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A new look at an old practice: Benefits from soil water accumulation in long fallows under Mediterranean conditions

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ABSTRACT

The practice of long fallowing, by omitting a year of cropping, is gaining renewed focus in the low rainfall zone of the northern agriculture region of Western Australia. The impetus behind this practice change has been a reduced use of pasture breaks in cereal crop rotations, and the belief that a fallow can improve soil water accumulation and thus buffer the negative effects of dry seasons on crop yields. We evaluated the benefits of long fallowing (full stubble retention, no weed growth allowed) in a continuous wheat sequence via simulation modelling with APSIM at two rainfall locations and five soil types. The simulated benefits to long fallowing were attributable to soil water accumulation only, as the effects on soil nitrogen, diseases or weeds were not evaluated.

The long-term (100 years) mean wheat yield benefit to fallowing was 0.36–0.43 t/ha in clay, 0.20–0.23 t/ha in sand and loam, and 0–0.03 t/ha in shallow sand and shallow loams. Over the range of seasons simulated the response varied from −0.20 to 3.87 t/ha in the clay and −0.48 to 2.0 t/ha for the other soils. The accumulation of soil water and associated yield benefits occurred in 30–40% of years on better soils and only 10–20% on poorer soils. For the loam soil, the majority of the yield increases occurred when the growing-season (May–September) rainfall following the fallow was low (<210 mm) and the difference in plant available soil water at sowing between fallowed and continuously cropped soil was high (>30 mm), although yield increase did occur with other combinations of growing-season rainfall and soil water. Over several years of a crop sequence involving fallow and wheat, the benefits from long fallowing due to greater soil water accumulation did not offset yield lost from omitting years from crop production, although the coefficient of variation for inter-annual farm grain production was reduced, particularly on clay soils during the 1998–2007 decade of below-average rainfall. We conclude that under future drying climates in Western Australia, fallowing may have a role to play in buffering the effects of enhanced inter-annual variability in rainfall. Investigations are required on the management of fallows, and management of subsequent crops (i.e. sowing earlier and crop density) so as to maximise yield benefits to subsequent crops while maintaining groundcover to prevent soil erosion.

1. Introduction

The dryland farming systems of Western Australia are characterised by a Mediterranean climate with hot dry summers and cool wet winters and the growing season for crops and pasture is typically from April/May until October when two-thirds of the annual rainfall occurs. Mean annual rainfall varies from 250 to 600 mm. Farms typically range from 1000 to 5000 ha and they are run as family-owned enterprises with some external labour. Farms are dominated by light textured soils (Schoknecht, 2002; Isbell, 1996) with low water holding capacity. Cropping sequences are based on spring wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), grain lupins (*Lupinus angustifolius*), canola (*Brassica napus* L.), annual pasture and fallow. It is common for 50–70% of arable land on a farm to be sown to crops with the balance being in annual pasture. Pastures usually consist of subterranean clover with volunteer annual grasses and herbs. Sheep are the predominant livestock enterprise, but on some farms, cattle can be important. Over 90% of farms use zero or minimum tillage to establish crops.

In the early years of agricultural development in this region, fallowing, the practice of omitting a year of cropping, was conducted to "rest" a paddock during a cropping sequence in order to boost crop production in subsequent years by mitigating the effects of weeds, diseases and declining soil fertility as well as accumulating

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additional soil water and available crop nutrients. However with on-going intensification of cropping sequences (Sadras and Roget, 2004), the advent of reliable weed control options and increased use of fertiliser (Kirkegaard et al., 2010), fallowing has been only practiced sporadically by farmers, usually in circumstances of dry seasons when cropping has not been possible.

Recently, long fallowing, where volunteer plants are controlled by a variety of means at various stages during the non-crop period, has received renewed attention from farmers. This is particularly so in the north-eastern region of the Western Australia agricultural zone, which covers 3 million hectares in the 300–400 mm mean annual rainfall zone, due to two main drivers. The first driver for renewed attention by farmers towards fallow is the reduction in sheep numbers in the farming system (Curtis, 2009), associated loss in pasture area and therefore reduced options to control weeds in the out-of-crop phase of the sequence. The second driver is a shift towards drier seasons that is associated with the drying trend in rainfall for much of the central and northern agricultural zone of WA during the last 30 years (Smith et al., 2000; Farre and Foster, 2009; Ludwig et al., 2009), and less reliable cropping and increasing reliance on crops to grow on stored soil moisture, as opposed to in-crop rainfall (Moeller et al., 2009). A number of farmers are now practising fallowing more widely on their farms and have seen impressive yield benefits to subsequent crops during the last decade of drier-than-average rainfall (Oliver et al., 2009a,b). A desk top analysis of a typical farm in the north-east low rainfall areas of the Northern Agricultural Region (NEAR) suggested that a system based on 25% of the farm fallowed every year would be financially viable based on a 1 t/ha long-term mean wheat yield, assuming a 0.3 t/ha benefit to crops following fallow (Weeks, 2008). A number of the assumptions underpinning this analysis need to be tested, such as the long-term mean benefit to fallow, and the wider applicability of the findings evaluated. While yield benefits following fallows are to be expected (greater stored moisture and lower weed burdens), there are concerns about risks of erosion during the 18 months of minimal vegetative cover.

Modelling analysis of the management of, and benefits and risks from, fallowing have been well-studied in Australia's summer-dominant rainfall regions (Littleboy et al., 1992; Probert et al., 1995, 1998; Moeller et al., 2009; Whish et al., 2009) and elsewhere in the world (Hartemink et al., 1996; Sanchez, 1999; Burgers et al., 2005) but there have been few attempts in Mediterranean environments where in-crop rainfall dominates crop water supply and the impact of initial stored soil water is of secondary importance(Asseng et al., 2001). The exceptions to this are the studies of Moeller et al. (2009) and Rinaldi (2004), who both found that the additional yield per mm of soil water at sowing was generally higher in seasons with below median rainfall, except when yields were severely water-limited by below median rainfall. These two studies did not explore the variability in accumulation of soil water, particularly in the context of long fallows.

Results from field studies on fallowing in the broadacre Mediterranean climate cropping regions of Australia have been published, with some studies comparing wheat after a fallow with wheat after wheat. Here we conduct a brief meta-analysis of those results. The literature includes two long-term trials (Grace et al., 1995; Hannah and O'Leary, 1995), four shorter term trials (Tennant, 1980; French, 1978; Mason and Fischer, 1986; Davoren et al., 2008) and a number of 2-year trials (Sanderson et al., 1998; Seymour, 2009; Bolland et al., 1987) with data taken from a range of sources including journals, departmental bulletins and a trials databases (Table 1). Of the 138 datapoints we assembled, 76 come from the long-term trial in the Wimmera region of Victoria over 1918–1993 (Hannah and O'Leary, 1995), with the other 62 datapoints from WA, South Australia (SA) and two from southern New South Wales (NSW) where trials were conducted from 1957 to 2007. Much of the literature was from before 1980 when cultivation was common, and few studies used a no-till fallow system, which is more common in recent times. Other studies compared a fallow–wheat with a pasture–wheat system in long-term trials in Victoria over 1985–2000 (Latta and O'Leary, 2003) and medium-term trials in Victoria, SA and WA (Schultz, 1971; Cooke et al., 1985; Bolland et al., 1987), wheat after mustard (O'Connell et al., 2002) and wheat after peas (O'Leary and Connor, 1997). This data covered 55 datapoints taken over 1964–2000.

The yield response of wheat after a fallow compared to wheat after a wheat varied from −2.32 to 3.32 t/ha with an mean yield increase of 0.92 t/ha. Associated growing-season rainfall (GSR) ranged from 121 to 525 mm (average 267 mm). The mean yield increase was 0.52 t/ha with a range of −0.4 to 2.63 t/ha when the data from the long-term trial of in the Wimmera (Hannah and O'Leary, 1995) was not included, as these bias the results to a grey cracking clay soil, which is not common in Western Australia and South Australia. On average, the yield of wheat after a fallow was 0.52 t/ha higher than wheat after a pasture and ranged from −1.15 to 1.94 t/ha with GSR ranging from 100 to 376 mm (average 224 mm) (Table 1).

Although insights have been gained from analysis of long-term rotation trial data (Hannah and O'Leary, 1995; Tennant 1980; Latta and O'Leary, 2003), it has been difficult to determine whether benefits were due to season, management, disease, weeds or nutrition. The trials also tended to use standard management and did not examine nutrient rates or other factors to ascertain if the benefits/losses from fallow were from differences in stored soil water, nutrients, weed management or disease. Across the collated literature there was no relationship between yield response and GSR (Fig. 1), which was likely due to variation in soil type, out-of-season (summer) rainfall and GSR distribution. Simulation modelling analysis can be used to understand the interactions between season, soil type, rainfall location and management on the soil water benefits of fallowing to crop production. This paper set out to examine the following questions, using simulation analysis, with sole focus on the soil water accumulation in low rainfall locations in Western Australia:

1. What is the effect of season and soil type on the water accumulation after a fallow (fallow efficiency)?
2. What is the effect of season, soil type and rainfall on the yield, after a fallow?
3. Can yield benefits to fallowing be classified according to a typology of seasonal rainfall sequences?

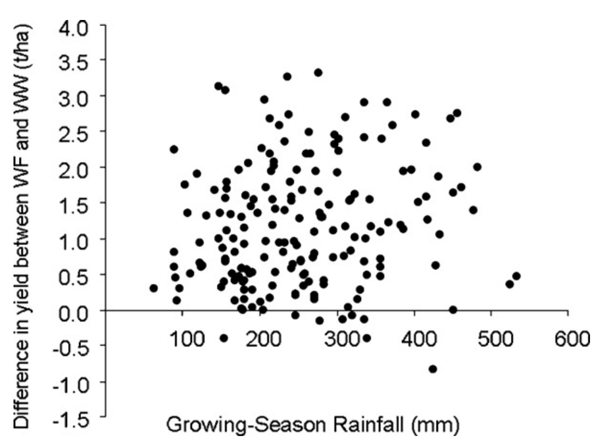

Fig. 1. Relationship between growing-season rainfall and yield difference between wheat after fallow and wheat after wheat or pasture from published studies in Australia (see Table 1).