Experiences from Cut Flower Centre peony herbicide testing.

Since 2019 there have been several trials looking at phytotoxicity side effects from pre-emergence herbicides, selective contact herbicides and contact herbicides. The tests were carried out on either trial crops located at National Cut Flower Centre or on areas of commercial cropping. Whilst not formal efficacy trials, informal visual observations on % weed cover were made.

CFC Trials on newly planted peony crops post planting 2019

Crops were planted in week 7, 2019 and the treatments were applied in week 8 (middle of February).

The peony cultivars assessed included: Alexander Fleming, Coral Charm, Sarah Bernhardt and Duchesse De Nemours which were planted on a double row bed system 45cm x 60cm, providing 3.5-4 plants per m^2. The herbicides were applied with a red flat fan nozzle and high-pressure Cooper Pegler diaphragm knapsack pump.

Table 1. Trial treatments and observations 2019

PRODUCT	DOSE RATE AND APPROVAL STATUS	VISUAL OBSERVATIONS
Flexidor (isoxaben)	0.50l/ha in 300L/ha water volume – on label approval	No visible damage or growth response, relatively good weed control, poor on grasses and thistles
Venzar 500 SC (lenacil)	0.40l/ha in 300L/ha water volume – approved under EAMU	No visible damage or growth response, good grass control, short persistence
Devrinol (napropamide)	7.00l/ha in 800L/ha water volume – approved under EAMU	No visible damage or growth response, good grass control, short persistence
Sunfire (flufenacet)	0.48l/ha in 300L/ha water volumes – approved under EAMU	No visible damage or growth response, good grass control, complete weed cover

Table 2. Photographs of 2019 trial plots at active growth stage in year one

Flexidor (isoxaben)

Venzar (lenacil)

Devrinol (napropamide)

Sunfire (flufenacet)

Although there were apparent differences in weed control, the peonies in all treatments remained healthy and without any signs of damage or growth suppression due to the applied herbicides and grew normally throughout the year to provide the plots for 2020 trials (as below).

CFC Trials on newly planted year 1 peony crops at start of shoot extension 2020

This trial investigated treatments outside of the standard treatments typically used by commercial growers in UK alongside the industry standard herbicide Stomp Aqua (pendimethalin). The objective of the trial was to test the products and mixtures at the start of and during shoot extension to ensure these products were safe on peonies at the most critical stage of growth. Note that the earliest variety Coral Charm (rep 2) was already at advanced shoot extension growth when treatments were applied whereas the others were only just starting to push through.

Picture 1. Second year of growth CFC peony trial planting

Table 3. Trial treatments and detail 2020

№	TREATMENT	ACTIVE SUBSTANCE AND CONCENTRATION	DOSE RATE / HA	APPROVAL STATUS
1	UNTREATED			
2	HURRICANE SC	500g/l diflufenican (SC)	0.25L/ha	EAMU 2018-3440
3	HURRICANE SC + STOMP AQUA	500g/l diflufenican (SC) + 455g/l pendimethalin (SC)	0.25L/ha + 2.90L/ha	EAMU 2018-3440 EAMU 2009-2919

Below are the final assessment results of various parameters noted during the testing. These should be taken with caution due to the small plot sizes covering 8-10 plants with some blind plants in some of the replicated plots (4 replicates).

Table 4. Trial assessment parameters for 2020.

AVERAGE OF TREATMENTS	DAMAGE	STEM LENGTH, CM	TOTAL STEM COUNT PER PLOT	% WEED COVER	
				13/06/2020	17/07/2020
Control	0.08	68.26	17.75	5.00	35.00
Hurricane	1.72	71.38	24.00	4.50	26.25
Hurricane + Stomp Aqua	2.03	70.94	23.00	2.75	35.00

Although there doesn't seem to be any corelation between number of stems and stem length the visual damage levels were obvious in all Hurricane (diflufenican) treatments and therefore it can be concluded that this active substance is not suitable for peony crops during the shoot extension growth stage. Hurricane also has a tendency to be very mobile and improve the herbicide efficacy of other substances and should not be considered in any herbicide programmes for peonies. The damage from Hurricane does not kill plants outright but does damage marketability. Its phytotoxicity symptoms are characterised with pink and white streaks and twisting of tips (tables 11-14).

Table 5. Phytotoxicity scoring from 2020 trial

PHYTOTOXICITY RESPONSE BY VARIETY	ALEXANDER FLEMING	CORAL CHARM	SARAH BERNHARDT	DUCHESSE DE NEMOURS
Hurricane	moderate	severe	moderate	severe
Hurricane + Stomp Aqua	moderate	severe	moderate	severe

Table 6. Visual information from the trial 2020 – P. Coral Charm.

Hurricane (diflufenican)

Hurricane (diflufenican)
+ **Stomp Aqua** (pendimethalin)

Table 7. Visual information from the trial 2020 – P. Alexander Fleming.

Hurricane (diflufenican)

Hurricane (diflufenican)
+ **Stomp Aqua** (pendimethalin)

Table 8. Visual information from the trial 2020 – P. Sarah Bernhardt.

Hurricane (diflufenican)

Hurricane (diflufenican)
+ **Stomp Aqua** (pendimethalin)

Table 9. Visual information from the trial 2020 – P. Duchesse De Nemours.

Hurricane (diflufenican)

Hurricane (diflufenican)
+ **Stomp Aqua** (pendimethalin)

In summary, the testing showed the risks associated with applying herbicides during active crop growth prior to harvesting flowers. The key challenge remains in finding products which can be applied during the dormant season but lasting until after cropping or products which are effective and can be applied much later up to bud formation but pose no risk to peony crops. It is important to also check the safety of the products when applied in dormant growth stage which was assessed in the 2021 trials (see below).

CFC Trials on newly planted year 3 peony crops dormant 2021

Work in 2021 continued on the same plots and therefore varieties tested in in 2019 and 2020 with herbicides applied at an earlier timing during dormancy. The treatments were applied by ORETO certified contactors (ADAS) with an Oxford precision pressure sprayer on 03/02/2021. All the plots were cleaned up using glyphosate in December 2020. The soil conditions at time of application were very wet however as the eyes were starting to become visible further delay would have resulted in missing the dormant stage.

Picture 2. Spraying of the trial plots in 2021 by ADAS

Table 10. Trial treatments and details 2021

№	Treatment	Active ingredient content (formulation)	Dose rate /ha	Approval
1	UNTREATED			
2	HURRICANE SC	500g/l diflufenican (SC)	0.25L/ha	EAMU 2018-3440
3	HURRICANE SC + STOMP AQUA	500g/l diflufenican (SC) + 455g/l pendimethalin (SC)	0.25L/ha + 2.90L/ha	EAMU 2018-3440 EAMU 2009-2919

Picture 3. typical tip twisting and pink tinge form applications of diflufenican.

This trial demonstrated that application of treatments at the dormant stage (before the eyes have started to develop) is safer than applications at when stem extension growth is underway as tested in 2020. Very slight tip damage occurred on plants treated with Hurricane (diflufenican) with symptoms appearing as a pink tinge on the end of leaves (picture 4) from which the crop recovered completely by the time the stems were ready to crop.

This highlights the importance of applying herbicides based on flowering times of the different varieties are especially where large blocks of mixed flowering times crops are present.

Grower Trials on mature commercial peony crop start of extension growth stage 2021

The objective for this trial was to look at the safety of approved herbicide products from sulfonylurea group as well as approved herbicides not typically used by commercial peony growers at start of shoot extension growth. The treatments were applied by ORETO certified contactors (ADAS) with an Oxford precision pressure sprayer on 09/03/2021. The crop was P. Catharina Fontijn (15+yrs) on 3 row system, 60 cm in the row.

Picture 4. Growth stage at application date 09/03/2021

The main weeds present in this field were speedwell, chickweed, mare's tail, willowherb, cleavers, and thistles. Due to the age of the crop, there was some moss and algae on soil which was not commercially important but it's worth noting that some of the herbicides had very good efficacy against these in the initial stages – TRT 1, 3, 5, 9, 10, 11.

Picture 5. Trial plot spraying by ADAS March' 2021

Table 11. Trial treatments and details 2021

№	Treatment	Active ingredient content (formulation)	Dose rate /ha	Approval
1	Boxer	florasulam 50g/l (SC)	0.15l/ha	EAMU 2022-0880
2	Samson Extra 6%	nicosulfuron 60g/l (OD)	0.75l/ha	EAMU 2021-1440
3	Titus	rimsulfuron 250g/kg (WG)	0.05kg/ha	EAMU 2022-3650
4	Defy	prosulfocarb 800g/l (EC)	5.00l/ha	EAMU 2013-1431
5	Eagle	amidosulfuron 750g/kg (WG)	0.04kg/ha	EAMU 2014-2508
6	Flexidor	Isoxaben 500g/l (SC	0.500l/ha	On label
7	Devrinol	napropamide 450g/l (SC)	7.00l/ha	EAMU 2020-1486
8	Venzar	lenacil 500g/l (SC)	0.400l/ha	EAMU 2019-4263
9	Hurricane	diflufenican 500g/l (SC)	0.250l/ha	EAMU 2018-3440
10	Logo	foramsulfuron + iodosulfuron-methyl-sodium 300g/kg + 10g/kg (SC)	0.150kg/ha	EAMU 2016-3437
11	Grower standard programme – metribuzin + pendimethalin			
12	UNTREATED CONTROL			

None of the treatments showed any significant commercially important damage by the time the stems were ready for harvest. However, it is important to note that Titus (TRT3), Defy (TRT4), Eagle (TRT5), and Logo (TRT10) treated crops all showed minor leaf twisting and leaf tenting/clumping during the leaf unfurling stages which lasted until the leaves hardened off and subsequently fully opened and developed normally. Interestingly, in this trial, TRT9 Hurricane (diflufenican) treated crops did not exhibit any damage suggesting a higher degree of tolerance to this product by more

mature peony crops. Given the limited weed control range of Hurricane the risks of its use versus the benefits are difficult to justify for peony crops.

Table 12. Visual observations from trial 2021

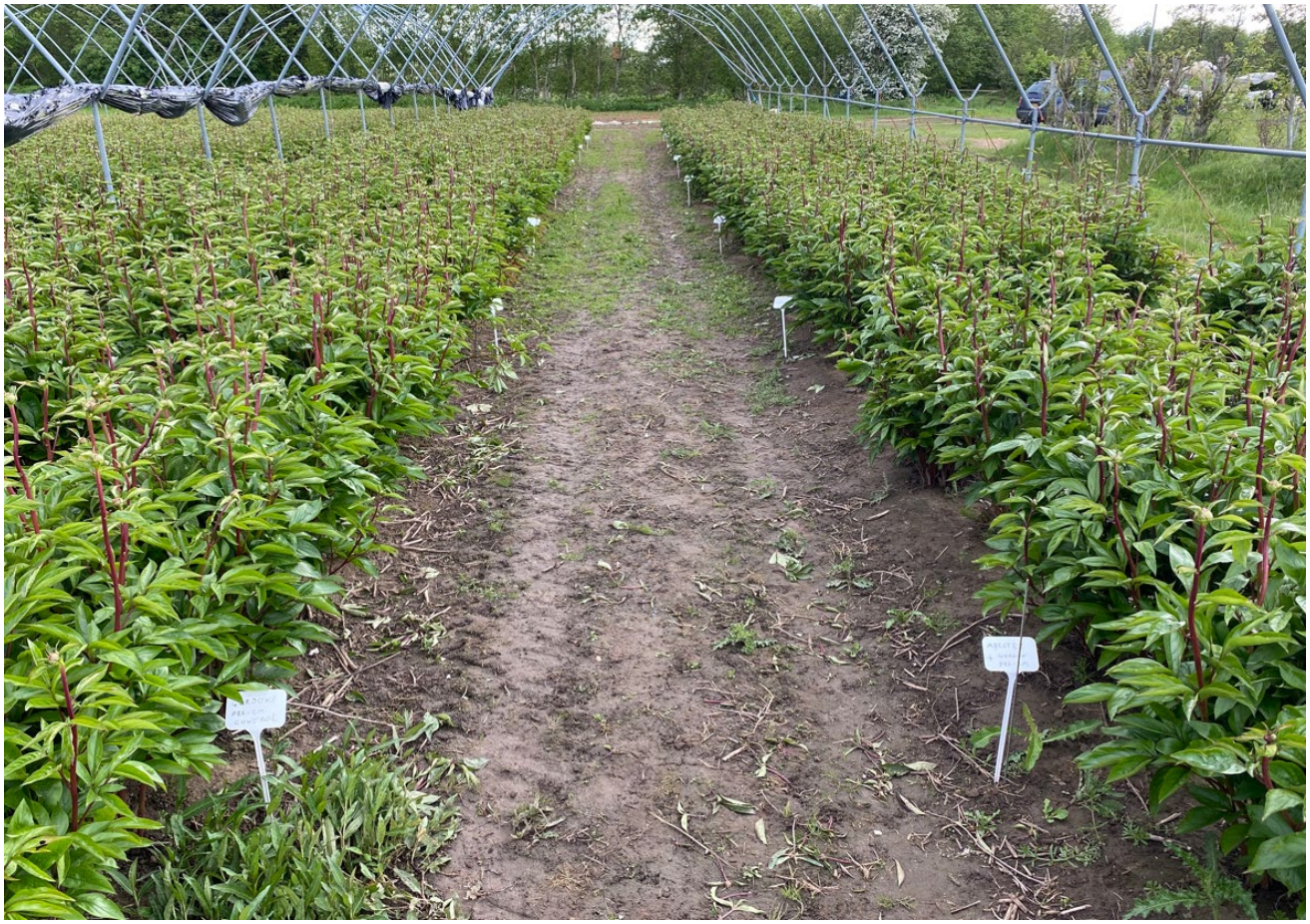
Titus (rimsulfuron) leaf tip twisting

Defy (prosulfucarb) leaf twisting/tenting

Eagle (amidosulfuron) leaf twisting/curling

Logo (foramsulfuron + iodosulfuron-methyl) leaf crinkling

While weed control efficacy was not the objective of this trial, visual observations were made on the overall performance from the treatments compared to untreated and grower standard and it was clear that the grower standard programme was very effective as well as TRT 10 Logo and TRT 5 Eagle. TRT 1 Boxer provided good efficacy against cleavers, but it did not control other weeds such as fat hen, grasses and plantains.



Picture 6. Visible weed control effect on the treated plots below crop canopy 2021.

Grower trials on mature commercial peony crops for pre-emergence herbicide mixtures at the start of extension growth stage 2022

Picture 7. Growth stage at time of application 2022 (most advanced plant)

This trial carried forward the trial work from 2021 and combined herbicide treatments in mixtures to check for crop damage and observe weed control efficacy when applied at the start of the shoot extension growth stage. The commercial crop of P. Sarah Bernhardt (15+yrs) had already been treated with glyphosate in December 2021. Treatments were applied on 25th of February 2022 with a standard diaphragm pump knapsack at high pressure and red flat fan nozzle - FF110-04 delivering 400L/ha water volume. The weed range on this site was dominated by mare's tail, volunteer daffodils, thistles, cleavers and annual meadow grass. The trial set up had 3 replicates and 4 treatments with each plot being 3m and spray width of 1m capturing 9 plants.

Table 13. Trial treatments and details.

№	Treatment	Active ingredient content (formulation)	Dose rate /ha	Approval
1	Boxer + Samson Extra 6%	florasulam 50g/l (SC) + nicosulfuron 60g/l (OD)	0.15l/ha + 0.75l/ha	EAMU 2022-0880 EAMU 2021-1440
2	Titus + Defy	rimsulfuron 250g/kg (WG) prosulfocarb 800g/l (EC)	0.05kg/ha + 5.00l/ha	EAMU 2022-3650 EAMU 2013-1431
3	Eagle + Flexidor	amidosulfuron 750g/kg (WG) + isoxaben 500g/l (SC)	0.04kg/ha + 0.500l/ha	EAMU 2014-2508 On label
4	Grower standard programme – metribuzin + pendimethalin			

None of the treatments showed any crop damage throughout the trial. During cropping, even on plants where some of the shoots were already starting to unfurl at time of application the treatments did not have any short- or long-term impact and therefore it is safe to conclude that these treatments can be used in commercial practice as part of the grower standard programme. TRT3 Eagle + Flexidor initially showed very good residual effect on the weed range in the first 6-8 weeks of the trial with obvious suppression of perennial weeds as well as annual weeds. However, by the end of the trial (flower bud swelling) the weed cover for this treatment was similar to that of the other treatments including the grower standard. It has been known that sulfonylurea herbicide

group does suppress mares' tail weeds and certainly Eagle has demonstrated this here and in previous trials.

Picture 9. Trial plots in 2022

Picture 10. Weed control residual effects from the Eagle + Flexidor treatment

Grower Trials on mature commercial peony crop for selective contact and total herbicides on peony stubble 2022

The objectives of this trial were to look at selective contact and total herbicides used as a clean-up spray in autumn after the crops have been topped down and applied to crop stubble. Treatments were checked for % weed control at 5 days after application (DAA), 15DAA, 61DAA and 90DAA. The trial had 3 replicates and 7 treatments with each plot being 3m and spray width of 1m capturing 9 plants. The most common weed species were stinging nettle, groundsel, mares' rail, red dead nettle, speedwell, thistles, creeping yellow cress, shepherds' purse, fat hen, nightshade, gallant soldier, annual meadow grass, plantain, cow parsley and chickweed.

Picture 11. Trial plots in 2022

Treatments were applied on 16/10/2022 using a standard diaphragm pump knapsack at high pressure and red flat fan nozzle - FF110-04 delivering 400L/ha water volume. All treatments were applied with pre-conditioned water using Nitric Acid 50% to neutralise alkalinity and achieve pH 5.0-5.5 to help with herbicide efficacy. Weed cover assessments were carried out on the day of application (DA), and then 5, 15, 61 and 90 days after application (DAA). The effect of herbicides on weeds were mostly visible in the first two assessments after treatment - 5DAA and 15DAA.

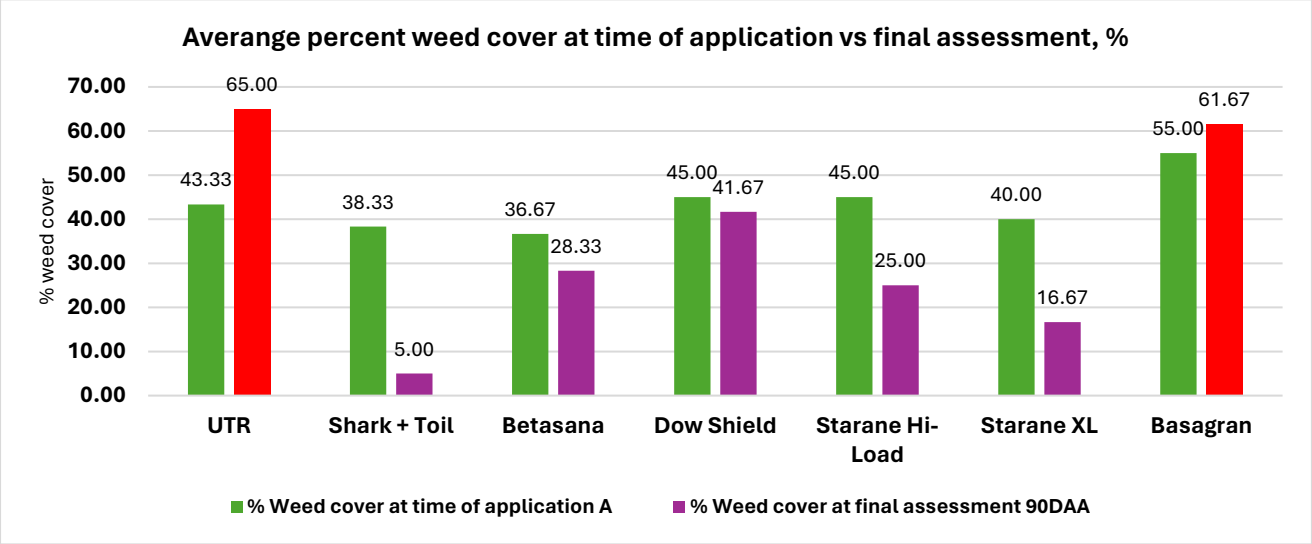
Table 14. Trial treatments and details.

№	Treatment	Active ingredient content (formulation)	Dose rate /ha	Approval
1	UNTREATED			
2	Shark + Toil	carfentrazone -ethyl 60g/l (ME) + adjuvant	0.800l/ha + 2.25l/ha	EAMU 2019-0630
3	Betasana	phenmedipham 160g/l (SC)	3.00l/ha	EAMU 2015-2050
4	Dow Shield	clopyralid 400g/l (SL)	0.500l/ha	EAMU 2022-1089
5	Starane Hi-Load	fluroxypyr 333g/l (EC)	0.600l/ha	EAMU 2021-0942
6	Starane XL	florasulam 2.5g/l + fluroxypyr 100g/l (SE)	1.80l/ha	EAMU 2008-2904
7	Basagran	bentazone 870g/kg (SG)	1.65kg/ha	EAMU 2008-2819

The total herbicides had the greatest impact on weeds at the time of application and at the end of the trial in terms of percent weed cover. The selective contact herbicides did not perform as they would in their optimum timings (mostly spring recommended selective herbicides) which may be

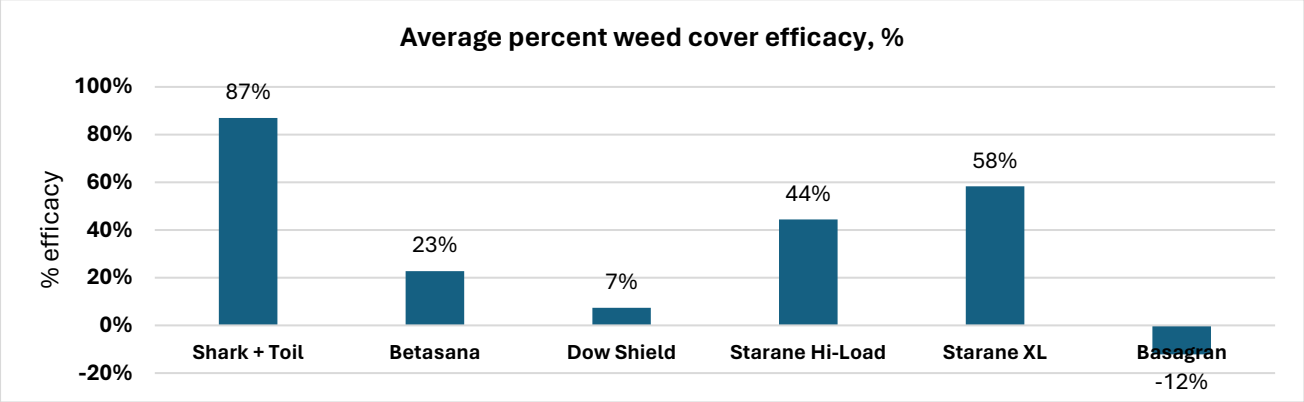
explained by the weather conditions after application (temperature, light levels) meaning weed growth stage and weed range were already out of product recommendation scope with weeds therefore too advanced, mature, and hardened off for the herbicides to work to their optimum.

Graph 1. Weed cover assessment from the 2022 trial.



Shark + Toil, which it is part of the grower standard programme, gave the greatest percent weed control, and in this trial showed some effect on supressing weed seedling germination even 90DAA which is useful when the product is used in early autumn, perhaps before the application of glyphosate to crop stubble in late November early December. It was also noted that where possible overlap and overdose has occurred particularly on field headlands where sprayers may slow down the speed or delay switching off, Shark + Toil could result in permanent damage to those plants. This observation has also been made by commercial peony growers independently of this trial.

Graph 2. Efficacy from weed cover assessment in 2022.



The selective contact herbicides based on fluroxypyr and florasulam i.e. Starane Hi-Load and Starane XL provided good control with good persistency, especially Starane XL which is known to have some residual effects. Both of these products will control cleavers very effectively and will have good efficacy on nightshade.

Dow Shield did not perform as well for thistle control as it does in spring and summer conditions, so the application timing in this trial was likely too late in the season for best efficacy. Whilst

Betasana did not provide sufficient weed seedling control in this trial, due to its relative safety, could be a very good option in combination with pre-emergence herbicides applied during the shoot extension growth stage.

Table 15. Visual observation from the 2022 trial.

UTR (DA)

UTR (61DAA)

Shark + Toil (DA)

Shark + Toil (61DAA)

Betasana (DA)

Betasana (61DAA)

Dow Shield (DA)

Dow Shield (61DAA)

Starane Hi-Load (DA)

Starane Hi-Load (61DAA)

Starane XL (DA)

Starane XL (61DAA)

Basagran (DA)

Basagran (61DAA)

Monitoring of the treated plots continued the following season in 2023 to make any observations up to cropping for any signs of crop phytotoxicity. None of the treatments showed any phytotoxicity symptoms the following spring, however there was some damage at the end of rows in a different location in the same field which showed some symptoms of overdosing with Shark which are worth noting as illustrated in the image below.

Picture 8. Damage from overdose of Shark (carfentrazone-ethyl) applied in dormant season.

Grower Trials on mature commercial peony crop with selective contact and total herbicides post cropping stage 2023

Herbicide application after harvesting flowers from commercial peony crops is difficult. Crop canopies will be very dense making broadcast application of herbicides over the top of the crop with any selective contact or total herbicides difficult as these will be too damaging and therefore result in a high risk of reducing yield in the following year or even total crop loss (e.g. with glyphosate). Crop residues on the ground following harvesting and the tendency of the peony crop to flop and open means getting herbicide treatments into the inter-row space is very difficult. Usually, mechanical weeding, handheld spot treatments or inter-row hooded spraying with contact herbicides are the only means of keeping on top of weeds. The objectives of the 2023 trial were to evaluate the level of acceptable damage to peony crops caused by selective contact and total herbicides when applied in post cropping situation over the top of peony plants in full canopy. The applications were made on 21/07/2023 using a standard diaphragm pump knapsack at high pressure and red flat fan nozzle - FF110-04 delivering 400L/ha water volume. The same plots were used from the trial the previous year above in P. Sarah Bernhardt. The assessment of the impact on peonies was made on 12/08/2023 (21DAA).

Table 16. Trial treatments and details

№	Treatment	Active ingredient content (formulation)	Dose rate /ha	Approval
1	UNTREATED			
2	Shark + Toil	carfentrazone -ethyl 60g/l (ME) + adjuvant	0.800l/ha + 2.25l/ha	EAMU 2019-0630
3	AHDB9897 + Toil	pyraflufen ethyl 26.5g/l (EC) + adjuvant	0.800l/ha + 2.25l/ha	Experimental Permit 2023-00920
4	Betasana	phenmedipham 160g/l (SC)	3.00l/ha	EAMU 2015-2050
5	Dow Shield	clopyralid 400g/l (SL)	0.500l/ha	EAMU 2022-1089
6	Starane Hi-Load	fluroxypyr 333g/l (EC)	0.600l/ha	EAMU 2021-0942
7	Starane XL	florasulam 2.5g/l + fluroxypyr 100g/l (SE)	1.80l/ha	EAMU 2023-2516
8	Basagran	bentazone 870g/kg (SG)	1.65kg/ha	EAMU 2008-2819
9	AHDB9700	clopyralid 200g/l + triclopyr 200g/l (SC)	1.00l/ha	Experimental Permit 2023-00920
10	Finalsan	pelargonic acid 186.7g/l (EC)	102.00l/ha	On label approval

Finalsan was applied in concentration of 17% in 600L/ha providing 102.00l/ha dose rate rather than the full 170L/ha.

All treatments were applied with tap water in this trial in comparison to previous years trial where water conditioning was adopted.

Table 17. Visual observations from trial 2023

UTR (DA)

UTR (21DAA)

Shark + Toil (DA)

Shark + Toil (21DAA)

AHDB9897 + Toil (DA)

AHDB9897 + Toil (21DAA)

Betasana (DA)

Betasana (21DAA)

Dow Shield (DA)

Dow Shield (21DAA)

Starane Hi-Load (DA)

Starane Hi-Load (21DAA)

Starane XL (DA)

Starane XL (21DAA)

Basagran (DA)

Basagran (21DAA)

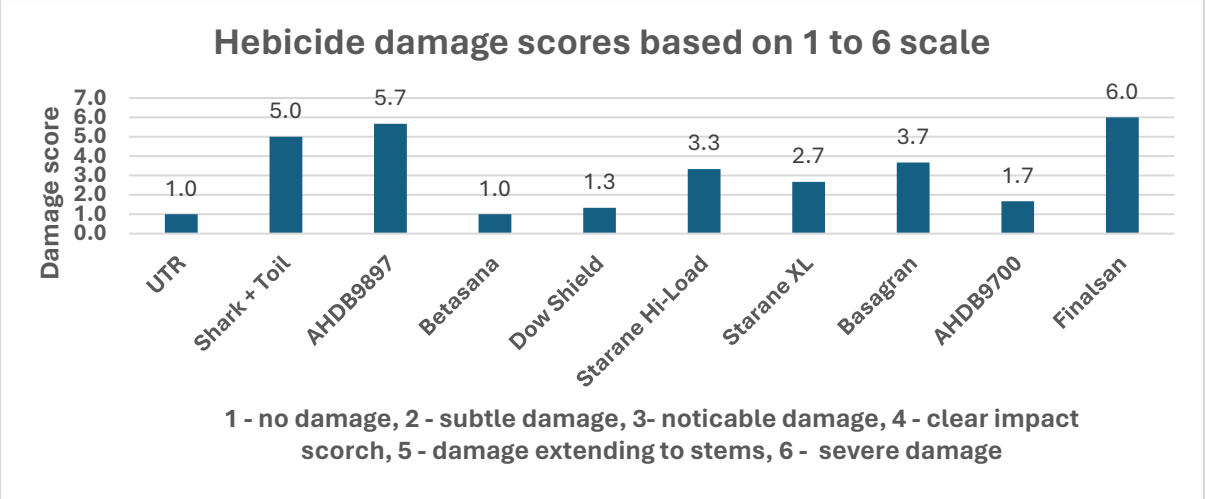
AHDB9700 (DA)

AHDB9700 (21DAA)

Finalsan (DA)

Finalsan (21DAA)

Graph 3. herbicides application damage scores for peony plants 2023



Note that when the applications were made the natural senescence process had not started but by the time the last assessment was made (12/08/2023 -21DAA) plants had started to senesce and even the untreated had some chlorotic foliage and general wilting.

The table below highlights observations of the treatment effects on weeds and crops. Surprisingly Basagran's weed control was good even at that late stage and the impact on peony crop was not anticipated. The Starane XL treatment was also surprising to see with less damage in comparison to Starane Hi-Load with very good weed control.

Dow Shield and AHDB9700 had very promising results with both having a low impact on the crop but high impact on specific weeds. Their selectivity is very helpful for pernicious perennial weeds where growers can adopt targeted hot spot treatments.

Shark and AHDB9897 mixed with Toil and Finalsan provided the greatest burn off on both weeds and crop. Finalsan was particularly quick and significantly damaged the peony stems. However, the Finalsan cost per litre is somewhat prohibitive and it is worth noting that the product was difficult to apply due to the formation of bubbles and foaming through the droplet diffusion and possibly water quality. In addition, Finalsan also had very distinctive heavy scent at time of application. It is important to condition the water when using Finalsan. Rapid crop senescence was associated with all three of these treatments and the plots will be monitored for their performance in 2024 to check for possible reduction in stem length and number of stems.

Table 18. Notes from observations at final assessment 21DAA

TREATMENT	OBSERVATIONS AT TIME OF FINAL ASSESSMENT (12TH August 2023 – 21DAA)
Shark + Toil	Very obvious scorch, where crop canopy was open the weeds below were also affected, with the exception of couch grass
AHDB9897 + Toil	Lots of scorch on peony plants and significant weed scorch, some sheltering of weeds but considered much better impact than Shark +Toil
Betasana	Unaffected crop foliage and weeds, with perhaps some very slight weed stunting and yellowing
Dow Shield	Stunting and twisting of sow thistle, no damage to peony plants, only slight leaf scorch
Starane Hi-Load	Interveinal chlorosis, stunting and leaf twisting, some purpling and bronzing of foliage, stunting was the most obvious, good control on cleavers

Starane XL	Visible yellowing and stunted growth, some slight twisting, similar to Starane Hi-Load but less crop damage better weed control
Basagran	Obvious scorch and leaf chlorosis, relatively good and unexpected level of weed control
AHDB9700	Yellowing of foliage, slight stunting, very good thistle control
Finalsan	Severe scorch on foliage and stems, sheltering effect visible, very quick burn off almost same day but short lived, weeds started to grow by 21DAA