Soil amelioration techniques: How they affect weed dynamics and weed seed burial

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Abstract

Soil amelioration has gained great interest in the Western Australia grain-belt over the past decades including incorporating lime, burying repellent soils or disrupting compacted soil. However, relatively little is known about its impact on weeds or the weed seed bank. A series of field and screen house trials were designed to understand better how soil amelioration techniques alter weed dynamics. Results from these trials suggest that the impact of amelioration on weeds varies with the type of mechanical amelioration treatment, proportion of topsoil disturbance and weed seed burial. We found that soil inversion was highly effective in reducing weed density (by 90-100% compared to control) while deep ripping stimulated weed emergence. Moreover, emergence of buried seeds collected from varying soil depths indicated that deep mixing by a rotary spader distributed weed seeds throughout the soil profile, whereas soil inversion by a mouldboard plough buried most weed seed at 10-20 cm. This research gives us a good insight of weeds' response to soil amelioration and aid in formulating better weed management strategies following amelioration.

Keywords

Weed density, weed management, soil amelioration, soil incorporation, weed seed burial

Introduction

Growers in the Western Australian (WA) wheat-belt are often challenged with multiple soil constraints, such as soil acidity, water repellence and soil compaction. These soil constraints are frequently alleviated by mechanical soil amelioration practices, such as deep ripping, soil mixing and soil inversion. Growers have widely adopted these practices to incorporate lime to manage soil acidity, bury repellent soils or physically disrupt compacted layers of soil. Soil amelioration methods lead to various degrees of soil mixing and can redistribute weeds along the soil profile though physical movement of the weed seed bank. Altered soil conditions from amelioration might affect weed and crop emergence times, growth and response to pre-seeding herbicides, and altered weed-crop competitive interactions during the growing season. To plan an effective integrated weed management strategy following amelioration, growers and agronomists need to understand how soil amelioration techniques alter weed dynamics. This investigation aims to assess changes in weed emergence, density, seed production and seed burial for two growing seasons after soil amelioration. The information generated from this investigation will allow growers to take an informed decision in managing weeds in ameliorated soils.

Methods

Field experiment at Yerecoin, WA, Australia

This field experiment was conducted at a farmer's paddock in Yerecoin (-30.892, 116.387) from 2019-2020. The soil type of the site was a deep yellow earth with $pH_{(CaCl)}$ of 6.0 (topsoil, 0-10 cm) and 4.2 to 4.8 (subsoil, 20-40 cm). The experiment was a split-plot design with six replications arranged over three banks, with each bank having two blocks of 4-paired (limed vs no lime) plots. Soil amelioration was the main plot factor and lime application was the subplot factor. Individual plot size was 20 m by 2 m with four buffer plots between each block and one between each paired plot. The soil amelioration included deep ripping (using an Agroplow), deep mixing (using an Imants rotary spader), soil inversion (using a 3-furrow Kverneland mouldboard plough) and control. After amelioration, each of the paired plot received either no lime (control), or lime (in the form of coastal lime at 2000 kg/ha) spread on the surface.

In 2019, each plot was sown with barley (cv. La Trobe) at 80 kg/ha at a 2 cm depth and 22 cm row spacing with a knifepoint seeder having press wheel (a no-tillage seeding system). During sowing, fertilizer (K-Start 10.7:12.1:12:3.9:0.1:0.2 % N:P:K:S:Cu:Zn Nutrien Ag solutions®, Australia) was banded 4 cm below the sowing depth at 100 kg/ha and urea was top-dressed at 30 kg/ha. The site received Spray.Seed® (2 L/ha) and Boxer Gold® (1.75 L/ha) as pre-emergent herbicides, Chlorpyrofos (0.2 L/ha) and Alpha-scud® (0.2 L/ha) as insecticides just after sowing, and Velocity® herbicide (0.8 L/ha) in-crop, on 25/07/2019 and 06/09/2019. Liquid N (Flexi N 42.2% N, CSBP Australia) was sprayed at 60 L/ha 2 months after sowing.

In 2020, wheat (cv. Ninja) was sown at 90 kg/ha with a similar sowing system as barley, with mixed fertilizer (Agstar Extra banded below seeds at 80 kg/ha and urea top dressed at 50 kg/ha). Liquid N (50 L/ha Flexi N 42.2% N) was sprayed twice, on 14/07/2020 and 21/07/2020, while MOP at 100 kg/ha was top-dressed on 06/08/2020. Pre-emergent herbicides were Spray.Seed® (2 L/ha), Sakura® (118 g/ha), and Treflan® 480 (2 L/ha), while Chlorpyrifos (0.2 L/ha) and Alpha-scud® (0.2 L/ha) were sprayed for insect control. For disease management, Atlantis® (330 mL/ha) with 1% MSO, and Pirimor® (300 g/ha) with 1% spray oil were applied on 08/07/2020.

Field experiment at Darkan, WA
A similar experiment with slightly different layout (6 replicates over two banks instead of three) was also established in Darkan in 2019-2020. The rest of the experimental design was the same as Yerecoin. The trial was on a hillslope where the top soil (0-20 cm) was a very dark brown humic loamy sand with medium water repellence (pH 5.3), while the subsoil (20-50 cm) was a light yellowish brown weak clayey sand (pH 5.5). Both top and sub soil contained 40% subrounded ferruginous ironstone gravel and 10-20% subrounded ferruginous ironstone stone. Weed and disease management practises were similar to the Yerecoin site.

Data collection
At both sites, weed density was assessed in two 50 cm × 50 cm quadrats per plot approximately six weeks after sowing. At maturity, weed heads were assessed from two similar quadrats per plot. Additionally, twenty random mature weed heads were collected from each plot and oven-dried at 60°C for 72 hrs. Seeds were separated from the heads and subsampled several times with a seed splitter. The final subsample was weighed and the number of seeds counted to determine weed seed production/m^2.

Screen house experiment at DPIRD, Northam, WA
During July to August 2020, soil samples were collected from the plots that received no lime at both sites using a soil corer of 4 cm diameter. Samples were collected at various depths (0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm), and five random samples were collected for each depth per plot and bulked. The bulked soils collected were evenly spread on emergence trays (15 cm by 30 cm) that were previously filled with a 4 cm layer of potting mix. The trays were placed in a screen house and watered with automated irrigation. Weed emergence was monitored and cumulative emergence was counted over seven months. This experiment will continue until August 2021.

Statistical analysis
An ANOVA was used to assess the effect of amelioration on weed density and head production usingGenstat. Means were compared using Fisher's protected LSD with significance at 0.05. graphs were generated in MS excel

Results and Discussion

Effects of mechanical amelioration on weed density and seed productivity
Annual ryegrass and great brome were the most prevalent weeds: other weeds (such as cape weed, clover, afghan melon etc.) were very sparse and were not included in the analysis. Soil amelioration significantly affected weed density in both 2019 and 2020 (Table 1). At Yerecoin, a full soil inversion significantly reduced weed emergence for the two consecutive years, with early-season weed numbers reduced by up to 90-100 % compared to control. Weed seed head set in soil inversion plots were 5

and 10 heads/m^2 in 2019 and 2020, compared to 113 and 202 heads/m^2 in the control plots. Similarly, at Darkan, effective weed control was observed in the soil inversion treatment, with 3 plants/m^2 in both years, and 4-7 seed heads/m^2 (Table 1). At Yerecoin, deep ripping weed density was nearly four times greater than deep mixing in both years, with the highest number of seed heads (163/m^2 in 2019 and 324/m^2 in 2020). Likewise, at Darkan deep ripping weed density was greater than all other treatments in 2019. Weed density following deep mixing or ripping was not significantly different to the control in 2020.

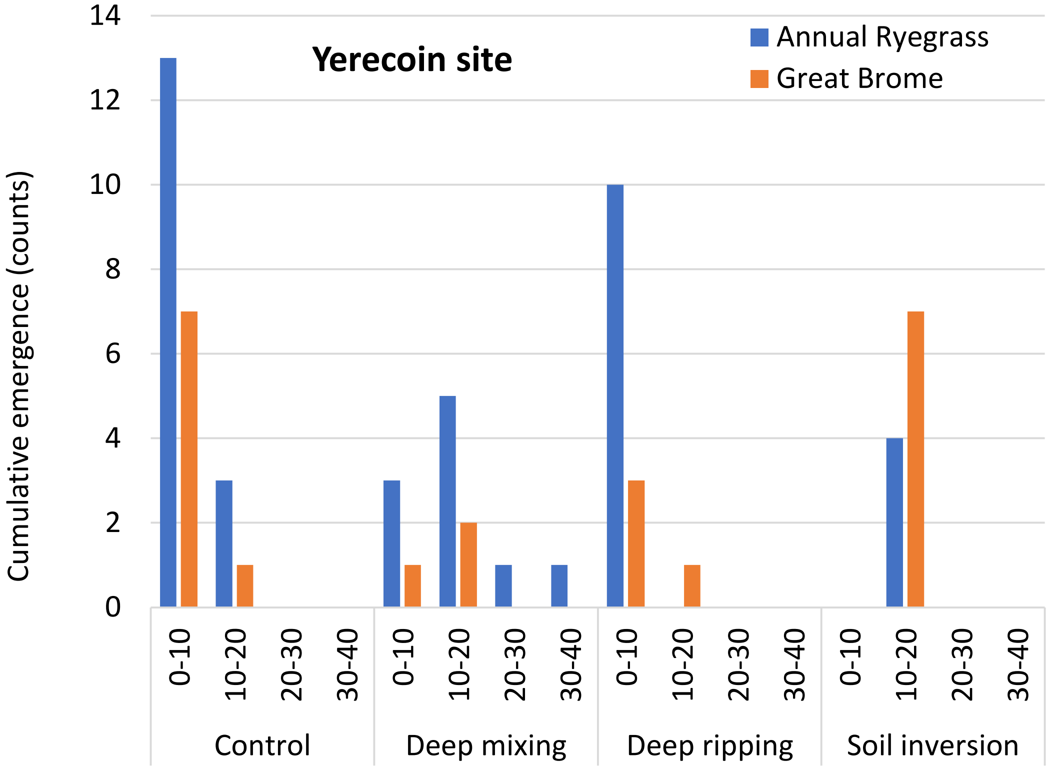
Table 1. Effect of soil amelioration on weed density and subsequent seed head production at Yerecoin and Darkan, WA in 2019 and 2020. Letters indicate where means are significantly different (P<0.05).

Location	Amelioration	Grass weed density (plants/m^2)		Grass weed head (number/m^2)	
		2019	2020	2019	2020
Yerecoin	Control	88 ^{bc}	115 ^{bc}	113 ^{b}	202 ^{b}
	Deep ripping	120 ^{c}	207 ^{c}	163 ^{c}	324 ^{c}
	Deep mixing	32 ^{ab}	57 ^{b}	97 ^{b}	100 ^{ab}
	Soil inversion	0 ^{a}	12 ^{a}	5 ^{a}	10 ^{a}
Darkan	Control	32 ^{b}	26 ^{bc}	20 ^{b}	68 ^{b}
	Deep ripping	42 ^{c}	20 ^{b}	23 ^{b}	87 ^{bc}
	Deep mixing	27 ^{b}	33 ^{c}	21 ^{b}	105 ^{c}
	Soil inversion	3 ^{a}	3 ^{a}	4 ^{a}	7 ^{a}

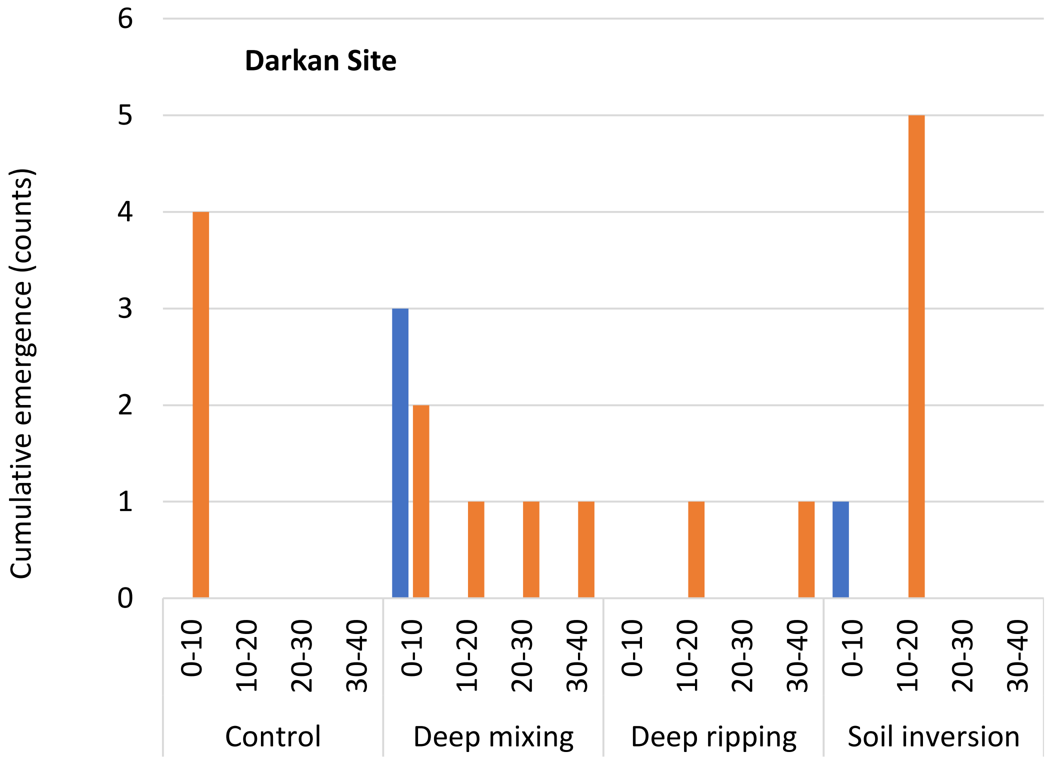
Results show that soil inversion effectively reduced weed density at both trials. By contrast deep ripping in Yerecoin stimulated weed emergence in the subsequent year after amelioration Results from these trials suggest that a full soil inversion provides long-term weed control. This is mainly achieved due to burial of the weed seeds by mouldboard to a depth that prevents successful emergence. However, other soil renovation techniques may stimulate weed growth in the short term (Brandsæter et al., 2017; Renton and Flower, 2015). Therefore, growers should plan an adequate weed management program such as delayed sowing along with use of a non-selective herbicide to control early weed cohorts. However, growers should be aware of the changed soil environment due to renovation, which might pose a risk of altered herbicidal behaviour and phytotoxicity, particularly for pre-emergent herbicides (Alletto et al., 2010; Ananda et al., 2018; Bakker and Poulish, 2015). Additionally, we found that lime application at the surface did not affect weed growth (hence not included in Table 1), although there are reports that lime incorporation may reduce weed density due to improved crop competition in acidic soil (Borger et al., 2020).

Emergence pattern of the weed seed in the screen house

Among the emerged weeds, annual ryegrass (*Lolium rigidum* Gaud.), great brome (*Bromus diandrus* Roth) were more abundant. Other emerged but less frequent weeds were cape weed, clover and afghan melon and they were not included in the analysis. Seed emergence were recorded from soil samples taken at the sites, with annual ryegrass more common at Yerecoin and great brome at Darkan. In the control (no tillage system), most weed seeds remained at the surface (0-10 cm) at Darkan and Yerecoin, although there were a few weeds (4) that also emerged from soil collected at a depth of 10-20 at Yerecoin (Figure 1). For soil samples from deep mixing plots, emergence was observed in soil from all four depths: 0-10, 10-20, 20-30, and 30-40 cm, indicating that this treatment distributed weed seeds throughout the soil profile. The emergence pattern in the deep ripped sample trays was variable and the soil inversion treatment buried most seed at 10-20 cm. (Figure 1).



A.



B.

Figure 1. Cumulative emergence of weeds from soil samples collected from increasing depths (0-40 cm) in each amelioration treatment of Yerecoin (A) and Darkan (B).

Generally, weed seed burial beyond the top 10 cm is sufficient to prevent seeds from successfully emerging. Burial of weed seeds may induce dormancy and these seeds may last longer in the seed banks. For example, studies have indicated that seeds buried at depth may remain viable after 13 years (Dawson and Bruns, 1975), 17 years (Burnside et al., 1996) or even 120 years(Telewski and Zeevaart, 2002). However, seeds buried in the upper 0-10 cm of soil might be returned to the soil surface in subsequent crop sowing events. Even deeply buried but viable seed can become a potential problem if they are returned to the surface during the next amelioration event if they have not degraded. Therefore, an understanding of the buried seed degradation process after amelioration could be a further extension of this study.

Conclusion

This research provides useful information regarding weed dynamics as altered by soil amelioration practices. Soil inversion provides effective weed control by burying weed seeds, mostly in the middle layers of the ploughing depth; whereas deep ripping, and deep mixing in some cases, stimulate weed emergence and seed head production. Deep mixing also distributes weed seeds throughout the soil profile. This study will help growers to formulate better weed management strategies after soil amelioration

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References

Alletto L, Coquet Y, Benoit P, Heddadj D, Barriuso E (2010) Tillage management effects on pesticide fate in soils. A review. Agronomy for Sustainable Development 30:367-400

Ananda S, Fabio S, Inge SF, Bo M, Luis AA, Per K (2018) Effect of Tillage Systems on the Dissipation of Prosulfocarb Herbicide. Weed Technology 32:195-204

Bakker D, Poulish G (2015) The phyto-toxicity of pre-emergence herbicides on mould boarded soils Proceedings Perth Industry Crop Updates 2015, Perth, WA

Borger CPD, Azam G, Gazey C, van Burgel A, Scanlan CA (2020) Ameliorating soil acidity reduced growth of Rigid ryegrass (Lolium rigidum) in wheat. Weed Science 68:1-22

Brandsæter LO, Mangerud K, Helgheim M, Berge TW (2017) Control of perennial weeds in spring cereals through stubble cultivation and mouldboard ploughing during autumn or spring. Crop Protection 98:16-23

Burnside OC, Wilson RG, Weisberg S, Hubbard KG (1996) Seed Longevity of 41 Weed Species Buried 17 Years in Eastern and Western Nebraska. Weed Science 44:74-86

Dawson JH, Bruns VF (1975) Longevity of Barnyardgrass, Green Foxtail, and Yellow Foxtail Seeds in Soil. Weed Science 23:437-440

Renton M, Flower KC (2015) Occasional mouldboard ploughing slows evolution of resistance and reduces long-term weed populations in no-till systems. Agricultural Systems 139:66-75

Telewski FW, Zeevaart JA (2002) The 120-yr period for Dr. Beal's seed viability experiment. Am J Bot 89:1285-8