Yield Limiting Factors in Relation to Precision Agriculture along the South Coast of WA

Derk Bakker[1], Grey Poulish[1] and Dan Murphy[2], [1]Department of Agriculture and Food Western Australia, Albany, [2]University of Western Australia, Perth

INTRODUCTION

The South Coast region (SCR) of WA, incorporating the southern part of the Katanning region, and the Albany, Jerramungup and Esperance regions, comprises an area of about 5 million ha. The region experiences a strong seasonal Mediterranean climate with cool, wet winters and hot summers. The rainfall in the region ranges from 700-800 mm near the coast to 300 –350 mm at a distance of 150 to 200 km from the coast. The soils in the region range from deep siliceous sands, Fleming gravelly sands on clay to grey clays. Crops grown in the region include wheat, barley, canola, lupins, oats, field peas and some opportunistically summer fodder crops.

Using the 'rule-of-thumb' to estimate water-limited yield potential of French and Schultz, a yield potential for cereals for the 450-700 mm annual rainfall zone of 4.5 – 8 t/ha should be expected and for canola, 3 – 4 t/ha. A more sophisticated approach using crop growth models estimated about 3.5 t/ha for a drier than average year and 6.2 t/ha for a wetter than average year for the Katanning region. However a benchmark survey from 1996 to 2001 of current yields showed an average wheat yield of 2.7 t/ha, 2.4 t/ha for barley and 1.4 t/ha for canola (Hill and Wall work, 2002).

On the Esperance Sandplain soil, work carried out in the mid 1990s showed that in the absence of water-logging and non-wetting, crop yields were amongst the highest in the nation. Commercial canola yields of 3.5 t/ha and experimental barley yields > 7 t/ha have been produced on the Sandplain soils (Hall, 2003). However, such yields are now very rarely achieved let alone sustained.

Failure to achieve the yield potential are attributed to physical, chemical and biological constraints associated with the dominant soil types in the SCR. Many of these are duplex soils with large differences in soil texture between the top- and the subsoil. The dense structure of the clayey subsoil severely restricts the internal drainage which results in waterlogging during the winter months, a time when winter sown crops are most susceptible to waterlogging. Significant yield reductions have been recorded due to waterlogging (Zhang *et al*, 2005c, Setter and Waters, 2003). It has however been demonstrated by Bakker *et al.* (2005) that waterlogging can be reduced and yields increased by improving the surface drainage using raised beds

In the absence of waterlogging a soil physical constraint such as soil compaction could also limit the rooting depth and therefore the plant available water and nutrients, particularly toward the latter part of the growing season when higher temperatures increase the evapotranspiration. The large and heavy tractors with very wide tyre-prints used under moist conditions, such as occur at seeding time, would be the main contributor to soil compaction. It is however difficult to estimate how wide spread this problem is in the SCR in the presence of duplex soils, soils that are naturally compact at depth..

The soil physical/chemical constraint of non-wetting is common in many of the soil types in the SCR and limits the plant available water particularly at the break of the season. Claying of the top soil has been carried out for a number of years to remedy this problem with many positive results (ie. yield increase).

The low soil fertility of many soil types dominant in the SCR is a further constraint in achieving the water-limited yield potential of many crops. A baseline study by Hill and Wallwork (2002) found that farmers in the high rainfall zone typically applied an amount of fertiliser of 50 – 70 kg/ha. That is only enough for half the potential wheat yield of 6 t/ha however in view of the uncertainty of the weather (ie. waterlogging, drought) applying more fertiliser can be very inefficient and/or uneconomical.

In summary many of the limiting factors for a sustainable production are well understood but not often identified in the field let alone the remedies implemented by the farmers. This paper describes the effort to identify these factors, some possible remedies and implications for precision agriculture.

METHODOLOGY

During the 2006 growing season some paddocks occupied by the major soil types representative of the SCR were selected on five properties located at Tambelup, Woodginellup, Gairdner, Jerramungup and Jerdacuttup, representing the breadth of the region. The paddocks were monitored during the season using digital multispectral images (DMSI), intensive soil sampling, determining the texture, moisture and nutrition for the major and micro elements, crop tissue testing at each sampling point and yield maps at the end of the season.

Following the results of 2006 and in consultation with the collaborating growers possible limiting factors, other than the lack of rain, were identified and some remedies in the form of field trials determined. Most of the trials were implemented by the farmers as large strips also to be harvested by the farmers. During the 2007 growing season detailed monitoring of crops and soils in the strip trials continues and will include again the use of high resolution DMSI and yield maps which will assist in the interpreting of the treatment results particularly where variable soil types and positions in the landscape might affect productivity.

RESULTS 2006

A number of variables and the range in each paddock investigated at the five farms are presented in Figure 1.

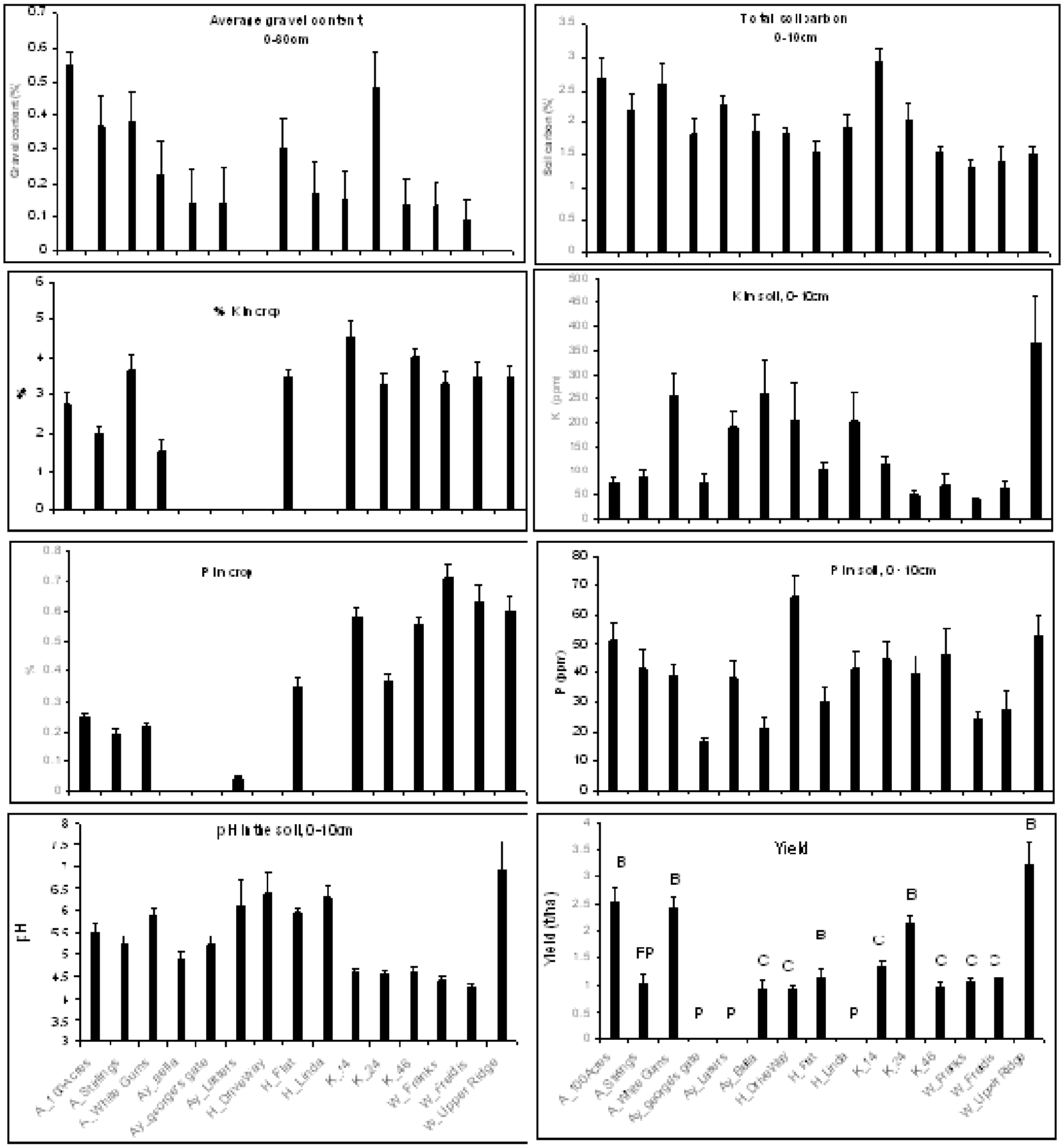

Figure 1. Some soil and crop tissue properties and the corresponding yield and standard deviation of the observations in all the paddocks.

All but two paddocks consisted of predominant gravely duplex soils but the range of gravel content between the paddocks varied considerably which affected the amount of soil moisture stored in the middle of July, see Figure 2.

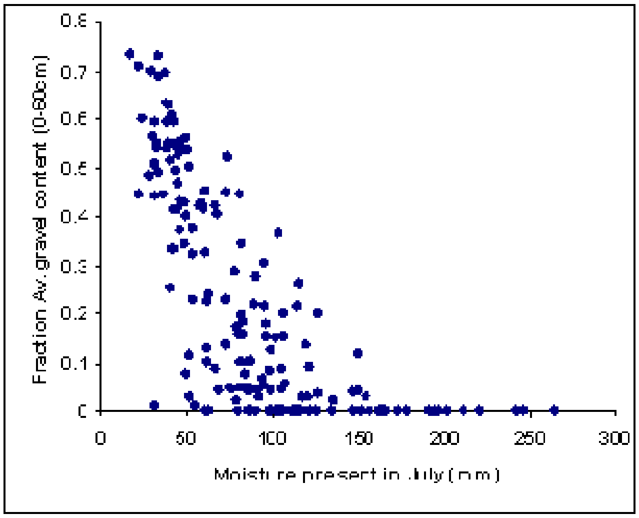

Figure 2. Soil moisture stored in the top 60 cm as a function of the fraction of gravel in 0 to 60 cm

The carbon levels in the top 10 cm also varied considerably between paddocks with some variation within the paddock, typically with a range of 1.2% to 3.7% for the highest mean C% paddock levels and 0.9% to 1.5% for the lowest mean. There was little variation in the K and P levels of the crop within the paddocks but considerable variation existed between paddocks. There was very little correlation between the soil P and K status and the level of P and K in the crop. The soil pH varied little within the paddock except for Ay-Latters, H-Driveway and W-Upper ridge where the pH varied by up to almost 3.5 units. In these three paddocks different soil types were identified where the pH was different which was also reflected in a different barley yield at W-Upper Ridge but not in the canola at H-Driveway. The range in yields as a function of the soil moisture present in July as presented in Figure 3 reflects this response.

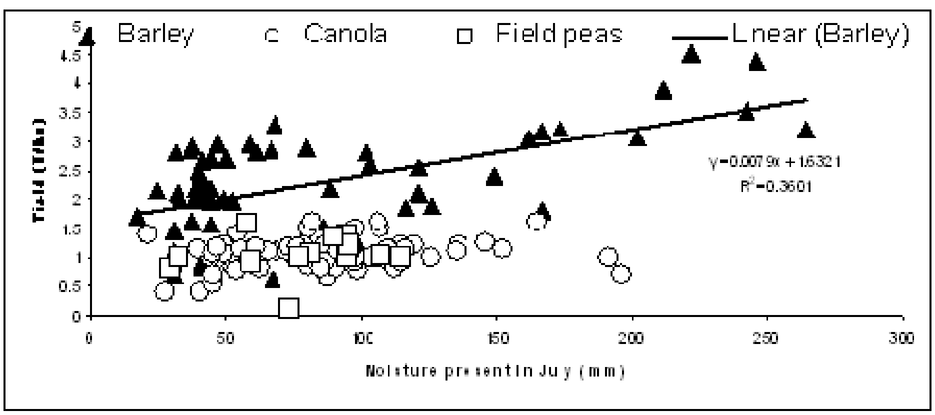

Figure 3. Yield at all the sampling sites as a function of the soil moisture in July 2006.

The barley responded to the variation in the moisture which was mainly determined by the difference in soil type but the canola did not respond in the same way. The canola yield was fairly similar between the various paddocks even though the growing season rainfall varied from 163mm in Jerramungup to 235mm at Jerdacuttup. Other than the relationship between barley yield and soil moisture no other obvious correlations were found between yield and other variables such as OC, total N, P, K, EC, pH or EC.

The low growing season rainfall would have played a major role in establishing the yield potential hence reducing the impact of other possible yield limiting factors. However despite the well below average rainfall there was still a range in the yield across each of the paddocks as indicated by Table 2, indicating that certain factors other than rainfall were affecting the yield. The yield potential was obtained from the Potential Yield Calculator (Tennant *et al*., 2000)

Table 2. Location, growing season rainfall (GSR), the crop types, the mean, minimum and maximum yield obtained in the paddock and the potential yield solely based on GSR.

Location	GSR (mm)	Crop	Mean (t/ha)	Min (t/ha)	Max (t/ha)	Potential (t/ha)
Tambelup	182	Canola	0.92	0.39	1.48	0.78
Wooginellup	193	Barley_1	2.4	1.7	2.8	2
		Barley_2	2.5	1.6	3.3	2
		Field peas	1	0.8	1.6	1.2
Jerdacuttup	235	Barley	3.2	1.8	4.5	5.1
		Canola_1	1	0.8	1.2	2
		Canola_2	1.1	1	1.2	2
Jerramungup	163	Barley	1.13	0.6	1.7	2.08
		Canola	0.91	0.7	1.2	0.8
Gairdner	218	Barley	2.1	1.6	2.5	4.2
		Canola_1	1.3	0.8	1.6	1.68
		Canola_2	0.97	0.7	1.2	1.68

At times the maximum obtained in the field was larger than the potential (Tambelup and Wooginellup) while at other times it was lower (Remainder of the locations). It is possible that this reflects the general agronomy approach of the farmers ("aim for the max" or "play it safe") and should be distilled a little further using 2007 data.

From the soil analysis several factors were identified as possibly yield limiting based on conventionally acceptable levels and trials were designed to test the effectiveness of some of the remedies. A summary of these is presented in Table 3.

Table 3 The location, paddocks, main finding of the soil and crop survey in 2006 and the proposed field trial for the 2007 season

Location	Paddock	Main finding, 2006	Field trial, 2007
Tambelup	1,2	Very compacted soils (clay)	Deep ripping
	3	Water repellence	Claying
Wooganellup	1	Low pH at surface and at depth	Liming and deep cultivation
	2	Low pH at depth	Deep cultivation
	3	Water repellence	Claying
Gairdner	1	Low K levels	K response trial
	2	Limited fertility	Various fertilisers (WMF) + and – microbes and CSBP
	3	Low pH	Liming
Jerramungup	1	Various soil types	Response to in-season N, according to soil type
	2	Low K and water repellence	K response, claying
	3	Nematodes	Break crop and nematices
Jerdacuttup	1	Low K	K response
	2	Low pH at surface and depth	Liming and deep ripping
	3	Hard-setting reddish soil	Gypsum response

From the survey and the monitoring of several paddocks it became clear that general crop management is a large contributor to intra-paddock variability. Liquid-N spray overlap, header strips, spreader overlap, seeder problems and herbicide damage were some of the causes of an increase in the intra-paddock variability responsible for 5% to 100% yield variation within the paddock. With careful management these factors can be brought under control therefore reducing the intra-paddock variability.

CONCLUSION

From the survey it was obvious that the inter-paddock variability was more prominent than intra-paddock variability which is much easier to manage from a precision farming point of view. Managing paddocks separately based on soil and tissue testing is within easy reach of many farmers without the need for greater detail in their soil and crop sampling strategy. Careful crop management would reduce the management effects on the yield variability further.

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