How far is too far: Precision sowing drives Microbiology trade-offs with Soilborne diseases

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INTRODUCTION

The abundance and activity of soil microorganisms in Australian agricultural soils with low organic matter is generally dependent upon carbon inputs from crop and pasture residues (1). The spatial distribution of microorganisms in soils is highly heterogeneous due to variation in the availability of C and nutrients and habitat suitability (2). While growing plants provide a constant source of easily available C and nutrients, crop residues (above-ground (stubble) and below-ground (roots)) are an important sources of biologically available C and nutrients for soil microorganisms. This leads to the concentration of a major component (>60%) of microbes in the surface soil and in microenvironments such as the rhizosphere and detritusphere (1).

The availability of precision sowing technology and Global Positioning System (GPS) guided seeding is increasingly common and presents the opportunity for strategic placement of seed in relation to last season's crop rows (3). Such precision sowing has been shown to provide benefits through water harvesting, increased nutrient levels and reduced weed seed populations. However, in continuous cereal cropping systems on-row sowing has the potential to increase the risk from soilborne diseases. In this paper, we present results from field experiments evaluating the benefits and disadvantages of on-row *vs*. inter-row sowing in a continuous wheat cropping system on Mallee sands at Karoonda and Loxton in South Australia.

MATERIALS AND METHODS

Field experiments and soil sampling: Surface soils (0-10 cm), were collected from field crop experiments with an inter-row spacing of 28cm at Karoonda (sandy soil, $pH_{(H2O)}$ 6.5) and Loxton (sandy soil, $pH_{(H2O)}$ 8.4) in South Australia. Soil samples were collected from the previous year's crop row (on-row) and in between rows (Inter-row) locations prior to sowing in 2015 and 2016 crop seasons. Details of field experiments have been reported (4).

Laboratory analysis: Soil samples were analysed for microbial biomass (MB), catabolic diversity and activity using chloroform fumigation-extraction and multi C-substrate response assays (Microresp®), respectively. Genetic diversity of bacterial community in the Karoonda soils was determined using 16S rRNA amplicon sequencing (Illumina-MiSeq®). Bioinformatics analysis of sequence data was done using online tools hosted at http://rdp.cme.msu.edu/index.jsp. Abundances of soilborne plant pathogens *R. solani* AG8, Ggt and Fusarium root rot were quantified through PredictaB RDTS laboratories (SARDI Molecular Diagnostics).

Statistical analyses: A minimum of 4 replicates were used for all treatments. Statistical analyses of all the results were conducted using the Genstat 18.1 (VSN Intl. Ltd). Multi-variate statistical analysis of 16S sequence data and diversity indices were calculated using the Primer6 software (Primer-E Ltd, Plymouth, U.K.).

RESULTS AND DISCUSSION

Microbial biomass, catabolic diversity and activity:

In general, MB levels were higher in on-row soils (Karoonda – 181±10 vs 140±15 µg C/g; Loxton – 230±19 vs 154±17 µg C/g) compared to that in inter-row soils. Results in Figure 1 show that microbial catabolic diversity was significantly (P<0.05) higher in the on-row soil samples. These differences reflect the variation in the quantity of C inputs available for microbial use from crop residues compared to that in the inter-row soils. At Karoonda, on-row soils had higher organic C (0.42±0.02%) compared to Inter-row (0.35±0.03%) soils. On-row soils also had significantly higher particulate and dissolved organic C compared to inter-row sols. Similar trends were observed in soils from experiments at Loxton, SA and in both years.

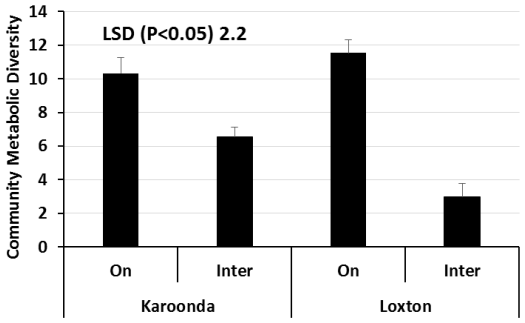


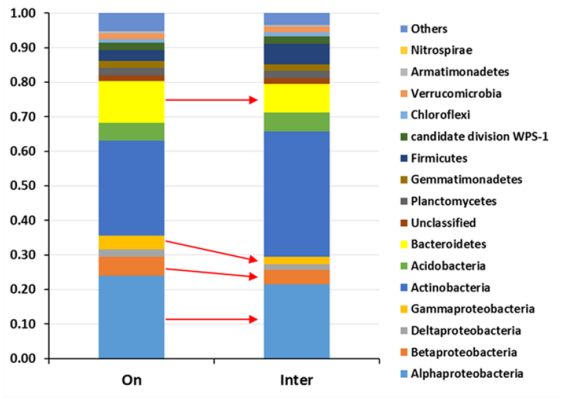
Figure 1. Catabolic diversity estimated using carbon substrate utilization data from Microresp® analysis of surface soils collected prior to sowing in May 2016 from field experiments.

Results in Figure 2 indicate that diversity of soil bacteria (e.g. species richness and evenness) was significantly higher in the soils from the previous crop's row compared to inter-row soils. Members belonging to bacterial groups such as Proteobacteria and Bacteroidetes were higher in the on-row soils, whereas actinobacteria were significantly higher in the inter-row soils (Figure 2). Previous research indicated that higher populations of copiotrophic bacteria (i.e. fast growing) belonging to the Phyla Proteobacteria were found in C-rich microsites compared to the bulk soils (1). Microbial populations in soils are generally concentrated at microsites rich in biologically available C and nutrients that provide suitable physico-chemical environments, e.g. rhizosphere and detritusphere (decomposing residues). However, the bacterial diversity has been shown to be lower in the rhizosphere compared to that in the bulk soil (1) due to the selective enrichment of specific members of the microbial community.

Pathogen inoculum levels and Disease incidence:

R. solani AG8 inoculum levels and resulting disease risk were generally higher for the on-row soils compared to inter-row soils at both sites (Table 1) and the trends were similar in 2016. On-row soils also showed higher *Ggt* and Fusarium pathogen levels. As diseased roots from a crop are a major source of pathogen inoculum, coupled with decomposing stubble they provide a key inoculum source for soilborne pathogens such as *R.*

solani, Ggt and Fusarium and common root rots (1). Similar trends were also observed for stubble borne pathogens such as Fusarium crown rot.



Position	Shannon index (H)	Species richness (d)	Species evenness (j)
OnRow	7.683	903	0.9502
InterRow	7.513	801	0.9461
LSD (P<0.05)	**0.087**	**64.5**	**0.003**

Figure 2. Bacterial diversity and community composition in the surface 10 cm soils at the time of sowing during 2015 and 2016 in field experiments at Karoonda and Loxton in South Australia.

Results in Figure 3 show that rhizoctonia root rot disease severity was higher in inter-row sown plants. Previous research has shown that the severity of Rhizoctonia disease incidence is due to a combination of inoculum level, microbial activity, N levels at seeding, soil temperature and moisture during seedling growth (5). Surface soils from the inter-row generally had lower microbial activity, MB, microbial catabolic diversity (product of microbial biomass C and DOC:DON) and lower moisture all of which would have contributed to the higher rhizoctonia disease incidence through reduced microbial competition. Additionally, lower diversity and abundance of known plant growth-promoting bacteria would have contributed to the higher disease in inter-row sown plants.

Table 1. Rhizoctonia root rot disease risk rating based on *R. solani* AG8 DNA concentrations in surface 10 cm soil at the time of sowing in 2015.

Site	Treatment	On-row	Inter-row
Karoonda	Early sown	Medium	Low
	Late sown	Medium-High	Medium
Loxton	Early sown	Medium	Low-Medium
	Late sown	High	Low

At Loxton, a delay in sowing between April and May meant that plants established in soils at lower temperatures resulting in slower root growth and reduced ability to grow through an infection zone. However, in the non-wetting sands at Karoonda, delayed and varied emergence at the earlier sowing date exacerbated disease impact, especially infection on the crown roots (Figure 3). These results suggest that observed benefits of early sowing in reducing soilborne disease impacts may not apply to non-wetting sands. Unlike the Rhizoctonia solani AG8 fungus, inocula for soilborne pathogens such as Fusarium crown rot and Take-All are more closely associated with stubble, hence inter-row sowing could help reduce disease severity. However, we did not find significant incidence of these diseases in on-row locations at Karoonda or Loxton.

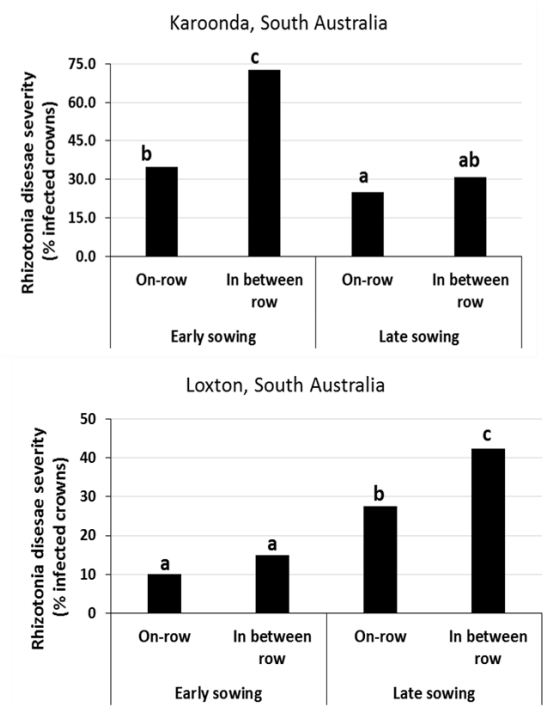


Figure 3. Disease incidence in 8 week old wheat seedlings, in the Dune experiment, as influenced by the location of sowing during 2015 crop season.

SUMMARY

- On-row surface soils rich in detritusphere harboured significantly greater bacterial diversity and microbial catabolic diversity and activity compared to inter-row soils.
- On-row plants were exposed to higher levels of soilborne pathogens with greater disease risk but showed lower disease incidence compared to that in inter-row plants.
- Results show precision sowing drives microbiology trade-offs with soilborne diseases in the Mallee soils.

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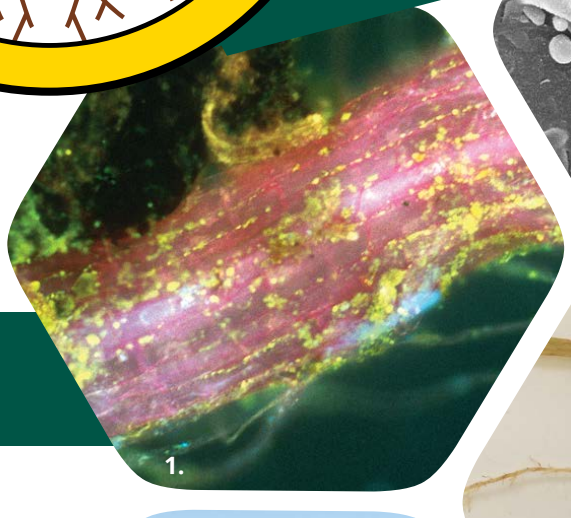
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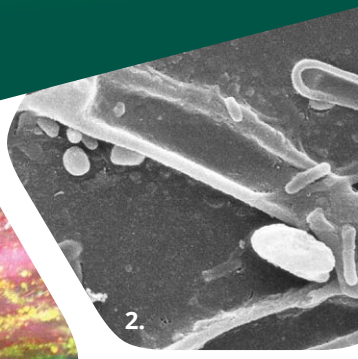
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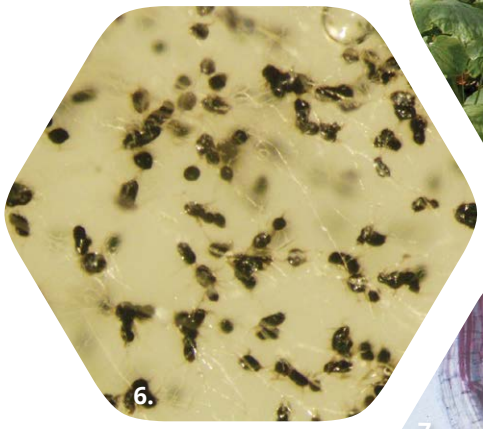
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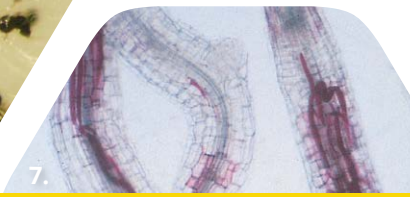
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