Improving crop water use efficiency in high rainfall zone (HRZ) Victoria, through appropriate practice change to overcome subsoil limitations

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Abstract

Recent water use efficiency (WUE) benchmarking data suggests that cereal crops in HRZ, Victoria may be performing at a greater WUE than earlier assumed (French & Schultz, 1984). While raised beds developed to overcome water logging in the region appear to have raised the WUE of crops to a new level, further amelioration of hostile subsoils through the practice of subsoil manuring may result in further increases, contributing to new benchmarks for the region. Rates of between 10 and 20 t/ha of poultry litter buried in a range of duplex and sodic subsoils has shown to almost double cereal yield through increased head number and grain number per unit area. These yield increases were also associated with extended green leaf area duration in a season of ‘dry finish’ suggesting the availability of more plant available water (PAW) during grain filling. Through a Participatory Action Research (PAR) programme in the South West of Victoria, subsoil manuring is currently being tested for its broad acre feasibility, economic viability and farmer adoption.

Key words

subsoil manuring, raised beds,

Introduction

Over a decade ago, when land use change began to occur in the high rainfall zone (HRZ) of Southern Victoria (SFS, 2000), the biggest single drawback to sustainable cereal production was water logging during the long, cool growing season. The raised beds in broad acre developed in the region contributed to better drainage, resulting in the expansion of cropping. The cropping area in Southwest Victoria increased from about 6800 ha in 1994 to 43,000 ha in 2001 (ABS, 2001). The area under raised beds increased from 300 ha in 1997 to about 35,000 ha in 2003 with an average yield increase of ~20% across sites and seasons (Wightman, unpublished data). The average cereal yield in the region still remains around 2.5 to 3.2 t/ha (SFS, 2002; ABS, 2001) with the more entrepreneurial farmers realising yields as high as 8.5 t/ha on raised beds in recent times with improved agronomic management. Currently the cropped area stands around 450,000 ha with approximately 60,000 ha of raised beds (Wightman et.al., 2005). Work to date suggests that improved yield on raised beds may be the result of better drainage during wetter years (SFS, 1997) and increased root proliferation (SFS, 2000) under conditions of minimum tillage (MT) and controlled traffic (CT) associated with the system.

Despite heavy crops in response to better drainage on raised beds (Wightman et.al., 2005), in many instances harvest index was low as a result of the crops running out of water in spring, not necessarily because of inadequate rainfall, but also due to lack of access to soil water in the dense, hostile subsoil during grain filling. Five years after the first raised beds were established in the region, changes were observed under beds, which worked slowly down the profile below depth of tillage, resulting in a gradual increase in both soil micro and macro porosity and plant available water capacity (PAWC) (Peries, et. al., 2010). However, this rate of soil amelioration through raised beds or the controlled traffic farming systems on flat paddocks (often satellite guided) evolving in the region, seemed inadequate to realise the full potential of cereal production in the region. Work on subsoil manuring (placement of large volumes of organic matter at depth in the subsoil) with pellets of lucerne or dynamic lifter at rates of 20 t/ha under raised beds, has shown to almost double the cereal yield and that was accompanied by a doubling of the macro porosity and a significant reduction in soil bulk density within 18-24 months of application, in areas under the bed that were undisturbed by the subsoiling operation (Gill et. al., 2008; 2009). This paper briefly discusses the results of a recent water use efficiency (WUE) survey conducted amongst the cereal farmers of South West Victoria and discusses a few key results from participatory action research, where subsoil manuring is being trialled for validation and adoption as a means of addressing some of the key subsoil hostilities in the region, with a view to improving PAWC and increasing WUE in otherwise hostile soils.

Materials and Methods

Seven farmers (out of about twenty five consulted) across the HRZ responded to a survey where we requested their grain yield and growing season (April- Nov.) rainfall. The data covered seven years from 2002 to 2009. The grain yield data for wheat and barley were plotted separately against the growing season rainfall. Despite considering the April to November rainfall as in-crop rain for consistency, it must be noted that not all crops may have been sown in April due to rainfall variability across the region. Two lines were fitted to the graph. One based on maximum WUE of 20 $kgha^{-1}mm^{-1}$ (French and Schultz, 1984) and the other based on 34 $kgha^{-1}mm^{-1}$ (Sadras and Angus, 2006).

While most of the selected sites are on the Western volcanic plains of Southwest Victoria (Joyce, 1983) with varying clay content in their subsoil, some are also more sodic (VRO, 1999) than others in the subsoil, presenting an additional impediment to the realisation of the full potential of the regions' generally favourable rainfall pattern (Nix, 1975).

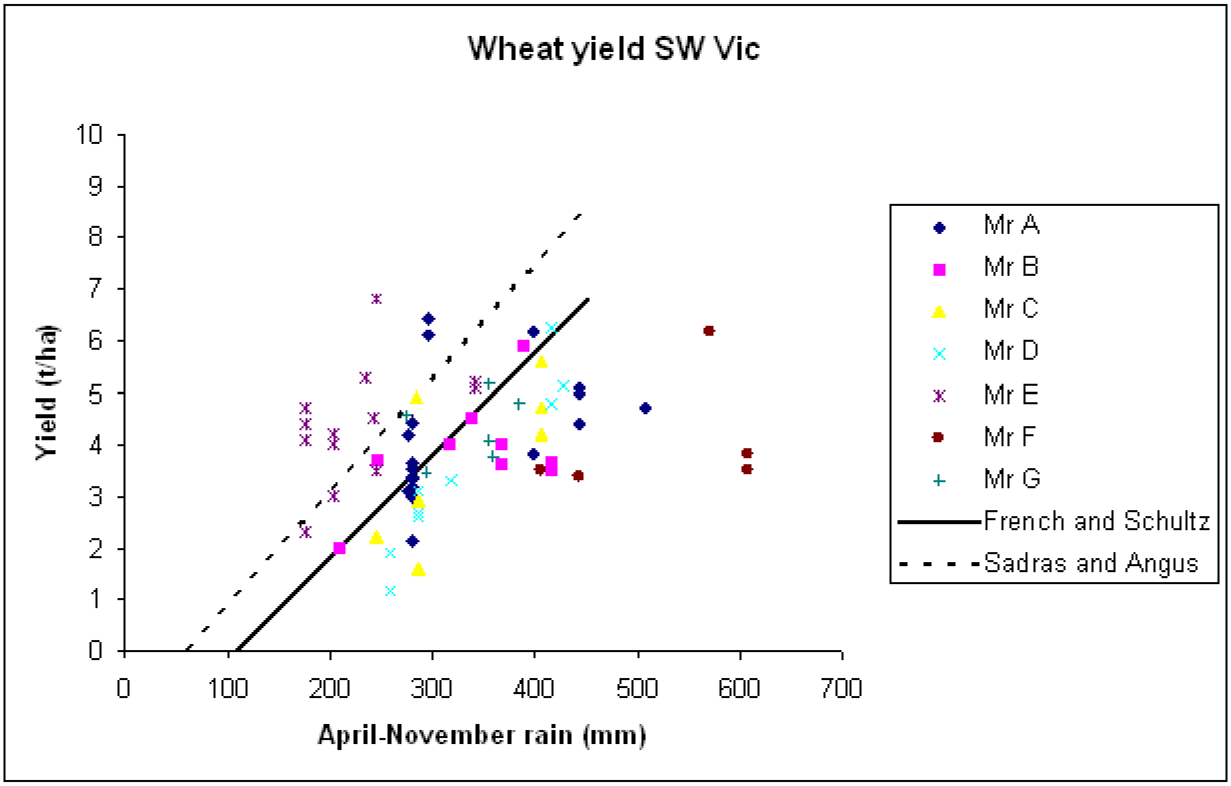
Based on the work of Gill et.al., 2008 and 2009 conducted initially on small plot trials, three farmer-scale subsoil manuring trials were established at Winchelsea, Derrinallum and Penshurst on the volcanic plains of West Victorian HRZ with a view to validating the results earlier obtained. Trials commenced in the growing season of 2009/10 and each of the trial sites consisted of six treatments with four replicates in a randomised block design. Treatments included 10 and 20 t/ha poultry manure, a deep rip only treatment, an inorganic nutrient treatment equivalent to 20 t/ha poultry manure and a 10 t/ha poultry manure with a nutrient supplement to match 20 t/ha poultry manure in the form of DAP. The poultry manure used in all trials was the deep litter from a single broiler farm that had been on a pile outside the sheds for nearly six weeks. The application of the manure was carried out in mid-March for an early May sowing. The placement of manure in the subsoil was carried out by a machine specially designed and modified for the purpose over a period of time, whereby two large tubes of ~10 cm diameter dropped the poultry manure through gravity behind two rippers placed approximately 80 cm apart. The depth of ripping and of placement was site specific and was based on the depth of the top soil, so that the deep ripping did not work into more than 10 cm of the heavy volcanic clay and bring it to the surface, or cause any lateral compaction.

Results and Discussion

Soil structure plays an important role in crop performance in HRZ Victoria, where duplex clays constrain the achievement of potential WUE of crops either through physical impediments (low hydraulic conductivity) or chemical impediments such as sodicity. Most farmers surveyed and reported here (70%), represent the more entrepreneurial ones who have overcome water logging through raised beds (over 10 years or so) and currently continue with raised beds or with at least CT on flat beds. The relationship of their wheat and barley grain yield to growing season rainfall is shown in Figures 1a and 1b respectively. The two lines representing the 20 and 34 kgha-1mm-1 values of WUE are based on current knowledge and consider the seasonal water loss through soil evaporation to be 110 and 60 mm respectively. While these values relate to the regions in which the data was generated or are results of a model, published values specific to Victorian HRZ currently do not exist and hence these values are used only as a guide.

Figure 1 suggests that some of the farmers in the HRZ have performed extremely well despite low rainfall, while others with higher seasonal rainfall have the potential to increase their WUE through better utilisation of the rainfall, which is currently either run-off from their paddocks or continue to waterlog their paddocks and impact on yield. At the lower end of the rainfall, it is very possible that limited soil hydraulic conductivity (lower macro porosity) is preventing the efficient utilisation of rainfall by crops and such water may be unproductively lost through soil evaporation. Subsoil manuring has shown to be capable of slowing down such a process through increasing the hydraulic conductivity of the otherwise hostile soil in addition to its contribution to crop nutrition.

The three sites where subsoil manuring was trialled had variable depth of subsoil, but the heavy clay B horizon in all of them had soil bulk density that was close to limiting point (1.5-1.6 gcm-3) for soil water infiltration and root growth (Cockroft and Olsson 1997: Gardner et.al., 1992) . The growing season rainfall was variable [Winchelsea, 245mm; Derrinallum 402 mm and Penshurst 608 mm] and the crop grown was either wheat (Derrinallum, Penshurst) or barley (Winchelsea). Figure 2 shows the yield response to different treatments at the three sites and the green leaf duration response to treatments at two out of the three sites.



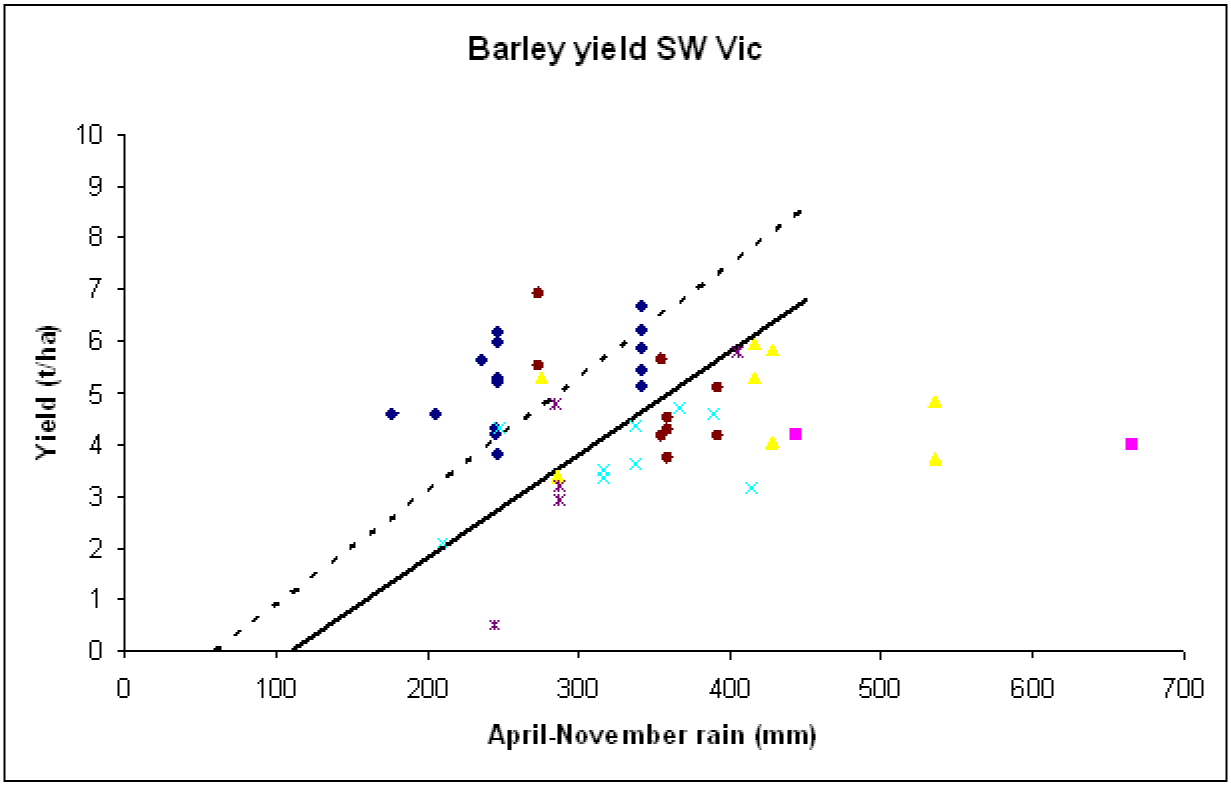
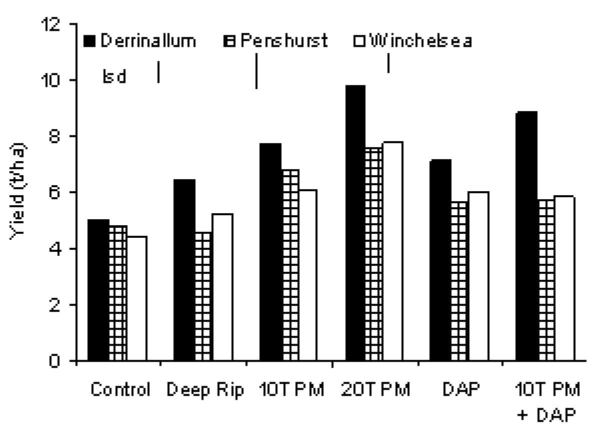


Figure 1. Relationship of grain yield to growing season rainfall for wheat (Fig. 1a) and barley (Fig. 1b) during the 2002-2009 period in high rainfall Southern Victoria. The two separate lines fitted to each graph correspond to WUE values of 20 and 34 kgha^{-1}mm^{-1}

At all three sites, there was a significant yield advantage as a result of the treatment where 20 t/ha poultry manure was placed at depth in the profile. The yield difference varied from 65% for barley at Winchelsea to 70% and 100% respectively for wheat at Penshurst and Derrinallum. Across the sites this yield difference was associated with the number of heads per unit area and the grain number per head. The extended green leaf duration suggests that more PAWC would have been created in manured plots that in turn would have helped achieve significant yield differences.



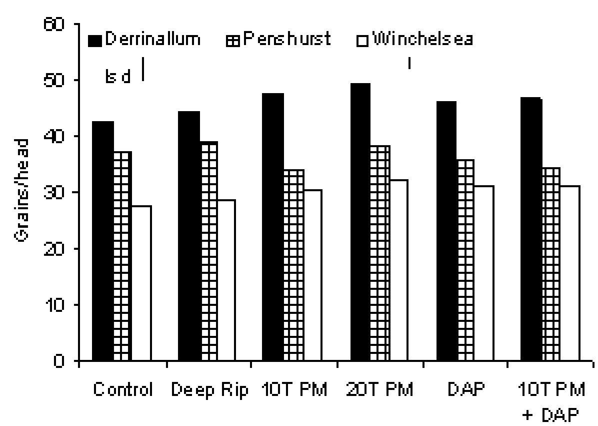


Figure 2a

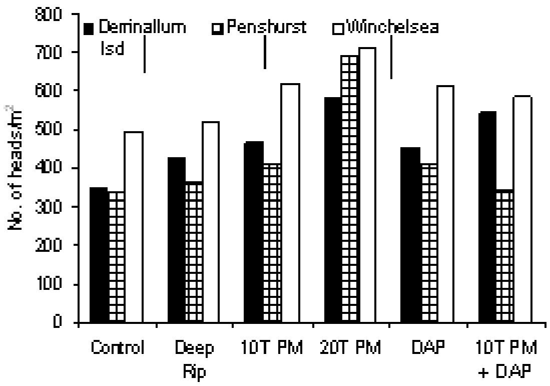


Figure 2b

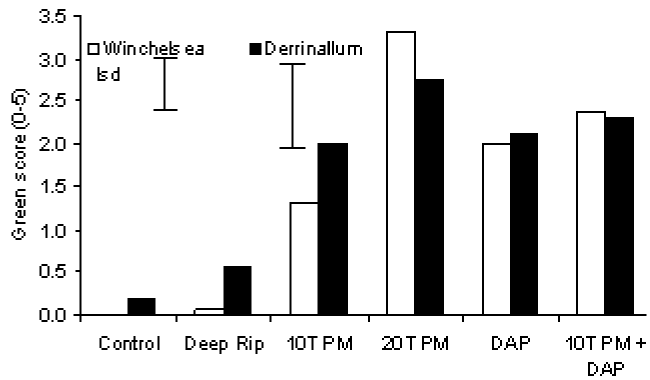


Figure2c

Figure 2d

Figure 2. Yield response to treatments at the three sites (Fig 2a), showing the contribution to yield through grain number/head (Fig 2b), number of heads per m^2 (Fig 2c) and the contribution of extended leaf area duration (Fig 2d) at two sites (Flag leaf greenness score: 1 = uniform yellow; 5 = uniform green)

In previous work (Gill et. al., 2009), improved yield response to subsoil manuring was associated with improved PAWC created in the subsoil through improved soil porosity and hydraulic conductivity. It has also been argued that sustainable soil structure improvements in the subsoil following manuring are related to improved root proliferation (Cresswell and Kirkegaard 1995) and also to microbial activity given the right conditions. The current results were obtained in a year where rainfall was not well-distributed throughout the season and where the crops went through an extreme heatwave half-way through grain-filling. These results are consistent with the findings of Gill et. al., (2008; 2009), and are being further verified through soil water measurements in the 2010/11 seasons. The cost of the manure and the energy consumed in its application are factors that could hinder the uptake of the technology. The participatory approach in which these trials are currently conducted, gives the farmer the opportunity to experience the approach first-hand and work through the associated issues. The work reported here are those from year 1 of a three year project which also includes a cost-benefit analysis of subsoil manuring.

Conclusions

There is a strong likelihood that some farmers in the Victorian HRZ, particularly those at the lower end of the rainfall scale, are operating at near or above the current, established benchmarks for WUE. Heavy and impervious subsoils remain a significant impediment to crop water use and therefore to the achievement of higher WUE. Subsoil manuring appears to be a promising practice that can enhance PAWC in the subsoil and contribute to higher WUE. Due to the volumes of manure required and the energy consumption associated with the practice change, its popularisation remains a challenge. However, farmer champions have taken the challenge on, while the ongoing work intends to guide adoption of the practice through bridging gaps in knowledge and providing a cost benefit analysis.

Acknowledgment

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