Flip-flop yields of crops on alkaline soils in gilgai country

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This paper reports a study that was undertaken as part of the GRDC project 'Improving the profitability of cropping on hostile subsoils'. The study aimed to increase our understanding of how relative grain yields in different parts of a paddock in the Mallee region vary year to year (and between crop types) and how these changes are related to soil type and seasonal rainfall.

Take Home Messages

- Grain yields can vary considerably within the paddock in the Victorian Mallee. The spatial pattern of this yield variation, however, is not always consistent, with relative yield patterns differing over consecutive seasons, and/or crop types, in a flip-flop (alternating) pattern.
- Consistently high yielding zones existed where the shallow subsoil (10-20cm) was a clay loam texture (33% clay) with low salinity. In contrast, consistently low yielding zones possessed a shallow subsoil of light clay (40% clay) and medium to high levels of salinity.
- Flip-flop yield zones were associated with gilgai (crab-hole) depressions where yields tended to increase in dry seasons (due to a concentration of surface water) but decreased in wet seasons (due to water logging of the heavy textured soils). In contrast where gilgai depressions and light textured soils occurred, crop yields were depressed in dry seasons.
- Overall, the flip flop patterns in grain yields observed within paddocks was attributed to the effect of gilgai microrelief and changes in soil texture which influence soil water availability to crops.

Background

Grain growers are aware of the substantial variations in grain yield that can occur within any particular paddock throughout the Mallee region of Victoria. However, the advent of yield monitors has highlighted that the pattern of this variation in grain yield often changes (on a relative basis) between years, here termed as the 'flip-flop' phenomenon. The occurrence of flip-flop zones potentially limits growers' ability to develop appropriate management strategies using precision agriculture technology.

Previous studies have demonstrated that a range of subsoil constraints such as high boron and high salinity within the subsoil, reduce crop growth. The link, however, between soil properties and yield is not simple and the presence or absence of subsoil constraints does not necessarily imply that crops will be consistently low or high yielding. We suggest that relative yield differences of various crops across seasons may be linked with variation of soil texture and gilgai microrelief within paddocks.

Methods

A survey within the Victorian Wimmera and Mallee of crop growth on 130 profiles (comprising Sodosols, Calcarosols and Vertosols) in farmer-sown paddocks was studied over three years. In this paper, we report results for 10 Calcarosol profiles in a single paddock at Brim, Victoria, where consecutive crops were chickpea (Sona), wheat (Yipti) and field pea (Alma). We used soil salinity (electrical conductivity) as an indicator to represent paddock variation with subsoil constraints to crop growth.

Results and Discussion

Rainfall over three seasons

Distinct differences in the amount and pattern of rainfall was recorded in the study period (2003 to 2005). In 2003, summer rainfall totalled 131 mm (Figure 1). Rainfall between sowing (June) and anthesis (flowering) was 219 mm with a minimum of 17 mm/month. In contrast no rain fell in the post-anthesis phase. For 2004, summer rainfall was 40 mm and 25 mm autumn rain. Growing season rainfall to anthesis was at least 24 mm/month. The exception was October (two weeks either side of crop anthesis) where only 4 mm was recorded. In late spring 70 mm fell, however, this occurred after the crop had reached maturity. In 2005, summer rainfall totalled 88 mm with little follow-up autumn rain. In the pre-anthesis phase, there was good early rainfall with at least 30 mm/month recorded. Around anthesis, 72 mm of rainfall was recorded with follow-up rainfall in November to coincide with maturing crops.

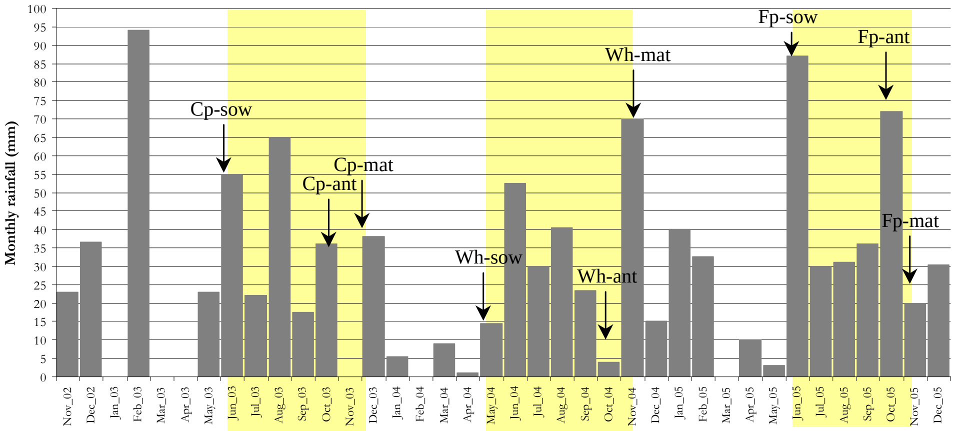

Figure 1: Monthly rainfall (mm) for three growing seasons at survey site at Brim, Victoria. Cp-chickpea; Wh-wheat; Fp-fieldpea; sow-sowing; ant-flowering and mat-maturity.

Soil characterisation

The paddock was dominated by crabhole, gilgai microrelief (Figure 2). All of the profiles assessed were Calcarosol soils. Points 6 and 9 were situated within gilgai depressions, 45 cm below the plain and pt 8 and 10 on the verge of depressions (12 and 30 cm below the plane respectively).

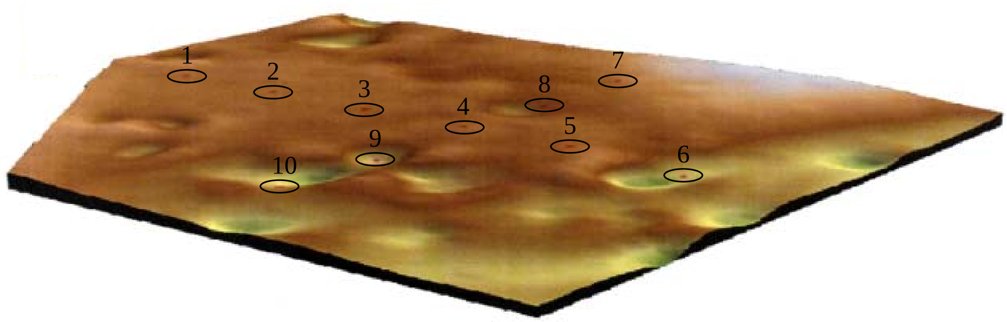

Figure 2: Topographic map of a paddock portion, Brim, Victoria with survey points marked. Distance between points is 50 metres. Height above sea level ranges from 98.3 (green) to 99.45 m (brown/white) (Farm Works 2005).

Soil texture and salinity varied considerably across the 10 Calcarosol profiles assessed (Figure 3). For example, the profile at point (pt) 3 graded rapidly into light clay (40% clay) in the shallow subsoil (10-20 cm layer) (Figure 3*a*) and was saline (> 4 dS/m) below 20 cm (Figure 3*b*). In contrast, pt 9 had loamy topsoil to 20 cm which overlay a clay loam soil, which extended to 60 cm, and was non-saline to at least 120 cm.

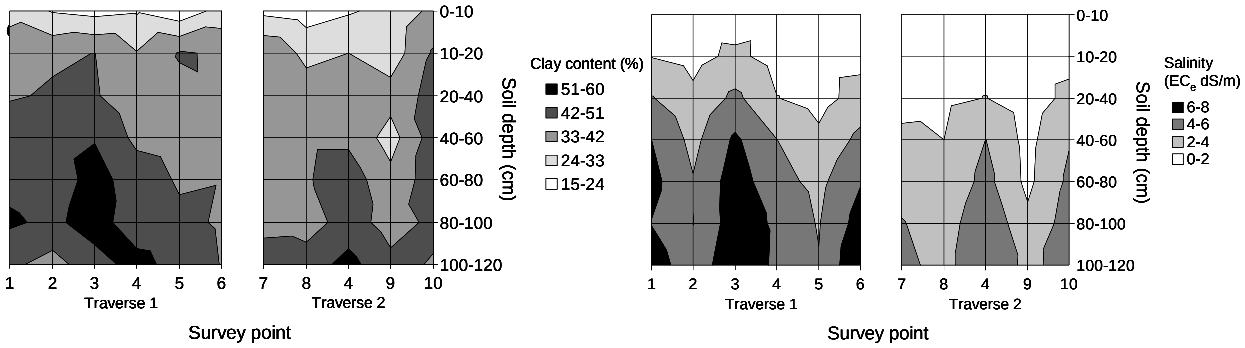

Figure 3: Clay content (%) (*a*) and salinity (EC_e dS/m) (*b*) for 10 soil profiles along two transverses (50 metre intervals) within a single paddock at Brim, Victoria.

Crop growth

Average yields (across 10 survey points) were 1.0t/ha for chickpea (2003), 1.1t/ha for wheat (2004) and 2.2t/ha for field peas (2005). For chickpea, yields ranged from 0.7 t/ha (pt 7) to 1.4 t/ha (pt 5) (Figure 4*a*). In the following year wheat yield ranged from 0.5 t/ha (pt 9) to 2.0 t/ha (pt 4). For field pea, there was less intra-paddock variation in relative yield, where lowest yield was 1.6 t/ha (pt 10) and the highest yields (2.7 t/ha) occurred at pts 1, 5 and 8. Points 4, 5, 6 and 9 showed flip-flop patterns in crop yield over the three years; where as pt 8 and pts 3 and 7 were consistently high and low yielding, respectively.

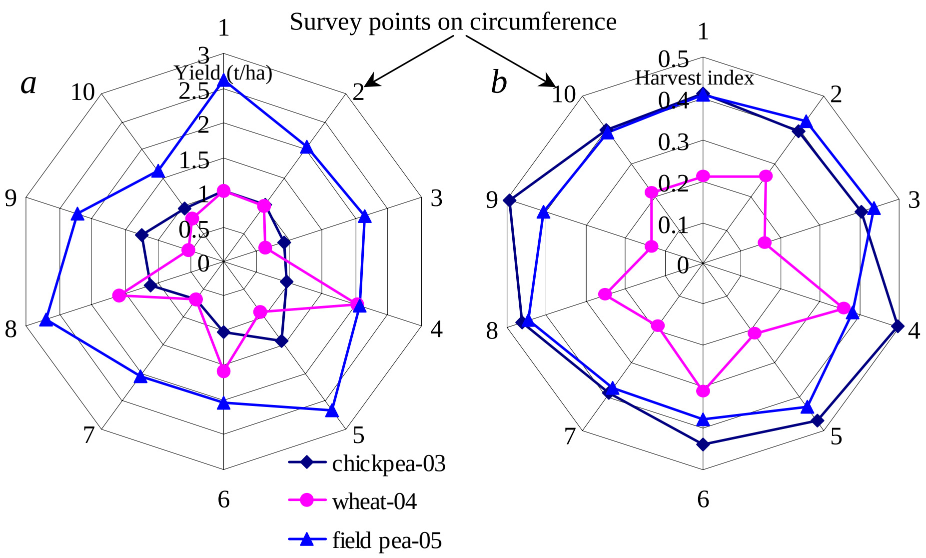

Figure 4: Variation in (a) grain yield (t/ha) and (b) harvest index of chickpea (2003), wheat (2004) and field pea (2005) for 10 points along two transverses (50 metre intervals) within a single paddock at Brim, Victoria.

The parts of the paddock that were either consistently high (pt 8) and moderate/high (pts 4 & 5) yielding were characterised by either sandy loam or loam over clay loam in the shallow subsoil (10-20 cm) (Table 1), and were not necessarily associated with a gilgai depression. Crops at points 4 and 8 also had a high harvest index (HI) (Figure 4*b*), indicating they were advantaged by being on medium textured subsoils in 2003 and 2004 growing season when little rainfall was recorded after anthesis. In contrast, the consistently low yielding zones (points 3 & 7) had loam topsoil over light clay at 10-20 cm. These low yielding zones also had no gilgai microrelief and exhibited medium/high salinity in the subsoil. The texture of the shallow subsoil (10-20 cm) ie. immediately below the plough layer, appears to control whether the paddock zone was consistently high or low yielding with soil texture strongly influencing the water-holding characteristics of the soil. In this study, we found that an alkaline soil with clay loam (33% clay) shallow subsoil produced consistently high yielding crops over three seasons.

Table 1: Summary of consecutive crop yield trends, nominated zone class, surface gilgai microrelief and subsoil salinity. Pt-survey point; h-upper quartile; m-around mean; l-lower quartile for yield; SL-sandy loam; L-loam; CL-clay loam; LC-light clay.

Pt	Crop yield pattern	Zone class	Texture trend	Gilgai depression	Salinity
8	h → h → h	consistently high	SL/CL	shallow	low
4	m → h → m	flip-flop (weak)	L/CL	none	med
5	h → m → h	flip-flop (weak)	SL/LC	none	low/med
6	m → h → l	flip-flop (strong)	L/LC	deep	high
9	h → l → m	flip-flop (strong)	L/L	deep	low
3	l → l → m	consistently low	L/LC	none	high
7	l → l → l	consistently low	L/LC	none	med

Some zones of the paddock showed strong flip-flop patterns in grain yield across the three seasons (pts 6 & 9). Point 6 had a texture trend of loam topsoil overlaying light clay subsoil with high salinity. In contrast pt 9 had loamy topsoil and shallow subsoil (10-20 cm) and clay loam subsoil to 1 metre. Deep gilgai depressions occurred at both pts 6 and 9. Point 6 exhibited comparable trends in soil texture and soil salinity to the consistently low yielding zones, but differed by being situated in a deep gilgai depression.

It is possible that a funnel-type flow occurs in gilgai depressions that concentrate surface water during rainfall, resulting in increased water availability to the crop at that point. The zone beneath the gilgai will consequently have greater plant available water than the surrounding area, thus overcoming potential matric (clay) and osmotic (salinity) effects at this point. This was evident in 2004, where the comparably greater water extraction and yield of wheat at pt 6 was linked with greater pre-sowing accruement of soil water (data not shown). The high HI of wheat for pt 6 also supports this notion. Similarly the depressed yield of field pea at this point in 2005 may have resulted from the combination of high growing season rainfall that was funnelled into the gilgai depression, resulting in the crop experiencing temporary water logging.

A localised zone of lighter textured material within a deep gilgai depression (point 9) also showed flip-flop patterns for grain yield in consecutive seasons. In 2004, wheat yield and HI at this point was poor. Intuitively, crops growing on light textured soils should be advantaged in seasons with low growing season rainfall compared with those growing on heavy textured soil. This was not the case and we believe that any additional water due to the funnel-type flow at this point was cancelled by the movement of water into adjacent clay soil by matric suction, thus reducing the plant available water in the zone of lighter textured material.

Conclusion

We identified 3 zones of crop yield within a single paddock over three years; *a*) consistently high yielding, *b*) consistently low yielding and *c*) flip-flop patterns. Consistently high yielding zones were linked with profiles where the shallow subsoil (10-20 cm) was clay loam, irrespective of seasonal rainfall for below average years. In contrast, consistently low yielding zones were where the shallow subsoil (10-20 cm) was light clay and high subsoil salinity existed. For zones where flip-flop yields occurred, numerous interactions between growing season rainfall, soil texture, gilgai microrelief, crop tolerance to subsoil constraints, and salinity could explain the flip-flop pattern. Finally, when assessing the contribution of soil constraints to crop growth, factors such as gilgai appear to be important in explaining crop water availability within-paddock and subsequent crop growth. Crop management based on precision agricultural systems may need to adjust crop inputs to account for this variation in micro relief due to its relationship with plant available water at the intra-paddock scale.

Acknowledgments

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