How important is season specific or soil specific wheat agronomy in southern Australia?

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Abstract

Historical sequences of wheat yield for locally relevant soil types, cultivars and agronomy for locations spanning southern Australia were obtained from the National WhopperCropper database. At each location, wheat performance was simulated in response to a factorial combination of agronomic treatments, including wheat variety, time of sowing and nitrogen management. Sources of variation, including main effects and interactions of season, soil type and agronomic treatments were assessed using RxAPSIM..

Year was the dominant component of variance at lower rainfall locations in WA and SA and all locations in NSW. Agronomy dominated at higher rainfall locations in WA and SA. Locations in VIC were between these two. The contribution of agronomy independent and dependent on rainfall (strategic and tactical agronomy respectively) has important implications for research, development, extension and management.

Key Words

Wheat, yield variability, soil type, season, agronomy

Introduction

Farmers work within a domain of possible yields, a yield space, which is constrained by the response of yield to soil type, season and agronomy. The size of the yield space is determined by variability in yield and the its shape is determined by sensitivity to treatments Understanding the nature of a yield space and the opportunities and risks it presents is the basis of adaptive agronomy and of agronomic services in Australia.

The concept of yield space was introduced by Abrecht *et al.* (2004) and used to examine the influence of a range of agronomic treatments on wheat yield on a range of soil types at Cunderdin and Merredin (Abrecht *et al.* 2006). Both these studies used APSIM wheat v1.55 to simulate wheat yield and both studies viewed the yield space from detailed aspects of agronomy such as time of sowing, variety and nitrogen fertilizer applications. The 2006 study considered that the yield space may change depending on whether the observer took an historical, landscape view or a within-season, within-soil-type view.

APSIM wheat successfully simulates crop performance in dryland wheat crop systems (Asseng 2004). APSIM simulation models have been used to predict the domain of possible yield for specified management decisions in Farmscape (Carberry *et al.* 2004), Yield Prophet and WhopperCropper (Nelson *et al.* 2002). In these examples, simulation is targeted toward specific situations with dimensions of the yield space limited to the dimensions of the decision, for example time of sowing, cultivar or application of fertilizer nitrogen.

We analysed simulated historical sequences of wheat yield to describe wheat yield space in southern Australia. The objective was to identify the factors explaining the majority of the variability. The implications of the results for investment and practical agronomy are discussed.

Methods

Simulated historical sequences of wheat yield for factorial combinations of agronomic treatments applied to a range of soils initialized at a range of soil water content were used to examine the principal influences on wheat yield at locations spanning the southern Australian wheatbelt (Table 1). Wheat yield data came from the National WhopperCropper project which coordinated simulation of wheat production across Australia based on locally relevant soil parameters and agronomic treatments (Nelson *et al.* 2002).

Simulation of wheat performance

Wheat production was simulated using APSIM wheat version 5.1. APSIM is an integrated set of simulation tools for agricultural systems (Keating *et al.* 2003) using historical climate data, soil and crop parameters as a basis for simulating historical sequences of wheat yield. In the main, wheat yield sequences were simulated for similar soil types and agronomic treatments at all locations within each state (Table 1).

Table 1. Site details, soils and number of agronomic treatments and soil water treatments.

					Soils	Treatments	
Location	Lat.	Long.	Elev (m)	Year range	PAWC (mm) †[1]	Agronomy (number)†[2]	Soil water @ April 1
	Western Australia (WA)						PASW (mm)
Mingenew	-29? 12	115? 26	153	1913-2006	63 76 83w 83nw 146	16800[a]	0 30
Mullewa	-28? 32	115? 30	282	1913-2006	63 76 83w 83nw 146	16800[a]	0 30
Brookton	-32? 22	117? 00	250	1913-2006	63 76 83w 83nw 146	16800[a]	0 30
Cunderdin	-31? 39	117? 14	221	1913-2006	63 76 83w 83nw 146	16800[a]	0 30
Merredin	-31? 29	118? 17	315	1913-2006	63 76 83w 83nw 146	16800[a]	0 30
Southern Cross	-31? 14	119? 19	355	1913-2006	63 76 83w 83nw 146	16800[a]	0 30
Kojonup	-33? 50	117? 09	305	1913-2006	63 76 83w 83nw 146	16800[a]	0 30

Lake Grace	-33? 06	118? 28	286	1913-2006	63 76 83w 83nw 146	16800[a]	0 30
	South Australia (SA)						% PAWC
Minnipa	-32? 51	135? 09	152	1913-2005	50 75	11520[b]	0 25 50 75
Maitland	-34? 23	137? 41	186	1913-2005	40 47 70 75 133	9216[c]	0 25 50
Lameroo	-35? 20	140? 31	99	1915-2006	**95** 112 115 132 **145** 180	17280[d]	0 25 50
	Victoria (VIC)						% PAWC
Birchip	-35? 59	142? 54	102	1900-2004	**95** 112 115 132 **145** 180	27648[e]	33 66 100
Donald	-36? 22	142? 59	118	1890-2004	**95** 115 **145** 240	27648[e]	33 66 100
	New South Wales (NSW)						% PAWC
Temora	-34? 22	147? 32	292	1913-2007	77 80 120 150	6912[f]	33 66 100
West Wyalong	-33? 56	147? 12	255	1913-2007	110 110sc 150 190	6912[f]	33 66 100
Condobolin	-33? 05	147? 09	199	1913-2004	77 80 120 150	6912[f]	33 66 100

†[1] Western Australian soils include 83w (water logging) and 83nw (non-waterlogging); West Wyalong soils include 110sc with sub-soil constraints; soils with bold numbers in SA and VIC are similar to each other.
†[2] number of treatment combinations, similar letters indicate the same agronomic treatments

Soils, Soil water and Agronomic treatments

Soil and crop parameters and agronomic treatments for each location were defined in consultation with agronomists and varied in plant available water content (PAWC), soil nitrogen profile and rooting depth. Agronomic treatments and levels were chosen to provide a wide range of soil and seasonal conditions rather than to represent best practice (Table 2). Treatments simulating summer rain or effective fallow were implemented in two ways. At locations in WA, a set increment in soil water was imposed across all soil types on 1 April. At all other locations the treatment was imposed as a proportion of PAWC (Table 1).

Table 2. Treatments levels for agronomic factors used in the simulation studies.

				Nitrogen management			
	Time of Sowing	Cultivar	Density	Soil test	Sowing	Tillering	Heading
	Day of year†[1]	†[2]	pl/m^2	N kg/ha			
All WA	115 130 140 150 160 170 185	Q S	100	40 80	0 20 40 80	0 20 40 80 160	0 20 40
SA Minnipa	120 135 151 166 181	Q M S	150 200	50 75 100 150	0 20 40 60	0 25 50 75	0 25 50
SA Maitland	120 135 151 166	Q M S	150	50 75 100 150	0 20 40 60	0 25 50 75	N/A
SA Lameroo	120 135 151 166 181	Q M S	150	25 50 75 100	0 20 40 60	0 25 50 75	N/A
All Victoria	135 150 166 181	Q M S	100 150	25 50 75 100	0 15 30 45	0 15 30 45	N/A
All NSW	121 135 150	M S	75 150	25 50 100 150	0 25 50 75	0 25 50	N/A

†[1] non-leap years,120=30 April, 130=10 May, 140=20 May, 150=30 May, 160=9 June, 170=19 June, 180=29 June

†[2] wheat varieties, quick(**Q**), medium(M), slow(S)

Data analysis and interpretation

Factorial combinations of Soil (**S**), Soil Water at April 1 (**SW**) and Agronomic treatments (**A**) were simulated for each location in each Year (**Y**). Data for each location were summarised and the principal sources of variation in wheat grain yield were identified by analysis of variance components (Snedecor and Cochran 1982) using RxAPSIM functions developed for the R statistical System (D'Antuono 2008, R Development Core Team 2008). Variation in yield at a location was expressed as the proportion of the variance attributed to **Y**, **S**, **SW**, **A** and their interactions, **YxS**, **YxSW**, **YxA**, **SxSW**, **SxA**, **SWxA**. Residual variance includes all second and higher order interactions amongst treatment variables.

Results and Discussion

The locations used represented a wide range of seasonal rainfall and mean grain yield (Figure?1a). The relationship between standard deviation of yield and mean yield (Figure 1b) is consistent with an increase in the responsiveness of wheat yield and an increase in yield space (variance) in higher yielding environments.

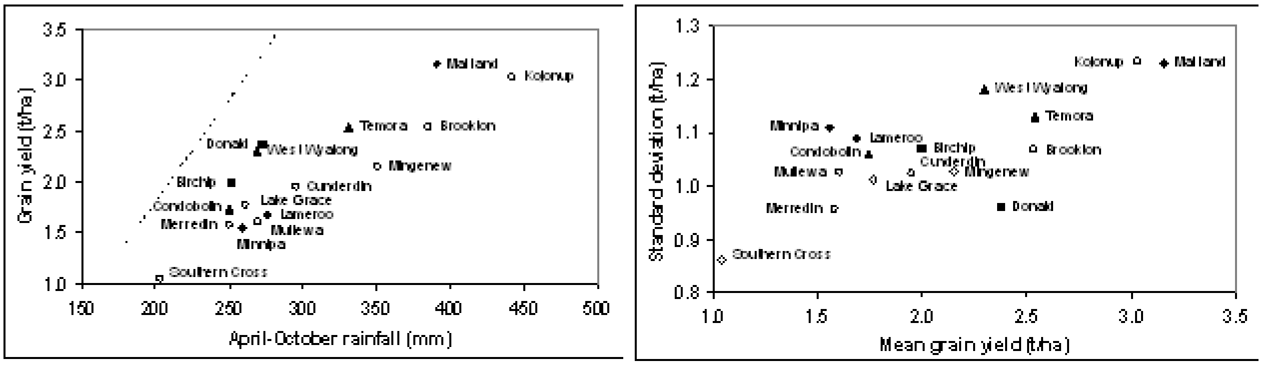

Figure 1. a. Increasing mean grain yield with mean growing season rainfall (April-October). Dotted line represents GY=0.015*(GSR-110) (French & Schulz 1984), b. Increasing standard deviation with mean grain yield for locations in WA (○), SA (u), Victoria (n) and NSW (▲). Mean grain yield calculated for treatments with plant available soil water (PASW) set at lower limit (WA), 25%PAWC (SA), 33% PAWC (Victoria and NSW) on April 1 in each year.

Variance components for WA locations are based on identical soils and agronomic treatments (Table 3). The dominant sources of variation are **Y**, **A** and **YxA**. As seasonal rainfall, mean yield and variability of the data increases the dominance of **Y** as a source of variation declines and the influence of **A** and **YxA** increases. **S** and its interactions, **YxS**, **SxSW**, **SxA** only accounted for 8–12% of variance at WA locations, with the exception of Brookton and Kojonup with 17% and 19% respectively. At the latter sites **S** accounted for most (13% and 12%) of this difference. **SW, YxSW** and **SxSW** show that 30mm added to soil water profiles on April 1 had a small (0-7%) influence on wheat yield with the least impact at Brookton and Kojonup.

Agronomy and its interactions accounted for 25% (Southern Cross) to 63% (Kojonup) of variance at locations in WA with notable influence of **A** at Brookton (32%) and Kojonup (40%) (Table 3). **A** represents the mean effect of agronomic treatments, an element amenable to strategic management, whereas interactions imply effects which are conditional upon other factors, such as season, **YxA**, soil, **SxA**, and soil water, **SWxA** and form the basis of tactical management. Realising benefits of conditional agronomy depends on identifying the conditions correctly, which, in the case of **YxA** implies knowledge of the season when agronomy is applied. 'Balance of agronomy' measures the relative influence of strategic agronomy and ranges from 45% for Mingenew and Mullewa to 63% for Brookton and Kojonup (Table 3). Variance due to **YxS** (season specific soil effects) and **SxA** (soil specific agronomy) was usually less than residual variance and considerably smaller than the influence of **S**, **A** or **Y**.

Minnipa, a strongly Mediterranean environment with soils of low PAWC, showed similar sources of variability to Southern Cross. Maitland, a high rainfall site on the Yorke Peninsula (SA), has a similar sized yield space and pattern of variance components to Kojonup and Brookton in WA, including the smaller relative influence of **Y**, importance of **S** and dominance of **A.**

Wheat yield space increased with rainfall and mean yield (Figure 1a & 1b) at NSW locations which all had similar patterns of variance components, including dominance of **Y**, strong influence of **S** and increasing balance of agronomy with rainfall (Table 3). There is a more even chance of rain throughout the year at NSW locations and the large **Y** component probably reflects annual variation in the distribution of rainfall.

Variance components for Birchip, Lameroo and Donald with identical soils and similar treatments (Table 3, data in brackets) show that, as the influence of **Y** increased, the influence of **A** declined. The balance shifted from dominance of strategic agronomy (Donald, 74%), toward more equal contributions of strategic and tactical agronomy at (Lameroo 56%). In contrast to Cunderdin, Merredin and Lake Grace in WA, there was a weaker influence of **S** at Lameroo and Birchip but a stronger influence of **SW** and **A**. The stronger influence of **SW** is probably due to the larger range of soil water treatments implemented at Lameroo and Birchip reflecting increased incidence of summer and autumn rain at those locations.

Table 3. Annual and growing season rainfall (GSR), mean, variance and variance components of wheat yield.

	Southern Cross	**Merredin**	**Mullewa**	**Lake Grace**	**Cunderdin**	**Mingenew**	**Brookton**	**Kojonup**	**Minnipa**	**Birchip †[1]**	**Lameroo †[1]**	**Donald †[1]**	**Condobolin**	**West Wyalong**	**Maitland**	**Temora**
State	WA	WA	WA	WA	WA	WA	WA	WA	SA	VIC	SA	VIC	NSW	NSW	SA	NSW
Mean rainfall (mm)																
Annual	296	328	334	355	367	406	454	530	346	368	386	400	444	459	501	542
GSR (April-October)	203	250	270	261	296	351	385	442	259	251	276	273	250	269	391	331
Wheat Yield (t/ha)†[2]																
Mean	1.22	1.76	1.75	1.96	2.09	2.25	2.61	3.06	1.85	2.35	2.11	2.67	2.07	2.58	3.56	2.70
Variance	0.74	0.91	1.01	1.02	1.05	1.05	1.14	1.52	1.23	0.85	1.19	0.92	1.12	1.39	1.52	1.53
Variance comp																

onents (%)																
Y	57	42	48	45	41	35	23	16	55	31 (35)	38 (44)	16 (22)	60	61	21	60
S	4	5	6	5	6	8	13	12	2	3 (4)	0 (1)	3 (2)	7	8	9	7
SW	4	3	2	3	2	1	0	0	5	8 (8)	10 (9)	5 (5)	6	2	6	1
YxS	3	3	3	3	3	3	4	3	1	1 (1)	0(0)	1 (1)	1	1	1	1
YxSW	1	1	1	2	2	1	1	1	3	6 (6)	4 (4)	6 (6)	3	3	4	2
SxSW	3	2	2	2	1	1	0	0	1	0 (1)	0 (1)	0 (0)	2	1	0	0
A	12	22	15	20	22	20	32	40	13	33 (27)	24 (22)	51 (45)	9	12	36	15
YxA	12	14	17	13	16	21	15	16	14	13 (13)	17 (18)	11 (13)	10	10	13	11
SxA	1	1	1	1	2	3	4	7	0	1 (1)	0 (0)	1 (1)	1	1	3	1
SWxA	0	1	0	0	0	0	0	0	1	2 (2)	2 (2)	3 (2)	1	0	2	0
Residual	4	5	5	5	6	6	7	6	4	2 (3)	4 (4)	3 (2)	2	2	6	1
Balance of agronomy	48	58	45	59	55	45	63	63	46	67 (63)	56 (52)	77 (74)	43	52	67	56

†[3]

†[1] figures in brackets for two Mallee sandy clay loam soils (PAWC 95mm & 145mm) at each site.
†[2] mean and variance for entire dataset
†[3] Strategic agronomy as a % of all agronomic variance components [A/(A+YxA+SxA+SWxA)]

Conclusion

The shape of the wheat yield space is driven by **Y** and **A** and their interactions, with **S** and **SW** as second order influences. The influence of soil specific agronomy was small compared to other sources of variance.

Impacts of **Y** and **A** varied amongst locations with Temora, West Wyalong and Condobolin showing the largest influence of **Y** and Brookton, Kojonup and Donald with the smallest. Brookton, Kojonup, Maitland , Birchip and Donald showed strong dominance (>60%) of strategic agronomy whereas Mullewa, Mingenew, Southern Cross, Minnipa and Condobolin had >50% tactical agronomy. The largest component of tactical agronomy at all locations was season specific agronomy (**YxA**).

The relative contribution of strategic agronomy and tactical agronomy has important implications for research, development, extension and management because it indicates the complexity of the drivers of yield which influences uncertainty at all levels in the knowledge supply chain.

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