Office Use Only	
Project Code	
Project Type	

FINAL REPORT 2016

Applicants must read the *SAGIT Project Funding Guidelines 2016* prior to completing this form. These guidelines can be downloaded from www.sagit.com.au

Final reports must be emailed to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.

PROJECT CODE	**:** PIRSA 0113
PROJECT TITLE	(10 words maximum)
Silverleaf nightshade – protecting clean farms and reducing SA yield losses	

PROJECT DURATION

These dates ***must*** *be the same as those stated in the Funding Agreement*

Project Start date	July 1 2013				
Project End date	June 30 2016				
SAGIT Funding Request	2013/14		2014/15		2015/16	

PROJECT SUPERVISOR CONTACT DETAILS

The project supervisor is the person responsible for the overall project

Title:	**First Name:**	**Surname:**
Dr	John	Heap

Organisation:

PIRSA (Primary Industries and Regions, South Australia)

Mailing address:

Telephone:	**Facsimile:**	**Mobile:**	**Email:**

ADMINISTRATION CONTACT DETAILS

The Administration Contact is the person responsible for all administrative matters relating to the project

Title:	**First Name:**	**Surname:**
Dr	Ross	Meffin

Organisation:

PIRSA (Primary Industries and Regions, South Australia)

Mailing address:

Telephone:	**Facsimile:**	**Mobile:**	**Email:**

PROJECT REPORT

Provide clear description of the following:

Executive Summary (200 words maximum)

A few paragraphs covering what was discovered, written in a manner that is easily understood and relevant to SA growers. A number of key dot points should be included which can be used in SAGIT communication programs

Biology and management of silverleaf nightshade (SLN) was investigated. Long-term herbicide experiments were established at Warnertown and Keith. Interim results after three years of consecutive treatments suggest that glyphosate and Starane are best for reducing perennial shoot density. There were significant reductions in shoot density measured in these treatments at Keith, but as yet not at Warnertown. A number of spot treatments reduced SLN shoot density after two consecutive applications at Keith, including Graslan (tebuthiuron), Arsenal Express (imazapyr/glyphosate), FallowBoss Tordon (2,4-D amine/picloram/aminopyralid), Hotshot (aminopyralid/fluroxypyr) and Uragan (bromacil). Arsenal Express, FallowBoss Tordon and Uragan (bromacil) also performed well at Warnertown.

Experiments at Cavan and Edinburgh suggest that glyphosate applied for seed-set control should be applied before the small berry stage, and that dusty leaves may not affect glyphosate efficacy as much as anticipated. Experiments simulating a range of rainfall events on glyphosate efficacy were confounded by an unusually-large February rainfall event (80 to 100mm) in 2014. Seedling emergence occurred after a single large summer rainfall event, however survival required several large follow-up events. A cohort of wild seedlings at Edinburgh was monitored; however, they perished during winter. SAGIT and this project also assisted in establishing a SLN biological control project.

Project Objectives

A concise statement of the aims of the project in outcome terms should be provided.

This project aimed to:

1. Conduct targeted practical field research on silverleaf nightshade (SLN) to reduce yield losses in grains crops, and help to minimise the rate of spread of SLN to clean, productive farmlands in SA.
2. Establish two regional collaborative research and demonstration focus sites to involve SA grain growers and promote ownership and rapid adoption of current and newly-discovered information on SLN management.
3. Deliver current and new best practice management information to SA grain growers so that they have both the tools and the economic confidence to reduce serious losses from SLN.

Overall Performance

A concise statement indicating the extent to which the Project objectives were achieved, a list of personnel who participated in the Research Project including co-operators, and any difficulties encountered and the reasons for these difficulties.

Overall the project was successful. Valuable information on the medium-term effects of successive herbicide applications on SLN has been gained. Seedling biology and recruitment in South Australia is now much better understood, providing better information on biology and spread to be communicated to farmers. Seed-set management in the field has been well defined, giving farmers a precise understanding of what is required. The effect of dusty SLN leaves on glyphosate efficacy has been examined, and found to be less of a potential problem than previously thought. The effect of soil moisture on glyphosate efficacy was not able to be defined due to the confounding effects of 80 to 100mm rainfall on 14 to 15 February 2014, at the start of the experiments. The experiment did however provide valuable data on the effect of glyphosate on SLN density.

Research using Precision Agriculture techniques to measure yield losses due to SLN were affected by data loss from grower's computer, drought, and a change of crop rotation. The main problems encountered were: The Keith host farmer's computer malfunctioned, resulting in the irretrievable loss of all stored data, including the 2014 wheat yield data from both paddocks; the Keith 2015 barley yield data from both paddocks was not available because the crops suffered severe drought and were baled for hay; and the Warnertown paddock was required to be sown to vetch in 2015, rather than the planned cereal, so no yield data was available. Despite these major constraints, there was still some useful data collected.

It should be noted that a major component (herbicide experiments at two focus sites) has been funded by SAGIT for an additional three years, and more definitive SLN control data will be available at the conclusion of the project in 2018.

Co-operators included Mr Alf Densley (Keith), who has generously hosted research on SLN since the 1980s, Mr Wayne Young (Warnertown), Mr Brian Tiller (Warnertown), and Mr Gordon Stopp (Keith). Hardi Australia, the Walker Corporation, and the Edinburgh air force base have also been very generous in allowing experiments on their land.

Key Performance Indicators (KPI)

Please indicate whether KPI's were achieved. The KPI's must be the same as those stated in the Application for Funding and a brief explanation provided as to how they were achieved or why they were not achieved.

Year	*KPI*	*Due*	*Achieved (Y/N)*	*If not achieved, please state reason.*
2013	Identify and establish field research sites throughout SA	Dec 31 2013	Y	
2013	Collect seed and commence seedling establishment experiment	Dec 31 2013	Y	
2013	Visit Parilla site to document native moth damage	Dec 31 2013	Y	
2014	Deliver three regional SLN workshops	April 30 2014	Y	
2014	Conduct broad-acre, spot-spraying and eradication experiments at two focus sites	May 31 2014	Y	
2014	Conduct soil moisture, leaf dust, berry stage and seedling establishment experiments	May 31 2014	Y	
2014	Conduct yield loss experiments in 3 paddocks	Dec 31 2014	Y	
2015	Conduct broad-acre, spot-spraying and eradication experiments at two focus sites	May 31 2015	Y	
2015	Conduct soil moisture, leaf dust, berry stage and seedling establishment experiments	May 31 2015	Y	
2015	Conduct yield loss experiments in three paddocks	Dec 31 2015	N	See notes in "Overall performance" heading above.
2016	Apply treatments and assess two focus research sites and liaise with grower groups for site handover	May 31 2016	Y	
2016	Deliver printed and electronic SLN information including best practice management guides, livestock quarantine guidelines and case studies, and deliver three regional SLN workshops	May 31 2016	N	See detailed explanation below. In hand, improved collaborative outcome underway with NSW researchers. Draft Feb, 2017. Completion May, 2017.
2016	Complete research data analysis and write research report	June 30 2016 (Nov 30, 2016)	N	Due to sickness, delivery dates extended as per PIRSA letter (Oct 6th, 2016) to SAGIT.
2016	Develop and submit Final Report to SAGIT	June 30 2016 (Nov 30, 2016)	N	Due to sickness, delivery dates extended as per PIRSA letter (Oct 6th, 2016) to SAGIT.

Technical Information (Not to exceed **three** pages)

Provide sufficient data and short clear statements of outcomes.

***Please note:* A separate full and detailed report on this project will be submitted as a separate document. This will be used as a basis for a published paper.**

Broad-acre herbicides. Successive applications of glyphosate and Starane reduced perennial shoot density at Keith, but not Warnertown. This may be due to lower rainfall and heavier soils at Warnertown, compared to Keith. While low rates of glyphosate and Starane may kill SLN shoots, the additional cost of higher rates (i.e.1620 g a.i. ha^{-1} glyphosate; 600 ml Prod. ha^{-1} Starane) may be warranted by a reduction in shoot density over several years. Starane at 600 ml Prod. ha^{-1} gave control similar to Nufarm Glyphosate 540 at 1.5 L Prod. ha^{-1} plus Pulse, and Starane gave better control than 2,4-D amine, at a similar price (n.s.). Starane can halt berry development and shoot growth when applied at flowering. The "Dual Action" strategy (Starane early, glyphosate later) promoted in NSW may not work well under dry autumn conditions in SA. "Dual action" treatments tested (early applications of glyphosate, Starane or 2,4-D amine, followed in autumn by Nufarm Glyphosate 540 at 3.0 L Prod. ha^{-1}) gave no better density reduction than the single early treatments alone (n.s.).

Garlon FallowMaster (triclopyr; 400 and 800 mL Prod. ha^{-1}), Fallowboss Tordon (picloram/aminopyralid/2,4-D amine; 300 mL Prod. ha^{-1}), Hotshot (aminopyralid/ fluroxypyr; 500 mL Prod. ha^{-1}) and glyphosate plus paraquat (24 hrs later) all gave poor long-term control. Nufarm Glyphosate 540 at 1.2 L Prod. ha^{-1}, plus Garlon FallowMaster at 80 mL Prod. ha^{-1}, plus Associate (metsulfuron-methyl) at 7g Prod. ha^{-1} represented a typical grower mixture for summer weeds (e.g. melons, heliotrope, caltrop etc). Shoot desiccation was achieved, along with a small (n.s.) long-term reduction in SLN density. *Solanum coactiliferum* (western nightshade) shoots were much less affected by most herbicides than SLN.

Spot treatments herbicides A number of spot treatments reduced SLN shoot density after two consecutive applications at Keith, including Graslan (tebuthiuron), Arsenal Express (imazapyr/glyphosate), FallowBoss Tordon (2,4-D amine/picloram/aminopyralid), Hotshot (aminopyralid/fluroxypyr) and Uragan (bromacil). Arsenal Express, FallowBoss Tordon and Uragan (bromacil) also performed well at Warnertown.

Eradication plots. One year after the second annual application of 1.62 kg a.i. ha^{-1} glyphosate in large plot (10 x 10m) experiments, shoot density was reduced by 90% at Warnertown, and 71% at Keith, compared to untreated control plots. This rate of decline was faster than expected, and demonstrates that annual applications of glyphosate, at high rates, have great potential to reduce large, established infestations.

Yield loss experiments. Yield maps and Crop Circle NDVI maps were used in conjunction with large glyphosate-treated strips to measure yield responses. Due to a number of adverse circumstances, these experiments were of limited value (see explanation in "Overall Performance"). At Warnertown there was no measured relationship between SLN shoot density and barley yield, or Crop Circle VI values. At Keith there was a moderate ($R^2 = 0.52$) correlation between SLN density and Crop Circle VI values in paddock M08. This suggests that it may be possible to map SLN infestations under some circumstances, and this data would be very useful to drive GPS-controlled Site Specific Weed Management (SSWM) techniques that apply herbicides only to mapped SLN patches.

Biological control of SLN – South African study tour. Mr Iggy Honan diverted from his private travels for six days to undertake a SLN biological control field research project on behalf of SAGIT and PIRSA. He interviewed members of the South African silverleaf nightshade biological control team, other researchers and farmers. He also observed, first hand, the effectiveness of the *Leptinotarsa texana* beetle on SLN in the field, and compared South Africa's soils, climate, farming systems and SLN management with those of South Australia. Mr Honan's report contributed greatly to Australia's assessment of the beetle, and ensured that collection and importation of a colony into Australian quarantine was smooth and successful. Mr Honan concluded that *L. texana* is likely to be an effective biocontrol for SLN in Australia. Mr Honan submitted a full report of his study, contacts and findings.

Seedling emergence and establishment. The effect of a range of simulated rainfall scenarios on SLN seedling emergence and establishment was measured. At the start of experiments, in February 2014, sites were subject to a prolonged heat-wave, followed by a record rainfall event. Seedling emergence was observed at both sites eight days after watering. Seedling growth was rapid under the warm and moist summer conditions. By day 14 seedlings were 18 to 24 mm wide, with 1.5 true leaves. At Day 48 some seedlings were at the 8 true leaf stage, with spines evident on the stems. On Day 282 (18 November 2014) the largest seedling had 18 true leaves and measured 80mm high by 50mm wide, and had spiny stems. Seedlings of this size were clearly well established and very likely to become established perennial plants. These results confirm anecdotal field observations that one large summer rainfall event (25 to 75 mm), even if followed up by several showers, is unlikely to result in significant recruitment in Mediterranean-type climates (i.e. wheat belt in WA, SA and Vic). Seedlings are killed by subsequent hot and dry weather. The only treatments that sustained significant numbers of seedlings were those with an initial large event (25 mm or 75 mm), followed by some showers, followed by a further large event of 50 mm. However, most seedlings had perished by November, presumably in response to cold conditions and short days, resulting in only minimal recruitment to the perennial shoot population. In Australian regions with a

Mediterranean-type climate, seedling recruitment may be rare in most years, but is nonetheless significant because it allows SLN to spread from one paddock or region to another, predominantly via sheep dung.

Effect of rainfall on glyphosate efficacy. These experiments measured the effect of a range of simulated rainfall scenarios (amount and timing; pre- and post-spraying) on glyphosate efficacy. Results were also heavily influenced by an exceptionally large summer rainfall event (80 to100 mm) on February 14 to 15 2014, prior to simulated rainfall and glyphosate application. Soil was saturated in all plots (including "non-watered" plots), largely nullifying subsequent irrigation treatments. All glyphosate treatments reduced shoot density compared to unsprayed plots, however there were no statistical differences between watering regimes, except in the second year at Edinburgh. Glyphosate (1.08 kg. a.i. ha^{-1}) at Cavan reduced SLN shoot density in the first year, but density recovered to some extent in all treated plots in 2015. In contrast, the higher rate (3.24 kg. a.i. ha^{-1}) applied at Edinburgh successively reduced shoot density for two years, achieving up to 80% reduction. Efficacy was highest (Edinburgh) in treatments that did not receive simulated watering before glyphosate application. It is assumed that plots receiving simulated rainfall before glyphosate treatment suffered soil saturation, causing oxygen starvation in SLN roots, thus reducing glyphosate absorption and translocation. The most valuable result from these experiments was confirmation that glyphosate at 3.24 kg. a.i. ha^{-1} was more effective in reducing the shoot density than 1.08 kg. a.i. ha^{-1}over two years.

Effect of leaf dust on glyphosate efficacy. These experiments measured the effect of dusty leaves on glyphosate efficacy. Measurements of shoot death three weeks after spraying and reduction in shoot density one year after treatment confirmed that leaf dustiness did not affect control. Shoot density was further reduced in all treated plots one year after the second glyphosate application, and there was a statistically significant decrease in efficacy on dusty leaves at the two highest rates of glyphosate. This experiment provided excellent glyphosate dose-response curve data for SLN. Clean leaves had a 60% reduction in shoot density over two seasons at 810 g a.i. ha^{-1}, increasing to 88% at 1620 g a.i. ha^{-1}. The 3240 g a.i. ha^{-1} rate gave a further small reduction, but the extra cost may not be economically warranted. These results suggest that dusty leaves may not be as important for SLN spraying as previously thought.

Effect of glyphosate timing on berry formation. Glyphosate was applied to SLN at various growth stages to measure subsequent seed set. Stemlets sprayed at flowering to first tiny berries stage set no berries, confirming that treatment at the flowering stage effectively prevents seed formation. Stemlets sprayed at the small green berry stage (4 to 8 mm diam.) produced fewer and lighter seeds, with abnormal seedlings and 23% dead seed. Seed production of stemlets sprayed when green berries were just turning (with an orange tinge) was slightly suppressed, but these still produced large, viable seed. Stemlets sprayed at the moist orange berry stage were unaffected and produced abundant large, viable seeds and normal seedlings. The mean mature berry diameter of small green berry stage treatments (7.6 mm), suggests that berries continued to grow for at least some time after treatment. These results, taken with data from NSW, suggest that SLN should be sprayed no later than the very small green berry stage (< 2 mm) to achieve good seed-set control. If near 100% seed set control is required, SLN should be sprayed at the flowering stage. However, it is common to find fresh flowers and large berries on the same plant, and to achieve near 100% seed set control in the field requires that SLN be sprayed at the early flowering stage of the earliest shoots to emerge in late spring. Treatments (e.g. glyphosate, fluroxypyr) can be used that will control these shoots for at least a few months, but in almost all situations later-emerging cohorts of shoots, and regrowth of early-treated shoots, will require a series of herbicide applications to prevent any plants producing seeds.

Best Practice Management Guide for SLN and Regional Workshops. Discussions were held with NSW researchers, who were also working on a BPM guide for SLN, and it was decided that SA and NSW would combine data, information, photographs and experience to produce one comprehensive BMP guide. Smaller derivative products on specific aspects of SLN management are also planned. Drafting of this document is well underway, and the BMP guide is expected to be completed in May, 2017. A series of three well-attended regional workshops on SLN were held at Keith, Jamestown and Balaklava in March, 2014. Audience participation was good, concluding with helpful discussion sessions. In April 2016 an update was given to the Warnertown focus group (Napperby Tennis Club). This was also very well attended, with good discussion throughout the presentation. A planned update for the Keith group in April 2016 was postponed at the request of the convener, and a new date will be set for early 2017.

Insects attacking SLN at Parilla in SA. Four insects were found attacking SLN near Parilla; two moths, *Australiopalpa tristis* and *Scrobipalpa leucocephala* (Det. Dr Ted Edwards, CSIRO, Canberra); a stem grub thought to be the Tomato Stem Borer *Symmetrischema tangolias* (or *plaesiosema*); and a fruit grub thought to be the Eggfruit Caterpillar/Poroporo Moth *Sceliodes cordalis* (a pest of kangaroo apple in NZ). These observations will inform host specificity tests for the new biological control project, and investigations will continue as opportunities arise.

Conclusions Reached &/or Discoveries Made (Not to exceed one page)

Please provide concise statement of any conclusions reached &/or discoveries made.

- Glyphosate and Starane are the most useful herbicides for reducing perennial shoot density in cropping rotations.
- Higher rates of glyphosate (i.e.1620 g a.i. ha^{-1}) or Starane (i.e. 600 ml Prod. ha^{-1}) may be warranted because of long-term reductions in shoot density.
- The "Dual Action" strategy (Starane early summer, glyphosate in autumn) promoted for use in NSW may not be as effective in SA, because conditions are drier, and SLN plants may not recover enough by autumn to absorb and translocate glyphosate adequately.
- Graslan is a convenient (applied as dry granules) and effective spot-treatment.
- Glyphosate applied to prevent seed-set should be applied before the 2mm green berry stage.
- Dusty SLN leaves may not reduce glyphosate efficacy as much as previously thought.
- Seedling emergence can occur after a single large summer rainfall event, however establishment and survival rely on several large follow-up events.
- Almost all seedlings die during winter, probably due to cold and short days, even before the first frost. Occasional survivors are, however, very significant for spread.
- A number of native and introduced pest insects were found to attack SLN at Parilla, and investigations will continue.
- The silverleaf nightshade leaf beetle (*Leptinotarsa texana*) appears to suited to South Australian conditions, and has a good chance of controlling SLN, if released.

Intellectual Property

Please provide concise statement of any intellectual property generated and potential for commercialisation.

This project did not generate any information or knowledge considered to be intellectual property.

Application / Communication of Results

A concise statement describing activities undertaken to communicate the results of the project to the grains industry. This should include:

- *Main findings of the project in a dot point form suitable for use in communications to farmers;*
- *A statement of potential industry impact*
- *Publications and extension articles delivered as part of the project; and,*
- *Suggested path to market for the results including barriers to adoption.*

Note that SAGIT may directly extend information from Final reports to growers. If applicable, attach a list of published material.

Main findings of the project in a dot point form suitable for use in communications to farmers

Please see dot points in Conclusions and Discoveries section above.

A statement of potential industry impact

This research has provided valuable information and understanding of SLN biology and management. Advances in management effectiveness will increase crop yields. At present, most large established SLN infestations are sprayed to desiccate shoots, at rates aimed at annual summer weeds. The herbicide experiments established in this project are on-going, but observations so far suggest that higher rates of glyphosate and Starane may be economically justified. This will give farmers an additional management option (i.e. long-term shoot density reduction). A number of herbicides (e.g. Graslan) appear to be suitable spot-treatments, but the long-term data will not be available until 2018. Farmers now also have defined windows for preventing seed set, and the new information should help to reduce ineffective late applications. Seedling biology and recruitment is now much better understood, allowing more reliable advice to be given to SA farmers. In most seasons nearly all seedlings perish before they become established, but the occasional survivors are very important, because they spread infestations. Farmers are also be advised to consider special monitoring and herbicide applications during summer/autumn when two or more large rainfall events (> 25mm each) occur within several weeks. This will help to reduce the establishment of new infestations.

Publications and extension articles delivered as part of the project

Research papers on the results of this research have been presented to:

19th Australasian Weeds Conference, Hobart, 2014

SA NRM Science Conference, Adelaide, 2014

20th Australasian Weeds Conference, Perth, 2016

5th SA Weeds Conference, Adelaide, 2016

A series of five farmer meetings (Jamestown, Keith, Balaklava, Nelshaby and Napperby) and one community meeting (Northern Adelaide Plains) have been attended to present SLN results and biology/management information. Further meetings are planned during the extension of this project. Articles on the SLN research were produced for SAGIT communications and the Stock Journal in 2015. A major outcome from this work will be the publication of a comprehensive SLN Best Practice Management manual by May, 2017. As discussed above, this is a major collaboration between this project and NSW researchers, who are also working on a BPM guide for SLN. Both SA and NSW have advanced drafts, and the decision to collaborate on a single definitive BMP manual will give farmers access to all recent SLN information available in Australia. Smaller derivative products on specific aspects of SLN management are also planned.

Suggested path to market for the results including barriers to adoption

The path to market is largely one of extension. There have already been conference papers, farmer meetings, and print media articles. The BMP manual discussed above, and smaller derivative extension publications, will be the cornerstone of future extension. Major points from the BPM manual will be presented and discussed at farmer meetings, and farmers will be given a copy to keep for reference. The research results so far will also be published in a scientific journal, based on the detailed research report (c. 70 pp) prepared from this project.

POSSIBLE FUTURE WORK

Provide possible future directions for the research arising from the project including potential for further work and partnerships.

SAGIT has kindly provided a further three years of funding to continue the herbicide experiments established at Warnertown and Keith. This will allow measurement of the decline of SLN density over five seasons, and provide rare and valuable data on the medium to long-term effects of herbicides.

The observed ability of Starane to reduce SLN shoot density over three seasons warrants further investigation. In particular, a dose-response experiment, run over three seasons, would be valuable to inform growers of the likely benefits from a series of application rates. The experiment might evaluate four levels of Starane against four levels of glyphosate.

SAGIT support was very important in gaining funding for a new three-year biological control project on SLN. The silverleaf nightshade leaf beetle (*Leptinotarsa texana*) has now been successfully imported into Australian quarantine, and a rearing program has established a viable population. If the biocontrol project successfully releases the beetle (after careful testing), SAGIT might consider a release, redistribution and monitoring project to ensure that SA maximizes the effect on SLN.

AUTHORISATION
Name: Dr Ross Meffin
Position: Manager, Weeds, NRM Biosecurity (PIRSA)
Signature:
Date:

Submit report via email to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.