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The Short Term Effects of Organic Matter and Ripping on Degraded Soil in Western Australia

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Abstract: The effect of wheat bran and ripping application on degraded soil such as saline soil, compacted soil and low fertile soil in Western Australia was investigated from the chemical and biological points of view. Ripping decreased ECe because of leaching of water soluble cation from topsoil. Wheat bran increased soil fertility due to enhanced enzyme activity. Potassium from bran displaced exchangeable sodium in soil, and resulted in reduction of soil dispersion and was absorbed by barley grain. Wheat bran increased number of spikelet and grain yield in degraded soil.

Keywords: Acid phosphomonoesterase activity, Available potassium, ECe, Ripping application, Wheat bran application

1. Introduction

Agricultural land is expected to produce food stably, because the number of malnourished people would reach 80 million at 2004 according to FAO (2008). On the other hand, degraded soil is expanding agricultural land in all over the world. Soil salinity, soil compaction and low fertile soil are the major land degradation issues in Australia as well as in other arid and semiarid areas in the world.

Recently importance of organic matter for salinity control in Europe was reported (Tejada *et al.*, 2006; Tejada and Gonzalez, 2006, 2008) with regard to soil chemistry (i.e. EC and/or ESP), soil physics (i.e. bulk density and/or permeability), and soil biochemistry (enzymatic activity). Physical practices can be a beneficial management of soil compaction, which are important for eliminating soil compaction, destroying hard pans and ameliorating hard setting soil. Ripping application is focused as a physical practice in Western Australia (WA) (Hamza and Anderson, 2005). We focused on wheat bran as an organic amendment because bran contains much nutrient (N, P, and K) and is decomposed easily.

The objective of this study was to assess the effect of wheat bran, ripping and their interactions as an amendment of soil salinity, soil compaction and low fertile soil in WA.

2. Materials and Methods

A field experiment planted with barley was conducted in Wallatin (31˚30' S, 117˚51' E, WA) during two consecutive growing seasons (2006 and 2007). Bran was applied at the level of 0, 10, 20 and 40 t ha^{-1} before ripping (BR) and without ripping (NR). Applied wheat bran had 420 g kg^{-1}, 25 g kg^{-1}, 1.2 g kg^{-1} and 14 g kg^{-1} of total carbon, total nitrogen, total phosphorous and total potassium, respectively, and its particle was less than 2 mm.

Topsoil (0-10 cm) samples were taken at the beginning of rainy (June) and dry seasons (November). ECe was determined by water saturated method. Water soluble cations (Ws-Na, K, Ca and Mg) within the same extraction were determined using SpectrAA-55B, VARIAN. Exchangeable cations (Ex-Na, Ex-K) were estimated as described in equation (1) and (2) after extraction from soil with neutral ammonium acetate.

$$\text{Ex-Na } (\text{cmol}_c\ \text{kg}^{-1}) = \text{Ammonium acetate extracted Na } (\text{cmol}_c\ \text{kg}^{-1}) - \text{WS-Na } (\text{cmol}_c\ \text{kg}^{-1}) \quad (1)$$

$$\text{Ex-K } (\text{cmol}_c\ \text{kg}^{-1}) = \text{Ammonium acetate extracted K } (\text{cmol}_c\ \text{kg}^{-1}) - \text{WS-K } (\text{cmol}_c\ \text{kg}^{-1}) \quad (2)$$

Neutral ammonium acetate extracted K was determined as an available potassium (available-K). Available phosphoric acid (available-P) was extracted by the Truog Method and P content in the extract was determined by the molybdenum blue method. Acid-phosphomonoesterase (aPM) assay was measured by a method of Tabatabai (1994b) except for toluene addition. In the present study, toluene addition to topsoil

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before incubation omitted to prevent excess of aPM assay. Diversion of soil particle was determined by sedimentation test. Plant analyses were conducted during planting and post harvest (number of spikelet, grain yield, and potassium in grain). GLM and CORR procedure in SAS 9.1 (SAS Institute Inc.) was used for statistical analysis.

3. Results and discussion

Figure 1 shows the results of ECe and WS-cation. The trend of ECe was similar with that of WS-cation, and ECe and WS-cation in BR was lower than those in NR significantly during experimental season. Hamza and Anderson (2003) reported ripping enhance infiltration. WS-cation would leach from topsoil with infiltration of rainfall, and would be difficult to rise to topsoil again. Consequently, ripping application reduces the effect of salt on plant in topsoil at least for two years compared to control.

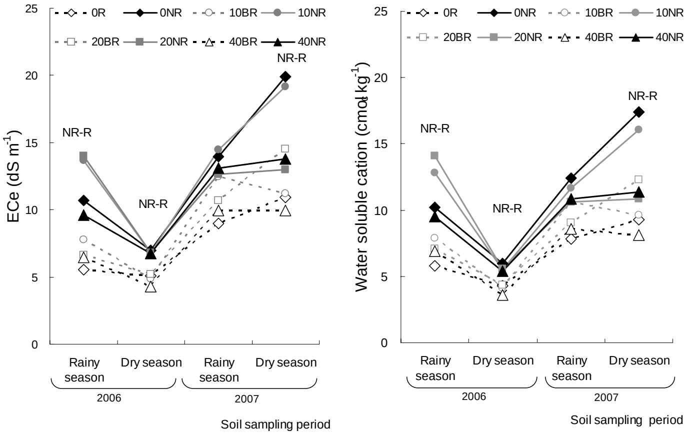

Fig. 1. Temporal variation of ECe‡‡ and water soluble Cation‡‡ in the topsoil. * and ‡ in the title shows the effect of bran and ripping is significant, respectively during the experimental period. ‡p<0.05, ‡‡p<0.01, ‡‡‡p<0.001. 0-10 t ha^{-1}, 0-20 t ha^{-1}, 0-40 t ha^{-1}, 10-20 t ha^{-1}, 10-40 t ha^{-1}, 20-40 t ha^{-1}, and NR-R in figure shows significant differences between levels (p<0.05).

Figure 2 shows the result of available-P and aPM activity in the dry season of 2006. Wheat bran application of 40 t ha^{-1} increased available-P. The most significant interaction between wheat bran and ripping application was on aPM activity. Especially, surface application of bran (10NR, 20NR, 40NR) enhanced aPM activity, which would play the role of substrate. Positive correlation between aPM activity and available-P was significant during experimental period (**Table 1**). This indicates applied wheat bran supplies available-P through mineralization by aPM, because aPM plays an important role in soil P-organic mineralization and plant nutrition (Tabatabai, 1994a).

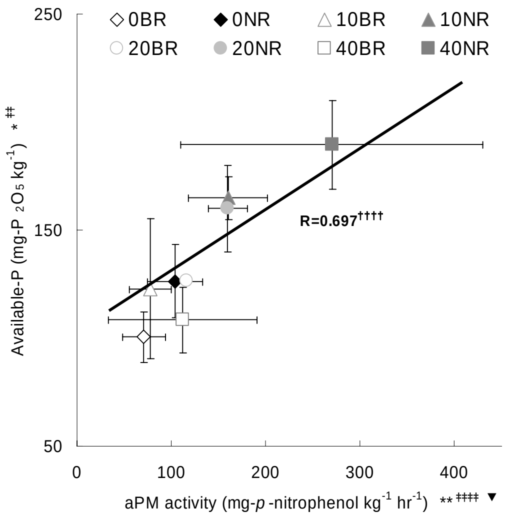

Fig. 2. Relationship between aPM activity and available-P in topsoil in dry season in 2006. *, ‡, and ▼ above the title of axis shows the effect of bran, ripping and their interaction is significant, respectively during the experimental period, *p<0.05, **p<0.01, ***p<0.001 ‡p<0.05, ‡‡p<0.01, ‡‡‡p<0.001. ▼p<0.05, ▼▼p<0.01, ▼▼▼p<0.001. † in figure shows result of correlation test. †p<0.05, ††p<0.01, †††p<0.001, ††††p<0.0001

Figure 3 shows temporal variation of available-K during the experimental period. Wheat bran application of 40 t ha^{-1} increased available-K since the dry season of 2006, and that of 20 t ha^{-1} was since the rainy season of 2007. Wheat bran contains much of potassium (14 g kg^{-1}). Available-K would be supplied through the similar process with available-P.

Figure 4 shows temporal variations of Ex-K, Ex-Na and dispersion of soil particle in 0 t ha^{-1} and 40 t ha^{-1} of bran during the experimental period. Ex-Na was decreased by bran application according to comparison of means. Ex-K at 40 t ha^{-1} of bran was higher than that at 0 t ha^{-1} of bran after the dry season

Table 1. Correlation coefficient between aPM activity and available-P.

	Available-P			
	Rainy season in 2006	Dry season in 2006	Rainy season in 2007	Dry season in 2007
aMP activity	0.478**	0.697****	0.454**	0.450**

Figures in the table show correlation coefficient
* above the correlation coefficient shows significance correlation (n = 32)
*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001

of 2006 statistically, and Ex-K in NR was also higher than that in BR. Wheat bran application decreased dispersion statistically. Dispersion of soil particle (< 0.02 mm) at 40 t ha^{-1} of bran was lower than that at 0 t ha^{-1} of bran during the experimental period. It is well known that the ratio of Ex-Na in cation exchangeable capacity affects soil dispersion, and that dispersible soil is easy to be consolidation. In the present study, Ex-Na tended to displace Ex-K from wheat bran. This exchange would cause reduction of dispersion. These results indicate that bran application can modify consolidation.

Figure 5 and **6** shows the result of the number of spikelet per head and grain yield, and potassium in barley grain in 2006 and 2007, respectively. It was drought in WA in 2006 and 2007, and the latter was heavier. The average of barley grain yield around the experimental field in 2006 and 2007 was 1.3 t ha^{-1} and 0.9 t ha^{-1}, respectively, and yield in most treatments higher than the averages. Grain yield in 2006 was increased 12%, 19%, and 15% for wheat bran application at 10 t ha^{-1}, 20 t ha^{-1} and 40 t ha^{-1}, respectively. Grain yield in 10NR, 20NR and 40NR in 2007 was higher than that in 0NR, but this was not significant because of heavy draught. Wheat bran application increased the number of spikelet per head in 2006 and 2007 significantly. Potassium in barley grain at 40 t ha^{-1} of bran was higher than that at 0 t ha^{-1} significantly. It was reported the grain number per head, thousand grain weight and grain yield were increased by topdressing of potassium sulfate (Hara *et al.* 2006). The results of increase of available-K in soil and potassium in grain indicate that increase of spikelet number would relate to decomposition of wheat bran.

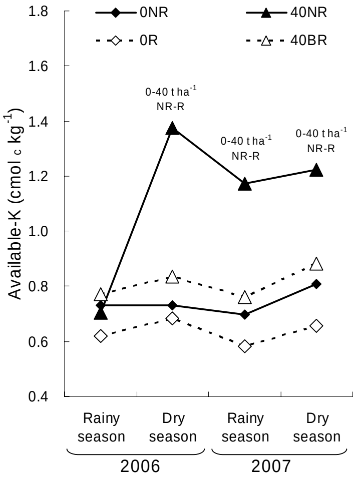

Fig. 3. Temporal variation of available -K* ‡‡ in topsoil in dry season in 2006.** * and ‡ above the title shows the effect of bran, ripping and their interaction is significant, respectively during the experimental period, *p<0.05, **p<0.01, ***p<0.001. ‡p<0.05, ‡‡p<0.01, ‡‡‡p<0.001. 0-40 t ha^{-1} and NR-R in figure shows significant differences between levels (p<0.05)

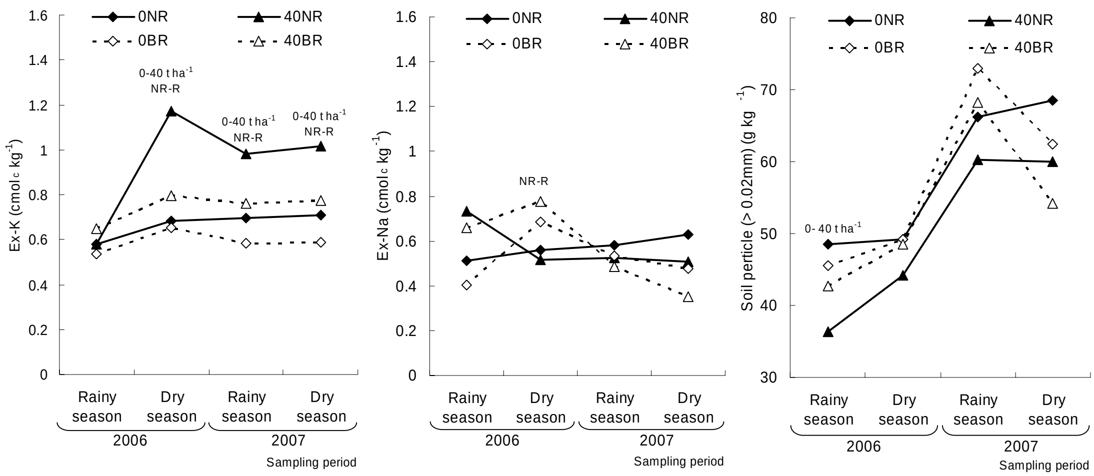

Fig. 4. Temporal variation of Ex-K* ‡‡, Ex-Na and soil particles (< 0.02mm) in topsoil.** * and ‡ in the title shows the effect of bran and ripping is significant, respectively during the experimental period. *p<0.05, **p<0.01, ***p<0.001. ‡p<0.05, ‡‡p<0.01, ‡‡‡p<0.001. 0-40 t ha^{-1} and NR-R in figure shows significant differences between levels (p<0.05)

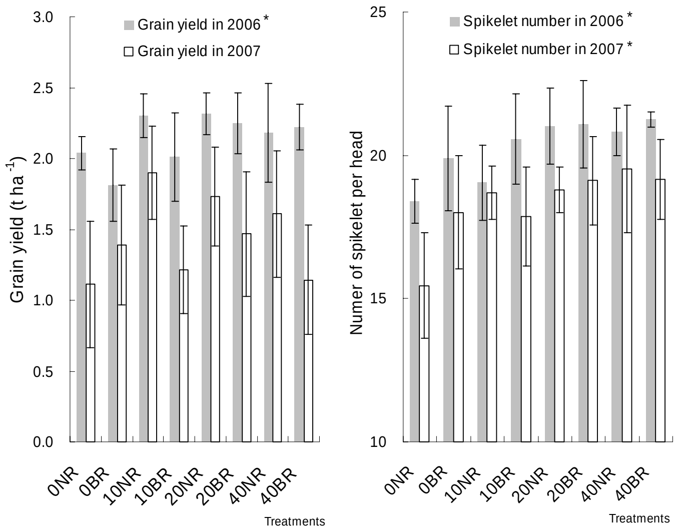

Fig. 5. Grain yield and spikelet number in 2006 and 2007. *, ‡ above the title of item shows the effect of bran, ripping and their interaction is significant, respectively during the experimental period. *$p<0.05$, **$p<0.01$, ***$p<0.001$. ‡$p<0.05$, ‡‡$p<0.01$, ‡‡‡$p<0.001$

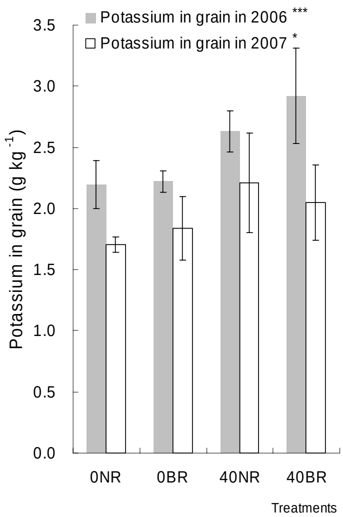

Fig. 6. Potassium in barley grain in 2006 and 2007. * and ‡ above the title of item shows the effect of bran, ripping and their interaction is significant, respectively during the experimental period. *p<0.05, **p<0.01, ***p<0.001. ‡p<0.05, ‡‡p<0.01, ‡‡‡p<0.001

4. Conclusions

Wheat bran and ripping application for amelioration of saline soil, compacted soil and low fertile soil in semi-arid region of WA were studied. Ripping application reduced ECe via leaching WS-cation and this effect can last at least two years. Wheat bran application improved soil fertility through the alteration of soil biology, because its application increased available-P due to enhancing aPM activity. Available-K was also increased by wheat bran application. The number of spikelet and grain yield of barley was increased by wheat bran application, because a lot of nutrition was supplied from its decomposition. Particularly decomposition of potassium in wheat bran induced increase spikelet number and grain yield. Decomposed potassium from wheat bran improves not only soil fertility, but also soil physical properties. Wheat bran application changed contents of soil exchangeable cation and this led to improvement of soil physical properties. Modification of soil compaction would be driven by exchange of Ex-Na for Ex-K, and this exchange was observed in wheat bran application at 40 t ha^{-1}.

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