Office Use Only	
Project Code	
Project Type	

FINAL REPORT 2020

Applicants must read the *SAGIT Project Funding Guidelines 2020* prior to completing this form. These guidelines can be downloaded from www.sagit.com.au

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

PROJECT CODE	UA 617
PROJECT TITLE	(10 words maximum)
Field testing of sodicity- and salinity-tolerant oat varieties	

PROJECT DURATION *These dates **must** be the same as those stated in the Funding Agreement.*			
Project start date	**1/07/2017**		
Project end date	**28/02/2020**		
SAGIT Funding Request	**2020/21**	**2021/22**	**2022/23**

PROJECT SUPERVISOR CONTACT DETAILS *(responsible for the overall project)*		
Title:	**First Name:**	**Surname:**
Dr	**Graham**	**Lyons**
Organisation:	**The University of Adelaide**	
Mailing address:		
Telephone:		**Email:**
Mobile:		

ADMINISTRATION CONTACT DETAILS *(responsible for all administrative matters relating to project)*		
Title:	**First Name:**	**Surname:**
Organisation:	**The University of Adelaide**	
Mailing address:		
Telephone:		**Email:**
Mobile:		

PROJECT REPORT: *Please provide a clear description for each 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.

About 60% of SA agricultural soils are sodic (high Na, etc) or saline-sodic (high NaCl & high Na, etc), which reduces yield. This study extended screening trials into two seasons of field trials at Redhill and Turretfield, to assess tolerance of oats to saline-sodic soils. Main findings:

- The most tolerant oats (grain yield) were early-to-medium maturity milling varieties: Bannister, Bilby, Mitika, Williams, Echidna, Kowari. My message to farmers: “To maximize yield and profitability from salty paddocks, sow milling oats Bannister, Bilby, Mitika, Echidna or Kowari”

- The most tolerant oats (biomass yield) were Kangaroo, Bannister, Wintaroo, Mulgara, Mitika. All oats listed are commercial varieties, available now

- The grain yields of tolerant oats at Redhill (the saline-sodic site, under low growing season rainfall of 170 mm) were outstanding, e.g. Bannister (3.2 t/ha), Bilby (3.1), similar to Compass barley (3.2) and much higher than Mace bread wheat (1.5) and Aurora durum wheat (1.1)

- Pasture oats (e.g. Bond, Wizard) and overseas oats were intolerant of saline-sodicity

- The pot and field trials showed that the ability of the plant to extract water from saline-sodic soil, rather than its ability to exclude sodium, is the key to acceptable yield on this type of soil.

Project objectives

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

1. Oat varieties which grew well under sodicity and salinity in the current SAGIT oat project (UA416), and are hence potentially tolerant to saline/sodic soils, will be validated in field trials, in collaboration with the SARDI oat breeding group.

2. Saline/sodic-tolerant oat varieties will be recommended to farmers, which can extend the range of oat production and increase profitability in marginal areas of South Australia.

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.

Achievement of objectives:
The project achieved its objectives, beyond expectations, as at the start it was not known whether sufficient genotypic variation existed in oats for tolerance of saline-sodic conditions to enable identification of varieties/lines with relative tolerance.

Personnel:
Graham Lyons, University of Adelaide (PI)
Julian Taylor, University of Adelaide (trial design, statistics)
Yusuf Genc, SARDI (advice and assistance throughout the study)
National Oat Breeding Group, based at SARDI: Pamela Zwer, Sue Hoppo, Michelle Williams, Kerri-Lee McMurray, Mark Hill, Peter Wheeler (seed provision; conducting 2018 Turretfield trial, and both 2019 trials)
Adelaide University Durum Breeding Group: Jason Able, Alistair Pearce (conducting 2018 Redhill trial)
John Harris, SARDI (seed multiplication, oat genetics advice)
Bruce Winter, Georgie Troup, Rehn Freebairn and Nigel Steinborner for seed.

Difficulties:
In 2018, Turretfield, due to limited late-season rainfall, transformed from a control (good conditions) site to a drought-tolerance site. This actually had the effect of enhancing the study's overall value. In 2019, the Redhill site was afflicted by patches of high surface soil Na, Cl, Mg, Ca and S, which lowered overall yield (see details below). Nevertheless, correlation between 2018 and 2019 yields was very high.

KEY PERFORMANCE INDICATORS (KPI)

*Please indicate whether KPIs were achieved. The KPIs **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.*

KPI	Achieved	If not achieved, please state reason.
2017: Seed multiplication and adaptation evaluation (in field) of around 80 oat varieties	Yes ☒ No ☐	
2018: Season 1 Field Trials planted	Yes ☒ No ☐	
2018/2019: Season 1 Field Trials harvested and evaluated	Yes ☒ No ☐	
2019: Season 2 Field Trials planted	Yes ☒ No ☐	
2019/2020: Season 2 Field Trials harvested and evaluated, including identification of sodic/salt-tolerant varieties	Yes ☒ No ☐	
Writing and submission of final report, and article for the 2020 Oat Newsletter.	Yes ☒ No ☐	

TECHNICAL INFORMATION (Not to exceed **three** pages)
Provide sufficient data and short clear statements of outcomes.

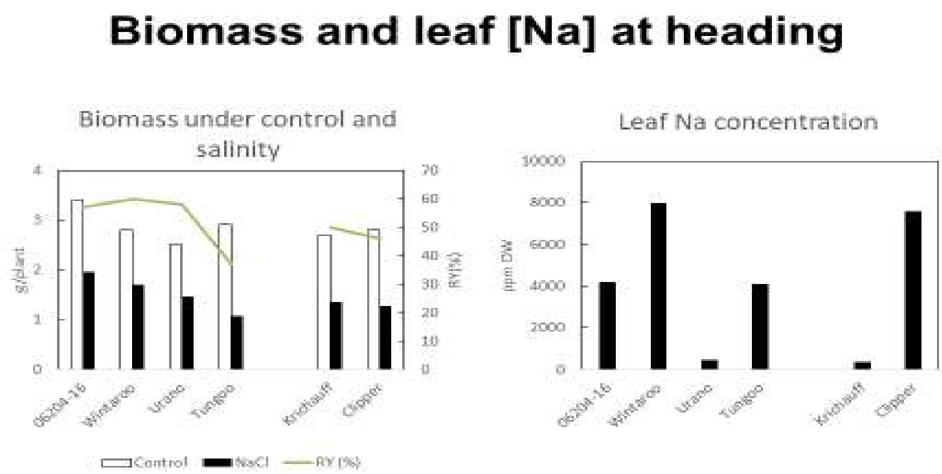
Pot trials

During this project, a further five pot screening trials, using UC mix, were conducted, which continued those conducted in growth rooms/greenhouse in the previous study (UA 416) in 2016/17. A wide range of oat genotypes was screened.

Figure 1 presents a sub-sample, showing genotypic variation in 7-week whole top biomass under control and salinity, and relative biomass. SARDI 06204-16 (which became the new variety, Bilby) shows the best biomass for both control and salinity, and close to best for relative yield. I believe *actual* yield under stress is the most important measure, as this is what is important for farmers. There was reasonable agreement between biomass at 7 weeks in the pot trials and biomass at heading, and grain yield, in the field.

Sodium accumulation: most oats are relatively high Na accumulators, like durum wheat and most barley varieties, and much higher than bread wheat. Nevertheless, Figure 1, depicting leaf [Na] under 100 mM NaCl treatment, shows that there is substantial genotypic variation within oats for Na accumulation. We also found variation in concentrations of K, Mg and Ca. For example, the Chilean milling oat, Urano, had the highest [K] (55,000 ppm), compared to the relatively low [K] hay/feed grain variety, Mulgara (20,000 ppm). There was good agreement between the controlled-environment trials and the subsequent field trials for indicator leaf cations at 7 weeks.

Figure 1.



In 2017 we grew the most promising 30 overseas oat varieties in the Waite birdcage, and just 8 of these produced sufficient grain to be included in the 2018 field trials: Noble 2, Troy, Florida 501, Hazel (all USA), Pro-Fi (Canada), Urano (Chile), Matilda (Sweden) and Drummond (Scotland).

Field trials

Trials were conducted in 2018 and 2019 in SA’s Lower- and Mid-North, at Turretfield (good soil) and Redhill (saline-sodic soil). Randomised block trial design, with 3 replications in 2018 and 4 in 2019. In 2018, 32 varieties/lines were trialled: 8 overseas, 17 Australian milling and hay/feed grain varieties, 7 Australian pasture/forage, and durum wheat and barley checks. Adjustments were made in 2019, with most of the low-yielding/non-adapted/non-tolerant varieties excluded. New, promising SARDI lines, along with a range of bread and durum wheats, were added.

Top biomass at heading (Zadok 53) was estimated, using combined visual scores and a sub-sample of 2 x 0.5 metre row samples per plot. Visual scores were also given at Zadok 25 (tillering) and 43 (booting). Also at heading, indicator leaves (flag leaf minus 1) were sampled and minerals analysed, and soil samples were collected.

Growing season rainfall at Redhill: 2018: 170mm; 2019: 175mm
Turretfield: 2018: 238; 2019: 277.

Ironically, due to its heavy clay soil and low late-season rainfall in 2018, Turretfield more resembled a drought trial than a favourable-conditions control. Although biomass yield at heading was higher at Turretfield (in both years), the Turretfield grain yield was well below that at Redhill in 2018.

Soil minerals

A subset of the soil minerals, etc data are presented in Table 1 to illustrate the contrast between a "normal" clay soil at Turretfield and the saline-sodic clay-loam soil at Redhill. "Good" is standard for this paddock, while "bad" is sampled from the bare patches (no seedling emergence) that appeared in 2019, but not in 2018 at the same site.

Table 1.

Soil minerals at 20cm depth 2019

	pH	Exch cations (mg/kg)				S	Cl
		Na	K	Mg	Ca		
Turretfield	6.6	240	230	93	260	7	18
Redhill							
good	7.9	3416	178	230	505	50	275
bad	6.7	13000	620	2114	5000	333	1830

Notes: subsoil pH: Turretfield 7.2; Redhill 9.2. Soil water content was quite high at both sites: Turretfield: 11% in 2018, 17% in 2019; Redhill: 14 – 16%, regardless of season or depth. ECe: ca 0.5 at Turretfield: Redhill normal: 2.5; bad patches: 11. Boron: 2ppm at Turretfield and 10 (good or bad areas), and 30 at 60cm depth.

Leaf minerals

Na: Redhill oats 3200 – 12500 (mean 6500 ppm) v durum wheats 6500 -7500 v bread wheats 250-700 ppm. There was no significant correlation between [Na, K, Mg, Ca, S] and biomass or grain yield. It is osmotic stress tolerance, not Na exclusion *per se,* that confers saline/sodic tolerance (Genc *et al* 2016, 2019). Subsoil B was high at Redhill, with consequent oat tissue levels of 140 – 760, mean 290 ppm, but did not affect yield. Aurora durum had only 90 ppm B, but low yield. There were some low tissue levels of P and Zn at both sites, but no deficiency symptoms.

Biomass yield

Less variation than for grain yield: Turretfield: 1.5-fold, mean 7.5 t/ha; Redhill: 2.7-fold, mean 5.7 t/ha.

Highest: Kangaroo, Wintaroo, Bannister, Mitika

Lowest: Saia, PG 38, Glider, Noble 2.

Grain yield

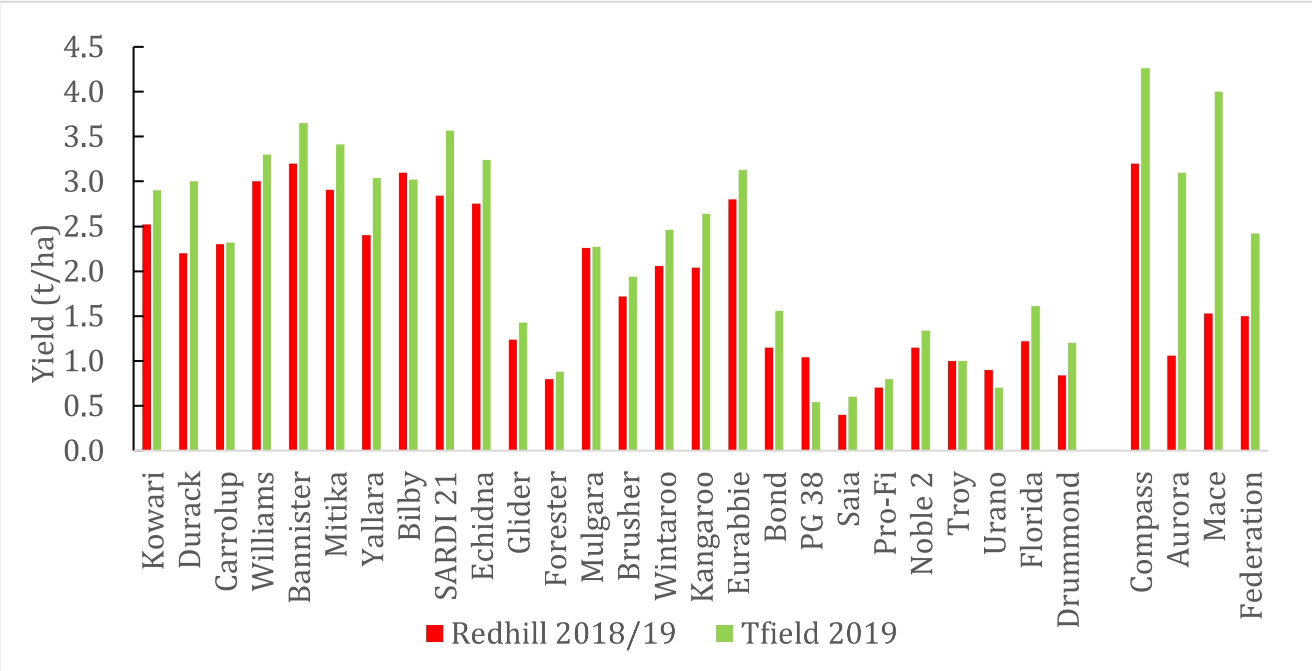
The data presented in Figure 2 comprise the mean values at Redhill for the 2018 and 2019 seasons, and the 2019 yields at Turretfield, a more realistic measure than the mean of both seasons, given that 2019 was an average year while 2018 was exceptionally poor. There was nevertheless a high correlation between the 2018 yields at both sites, and the variety order was the same.

The checks, Compass barley, Aurora durum and Mace & Federation bread wheats are on the right. The highest-yielding oats (on the left) were mostly milling varieties of short-to-medium maturity. Next were hay/feed grain varieties, then pasture and overseas varieties yielded relatively poorly. In contrast to wheat, most oats yielded nearly as high at Redhill as at Turretfield. These can all be regarded as relatively saline-sodic tolerant.

Highest: Bannister, Bilby, Mitika, Williams, Echidna, Kowari. It should be noted that Williams, especially under low rainfall, had more screenings than the other varieties, thus I recommend using the other five varieties ahead of Williams.

Lowest: Saia, Pro-Fi, PG 38, Urano, Troy, Drummond.

Figure 2.



CONCLUSIONS REACHED &/OR DISCOVERIES MADE (Not to exceed one page)
Please provide concise statement of any conclusions reached &/or discoveries made.

- We have demonstrated the versatility of oats, with the most resilient varieties (e.g. the milling varieties Bannister, Bilby, Mitika, Williams, Echidna, Kowari) yielding well on saline-sodic soil under moisture stress, and under control (fertile soil, reasonable rainfall) conditions. All of these are commercial varieties, available to farmers now
- Strong genotypic variation between oat varieties/lines for grain yield under saline-sodicity was again demonstrated, with an 18-fold variation at the Redhill site
- Milling oat varieties (e.g. Bannister 3.2 t/ha) generally yielded higher than hay/feed grain varieties (e.g. Wintaroo 2.1), while pasture (e.g. Bond 1.2) and overseas oats (e.g. Noble 1.2) struggled under saline-sodicity (mean of two seasons' grain yield at Redhill)
- Not surprisingly, early to midseason maturity was important under low rainfall; however, it is not the only trait to confer relative tolerance of saline-sodicity, e.g. the earliest-maturing oat, Durack, yielded lower than later-maturing Bannister at Redhill in both seasons
- The Redhill site in 2019, although with a similar growing season rainfall to 2018 (only 170 mm), was much tougher in 2019 due to the appearance of patches with very high levels of Na, Cl, Mg, Ca and S. Seedlings failed to emerge on these patches. Nevertheless, the trial still provided a useful comparison of varieties. The yields correlated well (by variety) with those in 2018, as well as those at the control site, Turretfield (moisture stress in 2018 and reasonable conditions in 2019)
- Biomass varied much less than grain yield at both sites: by around 2-fold (at heading) at Redhill and 1.6-fold at Turretfield, and was moderately correlated with grain yield at Redhill. Grain yield is clearly more discriminatory for assessing saline-sodic tolerance in the field. The best varieties for biomass were Kangaroo, Bannister, Wintaroo, Mulgara and Mitika
- The earlier glasshouse screening trials using 100 mM NaCl in UC potting mix as a model of salinity/sodicity were good predictors of leaf cation levels and reasonable predictors of grain yield in the field
- The SARDI Oat Breeding Group has used varieties identified in the preliminary salinity/sodicity tolerance trials in its crossing program
- Oats again yielded much higher than bread and durum wheat at Redhill in 2019, e.g. Mitika oats 3 t/ha, Mace bread wheat 0.9 t/ha, Aurora durum 0.6 t/ha. These wheat yields show how tough this site is. On the other hand, Compass barley yielded even higher than oats in 2019, with 3.4 t/ha. At Turretfield, Compass was also highest (4.3 t/ha), followed by Mace and Westonia bread wheats (4.1 and 3.9, respectively) and Bannister oats (3.8)
- Australia's most famous wheat, Federation (released in 1901) performed creditably at Redhill (0.8 t/ha) and Turretfield (3.1) in 2019
- All of the trials (field, glasshouse and growth room) support our assertion (elaborated in Genc et al, *New Phytologist* 2016 and *Frontiers in Plant Science* 2019) that Na exclusion *per se* is not an important determinant of tolerance of cereals to salinity or saline-sodicity. This finding has major implications for research in this area and shows why so little was achieved under this paradigm over the past 20 years.

INTELLECTUAL PROPERTY

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

I do not believe that new IP was generated by this project. However, the saline-sodic-tolerant oat varieties which were identified (and which can be recommended as such to farmers) are all current commercial varieties, subject to plant breeder's rights.

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 (from Executive Summary above):

- The most tolerant oats for grain yield were early-to-medium maturity milling varieties: Bannister, Bilby, Mitika, Williams, Echidna, Kowari. My message to farmers: "To maximize yield and profitability from salty paddocks, sow milling oats Bannister, Bilby, Mitika, Echidna or Kowari"

- The most tolerant oats for biomass yield at heading were Kangaroo, Bannister, Wintaroo, Mulgara, Mitika. All of the oats listed are commercial varieties, available to farmers now

- The grain yields of tolerant oats at Redhill (the saline-sodic site, under low growing season rainfall of 170 mm) were outstanding, e.g. Bannister (3.2 t/ha), Bilby (3.1), similar to Compass barley (3.2) and much higher than Mace bread wheat (1.5) and Aurora durum wheat (1.1)

- Pasture oats (e.g. Bond, Wizard) and overseas oats were intolerant of saline-sodicity

- Both the pot and field trials showed that the ability of the plant to extract water from a saline-sodic soil, rather than its ability to exclude sodium, is the key to achieving acceptable yield on this type of soil.

Potential industry impact

This project clearly identified oat varieties with superior yield on some of the toughest arable land in southern Australia, which is not suitable for wheat, under low rainfall. This provides farmers with an alternative to barley for saline, saline-sodic or sodic paddocks in marginal areas. Oat grain will provide a much higher return than barley, given current prices, as would oaten hay, compared to barley hay.

Publications/extension materials

- The findings of this research to date have been reported annually in the NOBP's *Oat Breeding Newsletter* (latest edition Nov 2019) and an article for the 2020 newsletter will be provided to the NOBG when this final report is completed. SARDI's Oat Breeding Group and John Wheaton (Redhill) have been provided with trial updates throughout the study, and the principal investigator is always keen to discuss and promote the findings.

- 2018 trial data were provided to Rehn Freebairn (Pasture Genetics) and Queensland oat breeder Bruce Winter (who provided seed). With the 2019 trials validating those of 2018, recommendations can be made in the 2021 SA Crop Sowing Guide.

- Findings have been publicised via *AgCommunicators* on ABC Regional Radio and in the *Stock Journal*.

- Three of the project's researchers published a related article in late 2019:

  Genc Y, Taylor J, Lyons G, Li Y, Cheong J, Appelbee M, Oldach K, Sutton T 2019. Bread wheat with high salinity and sodicity tolerance. *Frontiers in Plant Science* 10.3389/fpls.2019.01280

- The PI gave a talk on the project findings (building on a July 2018 talk to SARDI) to the Crop Science Society at Roseworthy in March 2020.

Suggested path to market

As all of the varieties identified as tolerant are available commercially, they are available for farmers now. The only barrier is lack of awareness of the findings, which the above activity attempts to address.

POSSIBLE FUTURE WORK

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

Firstly, I wish to acknowledge the funding support provided by SAGIT for this project, and the assistance provided by the SARDI oat breeding group, the University of Adelaide durum breeding group, Yusuf Genc, Julian Taylor and John Harris, and to John Wheaton (Redhill) and PIRSA (Turretfield) for hosting the trials.

A project proposal for one more season of field trials, including oats (to give promising new SARDI lines, in particular, two seasons at Redhill) and barley (given Compass's excellent yield in 2019), was submitted but was not successful, on the following grounds:

1. The research is not being pursued by GRDC. Previously, this provided a good reason for SAGIT to pursue it, provided it was warranted.
2. The research has been tried, but was low yielding in wheat. Wheat yields poorly at a strongly saline-sodic site like Redhill, as demonstrated in our trials, which is why we have focused on oats which (along with Compass barley) have yielded remarkably well there.
3. Other researchers have been unsuccessful in their attempts at this research. In two landmark articles, Genc, Lyons et al clearly demonstrated where other cereal salinity researchers went wrong for two decades. We did not fall into the same "sodium exclusion" trap.