Chasing water: Increasing sowing opportunity with small changes to sowing depth across the low and medium rainfall zones of Western Australia

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Abstract

Germination and emergence are key factors in successful annual crop establishment and are affected by numerous management decisions. Sowing time decisions are based on the seasonal break, variety availability, and the farmer's capacity to sow their whole program in a timely manner. We propose that sowing depth is also an important part of this decision.

Across the Western Australian grainbelt, growing season rainfalls are declining and the break of season is becoming less predictable and shifting to later in the autumn. These changing rainfall patterns can result in insufficient moisture near the soil surface during the desired sowing window. In the eastern areas of the WA grain belt however, recent years have shown a significant increase in summer and early autumn rainfall events. Using historical metrological data and modelling in APSIM (plus the SWIM3 soil/water model) we aimed to determine how often, and under what conditions, a situation occurs where these rain events create a moist seed bed at depth, providing deep sowing opportunities, even if soil near the surface were dry.

We show that, depending on location and soil type, sowing into deeper soil layers can often access extra moisture not available in surface layers. Increasing sowing depth by even small amounts (sowing at 50-100 mm) can offer higher sowing opportunities. Our results indicate that deep sowing could significantly increase sowing opportunity for crops that can be sown deeper than 50 mm (pulses, oats, and long-coleoptile wheat) across the LRZ and MRZ of Western Australia.

Keywords

soil water; crop establishment; sowing time; sowing depth; crop modelling; APSIM; deep sowing

Introduction

Germination and emergence are key factors in successful annual crop establishment, particularly as farmers balance risk of terminal drought, heat and frost across the growing season as traditional sowing times and methods are challenged by changing climate. Sowing in a timely manner is crucial to produce optimal emergence, duration of biomass accumulation, flowering time, and to maximise the chance of achieving yield potential.

Growers base sowing time decisions on the timing of the seasonal break, variety availability, and their capacity to sow their whole program in a timely fashion (Fletcher et al., 2016). In rainfed systems (such as WA) germination and establishment are reliant on autumn rainfall, so the timing of the seasonal break influences sowing time decisions. Across the Australian grain growing region, the autumn break of season is generally becoming less predictable and shifting to later in the season (Cai et al., 2012; Flohr et al., 2021). Delayed rainfall events and increasing farm size result in growers often sowing their programs outside the ideal sowing window. For many growers the difficulty in planning their sowing programs is compounded by a general decline in growing season rainfall across these areas, although yearly rainfall may be consistent or even increasing (Morgan et al., 2008).

Declining autumn rainfall and a more variable break of season can result in insufficient moisture for germination near the soil surface during the desired sowing window. However, in some areas, such as the low (LRZ) and medium (MRZ) rainfall zones in the northern and eastern areas of the WA grainbelt, recent years have shown a significant increase in summer rainfall (Morgan et al., 2008; Scanlon & Doncon, 2020). Summer rainfall and autumn rainfall events can result in subsurface moisture (deeper than 50 mm) being available across the sowing window (late March – June) which may be adequate for germination and establishment. If moisture is present at depth, deep sowing into this moisture would allow growers to sow and establish crops up with less reliance on the season break, potentially offering yield benefits and allowing for more flexibility within their sowing programs.

Sowing depth is an important management decision which strongly impacts crop emergence time and establishment, with associated effects to rooting depth, biomass, flowering time and yield. As well as allowing growers to utilise subsoil moisture and achieve early sowing times, deep sowing can reduce seed predation and assist in avoiding phytotoxicity of pre-emergent herbicides. Emergence from depth can, however, result in slower and/or reduced emergence and lower early leaf area, leading to lower weed competition and more soil evaporation. There are also logistical trade-offs to the benefits from deep sowing as sowing speeds can be lower, fuel consumption higher and a grower needs appropriate equipment if sowing to extreme depths.

Interest has been growing in WA about the potential to chase water by deep sowing of long-coleoptile wheats, oats, and pulses such as chickpea, however, there is little understanding of how often and in what locations deep sowing will offer a benefit. We aimed to gain an understanding of how often a situation occurs where deep sowing would be beneficial, i.e. when surface moisture may be sub-optimal for germination, but where deeper sowing (50-200 mm) could allow growers to sow into soils with significant moisture.

Methods

Simulations were compiled with the Agricultural Production Systems Simulator (APSIM; v 7.1; Holzworth et al., 2014). For accurate representation of soil water and evaporation at a fine layer scale we used the Soil Water Infiltration and Movement model (SWIM3; Huth et al., 2012). This module is based on the Richards and advection-dispersion equations and designed specifically for use in studies of soil water in agricultural systems simulation. Saturated hydraulic conductivity (K_s) is a key determining factor of soil water and is utilised in the SWIM3 module. As K_s is not included in the parameters of most generic APSIM soil due to difficulties in measurement, we sourced generic Australian soil type K_s values from McKenzie et. al. (2000) which corresponded well with value ranges for K_s by soil type given in recent meta-analyses (García-Gutiérrez et al., 2018; Gupta et al., 2020).

Figure 1: South-Western Australia with location of sites used in this study, along with main ports

Table 1: Location of sites used in this study with mean rainfall by month over the autumn sowing period and mean growing season rainfall (GSR; May – October) and probabilities of small rainfall events during the sowing season. Data is from the 50 years (1971 – 2020) used in simulations

Site	Average Rainfall (mm)				
	February	March	April	May	GSR
Salmon Gums	24	26	25	34	187
Southern Cross	20	28	28	33	190
Morewa	20	18	20	41	201
Wagin	18	19	24	47	283
Northam	15	18	23	50	325

Using metrological data from the SILO Patched Point Dataset we simulated soil water over the autumn sowing window (March through June) in response to climate and location. Here we present five representative sites in the wheatbelt of WA from 1971 – 2020 (Figure 1). Sites were selected to cover the range of seasonal condition experienced across the LRZ/MRZ wheatbelt of Western Australia; rainfall details of representative sites chosen are listed in Table 1. We present sowing opportunity data from two generic soils at each location (sand and clay) as these represent the extremes of soil water holding capacity. Simulations were run without summer weeds and with stubble coverage (1500 kg ha^{-1}).

We defined a sowing opportunity as a day where the soil had moisture where germination would not be constrained by moisture (at least 8% on sand and 18% on clay) and which was also followed by five consecutive days that also met this moisture criteria so that establishment would be likely to occur.

Results

Sowing opportunity is closely related to rainfall and temperature and interacts strongly with soil type; figure 2 shows daily sowing opportunities at standard sowing depths (20-50 mm) across the five sites.

As expected, probability of a sowing opportunity at standard sowing depths was very low in late March and increased as autumn progresses. The impact of higher May and June rainfall, plus lower evaporation rates, in the two locations in the MRZ (Wagin and Northam) becomes very evident in high probabilities of a sowing opportunity at these sites as the autumn sowing window progresses.

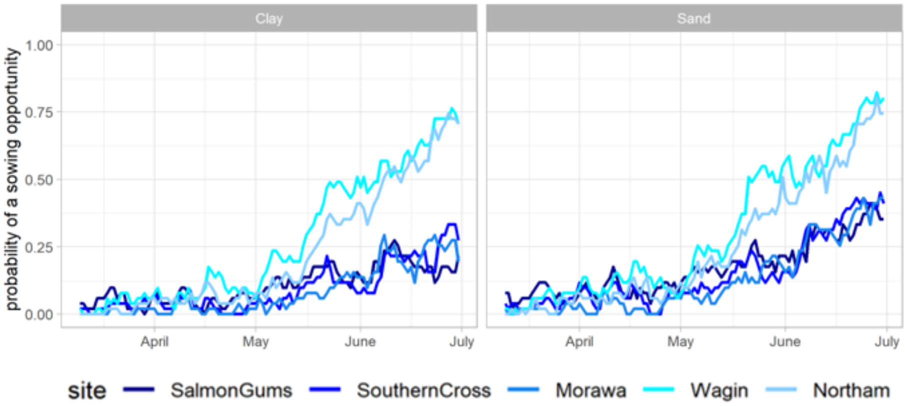

Figure 2: Daily probability of a standard sowing opportunity by location and soil type over the past 50 yrs. (1971-2020). Sowing opportunity was defined as availability of enough soil water for seed to germinate for at least six days in a row in the 20-50 mm soil layer.

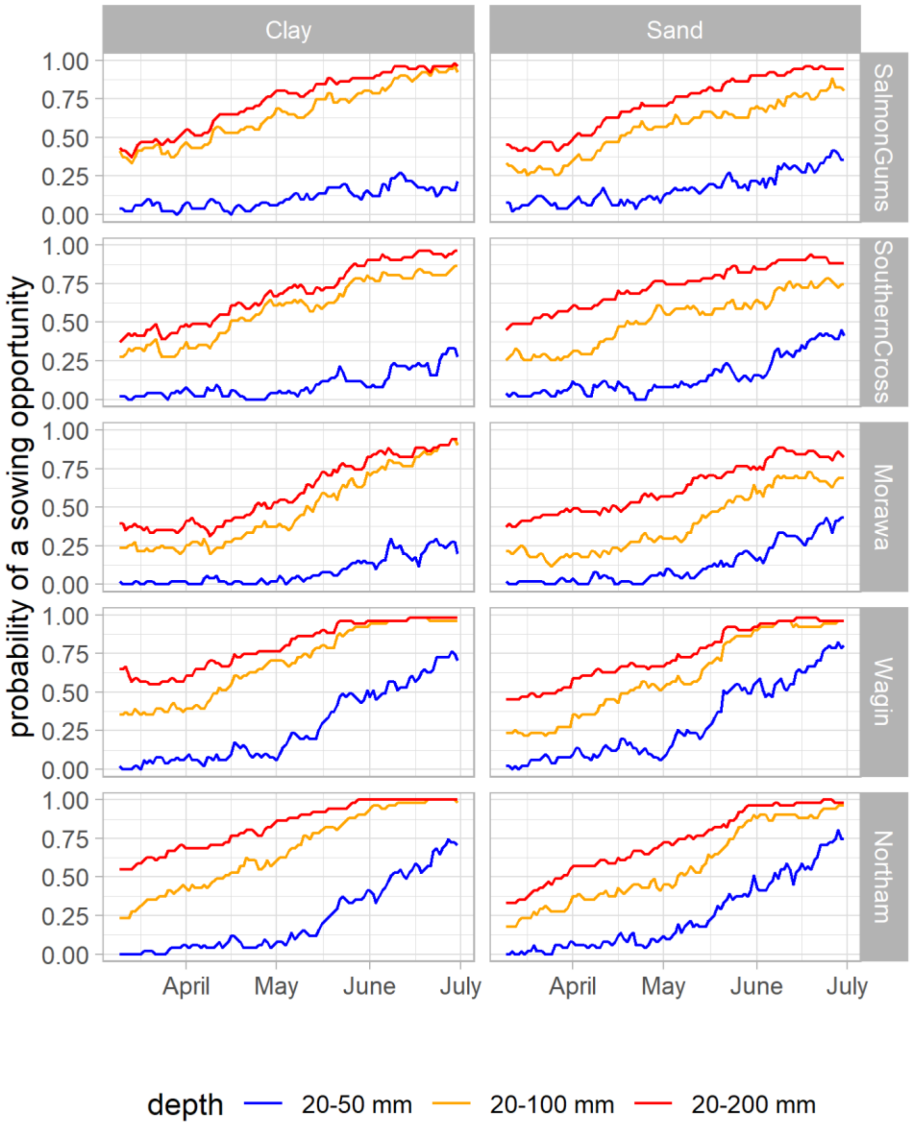

Figure 3: Daily probability of a sowing opportunity depending on depth of sowing undertaken. Sowing opportunity was defined as availability of enough soil water for seed to germinate for at least six days in a row in the soil of that depth. For the 20-100 mm (orange) and 20-200 mm (red) sowings, opportunity was calculated as opportunistic sowing to any 50 mm soil layer down to that depth where there was adequate moisture for the six days moisture, even if standard 20-50 mm (blue) sowing depths were dry. Data is presented by location and soil type over the past 50 yrs. (1971-2020).

Small rainfall events can penetrate the subsurface-soil layers and will then evaporate far slower than in the surface soils, resulting in increased sowing opportunity in deeper layers as compared to standard depths. There is higher soil moisture retained at depth, and therefore, if opportunistic sowing to 100 mm is undertaken, or even to extreme depths (200 mm), the probability of a sowing opportunity increases significantly (Figure 3).

In higher rainfall areas in the MRZ, (i.e. Wagin and Northam), deeper soils are permanently moist by the end of the sowing window, however, surface layers are also far more likely to present a favourable seed-bed due to a high likelihood of significant rainfall events. Given that deep sowing can cause reduction in emergence and establishment, it is not a management option usually undertaken when the surface soils have adequate moisture, so the likely advantage in these areas decreases over the sowing window. In dryer regions across the LRZ (i.e. Salmon Gums, Southern Cross and Morawa), where large rainfall events can be sporadic even late in the sowing window, the advantage of deep sowing continues throughout the autumn sowing window.

Conclusion

Depending on soil type and location, deep sowing opportunities may be present even when surface layers are dry. Across the LRZ and MRZ of Western Australia, increasing sowing depths by even a small amount into the 50-100 mm layer can significantly increase sowing opportunities. In dryer regions across the LRZ, where large rainfall events can be sporadic even late in the sowing window, the increased sowing opportunity offered by deep sowing continues throughout the autumn sowing window. Our results indicate that deep sowing could significantly increase sowing opportunity for crops that can be sown deeper than 50 mm (pulses, oats, and long-coleoptile wheat) across the LRZ and MRZ of Western Australia.

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