EMRC

Protecting Perth's Eastern Region

Steaming to Success

Alternative Weed Management Trial Report

December 2017

GOVERNMENT OF WESTERN AUSTRALIA

natural resource management program

Acknowledgements

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Disclaimer

The results and recommendations of this report were compiled using data collected from visual assessment at a site under specific environmental conditions. The views and opinions expressed do not necessarily reflect those of the project funding bodies or partners.

Terminology

Application(s)	refers to each of the treatment events in the trial.
Presentation Standard	refers to the acceptable appearance of a site that is being managed for weeds (Winer, 2014) as determined by the land manager. A Presentation Standard will determine the amount of weeds that can be tolerated at a site.
Treatment(s)	refers to the collective alternative weed management treatments used in the trial: steam; pelargonic acid; pine oil; salt and vinegar solution; mulch; and competitive planting.

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1 Introduction

The EMRC have been investigating alternative weed management techniques in response to the community's interest in integrating non-traditional methods into a more holistic weed management regime.

In 2015, the EMRC held a 'Working with Weeds' seminar with the Weeds Network to present the latest research and alternative weed management methods that are being utilised locally, nationally and internationally. The Steamwand SW900 machine was demonstrated as one type of alternative technology. The seminar was well attended with over 80 guests representing landcare groups, local governments, state government departments, environmental contractors and consultants.

Following on from the seminar, the EMRC was successful in receiving additional funding from the Department of Parks and Wildlife (now Department of Biodiversity, Conservation and Attractions), Rivers and Estuaries Division to purchase a Steamwand SW700 steam weeding machine and to provide operator training for people to hire out the machine. To date, 63 people have completed operator training from 21 organisations, and the machine is hired out regularly.

In March 2016, in response to ongoing interest in other weed management treatments, the EMRC developed a grant titled 'Steaming to Success' which was successful in receiving funding from the Western Australian Government's State Natural Resource Management Program. The project was developed to include an alternative weed management trial and an 'Innovative Weed Control Seminar and Site Tour' in order to discuss alternative weed management techniques and visit demonstration sites. The project was finalised in October 2017.

This report provides information on the alternative weed management trial aspect of the Steaming to Success project, including methodology, results, analysis and recommendations from the trial.

1.1 Objectives of the Trial

The objectives of the trial were to:

- Assess the effectiveness of alternative (non-traditional) weed management controls/treatments over time to defined presentation standards;
- Raise awareness of alternative weed management techniques; and
- Investigate the potential of integrating these methods into mainstream weed management plans and regimes.

The results of the trial will add to existing knowledge relating to weed control and revegetation techniques.

1.2 Out of scope

Soil testing was not undertaken as it was outside the scope of the project. A cost analysis was also not undertaken as it was outside of the scope of the project.

1.3 Description of Trial Site

The trial was undertaken on a site alongside the Railway Heritage Trail in Mount Helena (Figure 1) close to Riley Road. The trail is a gravel track popular with recreational users. The trail is bordered by native bushland and non-irrigated grassy areas which are normally maintained by mowing and spraying up to three times per year.

The Presentation Standard of the site is guided by fire hazard reduction values, safety values for recreational users and aesthetic values.

The soil present is a clay loam with underlying remains of rock ballast from the railway. The average annual rainfall at the site is 863 mL (Bureau of Meteorology, 2017).

The site was selected based on ease of access for the Steamwand machine, delivery of mulch, planting and regular monitoring.

The scope of the project and the results obtained from the trial are unique to these environmental conditions. This should be taken into account when comparing the results of this report with other sites with differing environmental factors.

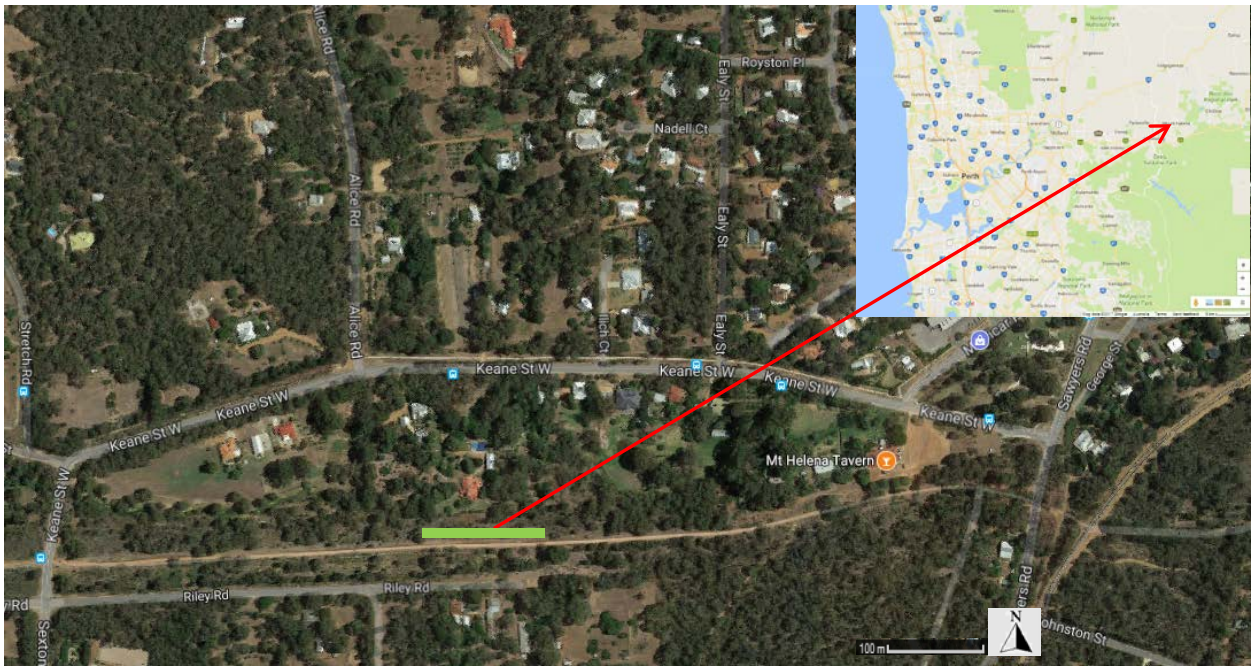


Figure 1. Alternative weed management trial site location

Common and scientific names of weeds identified within the trial plots are listed in Table 1. Common names will be used within the body of this report.

Table 1. Plant species identified within trial plots

Common name	Scientific Name
African lovegrass	**Eragrostis curvula*
Cape tulip	**Moraea sp.*
Capeweed	**Arctotheca calendula*
Caustic weed	**Euphorbia drummondii*
Dock	**Rumex sp.*
Flatweed	**Hypochaeris radicata*
Fluellen	**Kickxia spuria*
Fumitory	**Fumaria sp.*
Large clover (Trifolium)	**Trifolium sp.*
Lupin	**Lupinus cosentinii*
Native grasses	*^Austrostipa sp.*
Perennial veldt	**Ehrharta calycina*
Pimpernel	**Anagallis arvensis*
Plantain	**Plantago lanceolata*
Pom pom (Narrowleaf clover)	**Trifolium angustifolium*
Pussytail (Hare's Tail Grass)	**Lagurus ovatus*
Radish	**Raphanus raphanistrum*
Ryegrass	**Lolium rigidum*
Small clover (Trefoil)	**Lotus angustissimus*
Sow Thistle	**Sonchus oleraceus*
Staggerweed	**Stachys arvensis*
Stink weed	**Dittricha graveolens*
Storksbill	**Erodium sp.*
Tagasaste	**Chamaecytisus palmensis*
Verbascum	**Verbascum virgatum*
Vetch	**Vicia hirsuta*
Wild oats	**Avena sp.*
Wireweed	**Polygonum aviculare*

** Weed species* *^Native grasses*

2 Methodology

2.1 Alternative Treatments

The following alternative weed management treatments were used on a range of different weeds present at the trial site. They were selected as being representative of the most common alternative treatments currently available to local governments and community groups.

Salt and Vinegar Solution
Vinegar or acetic acid (at the correct concentration) has the ability to break down leaf cuticles causing them to leak and dry out. Salt has the ability to dehydrate plant cells. Salt and vinegar combined make an effective non-selective herbicide. It is important the herbicide is applied to all parts of the exposed plant.

Pine Oil
Pine oil is phytotoxic, meaning it is toxic to plants. Similarly to acetic acid, it works by desiccating plant cell walls so their contents leak and dry out. Pine oil also acts as a pre-

emergent herbicide by rendering weed seed unviable. It is important to coat all of the target plant with the herbicide to achieve the desired effect.

Pelargonic Acid

Pelargonic acid has a similar effect on weeds as acetic acid and pine oil and must be applied to all living parts of the plant to be effective. A spray solution of pelargonic acid (at the correct concentration) penetrates living plant cells and causes tissue damage leading to plant death. Pelargonic acid naturally occurs in many plants and some foods that we eat.

Please read manufacturer recommendations on product labels before using any of the above treatments.

Super-saturated Steam

The optimal temperature to control weeds using this technique is between 98°C - 103°C. The combination of saturated steam and water at 100°C delivers thermal shock to the weed. The rapid transfer of lethal heat destroys the plant cellular structure, thereby providing an effective method of weed control. Steam and hot water together will penetrate the meristematic cells of a plant (the parts where new growth occurs) to reduce the likelihood of the plant re-sprouting post-treatment (Winer, 2014).

Competitive (dense) Planting of Ground Covers

Competitive planting using native ground covers was selected as these plants spread laterally and have the potential to out-compete weeds for nutrients, moisture and space. This treatment is complemented by weed removal within the plant wells to give the ground covers the competitive advantage.

Mulch

Mulch has the ability to control weeds and suppress weed seed germination by smothering and reducing seed access to sunlight. Mulch helps retain soil moisture and protects the soil against erosion assisting native plant survival.

2.2 Trial Plot Layout

Five 3 metre x 16 metre plots were used to conduct the trial; each plot was then divided into four 3 metre x 4 metre sub-plots. Plots were measured out using a 100 metre measuring tape on a reel and marked at the corners with wooden stakes painted in yellow to increase visibility.

The trial was set up to distinguish four different combinations of each of the five treatments to assess the most effective treatment and/or combination. The five treatments being: a Control; Salt and Vinegar; Pine Oil; Pelargonic Acid; and (super-saturated) Steam. Each plot included a treatment only sub-plot and one combination sub-plot each of the treatment plus (competitive) planting; treatment plus mulch and planting; and treatment plus mulch (Figure 2).

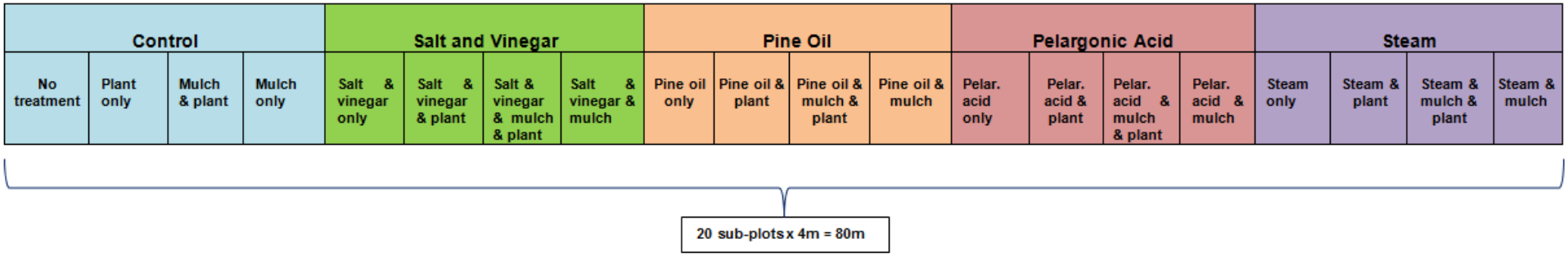


Figure 2. Alternative weed management trial plot layout

2.3 Treatment Applications

The first application of the Salt and Vinegar, Pine Oil, Pelargonic Acid and Steam treatments was applied to trial plots in the afternoon of 1 July 2016.

Mulch
Tree pruning mulch from the Shire of Mundaring was applied to the allocated mulch plots at 10 cm thickness by contract labour on 15 July 2016 (14 days after the first application of all treatments).

Competitive (dense) Planting of Ground Covers
Competitive planting sub-plots were planted by contract labour and a team of Green Army participants. The plots were planted after the initial treatments were applied and the corresponding treatment withholding period had passed (manufacturer safety and instruction labels were followed for specific withholding periods).

The following species of native ground covers, *Chorizema cordatum, Kennedia prostrata, Kennedia coccinea, Patersonia occidentalis* and *Hardenbergia comptoniana,* were planted at four plants per square metre and spaced randomly.

Control Plot
On 21 July 2016 following the mulch application, native ground cover plants were planted into one non-mulched and one mulched sub-plot.

Salt and Vinegar Solution
Trained and licenced Shire of Mundaring Landcare Officers applied a ready-to-use premixed solution of Salt and Vinegar (90g/L Acetic Acid, 40g/L Sodium Chloride) solution to the above ground parts of the weeds using a backpack sprayer. The first application was carried out on 1 July 2016 to all four sub-plots.

On 21 July 2016, native ground covers were planted into one non-mulched and one mulched sub-plot. For subsequent Salt and Vinegar solution application dates refer to Table 2.

Pine Oil
A Pine Oil concentration of 680 g/L at a mixing rate of 200 mL per litre of water was used in the trial. The product was applied by a licenced contractor using a boom spray unit mounted to a quad-bike. Only two applications were applied during the trial as per the manufacturer's recommendation which stipulated that no more than two applications per year could be applied to a treated area. The first application was completed on 1 July 2016 to all four sub-plots followed by the second and final application on 2 August 2016.

On 21 July 2016, native plants were planted into one non-mulched and one mulched sub-plot.

The final application of Pine Oil was applied to the Pine Oil Only sub-plot as the boom-spray application method does not allow spraying in between dense plantings. The mulched plots were not sprayed either as there were no weeds present.

Pelargonic Acid
The Pelargonic Acid product used contained 60% active ingredient. It was initially mixed with water at 5% (medium rate per manufacturer's instructions) and applied on 1 July 2016 by licenced Shire of Mundaring Landcare Officers using a backpack sprayer.

The initial application had little effect on the weeds present. Contact was made with the manufacturer and, per manufacturer's recommendation, the mixing rate was increased to 7% and used in the second application on 2 August 2016 and successive treatments.

Planting of the Pelargonic Acid and Plant sub-plot was delayed because the initial treatment at a rate of 5% and secondary treatment at 7% were both ineffective. It is thought that the secondary treatment of 7% was not applied as liberally as is required for the product to be effective.

The Pelargonic Acid, Plant and Mulch sub-plot was planted on 15 July 2016.

The third application of Pelargonic Acid solution (repeat of second application) was applied on 16 August 2016, delaying planting of the Pelargonic Acid and Plant sub-plot until 31 August 2016. For subsequent Pelargonic Acid solution application dates refer to Table 2.

Hand weeding of Plantain was conducted on 16 March 2017 for all Pelargonic Acid trial plots as this treatment was deemed ineffective for managing Plantain. The removal of Plantain was undertaken to allow for further observation of other weed species' response to Pelargonic Acid treatments.

Super-saturated Steam
The Steamwand SW700 machine was used throughout the trial by trained EMRC Officers to apply the Steam treatment. The machine includes a boiler, water pump and 1,000 L water tank mounted to a registered trailer. The 30 metre hose delivered super-saturated steam to the weeds through a lance with a closed head attachment fixed to the end. The vacuum-like head attachment concentrated steam to a 30 cm by 15 cm area. This allowed more area to be covered and was quicker than if the open-head attachment was used.

The first treatment was applied to all sub-plots on 1 July 2016 avoiding any native grasses present on the plot.

Native ground covers were planted on 15 July 2016 into the Steam and Plant and Steam, Plant and Mulch sub-plots. For subsequent Steam application dates refer to Table 2.

2.4 Monitoring

Two forms of monitoring were carried out during the trial:

- Photo monitoring; and
- Percentage cover using visual assessment.

Before every application photos were taken of each sub-plot facing north, east and west. At the same time, percentage cover of weeds, natives and mulch was recorded using visual assessments. The final monitoring was conducted at the end of the trial with two additional monitoring events occurring in August 2016 and February 2017. These methods were used for each of the 20 sub-plots over the course of the trial (see Table 2 for dates).

2.5 Trial Timeline

The initial baseline monitoring was conducted on the morning of 1 July 2016 with photo monitoring and percentage cover data recorded prior to the first application of each treatment. The first treatments were applied in the afternoon of 1 July 2016.

Six applications of each treatment were applied in winter 2016, spring 2016, summer 2016/2017 and autumn 2017 (see Table 2 for dates).

Monitoring was undertaken on the morning of each treatment application and intermittently throughout the trial to assess the effectiveness of the previous treatment application. A total of nine monitoring rounds were completed between July 2016 and July 2017 (Table 2) to give an accurate seasonal representation.

The final treatment was applied on 28 April 2017, with final monitoring conducted on 5 July 2017.

In line with traditional weed management techniques, the plant wells of all plots were hand weeded as required. Hand weeding of the plant wells was undertaken after the monitoring round was completed, and before the treatments were applied in the afternoons. The reason for hand weeding was to reduce spray contact with native ground cover plantings.

Table 2. Monitoring and treatment timeline detailing what occurred at each visit to the trial site

Visit	Date	Treatment application	Monitoring round (photos & %age cover)	Photo monitoring only	Notes
1	1 July 2016	1	1	-	Baseline data and first treatment application. Pelargonic Acid rate was 5%
2	5 July 2016	-	-	Yes	Photo monitoring 4 days after treatment application
3	15 July 2016	-	-	Yes	Photo monitoring before contractor mulching and planting of 'Steam, Plant and Mulch', 'Steam and Plant' and 'Pelargonic, Plant and Mulch'
4	21 July 2016	-	-	-	Green Army planted the following sub-plots 'Pine Oil, Plant and Mulch', 'Pine Oil and Plant', 'Salt and Vinegar, Plant and Mulch', 'Salt and Vinegar and Plant', 'Control, Plant and Mulch' and 'Control Plant Only'
5	2 August 2016	2	2	-	Pelargonic Acid rate increased to 7%. Second and final Pine Oil application to 'Pine Oil Only plot'.
6	16 August 2016	-	3	-	An additional application of Pelargonic Acid at 7% was applied.
7	31 August 2016	-	-	-	EMRC planted 'Pelargonic Acid and Plant' plot.
8	16 September 2016	3	4	-	Monitoring and treatment application

Visit	Date	Treatment application	Monitoring round (photos & %age cover)	Photo monitoring only	Notes
9	21 October 2016	4	5	-	Monitoring and treatment application
10	3 February 2017	-	6	-	Monitoring only
11	16 March 2017	5	7	-	Monitoring and treatment application
12	28 April 2017	6	8	-	Monitoring and treatment application
13	5 July 2017	-	9	-	Final monitoring

3 Results

3.1 Control

The Control plot was divided into four sub-plots in order to compare the effectiveness of mulch and competitive planting excluding other forms of treatment. The Control No Treatment sub-plot would be considered a 'true control' as it had no treatment at all.

3.1.1 Control - No Treatment

The Control No Treatment sub-plot (Figure 3) shows a high degree of variability in percentage of weed cover throughout the trial. Wild oats and Flat weed were the most prevalent weed species having the highest percentage cover throughout the trial.

In July 2016 at the start of the trial, Wild oats and Flat weed cover was 37% and 40% respectively. Wild oats cover increased to 60% by October 2016 before decreasing to 0% by February 2017. Wild oats remained at 0% cover until starting to increase again by July 2017 measuring 9%. Flat weed had increased to 42% cover by August 2016 before reducing to 0% in February 2017. Flat weed had increased to 20% cover by March 2017 then decreased to 4% before increasing again to 50% by July 2017.

All of the other weeds except Small clover were at or less than 5% cover until the last monitoring in July where a few saw a slight increase. Small clover had increased from 1-2% to 13% cover by October 2016 before showing a decrease to 0% in February and March 2017. By the end of the trial, Small clover cover had increased to 5%.

Plantain and Perennial veldt were recorded as 4% and 5% cover at the start of the trial before both decreasing to 0% by February 2017. Both species then increased in cover with Perennial veldt recorded at 7% and Plantain recorded at 15% by the end of the trial.

For photo monitoring refer to Appendix 9.2.

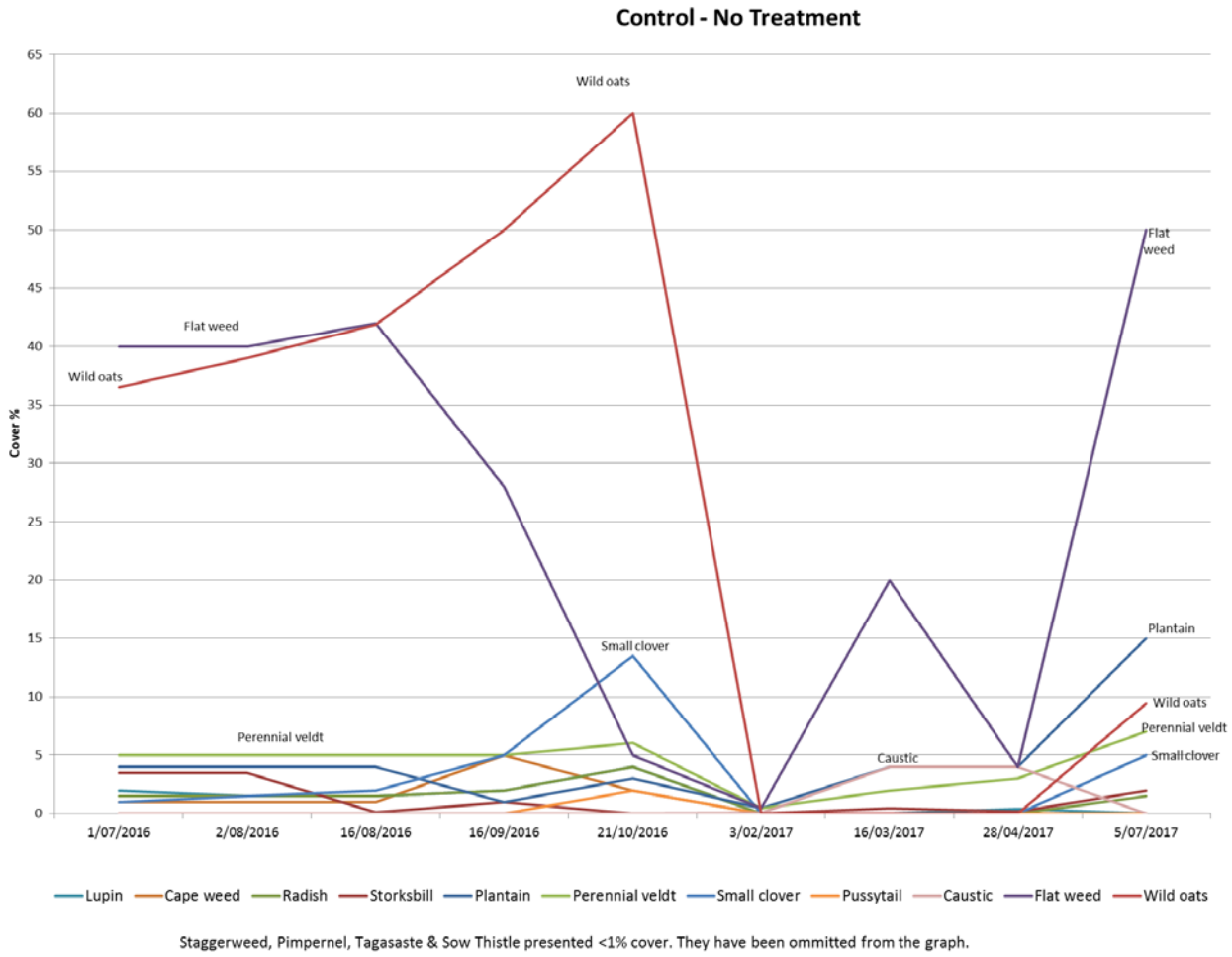


Figure 3. Percentage cover of weeds at Control No Treatment sub-plot over the course of the trial

3.1.2 Control - Plant Only

The Plant Only sub-plot (Figure 4) of the Control plot had native ground covers planted on 21 July 2016. Flat weed and Wild oats were the most abundant weeds present prior to planting, at 35% and 40% cover respectively, followed by Perennial veldt at 5% cover. Small clover had increased to 10% by October 2016, then decreased to 0% before increasing to 8% cover by July 2017.

Native ground covers planted increased in percentage cover to 5% by mid-August 2016. However, throughout the trial the cover of native plants decreased steadily to 1% by July 2017.

For photo monitoring refer to Appendix 9.3.

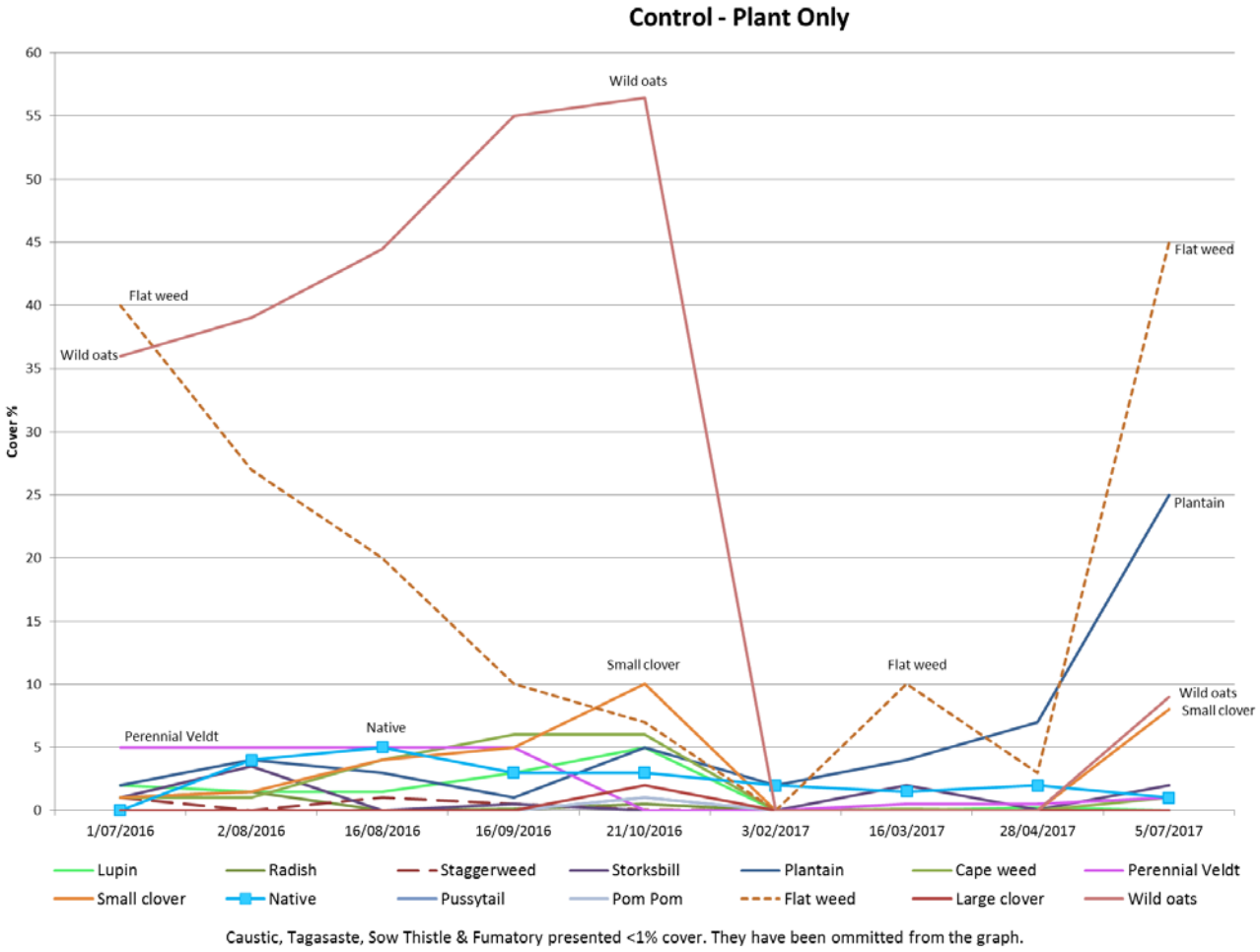


Figure 4. Percentage cover of weeds and native ground covers at Control - Plant Only sub-plot over the course of the trial

3.1.3 Control - Plant and Mulch

Wild oats and Flat weed were the most abundant weeds at the start of the trial in the Control Plant and Mulch sub-plot at 36% and 40% cover respectively (Figure 5). Following application of mulch and plants, cover of all but one weed reduced to 0%, with the exception of Plantain with less than 1% cover. Plantain had increased slightly to 4% cover by February 2017 before reducing to less than 1% as a result of hand weeding the plant wells (keeping consistency across the trial). Plantain had increased again to 5% cover by April 2017 then decreased to 4% by July 2017.

Following planting at the start of the trial, the cover of native plants was estimated to be 5% which showed a reduction to 1% in September and October 2016 before increasing again to 4% by July 2017. Flat weed had increased slightly to 2% cover recorded in August 2016 after mulching before decreasing to and remaining at less than 1% cover for the remainder of the trial.

Perennial veldt cover increased following mulching to 1% recorded in August 2016 before decreasing to 0% and again increasing to 4% by April 2017.

For photo monitoring refer to Appendix 9.4.

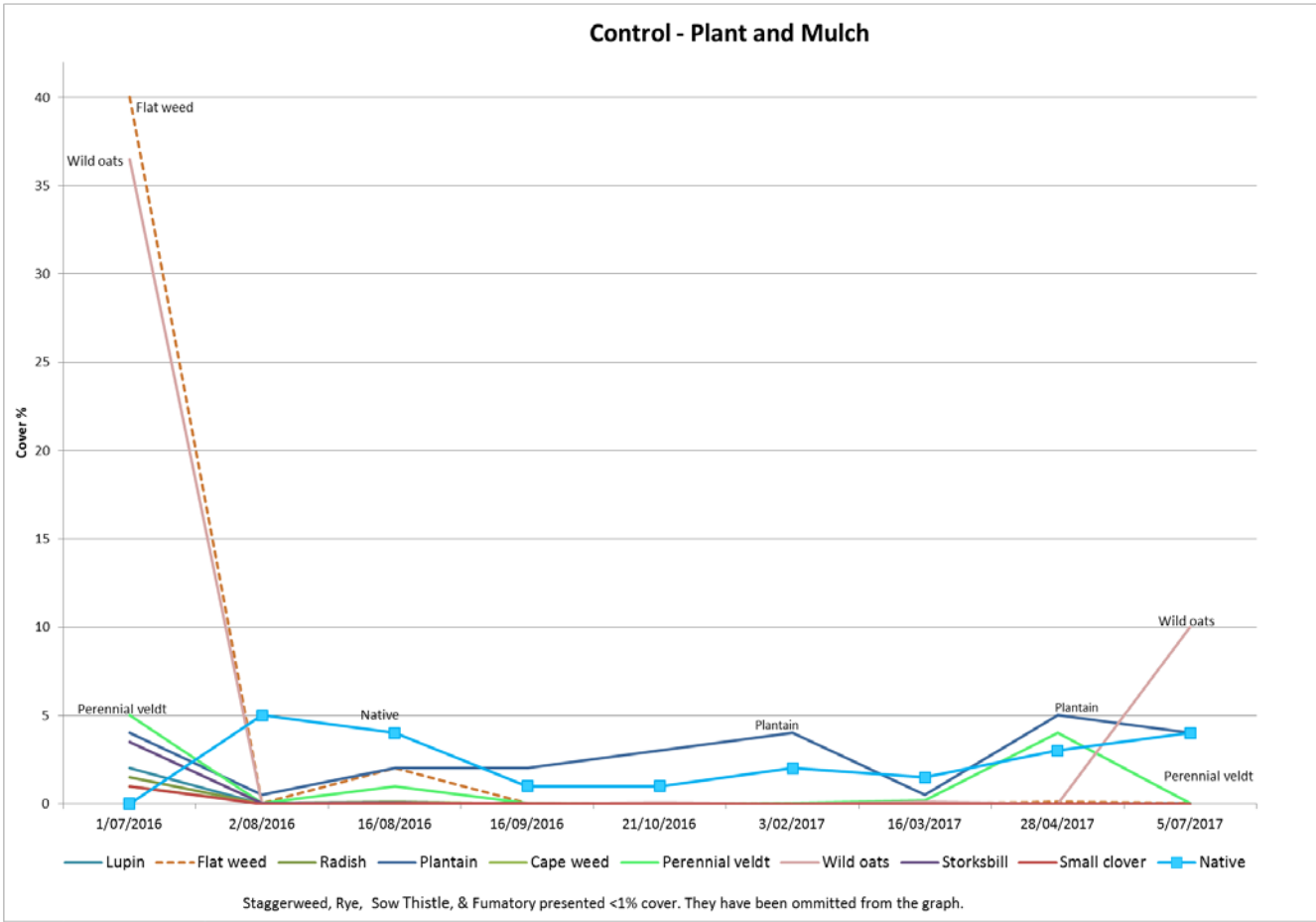


Figure 5. Percentage cover of weeds and native ground covers at Control/ Plant and Mulch sub-plot over the course of the trial

3.1.4 Control - Mulch Only

Control Mulch Only sub-plot had the highest percentage cover of Flat weed and Wild oats initially with 40% and 36% respectively (Figure 6). As evident from the graph, all weed species reduced to and remained at less than 5% cover for the remainder of the trial. Perennial veldt and Plantain increased slightly in February 2017 and were recorded at 2% and 1% cover respectively. Wild oats had increased by the end of the trial to 2% as recorded in July 2017.

For photo monitoring refer to Appendix 9.5.

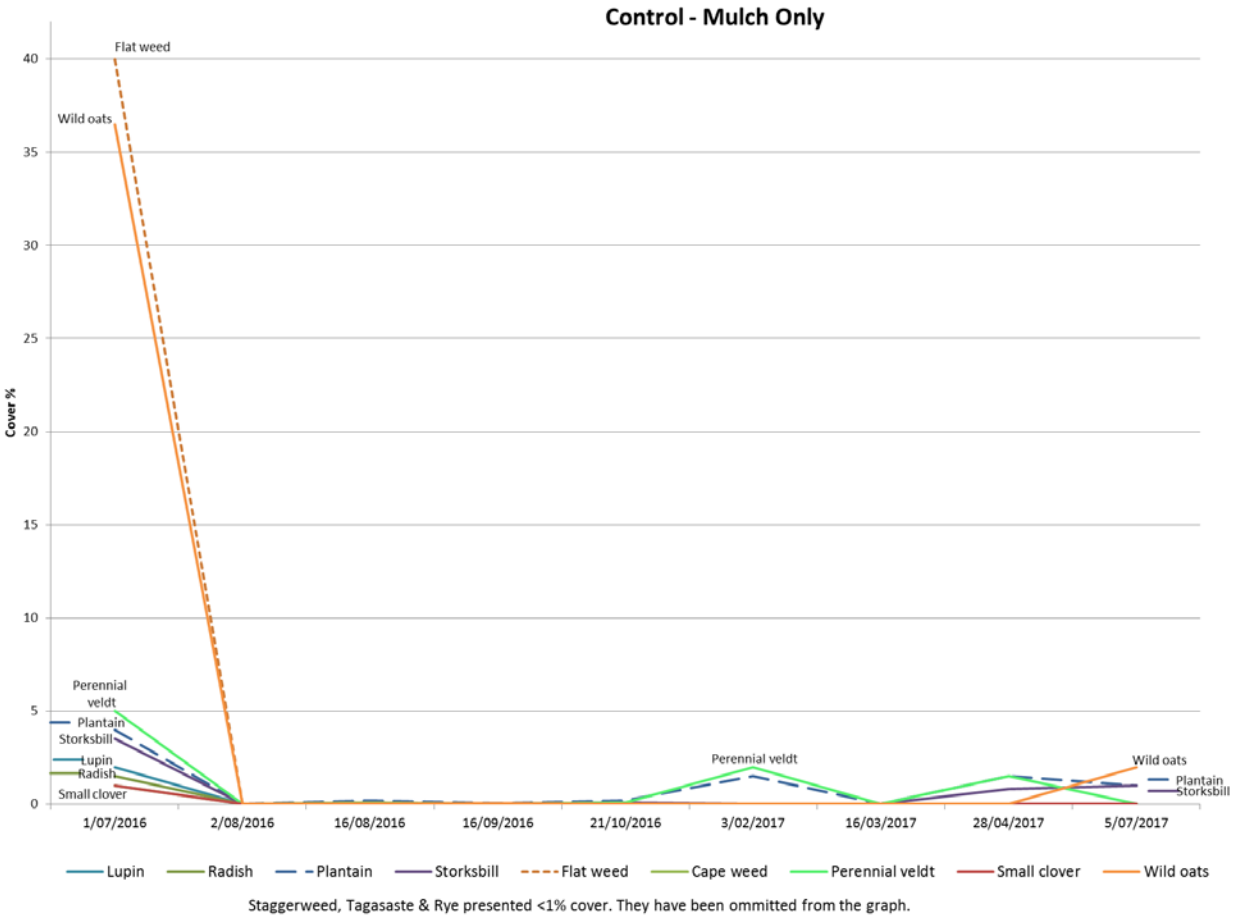


Figure 6. Percentage cover of weeds at Control/ Mulch Only sub-plot over the course of the trial

3.2 Salt and Vinegar

3.2.1 Salt and Vinegar Only

Salt and Vinegar Only sub-plot (Figure 7) had 14% cover of Cape weed and 13% cover each of Flat weed, Storksbill and Wild oats at the start of the trial. Perennial veldt and Staggerweed had cover of 5% each, Small clover had 3%, Plantain 2% and Lupin 1%. A degree of variability in the results was observed between the 1 July 2017, 2 August 2016 and 16 September 2016 applications, in particular with Wild oats. The results from the first application were negligible compared to the second application which proved to be very successful in decreasing Wild oats cover from 15% to 4%. A further application on 16 September 2016 had no effect on Wild oats cover as it increased to 10%. A decrease in cover to 9% was recorded on 21 October 2016. These results were observed during the active growth period for Wild oats before the natural decline was observed over summer as the species dies off.

All other weeds remained at or less than 1% cover with minor fluctuations in line with each application.

Native grasses present on the sub-plot experienced an overall increase over time measuring less than 1% cover at the start of the trial and 2% at the end of trial.

For photo monitoring refer to Appendix 9.18.

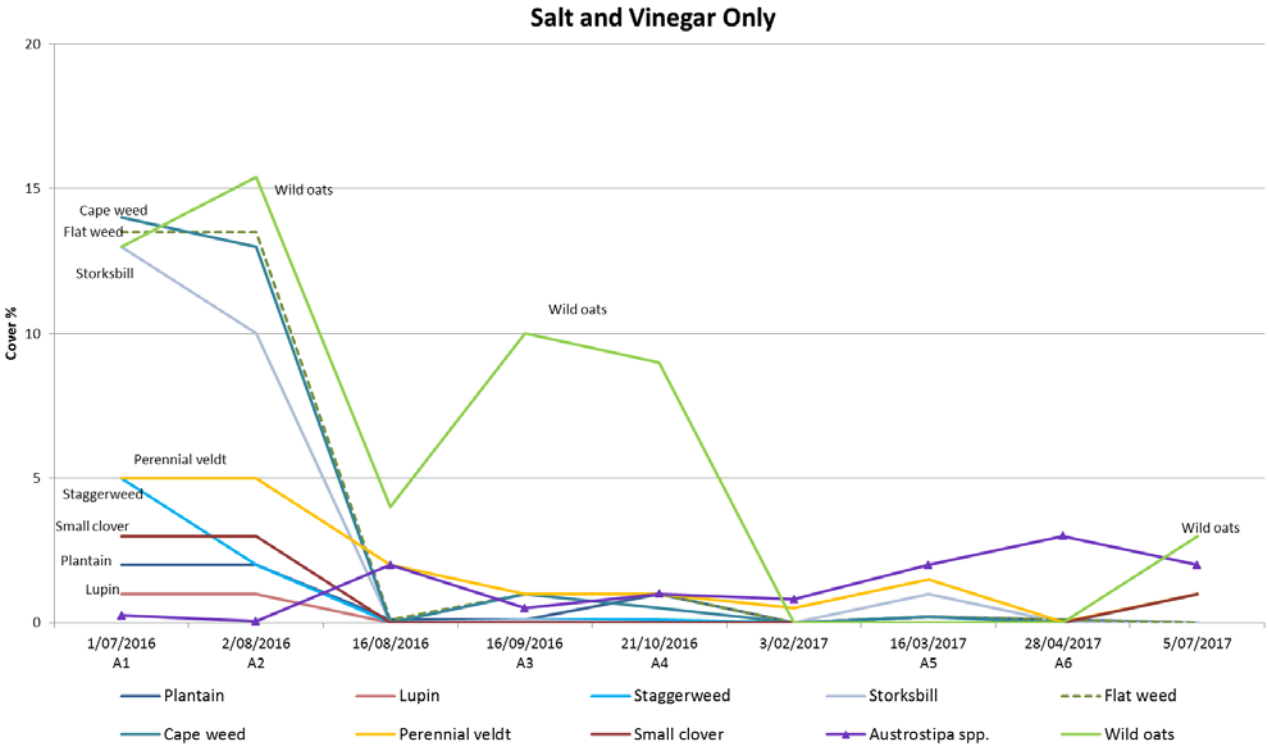


Figure 7. Percentage cover of weeds and native grasses at Salt and Vinegar Only sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

3.2.2 Salt and Vinegar and Plant

Flat weed was the dominant weed in the Salt and Vinegar and Plant sub-plot at the start of the trial measuring 30% cover, followed by Storksbill at 17% and Cape weed at 16%. Other weeds present were Staggerweed, Wild oats and Perennial veldt at 5% cover each, Small clover at 3%, Plantain at 2% and Lupin at 1% (Figure 8). Following the first application, all weeds except Plantain decreased. Following the second application, most weeds measured 0% cover in August 2016 (including Plantain), however Perennial veldt and Wild oats increased. Perennial veldt peaked at 5% as recorded in September 2016 and then fluctuated in line with each treatment application. Wild oats peaked at 7% cover as recorded in October 2016 before decreasing to 0% by February 2017. At the end of the trial, Wild oats was recorded at 3% cover, Perennial veldt, Staggerweed and Cape weed at 2% each, and Small clover, Storksbill and Flat weed at 1% each.

Native ground covers planted at the start of the trial increased to 5% cover by August 2016 before decreasing to 1% by February 2017.

For photo monitoring refer to Appendix 9.19.

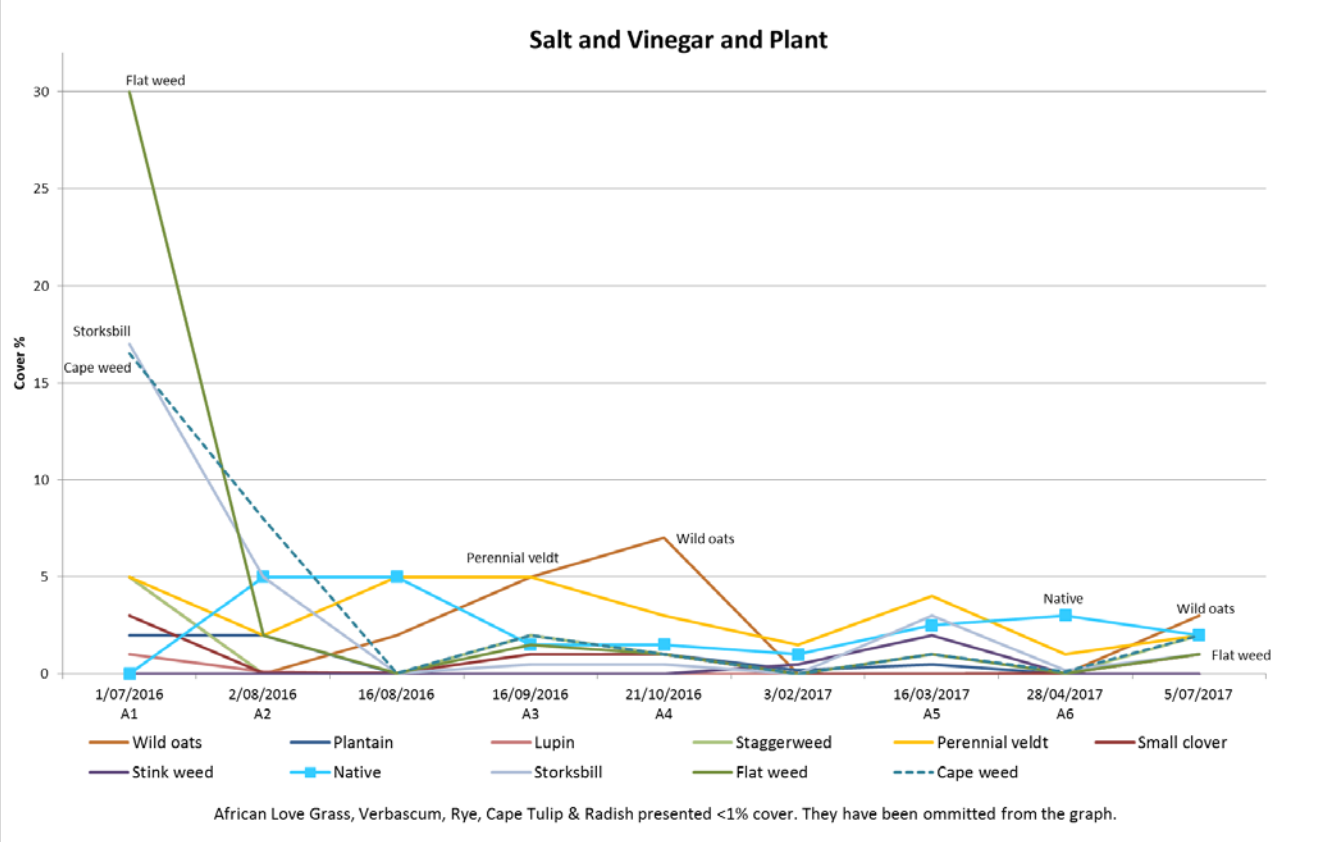


Figure 8. Percentage cover of weeds and native ground covers at Salt and Vinegar and Plant sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

Photo 1 shows the variable effects of Salt and Vinegar on Wild oats. Please note the grass tufts in the foreground are native grasses and were not sprayed. The first application on 1 July 2016 had negligible effect on the Wild oats as recorded on 2 August 2016. The second round of application on 2 August 2016 indicated an effective control of Wild oats as recorded on 16 August 2016.

Photo 1: Effects of Salt and Vinegar on Wild oats (2 August 2016 – left, 16 August 2016 - right)

3.2.3 Salt and Vinegar, Plant and Mulch

Flat weed was the dominant weed in the Salt and Vinegar, Plant and Mulch sub-plot at the start of the trial measuring 40% cover, followed by Storksbill at 23% and Perennial veldt and Plantain at 8% each. Other weeds present were Small clover, Plantain and Wild oats at 5% cover each, and Cape weed at 1% (Figure 9). Following the first Salt and Vinegar application and application of mulch, all weeds measured 0% cover. By February 2017, Plantain cover had increased to 1.5% and Perennial veldt to 1%. By the end of the trial, Wild oats was the only weed present measuring 1% cover.

Native ground covers planted at the start of the trial increased to 14% cover by August 2016 before decreasing to and remaining at 2% as recorded in September and October 2016. From February 2017, native ground covers increased sharply, measuring 71% at the end of the trial.

For photo monitoring refer to Appendix 9.20.

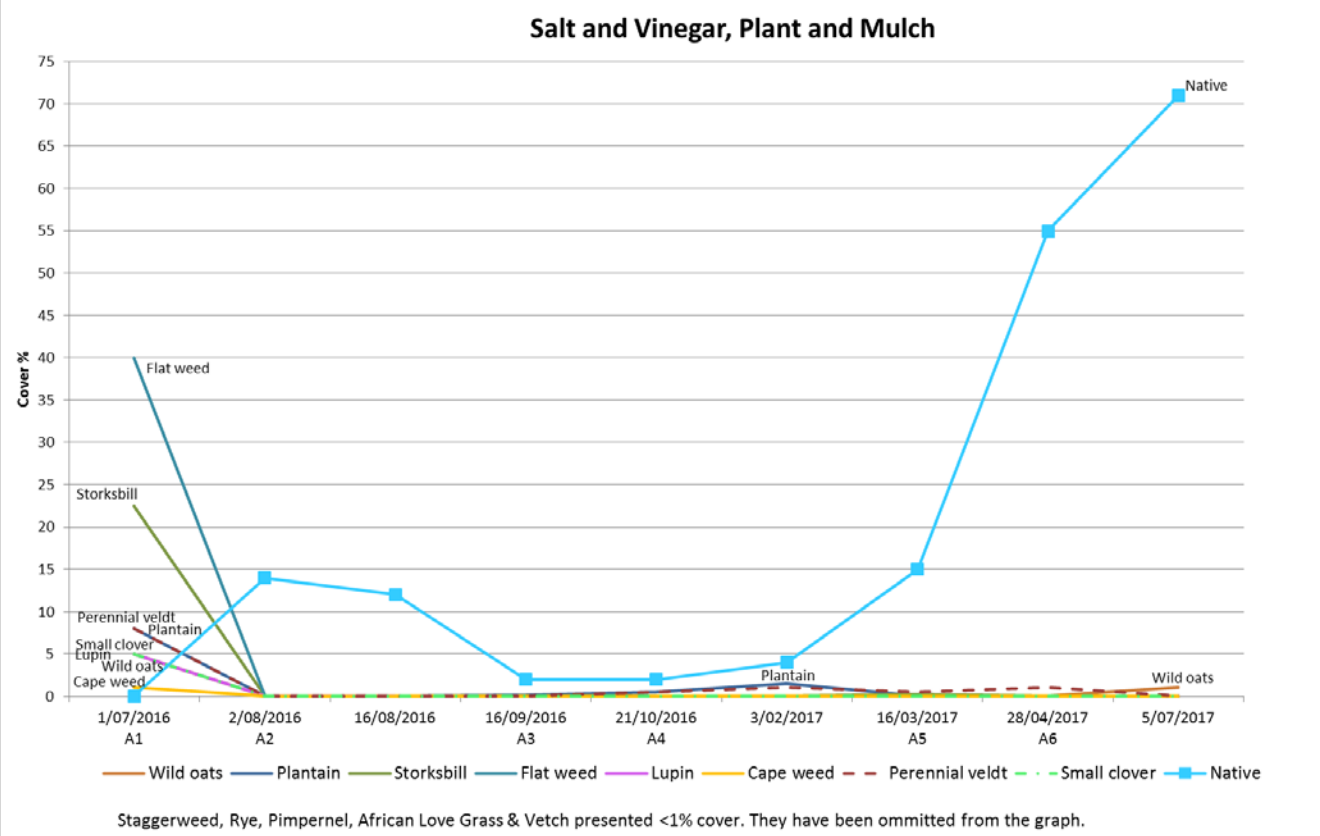
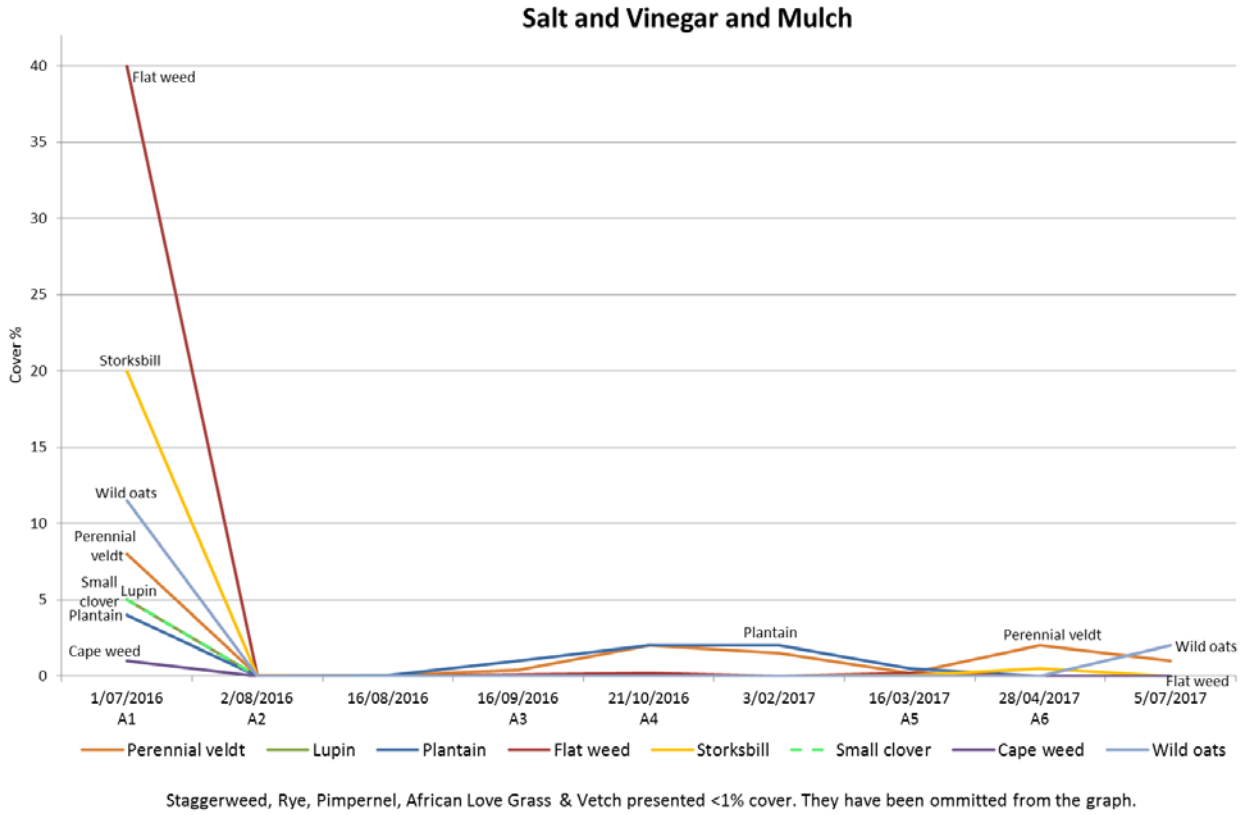


Figure 9. Percentage cover of weeds and native ground covers at Salt and Vinegar, Plant and Mulch sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

3.2.4 Salt and Vinegar and Mulch

Before the first treatment application Flat weed was most abundant in the Salt and Vinegar and Mulch sub-plot measuring 40% cover (Figure 10). Storksbill was second with 20% cover, followed by Wild oats at 11%, Perennial veldt at 8%, Small clover and Lupin at 5% each, Plantain at 4% and Cape weed at 1%. Following the first application of Salt and Vinegar solution and mulch, all weeds measured 0% cover. Plantain and Perennial veldt had each increased to 2% cover by October 2016 monitoring. In March 2017, cover of Plantain and Perennial veldt had reduced to less than 1% and 0% respectively. Perennial veldt cover increased again by April 2017 to 2%. By the end of the trial, Wild oats cover had increased to 2% while Perennial veldt was measured at 1% cover.

For photo monitoring refer to Appendix 9.21.



Staggerweed, Rye, Pimpernel, African Love Grass & Vetch presented <1% cover. They have been ommitted from the graph.

Figure 10. Percentage cover of weeds at Salt and Vinegar and Mulch sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

3.3 Pine Oil

3.3.1 Pine Oil Only

Perennial veldt and Wild oats were most abundant at Pine Oil Only sub-plot at the start of the trial with percentage cover of 15% each (Figure 11). Flatweed had 10% cover, Cape weed and Plantain 8% and Storksbill and Lupin 5% cover each. Large clover and Staggerweed were present at 2% and 1% cover respectively. Following the first application, all weeds except Cape weed and Storksbill decreased. Following the second and final Pine Oil application, all weeds decreased significantly with most presenting at 0% cover at the August 2016 monitoring, with the exceptions being Plantain at 2% and Storksbill, Cape weed and Perennial veldt at 1% each. Most weeds remained at 0% cover or had increased very slightly between August 2016 and March 2017. During this period, Wild oats, Plantain and Perennial veldt increased slightly to 7%, 4% and 3% respectively.

In March 2017, the only weeds present were Stink weed with 5% cover, Rye with 3% and Perennial veldt with 2% cover. The following month, Rye decreased to 0% cover while Stink weed increased to 15% before measuring 0% in July 2017. Perennial veldt and Plantain increased significantly at the end of the trial to 25% and 20% respectively. Flat weed and Wild oats increased slightly measuring 1% cover each in July 2017.

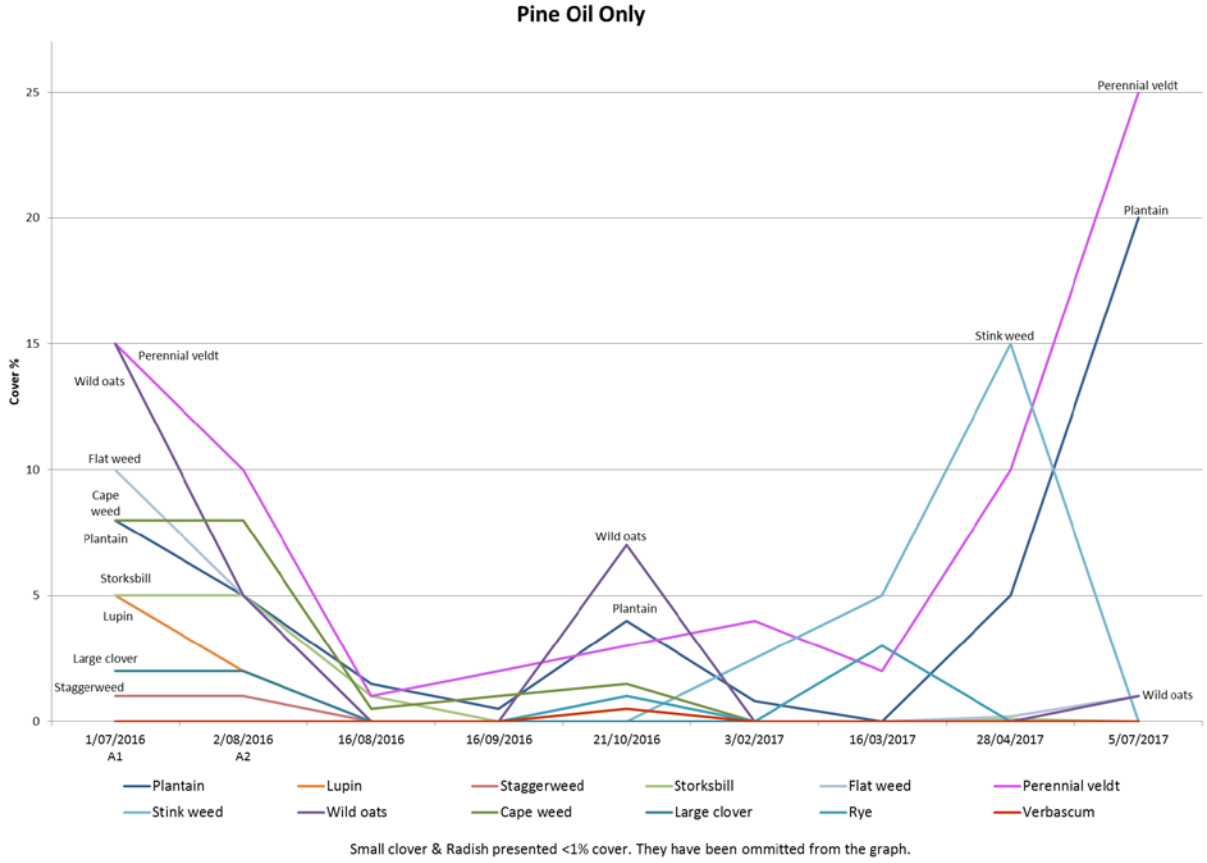


Figure 11. Percentage cover of weeds at Pine Oil Only sub-plot over the course of the trial (treatment applications represented using A1 and A2)

Photo 2 shows the Pine Oil Only sub-plot after the second and final application compared to the Pine Oil and Plant sub-plot after one application. Following this, the weeds in the Pine Oil and Plant sub-plot matured and set seed.

For photo monitoring refer to Appendix 9.14.

Photo 2: The Pine Oil Only sub-plot in the foreground and the Pine Oil and Plant sub-plot in the mid-ground

3.3.2 Pine Oil and Plant

Wild oats, Plantain and Flat weed were the most abundant weeds in the Pine Oil and Plant sub-plot at the start of the trial with percentage cover of 15%, 10% and 10% respectively (Figure 12). Storksbill and Cape weed measured 8% cover each followed by Perennial veldt at 7% and Lupin at 5%. Following both the first and final applications of Pine Oil, cover of most weeds were reduced. However Wild oats increased significantly, peaking at 40% cover in October 2016 before decreasing to 0% by February 2017. Wild oats cover at the last monitoring in July 2017 measured 1%. Plantain returned to the same level of cover as pre-treatment following the initial application and then plateaued at 10% between August and October 2016 before decreasing to 3% in March 2017. Plantain measured 5% cover at the end of the trial. Flat weed and Storksbill measured slight increases in August 2016 following the initial decrease after the Pine oil was applied. Cover of both Flat weed and Storksbill decreased to 0% cover by February 2017 before increasing to 5% towards the end of the trial.

The native ground covers increased to and remained at 5% between August and October 2016 before decreasing to 1% in February and March 2017. Cover remained 2% from April through to July 2017.

For photo monitoring refer to Appendix 9.15.

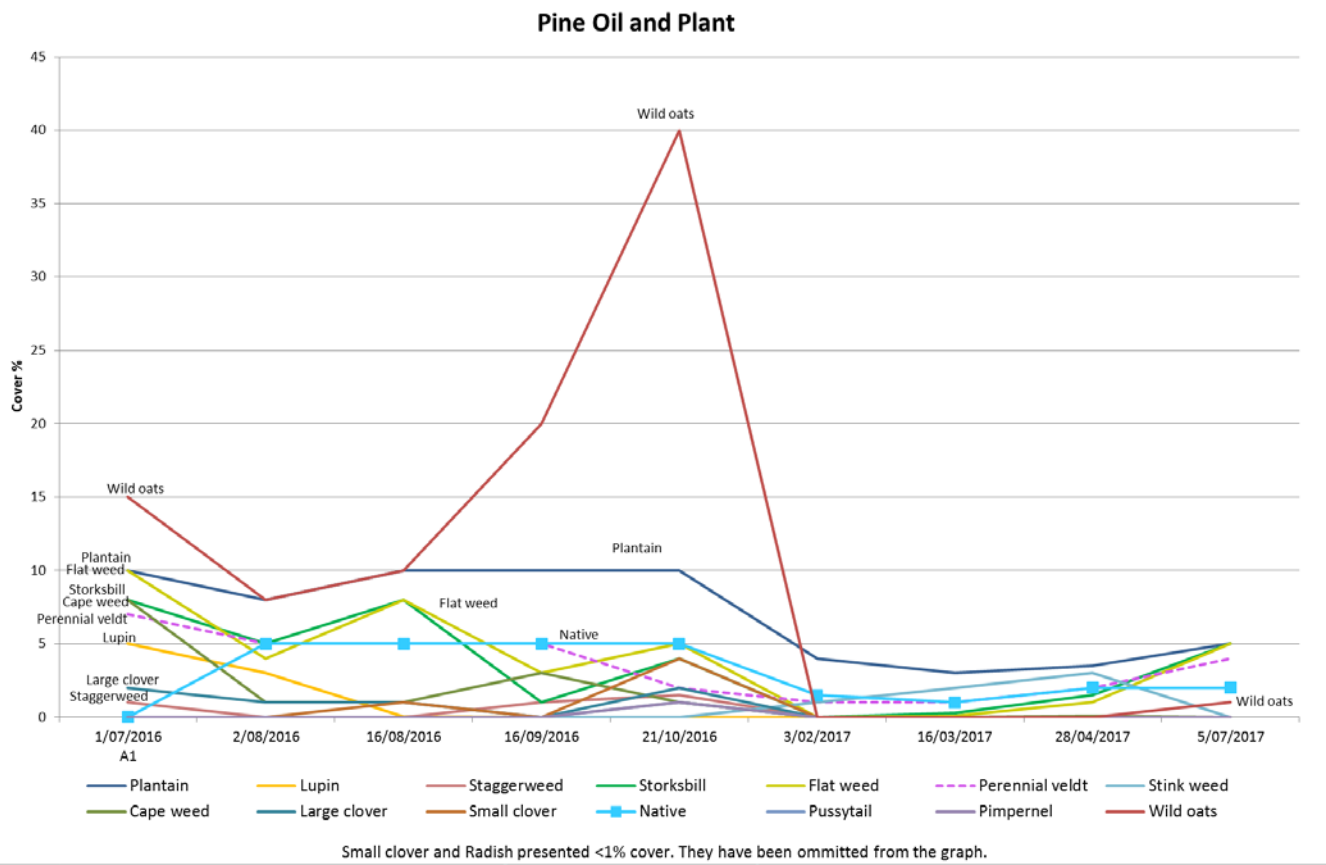


Figure 12. Percentage cover of weeds and native ground covers at Pine Oil and Plant sub-plot over the course of the trial (treatment application represented using A1)

3.3.3 Pine Oil, Plant and Mulch

Wild oats were the most abundant weed present at the start of the trial in the Pine Oil, Plant and Mulch sub-plot with 37% cover followed by Plantain, Flat weed and Cape weed with 15% each (Figure 13). Following the application of mulch and planting, all weeds with the exception of Plantain remained at less than 1% cover. Plantain cover was approximately 5% prior to hand weeding of plant wells in February 2017. Plantain cover had increased to 3% by the end of the trial. Wild oats cover was 2% and Cape weed 1% by the end of the trial.

Native ground covers increased to 5% in August 2016 and remained at this level until March 2017 when the cover increased sharply to 84% by the end of the trial.

For photo monitoring refer to Appendix 9.16.

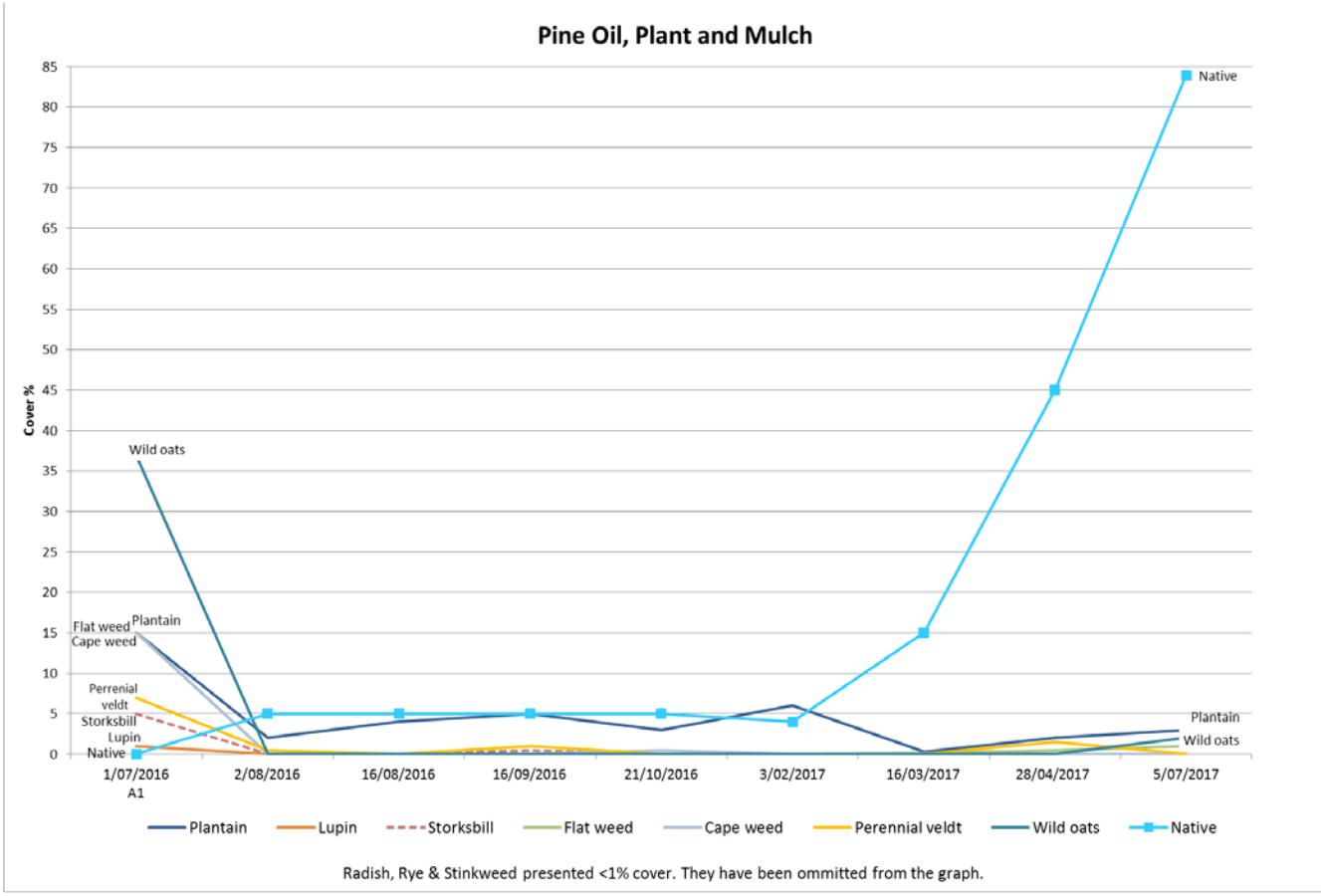


Figure 13. Percentage cover of weeds and native ground covers at Pine Oil, Plant and Mulch sub-plot over the course of the trial (treatment application represented using A1)

3.3.4 Pine Oil and Mulch

Pine Oil and Mulch sub-plot had the greatest cover of Wild oats (37%), followed by Cape weed, Plantain and Flat weed (15% each) at the start of the trial. Other weeds included Perennial veldt (7%), Storksbill (5%) and Lupin (1%) (Figure 14). Following the first and only application of Pine Oil and application of mulch in July 2016, cover of all weeds was recorded at 0% in August 2016. Plantain fluctuated between 1% and 2% before plateauing at 5% between April and July 2017. Wild oats was another weed that increased in cover to 5% by the end of the trial.

For photo monitoring refer to Appendix 9.17.

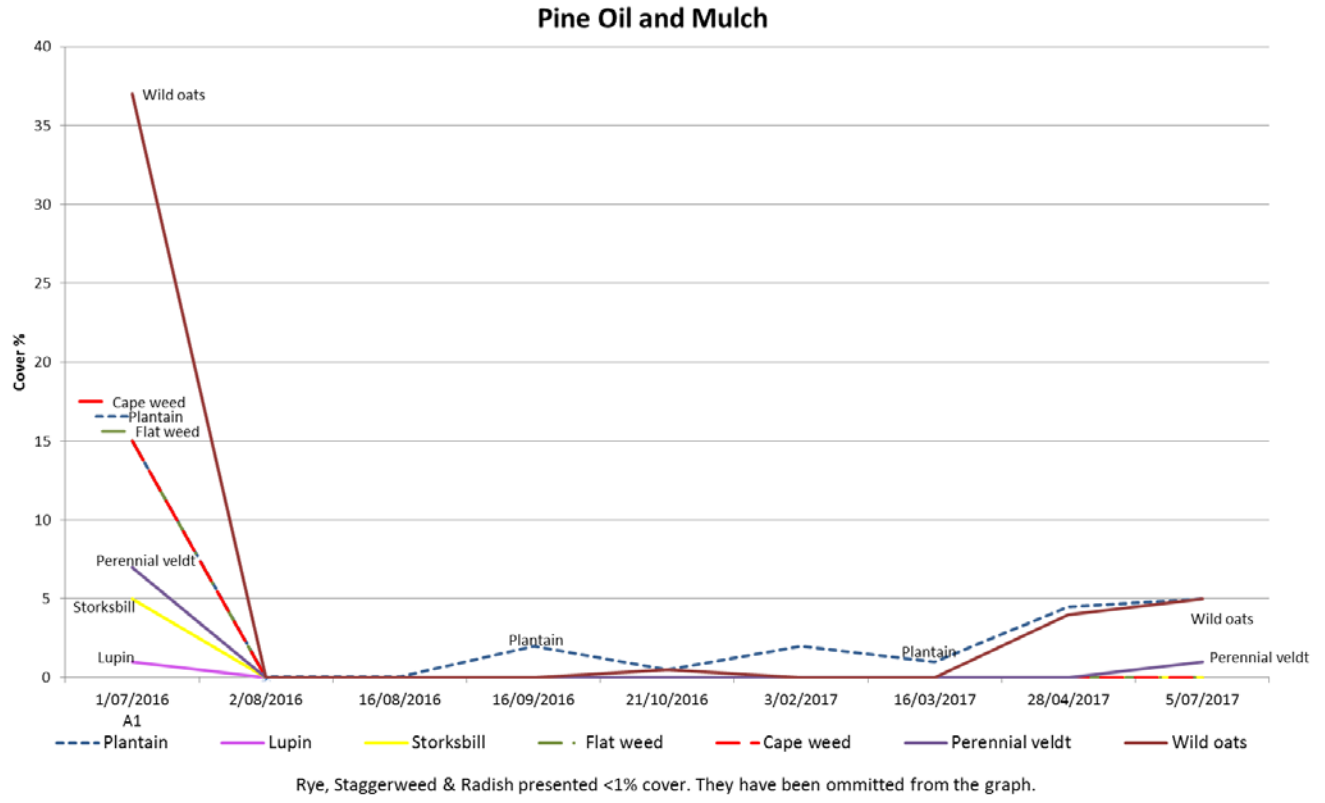


Figure 14. Percentage cover of weeds at Pine Oil and Mulch sub-plot over the course of the trial (treatment application represented using A1)

3.4 Pelargonic Acid

3.4.1 Pelargonic Acid Only

The weeds recorded at the Pelargonic Acid Only sub-plot prior to treatment were Plantain 30% cover, Cape weed 20%, Wild oats 20% and Perennial veldt 10% (Figure 15). These values remained the same between the first and second applications. The application rate was increased to 7% for the second application round. Following this, there was a minor decrease in Plantain, Cape weed and Wild oats cover. Radish and Perennial veldt had a more significant decrease from 20% to 5% and from 10% to 2% cover respectively. On 16 August 2016, the second application was repeated at 7% (marked as A2.1 in Figure 15).

It was thought the Pelargonic solution on 2 August 2016 was insufficiently applied. Subsequent to the additional application, Cape weed and Wild oats decreased from 15% to 5% and 15% to 6% cover respectively. Wild oats spiked in October 2017. 72 mL of precipitation was recorded in early October before this monitoring event and potentially influenced the increase in Wild oats.

Plantain increased between the February and March applications to 35% cover. The Plantain was removed (hand weeded) on 16 March 2017 shown by the steep decline in cover recorded on 28 April 2017. Wild oats had increased significantly by the end of the trial to 76% cover. There was 164.8 mL of rain recorded between the 28 April 2017 and 5 July 2017 monitoring visits (see Appendix 9.1).

For photo monitoring refer to Appendix 9.10.

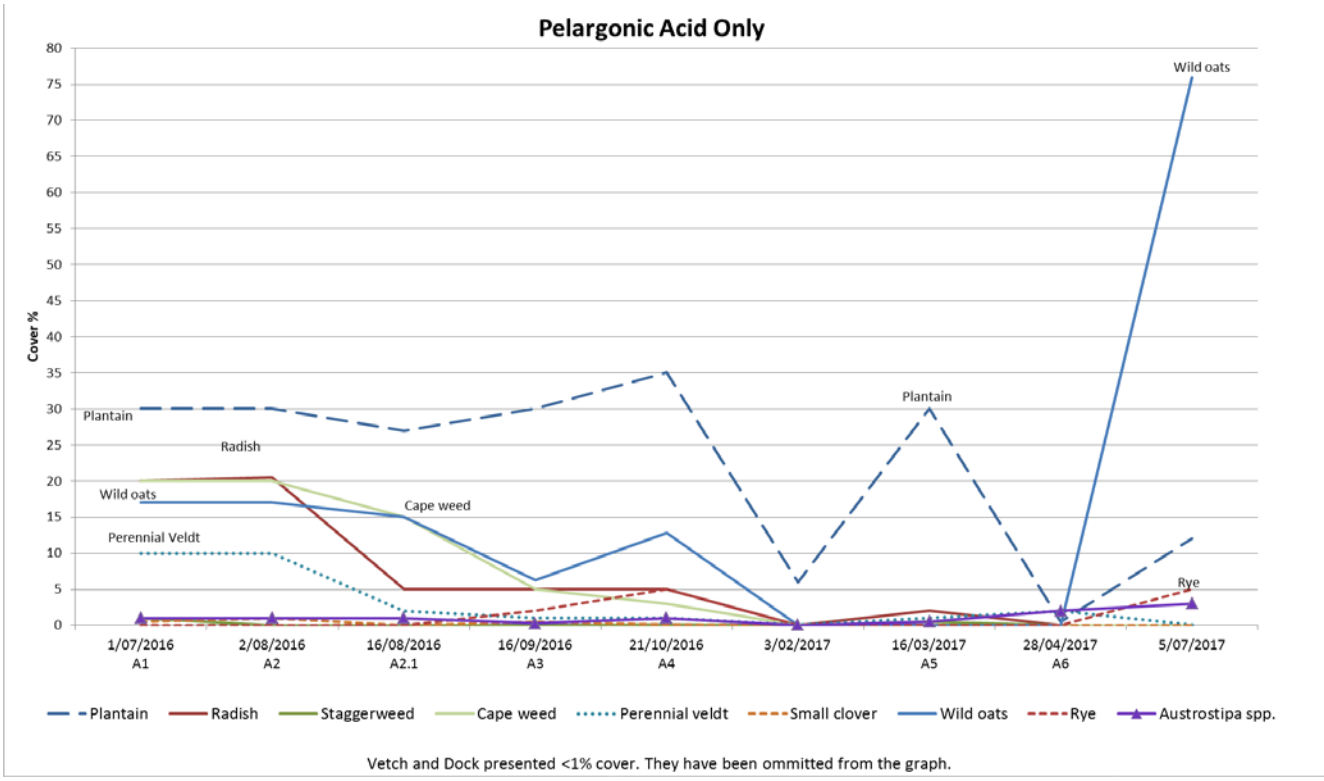


Figure 15. Percentage cover of weeds and native grasses at Pelargonic Acid sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

The effect of Pelargonic Acid on Cape weed and Wild oats are shown in Photo 3. Cape weed and Wild oats are flowering in the surrounding untreated areas suggesting the positive effect from the third and fourth Pelargonic Acid applications on these weeds. Unaffected Plantain is also prominent in both monitoring periods.

Photo 3: Pelargonic Only plot following A2.1 applications (16 September 2016, left) and following A3

3.4.2 Pelargonic Acid and Plant

Weed cover at the Pelargonic Acid and Plant sub-plot was recorded at 26% Plantain, 20% Radish, 20% Cape weed and 16% Wild oats (Figure 16) prior to treatment. There was no change in percentage cover following the first application on 1 July 2016, where Pelargonic Acid was applied at 5%. The second application of Pelargonic Acid on 2 August 2016 was applied at 7%, resulting in a slight decrease in weed cover of Plantain and Cape weed and an increase in Radish and Wild oats. A follow up application was carried out on 16 August 2016 using 7% Pelargonic Acid. Following subsequent applications, percentage cover of all four species decreased with an exception of Wild oats which increased to 30%. The fourth application reduced Wild oats to 0%. There were no Wild oats present at the time of sixth application however by the time of final monitoring Wild oats cover had increased to 76%. Of note, there was 164.8 mL of rain recorded between the 28 April 2017 and 5 July 2017 monitoring visits (see Appendix 9.1). The Plantain was removed (hand weeded) on 16 March 2017 as indicated by the steep decline in cover before the 28 April 2017 monitoring.

Perennial veldt cover was 5% at the start of the trial and remained constant until October 2016 where it increased to 7% before reducing to 1% after the fourth application. Between the fifth and sixth applications Perennial veldt cover returned to 5% and after the sixth application at the end of the trial was measured at 3%.

Native ground covers in Pelargonic Acid and Plant sub-plot were not planted at the same time as other sub-plots due to the follow-up/repeat application, as previously discussed. Native ground covers were planted on 31 August 2016, and were recorded at 4% cover on 16 September 2016. By the end of October 2016, cover of native plants had decreased to 1% and remained at 1% to the end of the trial.

For photo monitoring refer to Appendix 9.11.

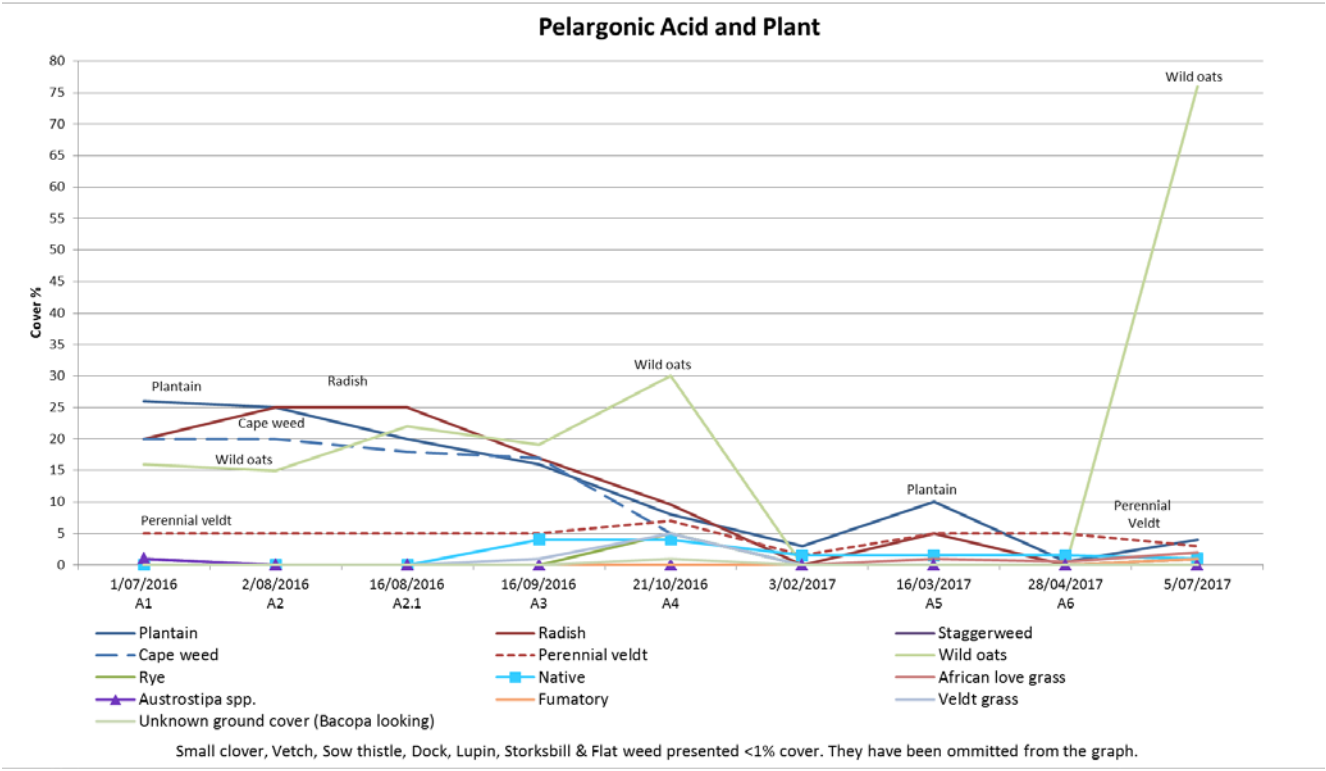


Figure 16. Percentage cover of weeds, native grasses and native ground covers at Pelargonic Acid and Plant sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

3.4.3 Pelargonic Acid, Plant and Mulch

Plantain was the most abundant weed present in the Pelargonic Acid, Plant and Mulch sub-plot at the start of the trial with 36% cover, followed by Perennial veldt 20%, Wild oats 19% and Cape weed 15% (Figure 17). Following the first application of Pelargonic Acid and mulch application, most weed cover was measured at 0%, however Radish was still present at 2% and Plantain, Cape weed and Perennial veldt at 1% each. Following the second application, Plantain continued to increase to 30% cover by March 2017. Hand weeding of Plantain was carried out after the monitoring was completed on 16 March 2017 before the fifth application. Following the hand removal of Plantain, the native ground covers increased significantly to 25% cover by the end of the trial in July 2017. During the last monitoring session, cover of Wild oats was recorded at 2%.

For photo monitoring refer to Appendix 9.12.

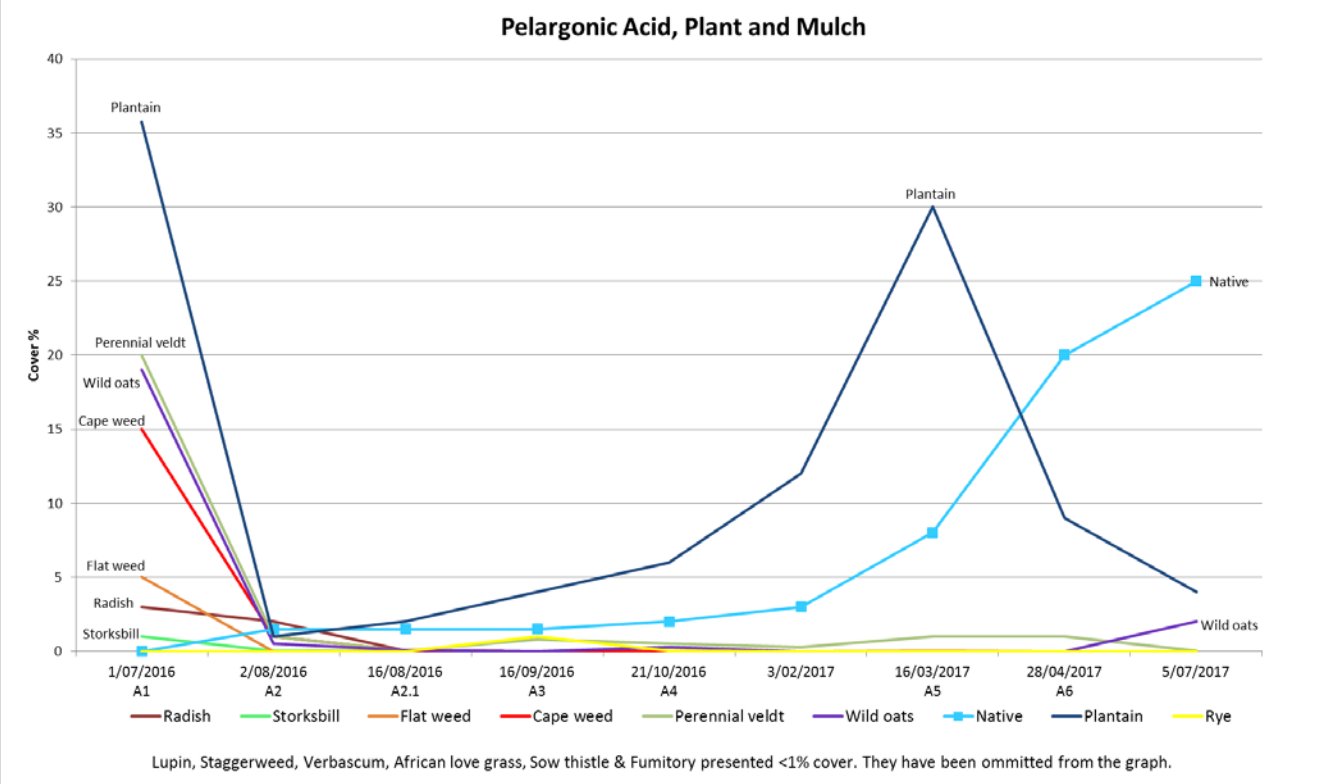


Figure 17. Percentage cover of weeds and native ground covers at Pelargonic Acid, Plant and Mulch sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

3.4.4 Pelargonic Acid and Mulch

Prior to treatment, the Pelargonic Acid and Mulch sub-plot had greatest cover of Plantain and Wild oats at 30% and 20% respectively, followed by Cape weed and Radish at 10% and 8% respectively (Figure 18). Following the first application of Pelargonic Acid and application of mulch, most weed cover reduced to 0% with the exception of Radish which was recorded at 1% and Plantain and Perennial veldt at less than 1%. Most weeds remained at less than 1% cover throughout the trial with exception of Plantain and African lovegrass. Plantain continued to increase in cover to 12% by March 2017.

Hand weeding of Plantain was carried out after the monitoring was completed on 16 March 2017 before the fifth application. African lovegrass had increased to 2% cover by February 2017, then fluctuated between 2% and 3% cover to the end of the trial. Wild oats percentage cover increased slightly to 2% by the end of the trial.

For photo monitoring refer to Appendix 9.13.

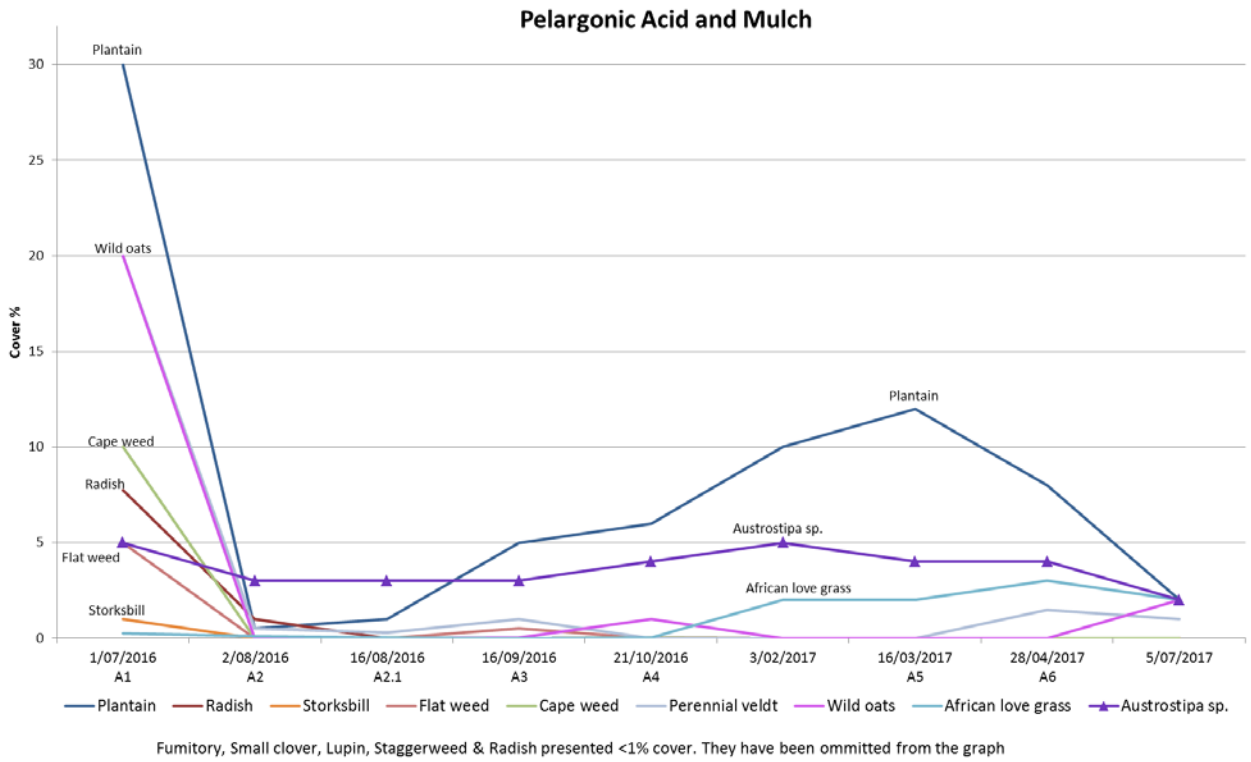


Figure 18. Percentage cover of weeds and native grasses at Pelargonic Acid and Mulch sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

3.5 Steam

3.5.1 Steam Only

Before the treatment was applied to the Steam Only sub-plot, Storksbill had the highest cover at 30%, followed by Flat weed at 20% and Cape weed at 11% (Figure 19). Weeds with cover between 5% and 10% were Perennial veldt, Small clover, Wild oats and Plantain, with other weeds present with cover less than 5%, were Radish, Lupin and Large clover. Native grasses were also present at 3% cover.

The first Steam application reduced all weeds except Plantain and Storksbill to less than 1% cover, with the exception of native grasses which were avoided in the treatment process. Plantain was reduced to 1% by mid-August after the second application, however it increased to 5% between the second and third application. Following the fourth application, Plantain decreased to 1% cover reducing further to 0% by April 2017, then by July 2017 had increased to 3% cover.

Small clover increased to 4% by October 2016 then reduced to 0% after the third treatment; by July 2017 it had increased to 15% cover. Native grasses cover increased over the course of the trial with 6% recorded at the last monitoring event. Perennial veldt increased to 10% by the end of the trial from 0% cover after the first Steam application.

For photo monitoring refer to Appendix 9.6.

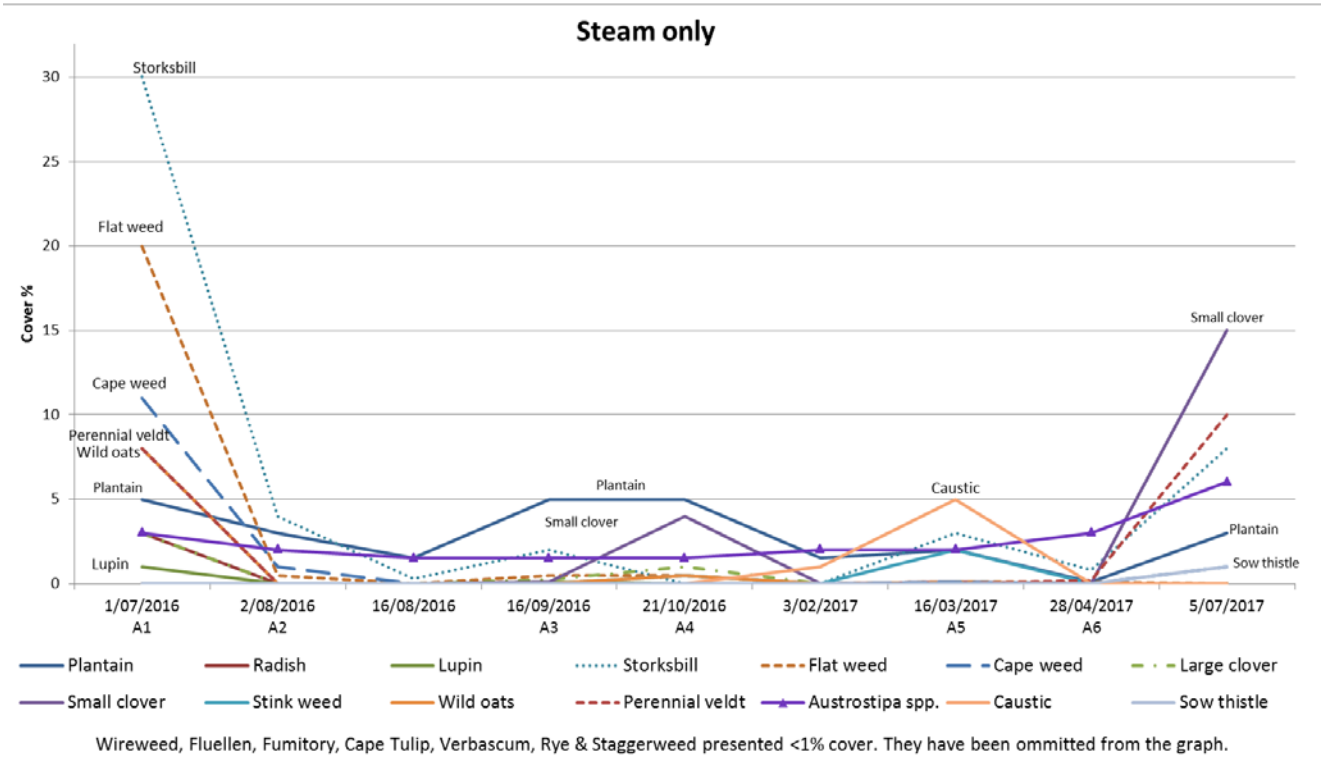


Figure 19. Percentage cover of weeds and native grasses at Steam Only sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

3.5.2 Steam and Plant

High variability was observed in the Steam and Plant sub-plot with Storksbill and Flat weed having the greatest percentage cover at 25% and 15% respectively (Figure 20). Cape weed and Small clover followed at 10% and 8% respectively. One month after the first application, all weeds were measured at 0% cover with Flat weed, Cape weed and Small clover returning to 10%, 7% and 5% cover respectively by September 2016. Storksbill also returned, however only to 4% cover compared to 25% before the first application. Plantain cover increased to 5% by October 2016 and did not show significant decrease following the October application. Plantain continued to increase to 10% cover in March 2017 before decreasing to 7% by the end of the trial.

Native ground covers planted at the start of the trial increased to 4% by September 2016 before decreasing to 2% by March 2017. Flatweed, Storksbill and Plantain cover increased again by the end of the trial, being 2% higher than the same time in the previous year. Storksbill cover was significantly reduced from 25% at the start of the trial to 9% at the end of the trial.

For photo monitoring refer to Appendix 9.7.

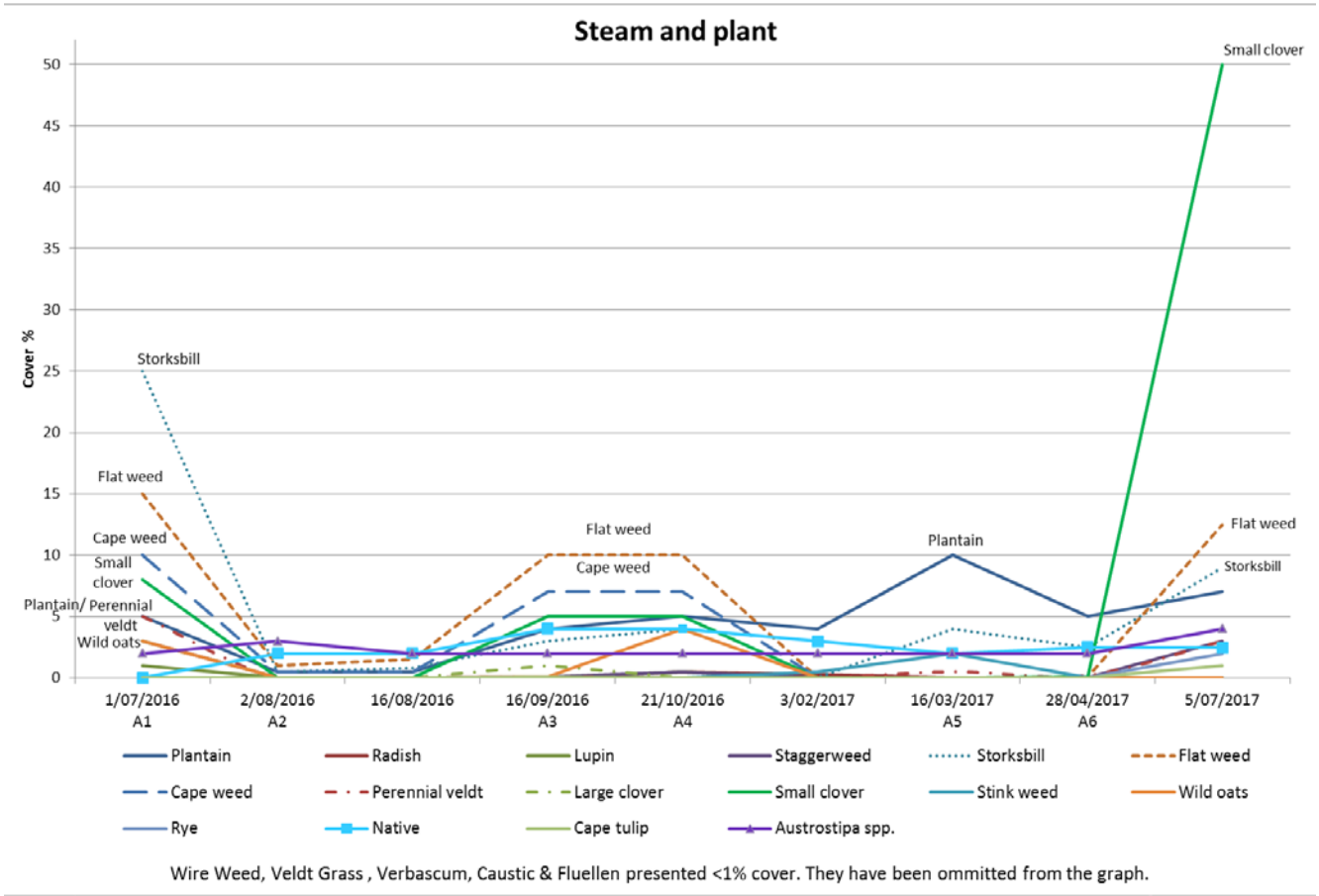


Figure 20. Percentage cover of weeds, native grasses and native ground covers at Steam and Plant sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

3.5.3 Steam, Plant and Mulch

Steam, Plant and Mulch sub-plot shown in Figure 21 shows a sharp increase in percentage cover to the end of the trial for the native ground covers planted.

Small clover and Plantain were the most abundant at the start of the trial with 20% and 10% cover respectively, with Perennial veldt cover of 8%. Following the first Steam application in July 2016 and with the application of mulch and planting of native ground covers, percentage cover of all the weeds present reduced to 0% and remained there until September 2016 when Small clover, Perennial veldt and Storksbill were measured at less than 1%. Flatweed and Rye increased slightly to 1% and Wild oats to less than 1%. Plantain had increased to 5% by March 2017 then decreased to 0% by April 2017 following a fifth application of Steam and hand weeding in the plant wells.

For photo monitoring refer to Appendix 9.8.

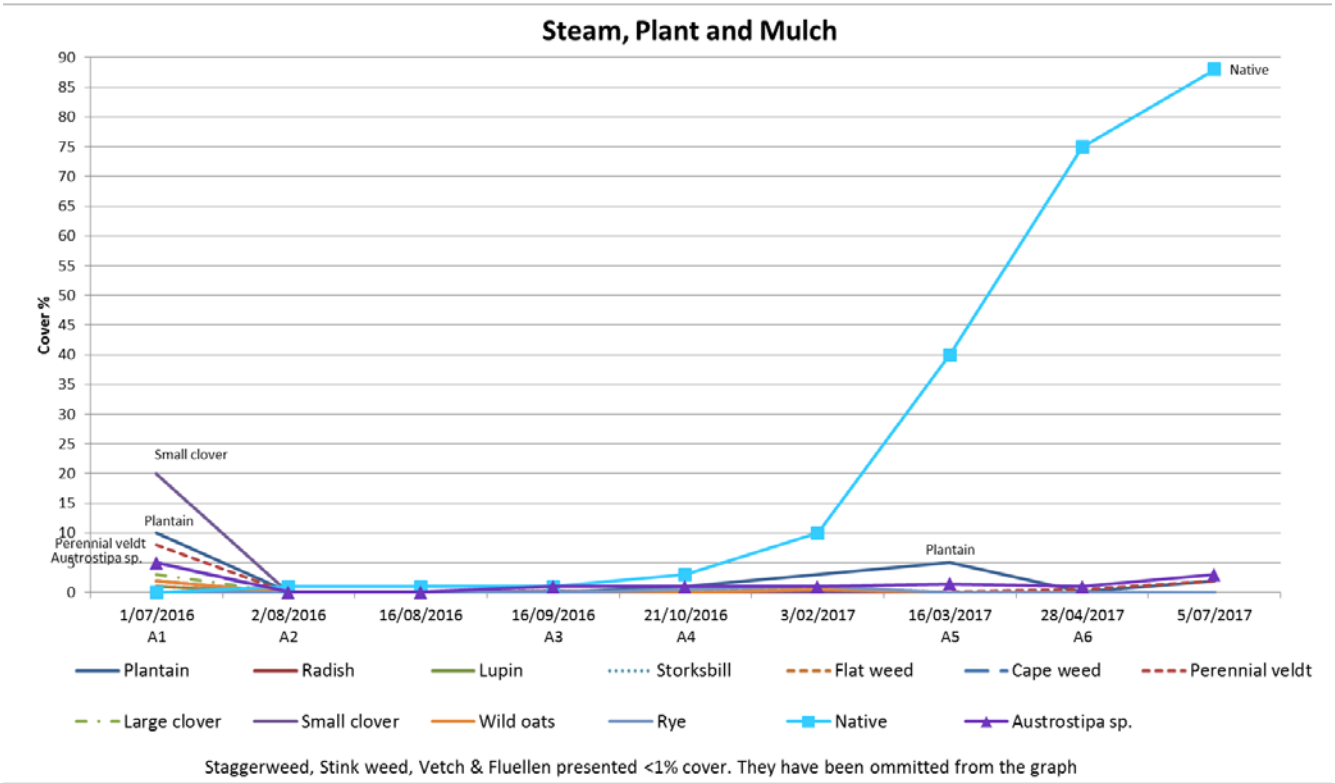


Figure 21. Percentage cover of weeds, native grasses and native ground covers at Steam, Plant and Mulch sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

3.5.4 Steam and Mulch

Steam and Mulch sub-plot (Figure 22) had Storksbill and Small clover as the most abundant weeds at the start of the trial with 20% cover each. Plantain was at 10% cover and Perennial veldt at 8%. Following the first Steam application and after the mulch was applied in August, all weeds were recorded at 0%. Fourteen days after the second application of Steam, Perennial veldt was recorded at 1% cover. However, after the third application it reduced to 0% cover where it remained until the end of the trial. Plantain was recorded at 1% cover in September 2017 then remained at less than 1% until March 2017. One month after the last application, Plantain and Perennial veldt were the only weeds present at less than 1% cover each.

For photo monitoring refer to Appendix 9.9.

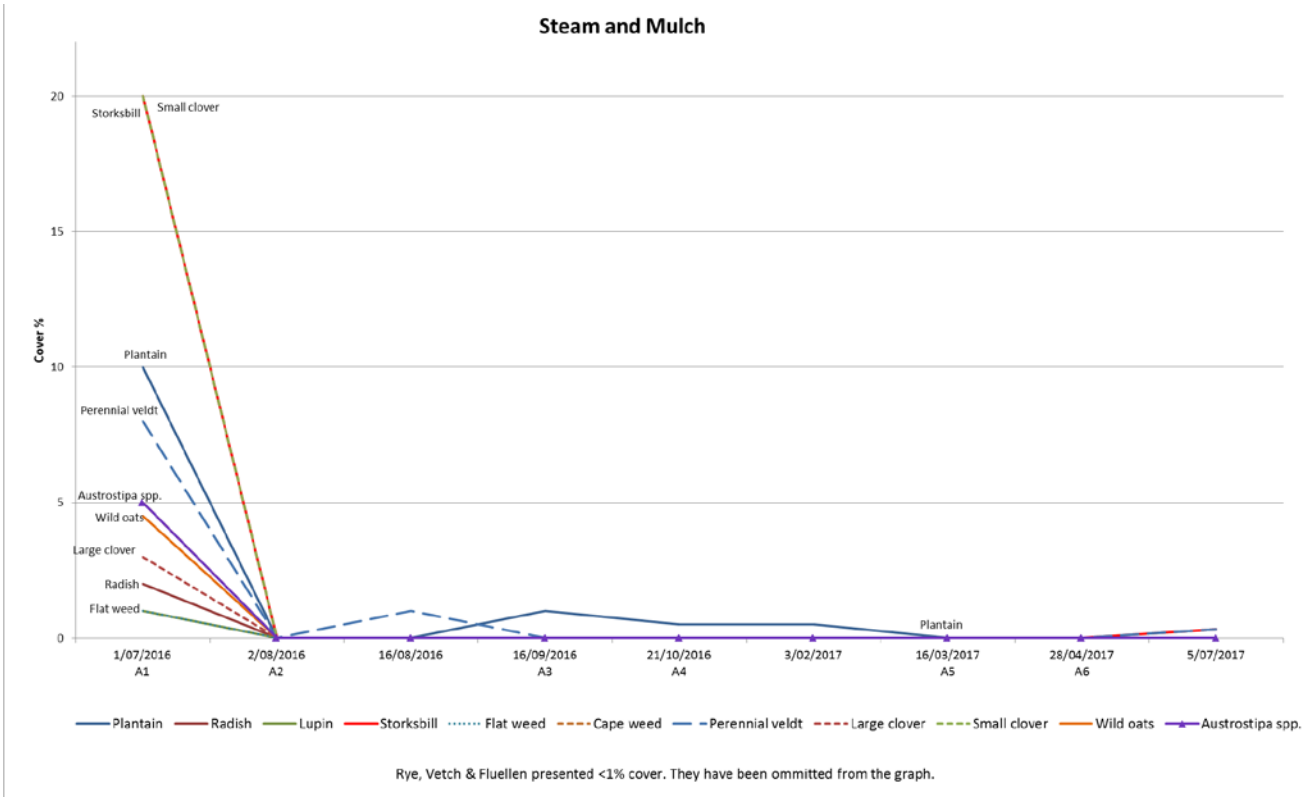


Figure 22. Percentage cover of weeds and native grasses at Steam and Mulch sub-plot over the course of the trial (six treatment applications represented using A1, A2, A3…)

4 Analysis of Results

Variability of growth and abundance of plant and weed species is expected in natural systems due to seasonal and environmental factors. Therefore the results shown in the table below should be used as a general guide only.

It should also be noted that the results obtained from the trial are unique to the environmental conditions present at the trial site. This should be taken into account when comparing the results of this report with other sites with differing environmental factors.

Weed species and abundance varied across the length of the trial. There was a small presence of native grasses and bare areas in sub-plots which could have influenced the results.

The effectiveness of the treatments has been averaged over the course of the trial and is shown in Table 3 . The baseline monitoring results were excluded from the averages.

The analysis shows that Mulch either by itself or in combination with a treatment and competitive planting has proven to be very effective in maintaining average weed cover.

The effectiveness of competitive planting is illustrated in Table 4. It shows weed versus native ground cover percentage over a one year period. Steam, Mulch and Plant sub-plot had the highest percentage cover of native ground covers (88%), followed by Pine Oil, Mulch and Plant with 84% native ground cover at the end of the trial.

Table 3. Effectiveness of all treatment trials presented as average weed percentage cover of all weeds over the course of the trial

	Control Only	Control & Plants	Control Mulch & Plants	Control & Mulch	Steam Only	Steam & Plants	Steam Mulch & Plant	Steam & Mulch	Pelargonic Only	Pelargonic & Plant	Pelargonic, Mulch & Plant	Pelargonic & Mulch	Pine Oil Only	Pine Oil & Plant	Pine Oil, Mulch & Plant	Pine Oil & Mulch	S & V Only	S & V & Plant	S & V, Mulch & Plant	S & V Mulch
Average % weed cover	67	59	5	2	11	24	2	1	51	56	10	8	20	30	4	3	13	11	1	2
Best sub-plot per treatment	Control & Mulch				Steam & Mulch				Pelargonic & Mulch				Pine Oil & Mulch				S & V, Mulch & Plant			

Note: The baseline monitoring round was excluded from these averages. Averages were taken from the results of the 2 August 2016 monitoring round until the 5 July 2017 monitoring round.

Table 4. Percentage cover totals of weeds and native plants as at 5/7/2017

	Control Only	Control & Plants	Control Mulch & Plants	Control & Mulch	Steam Only	Steam & Plants	Steam Mulch & Plant	Steam & Mulch	Pelargonic Only	Pelargonic & Plant	Pelargonic, Mulch & Plant	Pelargonic & Mulch	Pine Oil Only	Pine Oil & Plant	Pine Oil, Mulch & Plant	Pine Oil & Mulch	S & V Only	S & V & Plant	S & V, Mulch & Plant	S & V Mulch
Weed % cover	90	91	14	4	38	38	4	1	93	88	6	7	47	20	6	11	6	12	1	3
Native ground cover %	-	1	4	-	-	2	88	-	-	1	25	-		2	84	-	-	2	71	-
Best sub-plot per treatment	Control & Mulch				Steam & Mulch				Pelargonic, Mulch & Plant				Pine Oil, Mulch & Plant				S & V Mulch & Plant			

Note: Native grasses totals were excluded from the totals shown in the table as these were pre-existing not planted and do not reflect the results of the competitive planting of native ground covers trial.

5 Discussion

5.1 Mulch

Mulch has proven to be very effective at supressing weeds. As shown in Figure 6 (the Control and Mulch Only sub-plot), weeds have been maintained less than 5% over the course of the trial. Radish, Lupin, Staggerweed, Flat weed, Cape weed and Small clover were all effectively suppressed by mulch.

There were some mature Plantain, Perennial veldt and Storksbill weeds that did emerge through the mulch during the trial; however the coverage of these species did not exceed 2% at any stage of the trial. When the mulch was applied to the larger weeds, the mulch may not have provided complete coverage giving the weed access to sunlight and space thereby enabling it to emerge through the mulch. Additionally, the root systems of these weeds have stored energy available to be able to emerge through the mulch.

The results of the trial suggest that using mulch on its own to manage weeds is just as effective as using mulch in conjunction with other treatment options. As shown in Table 3 the Control and Mulch sub-plot maintained an average of 2% weed coverage throughout the trial. The most successful treatment and mulch sub-plot was the Steam and Mulch sub-plot with 1% average weed coverage.

Further studies would need to be conducted to validate the effectiveness of mulch alone and mulch in conjunction with another treatment as a weed suppressor. Baseline monitoring at the site identified variabilities in weed species and coverage across the length of the trial site. This should be taken into account when reviewing the mulch effectiveness results in this trial.

5.2 Competitive Planting

Best performing plot

The results of the trial suggest that competitive planting with native ground covers used as a treatment on its own or with mulch is mostly ineffective. The effectiveness substantially increased when planting was used in conjunction with mulch and another treatment.

This result was consistent across all of the plots with plants and mulch except for the Control and Steam plots. It has been observed that digging the holes to plant the ground covers in the Control and mulch plot exposed the weeds allowing them to grow through the mulch. The mulch did not have sufficient time to smother the weeds before the sub-plot was planted. If there was a longer period of time between mulching and planting, it is believed that the Control, Mulch and Plant plot would have been more effective at managing weeds than the Control and Mulch plot.

The success of the Steam, Mulch and Plant plot was also inconsistent with the other results. When applying Steam, it was a challenge to treat the weeds without the hot water flowing into the plant wells and impacting the native plants. Therefore, applying Steam in both of the planted plots was limited in order to protect the ground covers. As such, the Steam and Mulch plot received a better result for weed cover over the Steam, Mulch and Plant plot.

Challenges

Managing weeds amongst the planted plots was difficult because of the density of native ground covers planted. Avoiding contact with native plants when applying a treatment was a challenge requiring a more careful application technique. Particularly challenging was applying the Pelargonic Acid and Salt and Vinegar treatments as they required a liberal application to be effective. As a consequence, some of the native plants were impacted by drift spray. Steam treatment sent hot water flowing into the plant wells which also impacted the plants.

Observations

The health of the native plants increased with the addition of mulch, which was most likely due to the moisture retention qualities of mulch and the suppression of weeds that would otherwise compete with the plants for nutrients and moisture.

The health of native ground covers significantly decreased in plots where there were patches of bare soil exposed to the hot drying sun. Consequently, many plants died in these plots. In the Control plot it appeared that the dead Wild oats provided shelter from the sun and some protection from rabbits when compared to adjoining plots where native plants were more exposed to the elements and not growing as vigorously.

By the end of the trial, the native plants in the mulched plots were more established providing more amenity, low weed cover and some habitat values.

5.3 Salt and Vinegar

Salt and Vinegar was very effective at managing Staggerweed, Storksbill, Flat weed, Cape weed, Small clover and Lupin. Following two treatments these weeds were maintained at 1% or less than 1% throughout the trial.

There were notable differences in the levels of Wild oats weed cover following each treatment. This is most likely attributed to differences in the application technique together with increased weed vigour and germination rates in the active growth season. A number of spray operators applied the Salt and Vinegar over the course of the trial, therefore the amounts of solution and coverage of weeds per treatment may not have been consistent resulting in a steep decline in Wild oats following the 2 August 2016 application and the negligible impact following the 16 September 2016 application.

The frequency of applications may have been insufficient in the active growing season for Wild oats allowing the more mature plants to regenerate post-treatment. Of note, there was rain in early October 2016 that may have germinated dormant Wild oats seeds.

It is unclear if Plantain was effectively managed using the Salt and Vinegar treatment. The cover was reduced from 2% to less than 1% over the course of the trial, however it is not certain if the Plantain was regrowth from treated weeds or new seedlings. Regardless, the photos suggest treatment was successful in preventing the original plants from flowering or setting seed.

5.4 Pine Oil

Pine Oil is very effective at managing Lupin, Staggerweed, Flat weed, Large clover, Wild oats and Storksbill. After two applications these weeds were reduced to 1% or less. Maintaining the weed cover at this level was however compromised by the product's restriction to two

applications per year. As a consequence, new Wild oats and Stink weed seedlings as well as re-sprouting Perennial veldt and Plantain populated the sub-plot.

The two applications of Pine Oil did have an effect on Perennial veldt and Plantain but with the lack of a follow up treatment, the plants were able to regenerate and establish a larger presence by the end of the trial.

It does not seem that the addition of mulch or competitive planting assisted in maintaining the initial Pine Oil treatment over and above what mulch alone achieved. This outcome may have differed if the two initial Pine Oil applications were applied before the mulch and competitive planting.

Pine Oil can only be applied with a boom spray unit. This prevented a follow up application to the competitive planting plots. Subsequently, most of the weeds were able to regenerate in the Pine Oil and Plant plot compared to the decline in weed cover after the follow up treatment in the Pine Oil Only plot.

Pine Oil has a strong smell that lingers post-treatment.

5.5 Pelargonic Acid

Results from the trial suggest that Pelargonic Acid treatment was most effective for controlling Wild oats, Perennial veldt and Cape weed. Two careful applications and one quick application using variable dilution rates were used to gain desired results. More investigation is required to establish the treatment regime required to achieve the desired result. The trial has indicated that the 7% solution is more effective than a 5% solution. This treatment method was shown to be effective at managing Wild oats, Perennial veldt and Cape weed.

The large spike in Wild oats recorded at the last monitoring round is believed to be a result of the rainfall experienced between the April and July 2017 visits causing new seedlings to germinate. Additional applications during this time most likely would have reduced the Wild oats coverage recorded at the July 2017 monitoring round.

Mature Radish was significantly reduced using Pelargonic Acid as shown between the July 2016 to September 2016 application rounds. There was some Radish that produced flower and set seed but it is unclear if this was incorrectly treated or if it was regrowth post-treatment.

Pelargonic Acid was ineffective at managing Plantain due to the stored energy in the tap root allowing it to regenerate post-spray. There was some visible leaf die-off of Plantain leaves immediately after a Pelargonic acid treatment was applied, but the plants quickly regenerated. After five unsuccessful treatments, it was decided that Plantain was preventing other results from being obtained so the Plantain was removed (hand weeded) from all four sub-plots where Pelargonic acid was being trialled.

After two applications of Pelargonic Acid, Radish seedlings decreased from 2% to less than 1% in the Pelargonic Only sub-plot during its active growing season. This result was also observed in the Pelargonic and Plant plot with a reduction from 5% reduction to less than 1%.

Variable results were achieved using this treatment; this was attributed to different spray operator techniques when applying Pelargonic Acid to the weeds. The best results were achieved when a more liberal and careful application was given to the plants allowing the physical mode of action (breakdown of cellular structure) to have an effect on the whole plant so it could not regenerate. Ensuring a good coverage of the spray is important when using this method.

5.6 Steam

The results of the trial suggest that Steam is an effective management technique for Radish, Lupin, Perennial veldt, Clover, Wild oats, Stink weed and Caustic weed. Just one Steam treatment was required to manage these weeds successfully and prevent seed set. Steam did have a significant impact upon Storksbill, Flat weed and Cape weed after two treatments. Storksbill did register a slight increase at the September 2016 monitoring visit and it is assumed that some of the weed was missed by the operator during in the second treatment.

The spike in Clover and Caustic weed cover were from new germinates taking advantage of the bare ground in the sub-plots. The spike occurred in the active season for these species.

Steam was not as effective in managing mature Plantain. Plantain has stored energy in the tap root that allowed the plants to re-sprout post treatment. Smaller seedlings were treated successfully.

6 Recommendations

It is recommended that weed managers use this report as a guide only when incorporating alternative weed management treatments into a weed strategy or regime. Each site has its own specific environmental conditions; therefore the treatments applied in this trial may not provide the same results in different environmental conditions.

Before a trial of a new weed management technique is commenced, it is recommended to first clearly outline the reasoning, objectives, expectations and Presentation Standards to be applied and to communicate this with all levels of management and on-ground staff. It is also recommended to keep the community informed throughout the process to ensure transparency and therefore gain trust and support.

It is of note that the treatment, process, resources and expected outcomes (both negative and positive) of alternative techniques may differ from traditional methods.

It is important to establish what the Presentation Standards are for each site, as these may be higher or lower than the standards that have been normalised over time. For example, an area that is often in the public eye may have a Presentation Standard of no more than 5% weed cover but a verge on a busy road or in a bushland reserve may have a Presentation Standard of no more than 20% weed cover.

Ensuring that the application methodology and recommendations of the product being trialled is well known by management and on-ground staff is vital for a successful trial. Only trial a product on the type of weeds that the product recommends will work. Avoid trying to use Pine Oil on a mature woody weed, for example. Alternative weed management methods often require a more thorough application than traditional chemicals. Misapplication can mean that only partial die off is observed which can lead to unsatisfactory results early on in a trial.

It is recommended to maintain a close relationship with operators applying the treatments. This will help ensure there is consistency in the application technique and appropriate feedback is provided on any challenges or obstacles that may be able to be overcome. This is important when transitioning to new methods that are different from traditional techniques.

If the above factors have been taken into account and communicated well, a balanced trial will result which will assist with determining if an alternative method is appropriate for the site.

6.1 Mulch

Using mulch alone is very effective at managing weeds. The trial demonstrated that mulch alone is almost as effective as using mulch with another treatment. More investigation is required to confirm this result; however this study has shown a positive result for mulch as a solo treatment over an annual cycle.

Where mulch alone is less effective is on the more persistent weeds such as Perennial veldt and Plantain. This may be overcome if pre-treatments are applied to these weeds before mulch is spread. Some weeds were re-establishing after the mulch had been present for an annual cycle. Annual top-ups of mulch could combat this in the lead up to the season when the most germination occurs at the site being managed.

Lessons learnt from the trial are that mulch should be applied early before the planting season to allow time for the mulch to smother the existing weeds; applying additional treatments to existing weeds before applying mulch will deter persistent weeds from pushing through the mulch; and lastly more work is required to determine the optimum amount of ground covers per metre to allow for follow up weed control while still achieving the competitive coverage of plants.

6.2 Competitive Planting

Competitive planting is effective at managing weeds when used in conjunction with mulch and another treatment. Although negligible, there will be some weeds that persist using this method. Due to the density of plantings required, follow-up weed control may be more difficult. If the Presentation Standard permits some weed coverage, this method is recommended. This method is favourable when aesthetic and habitat values are to be considered in conjunction with weed control.

6.3 Salt and Vinegar

Salt and Vinegar has proven to be very effective at managing Staggerweed, Storksbill, Flat weed, Cape weed, Small clover and Lupin.

It is recommended to increase the frequency of applications during the active growing season of the target weed species. This will increase its success rate, prevent re-growth and control any new seedlings. To achieve optimum results, it is vital to coat all parts of the plant with the solution. More attention to detail is required when applying this spray when compared to traditional methods. More investigation is required to determine the minimum applications required in the active growth period to achieve desired results.

The successful result of the treatment on Plantain was surprising; more investigation is needed to confirm if Salt and Vinegar can manage this persistent weed within acceptable levels.

6.4 Pine Oil

Pine Oil has been shown to be very effective after two applications. Lupin, Staggerweed, Flat weed, Large clover, Wild oats and Storksbill were specifically impacted by the Pine Oil treatment. The product's restriction of two applications per year did impact the maintenance of the initial results. To combat this, another treatment could be utilised in conjunction with Pine oil to maintain the Presentation Standards achieved by the initial two Pine oil applications.

The product used in this trial required it to be applied with a boom-spray. With this product it is best used in large areas where a boom-spray can manoeuvre around existing vegetation. It is recommended not to use Pine Oil in highly trafficked areas as it has a strong persistent odour that may be an irritant to some people.

Other Pine Oil products are available that can be applied using a knapsack and less restrictions on the number of treatments applied. More investigation will be required to determine the efficacy of this method.

6.5 Pelargonic Acid

Pelargonic Acid has been shown to be effective at managing Wild oats, Perennial veldt and Cape weed. Young Radish seedlings were also reduced using Pelargonic Acid. It is unclear the minimum number of applications required to achieve these results, however the 7% application rate has shown to be the most effective.

To achieve the best results, it is vital that the solution covers all above ground parts of the weed during application. This will give the active ingredient the best opportunity to break down the weed cellular structure and therefore reduce the likelihood of the plant re-sprouting. It is important to ensure that operators are consistent with the application as this technique is different to traditional methods. It is also recommended to have discussions with the product's manufacturer before and while undertaking a trial.

More applications during the active growth period of target weeds will help to reduce regrowth of treated weeds.

It is not recommended to use Pelargonic Acid on mature plants with large underground energy storage systems, such as Plantain.

6.6 Steam

Steam has been shown to be effective at managing most weeds with the exception of mature weeds with a large underground storage system that have the ability to regrow post-treatment. For this reason it is not recommended to treat Plantain with Steam unless they are young seedlings.

It is recommended to use Steam to manage Radish, Lupin, Perennial veldt, Clover, Wild oats, Stink weed, Caustic weed, Storksbill, Flat weed and Cape weed. For this method to be effective, it is recommended to undertake more regular follow-up treatments in late winter and spring during the active growth season. This will ensure any regrowth from weeds such as Storksbill and Cape weed is managed and any new seedlings are treated.

7 Conclusion

The trial has successfully shown the effectiveness of a number of alternative weed management treatments, both alone and in combination with other treatments, at a specific site and highlighted some of their advantages and disadvantages. The results of the report can be utilised by weed managers as a guide for future trials and to implement non-traditional methods.

Mulch has been shown to be very effective at managing weeds with minimal resource requirements. Competitive planting in conjunction with mulch and follow-up treatment is effective at managing weeds and has the added benefits of improved aesthetics and enhanced habitat values. Steam is also effective at managing most weeds with the exception of mature weeds or weeds with large underground energy storage systems. Pelargonic Acid has been shown to be effective on some weeds if the appropriate follow-up is undertaken. Pine Oil also has the ability to manage some weeds however the product's restriction to two applications per year in the same area did reduce the effectiveness of this treatment. Salt and Vinegar is effective at managing weeds if all parts of the plant are covered with the solution and follow-up applications are completed.

It is recommended that this report is used as a guide only when incorporating alternative weed management treatments into a weed strategy or regime. Each site has its own specific environmental conditions; therefore the treatments applied in this trial may not provide the same results in different environmental conditions. The findings of this report are a reflection of the specific environmental conditions at the Railway Heritage Trail in Mount Helena.

8 References

Bureau of Meteorology, Commonwealth of Australia, Daily Rainfall Mount Helena, Retrieved 17 November 2017, from: http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_display_type=dailyDataFile&p_nccObsCode=136&p_stn_num=009202&p_c=-17117122&p_startYear=2017

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9 Appendices

9.1 Precipitation

	2016								2017						
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1st	0	0	0	3.4	1.6	7.2	0	0	0	16.6	0	0	0	0	7.2
2nd	0	0	0	0	0	8.6	0	0	0	0	6.2	0	0	0	39.4
3rd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4th	0	10.4	0.2	2.8	0	4.2	0	1.4	0	0	0	0	0	0	3
5th	0	0	0	0.6	0	0	0	0	0	0	0	0	8	0	3
6th	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	12
7th	18	13.6	0	15.4	10.6	0.2	0	0	0	9	0	0	0	0	11.2
8th	2	0	15	20	12	19.6	0	0	0	0	0	0	0	0	0.2
9th	0	0	18	12		16.8	0	0	0	10.4	0	0	1.4	0	0
10th	0	0.6	28	2.8	0	0	0	0	0	64.2	0	0	0	0	0
11th	0	0.6	0.4	3	0	0	1.4	0	0	23.6	0	0	0	0	0
12th	0	0	0	0	0	0	0	9.4	0.4	0.2	0	0	0	0	10
13th	0	21.4	0	0	0	0	0	3.4	0	1.2	13	0	0	0	9.2
14th	5.2	0	0	0	0	0.8	0	0	0	7	2	0	0	8.4	0
15th	0.2	0.6	0	0	0	8.2	0	0	0	0	2.2	0	4.8	0	0
16th	0	0	0	7	5.2	1	0	0	0	0	0	0	8.2	0	11.4
17th	0	0	38.8	1.4	0	0	13	0	0	0	0	0	0	0	0
18th	0.4	0	10.2	33	0	0	0	0	0	0	0	0	0	0	0
19th	0	0	0	0	14	0	0	0	0	0	0	0	3.4	0	7
20th	0	2.6	0	7.8	0	5.4	0	0	0	0	0	0	5.8	0	25.4
21st	36.8	3.2	21.4	1	0	0	0	0	0	1.6	0	0	29.4	0	3.8
22nd	26.1	1.2	9.4	3.6	0	0	0	0	0	0	5.2	0	7	23.2	10
23rd	1	2.4	0	0	8.2	0	0	0	0	0	1.6	0	3.4	8.2	2
24th	20	0.2	0.4	0	1	0	0	0	0	0	0	0	3	0	9.4
25th	0.8	2.4	0.2	0	3.8	0	0	0	0	0	0	0	1	0	4.4
26th	5.6	6.2	0	0	0	0	0	0	0	0	1.6	0	0	0	0.4
27th	0.4	0.2	0	34	2.4	0	0	0.6	0	0	0	0	0	0	7.6
28th	4.6	0.2	0	7.8	13	0	0	0.2	0	0	0	0	0	0	13.6
29th	0.4	10.8	0	0	0	2.2	0	0	0.6		0	0	0	0	13.4
30th	0	0.2	3.6	0	0	1.4	0	0	11.6		0	0	0	0	12
31st	0		11.8	6.2		0		0	48.2		0		0		0
Highest Daily	36.8	21.4	38.8	34	14	19.6	13	9.4	48.2	64.2	13	0	29.4	23.2	39.4
Monthly Total	121.5	76.8	157.4	162.4		75.6	14.4	15	60.8	133.8	31.8	0	75.4	39.8	215.6

Source: Commonwealth of Australia, Bureau of Meteorology