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Factors underpinning improved productivity in the WA wheat industry.

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Authors

Roy Murray-Prior[1a], M. F. Rola-Rubzen[1], L.D. Martin[1] and W. M. Sirisena[2]
[1] Department of Agribusiness, Muresk Institute, Curtin University of Technology, Northam WA 6401, Australia.
[2] The Regional Institute, University of Peradeniya, Sri Lanka.
[a] Corresponding author - Tel: +61 8 9690 1595; Fax: +61 8 9690 1500; Email: r.murray-prior@curtin.edu.au

Roy is Senior Lecturer in Farm Management and Agricultural Extension at the Muresk Institute, Curtin University of Technology in Western Australia. Apart from WA he has worked in NSW, USA, and the South Pacific (lecturing in agricultural extension) and Tasmania (as an extension officer). Roy has more recently been involved in projects in South Africa, the Philippines, East Timor and PNG as well as WA and Qld. His research interests are in the application of pluralistic soft and hard systems approaches to analysis of agribusiness systems, farming systems, management decision making, adoption and rural development. His undergraduate training was in Rural Science (UNE) with postgraduate training in Agricultural Economics (Cornell - MSc; UNE - PhD) and a Graduate Diploma in Agricultural Extension from Melbourne University.

IFMA Paper No. 8: Factors underpinning improved productivity in the WA wheat industry

Keywords

wheat, productivity drivers, yield, management

Abstract

Wheat yields in the Western Australian wheat industry have risen by about 3.9 percent per year over a period of 20 years. This has coincided with a decline in growing season rainfall over the grain belt. However, in the last few years yields have been highly variable because of fluctuations in rainfall and because two of the three driest years in the last 70 years have occurred during the last five years. Farm managers, consultants, researchers and research funders need to understand the key drivers of improvements in productivity. Researchers from the Department of Agriculture, Western Australia have conducted intensive research on wheat varieties and management practices needed to achieve high wheat yields. These have been combined into recommendations known as High Yield Packages (HYPs) for the regions of the state. The question addressed in this paper is which elements of these packages have been important and what other factors may have contributed to the improvements in productivity.

Using graphical, statistical and regression analysis of benchmark data from PlanFarm Consulting group for 1995 to 2004, supported by in-depth qualitative analysis of 40 case study farmers, and a random telephone survey of 100 farmers, key factors associated with yield increases were investigated. The evidence suggests farmers have increased their water use efficiency since 1995 and that improvements in productivity are associated with nitrogen and phosphorous use, herbicide use, higher seeding rates and management performance. There is also qualitative evidence to suggest that the widespread adoption of one pass operations or no-tillage systems has been an important complementary factor.

Introduction

In 2005/06 the Western Australian grains industry exported 52 percent of Australia’s wheat exports and 6.8 percent of the world’s wheat exports

(DAFWA 2007) so it is a major contributor to the state and national economies. However, it still faces competition from other exporting countries. In the face of international competition in a free market environment, over the past twenty years Australian and Western Australian grain farmers have been forced to improve their productivity to compete and maintain their profitability. Over the 20 years to the turn of the century Australian wheat yields rose by 2.5% per year on average compared with 0.6% in the United States, 1.5% in Canada and 2.3% in Europe (Knopke et al. 2000). Yields in WA rose by more than the national average at 3.9% per annum. Water-use efficiency has also doubled (Anderson et al. 2005). WA at 3.5% has also had higher annual growth in Total Factory Productivity than the national average (Knopke et al. 2000).

The Western Australian grain industry exists in a Mediterranean environment with mild wet winters and hot dry summers. Most wheat is produced in the belt receiving between 250 to 500 mm annual rainfall. However, evidence from a number of sources including rainfall records from Curtin University's farm, appear to show a decline in rainfall in recent years, particularly in winter rainfall. Two of the three driest years in the last 70 years have occurred during the last five years. Soils are low in fertility derived from a highly eroded and weathered landscape (one of the oldest in the world) and are mainly of a sandy texture with gravel and/or clay subsoils. High salt levels in some soils and rising water tables due to land clearing are resulting in some land becoming too saline for cropping. Common rotations include cereal grains (mainly wheat & barley) with leys of annual legumes grazed by sheep. However, many farmers do not have livestock and instead use cereal legumes such as lupin in the rotations. Canola and oats for hay are also used for disease and weed control reasons. Most crops are sown using minimum or zero tillage techniques often straight into the previous crop's stubble in a one-pass operation. Some stubble burning is still practiced for ease of seeding, disease and weed control reasons.

Until recently the WA Department of Agriculture (now Department of Agriculture and Food - DAFWA) carried out much of the research for the WA wheat industry. Since the early 1990's DAFWA have been promoting a high yield package (HYP) for producing premium quality wheat (based on research published in Anderson 1992). Five key elements are the basis of the HYP

(Anderson & Garlinge 2000, p. 151): 1. Select good cropping land; 2. Use a legume rotation; 3. Control grass weeds one or two years before the wheat crop; 4. Select productive cultivars and sow them at the appropriate times; and 5. Increase nitrogen and seed rates to take advantage of improved yield potential. These principles have been refined to provide specific packages for the production of high protein, (Anderson et al. 1995), noodle (Anderson et al. 1997) and soft wheats (Anderson and Sawkins 1997), although the five elements remain essentially the same. The question addressed in this paper is which elements of these packages have been important to the improvements in productivity over the last 20 years and what other factors may have contributed to productivity increases.

Methods

Work on the project commenced in February 2004. To get a comprehensive picture of the diffusion of the HYP among wheat farmers and its impact on productivity, three strategies were chosen based around components using different methodologies.

1. In-depth interviews with 48 wheat farmers from the grain region. This component aimed at capturing agronomic practices related to wheat farming used by West Australian farmers representing four phases, 1990, 1995, 2000 and 2003. A benchmark year was used (1990) to see how the practices changed gradually over the years during the last decade or so as a result of adopting the HYP introduced by DAWA. The interviews also incorporated questions to evaluate the perceptions of farmers about these new practices and also where they sourced their information. Before the interviews farmers were faxed a series of questions asking them to check their records and have them available for the interviews. In some cases information from earlier years was available, in others we had to rely on memory.

2. A five-page telephone survey of 110 farmers using a stratified random sample (Churchill 1995) to represent the Northern, Central, Eastern and Southern wheat belt. From these 94 usable replies were obtained.

3. Descriptive and regression analysis of data on wheat production in Western Australia obtained from the Farm Business Surveys conducted by the Planfarm consulting group. This database is a cross-sectional time series covering the period from 1995 to 2004. It contains 894 different farms, most of which are not present in each year, and 3,834 data points. The data were cleaned for obvious errors before analysis commenced. Descriptive analysis and simple linear regressions have been conducted.

Results

The results presented here focus on evidence for the adoption of the elements of the HYP which research had shown should be correlated with high yields and the evidence that these and other factors have been associated with yield improvements.

Adoption of elements of HYP

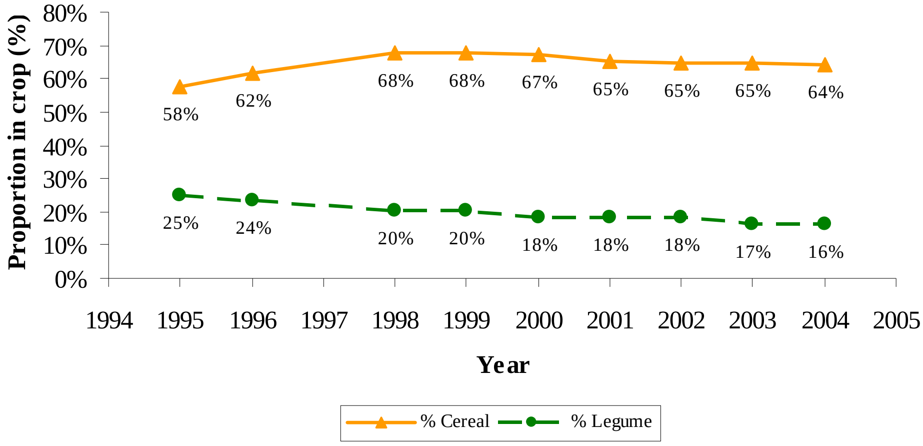
Select good cropping land

Hard evidence on whether good cropping land was selected was not collected because this would have required a subjective assessment of paddocks at seeding and resources and time to undertake this were not available. However, evidence from the case study survey suggests many are selecting land for cropping based on its productive potential often assessed by potential yield.

Use a legume rotation

Farmers appear to be willing to include legumes as part of the rotation with 47% of those in the telephone survey indicating their wheat follows a legume or pulse crop. However, the proportion of legumes in rotations appears to be declining (Figure 1) with the Planfarm data signifying a decline in the proportion of crops sown as legumes from 1995 (25%) to 2004 (16%). This decline appears to have stabilised more recently. Poor wool prices and relatively good grain prices during the 90's combined with the adoption of no-till farming techniques have encouraged many farmers out of sheep altogether with the consequent removal of pasture legumes from rotations. The in-depth interviews indicated that farmers are aware of the benefits of legumes in the rotations, but also take account of the economic tradeoffs involved.

Figure 1: Proportion of land sown to cereal & legumes from 1995 to 2004



Source: Derived from Planfarm Farm Business Surveys (Planfarm 2005).

Control grass weeds before wheat crop

Results from the telephone and in-depth interviews indicated that the messages about grass weed control are widely practised. A range of practices including pasture topping, crop topping, single pre-seeding knock-down spray and double pre-seeding knock-down spray prior to seeding and cultivation are used to help weeds and to overcome problems with herbicide resistance. Green manuring and brown manuring are also practised.

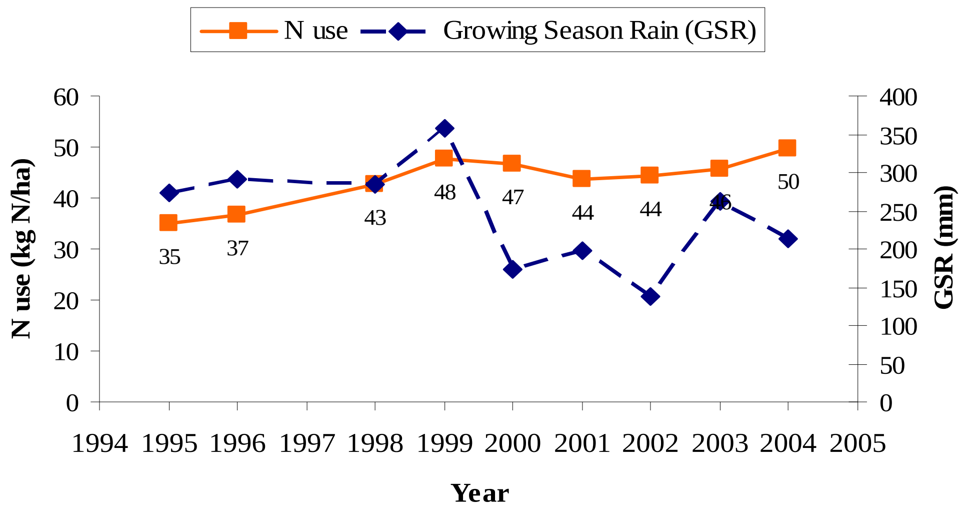
Select productive cultivars and sow at the right time

This is a complex element because the selection of cultivar depends on issues such as soil moisture, the timing of the break of season, soil fertility, position in the landscape and likelihood of frost. Over 80% of telephone survey respondents were using at least one recommended cultivar from the Crop Variety Sowing guide recommendations (Littlewood 2003) for their area. These recommendations rank the many cultivars available based on yield and recommend one or two per region. They also provide information about length of growing season which can be used to determine when the cultivar is likely to flower given a particular planting time. Nearly all (95%) are aware of the concept of a ‘flowering window’ (Anderson & Garlinge 2000) while 51% use it. Avoiding frost damage at flowering is the main relevance of ‘flowering window’ to cultivar selection. Most of those who don’t use it are in areas where frost is not an issue. Farmers are also aware of the impact of delayed seeding on yields and are keen to start as early and finish as quickly as possible. This is a greater problem than frost for those in the north and north-eastern parts of the grain belt because of their shorter seasons.

Increase nitrogen and seed rates to take advantage of yield potential

Nitrogen use has increased by about 30% between 1995 and 2004, from around 35 kg/ha in 1995 to 50 kg/ha in 2004 according to the Planfarm data. Most of the increase occurred in the first five years and the levelling off during the latter five years appears to be due to the lower rainfall experienced during that period (Figure 2). Compared to fifteen years ago, farmers have become more precise in their application of fertilisers by adjusting rates depending upon expected yield, prices, soil fertility and crop requirements. Farmers are also concerned about the quality of wheat, and they are aware of the links between nitrogen needed to achieve appropriate protein levels and price premiums for certain varieties of wheat.

Figure 2: N use on wheat and relationship to growing season rainfall



Source: Derived from Planfarm Farm Business Surveys (Planfarm 2005)

Over three-quarters of farmers have increased their seeding rates since 1990. Some farmers are also making tactical use of increased seeding rates to control weeds.

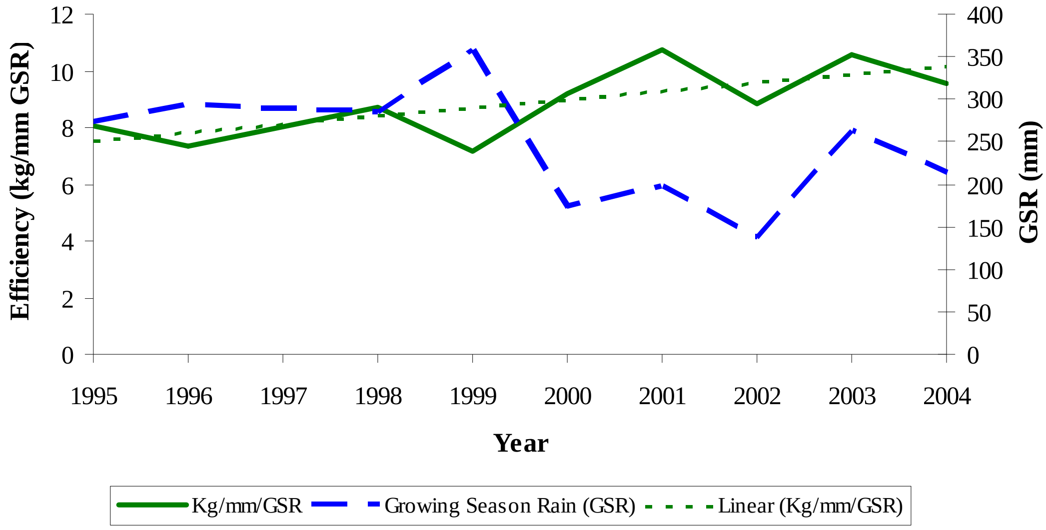
Improvements in wheat productivity

A key objective of the high yield package is to increase yields, however, the range in rainfall between regions and years makes it difficult to use yield trends to determine improvements in productivity and to link these to changes in farm practices. There is no obvious increase in yields over the period 1995 to 2004. Two approaches were chosen to deal with this issue using the data from Planfarm. One was to use water use efficiency defined as kg grain harvested/mm of growing season rainfall and to examine its trend over time. The other was to use simple linear regression using yield as the dependent variable.

Trends in water use efficiency

Water use efficiency is not as susceptible to variation in rainfall although in some areas it tends to be lower during high rainfall years due to water logging and overall it tends to be higher during dry years. Frosts, which are more likely to occur in dry years, can also be a confounding factor because they can abort grain formation. A simple trend line of average water use efficiency shows an upward trend of about 0.3 kg/mm GSR per year (Figure 3).

Figure 3: Trend in average wheat water use efficiency from 1995 to 2004 along with average growing season rainfall.



Source: Derived from Planfarm Farm Business Surveys (Planfarm 2005)

Regression of factors influencing wheat yield

The data obtained from Planfarm have mainly been used for Benchmarking farm performance and consists mostly of income and cost data apart from limited information on production data such as total areas, crop areas and tonnages, labour units and N and P use per hectare. Variables were selected from this data base for regression on wheat yield based on hypotheses derived from elements in the high yield package and other variables that were hypothesised to have an influence on wheat yield at the farm level. The only variables available of those recommended in the HYP recommendations were nitrogen use per hectare and percentage legumes. Both were hypothesised to have a positive relationship with yield although ‘percentage legumes’ is only a proxy for a legume rotation. Herbicide cost per hectare was also included as a proxy for weed control and seeds and grading per hectare for seeding rate, both with hypothesised positive relationships. However, seeds and grading also sometimes includes seed treatments which would be expected to have a positive effect. No variables were available for ‘Selecting good cropping land’, ‘Selecting appropriate cultivars’ or ‘Sow at appropriate times’. Plant repairs per hectare was included as it was expected that it would correlate with older machinery and delayed seeding times which would be negatively related to yield.

Other factors included were:

- Growing season rainfall – expected to have a positive relationship to yield.
- Total effective area – expected to have a negative relationship
- P use per hectare – expected to have a positive relationship
- Fuel cost per hectare – expected to have an indeterminate relationship because fuel could measure cultivation time which would be expected to be negatively related, but fuel cost was positively correlated with water use efficiency
- Wages per hectare – expected to have a positive relationship
- Permanent labour – expected to have a negative relationship
- Operating surplus/farm assets – included as a proxy for management expertise and expected to have a positive relationship.

Dummy variables were also included for years with 1995 being the base year. While amount of rainfall is important, distribution of rainfall can also be a factor as are frost occurrences.

A number of variations of the model were run in SPSS ver. 14, with results from three of these presented in Table 1. An initial model included all variables mentioned above. Results showed an adjusted R^2 of 0.62 with most signs being as expected. Permanent labour was then excluded for two reasons; it's p-level showed it was not significant and because the variance-decompositon statistics indicated a multicollinearity problem (Judge et al. 1985) and linear dependence between the variable and 'Total effective area'. Successive variables were then removed if their p-level was > 0.05. The final model presented includes all the significant variables.

All models have reasonable adjusted R^2 with that for the final model being 0.62. Overall, the statistically significant variables in the regressions had coefficients with the expected sign. Multicollinearity does not appear to be an important issue because both the Condition Indexes (<30) and the Variance Inflation Factors (<10) were at acceptable limits. Normal plots of standardised residuals appear appropriate. However, the Durbin-Watson test gives results close to the lower limit (Patterson 2000) but below the upper limit for the number of observations and variables. This indicates possible serial correlation although the most likely explanation is a misspecification problem.

Factors that appear to be positively related to wheat yield include: growing season rainfall, N use, P use, use of herbicides, use of fuel, seed costs, level of labour and management expertise. Total effective area and plant repairs are negatively related. The years with low growing season rainfall (2000, 2001, 2002 and 2004) had negative coefficients. One explanation for this is that many regions experienced frosts in these years. The 1996 year was also a difficult year to predict for crop models based on historical rainfall data (James Fisher [Muresk Institute, Curtin University of Technology] 2007, pers. comm.).

Table 1: Regression results for wheat yield derived from Planfarm Farm Business Survey data – 1995 to 2004

Variable	All variables		Permanent labour excluded		Only significant variables	
	Coefficient sign	p-level	Coefficient sign	p-level	Coefficient sign	p-level
Intercept	+	0.000	+	0.000	+	0.000
Growing season rainfall (mm)	+	0.000	+	0.000	+	0.000
Total effective area (ha)	-	0.000	-	0.000	-	0.000
N use cereals (kg/ha)	+	0.000	+	0.000	+	0.000
P use cereals (kg/ha)	+	0.000	+	0.000	+	0.000
Herbicide cost ($/ha crop)	+	0.000	+	0.000	+	0.000
Fuel cost ($/ha crop)	+	0.000	+	0.000	+	0.000
Seeds & grading ($/ha)	+	0.000	+	0.000	+	0.000
Wages ($/ha)	+	0.000	+	0.000	+	0.000
Plant Repairs ($/ha)	-	0.149	-	0.149	-	0.036
Permanent labour (#)	+	0.233				
% Legumes	+	0.697	-	0.900		
Operating Surplus/Farm Assets	+	0.000	+	0.000	+	0.000
Year 1996	-	0.000	-	0.000	-	0.000
Year 1998	+	0.560	+	0.379		
Year 1999	+	0.378	+	0.559		
Year 2000	-	0.000	-	0.000	-	0.000
Year 2001	-	0.001	-	0.003	-	0.000
Year 2002	-	0.000	-	0.000	-	0.000
Year 2003	+	0.000	+	0.000	+	0.000
Year 2004	-	0.268	-	0.431	-	0.005
Adjusted R^2		.622		.615		.622
F (p-value)		0.000		0.000		0.000
Durbin-Watson		1.573		1.538		1.513
Condition Index		25.707		24.405		21.055

Discussion

The results presented here provide further evidence that improvements in productivity have occurred over the last 20 years, with steady improvements in wheat yield and water use efficiency. The improvements in productivity are associated with increased nitrogen and phosphorous use, herbicide use, higher seeding rates and management performance. There is also qualitative evidence to suggest that the widespread adoption of one pass operations or no-tillage systems has been an important complementary factor. This study was not able to measure the impact of plant breeding through selection of appropriate cultivars and seeding times on productivity except that farmers appear to be adopting the newer varieties.

However, the recommendation by DAFWA to use a good legume rotation may not be as relevant. Farmers have decreased their percentages of legumes in the rotation (Figure 1) and yet have increased water use efficiency (Figure 3). In the regressions (Table 1), 'percentage legumes in the rotation' was also not significantly related to wheat yield. In the in-depth interviews farmers indicated they had decreased the use of legumes for economic reasons, partly related to the lower returns from legume enterprises. This is a logical response from rational decision makers and it appears this has not resulted in lower yields, which means that rotations with lower proportions of legumes are more profitable. While not measuring exactly the same thing, the analysis of total factor productivity by Alexander and Kokic (2005) also found a negative relationship between 'pasture area as a proportion of total rotation area' and total factor productivity. However, fertilizer nitrogen could be substituting for legume nitrogen in the rotations and 'pasture' has a fairly loose definition with farmers, varying for excellent legume stands to weedy fallows.

It is not surprising that there should be evidence of misspecification problems in the regression analysis as the model presented excludes many potentially important variables due to lack of data such as soil type, cultivars, seeding rates and other important variables that may influence drop productivity. It would be valuable to have measures of soil type, nutrient levels, weed burdens, cultivars and seeding rates to enable further comparison with high yield package recommendations. Evidence from the ABARE study of total factory productivity using surveys of farmers by Alexander and Kokic (2005) found factors such as tillage methods, some agronomic practices, significant degradation problems and farmer characteristics (e.g. participation in demonstrations/field days, completion or participation in university or TAFE, use of external advice, off-farm wages and off-farm investments as a proportion of total farm cash receipts) had a significant impact on total factor productivity. A review of the relative contributions of agronomy and plant breeding to improvements in wheat yields in WA by Anderson et al. (2005) provides some other possibilities. It might prove beneficial to include some of these variables in the benchmarks collected by Planfarm to enable greater analysis of their impact on profitability and productivity. In addition, further work is required to examine the possibility of misspecification due to functional form.

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