Identifying the causes of spatial variability

Roger Armstrong (DPI, Horsham), Janine Fitzpatrick (DPI, Horsham), Abdur Rab (DPI, Tatura), Peter Fisher (DPI, Tatura) & Cherie Reilly (BCG)

Take Home Messages

Experimentation was conducted in a commercial lentil crop (2006) in a paddock considered representative of the southern Mallee region of Victoria (McCellands Jil Jil East). The study identified that seasonal variations in the spatial pattern for grain yield were explained principally by differences in the 'effective plant available water' (ePAW) rather than differences in nitrogen supply. ePAW was considered to be related to both the textural properties of the surface soil (eg. small rainfall events at the season break are more effective in coarser textured soils than in clay soils) and the presence of physio-chemical in the subsoil which can limit crop access to stored water.

Background

Four major constraints exist to the adoption of precision agriculture. These are:

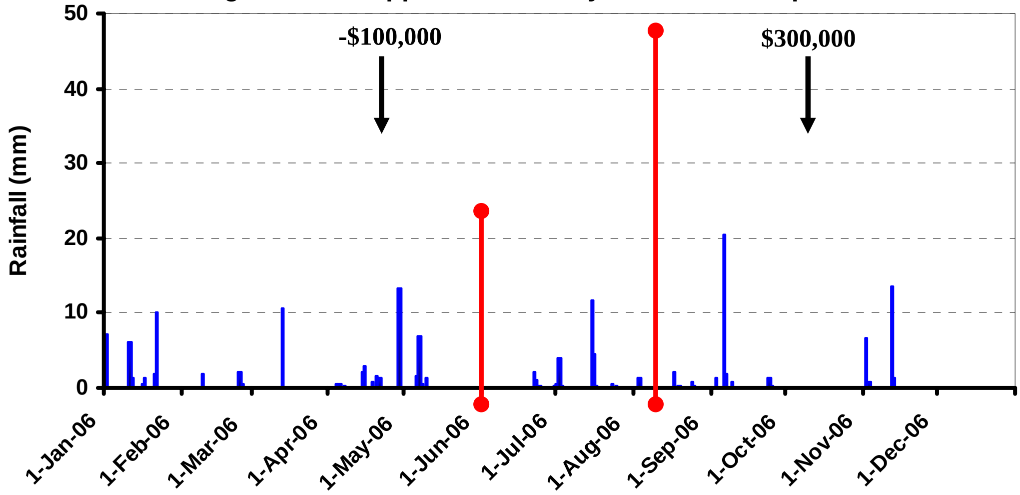
- A lack of confidence by growers that the variability within their operational zones is sufficiently large to be economically worth managing.
- The agronomic causes of crop variability are difficult to identify and understand.
- Options for managing within paddock variability that enable growers to increase gross margins and income security are often difficult to devise.
- The predictability, from season to season, of within paddock variability and its agronomic causes, is imprecise. This means that recommending management solutions is far more risky.

This report documents the results of an experiment to address the last point. The experiment was a component of a collaborative project (DAV00030) between DPI, BCG/WFS and GRDC that aimed to improve the management of grain crops in the Mallee region of Victoria using precision agricultural technology. The experiment specifically aimed to improve our understanding of the causes of spatial variability within a paddock and its interaction with seasonal conditions as this knowledge is regarded as essential to developing appropriate management strategies in precision agriculture.

Methods

A range of points representing three yield zones (low, moderate and high) and seasonal stability (stable or variable) were selected across a 170 ha paddock. Of these points 40, which had been characterised for a range of soil physico-chemical properties, were monitored for lentil crop establishment, dry matter production at mid pod fill and maturity, grain yield and yield components, rooting depth, profile mineral N at sowing and soil water dynamics. Due to extremely dry seasonal conditions in 2006 (< Decile 1: see Figure 1), data collection focused on plots located in representative zones; each plot was 3.5 m long x 1.6 m wide, 40 'dryland' and 21 'irrigated' subplots (i.e. located immediately adjacent to the dryland plots), were both irrigated (25 mm) in early July. In mid September, the 21 'irrigated' plots received a further 48 mm of irrigation.

Figure 1: Daily Rainfall + irrigation applied at PA Site (2006). Irrigation was applied on 12 July and 18th of September



Results

- Cone penetrometer resistance, which is an indicator of a roots ability to penetrate soil, in the top 7 cm of the soil profile did not differ between yield/stability zones but thereafter increased to levels likely to restrict root growth (> 2000 KPa) with increasing depth (Figure 2). At depths between 9 and 15 cm penetrometer resistance was significantly greater in the Moderate and High than in the Low Yield zone. Although cone penetrometer readings were made in the irrigated plots, measurements taken at the time of the penetrometer readings indicated that soil moisture was greater in Low Yielding zones. At equivalent soil water contents, soil resistance was likely to be greater in the Low Yield zones.

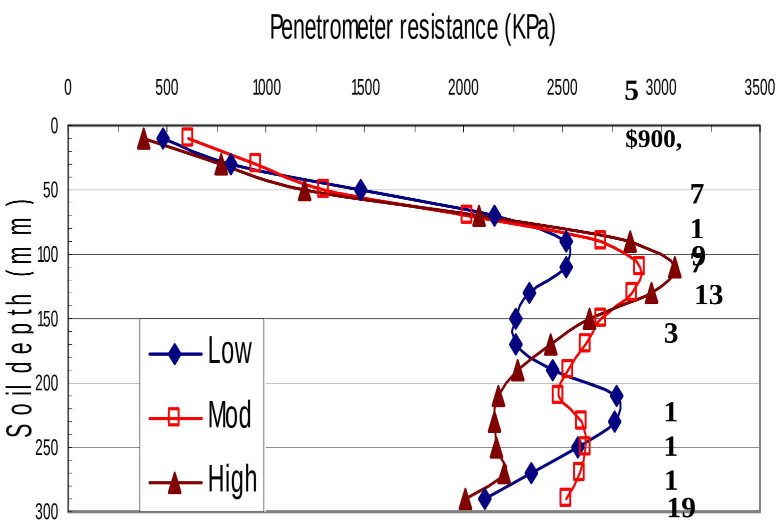


Figure 2: Cone penetrometer resistance in relation to Yield Zone (2006). n.s. = P > 0.05; * P < 0.01

- Volumetric soil water at sowing, and to a lesser extent at maturity, was significantly greater in the Low Yield than Moderate and High Yield zones and higher in seasonally Variable than Stable zones (Figure 3a,b).

Figure 3a: Soil water at sowing (June 2006)
GLM: Yld zone * Variability **; Yld zone * depth *

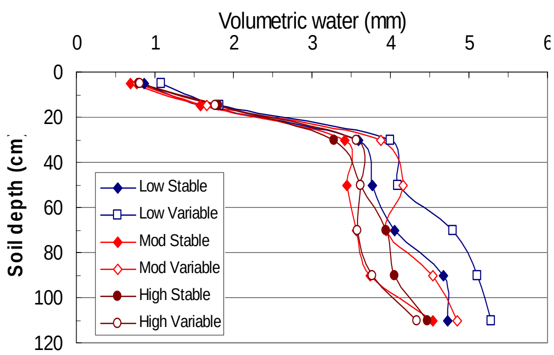
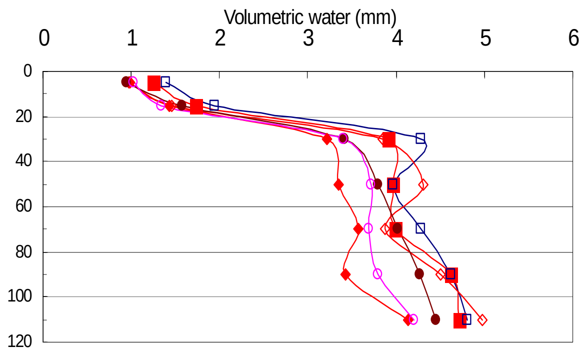
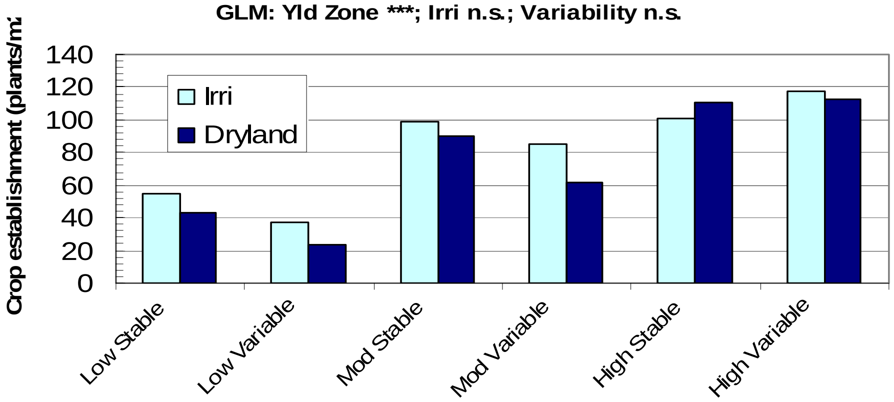


Figure 3b: Soil water at Maturity (Nov 2006)
GLM: Yld Zone * Variability ***



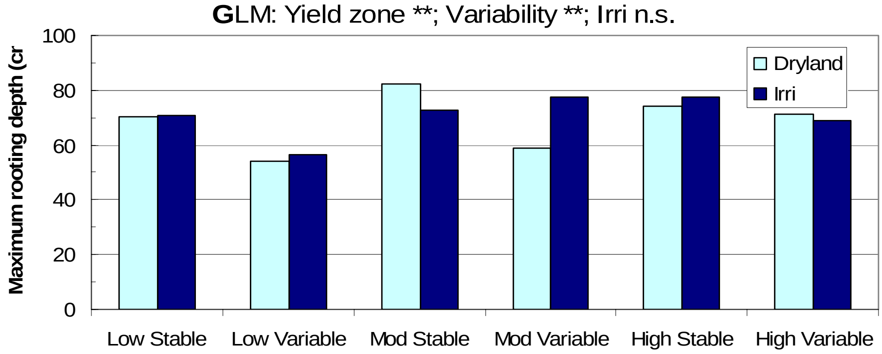
- Lentil establishment was significantly poorer (average of 39.5 plants/m^2) in the Low Yield zones compared to the Moderate (84 plants/m^2) and High Yield zones (110.2 plants/m^2). Establishment did not differ (P > 0.05) between seasonal stability zones (Figure 4).

Figure 4: Lentil establishment in dryland and irrigation.
GLM: Yld Zone *; Irri n.s.; Variability n.s.**



- The maximum depth of rooting (at mid pod fill) was significantly lower in the Low Yield Zone (average of 62.3 cm) compared to the Moderate (74.4 cm) and High (72.5 cm) Yield zones. Maximum rooting depth was significantly higher (P > 0.01) in Seasonal Stable than Variable zones (Figure 5).

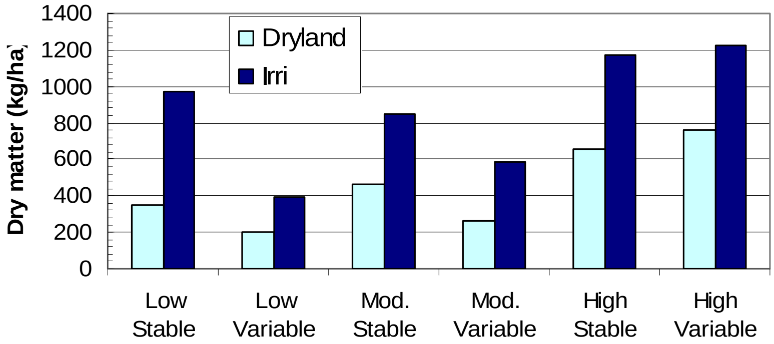
Figure 5: Maximum rooting depth of lentils
GLM: Yield zone **; Variability **; Irri n.s.



- Dry matter production of lentils at mid pod fill (Figure 6) and grain maturity were significantly lower in the Low Yield zone. Irrigation (48 mm) applied in mid September significantly increased dry matter across all Yield/Variability zones. Although there appeared to be a trend for irrigation to even out differences between the Yield Zone, there was no significant interaction (P > 0.05).

Figure 6: Dry matter of lentil at Mid Pod Fill

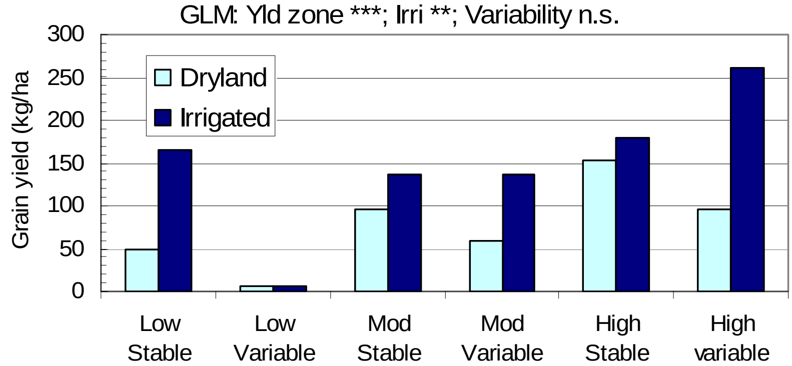
GLM: Yld zone *** ; Irri ***; Yld zone * Irri n.s.



- Grain yields were extremely low across all zones and even irrigated plots produced < 260 kg grain/ha (Figure 7). Grain yield responses closely reflected the pattern of dry matter production.

Figure 7: Grain yield of lentils

GLM: Yld zone ***; Irri **; Variability n.s.



Interpretation

The use of rhizobium inoculated lentils for the 2006 study ensured that potential differences in soil mineral N between management zones identified in 2005 and cereal borne root diseases were unlikely to have any effect on the spatial pattern of crop growth and yield. Lentils are extremely sensitive to subsoil limitations and are generally regarded as more susceptible to water stress than cereals. None the less, significant differences in both the growth and yield of lentils were recorded between the three designated yield zones. Irrigation applied prior to pod filling also significantly improved subsequent dry matter production and grain yield. There was however no significant interaction between yield zone and irrigation as recorded for barley at this site in 2005. This may reflect the extremely poor seasonal conditions recorded in 2006, and even where up to 75 mm of irrigation had been applied, some zones eg. Low Yield/Seasonally Variable produced nearly no grain. Results for the lentils were also potentially affected by unseasonally late frosts and there was evidence of grain damage by insects.

The underlying hypothesis of this study was that spatial variability within a paddock could be explained by ‘effective plant available water’ (ePAW), which is a function of both soil texture and the presence of physio-chemical constraints in the subsoil. In 2006, clear differences between the Yield zones were apparent early in the season with seedling emergence much poorer in the Low Yield zones than in the Moderate and High Yield zones. The 2006 season was characterised by very low rainfall in the month prior to optimum sowing time for lentils in this region (late May) and these dry conditions persisted throughout the remainder of the year. Small rainfall events are much more effective in promoting germination and emergence in coarse textured than fine textured clay soils. A supplementary irrigation of 25 mm was applied several weeks after sowing, but this had little effect on germination rates in the Low Yielding zone, possibly being a case of ‘too little, too late’. The initial growth advantage of lentils in the Moderate and High yielding zones was thereafter maintained for the rest of the season.

Marked differences in the extent of physio-chemical constraints in the subsoil have been recorded between the different Yield and Seasonal Stability zones at this site, where they are generally much greater in the Low Yield and Seasonally Variable zones. The maximum rooting depth of lentils were on average up to 12 cm (or 16%) deeper in the Moderate and High Yielding zone compared to those in Low Yield Zone. The maximum rooting depth was also greater (10.5 cm or 14%) in the Stable than the Seasonal variable zones. Although relative small difference in rooting depth can be of great biological advantage in gaining access to extra soil water in the subsoil, it did not translate to greater dry matter or grain yield by the lentils in the Stable zones. This may reflect the lack of any significant amount of water in the subsoil and the extremely dry seasonal conditions recorded throughout the growing season which would have prevented the profile soil water to be recharged. Furthermore, lentils are a relatively shallow rooting species compared to cereals, and although they are much more susceptible to subsoil constraints such as salinity and high boron, these particular constraints only became potentially limiting at depths greater than 60 to 80 cm in this paddock.