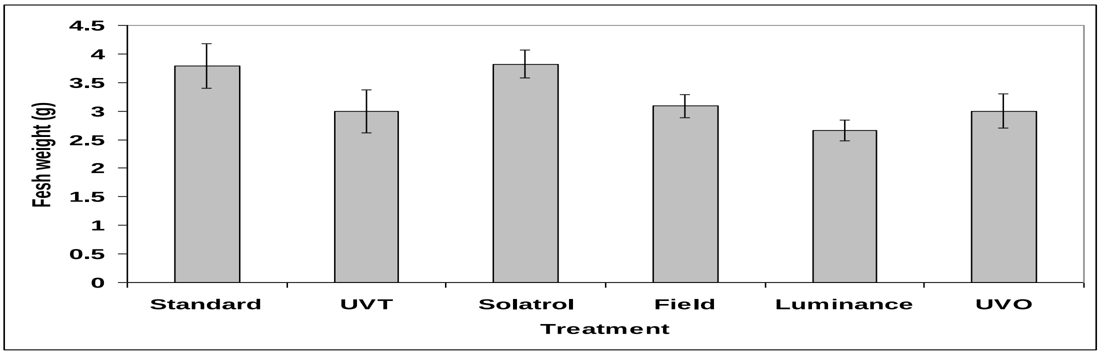
There was no consistent pattern in plant fresh weights across all 4 batches (figs. 11.a. – 11.d). In batch 1, UV-transparent produced a significant increase in fresh weight when compared to all remaining treatments while in batch 2 Solatrol significantly increased fresh weights relative to all treatments but Standard (figs. 11.a. & 11.b). The Field crop produced increases in fresh weight when compared to all treatment in batch 3 but this was only significant relative to Solatrol (fig. 11.c). Luminance produced significant increases in plant fresh weight when compared to Standard, Solatrol and Field only in batch 4 (fig. 11.d). There was no consistent effect of treatments on plant dry weights across the season's four crop batches (figs. 12.a. – 12.d). However, in batches 3 and 4 Solatrol produced significant reductions in dry weight relative to all remaining treatments (figs. 12.c. & 12.d). There was no consistent effect of treatments on leaf area at the time of harvest (figs. 13.a. – 13.d). In batch 1, UV-transparent produced a significant increase in leaf area when compared to all remaining treatments (fig. 3.a). Solatrol produced a significant increase in leaf area in batch 2 relative to Field, Luminance and UV-opaque only (fig. 13.b). In batches 3 and 4 leaf areas were generally increased in Luminance and UV-opaque when compared to the remaining crop treatments, while Solatrol significantly reduced areas relative to all treatments except Standard in batch 1 and Field in batch 2 (figs. 13.c. & 13.d). Plant height was reduced in Field in batches 1, 2 and 3 when compared to the remaining treatments (figs. 14.a, 14.b. & 14.c). In batch 1 this was a significant reduction compared to Standard, UV-transparent and Luminance (fig. 14.a). In batch 2 this reduction in Field crop height was significant when compared to Standard and Solatrol treatments only and in batch 3 the reduction was significant compared to UV-opaque only (figs. 14.b. & 14.c). Leaf thickness was significantly increased in Field when compared to all remaining treatments in batch 3 and all but UV-transparent in batch 4 (figs. 15.c. & 15.d). In the early season crop batches there was a significant increase in leaf thickness in Field compared to UV-transparent and UV-opaque in batch 1 and Luminance and UV-opaque in batch 2 (figs. 15.a. & 15.b).

Figure 11. Effect of treatments on shoot fresh weight in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Red chard for bagged salads.

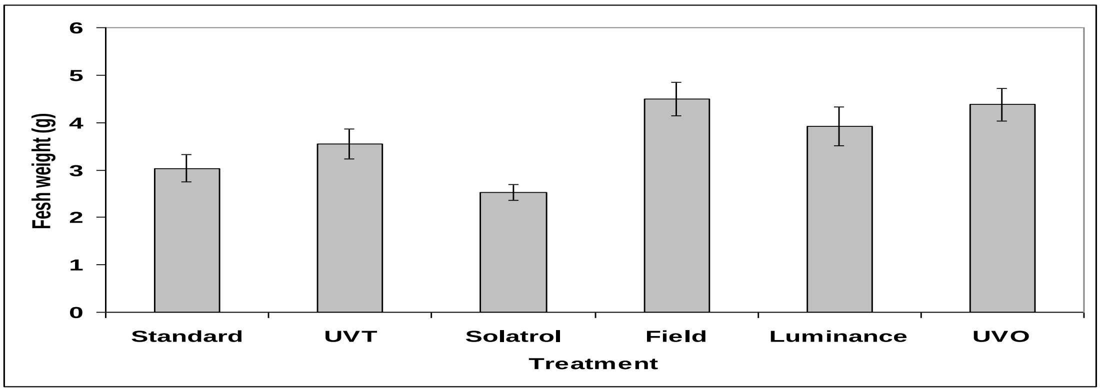
a)



b)



c)



d)

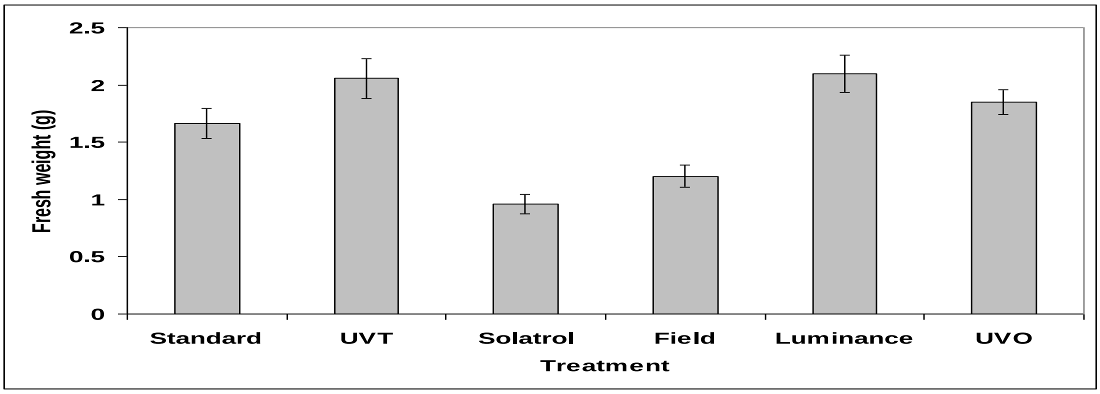
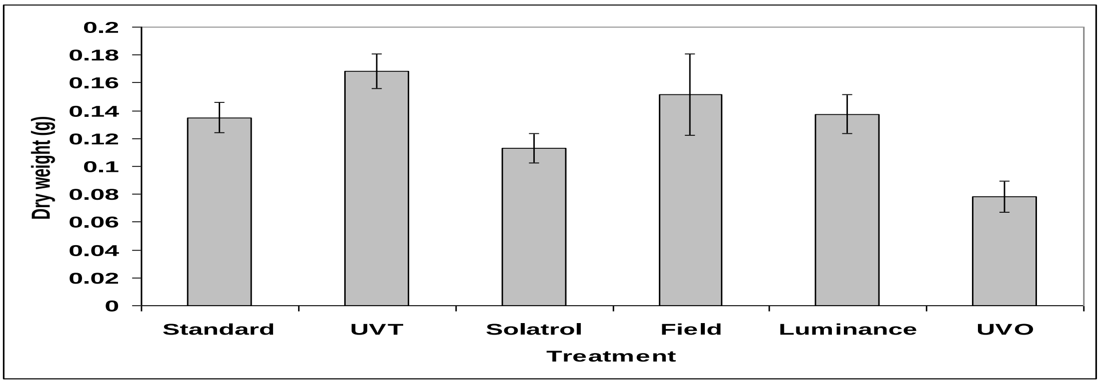
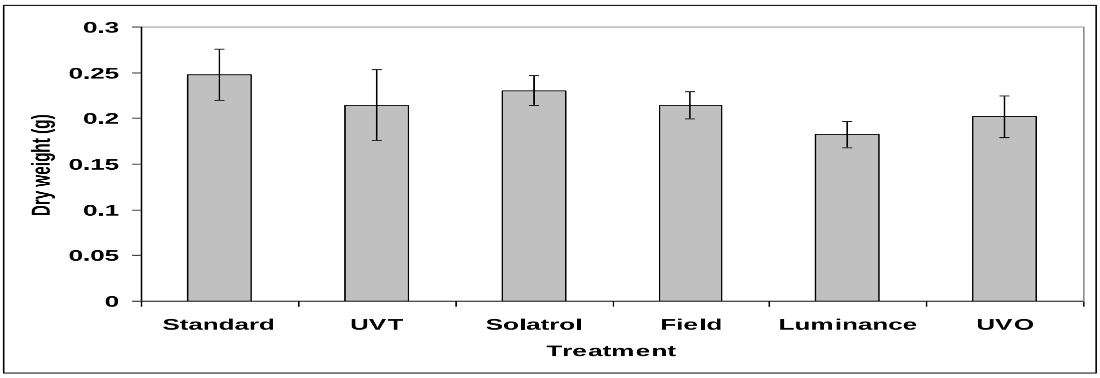


Figure 12. Effect of treatments on shoot dry weight in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Red chard for bagged salads.

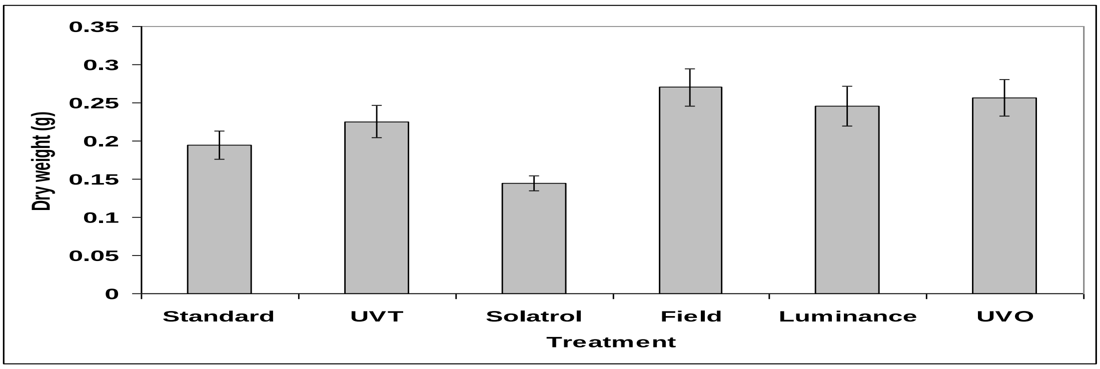
a)



b)



c)



d)

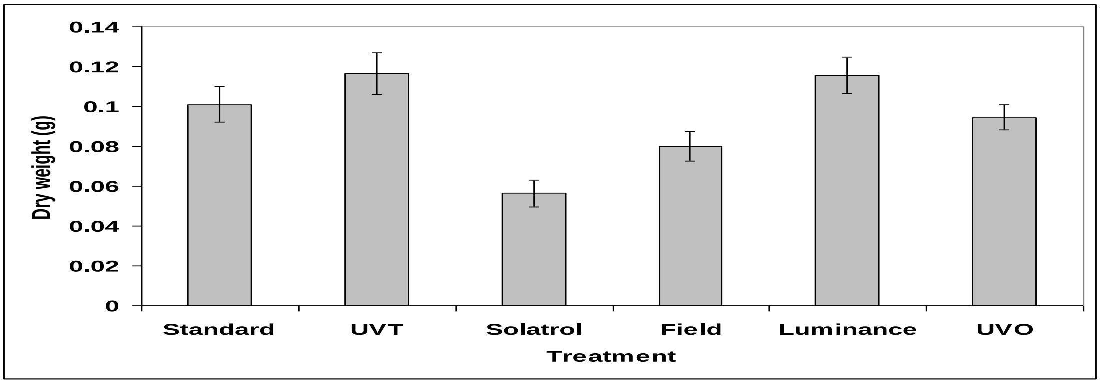
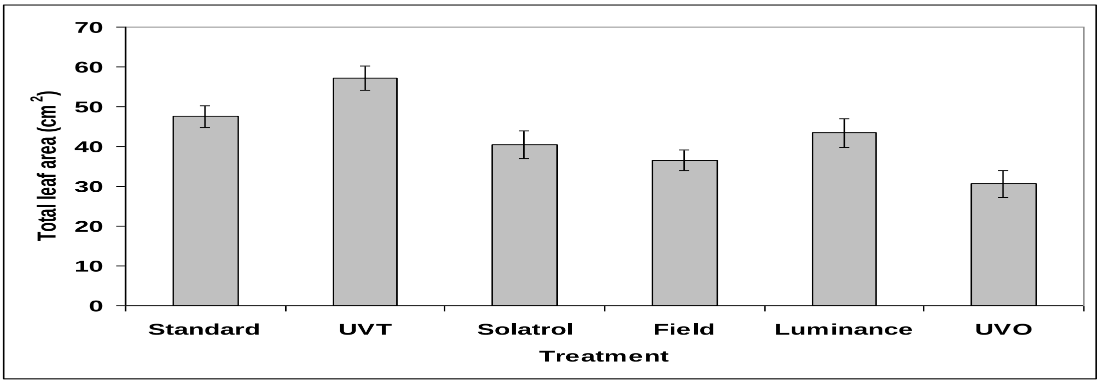
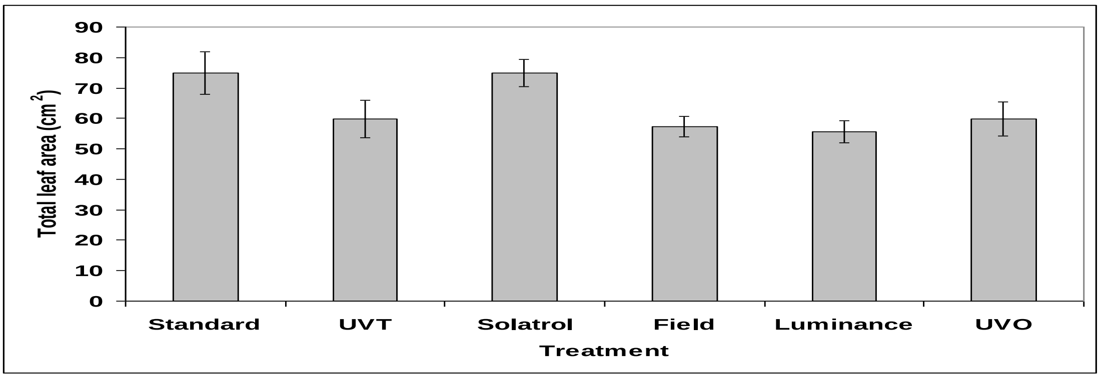


Figure 13. Effect of treatments on total leaf area in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Red chard for bagged salads.

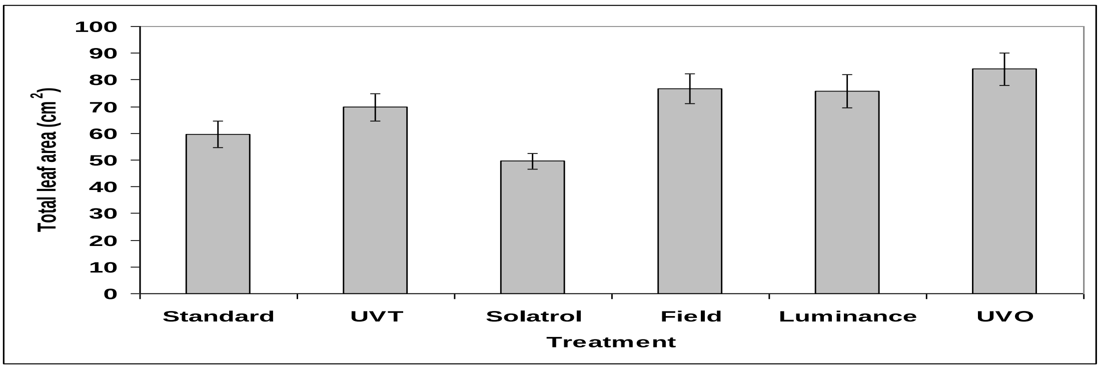
a)



b)



c)



d)

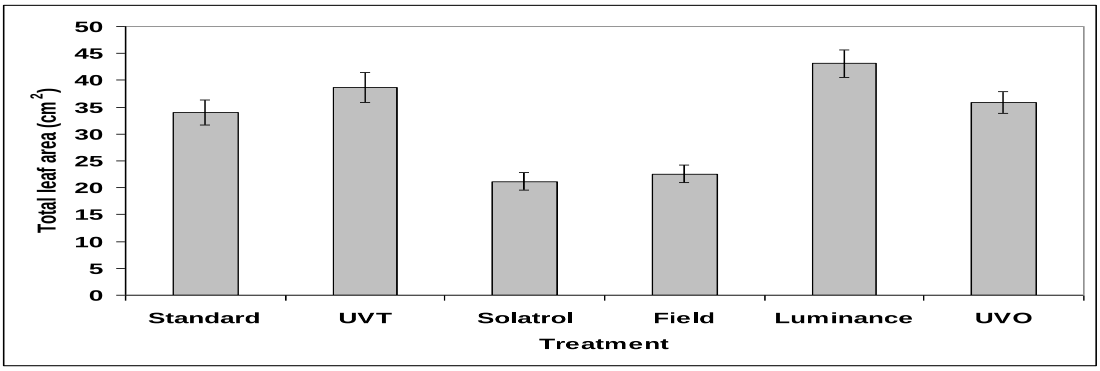
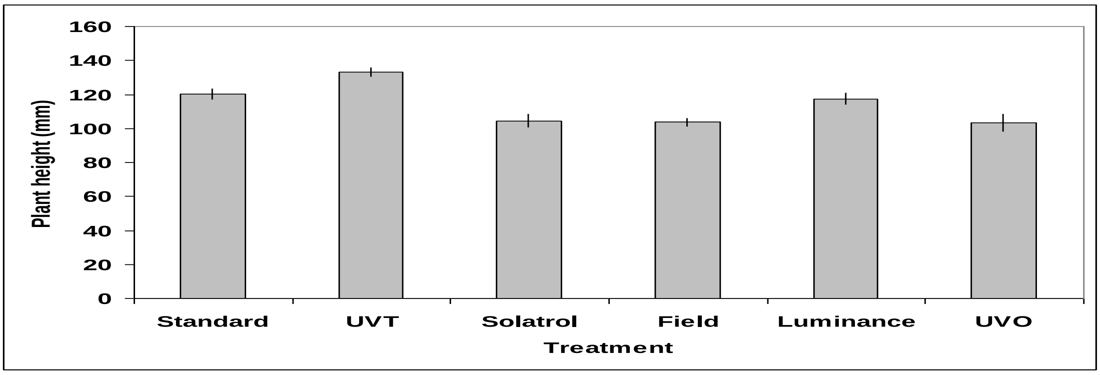
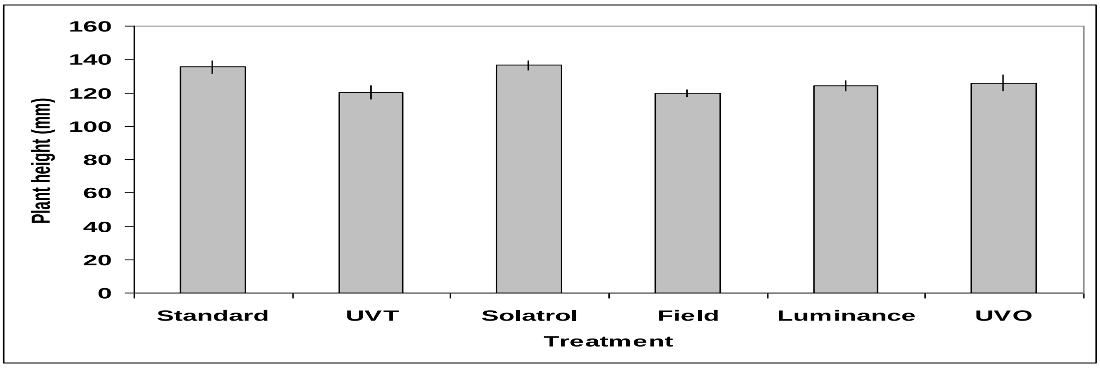


Figure 14. Effect of treatments on plant height in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Red chard for bagged salads.

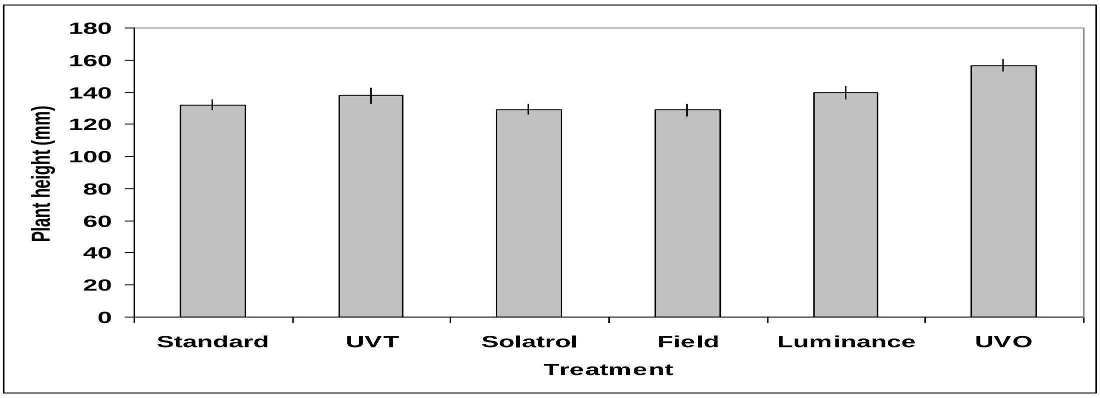
a)



b)



c)



d)

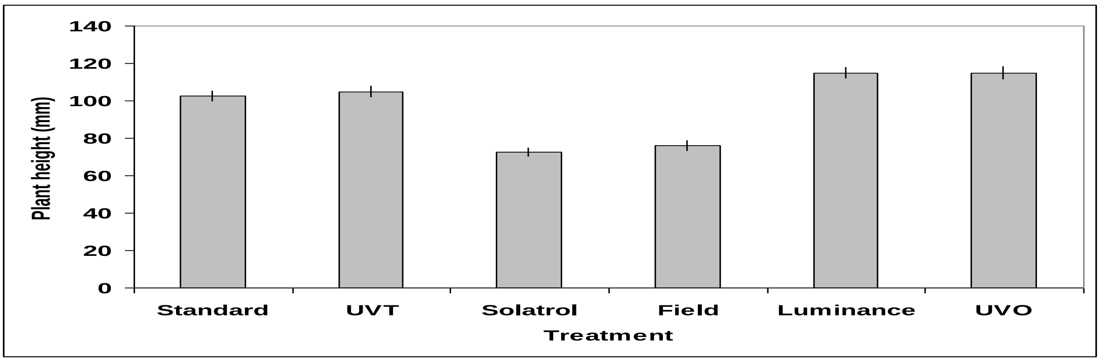
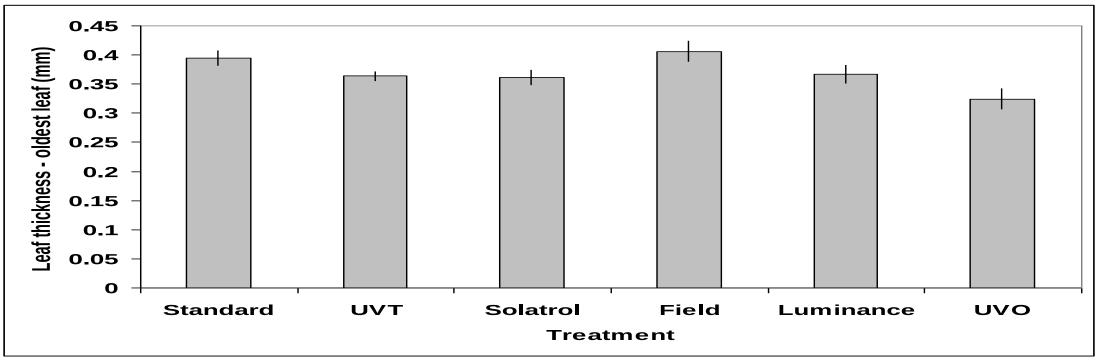
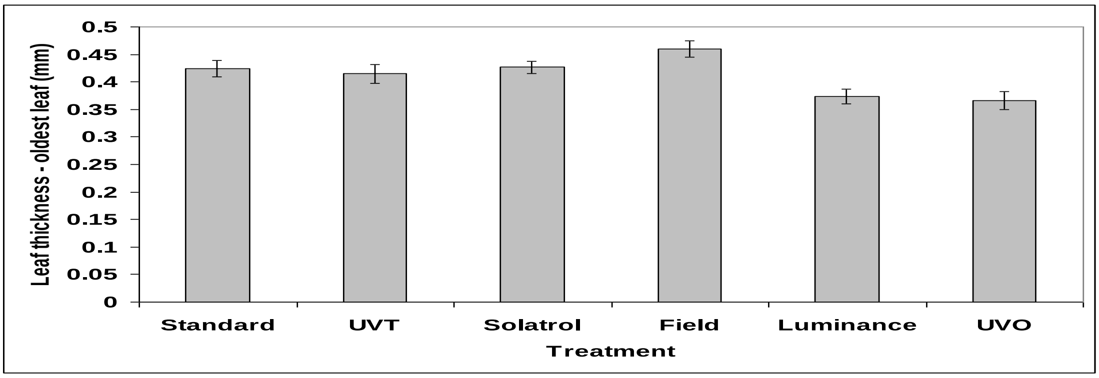


Figure 15. Effect of treatments on thickness of the oldest leaf in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Red chard for bagged salads.

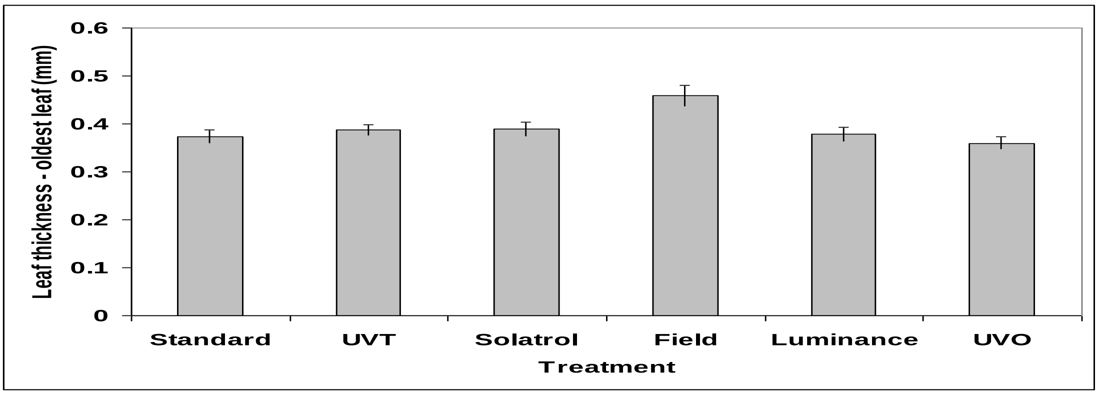
a)



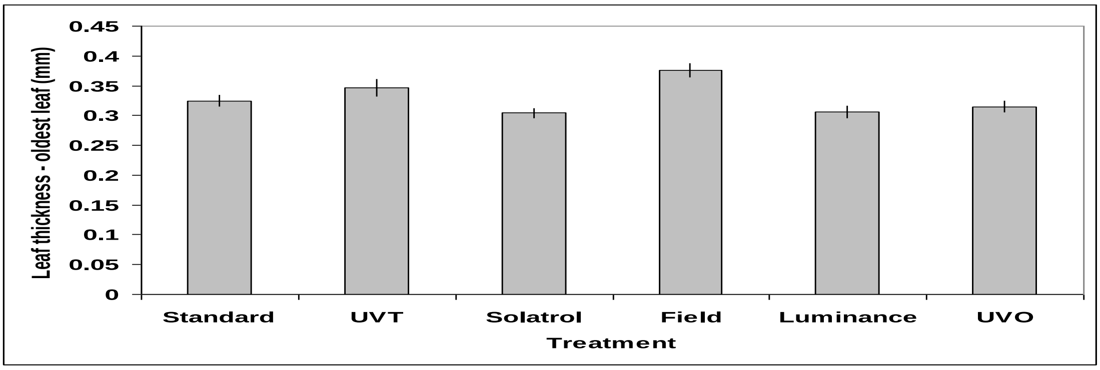
b)



c)



d)

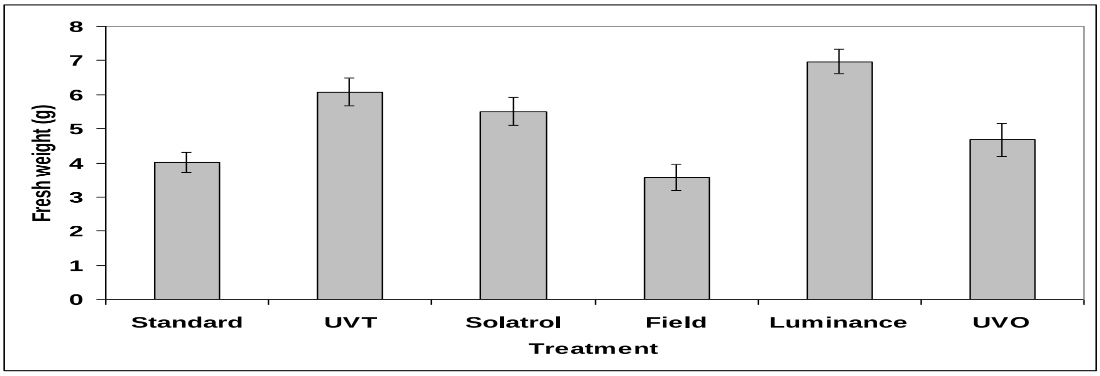


MIZUNA FOR BAG SALADS – MEASUREMENTS TAKEN AT THE COMMERCIAL MARKETABLE STAGE

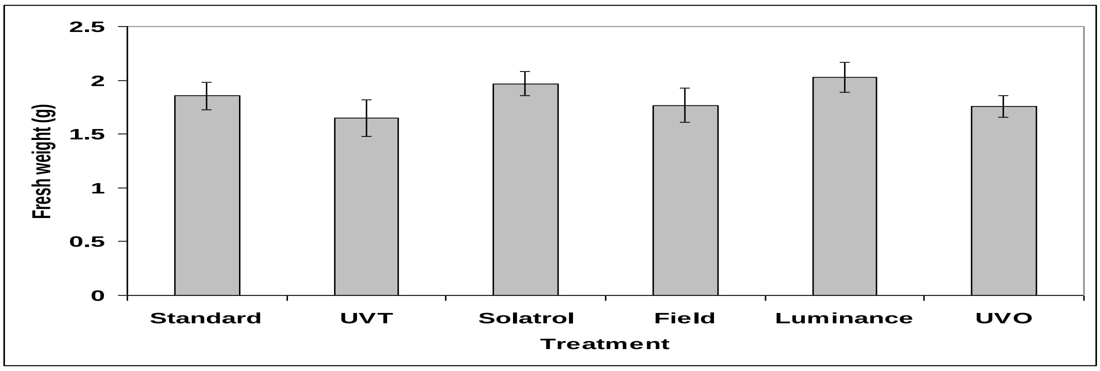
There was no consistent pattern in plant fresh weights across all 4 batches (figs. 16.a. – 16.d). In batch 1, Luminance produced a significant increase in fresh weight when compared to all remaining treatments except UV-transparent (fig. 16.a). Again, in batch 2, Luminance increased fresh weights when compared to all remaining treatments but this did not represent a significant increase (fig. 16.b). UV-opaque significantly increased fresh weights in batch 3 when compared to UV-transparent and Luminance only and when compared to all remaining treatments except field in batch 4 (figs. 16.c. & 16.d). There was no consistent effect of treatments on plant dry weight across the seasons four crop batches (figs. 17.a. – 17.d). In batches 1 and 2 total leaf areas were increased in Luminance when compared to all remaining treatments (figs. 17.a. & 17.b). In batch 1 this increase was significant when compared to all remaining treatments except UV-transparent and in batch 2 relative to Field only (figs. 18.a. & 18.b). In batch 3 UV-opaque produced significant increases in leaf area compared to UV-transparent and Luminance only and in batch 4 compared to all remaining treatments (figs. 18.c. & 18.d). Plant height was significantly increased in Luminance when compared to all remaining treatments in batches 1 and 2 and this was significant relative to all but the Standard treatment (figs. 19.a. & 19.b). UV-opaque significantly increased plant height compared to UV-transparent and Luminance only in batch 3 (fig. 19.c) and compared to all remaining treatments in batch 4 (fig. 19.d). In batch 1 there was a significant increase in leaf thickness in UV-transparent when compared to Standard and UV-opaque only (fig. 20.a). In batch 2 there was no significant effect of treatments on leaf thickness (fig. 20.b). Leaf thickness was significantly increased in Field when compared to all remaining treatments in batch 3 (fig. 20.c).

Figure 16. Effect of treatments on shoot fresh weight in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Mizuna for bagged salads.

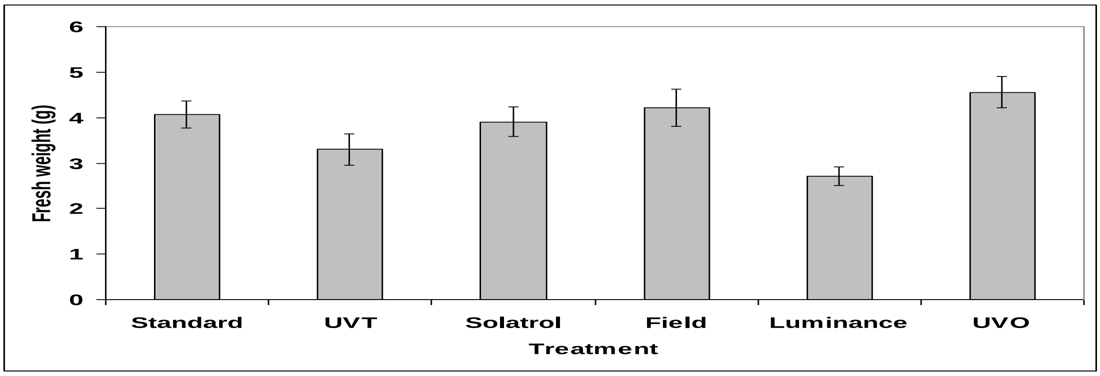
a)



b)



c)



d)

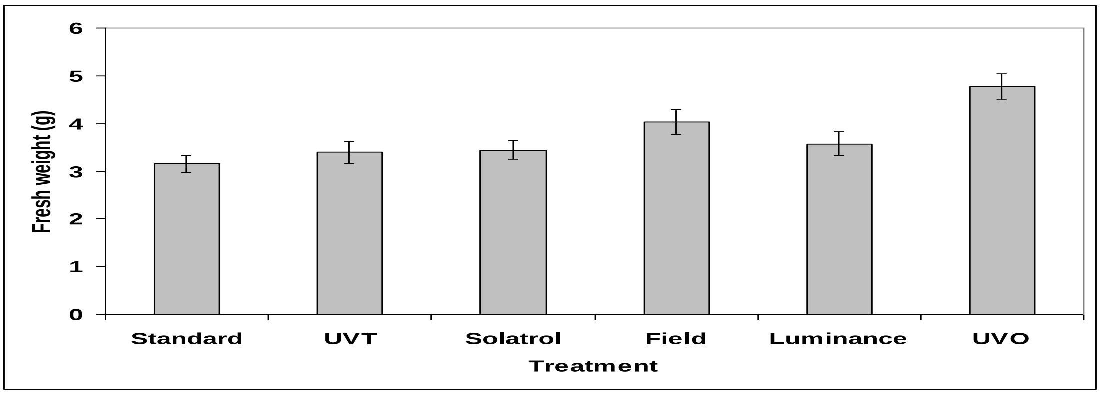
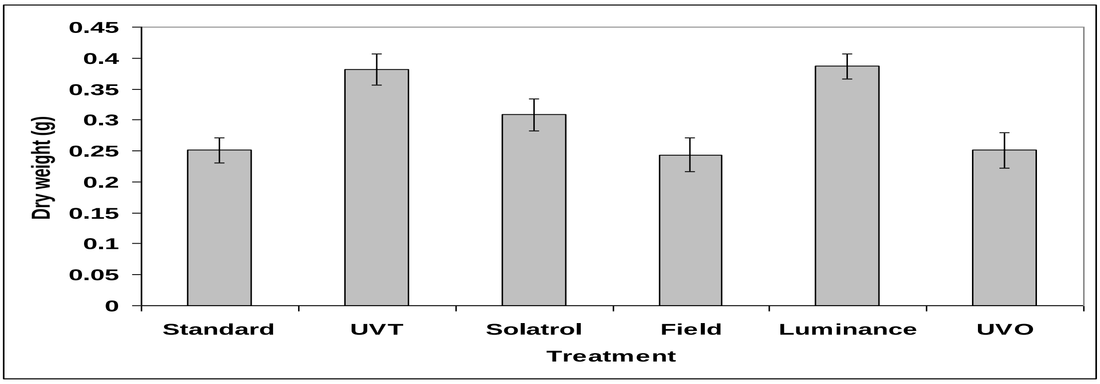
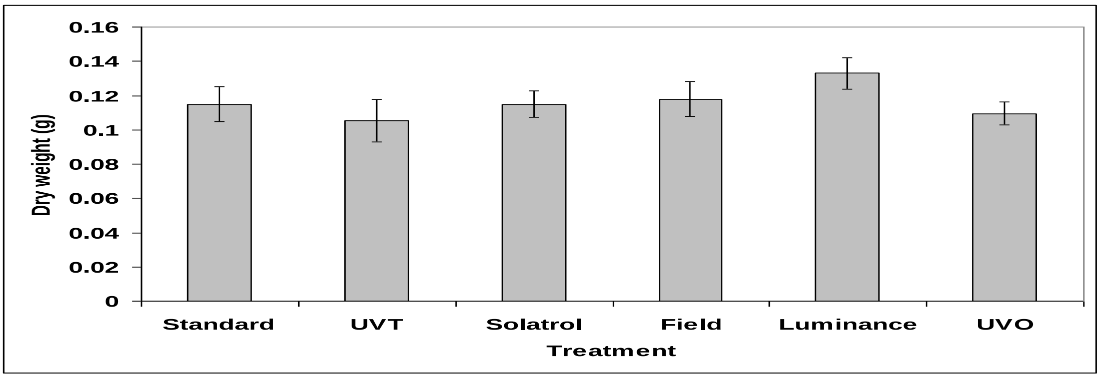


Figure 17. Effect of treatments on shoot dry weight in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Mizuna for bagged salads.

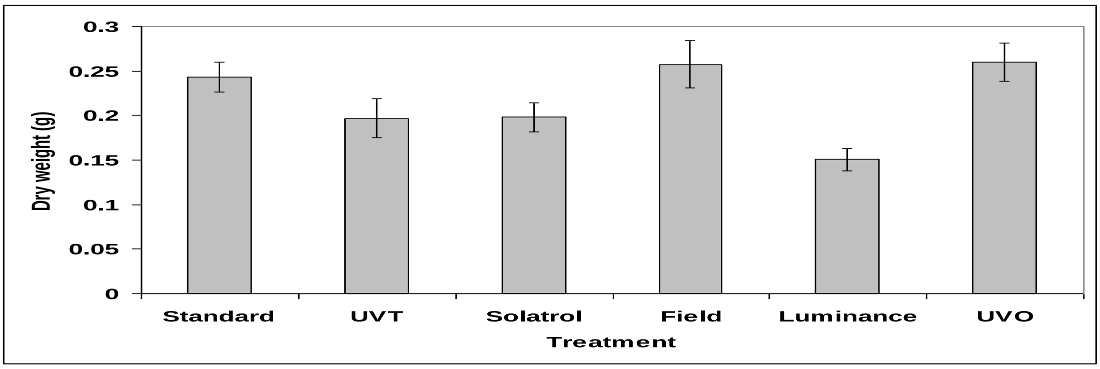
a)



b)



c)



d)

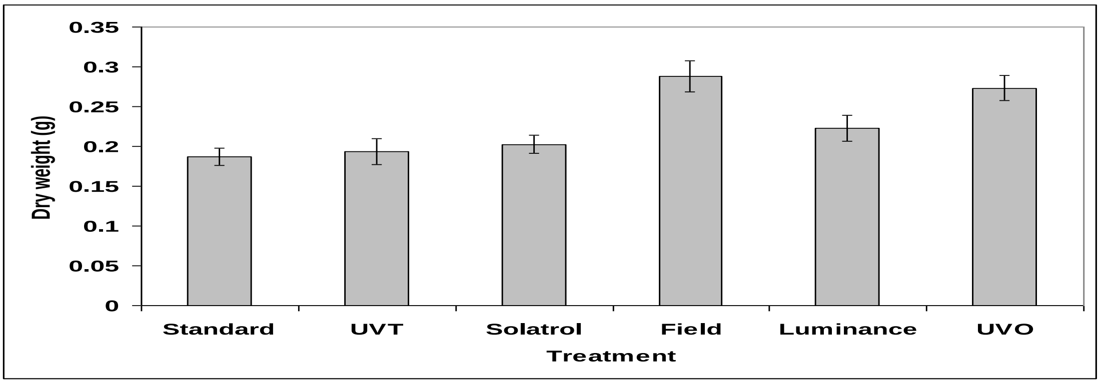
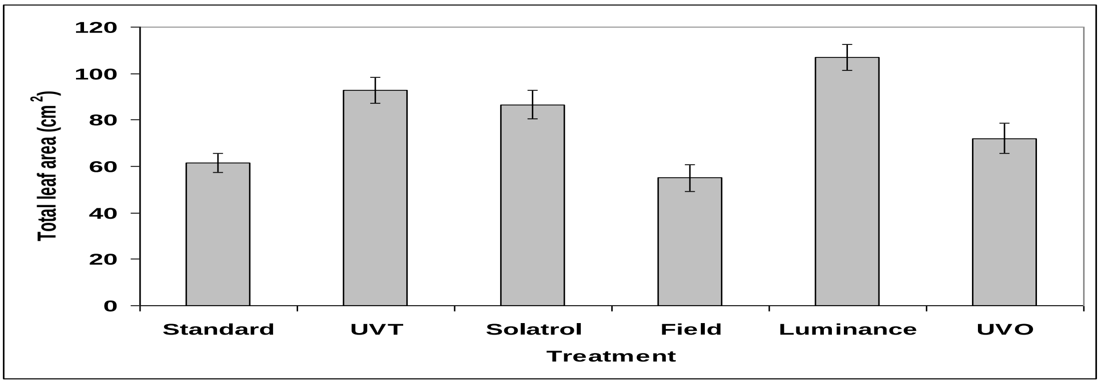
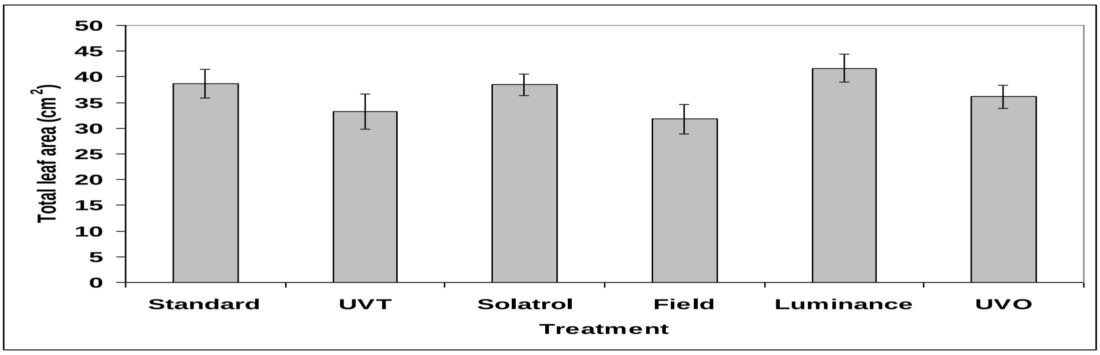


Figure 18. Effect of treatments on total leaf area in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Mizuna for bagged salads.

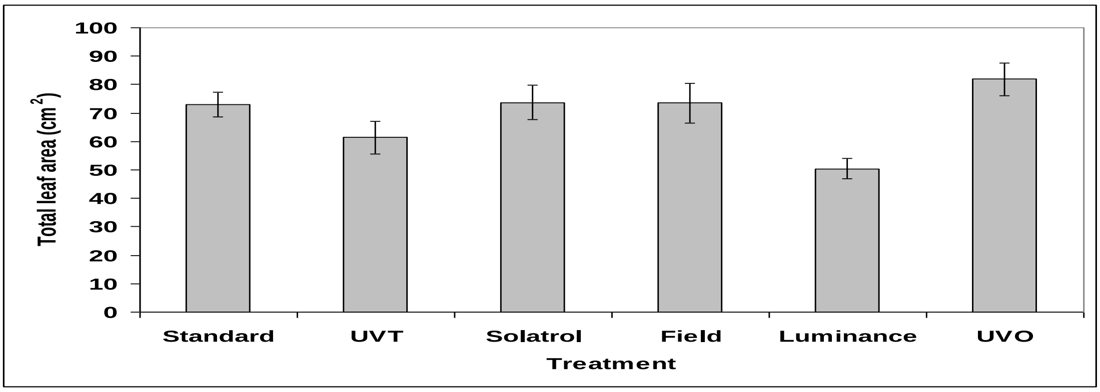
a)



b)



c)



d)

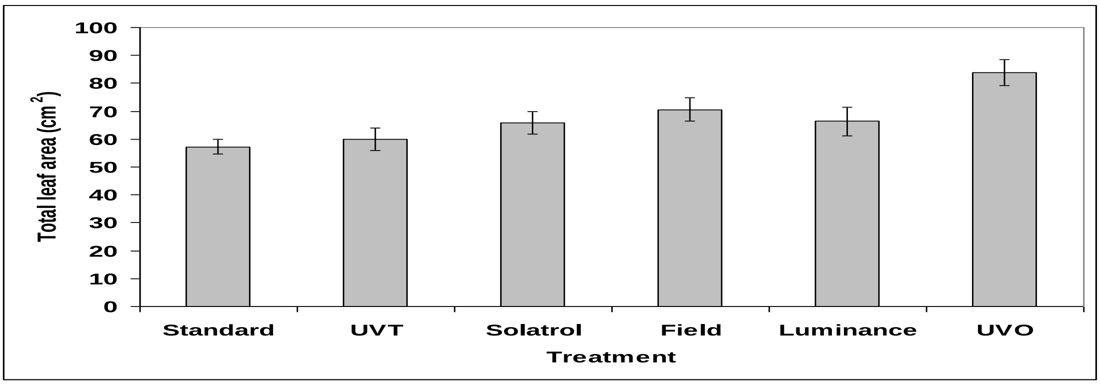
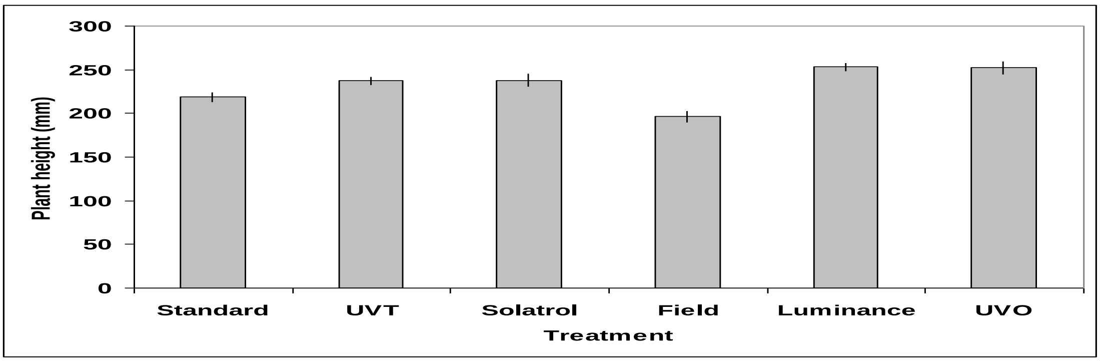
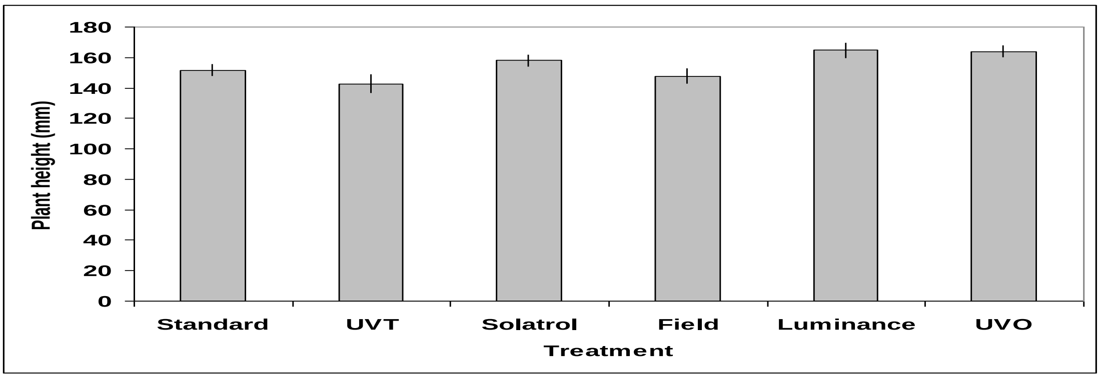


Figure 19. Effect of treatments on plant height in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Mizuna for bagged salads.

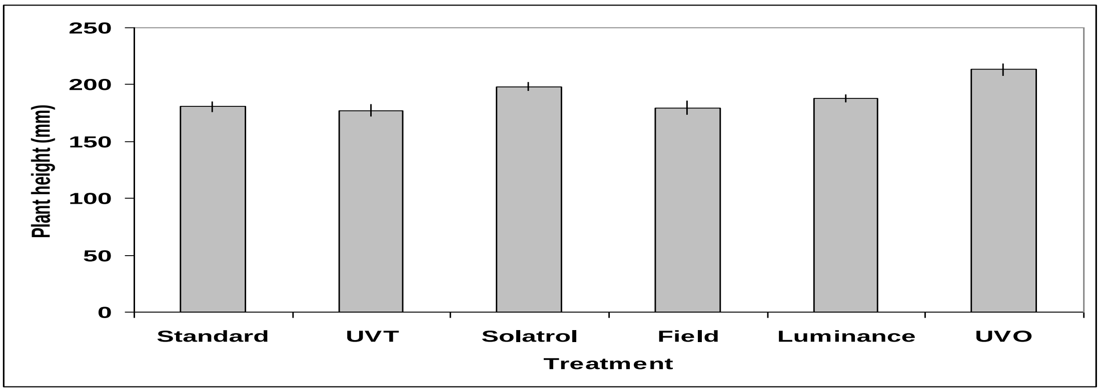
a)



b)



c)



d)

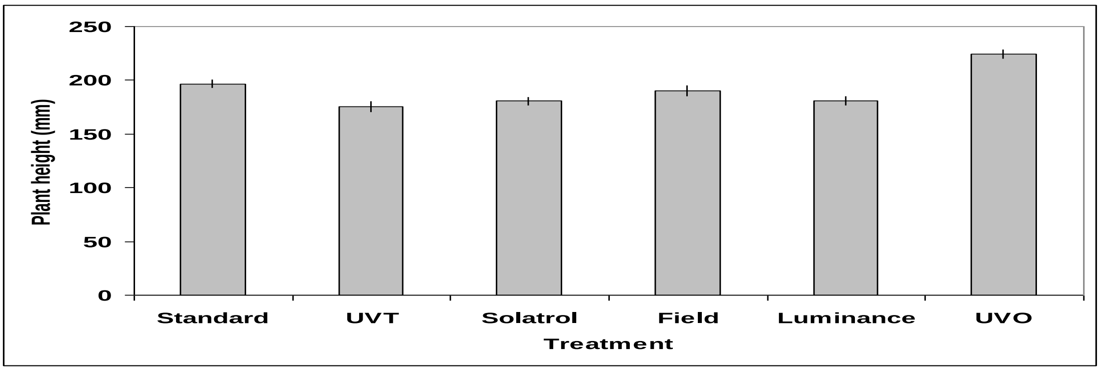
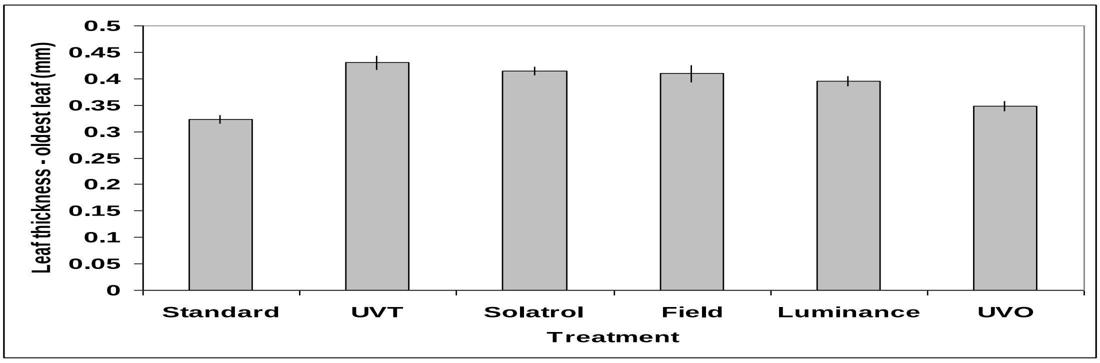
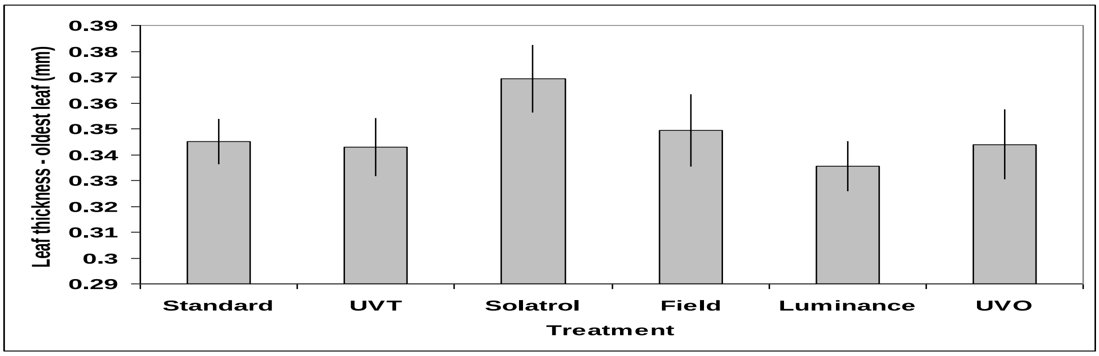


Figure 20. Effect of treatments on thickness of the oldest leaf in a) batch 1, b) batch 2, c) batch 3 and d) batch 4 of Mizuna for bagged salads.

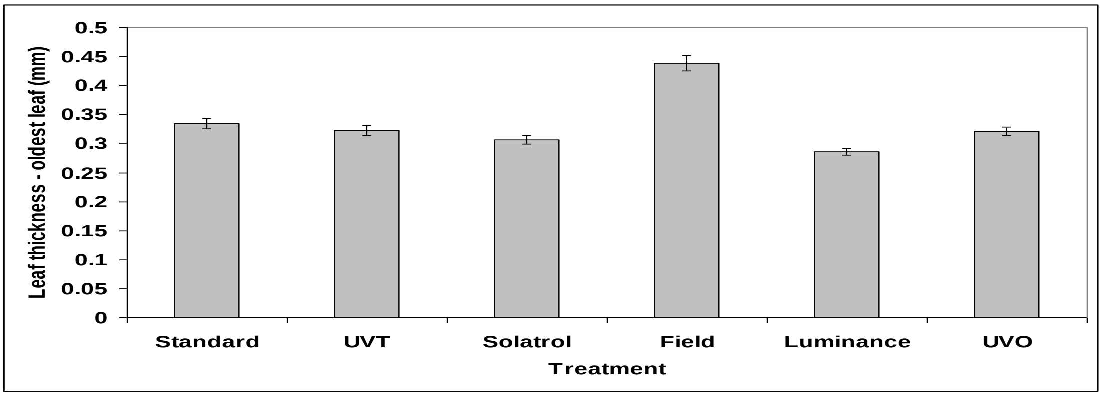
a)



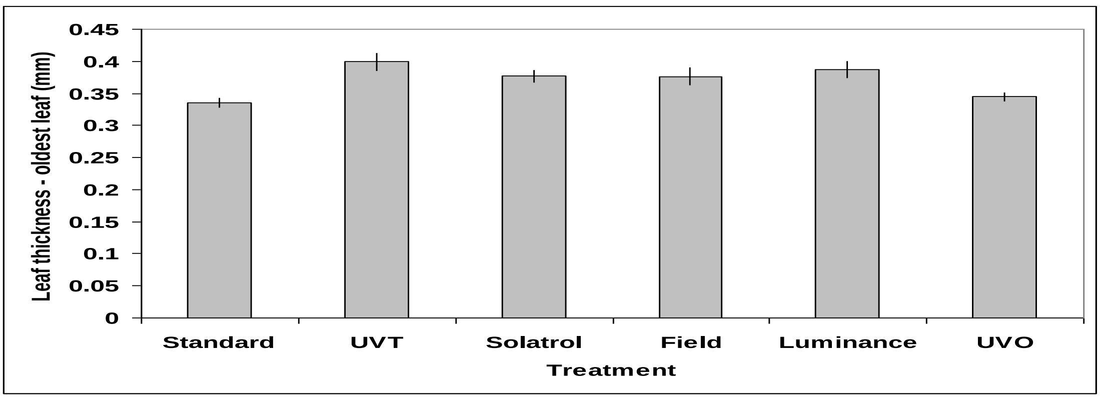
b)



c)



d)



DISCUSSION

Bagged salads were first retailed in the early 1990's and by 2004 two-thirds of households were buying them regularly. The value of the UK salad vegetable market grew by 90 per cent between 1992 and 2002 when it was worth approximately £1.25 billion. This does not mean that UK consumers are eating 90% more salad; volumes have grown only by 18 per cent over the same period; just that the food industry has found ways to make much more money out of salad. Global sourcing and advances in packaging technologies have made it possible to supply the market for bagged salads year round. Modified-atmosphere packaging (MAP) can extend the shelf life of prepared salad by more than 50 per cent, making it possible for supermarkets to sell washed and bagged salad from around the world. Lettuce and salad leaves are harvested from fields in the UK, or increasingly from growers in southern Europe or the US. However, the requirement for international transport of the crop affects unit costs, especially in a market where oil prices are increasing and taxation on aviation fuel is being seriously considered in response to concerns over global climate change. For this reason developing economically viable methods for increased sourcing from UK growers will become important. Issues that will need to be addressed before this can happen include improving crop yield and quality, extending the UK growing season and reducing chemical inputs. One possible option therefore is to employ low cost temporary structures to protect the crop in the unpredictable UK climate and so in the 2005 season we included 4 main constituents of bagged salads across three normal UK season trials and extended, early autumn, trial.

Results from Rocket show that there are substantial yield benefits to be gained from moving away from Field production. Across the full season there was a significant reduction in plant fresh weight in Field crops when compared to the majority of the filter treatments (figs. 1, 6, 11 & 16). However, in Spinach, Red chard and Mizuna there was no consistent improvement in yield under any of the filters when compared to the Field grown crop (figs. 1.a, 6.a.) despite the obvious visible differences in the 4 crops (see below). Changes in total leaf area at harvest can account for some of the observed visual differences in the crops. In Rocket, leaf area tended to be increased under Standard and UV-transparent treatments, especially compared to the Field crop which produced substantial reductions in area at harvest (fig. 3.a. & 3.c). In Spinach there was no consistent effect of treatments on leaf area at the time of harvest with early season batches producing increased leaf areas in Field grown crops but in late season crops this pattern was reversed (figs. 3.a. & 3.c). Trends in leaf areas in Red chard were, again, inconsistent across the season. In the first 2 batches UV-transparent and Solatrol produced significant benefits in terms of increased leaf area but in the latter half of the season Luminance and UV-opaque increased harvestable leaf areas at the expense of the remaining treatments (figs. 13.a. - 13.d).

One potentially important component of plant development for the industry is leaf thickness. Changes in leaf thickness, and the mechanical strength of the tissue, may impact on the crops ability to withstand a commercial wash cycle. In Rocket, the Field grown crop leaf thickness was significantly increased in Field when compared to all remaining treatments except UV-transparent but in the latter part of the season leaf thickness was reduced in Field relative to the majority of the filter treatments (figs. 5.a. – 5.d). In Red chard leaf thickness was generally increased in Field throughout the majority of the season (figs. 15.a. -15.d).
In Mizuna there was no consistent effect of treatments on leaf thickness throughout the season (figs. 20.a. - 20.d). Coupled with changes in leaf thickness, a more compact leaf may also reduce the potential for damage to the product when the bagged salads are sealed. Therefore changes in plant height in the various treatments may be of commercial importance. In Rocket, Spinach and Red chard plant height was consistently reduced in Field across the season's crops when compared the majority of the remaining treatments (figs. 4.a - d., 9.a. – d. & 14.a – d). Of the filters, both UV-transparent and Solatrol reduced plant height most consistently across all the crops throughout the season (figs. 4.a - d., 9.a. – d., 14.a – d. & 19.a - d). What is clear from results from the first seasons work is that there are no obvious gains to be made, with regards to increased leaf thickness and the development of more compact plants, by switching to production under spectral filters.

The aforementioned advances in agronomic, processing, preservation, packaging, shipping, and marketing technologies on a global scale have enabled the fresh fruit and vegetable industry to supply consumers with a wide range of high-quality produce year round. Likewise, the relative importance of fruits and vegetables as a source of food-borne illness has likewise increased

Figure 21. Spinach: comparison of plants from different locations

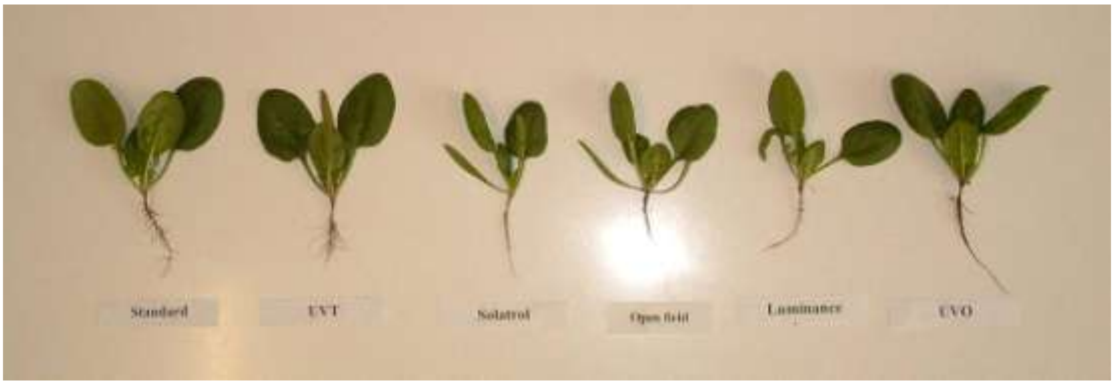


Figure 22. Red Chard: comparison of plants from different locations

Figure 23. Rocket: comparison of plants from different locations

Figure 24. Mizuna: comparison of plants from different locations

Part 5. ASPARAGUS

INTRODUCTION

Asparagus has been grown for millennia: the Ancient Greeks and Romans relished this crop. It originated in Asia Minor and is a member of the lily family. Asparagus is a dioecious plant, meaning that there are both male and female plants. Generally, females produce larger spears than males, but the males produce greater numbers of smaller diameter spears. Only female plants produce berries. Breeding work is in progress at various locations and institutions worldwide to produce high yielding all male asparagus lines. The primary benefit from an all-male hybrid is that it does not produce seed, which can later germinate and create a significant weed problem in the form of several volunteer asparagus seedlings. Asparagus spears produced from all male hybrids are usually very uniform. For many years, the most common varieties have been from the Washington series (Mary, Martha, Waltham), developed by the U.S. Department of Agriculture which are dioecious. However, several of the all-male hybrids developed in New Jersey (Rutgers University) offer proven higher yields and increased rust resistance and tolerance to Fusarium crown rot and are often the preferred choice. 'Jersey Giant' is one of those varieties and is used in this trial.

The retail value of asparagus in the UK is approximately £50 million per annum. 35% of this is home grown, being produced in a short season, lasting a maximum of ten weeks and often less. In 2004 during the UK season (April, May, June), the value of imports was £2 ½ million.

As with most fresh produce, the multiples are now marketing a high percentage of the crop, making it available to a larger customer base. Additionally a solid PR campaign in 2004 has achieved increased market penetration and annual, per capita, consumption is now 120gm in the UK. There are currently 1000Ha of asparagus production in the UK being grown by some 200 businesses using production systems that have changed little for many years. In an expanding market place, the industry needs to understand whether cost effective, cultural techniques, can improve yield, quality and therefore return. Therefore the inclusion of asparagus in the project being undertaken at Stockbridge House, evaluating the technical and economic benefits of modified plastic crop covers, is an opportune one.

The project will investigate which, if any, of the spectral filters could assist in:

- Accelerating the plants establishment in its early, non-productive, years. Specifically, can the time taken to achieve its critical root mass, currently accepted as five years, be reduced significantly?
- Giving season extension/yield improvement with particular focus on improved percentage class 1.
- Showing reduced period of carbohydrate recharge in the fern phase.
- The reduction of disease in the fern phase offered by the improved environment.

While preliminary results are reported here from the second season, the productive stage of the crop begins in the third year and so what follows are preliminary data and should be treated as such.

RESULTS

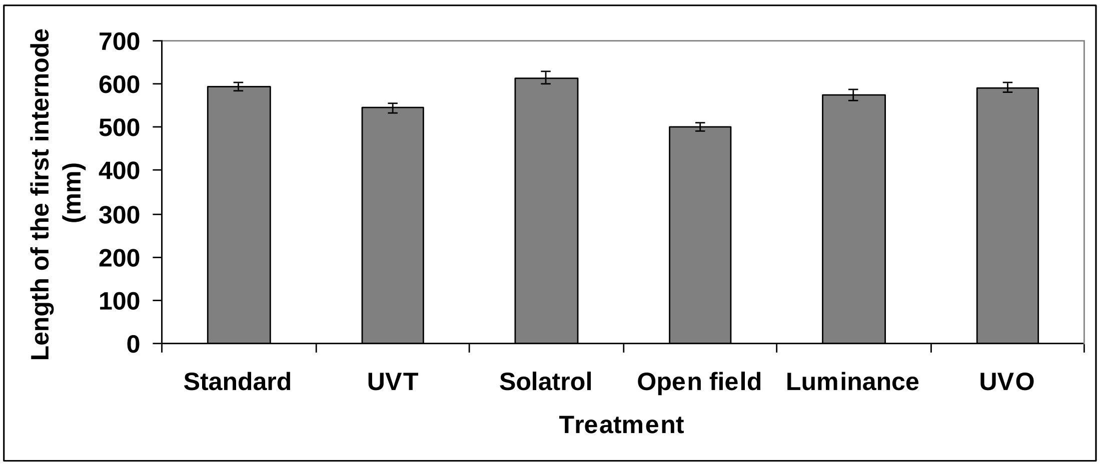
JERSEY GIANT

In the Open field crop the length of the first internode was significantly reduced when compared to all treatments (fig.1.a). Solatrol increased internode length when compared to treatments but this was only significant relative to UVT, Open field and Luminance (fig. 1.a). The total number of viable spears per plant was significantly increased in Standard when compared to UVT, Solatrol Luminance and Field but not

UV-opaque (fig. 1.b). Open field reduced the number of spears relative to Standard and UV-opaque only (fig. 1.b). Open field produced a significant reduction in the total number of viable spears per plant >1cm when compared to all filter treatments (fig.2.a. The number of aborted spears was significantly reduced in Solatrol when compared to all remaining treatments except Open field (fig. 2.b. Although Luminance increased the number of aborted spears this was only significant relative to Solatrol and Open field (fig. 2.b. The thickness of viable spears at the base was significantly reduced in Open field when compared to all filter treatments (fig. 2.c. There was no significant difference in stem thickness between the 5 filter treatments (fig. 2.c).

Figure 1. Effect of treatments on (a) length of the first internode and (b) total number of viable spears per plant in Jersey giant. Each value is the mean ≥ S.E. of 16 replicates.

a)



b)

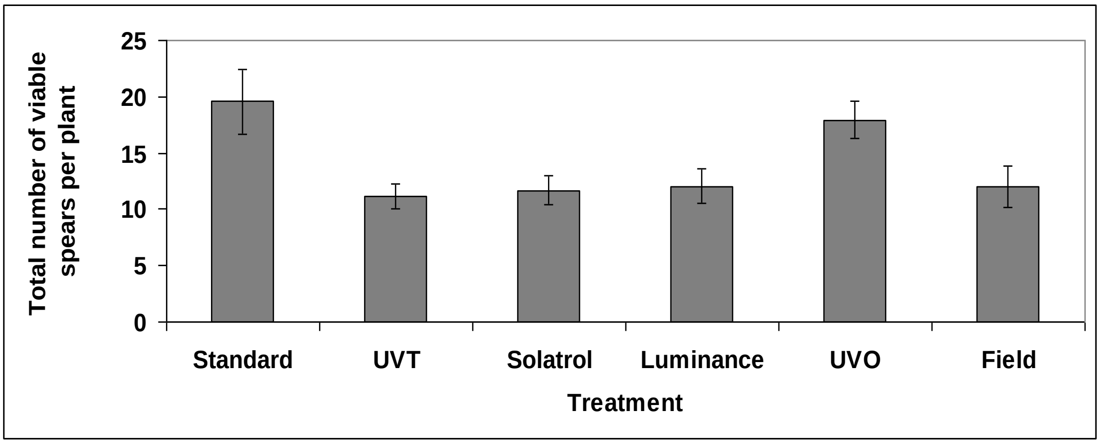
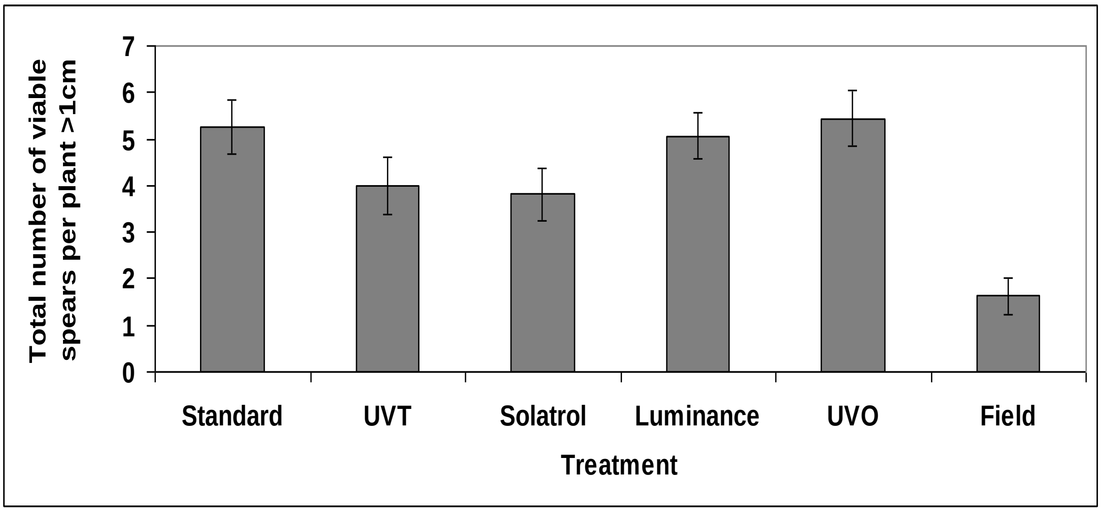
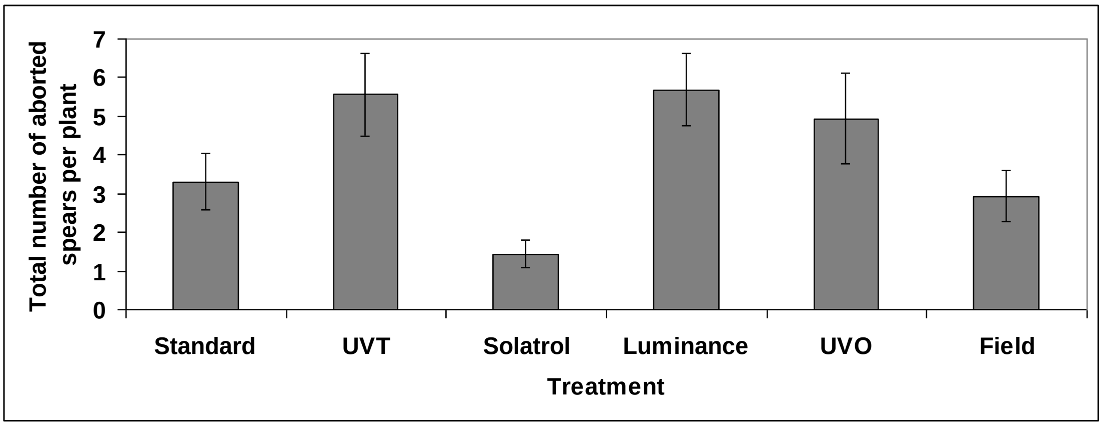


Figure 2. Effect of treatments on (a) total number of viable spears per plant >1cm, (b) total number of aborted spears per plant and (c) thickness of viable spears at the base in Jersey giant. Each value is the mean $\geq$ S.E. of 16 replicates.

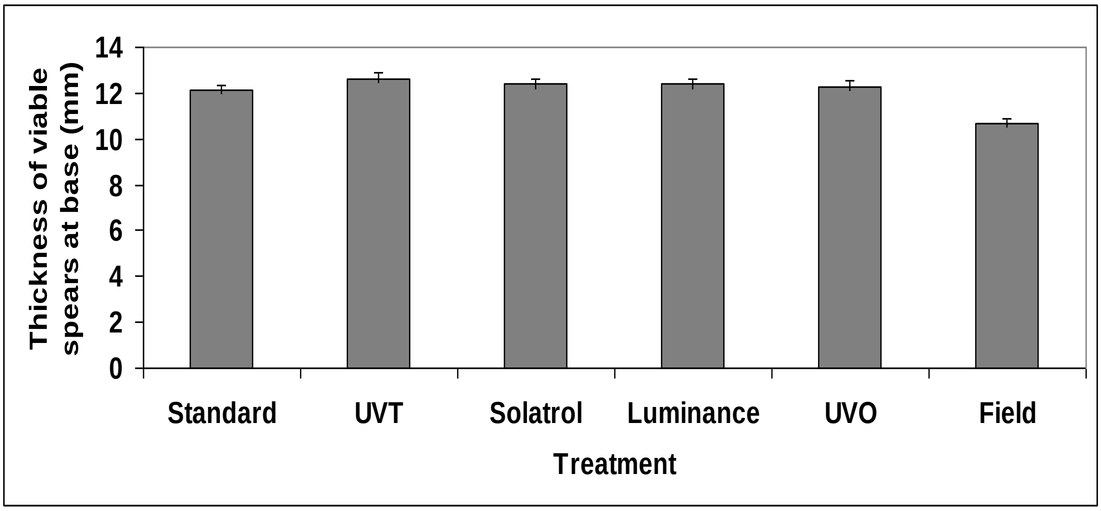
a)



b)



c)

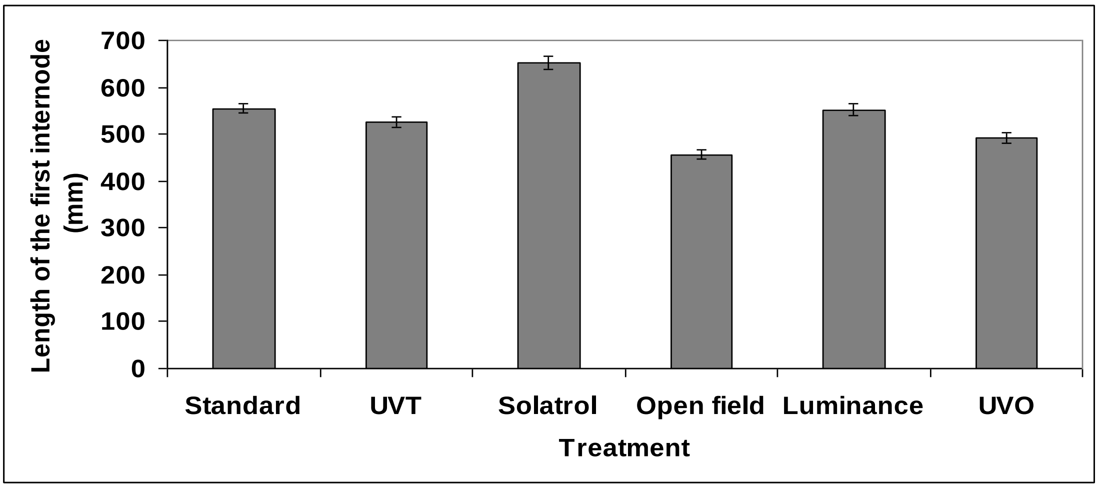


GYMLY

In the Open field crop the length of the first internode was significantly reduced when compared to all treatments (fig.3.a). Solatrol increased internode length when compared to all treatments (fig. 3.a). The total number of viable spears per plant was significantly increased in UV-opaque when compared to all remaining treatments except Standard (fig. 3.b). UVT significantly reduced the number of spears relative to all remaining treatments including the Open field crop (fig. 3.b). Open field produced a significant reduction in the total number of viable spears per plant >1cm when compared to all filter treatments (fig. 3.c). The number of aborted spears was significantly reduced in Open field relative to UV-opaque only (fig. 4.a). Although UV-opaque increased the number of aborted spears this was only significant relative to Open field (fig. 4.a). The thickness of viable spears at the base was reduced in Open field when compared to all filter treatments but this only represented a significant reduction when compared to Luminance (fig. 4.b). There was no significant difference in stem thickness between the 5 filter treatments (fig. 4.b).

Figure 3. Effect of treatments on (a) length of the first internode and (b) total number of viable spears per plant in Gymly. Each value is the mean > S.E. of 16 replicates.

a)



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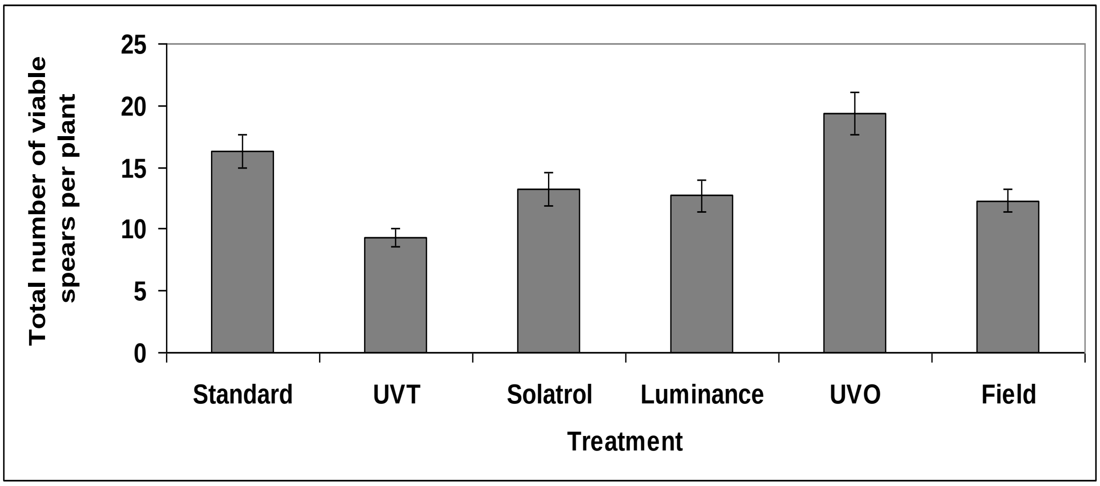
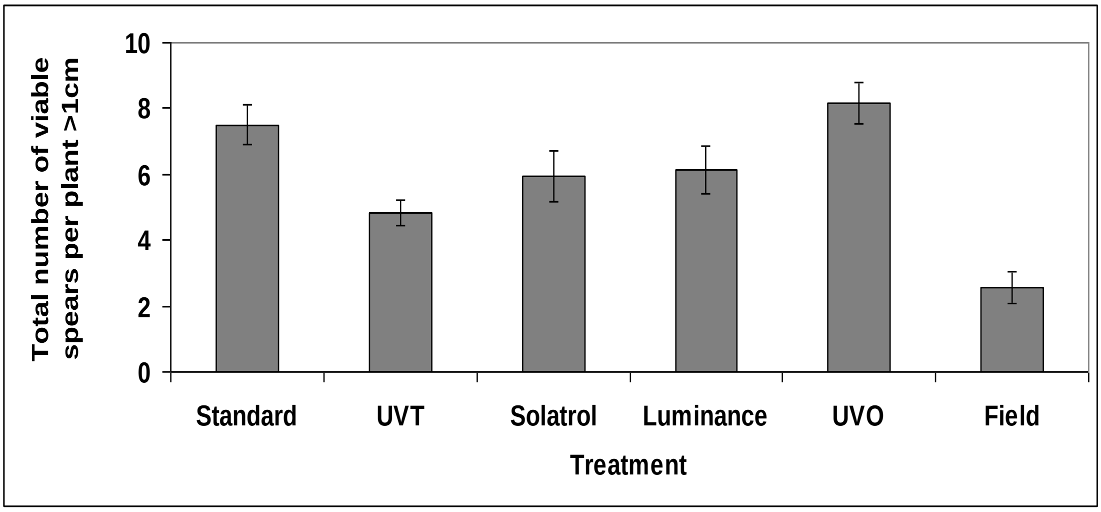
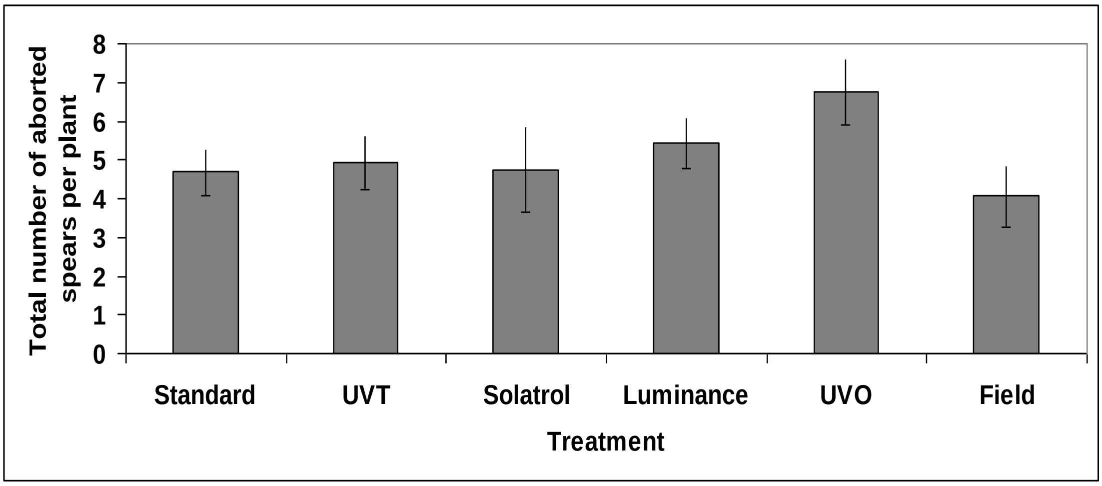


Figure 4. Effect of treatments on (a) number of viable spears per plant >1cm, (b) total number of aborted spears per plant and (c) thickness of viable spears at the base in Gymly. Each value is the mean $\geq$ S.E. of 16 replicates.

a)



b



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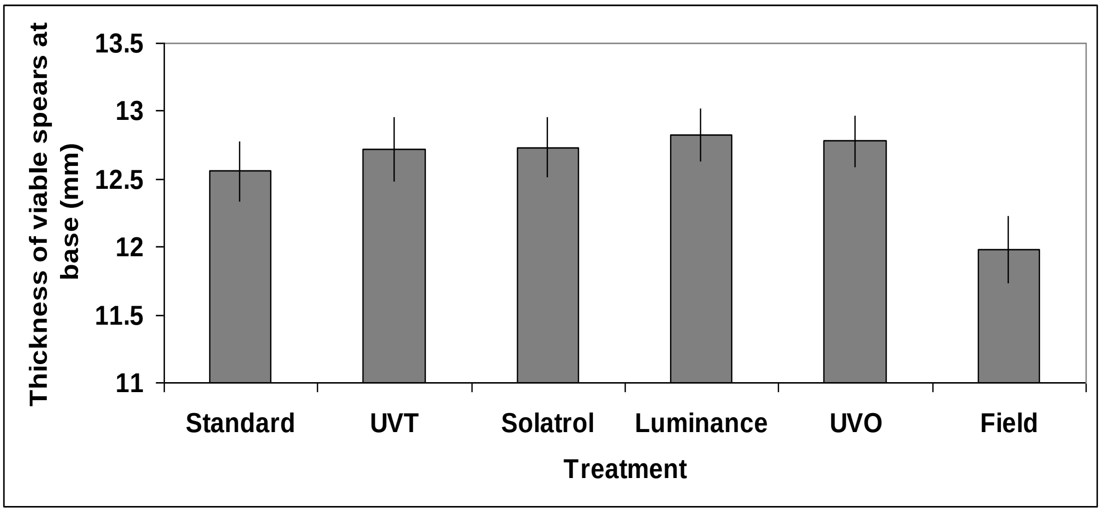


DISCUSSION

Asparagus is a high value specialty crop and the earliest producing spring vegetable. It currently is priced as a gourmet item and will remain in this category until growing, harvesting, and processing costs can be reduced. The cost to establish an asparagus field is substantial and for that reason new methods of bringing the productive season forward, increase quality and quantity of yield, reduce disease pressure and extend season are being sought. In a number of crops spectral filters have proved effective in delivering on some, or all, of the above requirements and for that reason a mid-term crop such as asparagus was included in this project.

The purpose of the first two year's trials was to first establish the crop and then to monitor the development of subsequent plant biomass, paying particular attention to the filters ability to accelerate plant establishment and susceptibility to pests and disease. In both Gymly and Jersey giant varieties the length of the first internode was significantly reduced in the Field crop (figs. 1.a. & 3.a). The number of viable spears per plant was significantly increased in both Standard and UVO treatments when compared to all remaining treatments in Jersey Giant (fig. 1.b). In the Gymly variety UVO increased viable spear numbers when compared to all remaining treatments except Standard. Standard increased spear numbers when compared to UVT and Field only (fig. 3.b). The number of recorded spears >1cm in diameter was significantly reduced in Field relative to all remaining treatments (figs. 2.a. & 4.a). In both varieties UVO produced the highest number of spears per plant >1cm in diameter, but this was only a significant increase relative to Field in Jersey giant (fig. 2.a) and in Gymly the increase was significant relative to all remaining treatments except Standard (fig. 4.a). There was no significant effect of treatments on the number of aborted spears in Gymly (fig. 2.b) but in Jersey giant Solatrol significantly reduced the number of aborted spears relative to all remaining treatments but Field (fig. 4.b). The thickness of viable spears was significantly reduced in the Field in Jersey giant when compared to all treatments (fig. 2.c). In Gymly the thickness of the spears was reduced relative to all treatments except Luminance (fig. 4.c).

Early results from both the first two seasons of the crop suggest that the spectral filters can modify plant development in economically beneficial ways. However, this will not be confirmed until the 2006 season when commercial harvests on the crop will begin.

Figure 5. Photo taken under Standard in early September 0f 2004.

Figure 6. Photo taken under UV-transparent in early September of 2004.

Figure 7. Photo taken under Solatrol in early September of 2004.

Figure 8. Photo taken in Field in early September of 2004.

Figure 9. Photo taken under Luminance in early September of 2004.

Figure 10. Photo taken under UV-opaque in early September of 2004.

Part 6. CULINARY HERBS AND ESSENTIAL OIL ANALYIS.

INTRODUCTION

Approximately 1,000 ha of herbs are cultivated in the UK and the potential for market growth is considerable since the majority of UK consumed produce is imported from Mediterranean countries. The industry primarily supplies the food-manufacturing sector, which accounts for 50-60% of total sales (fresh, dried, frozen and volatile oils) and is second only to the retail and catering sector; with a small market developing in the medicinal industry. Herb growers also supply the culinary industry, with the current market valued at approximately 32m and consumption increasing by about 10% per year. Both culinary and medicinal herbs are utilised in the food, cosmetic, pharmaceutical and beverage industries and are currently supplied between a variety of both small and large-scale herb producers throughout the UK.

A wide variety of herbs can be successfully cultivated in Northern Europe, with a number of exceptions, including plants grown for seed production, or plants with specific growth requirements. Incorporating the use of spectral filters into UK herb production may provide several benefits to UK growers. These include standard protection from the unpredictable climate and the ability to time production to more accurately meet market demand. Furthermore, there is preliminary evidence that suggests that a number of new spectral filters modify plant development in such a way as to improve herb quality and enhance essential oil production in an economically beneficial way.

The aim of the work in 2005 was to investigate how the use of specific filters would affect the quality of the plant grown under the different plastics, and how the plastics may influence essential oil production. To assess the impact on the quality of herbs basil, coriander, dill and fennel were sown in 9cm pots (10 seed per pot) filled with a peat-free substrate, and germinated in a glasshouse. After full cotyledon expansion the plants were moved into the 5 different plastic tunnels and a glasshouse which acted as a commercial control, and left in these locations until ready for marketing, when an assessment was made on plant quality.

After discussions at a British Herb Trade Association meeting in May 2005 it was decided to assess if the plastics would alter the essential oil composition, building on the data obtained for perennial herbs in previous years. It was recognised that both (a) the late decision to include this element and (b) the limited resource available for what is potentially very expensive research would mean that these assessments of oil quality would be limited in scale and focussed on a specific crop. Nonetheless, these initial data were felt to be valuable as indicating possible trends and areas for future research. Thus, with advice from the panel coriander was chosen as the target crop, It is known that in this herb the relative levels of aldehydes and alcohols present can affect taste, and high levels of camphor or linalool in coriander can give an ‘off’ taste. These elements of chemical composition can change with plant developmental stage, and between variety. Analyses were made of both a soil and pot grown coriander, with the ‘Santo’ cultivar grown in the soil under the 5 plastics and a field plot, and ‘Topf’ cultivar grown in 9cm pots in 5 tunnels and in a glasshouse.

Over a 4 week period foliage samples were taken from the plants and steam distilled, then the essential oils collected and stored in a fridge in sealed containers. When all the foliage samples had been processed, they were despatched to by Dr. Ray Marriot at Botanix for analysis by gas chromatography. This allowed identification particular components of the oil samples, and estimation of their relative concentrations. Clearly the resulting datasets is too large and complex to present in full here, comprising data for many components. To summarise key trends in response to plastics the data are summarised here as (i) the ratio of aldehydes to alcohols, and (ii) the relative quantities of camphor and linalool to total aldehydes and alcohols.

OBJECTIVES

To identify a filter(s) that produces a compact, well branched product that makes an attractive product, and assess effect of plastics on essential oil composition.

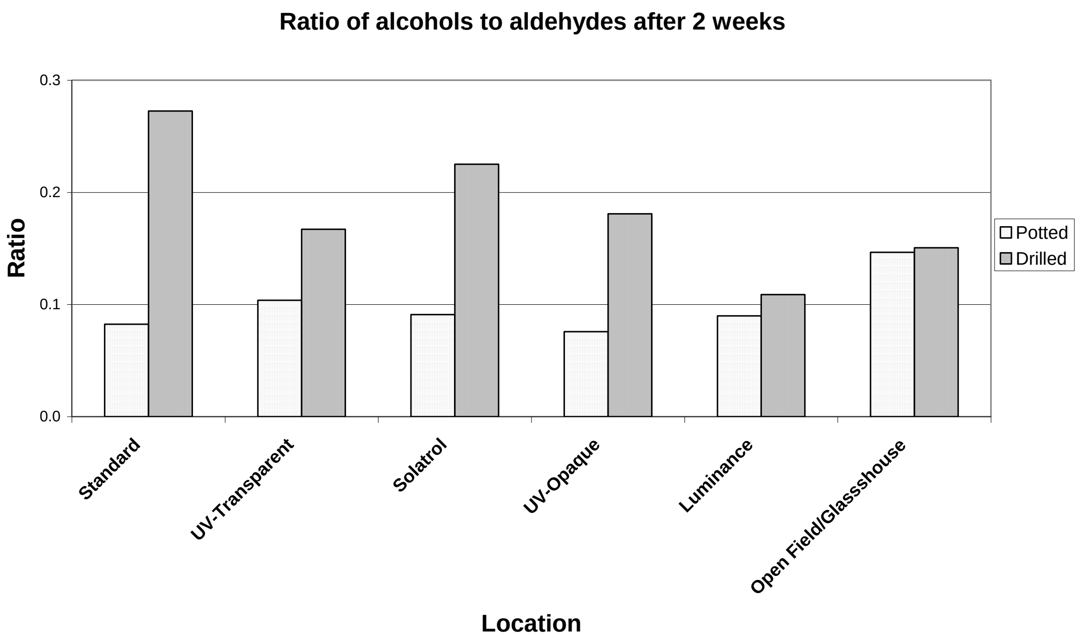
RESULTS

The differences between the different plastics in relation to plant quality were not as pronounced as expected from results with other species. The greatest difference was seen in the glasshouse grown crops which exhibited softer growth than the tunnel grown herbs, which tended to be stockier and more robust. This was probably due more to the higher average temperatures experienced in the greenhouse, in addition to the effects of the wind in the tunnels resulting in slower growing, but tougher plants. This impact was most noticeable in coriander, with the differences in growth in the other herbs being less pronounced.

Figure 1. Coriander crop produced under all five spectral filters and under commercial glass.

Standard UVT Solatrol Luminance UVO Commercial glass

a)



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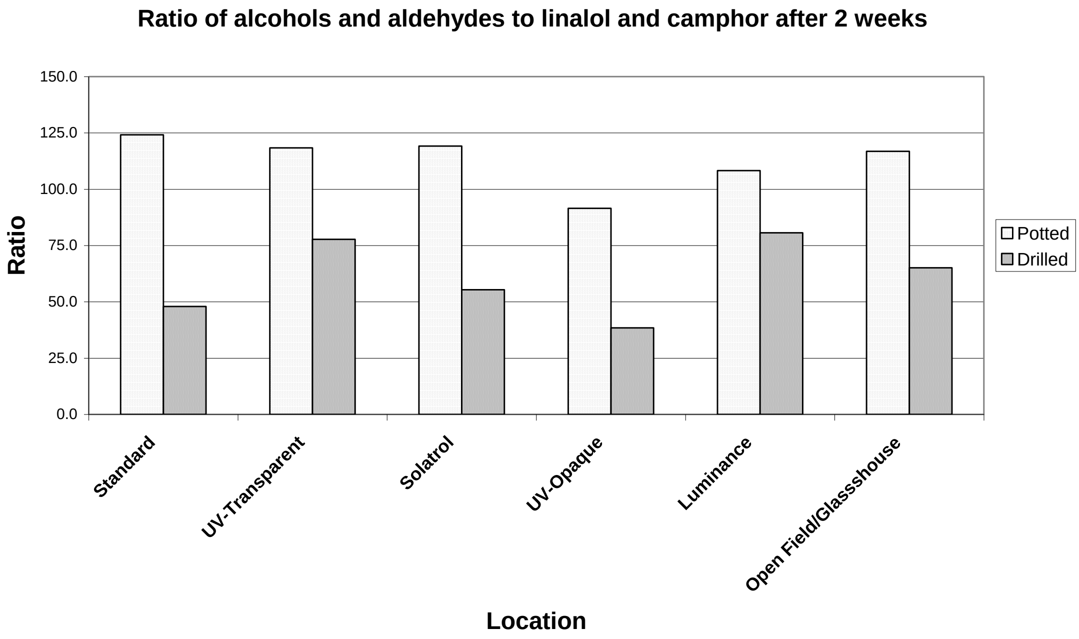
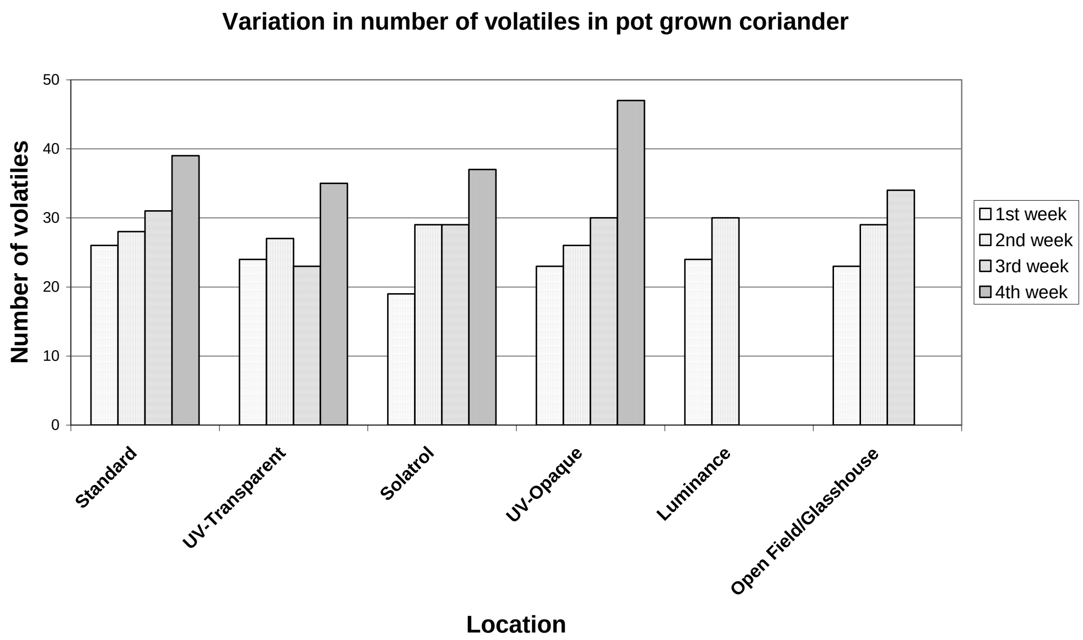


Figure 2. Ratio of sum of all alcohols to sum of all aldehydes in coriander after 2 weeks (a), and ratio of sum of alcohols and aldehydes to sum of linalool and camphor in coriander after 2 weeks (b).

a)



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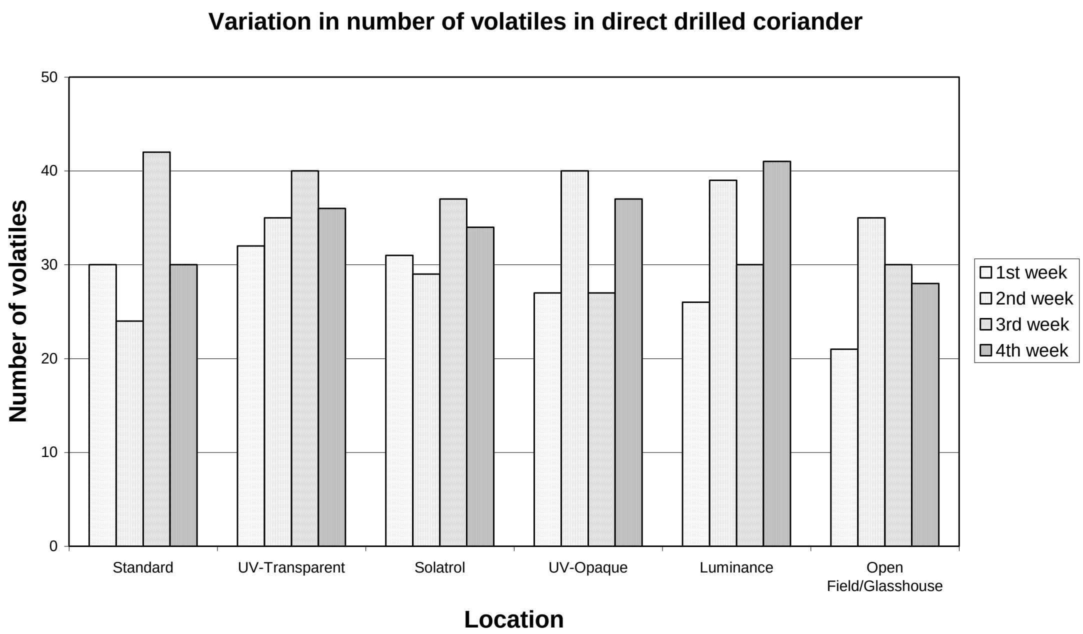

Figure 3. Variation in number of volatiles detected by gas chromatography in pot grown coriander (a), and direct drilled coriander (b) over a 4 week period under different plastics, and either a field or glasshouse control.

It was recognised from the outset that the analyses of oil composition in coriander was restricted to a focussed scoping exercise due to limitations on resources for this element within this years work programme. The data confirmed that oil composition varied substantially between the two coriander cultivars and over the course of plant development. There is a clear contrast here with the analyses performed with perennial herbs in previous seasons, where single harvests and chemical analyses were made late in the season. For those relatively slow-growing herbs such analyses were considered representative of material at the time of normal commercial harvest. However, for a fast-growing herb like coriander the 'baseline' composition against which any effect of plastics could be determined itself varied with time in the season, stage of development and cultivar. In addition, the minute quantities of oil produced from each sample (~0.25ml) prevented accurate calculation of oil yield as a % of weight as we did with the perennial herbs the previous year. Thus, the data from this single season need to be interpreted with a degree of caution, and seen as indicative of changes that merit further investigation. Within those limits, some interesting patterns were evident, and while it was clear the relative levels of essential oils are heavily influenced by the choice of cultivar (or cultivation), the plastics produced consistent effects on certain aspects of oil chemistry.

It can bee seen in Fig. 2a that the ratio of alcohols to aldehydes was lowest in the pot grown coriander when plants grown under UV-opaque compared to the other plastics, and this effect was more pronounced when the relative levels of camphor/linalool to alcohols/aldehydes were compared. As can be seen in Fig.2b the change in the ratio of these essential oils was again most pronounced under UV-opaque, with both the soil and pot grown material.

Another interesting pattern seen in the results was the rise in the number of volatiles produced by the coriander as it matured over the 4 week harvesting period. This was most clearly seen in the pot grown coriander (Fig. 3d) grown under the UV-opaque plastic where the number of volatiles increased from 23 in 1st sample, to 47 in 4th sample. The rise is less dramatic in the other samples (from 26 to 35 under UV-transparent plastic), and the pattern was less distinctive in the field grown coriander (Fig. 3c). This may be a result of the field grown crop maturing faster than the pot grown coriander, as it is known that as coriander matures and switches from vegetative growth to flowering the number and type of essential oils produced in the plants changes rapidly. Not all of these volatiles contribute towards the taste and smell of coriander, but this change can affect the quality of the essential oils extracted.

Overall, this initial investigation into the impact of plastics on essential oil composition fulfilled its aim of indicating that there are interesting effects of the type of spectrally modifying plastic on essential oil composition in coriander, and that this interacts with the age of the plant. The work in 2005 also confirmed that this is a complex area of investigation that is hard to deliver within the context of a multi-sector project such as CP19. Thus, research to advance this area further through more detailed work is probably best achieved through a separate project focussed on oil chemistry and its consequences for taste and quality as perceived by growers and consumers.

