Seedling emergence of wheat varieties under different surface crust condition in sodic soils

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Abstract
In semi-arid regions of Australia, crop emergence is seriously affected by surface soil crust that results in reduced seedling emergence and grain yield at harvest. Seedling emergence of wheat genotypes is an important parameter influencing plant density. Seedling emergence of 38 wheat varieties was investigated in the presence of two artificially created surface crusts, (i) relatively 'weak crust' and (ii) relatively 'hard crust' using sodic dispersive soil in the glass house. Surface soil crust strength significantly influenced seedling emergence rate and timing of emergence of different wheat varieties. The average seedling emergence was lower in the 'hard crust' (proportional emergence = 0.20) than in the 'weak crust' (proportional emergence =0.68). Significant variation in proportional emergence was observed between the genotypes. Genotypes which germinated and emerged quickly achieved a higher proportional emergence. Seedling biomass, root length and seed parameters were not significantly different among three groups of varieties that could be classified as sensitive, very sensitive or tolerant to the surface soil crust conditions examined. These results indicate that there was variation that could allow selection of suitable wheat varieties for improved seedling emergence in the presence of surface soil crust in sodic dispersive soils.

Keywords
Genotypes, exchangeable sodium percentage (ESP), crust simulation.

Introduction
In the semi-arid tropics of Australia, wheat is commonly grown on sodic dispersive soils with poor physical structure, which are prone to surface soil crusting or capping. Surface soil crust strength is affected by moisture content, rainfall intensity and duration, timing of rain and rate of drying. Poor seedling emergence of crops can be a significant problem arising from soil crusting. Emergence of wheat genotypes can be delayed and rate of seedling emergence can be reduced because of surface soil crust. Soil surface crust has been shown to delay wheat emergence by 1.2 days (Braunack and Dexter 1988) and reducing the proportional emergence by 25%.

Seedling emergence may be improved by adapting good management practices such as mulching, chemical applications and tillage (Mehta and Prihar 1973; Agarwal and Sharma 1980; Chaudhary and Prihar 1974). It has also been suggested that selection of genotypes with greater emergence would be further advantageous (Awadhwal and Thierstein1985). Major requirements to achieve this would include; i) variation in crop response and ii) reliable technique for identifying this variation (Peters 1978). Variation for seedling emergence through surface soil crust has been found for number of crops including soybean (Rathore et al. 1983), sorghum and pearl millet (Soman et al. 1992).

The impact of surface crust on seedling emergence could be screened using a simulated surface crust (Busch et al., 1973, Tackett and Pearson, 1965). Rainfall simulators are used to produce soil crust under varying rainfall intensity, duration and drying condition. Holder and Brown (1974) reported that different durations of rainfall at similar intensities resulted in a larger difference in the impedance of soil crust formation than did different intensities for the same duration. We investigated the seedling emergence, growth and morphology of wheat varieties under two different surface soil crust conditions to find a suitable screening technique and to determine whether genetic variation exists among commonly grown wheat varieties in semi-arid regions of Australia.

Methods

Soil collection and analysis

Sodic dispersive soil was collected from 'Binara', near Goondiwindi in Southern Queensland (N-0215850, E-6890715). Surface soil samples were obtained, air-dried and ground to pass through < 2 mm sieve. Soil pH, electrical conductivity (EC) and exchangeable sodium percent (ESP) were measured as described in (Rayment and Lyons 2011).

Seed *germination test*

A total of 38 wheat varieties were selected. All the seed samples originated from a harvest site at Queensland Breeding Station in 2015. Germination was assessed in petri dishes containing 100 seeds each on filter paper kept in the dark for 5 days and then 3 days under a light/dark regime at 20^{o}C. Seed parameters were determined prior to sowing including thousand grain weight (TGW) ranged from 34-64 g, length ranged from 5.5-8 mm and width ranged from 2.5 to 4 mm.

Soil preparation and crust simulation

Air-dried surface soil (0-10 cm) was ground and sieved to < 2 mm size. Soil was then filled into rectangular plastic pots of 70 cm length, 22 cm width and up to 11 cm depth. Soils were moistened to 70% field capacity using deionised water. Water was spayed into the soil evenly from the top after 24 hours to maintain even distribution of water in the pot. Thirty-eight selected wheat genotypes were sown into the pots with six replicates for each genotype. Each pot contained twelve seeds at 10 cm spacing. The seeds were then covered with 3 cm of dry soil. To simulate rainfall, the pots were placed into a spray cabinet located at the Leslie Research Centre, Toowoomba, Queensland. The intensity and duration of the rainfall were chosen based on climate data of Burilda station, 14.5 km away from the soil collection site where the average rainfall during the typical sowing periods was 40 mm. Two rainfall treatments were performed to create crust of two different soil strengths : i) hard crust- simulator ran for 22 minutes at 40 mm/h intensity (225 ml water/ pot) and ii) weak crust – simulator ran for 11 minutes at 40 mm/h rain intensity (112.5 ml/pot). Weak crust pots which initially received less water were spayed manually with 112.5ml/pot on day 2 and on day 3 so that at the time of seedling emergence both pots had received the same amount of water. After the rainfall and manual watering, both the treatments had reached field capacity. Each treatment contained a total thirty-eight genotypes with six replicates. Pots were arranged in a temperature controlled glasshouse using a randomised complete block design. Soil samples were collected from the pots using a soil corer (diameter 3 cm) at three different times at one day after water spray, at the time of emergence and at the end of the experiment) Seedling emergence and date of emergence were noted daily for the duration of the experiment (12 days). Soil crust thickness and soil crust strength were measured daily for each pot using a digital cone penetrometer with a cone diameter of 1 cm. Root length and number and biomass weight of the plants were measured after harvesting on day 12.

Results

The surface soil (0-10 cm), collected from 'Binara' had ESP 10%, pH>8, EC 0.4 dS/m and field capacity of 40%. High ESP in the surface soil is a major reason for soil dispersion which leads to surface crusting due to the rainfall before the emergence of the crops. Other soil constraint e.g. high pH is also the reason for poor soil structure which poses adverse effects on seedling emergence. The volumetric soil moisture (Figure 1) at three different times of the experiment ensured that both the treatments contained similar soil moisture at the time of seedling emergence. The seeds also received sufficient soil moisture at the germination depth (3-4 cm).

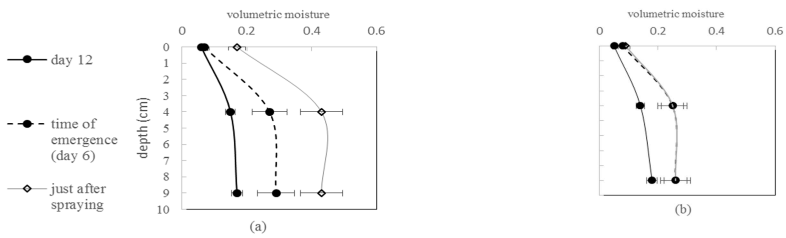

Figure 1. Volumetric moisture at three different times during the experiment (a) hard crust (b) weak crust respectively.

Table 1 presents the development of crust strength and thickness with time in both treatments ‘weak crust’ and ‘hard crust’. The rise in soil crust strength and crust thickness over time is slower in ‘weak crust’ treatment compared to ‘hard crust’. At the time of emergence (from day 4 to day 6) the soil strength ranged from 0.78 -1.2 kg/cm^2 for ‘weak crust’ as compared to 1.47-2.69 kg/cm^2 for ‘hard crust’. Crust strength for the “hard crust” was similar to measurements taken in field (crust strength 1.2-2.75 kg/cm^2 and thickness 1.4-3 cm) at Binara at the time of crop emergence.

Table 1. Development of surface crust with time.

	Weak Crust				*Hard Crust*			
Day	Crust strength kg/cm^2	Standard error	Crust thickness cm	SE	Crust strength kg/cm^2	Standard error	Crust thickness cm	SE
2	0.50	0.07	0.39	0.01	1.21	0.05	-	-
4	0.78	0.01	0.51	0.00	1.47	0.11	1.37	0.02
6	1.03	0.04	0.74	0.01	1.78	0.11	1.76	0.03
8	1.16	0.04	0.84	0.02	2.43	0.07	1.80	0.01
10	1.20	0.04	0.95	0.00	2.69	0.10	2.16	0.06
12	1.20	0.04	1.10	0.00	2.75	0.04	2.52	0.02

Proportional seed germination was similar in both treatments (hard crust = 0.88, weak crust = 0.89). However, seedling emergence was significantly reduced in the ‘hard crust’ treatment. Some seedlings failed to emerge through the thick, hard crust in spite of successful germination underneath the crust.
Based on seedling emergence results the varieties could be divided into three groups: sensitive, very sensitive and tolerant to soil crust. The examined varieties also showed differences in proportional germination rate. The tolerant varieties tended to have higher germination rate than the other two groups.

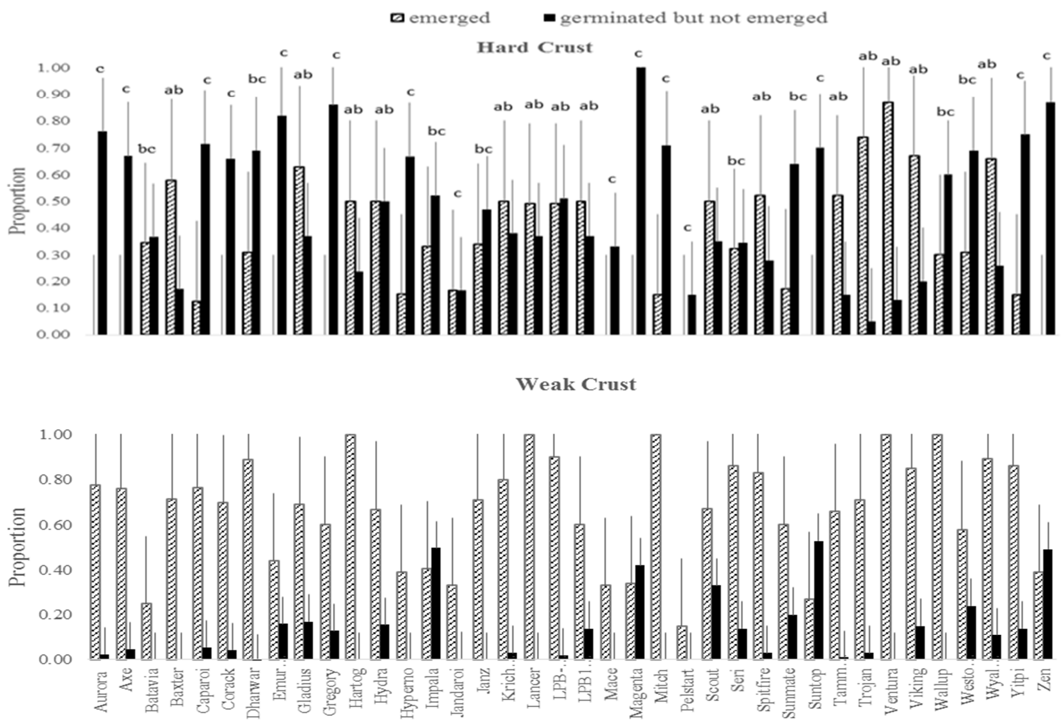

Figure 2. Proportion of seeds from which seedlinges emerged through the crust (emerged) and proportion of seeds which germinated but seedlings did not emerge at ‘hard crust’ (top panel) and ‘weak crust’ (lower panel). Means followed with the same letter were not significantly different within treatments. Varieties were grouped according to emergence in the “hard crust’ treatment as ab= tolerant, bc=sensitive and c= very sensitive.

The varieties in the tolerant group in the ‘hard crust’ treatment showed proportional emergence proportion above 0.49 and 0.67 for ‘weak crust’. Only 15 wheat varieties maintained an emergence proportion of 0.49 in ‘hard crust’ whereas, in the weak crust treatment, 29 varieties showed emergence proportion above 0.49

(Figure 2). The differences in the proportion of seedling emergence in the different soil crust treatments demonstrates the impact of crust strength on the wheat seedling emergence.

The emergence of wheat seedling was impacted by its ability to germinate and emerge before the crust was fully formed and hardened. For example, Wyalkatchem, Lancer which started emerging from day 4, generally performed well in the hard crust treatment due to rapid emergence. Emergence of most genotypes was delayed in the 'hard crust' treatment. For example, genotype 'Scout did not emerge till day 10 in the 'hard crust' treatment, whereas, in the weak crust treatment all the genotypes started emerging by day 6. No significant differences were observed in plant biomass weight, root length and seed parameters.

Conclusion

Genetic variability for seedling emergence through the soil crust between wheat varieties suggest that genotype selection for improvement in this trait may be possible. Proportional emergence was related to the speed of seed germination and emergence. Therefore, rapid emergence could be used as a pre-selection criterion for genotypes adapted to soil crust situations.

There still exits a possibility that higher seedling emergence was connected with other properties of seeds not evaluated in this study. In this case searching for the impact of these seed parameters, for example seedling emergence force, could be useful for the selection of wheat genotypes adapted to crusted soil conditions.

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