

Use of Ultraviolet-C (UV-C) for powdery mildew control in greenhouse grown gerbera

In Ontario, gerbera daisy (*Gerbera jamesonii*) is produced mainly under greenhouse conditions. Powdery mildew is a significant fungal disease in gerbera that may be caused by either *Erysiphe cichoracearum* or *Podosphaera fusca* (Daughtrey *et al.*, 1995). This disease affects all plant parts and reductions in growth and quality are the most important components of economic loss. Most greenhouses use repeated applications of fungicides to manage the disease (Larson and Nesheim, 2000). However alternative methods for disease management are now expected by consumers due to increasing concerns that fungicides negatively impact the environment and human health (Gullino *et al.*, 1999).

Artificial Ultraviolet C (UV-C) lamps have been shown to be very effective in the laboratory for destroying bacteria, molds, viruses and some plant pests (e.g. spider mites) as well as other biological contaminants in air, liquids or on solid surfaces. UV-C has a wavelength between 185 and 280 nm (short wave ultraviolet radiation). UV-C rays are able to penetrate the outer membrane of microbes and damage their DNA essentially killing them. The same appears to be true for plant pests and their eggs (the smaller the pest the more susceptible they appear to be to UV-C). The specific wavelength of 253.7 nm has been demonstrated to denature the DNA of pathogens so they can no longer reproduce.

Based on this information, this research initiative is focused on the implementation of a process which employs UV-C radiation for the control of powdery mildew in Gerbera. Some of the proposed benefits of this approach are: saving on pesticide sprays (at least 50%); improved crop quality; no residue on the crops; less stress for the crops; no re-entry time; ensuring a healthy environment for greenhouse workers; biological control agents are not harmed and; UV-C is effective against a whole host of organisms including viruses, bacteria, fungi and insect pests and so can have other benefits in addition to powdery mildew control.

The effect of UV-C for the control of powdery mildew in gerbera daisy has not been investigated. Since UV-C was effective in controlling powdery mildew in other crops such as roses (Horticultural News, January-February 2012) and prunus (Minden, 2011), among others, it is hypothesized that adding UV-C to current greenhouse practices might decrease disease severity caused by *E. cichoracearum* or *P. fusca*. The main objective of this study then is to evaluate the efficacy of UV-C for the management of powdery mildew in gerbera daisy grown under greenhouse conditions in Ontario.

RESEARCH PLAN

This project will evaluate:

- 1) Can precise doses of UV-C be used to treat plants directly in order to eradicate or control powdery mildew without harming the plants;
- 2) Will UV-C treatment result in fewer pests and increased flower yields;
- 3) What is the amount of UV-C light (Joules) during a period of 24 hours which will control pathogen growth without harming the plant;

- 4) Is it better to use small, regular doses of UV-C or a single, large dose;
- 5) Would plant size have an effect on UV-C effectiveness;
- 6) Would younger plant tissue be less able to tolerate UV-C exposure;
- 7) What is the best way to arrange the UV-C lights so that all plants are being exposed evenly from top to bottom?

Many factors will need to be evaluated in this study: strength / distance of UV light source; duration of exposure; location of light source and angles; use of a mobile UV-C lamp that could travel up and down the rows of crops periodically; continuous dose or short intermittent doses; time in between doses; when to dose the crops (specific time of day). Several tasks will therefore be carried out to evaluate the effect of UV-C on powdery mildew development in gerbera plants. Gerbera varieties Nuance, Soul Sister and Bayadere, which have different susceptibilities to powdery mildew will be evaluated in this study. Four rows of plants (250 plants per row) will be used in which two rows will be treated with UV-C light and two rows will serve as negative controls and not receive UV-C exposure, for each variety. Symptoms of powdery mildew developing on plants from natural inoculum will then be determined. These evaluations will take place on a weekly basis. In addition to disease severity the effect of UV-C on horticultural traits of gerbera flowers will also be evaluated since research on other crops has provided evidence that UV-C can improve the health of the plant and could therefore affect flower quality and yields.

During the trial, plants (trial and control) will be evaluated for disease. For this purpose a rating scale will be employed using a scale of 0 – 5, based on disease severity:

- 0 no disease symptoms
- 1 <10% of leaf surface coverage with powdery mildew
- 2 10-25% of leaf surface covered with powdery mildew
- 3 25-50% of leaf surface coverage with powdery mildew
- 4 50-75% of leaf surface coverage with powdery mildew
- 5 >75% of leaf surface coverage with powdery mildew

In addition to rating plant disease severity, we will evaluate quality of flowers by measuring flower size and color as well as stem length and stem strength and comparing between test and control plants. In this way the effect of UV-C on flower quality can also be measured.

Effect of UV-C on the incidence of powdery mildew on Gerbera strains Soul Sister, Nuance and Bayadere.

In this trial (duration = 1 year) four rows of plants will be evaluated for the incidence of powdery mildew following daily treatment with Ultraviolet-C radiation for each variety of gerbera (Soul Sister, Nuance and Bayadere). Two rows of plants will remain untreated (control) and two rows of plants will receive a daily dose of UV-C radiation (once per day, every day at 7:30 am). To accomplish this goal, eight Clean Light XL modules will be mounted onto currently used picking cart approximately 6 inches above the top and down the sides of the crop canopy (**Figure 1 below**). To dose the plants the picking cart will be moved down the rows of crops at a rate which will allow them to receive a dose of UV-C necessary to kill powdery mildew disease. Initial dose of 5.2 Joules was increased by 50% when it was determined to be ineffective. Dose was then increased to 7.8 Joules. This dose was also ineffective and so the UV-C was again increased by 50% up to 11.7 Joules. At the highest dose evaluated plants began to be damaged and for this reason no further increase in Joules could be evaluated.



Figure 1. Light arrangement for trial to provide exposure to top and along sides of crop canopy. Light modules added to picking carts in specific arrangement to provide optimal coverage of plants while dosing with ultraviolet C. Trial will include gerbera varieties Nuance, Bayadere and Soul Sister.

Three varieties of gerbera are being used in the trial: Soul Sister, Nuance and Bayadere. **Figure 2** demonstrates the arrangement of each of these varieties in the greenhouse and locations of treated and untreated control plants.

House 2 Nuance Treated UVC, North		House 3 Soul Sister Control, South
House 2 Nuance Treated UVC, North		House 3 Soul Sister Control, South
House 2 Nuance, North (not included in trial)		House 3 Soul Sister, South (not included in trial)
House 2 Nuance Control, North		House 3 Soul Sister Teated UVC, South
House 2 Nuance Control, North		House 3 Soul Sister Teated UVC, South
House 2 Bayadere Control, North		House 3 Bayadere Treated UVC, South
House 2 Bayadere Control, North		House 3 Bayadere Treated UVC, South

Figure 2. Test layout in J1 greenhouse for trial testing ultraviolet C light modules on gerbera varieties Nuance, Soul Sister and Bayadere. In this phase of the trial four UV-C light modules will surround each row of plants being treated to better cover plants on both the tops and penetrating into sides of foliage. Three varieties will be evaluated: Nuance and two varieties newly introduced into the greenhouse: Bayadere and Soul Sister. The Bayadere and Soul Sister are young plants and will allow us to also evaluate the effect of UV-C on younger plant tissue.



Figure 3. Use of UV-C in the greenhouse. This figure demonstrates the use of UV-C in the greenhouse to treat gerbera. Lights are turned on and allowed to warm up for 30 seconds prior to use. Growers treating the plants are required to wear both protective, tightly woven clothing and a face shield which offers protection against ultraviolet radiation (polycarbonate material). The dosage ranged from ~5 to 12 Joules total per row of plants. The smallest dose (5.2 Joules) is the dosage of UV-C demonstrated to kill fungal mycelium while not harming plant tissues in the literature.



Figure 4. Gerbera varieties chosen for trial. Photos of each of the three varieties of gerbera used in trial, including: Bayadere; Soul Sister and Nuance. Lower left photo is a shot of Soul Sister variety showing young healthy plants with no signs of powdery mildew disease. As these plants are at different developmental stages when introduced into the trial, it allowed us to evaluate the effect of UV-C on plants of different ages, developmental stages and degrees of canopy density.

RESULTS

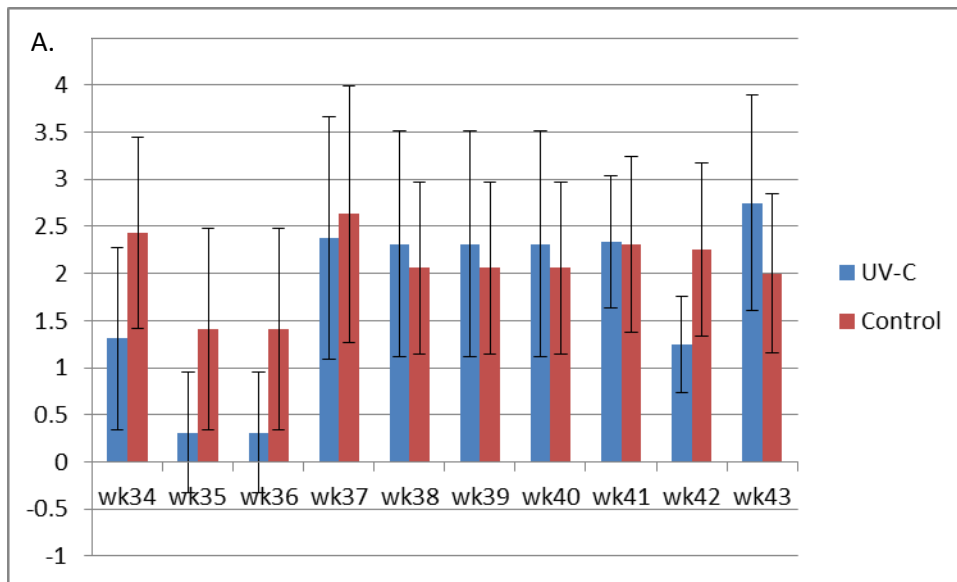
Powdery Mildew

Both the severity and incidence of powdery mildew was evaluated on Ultraviolet-C treated and untreated control plants. Disease **severity** can be defined as the proportion of a plant area that is affected by the disease. For example, on a single plant how much of the leaf surface is covered with powdery mildew. The **incidence** of a disease can then be defined as the proportion of a plant community that is diseased. For example in a given row of gerbera, how many plants in that row are found to have signs of powdery mildew disease out of the total number of plants.

Table 1. Powdery mildew severity on Ultraviolet-C treated Soul Sister gerbera leaves

Date	Ultraviolet C Treated*	Control*
Week 34	1.31 ± 0.97	2.43 ± 1.01
Week 35	0.31 ± 0.64	1.41 ± 1.07
Week 36	0.31 ± 0.64	1.41 ± 1.07
Week 37	2.38 ± 1.29	2.63 ± 1.36
Week 38	2.31 ± 1.20	2.06 ± 0.91
Week 39	2.31 ± 1.20	2.06 ± 0.91
Week 40	2.31 ± 1.20	2.06 ± 0.91
Week 41	2.34 ± 0.70	2.31 ± 0.93
Week 42	1.25 ± 0.51	2.25 ± 0.92
Week 43	2.75 ± 1.14	2.00 ± 0.84
Week 44	2.69 ± 1.28	1.88 ± 0.79
Week 45	2.66 ± 0.79	2.13 ± 0.79
Week 46	2.69 ± 0.97	2.06 ± 0.76
Week 47	2.38 ± 0.94	1.91 ± 0.86
Week 48	2.91 ± 0.96	2.06 ± 0.88
Week 49	2.50 ± 0.62	1.94 ± 0.72
Week 50	2.38 ± 0.49	2.00 ± 0.80
Week 51	1.66 ± 0.65	2.13 ± 0.91
Week 52	1.50 ± 0.57	1.84 ± 0.68
Week 1	1.47 ± 0.51	1.75 ± 0.57
Week 2	1.38 ± 0.55	1.56 ± 0.72
Week 3	1.41 ± 0.61	2.00 ± 1.16
Week 4	1.88 ± 1.07	1.69 ± 0.86
Week 5	2.13 ± 1.36	2.13 ± 0.94
Week 6	2.97 ± 1.43	2.59 ± 1.27

*Data represents the mean ± standard deviation of disease severity on 32 randomly selected leaves



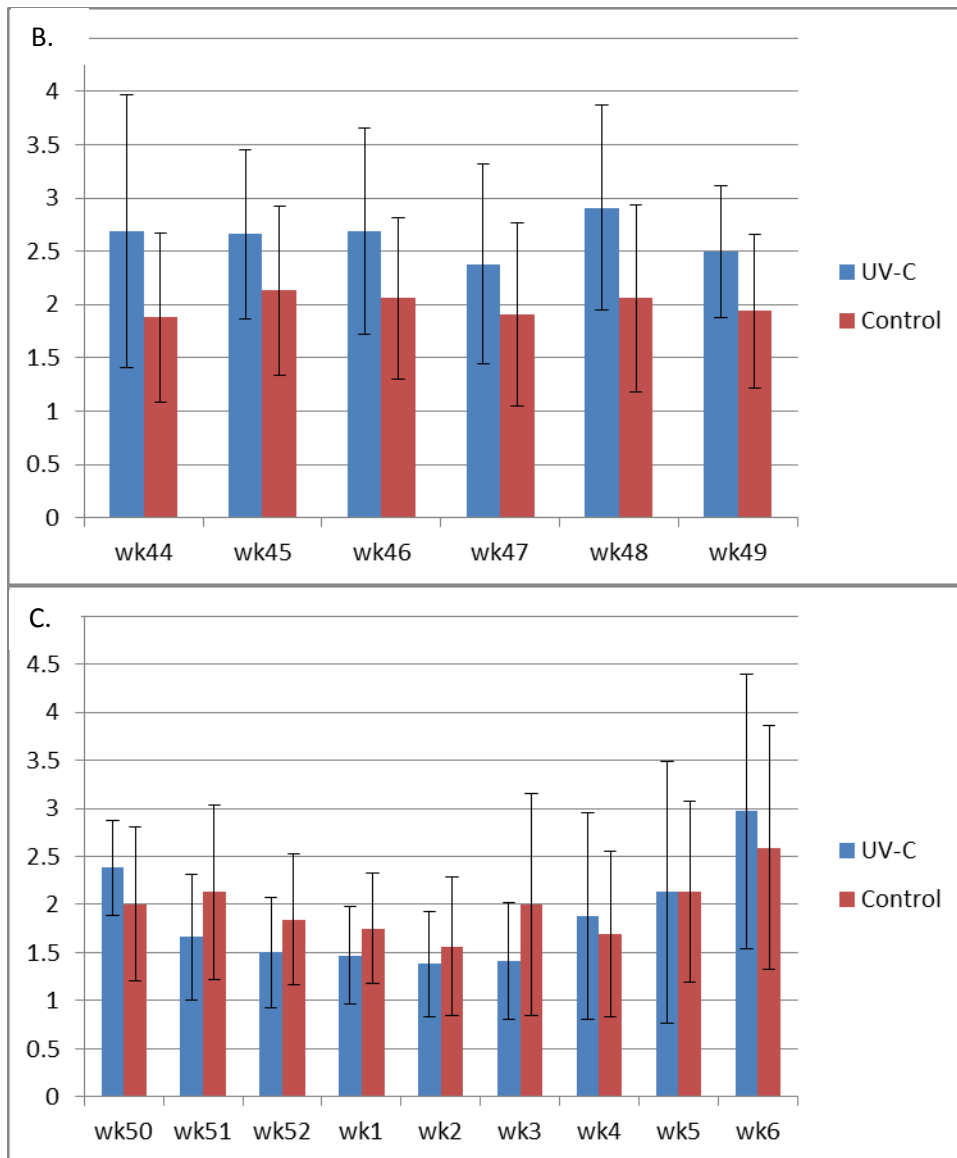


Figure 5. Powdery mildew severity on gerbera variety Soul Sister. A. Weeks 34 through 43. Data represent the mean \pm standard deviation of powdery mildew severity on 32 randomly selected plants. Powdery mildew decreased on UV-C treated gerbera variety “Soul Sister” from week 34 through week 37. On week 38 begin to see a slightly higher amount of powdery mildew on UV-C treated gerbera leaves, which continued through week 41. On week 42 the amount of powdery mildew on UV-C treated Soul Sister is 44% lower than what is observed on control plants, however this disappears again in week 43 with powdery mildew levels being higher on UV-C treated plants. **B. Weeks 44 through 49.** Powdery mildew consistently higher on UV-C treated gerbera. **C. Weeks 50 through 6.** Beginning to see a decline in powdery mildew on UV-C treated plants on week 51 which continues through week 3. In week 4 we again observe a higher amount of powdery mildew on UV-C treated Soul Sister. No difference in mildew on week 5 of the trial with higher amounts observed on treated plants in week 6.

As shown in **Figure 5** there was no statistically significant differences in the disease severity between UV-C treated Soul Sister and control plants.

Table 2. Powdery mildew incidence on Ultraviolet-C treated Soul Sister gerbera leaves

Date	Ultraviolet-C treated	Control
Week 50	30%	30%
Week 51	20%	25%
Week 52	10%	15%
Week 1	10%	15%
Week 2	20%	40%
Week 3	20%	40%
Week 4	20%	40%
Week 5	40%	40%
Week 6	45%	40%

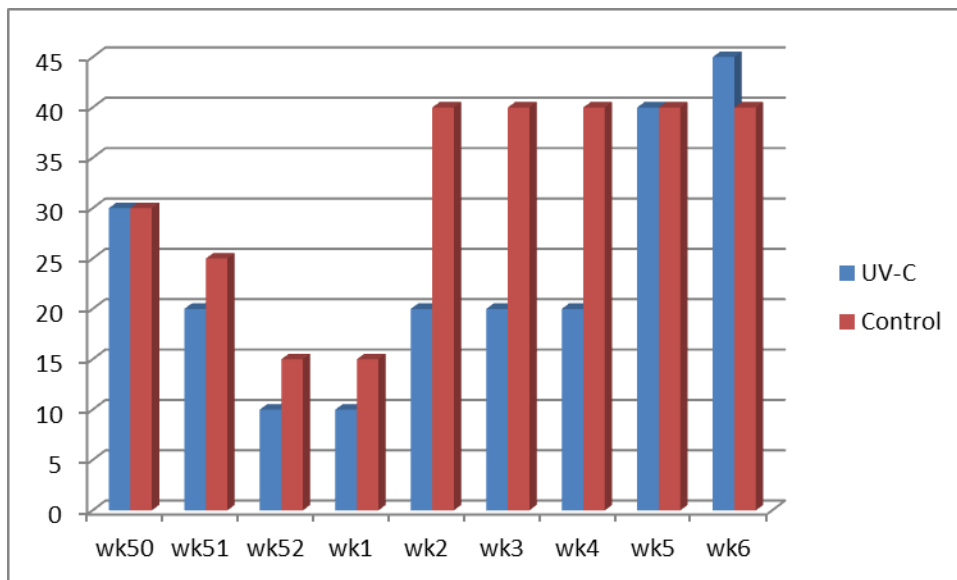
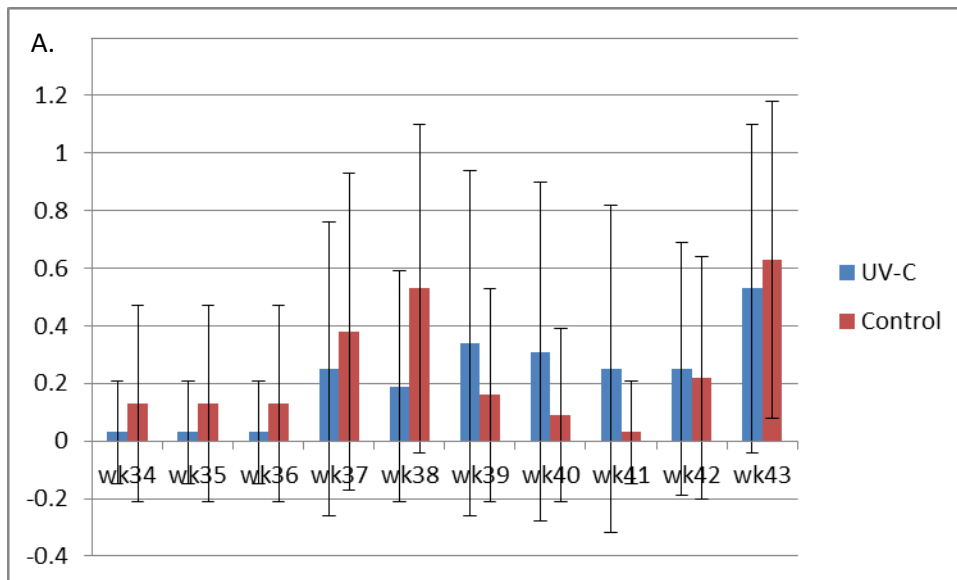


Figure 6. Powdery mildew incidence on UV-C treated Soul Sister for weeks 50 through 4. Similar to disease severity the incidence of powdery mildew begins to decrease on UV-C treated plants on week 51. This trend continues through week 4 of the trial. No difference in disease incidence on week 5 of the trial with higher disease on UV-C treated plants in week 6.

Similar to disease severity, there was no consistent difference in the disease incidence on Soul Sister whether treated with UV-C or remaining untreated (**Figure 6**).

Table 3. Powdery mildew severity on Ultraviolet-C treated Nuance gerbera leaves

Date	Ultraviolet C Treated	Control
Week 34	0.03 ± 0.18	0.13 ± 0.34
Week 35	0.03 ± 0.18	0.13 ± 0.34
Week 36	0.03 ± 0.18	0.13 ± 0.34
Week 37	0.25 ± 0.51	0.38 ± 0.55
Week 38	0.19 ± 0.40	0.53 ± 0.57
Week39	0.34 ± 0.60	0.16 ± 0.37
Week 40	0.31 ± 0.59	0.09 ± 0.30
Week 41	0.25 ± 0.57	0.03 ± 0.18
Week 42	0.25 ± 0.44	0.22 ± 0.42
Week 43	0.53 ± 0.57	0.63 ± 0.55
Week 44	1.00 ± 0.00	1.00 ± 0.00
Week 45	0.56 ± 0.56	0.84 ± 0.45
Week 46	0.75 ± 0.44	1.06 ± 0.35
Week 47	0.91 ± 0.53	0.88 ± 0.42
Week 48	1.03 ± 0.18	1.09 ± 0.39
Week 49	0.91 ± 0.39	0.91 ± 0.59
Week 50	0.91 ± 0.39	0.91 ± 0.59
Week 51	0.91 ± 0.39	0.91 ± 0.59
Week 52	0.91 ± 0.39	0.91 ± 0.59
Week 1	0.91 ± 0.39	0.91 ± 0.59
Week 2	1.00 ± 0.00	1.00 ± 0.00
Week 3	1.41 ± 0.76	1.06 ± 0.76
Week 4	1.19 ± 0.47	1.53 ± 0.84
Week 5	1.56 ± 0.98	1.59 ± 1.04
Week 6	1.47 ± 0.92	1.81 ± 1.18



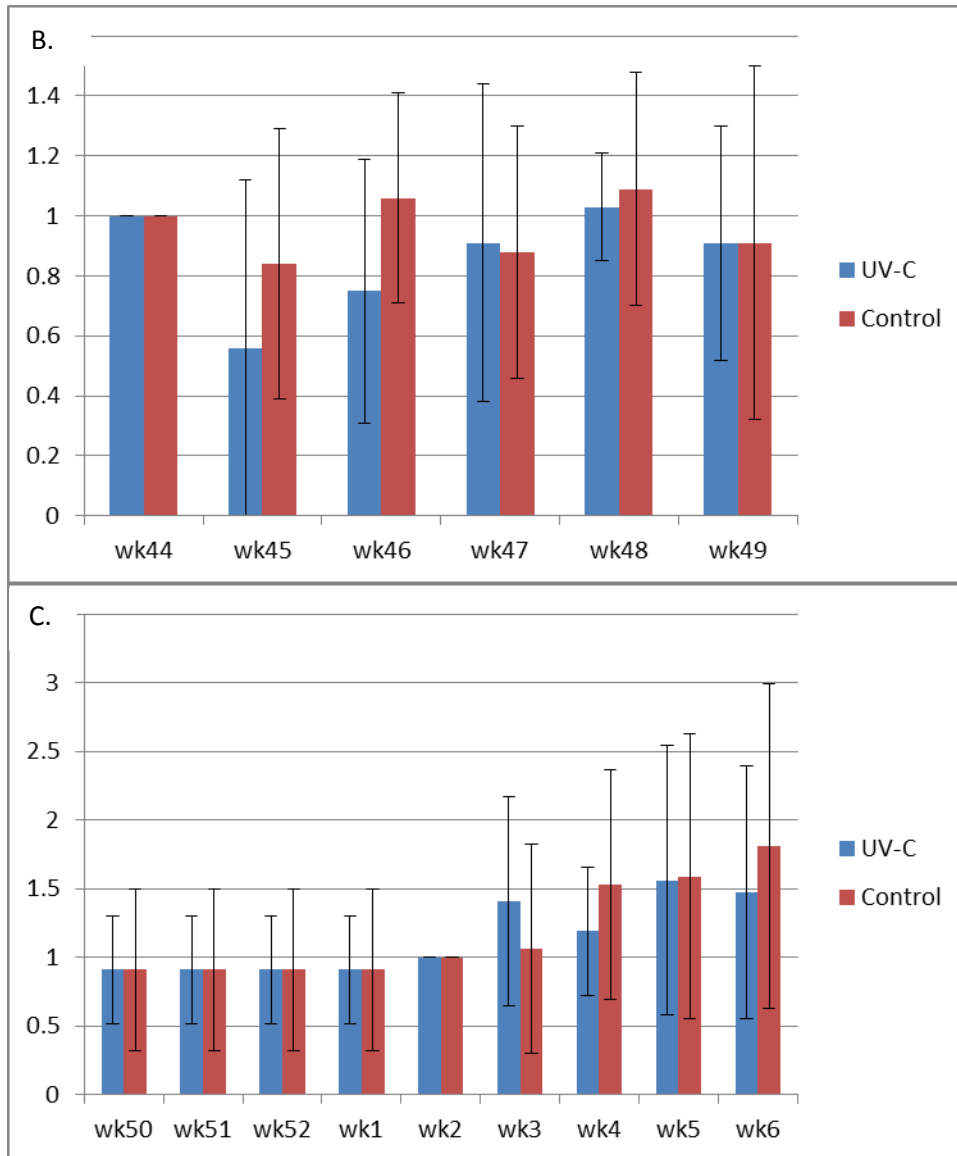


Figure 7. Powdery mildew severity on leaves of gerbera variety Nuance. A. Weeks 34 through 43. Data represents the mean \pm standard deviation of powdery mildew severity on 32 randomly selected plants. Severity of powdery mildew disease is decreased on treated plants until week 38 at which time the amount of powdery mildew becomes slightly higher on UV-C treated plants (weeks 39-42). Similar to Soul Sister, powdery mildew is higher on control plants in week 43. **B. Weeks 44 through 49.** Powdery mildew was reduced on UV-C-treated plants on weeks 45, 46, 48, and 49, however there is no clear relationship between the severity of powdery mildew and UV-C treatment on Nuance at this time. **C. Weeks 50 through 6.** No statistically significant difference in powdery mildew severity on UV-C treated plants versus what is observed on controls. In week 3 see higher powdery mildew on UV-C treated Nuance, which disappears in week 4 with lower powdery mildew on UV-C treated plants.

Similar to other varieties there was no statistically significant differences in disease severity on Nuance between UV-C treated versus control plants (**Figure 7**).

Table 4. Powdery mildew incidence on Ultraviolet-C treated Nuance gerbera leaves

Date	Ultraviolet-C treated	Control
Week 50	0%	0%
Week 51	0%	0%
Week 52	0%	0%
Week 1	0%	0%
Week 2	0%	0%
Week 3	0%	0%
Week 4	0%	0%
Week 5	0%	0%
Week 6	0%	40%

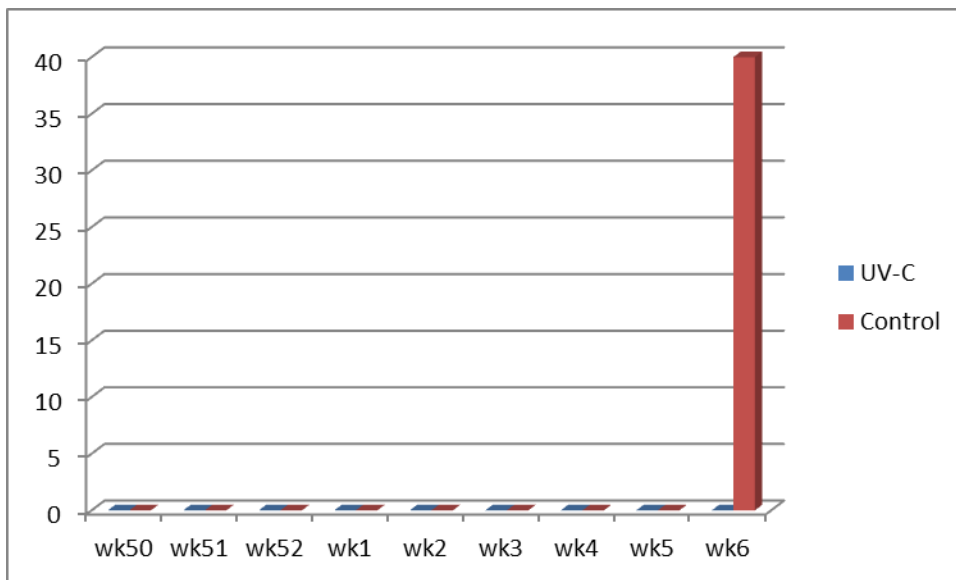
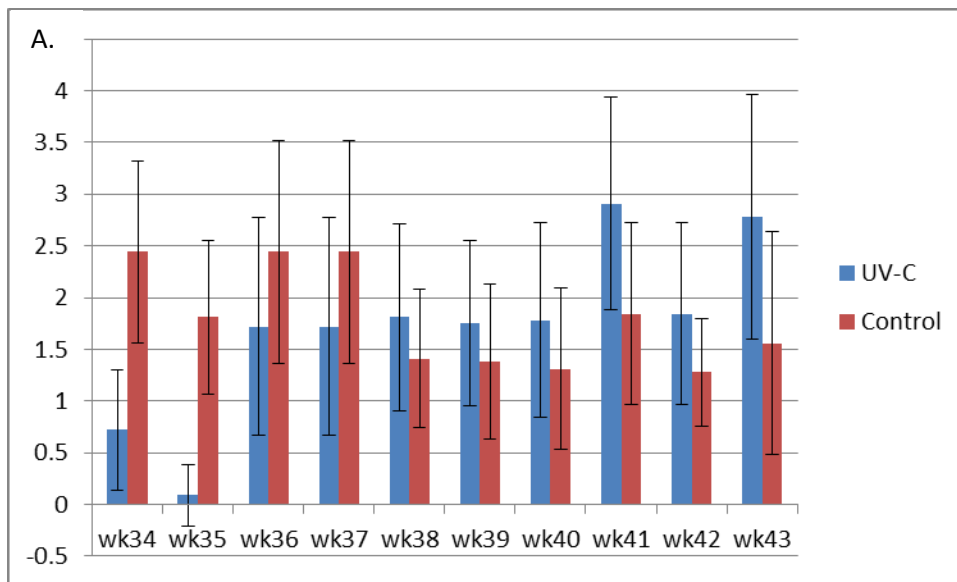


Figure 8. Powdery mildew incidence on Nuance. Disease incidence was determined on UV-C treated plants and controls for weeks 50 through 6. Disease incidence was very low during this time period of the trial and no difference was observed between treated and control plants. In week 6 do observe a much higher disease incidence on control plants than what was observed on treated plants, however this observation seems limited to this week of the trial.

Disease incidence was very low on Nuance variety. It was observed on week 6 that disease incidence increased by 40% on control plants. This is likely unrelated to UV-C treatment and so it is concluded here that UV-C treatment does not affect disease incidence of powdery mildew in gerbera daisy variety Nuance (**Figure 8**).

Table 5. Powdery mildew severity on Ultraviolet-C treated Bayadere gerbera leaves

Date	Ultraviolet C Treated	Control
Week 34	0.72 ± 0.58	2.44 ± 0.88
Week 35	0.09 ± 0.30	1.81 ± 0.74
Week 36	1.72 ± 1.05	2.44 ± 1.08
Week 37	1.72 ± 1.05	2.44 ± 1.08
Week 38	1.81 ± 0.90	1.41 ± 0.67
Week 39	1.75 ± 0.80	1.38 ± 0.75
Week 40	1.78 ± 0.94	1.31 ± 0.78
Week 41	2.91 ± 1.03	1.84 ± 0.88
Week 42	1.84 ± 0.88	1.28 ± 0.52
Week 43	2.78 ± 1.18	1.56 ± 1.08
Week 44	2.97 ± 0.97	2.19 ± 0.82
Week 45	2.88 ± 0.94	2.03 ± 0.93
Week 46	3.00 ± 0.92	1.84 ± 0.99
Week 47	2.59 ± 0.91	1.94 ± 1.22
Week 48	2.41 ± 0.95	1.94 ± 1.13
Week 49	2.28 ± 0.85	1.56 ± 0.84
Week 50	2.28 ± 0.85	1.56 ± 0.84
Week 51	2.28 ± 0.85	1.56 ± 0.84
Week 52	2.28 ± 0.85	1.56 ± 0.84
Week 1	2.28 ± 0.85	1.56 ± 0.84
Week 2	1.56 ± 0.67	1.44 ± 0.62
Week 3	1.84 ± 1.05	1.50 ± 0.72
Week 4	1.81 ± 0.97	1.69 ± 0.97
Week 5	2.00 ± 1.16	1.59 ± 1.13
Week 6	2.41 ± 1.54	2.25 ± 1.32



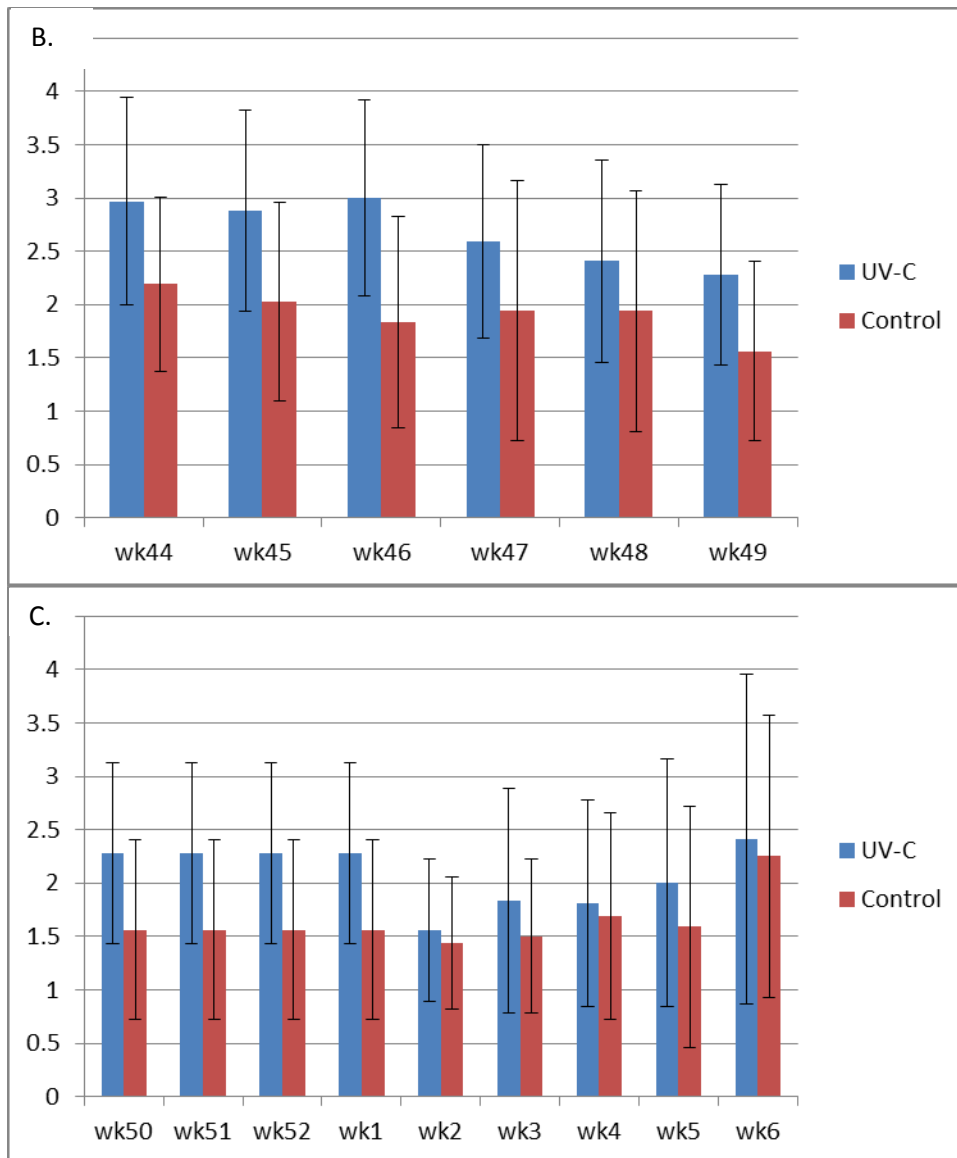


Figure 9. Severity of powdery mildew on Bayadere leaves following daily treatments of ultraviolet C. A. Weeks 34 through 43. Data represent the mean \pm standard deviation of powdery mildew severity on 32 randomly selected plants. In this variety powdery mildew severity was reduced on leaves treated with ultraviolet C compared to untreated controls for weeks 34 through 37. Similar to Soul Sister on week 38 begin to see an increase in powdery mildew on treated plants over what is observed on control gerbera, which continues through week 49. **B. Weeks 44-49.** Consistently observe higher powdery mildew on UV-C treated Bayadere versus controls. **C. Weeks 50 through 6.** Consistently observe higher powdery mildew on UV-C treated Bayadere versus controls.

Similar to other varieties observed a decrease of powdery mildew severity on UV-C treated plants in the first four weeks of the trial. This observation did not continue and it was observed that there was no statistically significant differences between disease on UV-C treated or control Bayadere (**Figure 9**).

Table 6. Powdery mildew incidence on Ultraviolet-C treated Bayadere gerbera leaves

Date	Ultraviolet-C treated	Control
Week 50	40%	40%
Week 51	40%	40%
Week 52	40%	40%
Week 1	40%	40%
Week 2	40%	20%
Week 3	40%	20%
Week 4	40%	0%
Week 5	40%	20%
Week 6	40%	60%

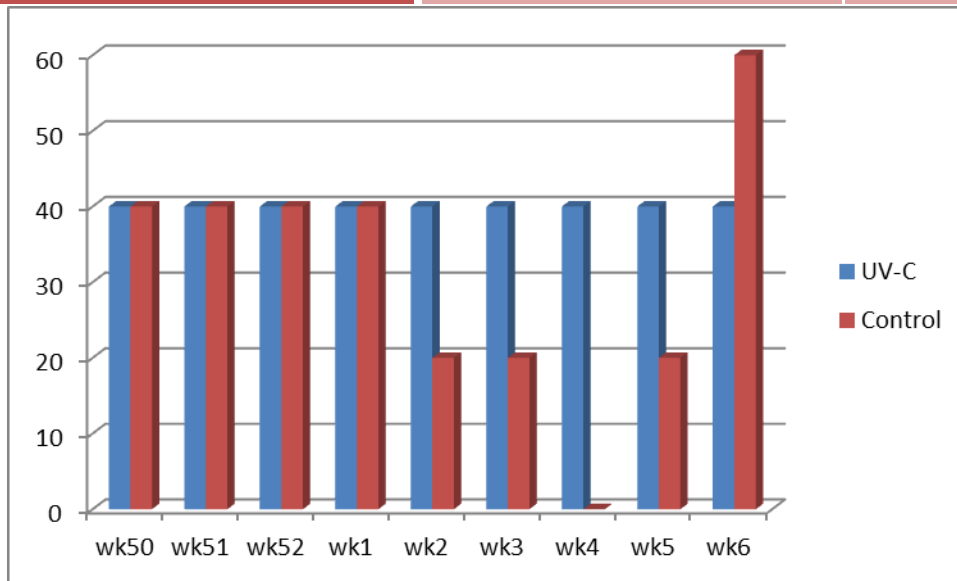


Figure 10. Powdery mildew incidence in UV-C treated Bayadere. On week 2 observe a decrease in the amount of powdery mildew on control plants versus what is observed on UV-C treated plants. This observation continues through week 5, but on week 6 observe higher disease on control plants.

The severity of powdery mildew disease on ultraviolet C treated gerbera is consistently reduced when compared to untreated controls during the early weeks of the trial. This effect is better observed in newly introduced varieties Soul Sister and Bayadere. In Nuance variety which was already established in the greenhouse powdery mildew is present at a very low level in both treated and untreated controls and so it is difficult to determine whether the reduction in disease severity in treated plants is due to ultraviolet C treatment. The results in Nuance do however coincide with the other varieties. Amount of powdery mildew is slightly higher in Soul Sister compared to Bayadere with very low levels in Nuance. These differences may either be due to location within the greenhouse or due to genetic differences in powdery mildew disease susceptibility between the varieties of interest to this study. On week 38 see a trend where powdery mildew disease is higher on UV-C treated plants than what is observed on controls for both Soul Sister and Bayadere.

Flower Yields

Table 7. Monthly flower yields in Ultraviolet-C treated gerbera

Month	Bayadere + UV-C	Bayadere Control	Soul Sister + UV-C	Soul Sister Control	Nuance + UV-C	Nuance Control
August 2012	NA	NA	NA	NA	NA	NA
September 2012	109	505	NA	NA	NA	NA
October 2012	463	799	NA	NA	NA	NA
November 2012	1309	1813	NA	NA	NA	NA
December 2012	570	1069	1070	1190	1707	1752
January 2013	1071	1102	*1408	1252	1317	1471

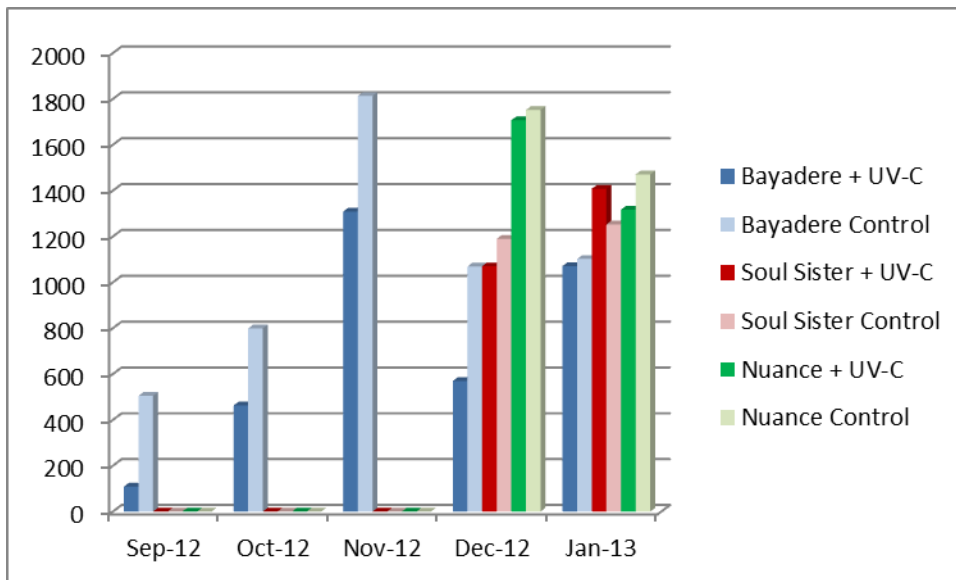


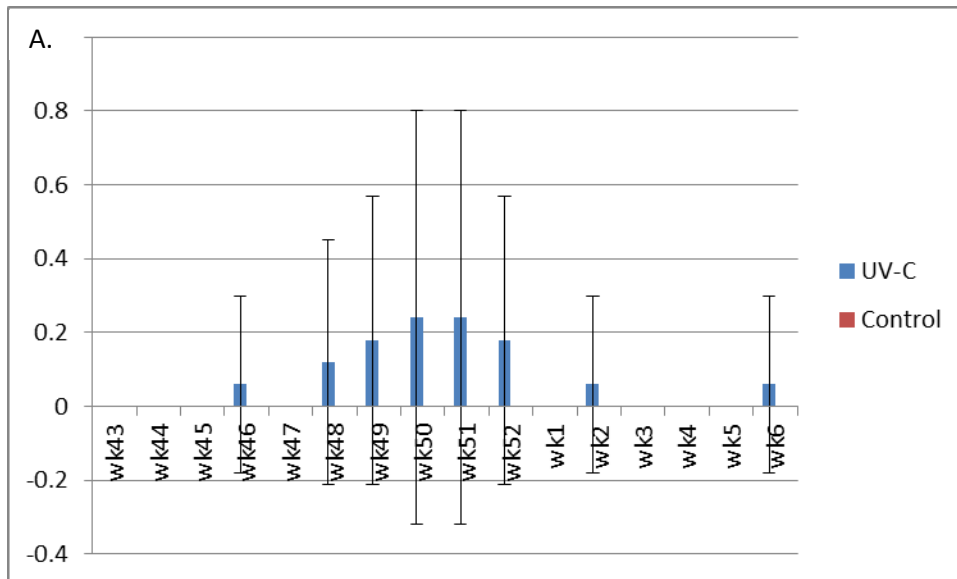
Figure 11. Effect of Ultraviolet-C on flower yields in gerbera. In almost all cases the flower yields are higher in control plants versus observed flower yields in UV-C treated plants (Soul Sister did have higher flower yields in January for UV-C treated plants).

UV-C may negatively impact plant health and therefore flower yields in *Gerbera jamesonii* (Figure 11). Indeed it was observed that as the UV-C dose was increased from 5.2 up to 11.7 Joules plant damage (including stunting, burning and leaf curling) was observed. A UV-C dose which could control disease but without harming the plants was not identified in this study. In addition, the flower quality (stem length, flower colour, flower size) was similar, whether or not the plants received the UV-C supplementation.

Pest Infestation

Table 8. White fly infestation in UV-C treated gerbera.

Week	Nuance		Soul Sister		Bayadere	
	+ UV-C	Control	+ UV-C	Control	+ UV-C	Control
43	0.00 ± 0.00	0.00 ± 0.00	0.29 ± 0.69	0.29 ± 0.69	0.24 ± 0.44	0.24 ± 0.44
44	0.00 ± 0.00	0.00 ± 0.00	0.29 ± 0.59	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
45	0.00 ± 0.00	0.00 ± 0.00	0.18 ± 0.39	0.18 ± 0.39	0.00 ± 0.00	0.00 ± 0.00
46	0.06 ± 0.24	0.00 ± 0.00	0.12 ± 0.33	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
47	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
48	0.12 ± 0.33	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.18 ± 0.39	0.00 ± 0.00
49	0.18 ± 0.39	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.18 ± 0.39	0.00 ± 0.00
50	0.24 ± 0.56	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.24 ± 0.56	0.00 ± 0.00
51	0.24 ± 0.56	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.24 ± 0.56	0.00 ± 0.00
52	0.18 ± 0.39	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.18 ± 0.39	0.00 ± 0.00
1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2	0.06 ± 0.24	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.06 ± 0.24	0.00 ± 0.00
3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.06 ± 0.24	0.00 ± 0.00
4	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
6	0.06 ± 0.24	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00



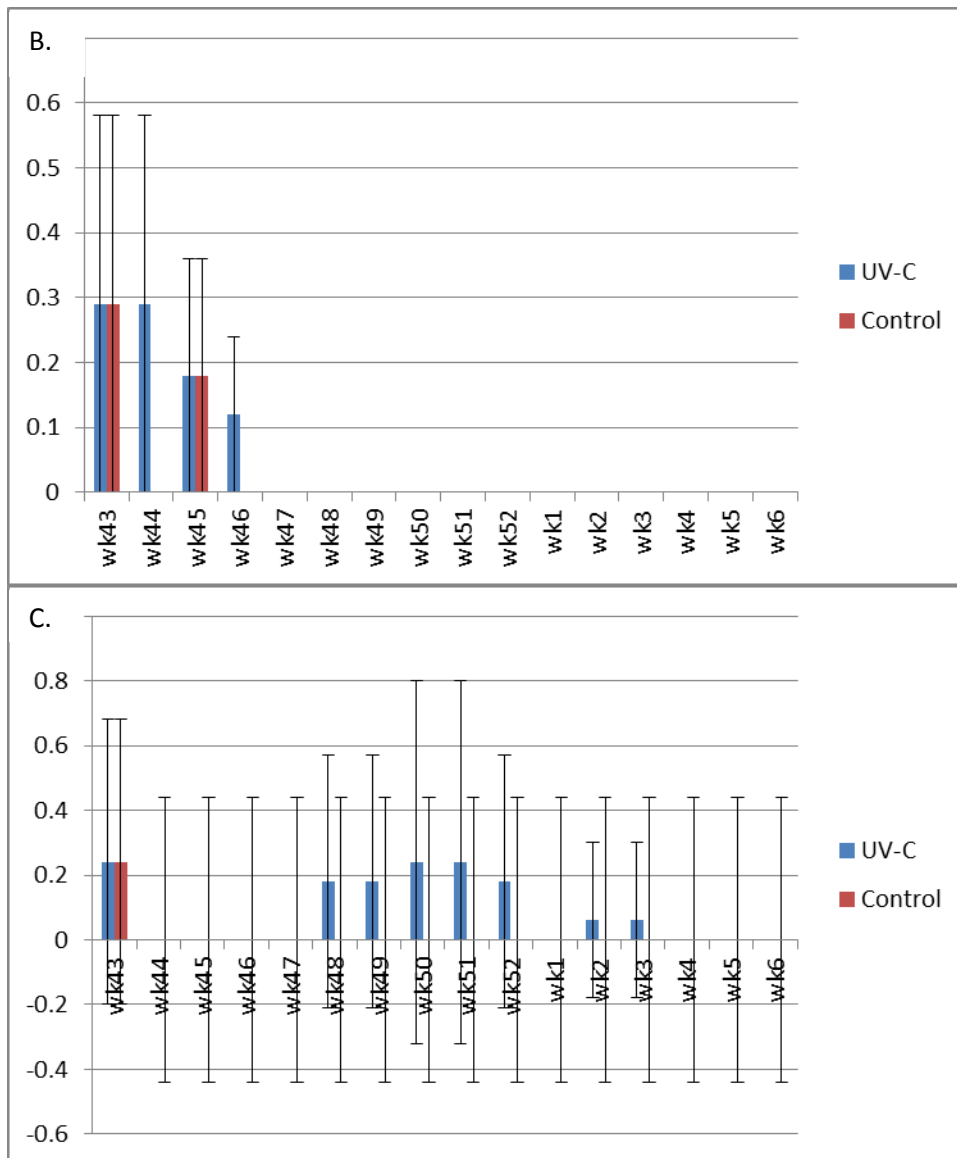
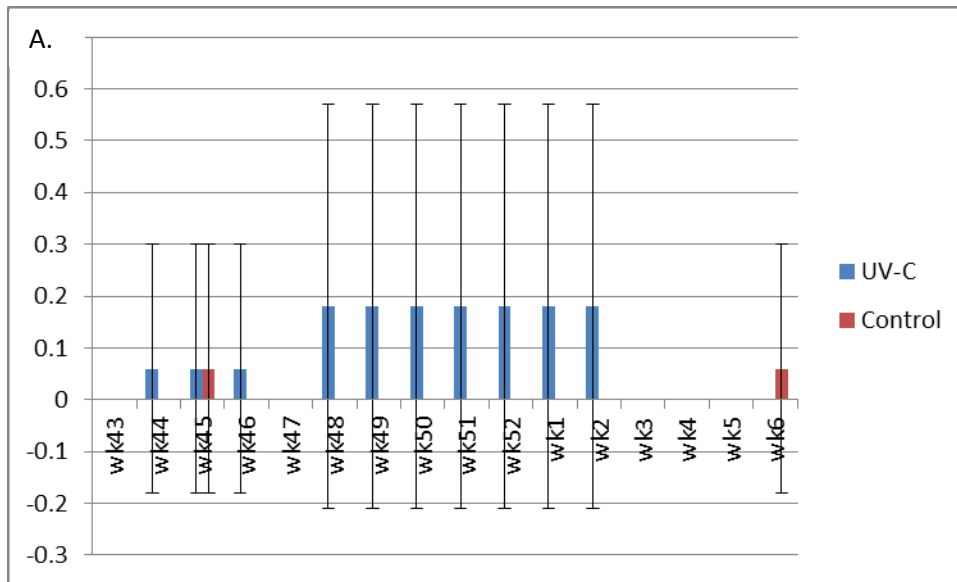


Figure 12. White fly infestation on UV-C treated gerbera. A. Nuance. Pest numbers slightly higher in UV-C treated plants on weeks 46 through 2. No white fly detected on control Nuance plants. White fly levels very low in both control and UV-C treated plants and fall well below objective (<5) and control thresholds (10). **B. Soul Sister.** White fly numbers very low in this variety for both control and UV-C treated plants. **C. Bayadere.** No relationship between UV-C and powdery mildew severity for any of the varieties under evaluation for weeks 43 through 6.

There was no observable differences in the amount of white fly infestation on UV-C treated gerbera versus what was observed on control plants for all varieties under evaluation in this study (**Figure 12**).

Table 9. Thrips infestation on UV-C treated gerbera

Week	Nuance		Soul Sister		Bayadere	
	+ UV-C	Control	+ UV-C	Control	+ UV-C	Control
43	0.00 ± 0.00	0.00 ± 0.00	0.71 ± 1.21	0.71 ± 1.21	0.00 ± 0.00	0.00 ± 0.00
44	0.06 ± 0.24	0.00 ± 0.00	0.18 ± 0.39	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
45	0.06 ± 0.24	0.06 ± 0.24	0.06 ± 0.24	0.00 ± 0.00	0.12 ± 0.33	0.12 ± 0.33
46	0.06 ± 0.24	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.12 ± 0.33	0.00 ± 0.00
47	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
48	0.18 ± 0.39	0.00 ± 0.00	0.24 ± 0.44	0.00 ± 0.00	0.06 ± 0.24	0.00 ± 0.00
49	0.18 ± 0.39	0.00 ± 0.00	0.35 ± 0.49	0.00 ± 0.00	0.24 ± 0.75	0.00 ± 0.00
50	0.18 ± 0.39	0.00 ± 0.00	0.59 ± 1.00	0.00 ± 0.00	0.24 ± 0.75	0.00 ± 0.00
51	0.18 ± 0.39	0.00 ± 0.00	0.59 ± 1.00	0.00 ± 0.00	0.24 ± 0.75	0.00 ± 0.00
52	0.18 ± 0.39	0.00 ± 0.00	0.59 ± 1.00	0.00 ± 0.00	0.24 ± 0.75	0.00 ± 0.00
1	0.18 ± 0.39	0.00 ± 0.00	0.35 ± 0.61	0.00 ± 0.00	0.24 ± 0.75	0.00 ± 0.00
2	0.18 ± 0.39	0.00 ± 0.00	0.18 ± 0.39	0.00 ± 0.00	0.06 ± 0.24	0.00 ± 0.00
3	0.00 ± 0.00	0.00 ± 0.00	0.06 ± 0.24	0.12 ± 0.33	0.00 ± 0.00	0.00 ± 0.00
4	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
6	0.00 ± 0.00	0.06 ± 0.24	0.00 ± 0.00	0.06 ± 0.24	0.00 ± 0.00	0.06 ± 0.24



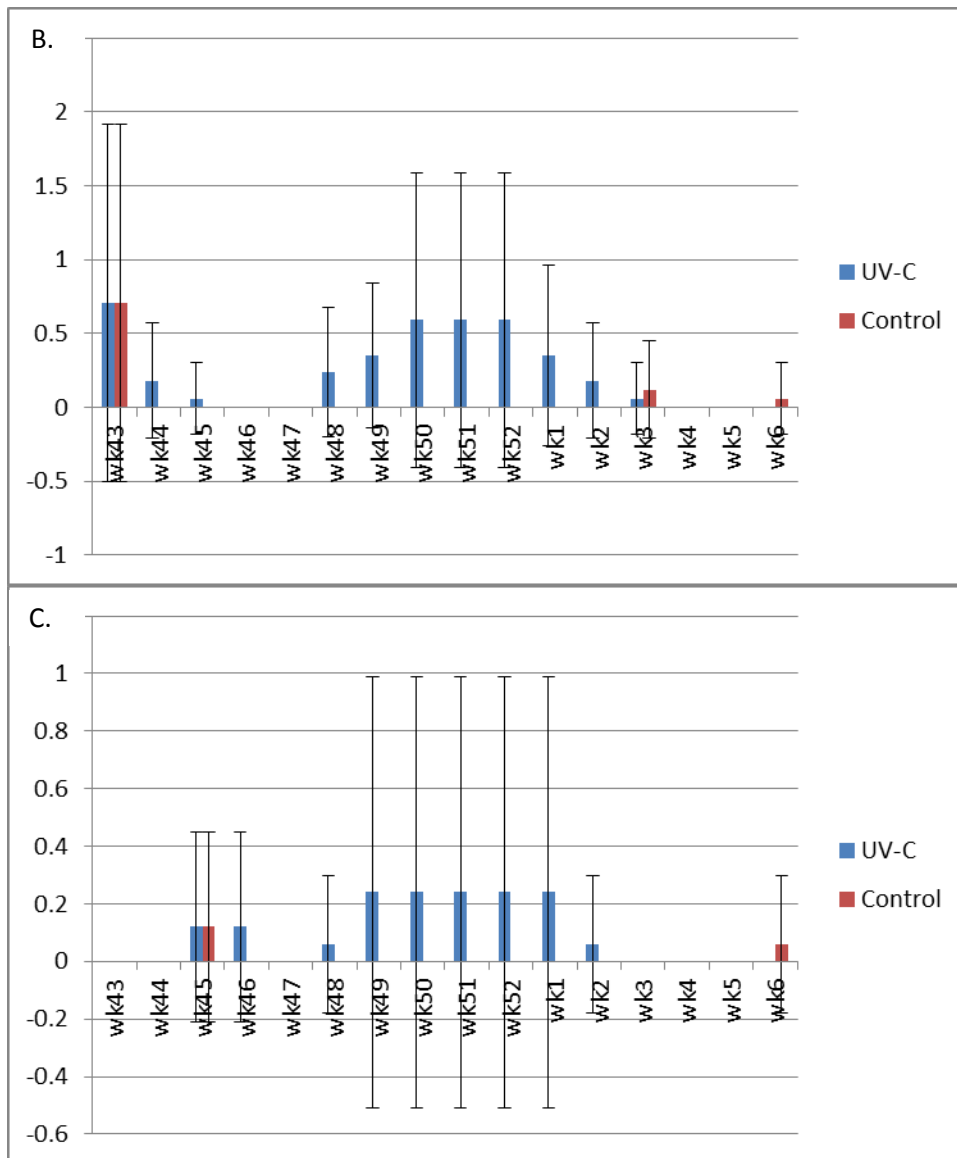


Figure 13. Thrips infestation levels on UV-C treated gerbera. A. Nuance. B. Soul Sister. C. Bayadere. Thrips levels are low and fell below the control threshold level of 1. Differences in pest levels between UV-C treated plants and controls are not statistically significant.

Similar to white fly numbers there was also no difference between the amount of Western Flower Thrips (thrips) between UV-C treated and untreated control gerbera plants (**Figure 13**).

Table 10. Fungus gnat + Shore fly infestation on gerbera

Week	Nuance		Soul Sister		Bayadere	
	+ UV-C	Control	+ UV-C	Control	+ UV-C	Control
43	0.47 ± 0.62	0.47 ± 0.62	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
44	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
45	0.06 ± 0.24	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
46	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
47	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
48	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
49	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
50	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
51	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
52	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
4	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
6	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

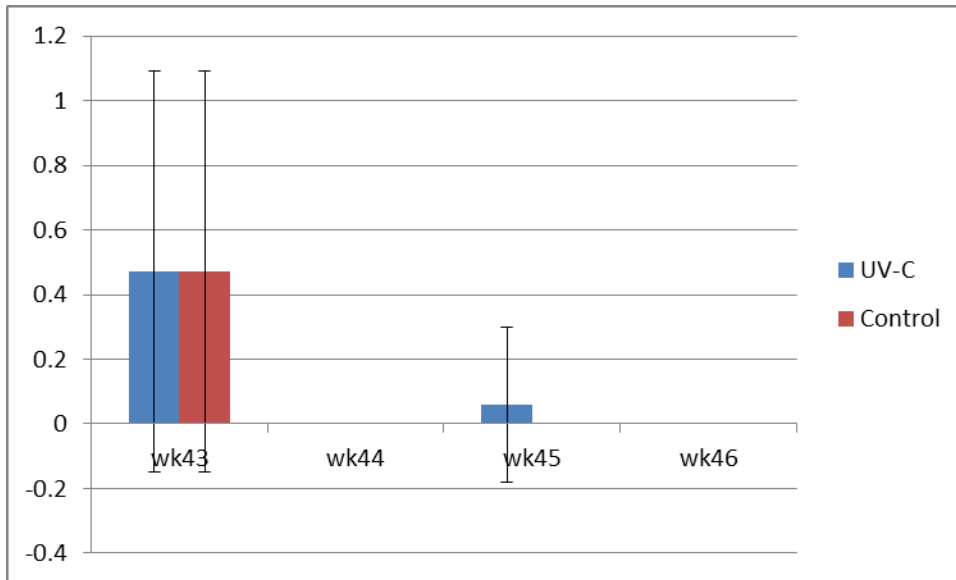


Figure 14. Fungus gnat/Shore fly infestation on gerbera. Data is for Nuance variety only as other varieties did not have any indication of these pests. No difference in pest numbers between UV-C treated and control plants for period spanning weeks 43 through 45. No shore fly or fungus gnat observed from week 46 through 6 of the study for any variety.

Fungus gnat/Shore fly were found in very low numbers in the greenhouse during the trial period. There was no effect on pest numbers by UV-C treatment (**Figure 14**).

Table 11. Leafminer infestation on gerbera.

Week	Nuance		Soul Sister		Bayadere	
	+ UV-C	Control	+ UV-C	Control	+ UV-C	Control
43	0.12 ± 0.33	0.12 ± 0.33	0.12 ± 0.33	0.12 ± 0.33	0.24 ± 0.56	0.24 ± 0.56
44	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
45	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
46	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
47	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
48	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
49	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
50	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
51	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
52	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
4	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
5	0.06 ± 0.24	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
6	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

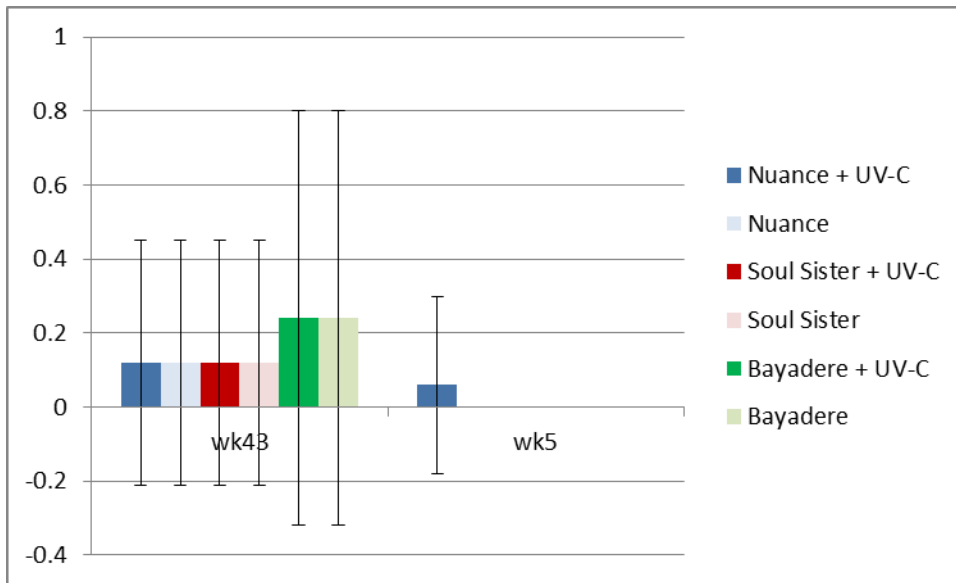


Figure 15. Leafminer infestation on UV-C treated gerbera. Numbers of pests occurring in week 43 of the study do not differ statistically between UV-C treated and control plants for this pest. No leafminer observed in any variety from week 44 through 4 of the study. Some leafminer observed in week 5 on Nuance (UV-C treated only). Pest numbers well below objective (<3) and control thresholds (5) for all varieties.

Leafminer was also not affected by exposure to UV-C during this trial (**Figure 15**). Other pests monitored in the greenhouse included: 1) japanese beetle; 2) aphids and; 3) spider mites. However none of these pests were detected in either UV-C treated or untreated control plants and so this data is not shown here.

SUMMARY AND CONCLUSIONS

The most common and effective strategy to control fungal disease in ornamental crops is the application of fungicides. The use of these fungicides however can have a negative impact on the environment and human health. In addition, frequent use of these fungicides can lead to the development of resistance. As a result stronger limits concerning the maximum residue level have been set up by retailers and the export industry. It is becoming an increasing challenge to produce high quality crops with a minimum input of these pesticide sprays. For this reason the search for alternative methods such as biological control, which are able to efficiently reduce disease is required.

An alternative approach is the development of a physical technique for the reduction of disease and infestations in crops. The technique incorporates ultraviolet c radiation. The technology is based on the fact that fungi are killed by low doses of ultraviolet light, while plant cells can tolerate much higher doses. It has also been demonstrated *in vitro* that insect eggs can also be killed by low doses of ultraviolet c. Based on these observations, it seemed possible to employ doses of ultraviolet c in the greenhouse which were high enough to kill the disease fungi and pest eggs, while avoiding damage to the gerbera crop.

This technology was then evaluated at Bayview Flowers for its capacity to reduce powdery mildew on greenhouse grown Gerbera leaves and flowers. Its effect on pest infestations was also evaluated with a focus on white fly, thrips, shore fly, fungus gnats, leafminer, aphids and spider mites, all common pests in our greenhouse. The applied exposure ranged from 5.2 up to 11.7 Joules (total cumulated radiation per row of plants). The effect of the UV-C on the establishment of powdery mildew was then determined and compared to untreated plants.

The severity of powdery mildew disease on ultraviolet C treated gerbera was consistently reduced when compared to untreated controls from weeks 34 through 37 (first 4 weeks of trial). This effect is better observed in newly introduced varieties Soul Sister and Bayadere and may be a result of the plants having a less dense canopy, allowing better penetration of the UV-C light. In Nuance variety which was already established in the greenhouse powdery mildew is present at a very low level in both treated and untreated controls and so it is difficult to determine whether the reduction in disease severity in treated plants is due to ultraviolet C treatment. Amount of powdery mildew is slightly higher in Soul Sister compared to Bayadere with very low levels in Nuance. These differences may either be due to location within the greenhouse or due to genetic differences in powdery mildew disease susceptibility between the varieties of interest to this study. It was concluded that there was no statistically significant difference in the amount of powdery mildew between the ultraviolet c treated and control plants and this method is therefore not effective for the control of this disease in *Gerbera jamesonii*.

With the exception of flower yields in UV-C treated Soul Sister in January all flower yields were consistently lower in UV-C treated plants than those of control plants. It is possible that the UV-C dose is high enough to cause stress in the plants resulting in a decrease in flower yields and is therefore having a negative impact on plant health and productivity. Plants treated with UV-C also appeared to be somewhat stunted when compared to their control counterparts.

In terms of pest management there did not appear to be any relationship between pest numbers and UV-C treatment. As white fly is most commonly found on the underside of leaves they are likely protected from the radiation as it cannot penetrate the leaf surface. Plant surfaces may provide physical

protection from the ultraviolet c and would therefore prevent this method of being effective in pest control.

Based on the negative results of this trial, it was decided to end the trial on February 15, 2013. Ultraviolet C is an ineffective control method for both disease and pest infestations in greenhouse grown *Gerbera jamesonii* and it is recommended not to use this physical method for disease control.