Office Use Only

Project Code	
Project Type	

FINAL REPORT 2018

Applicants must read the *SAGIT Project Funding Guidelines 2017* 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 :	**USA114**

PROJECT TITLE (10 words maximum)
The application of bent leg technologies to higher speed tined seeding of cereal grains

PROJECT DURATION

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

Project Start date	01/07/2014					
Project End date	30/06/2017					
SAGIT Funding Request	2014/15		2015/16		2016/17	

PROJECT SUPERVISOR CONTACT DETAILS

The project supervisor is the person responsible for the overall project

Title:	**First Name:**	**Surname:**
Mr	John	Fielke

Organisation:

University of 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:**

Organisation:
Grant Management Team Research & Innovation Services University of South Australia
Mailing address:

Telephone:	**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

Australian tine-style no-tillage seeding operations cause excessive soil disturbance which typically limit speed to 8-9 km/h. In this project, the low disturbance bentleg opener is investigated for its use in high speed. The discrete element method (DEM) computer modelling technique is used to optimise performance and develop bentleg openers for integrated use in bentleg seeding systems. The key findings were:

- The developed modelling techniques could simulate the performance of no-till openers, including tillage forces, soil loosening, soil mixing and soil throw providing a valuable tool for opener design and evaluation.
- Bentleg openers combined with a beveled leading edge mostly cancel soil throw, maximise furrow backfill and minimise draught requirement if designed correctly. They offer an unprecedented ability for high speed, low soil throw tine seeders.
- Latest research on integrating bentleg openers into tine seeding systems showed the potential to adequately control seed and fertiliser placement and establish wheat crops similar to common knife point technology at 8 km/h. Importantly, the bentleg seeding systems were able to increase operating speeds by 50% to 12 km/h without any emergence penalty, in contrast to that commonly seen with knife point seeding system.

The bentleg seeding system represents an unprecedented opportunity for the improvement of tine seeder work-rate, with significant implications for timeliness of no-tillage seeding.

Project Objectives

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

1. Investigate the potential for high speed seeding with tine-type openers.
2. Develop a computer model for soil movement using Discrete Element Modelling.
3. Validate the model using results from soil translocation experiments.
4. Use the model to minimise lateral soil throw and soil layer mixing by various furrow opener designs.
5. Investigate methods for seed and fertiliser placement with minimal lateral soil throw and soil layer mixing at higher than current sowing speeds.

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.

James Barr was the PhD student under supervision of Professor John Fielke and Dr Jack Desbiolles.

All KPI were meet as required. A 6 month extension was granted to enable completion of an extra KPI: Parameter sensitivity analysis using discrete element method for bentleg opener optimisation. This was completed and will provide useful information for commercialisation, as well as form the basis of a journal publication.

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.*

KPI	***Achieved (Y/N)***	***If not achieved, please state reason.***
James Barr has completed his research proposal	Y	
James Barr has completed his 2014 trial	Y	
James Barr has completed his 2015 trial	Y	
James Barr has completed his 2016 trial	Y	
James Barr has completed his thesis	Y	

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

Provide sufficient data and short clear statements of outcomes.

Narrow openers commonly used in Australian no-tillage seeding operations cause excessive soil disturbance which typically limit speed to 8-9 km/h. In this thesis, the low disturbance bentleg opener is investigated for its use in high speed no-tillage seeding. The discrete element method (DEM) of modelling is used to optimise performance and develop bentleg openers for integrated use in bentleg seeding systems.

A virtual soil bin was generated with DEM to simulate the effect of opener rake angle (35-90°) and compare to previous soil bin studies conducted in a sandy loam soil (see Figure 1). The predicted furrow profile parameters of loosened area, ridge height, dip area, furrow backfill and lateral soil throw fell within 9%, 16%, 14%, 0.8% and 9% of the measured values, respectively. Additionally, the predicted rake angle trends on soil failure boundaries, soil layer mixing and tillage forces followed those published in literature. These findings validate the DEM soil-tool interaction model, enabling its use for development of bentleg openers.

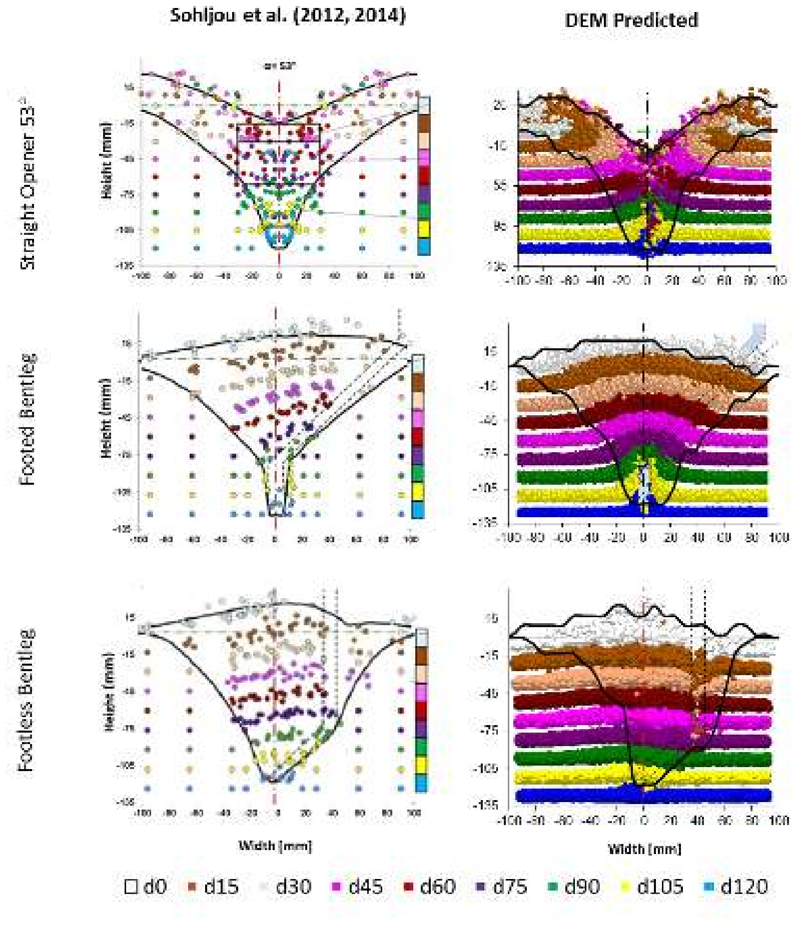


Figure 1. Measured vs DEM predicted soil movement results

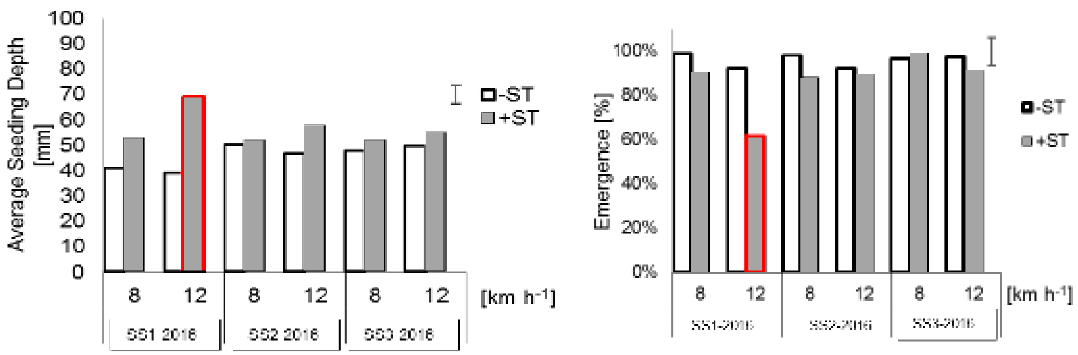
DEM predicted results show soil disturbance with bentleg openers is minimised by streamlining the opener by reducing its thickness and maximising its leading chamfer. A curved – rather than angular- transition connecting the side leg to the vertical shank portion also reduces the extent of soil disturbance. The bentleg foot is the key feature initiating soil failure and driving soil loosening, draught and penetration forces.

However, the vertical upheave caused by the foot increases soil throw at shallower settings (< 90 mm). Removing the foot reduces the loosened soil upheave height, minimising soil disturbance for shallow (60 mm) and high speed operation. These benefits come at the cost of furrow loosening capacity, limiting the operating range of footless bentleg openers to shallower depths (< 120 mm). However, a footless bentleg opener with a side-leg forward rake angle greater than 90° can offer benefits similar to steep rake angle straight openers, but without the associated penalties of reduced furrow size, increased draught and vertical up forces. Benefits include the potential to lower field surface roughness that then improves harvest-ability of crops and reduces the need for post seeding rolling operations in stony soils.

An opener performance evaluation in a dry silt-loam field soil showed a bentleg opener with 95 mm offset could maintain 100% backfill and operate with a lateral soil throw less than half that of knife point openers at 8 km/h. A smaller 45 mm offset bentleg opener was sensitive to speed, reducing furrow backfill and increasing lateral soil throw at 16 km/h (reaching similar values to those of knife point openers). The 95 mm offset bentleg was able to maintain its low soil disturbance characteristics at speeds up to 16 km/h.

Two seed and fertiliser banding techniques were developed and evaluated in a field trial. The seeding system techniques placed seeds into furrow backfilling soil tilth using a furrow closing plate (SS2); or placed seeds on an undisturbed side-ledge (side banded) within the furrow (SS3) and were compared to a district double chute knife point technology (SS1).

Results show both closer plate and side banding bentleg seeding systems can increase operating speeds by at least 50% (i.e. from 8 to 12 km/h) with no penalty to wheat crop emergence or grain yield. In contrast, the knife point seeding system SS1 increased seeding depth by 30.1 mm as a result of excessive soil throw at 12 km/h, thus reducing crop emergence by 31% (on the affected seed rows.) The effect of the seeding systems on crop safety was also investigated with three soil applied herbicides incorporated by sowing. The results showed no significant difference in emergence or yield with knife point or bentleg seeding systems.



(a) (b)

Figure 2. The effect of seeding system, speed and soil throw on average seeding depth (a) and emergence (b) at the 2016 Loxton trial (sandy loam soil type). Error bar represents the least significant different between three factors at P=0.05)

An interesting consequence of the controlled soil disturbance by bentleg openers was realised during field trials conducted in moist sandy-loam soil and heavy wheat residue conditions, using a 6 tine, 4 rank layout at 25cm row spacing. During the trial, minimal soil/residue interactions were highlighted in video footage and by inspection of the resulting straw clumps being almost soil free and much lighter with the low disturbance bentleg openers than under straight openers. One would anticipate that a given size clump created by a bentleg opener tine seeder, of lighter density, would have a much lesser impact on hindering seedling emergence, than a similar one of greater density created by a straight opener tine seeder. More work is required to verify such benefits. It is unclear if soil upheave by a straight opener does in any way contribute to help clear residue off the shank, and promote smaller clumps, as no clear evidence of greater overall clumping could be observed under the bentleg opener layout.

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

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

The key findings of the project are:

1. The discrete element method provides a soil-tool interaction model that can simulate the whole of performance of narrow point openers, reducing the need for costly soil bin experiments. This model can be used in future research and industry consultation. Its first inclusion is to be in the GRDC sandy soils mitigation project, simulating the backfill of non-wetting sands around various no-till openers.
2. Bentleg openers can reduce soil disturbance, namely lateral soil throw and furrow backfill, offering improved performance at high (16km/h) speed (relative to knife points at 8km/h). However, opener design is critical, particularly at higher speeds. Design recommendations provided in this report, and in James Barr's thesis should be followed to maximise opener performance.
3. Bentleg seeding systems have the ability to increase operating speed by 50%, while maintaining seeding quality and crop emergence performance. This represents an unprecedented opportunity for the improvement of tine seeder work-rate, with significant implications for timeliness of no-tillage seeding operations in Australian context.

Intellectual Property

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

The following intellectual property has been generated from the project:

Description	Restriction for commercialisation
Discrete element modelling techniques for modelling soil-tool interaction.	Nil
Bentleg opener/seeding system designs	Nil
Field test results	Nil

Previous patents for the Howard Paraplow limit the patentable potential for the bentleg opener. This opens the door for any willing party to develop the bentleg seeding system without restriction.

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.

The main findings of the project are:

- The discrete element method can simulate the performance of no-till openers, including tillage forces, soil loosening, soil mixing and soil throw providing a valuable tool for opener design and evaluation.
- Bentleg openers combined with a beveled leading edge mostly cancel soil throw and maximise furrow backfill. They offer an unprecedented ability for high speed, low soil throw no-till tine seeders.
- Latest research on integrating bentleg openers into tine seeding systems showed the potential to adequately control seed and fertiliser placement and establish wheat crops similar to common knife point technology at 8 km/h. Importantly, the bentleg seeding systems were able increase operating speeds by 50% to 12 km/h without any emergence penalty commonly seen with knife point seeding system.

These finding represents an unprecedented opportunity for the improvement of tine seeder work-rate, with significant implications for timeliness of no-tillage seeding operations in Australian context.

Journal Publications:

- *Barr, J. B., Desbiolles, J. M. A., & Fielke, J. M. (2016). Minimising soil disturbance and reaction forces for high speed sowing using bentleg furrow openers. Biosystems Engineering, 151, 53-64. doi: http://dx.doi.org/10.1016/j.biosystemseng.2016.08.025*
- *Barr, J. B., Ucgul, M. Desbiolles, J. M. A., & Fielke, J. M. (, Simulating the effect of rake angle on narrow opener performance with the discrete element method, Biosystems engineering, Accepted for publication.*

Journal Publications in review with supervisors:

- *Barr, J. B., Ucgul, M. Desbiolles, J. M. A., & Fielke, J. M, Parameter sensitivity analysis using discrete element method for bentleg opener optimisation, to be submitted to Biosystems Engineering.*
- *Barr, J. B., Desbiolles, J. M. A., & Fielke, J. M, Development and field evaluation of a 12 km h^{-1} no–till seeding system, to be submitted to Biosystems Engineering.*

Conference Publications:

- *Barr, J. B., & Fielke, J. M. (2016). Discrete element modelling of narrow point openers to improve soil disturbance characteristics of no-till seeding systems. Paper presented at the 2016 ASABE Annual International Meeting, St. Joseph, MI. http://elibrary.asabe.org/abstract.asp?aid=46995&t=5*
- *Barr, J. B., Desbiolles, J. M. A., & Fielke, J. M. (2017). A New Method of Quantifying Discrete Element Method Predicted Furrow Profiles of Narrow Point Openers. Paper presented at the 2017 ASABE Annual International Meeting, St. Joseph, MI. http://elibrary.asabe.org/abstract.asp?aid=48113&t=5*

Other publications:

Project findings have been published in the following extension articles:

- *GRDC Research Update Papers 2015*
- *Mallee Sustainable Farming R&D Results Compendium 2014*
- *Eyre Peninsula Farming Systems Newsletter 2015*
- *SANTFA "The Cutting Edge" Winter 2015*

Project findings have been published in the following press releases:

- *GRDC Groundcover magazine (to be published)*
- *The Stock Journal (1st of October 2015)*
- *GRDC driving agronomy podcasts (14th of September 2015)*
- *GRDC media release (8th of September 2015)*
- *SAGIT YouTube video "The use of bentleg openers for cereal seeding" (24th of June 2015)*
- *Australasian Farmers' & Dealers Journal November/December 2015*

Project findings have been disseminated at the following extension events:

- *GRDC Advisors Update (Adelaide Convention Centre) (10th of February 2015)*
- *GRDC Southern Panel Updates Kadina (13th of August 2015)*
- *GRDC Southern Panel Updates Cleve (20th of August 2015)*
- *GRDC Southern Panel Visit Mawson Lakes (15th of September 2015)*
- *GRDC Driving Agronomy Podcast (14th of September 2015)*
- *Mallee Sustainable Farming Annual Field Day (1st of September 2015)*
- *Geranium Ag Bureau Meeting (10th of August 2015)*
- *Karoonda Ag Bureau Meeting (16th of September 2015)*
- *Tailem Bend Ag Bureau Meeting (22nd of September 2015)*
- *Mallala Ag Bureau Meeting (3rd of March 2015)*
- *Independent Consultant Group - Waite Institute (4th of February 2016)*
- *GRDC Advisors Update Wagga Wagga (16th of Februrary 2016)*
- *Hart Field Day (20th September 2016)*
- *Mallee Sustainable Farming Field Day (12th of October 2016)*

Path to market:

The bentleg furrow opener can be adopted with least modifications on split tine seeding systems, where suitable and offer benefits of reduced soil throw and higher operating speeds. This technology has raised significant interest among grain growers. In this research, the concept of an integrated, purpose designed bentleg seeding system has successfully been proved in sandy loam soils. However, there is still research and development work required to make these bentleg seeding systems a commercial reality. The key development areas include developing a robust design(s) for consistent performance across varying field conditions and soil types, optimizing manufacturing solutions, maximizing life span (strength and wear) and optimizing cost.

The current focus has been to collate all soil bin, field, and simulation data which, when combined with UniSA design expertise, will provide an attractive package for a collaborative development with an industry partner. Initial discussions have been held with Agrotil (Qld), Primary Sales Australia (WA), and Hard Metals Australia (NSW) during 2016-17 with the expectation of some commercial collaboration to be initiated during 2018 as further contract research.

POSSIBLE FUTURE WORK

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

The low soil disturbance (particularly the low vertical soil layer mixing) resulting with bentleg seeding systems has further predicted benefits including reduced weed seed bank disturbance and reduced residue clumping – both of which should be formally validated in field evaluations.

Weed seed banks dynamics have been reviewed in previous literature1, showing potential for bentleg seeding systems to reduce the weed seed bank of three horn bedstraw, wild turnip, small flowered mallow and annual ryegrass. This aspect has recently been evaluated in field trials2, validating some benefits of bentleg openers in the Iranian context. Future work should include an evaluation of benefits with a broader range of weed seeds, in the Australian context.

Residue clumping is a common issue in high residue situations with straight opener seeding systems. Soil travels up the opener face and mixes with residue wrapped around the tine shank, causing intermittent blockages and leaving straw/soil clumps over the field that (1) impedes emergence (through an increase in soil cover over seeds) and (2) reduce harvest-ability of low lying crops. The severity of residue and soil clumping is a function of opener soil disturbance, residue load in the field and residue handling ability of the tine. As such, the low vertical soil layer mixing soil throw with bentleg openers has potential to minimise the negative impacts of residue clumping on crop establishment.

1- Solhjou, A. (2013). Study into the mechanics of soil translocation with narrow point openers. PhD Thesis, University of South Australia.

2- Solhjou, A., Jamali, M. R., & Joukar, L. (2018). Opener geometry effect on weed seed bank. Engineering Research in Agricultural Mechanization and Systems, 18(69), 19-30. doi: 10.22092/erams.2017.106550.1101

AUTHORISATION
Name: John Fielke
Position: Principal Supervisor
Signature:
Date: 7 June 2018

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.