Visualising the yield space for wheat production in the eastern wheatbelt of Western Australia

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Abstract

We propose the concept of a "yield space" that represents the response of crop production to agronomic factors. The yield space can be thought of as a multidimensional polygon, with size defined by the magnitude of yield and shape determined by the response to agronomic treatments. The yield space concept was illustrated using simulated yield data for wheat at Merredin, Western Australia. Analysis of the size and shape of the yield space showed that the potential for managers to influence yield through agronomic practices and the factors of greatest importance varied from year to year. This concept is being explored further as a means of developing agronomic understanding and advice for dealing with seasonal variability.

Media summary

Analysis of 45 years of wheat yields suggests that the effects of agronomic factors and their potential to "make a difference" varies with season.

Key Words

wheat, season, yield, agronomy, dry-land agriculture, simulation model

Introduction

Each year farmers operate within a domain of possible yields on a given soil type and at a given location. The domain of yields can be visualised as a multidimensional polygon, or "yield space", with size defined by the magnitude of yield and shape determined by the response to agronomic treatments. Visualisation of the yield space requires a data set covering the range of possible outcomes. Output from a validated crop simulation model that is sensitive to agronomic factors such as time of sowing, nitrogen application and crop variety can provide such a data set and be used to illustrate the concept of the yield space.

The Agricultural Production Systems Simulator, APSIM, has been validated against data sets from the Western Australian (WA) wheatbelt (Asseng et al. 1998a; Asseng et al. 1998b; Asseng et al. 2002; Fisher et al. 2001). Scanlan et al. (2003) used APSIM to produce a database, WA Wheat, of wheat production in response to a factorial construction of agronomic options for 102 years (1900-2001) and 20 locations in WA.

A subset of simulated yields from WA Wheat was used to explore the yield space for Merredin, which is in the low rainfall dry-land agricultural area of Western Australia. Abrecht and Balston (1996) found that yield in this environment was influenced by stored soil water and the timing of the break of season. We hypothesised that the dominant agronomic factors influencing the yield space, or response surface of wheat production in the low rainfall area of Western Australia would vary with season.

Methods

Location

An exploration of the concept of the yield space was conducted using simulated yield data for wheat grown at Merredin (31?29’ S, 118?17’ E) in the eastern wheatbelt of Western Australia. The area has a Mediterranean-type climate, typified by hot, dry summers and cool, wet winters. Rainfall is winter-dominated. Average annual rainfall is 325 mm and the average growing season (May to October) rainfall is 226 mm. The climate is highly predicable, but there is considerable variability in the start of the opening rains for the season, the distribution of rainfall during the season and the duration and intensity of the finishing (spring) rains.

Data

A subset of simulated yield data from the WA Wheat database was used to explore the yield space concept. These data were for wheat grown at Merredin on a yellow deep sand based on a factorial construction of 2 rotations (continuous wheat and pasture-wheat), 2 levels of stored soil moisture at the beginning of April (lower limit and half-full profile), 2 ‘varieties’ (long and short season), 6 times of sowing (25th April, 10th May, 30th May, 5th June, 15th June, 5th July), 4 rates of nitrogen at sowing (0, 30, 50, 100 kg N/ha), 3 rates nitrogen at four weeks after sowing (0, 30, 50 kg N/ha) and 3 rates nitrogen at ten weeks after sowing (0, 30, 50 kg N/ha). Data for 45 years were used (1957-2001). This gave 1 728 records for each year and a total of 77 760 records.

Analyses

For each year an analysis of variance (ANOVA) of the yields was used to fit main effects and first-order interactions of the 7 factors. The total sums of squares (SS) from these ANOVAs were used to identify groups of years by a regression tree analysis. The variation in yield for a sample year from each of the groups was visualised using trellis plots. These analyses and summaries were performed with the R Statistical System (2004).

Results and Discussion

The yield space determined by the data used in this analysis was conceptualised as a 9-dimensional surface representing the simulated yield for each of seven agronomic factors in each year. When viewed through the year axis, the surfaces would appear as a series of layered polygons—one for each year—with size and shape determined by the magnitude of the yield and the response to agronomic manipulations in each year. A projection of each surface along the plane of yield and year shows the variation in the magnitude of the yield space for each year. Presentation of the data in this plane illustrates that the potential for agronomic treatments to influence wheat yield varies from year to year (Figure 1). There were years with a small yield space, such as 2000, years with a moderate yield space, such as 1990, 1995, and other years with a large yield space, such as?1996 which are highlighted in (Figure?1).

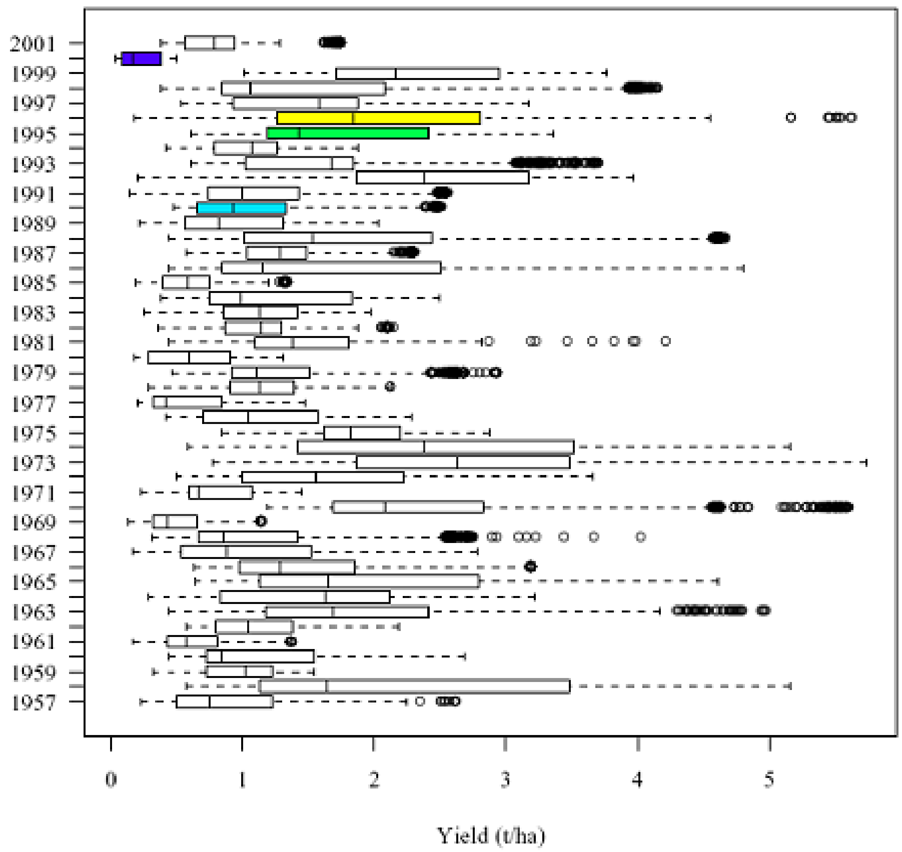

Figure 1: Box-whisker plots showing the range of simulated yields of wheat over 45 years on a deep sand at Merredin. The colours relate to regression tree analyses below.

Regression tree analysis based on the total SS for grain yield identified four groups of years (Figure?2a). Representative years from each of the regression tree groups highlight the different responsiveness to the factors and interactions (Figure?3a). Across all years the yield space was dominated by three factors, time of sowing, stored soil moisture at the beginning of April and variety, and their interactions (Figure 2b). The importance of these factors varied with individual years (Figure?2b). The display of the 1996 yield space according to the main factors illustrates the influence of sowing time x variety interaction (Figure?3b).

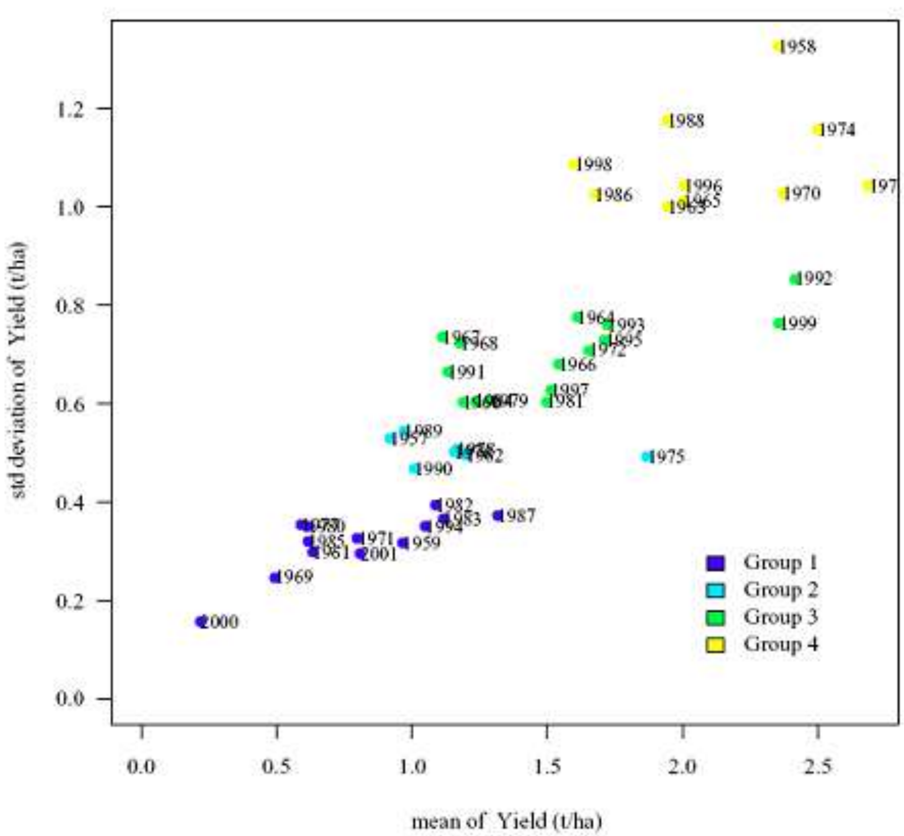

Figure 2a:Standard deviation versus mean yields for each year labelled by groupings from the regression tree analysis based on the total SS, where the groups formed are in increasing mean "total SS" whilst maximising the variance between the groups and minimising the variance within the groups.

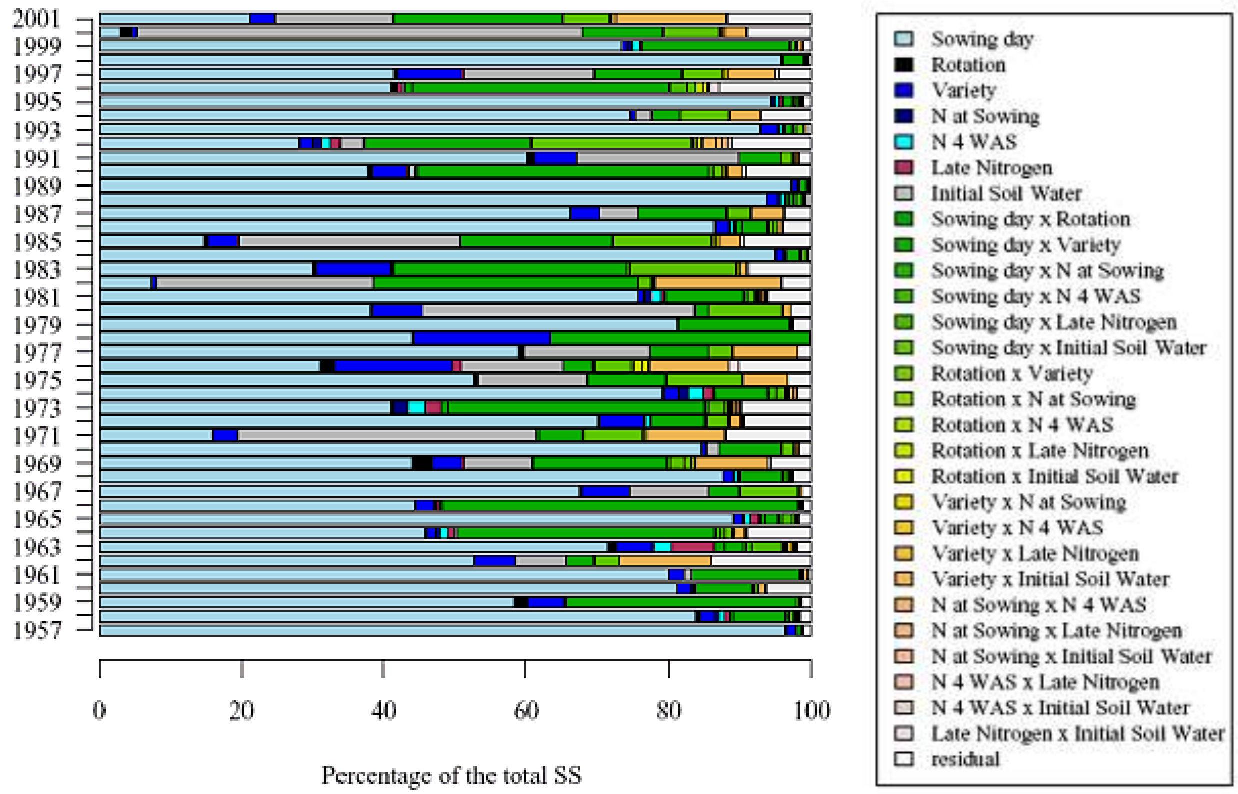

Figure 2b: Percentage of the total SS explained by the main effects and first order interactions in the ANOVA model illustrating factors affecting the "shape" of the yield space.

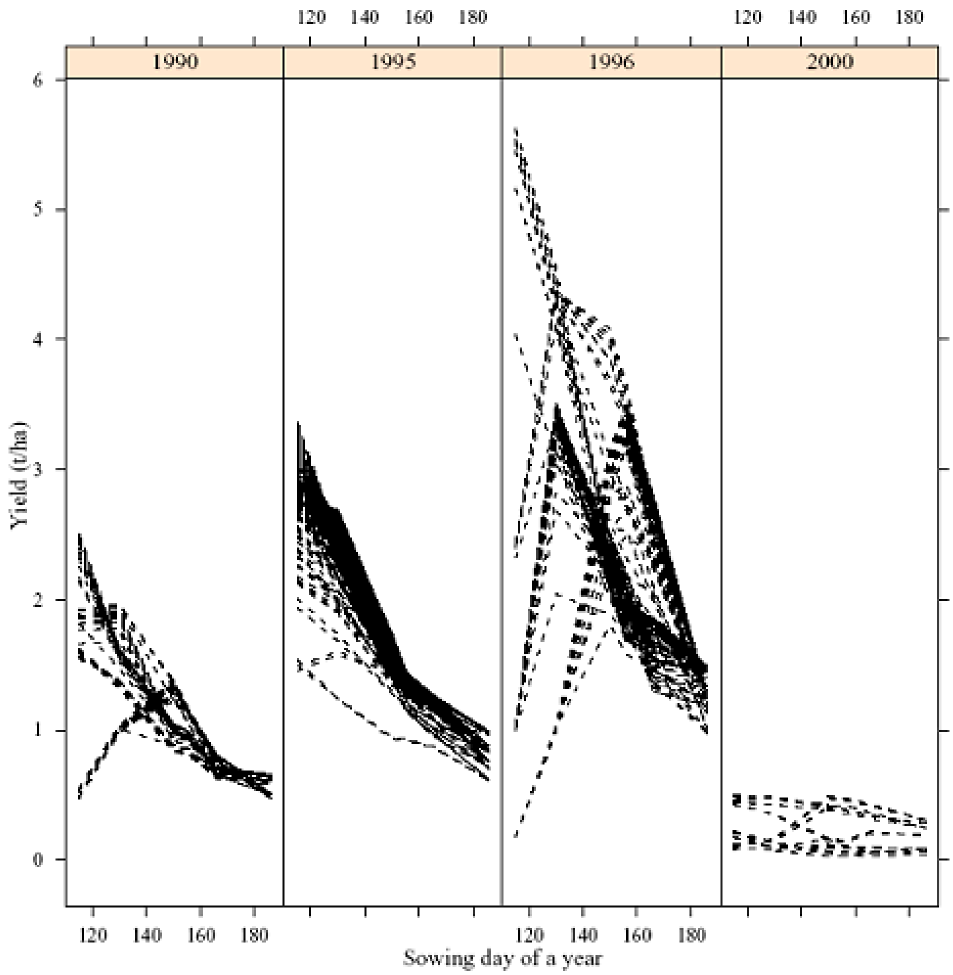

Figure 3 a. Trellis plots of yield against time of sowing for the years 1990, 1995, 1996 and 2000.

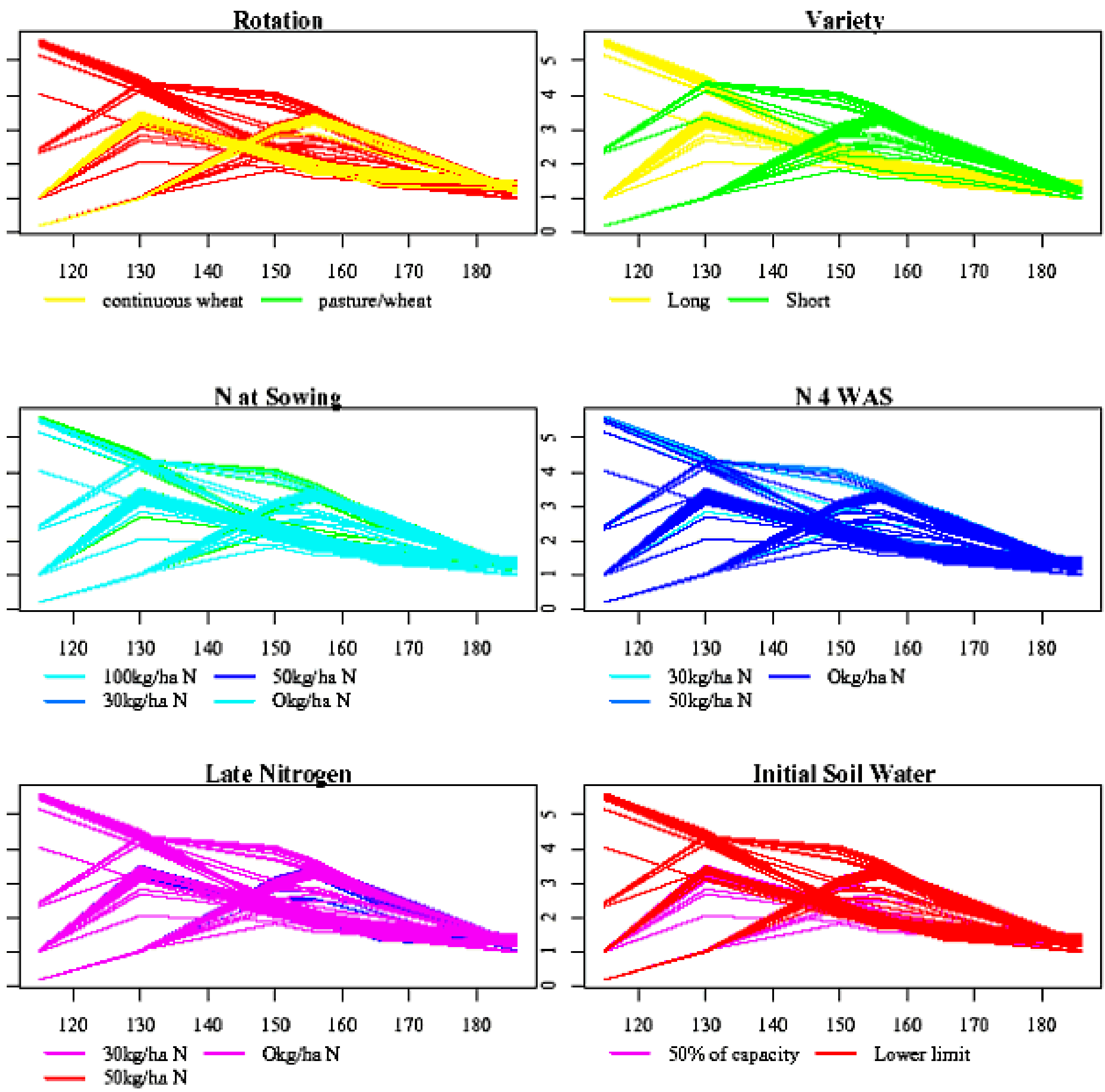

Figure 3b. Yield against time of sowing for the year 1996 expanded to show the six main factors on separate panels.

Conclusion

The size and shape of the yield space varied with season. This illustrates that the potential for farmers to influence yield through agronomy and the agronomic factors which have the greatest impact on yield varies from year to year. This finding raises questions for the transferability of empirical field research and the wisdom of the applying 'set piece' agronomy, such as early sowing, irrespective of the type of season.

We identified groups of years based on the size of the yield space measured by total SS, and related these to the agronomic factors which had the greatest impact on yield in a year, *i.e.* the shape of the yield space. Further analyses, including investigations of common characteristics of years within groups, will lead to consideration of the predictability and usefulness of these concepts for farmers in their decision making. Examination of the differences in yield space amongst soil types and locations will test the robustness of this concept. Such analyses will add to the development of agronomic advice to assist in managing seasonal variability.

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