Are flip-flop yields of crops on alkaline soils in the Victorian Mallee related to subsoil physicochemical constraints?

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Abstract

Alkaline soils used for dryland cropping across semi-arid regions of south-eastern Australia typically have high levels of salinity (EC_e), sodicity (ESP) and soluble boron (B) in the subsoil. These soil constraints are usually highly correlated and operate simultaneously to decrease crop water use and grain yield. The link, however, between soil properties and yield is not straightforward where alternating (flip-flop) patterns in the relative grain yield of crops at various zones in a single paddock can occur over consecutive years. For example, in a paddock at Brim, Victoria, with a Calcarosol soil, the yield at 10 fixed points (pt) revealed marked differences in the relative yield of 3 consecutive crops. In 2003, chickpeas were low yielding (1.0 t/ha) at pt 6, however, 50 m away (pt 5) yield was 1.4 t/ha. In the subsequent year (2004), the grain yield of wheat exhibited a flip-flop pattern (pt 6, 1.6 t/ha v. pt 5, 0.9 t/ha). In 2005, the pattern in 2003 was repeated with field pea yielding 2.0 t/ha at pt 6 compared with 2.7 t/ha at pt 5. Overall, our results suggest that consistently high yielding zones were associated with clay loam shallow (10-20 cm) subsoils whereas consistently low yielding zones had light clay shallow subsoils and high salinity in lower parts of the profile. Flip-flop yield patterns related to interactions between seasonal rainfall, microrelief and crop type. We suggest that for studying plant/soil interactions in rain-fed environments, assessing the impact of texture due to matric water stress to crop growth is required.

Key words

salinity, sodicity, boron, wheat, chickpea, field pea

Introduction

Within semi-arid regions of south-eastern Australia, alkaline soils used for dryland cropping typically have high and variable salinity (EC_e), sodicity and soluble boron in the subsoil. The correlation that usually exists between these constraints means they are likely to operate simultaneously to decrease root growth and activity of crops thus limiting available water and subsequent crop yield. The link however between soil properties and yield is not simple where alternating (flip-flop) patterns in the relative grain yield of crops exist within paddocks over consecutive years. These flip-flop patterns may reflect interactions between tolerance of the particular crop to different soil physicochemical properties, microrelief, and seasonal conditions such as rainfall and frost. This paper considers some of these interactions.

Methods

A survey within the Victorian Wimmera and Mallee of rain-fed crop growth on 130 profiles (comprising Sodosols, Calcarosols and Vertosols) in broad acre paddocks was studied over 3 years. In this paper we examine the results for 10 profiles in a single paddock at Brim, Victoria, where consecutive crops were chickpea, wheat and field pea. In this paper we use soil salinity as the surrogate to represent variation in soil chemical constraints.

Results and Discussion

Rainfall over three seasons

In 2003, summer rainfall totalled 131 mm (Fig 1). The growing season total to anthesis was 219 mm with at least 17 mm/month. In contrast no rain fell in the post-anthesis phase. For 2004, summer rainfall was

40 mm and 25 mm in the autumn. Growing season rainfall up to anthesis was at least 24 mm/month. The exception was October (2 weeks either side of crop anthesis) where 4 mm was recorded. In late spring 70 mm fell, however, this was after crops had reached physiological maturity. In 2005, summer rainfall was 88 mm with little follow-up autumn rain. In the pre-anthesis phase, there was good early rainfall and at least 30 mm/month. Around anthesis, 72 mm of rainfall was recorded with follow-up rainfall in November to coincide with maturing crops.

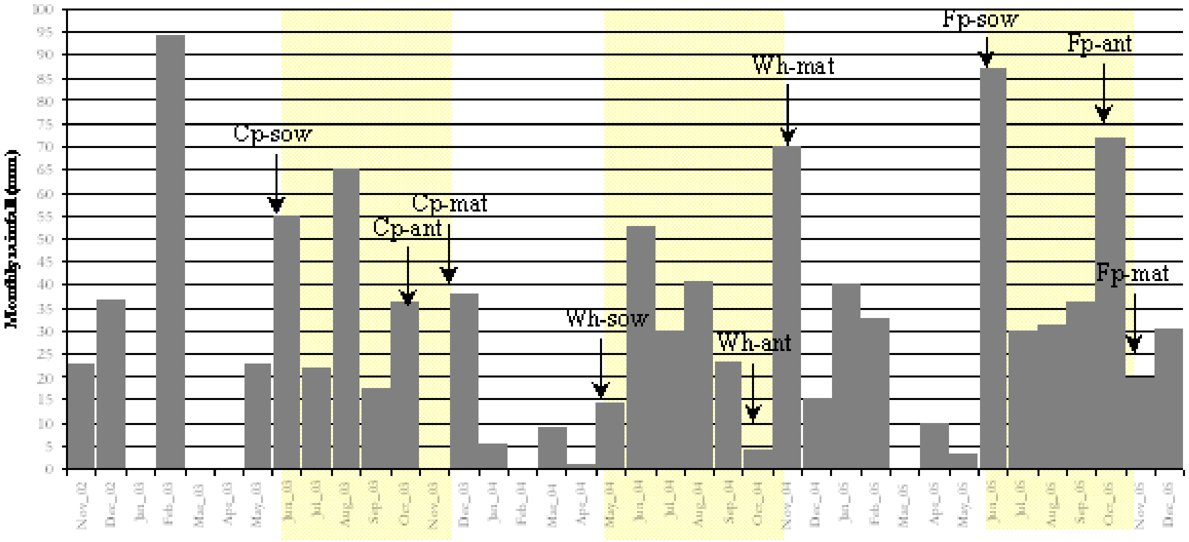

Figure 1. Monthly rainfall (mm) for three growing seasons at survey site at Brim, Victoria. Cp-chickpea; Wh-wheat; Fp-fieldpea; sow-sowing; ant-anthesis and mat-maturity.

Soil characterisation

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

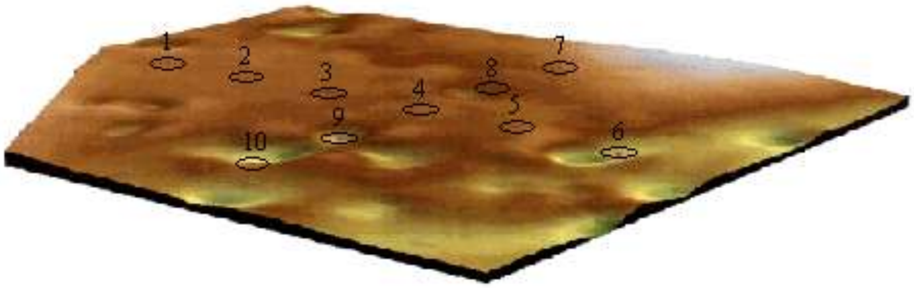

Figure 2. Topographic map of a paddock portion, Brim, Victoria with survey points marked. Distance between points is 50 metres. Height above sea level ranges from 98.3 (green) to 99.45 m (brown/white) (Farm Works 2005).

Soil texture trend and salinity varied with depth across the 10 Calcarosol profiles assessed (Fig 3). For example, the profile at point (pt) 3 graded rapidly into light clay in the shallow subsoil (10-20 cm layer) and heavy clay (P_{2um} > 50%) at 40 cm (Fig 3*a*). Correspondingly, the soil was saline in this layer (Fig 3*b*). In contrast, pt 9 had a loamy soil to 20 cm over a clay loam soil, which extended to 60 cm, and was non-saline to this depth.

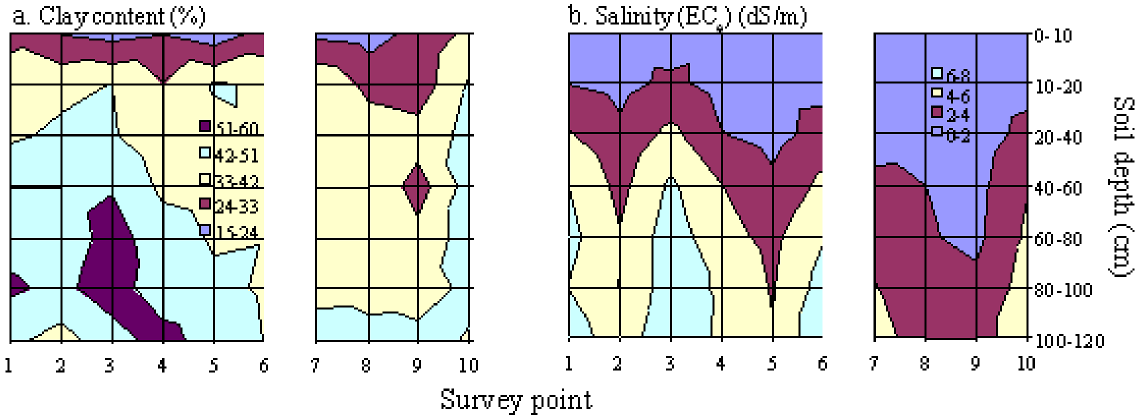

Figure 3. Clay content (%) (*a*) and salinity (EC$_e$ dS/m) (*b*) for 10 soil profiles along two transverses (50 metre intervals) within a single paddock at Brim, Victoria.

Crop growth

Average yields (pooled across 10 survey points) of chickpea (2003), wheat (2004) and field pea (2005) were 1.0, 1.1 and 2.2 t/ha respectively. For chickpea, yields ranged from 0.7 t/ha (pt 7) to 1.4 t/ha (pt 5) (Fig 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 yield, where lowest yield was 1.6 t/ha (pt 10) and high yields 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 p7 were consistently high and low yielding respectively.

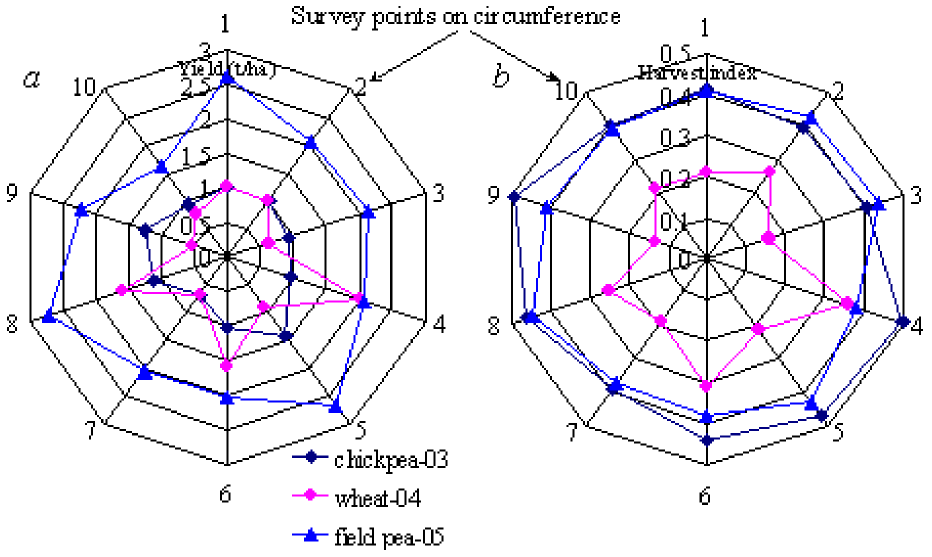

Figure 4. Variation in (a) grain yield (t/ha) and (b) harvest index of chickpea (2003), wheat (2004) and field pea (2005) for 10 points along two transverses (50 metre intervals) within a single paddock at Brim, Victoria.

The consistently high (pt 8) and moderate/high (pt 4) yielding zones were either sandy loam or loam over clay loam in the shallow subsoil (10-20 cm) (Table 1). Crops at pt 4 and 8 also had high harvest index (HI) (Fig 4*b*), indicating they were advantaged by being on medium textured subsoils in 2003 and 2004 growing season where there was low post anthesis rainfall. 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 micro-relief and medium/high subsoil salinity. The texture of the shallow subsoil (10-20 cm) appears to control whether the zone was consistently high or low yielding where texture infers 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, microrelief and physicochemical properties. 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 (yield)	Texture trend	Gilgai depression	Salinity
8	h → h → h	consistently high	SL/CL	shallow	low
4	m → h → m	flip-flop	L/CL	none	med
5	h → m → h	flip-flop	SL/LC	none	low/med
6	m → h → l	flip-flop	L/LC	deep	high
9	h → l → m	flip-flop	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 flip-flop patterns in crop yield across the three seasons (pts 5, 6 & 9). Both pts 5 and 6 had texture trends of sandy loam/loam topsoil over light clay and medium/high subsoil salinity. In contrast pt 9 had loamy topsoil and shallow subsoil (10-20 cm) and a clay loam subsoil to 1 metre. Deep gilgai depressions occurred at pts 6 and 9, but not at pt 5. Point 6 had comparable texture trend and soil salinity to the consistently low yielding zones, however differed by being situated in a deep gilgai depression. We propose that a funnel-type flow occur in gilgai depressions that concentrates surface water from 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, 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 and the funnel-type concentration of the gilgai creating temporarily water logged soil.

A localised zone of lighter textured material within a deep gilgai depression, (point 9) also showed flip-flop patterns in consecutive seasons. In 2004, wheat yield and HI at this point was poor. Intuitively, light textured soils and low growing season rainfall should advantage crops, compared with those 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 negated by the lateral flow of water into adjacent clay soil (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. In contrast, consistently low yielding zones had shallow subsoil was light clay and high subsoil salinity. For zones where flip-flop yields occurred, numerous interactions between growing season rainfall, soil texture trend, microrelief, crop tolerance to subsoil constraints, and salinity could explain the flip-flop pattern, where several scenarios were considered. Finally, in assessing the contribution of physicochemical constraints to flip-flop patterns of crop yield, variation in shallow subsoil texture and associated matric stress in conjunction with water accruement patterns appear vital for explaining crop growth in semi-arid environments.

Acknowledgments

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