Changes in Characteristics of NSW Wheat Varieties, 1965-1997

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List of Acronyms and Abbreviations Used in the Report

ACIAR	Australian Centre for International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center (Mexico)
COD	Coefficient of Diversity
COP	Coefficient of Parentage
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GRDC	Grains Research and Development Corporation
IVYI	Index of Varietal Yield Improvement
NSW	New South Wales
WAA	Weighted Average Age
WCOD	Weighted Coefficient of Diversity
WCOP	Weighted Coefficient of Parentage

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Executive Summary

As part of a broader study of the genetic diversity of the wheat varieties that farmers grow, a study was made of the changes from 1965 to 1997 in wheat varieties grown in selected shires in NSW. The eight shires selected to represent farming systems across NSW were Wagga, Temora, Cowra, Carrathool, Lachlan, Coonabarabran, Gunnedah and Narrabri.

The varieties grown by farmers have continually changed, as growers sought the most appropriate mix of varieties for their environment. This study provides insights into the reasons for those changes and an assessment the impacts on the NSW wheat industry.

An average of approximately 8-10 wheat varieties were grown in each shire each year. Generally, three of those varieties were grown on a substantial proportion of the area; the minor varieties were either new varieties in the process of being built up to their peak adoption or older varieties in the stage of being replaced. In southern shires, there has been a tendency to reduce the total number of varieties grown each year, while in the northern shires the number of varieties grown has increased over the past 30 years.

The rate of turnover from old to new varieties has increased in the southern shires since the 1960s, but has slowed in the northern shires. The pattern of adoption and disadoption of varieties shows that, on average, varieties reached a peak share of 15% of the wheat area in the shire in the fifth year after release, but continued to be grown for a further 17 years.

The progress of breeders in developing both higher-yielding and higher-quality varieties has been notable over the past 30 years. Wheat yields increased markedly in all shires since 1965, at an average rate of 2.2% per year. When the relative yields from variety trials were weighted by the proportion of the area sown to each variety, the overall average rate of varietal yield improvement was 1.2% per year throughout the period. The rates of yield improvement were broadly the same in the southern shires as in the north. Thus, of the 2.2% per year increase in shire yields since the late 1960s, 1.2% is attributable directly to varietal improvement and 1.0% per year is due to other factors such as management and agronomic practices.

At the same time, the bread-making quality of the varieties grown in southern NSW has also increased markedly since the 1960s. In some northern shires, where Prime Hard wheats were already being produced in the 1960s, there has been little change in the overall bread-making quality of the varieties grown. In other shires, especially in the south and central west of NSW, there has been rapid growth in the bread-making quality of the varieties grown. On average, varietal quality for bread-making has increased at 1.2% per year over the period since 1965, a similar rate to varietal yield increases.

The relevance of NSW Agriculture s role in providing information and advice on varieties to growers is shown by the fact that farmers have generally grown the varieties on NSW Agriculture s list of recommended or approved varieties for each region, with an average of 81% of the area sown to such varieties each year. In addition, the majority of the varieties grown in each shire have been released by breeding programs in the local region.

As well as changing yield and quality of varieties, breeders have brought about a change in the morphological characteristics of the varieties that farmers grow. Over the period since 1965, varieties have generally become shorter, with stronger straw, a lighter coloured grain and more awned. There has also been a significant shift since the 1970s away from growing varieties with a mix of maturity types to a concentration on mid-maturing varieties.

There was little change in the diversity of the mix of varieties grown in most shires up to the 1980s, but there has been some decline in the level of varietal diversity in the southern shires in the 1990s. While the varietal mix has been changing, there has also been a decline in the underlying genetic diversity of those varieties. In some shires, the genetic diversity of the varieties grown has generally declined since the 1980s, raising some concerns about the capacity to manage crop pests and diseases in the future.

In summary, wheat growers in NSW have adopted the higher-yielding and higher-quality varieties from the wheat breeding programs, while relying strongly on Departmental advice on which varieties to grow. Together these changes have led to substantial benefits for NSW wheat growers. If farmers had continued using varieties with yields similar to those grown in 1965, their income would have been, on average across the eight shires analysed, $103 per hectare lower in 1997. However, in some areas, the concentration on a smaller number of varieties in recent years has raised some concerns that the genetic base of the varieties grown is becoming narrower and more vulnerable to pests and diseases.

In conclusion, it is clear from the results of the study that wheat breeders have provided valuable improvements in varieties for NSW farmers since 1965. The future of wheat growing in NSW will depend on maintaining the level of varietal improvements in the coming years.

Changes in Characteristics of NSW Wheat Varieties, 1965-1997

1. Introduction

The choice of which variety or varieties to grow is one that affects all aspects of a wheat farmer s productivity. The responses from all types of inputs are affected by the varieties that are grown. When examining the wheat varieties that farmers grow, one of the key features is the fact that they are continually changing. As breeding programs release new varieties with improved characteristics, growers change varieties. Sometimes those improvements result from the old varieties succumbing to evolving races of diseases or changes in the growing environment. In other cases, breeders can incorporate features that increase the yield potential or improve the market quality. The rate at which changes occur, and the way in which farmers change varieties are important factors in determining the level of economic well-being in the wheat industry.

As part of a broader study of the genetic diversity of the wheat varieties that farmers grow (see Meng and Brennan 2001), changes in wheat varieties in NSW have been studied. Data have been collected on the set of varieties that farmers grew in selected shires in NSW grew over a period from the mid-1960s to the late 1990s. That data set allows analysis of the changes that have occurred in NSW wheat varieties in that period, and enables considerable insights into the reasons for those changes and the impacts on the NSW wheat industry.

In this report, the shires used in the analysis are identified in section 2. A description of the data that have been collected is provided in the following section. In sections 4 to 6, changes over time in the varieties grown, their yield and quality and their other characteristics are identified and analysed. In section 7, changes over time in varietal diversity and the underlying genetic component of that diversity are analysed. In the final two sections, the implications of the results are outlined and some conclusions are drawn.

2. Shires Selected for Analysis

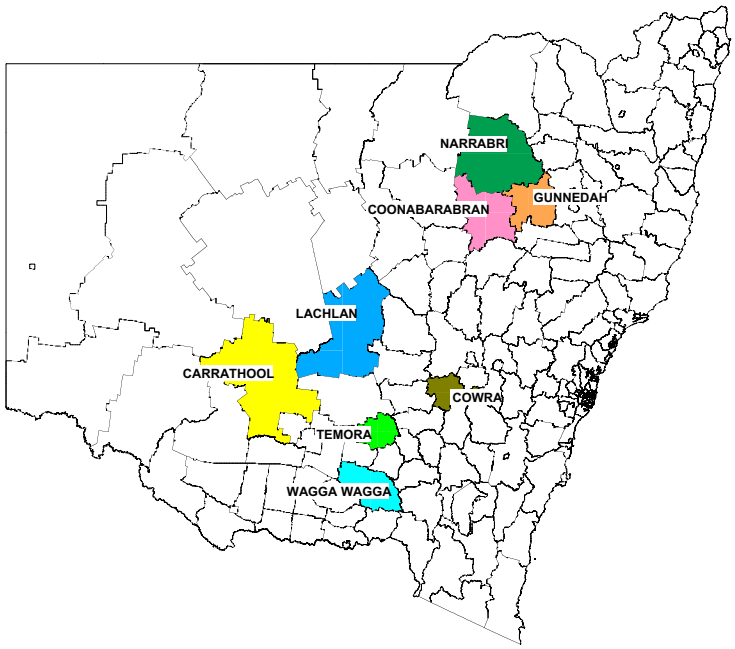
There are some 68 wheat-growing Local Government Areas (generally called shires) in NSW. A subset of eight shires was selected for data collection and analysis. The shires selected for analysis are shown in Table 2.1 (listed from south to north) and in Figure 2.1. The shires were selected on the basis of the following criteria:

- Representative of farming systems across NSW wheat belt
- Associated with research stations, where possible (to increase availability of data)

Table 2.1: Shires Selected for Analysis and Associated Data Points

Region	Shire	Silo
South	Wagga	Marrar
	Temora	Temora
	Cowra	Woodstock
	Carrathool	Hillston
North	Lachlan	Condobolin
	Coonabarabran	Baradine
	Gunnedah	Gunnedah
	Narrabri	Edgeroi

Figure 2.1: Shires Selected for Analysis



Some recent wheat area, yield and production data for each of the selected shires are shown in Table 2.2. Lachlan, Narrabri and Carrathool shires have the highest average area sown to wheat, while Cowra, Wagga and Temora have the highest average yields. Between them these shires represented 21% of the area and production of NSW over that period, and the weighted average yield per hectare of the eight selected shires is marginally higher than the State average.

Table 2.2: Wheat Production Data for Selected Shires, Average of 1990-1997

	Area sown (000 ha)	**Production (000 t)**	**Yield (t/ha)**
Wagga	23	62	2.6
Temora	33	87	2.5
Cowra	14	41	2.9
Carrathool	83	151	1.7
Lachlan	149	239	1.5
Coonabarabran	22	48	2.0
Gunnedah	44	105	2.3
Narrabri	94	202	2.0
- Total (8 shires)	***462***	***935***	***2.0[a]***
NSW State average, 1990-97	2213	4441	1.9
- Selected shires as % of NSW	*21%*	*21%*	*106%*

a: Weighted average across the 8 selected shires
Source: Australian Bureau of Statistics.

3. Data on Varietal Characteristics

3.1 List of Varieties

All varieties grown in each shire in the period 1965 to 1997 were identified (see section 3.3 below). Varieties for which there were ten or fewer shire-by-year observations across all shires AND which reached a maximum in any one shire of less than 5% of the area were excluded from the list. The result was a set of 56 varieties, covering at least 80% of the area sown to known varieties in each shire in each year (in some shires in the 1960s, the Other / Unknown category reached 15% in some years). The common set of varieties was used across all shires, with most varieties only being grown in some of the shires, because of the environmental differences between the north and the south of the state. A list of the varieties selected for the analysis is shown in Table 3.1.

Table 3.1: List of Varieties Included in Analysis

Variety	Year of release	Variety	Year of release
Bencubbin	1929	Banks	1979
Gabo	1945	Harrier	1981
Insignia	1946	Sunkota	1981
Pinnacle	1946	Hartog	1982
Glenwari	1948	Kamilaroi (D)	1982
Spica	1952	Suneca	1982
Olympic	1956	Osprey	1983
Winglen	1957	Quarrion	1983
Heron	1959	Sunstar	1983
Falcon	1960	Takari	1983
Gamenya	1960	Corella	1984
Mengavi	1960	Sundor	1984
Festivguay	1963	Sunelg	1984
Mendos	1964	Rosella	1985
Gamut	1965	Vulcan	1985
Robin	1966	Sunco	1986
Timgalen	1967	Dollarbird	1987
Eagle	1969	Hybrid Meteor	1987
Gatcher	1969	Yallaroi (D)	1987
Teal	1972	Miskle	1988
Condor	1973	Janz	1989
Egret	1973	Cunningham	1990
Kite	1973	Sunbri	1990
Songlen	1975	Batavia	1991
Cook	1977	Sunstate	1992
Shortim	1977	Swift	1993
Millewa	1978	Wollaroi (D)	1993
Avocet	1979	Sunbrook	1995

D: denotes durum wheat variety

3.2 Variety Breeding Program and Year of Release

Data on the year of release of each variety and the breeding program developing the variety (Table 3.1) were obtained from Fitzsimmons (1998) and Macindoe and Walken Brown (1966) (see Appendix A). From these data, the varieties that were bred locally for each shire were identified. The local varieties for southern shires (Wagga, Temora, Cowra and Carrathool) were those released by the breeding programs at Wagga and Temora. Local varieties for the other shires were those released by the breeding programs at Narrabri, Tamworth or Glen Innes.

3.3 Variety Share Data

From 1962 to 1988, data were taken from Fitzsimmons (1991), which is a compilation of data from the Australian Bureau of Statistics (ABS). The ABS data were the percentage of the area of wheat sown to each variety in each shire, and were collected in an annual census of all farms.

From 1990 to 1997, the only available variety data were the percentage of wheat receivals at local silos, and were obtained (on a confidential basis) from the AWB Limited (formerly the Australian Wheat Board). Thus, it related to production delivered by farmers to a local silo rather than area sown. This discontinuity in the series was taken as unimportant, and the series of variety share was assumed to be a comparable one, whether the share referred to area or production. The silo data did not refer to the same geographical area as the share area data, since there are generally more than one silo in each shire (often more than 10). To provide comparable data, a representative silo was selected in each shire (Table 2.1), and the variety share data for that silo taken to represent that of the shire as a whole. This, of course, was subject to error, but was taken as the best practical approach, given the limited data.

No data were available from either source on variety share for 1989, so the data were interpolated from 1988 and 1990 data.

3.4 Relative Yield Data

Variety yield data were taken from all advanced (S4) variety trials conducted by NSW Agriculture from 1982 to 1998. All sites within the selected shires in those years were combined, and the trial yields analysed to provide a ranking of all varieties against standard varieties. Where these data did not provide coverage of varieties, selected years of trials at sites (obtained from NSW Agriculture s annual publication *Winter Crop Variety Trial Data*) within the selected shires were added. A number of years of additional data were needed in each shire to obtain a full comparable set of relative yields for all the varieties grown in that shire. For convenience, relative yields obtained in this way for each shire were then expressed as a percentage of Banks (a widely-grown variety released in 1979). The relative yields for each variety in each shire are shown in Appendix B.

3.5 Variety Maturity

Varieties were classified into three maturity types: Late-maturing (or early -sown), Mid-maturing (or mid-sown), and Early-maturing (or late-sown). Information for classifying varieties was obtained from the following sources:

- NSW Agriculture s annual *Winter Cereal Sowing Guide,* 1985 to 1997

- Maturity estimates from early, mid and late sowing recommendations in NSW Agriculture s *Winter Cereal Variety Guide* (1979 to 1984)
- NSW Agriculture s *Agricultural Gazette* to 1978.

The classification of each variety is shown in Appendix A.

3.6 Variety Bread-making Quality

Varieties were assessed for their bread-making quality, on a scale of 1 to 10, with 10 being perfect for bread-making. The scores were obtained from the following two sources:

- Antony and Brennan (1988)
- Scores for more recent varieties were made by J. Oliver and H. Allen, NSW Agriculture (Personal communication, April 1999 and January 2000)

The scores were such that durum varieties were rated as 1 , and biscuit wheat varieties were rated 2 to 3 . Scores for each variety are shown in Appendix A.

3.7 Other Variety Morphological Characteristics

Data on the morphological characteristics of varieties were obtained from the variety registration papers where available, and in some cases the published records of new varieties. Some gaps with missing data were filled by personal communication with Peter Martin, NSW Agriculture s wheat breeder at Wagga. Data were obtained on the following characteristics:

- Growth habit (1=winter, 2=spring, 3=facultative)
- Stature (1=very short, 2=short, 3= short-medium, 4=medium, 5=medium-tall, 6=tall)
- Straw strength (1=weak, 2=weak-medium, 3=medium, 4=medium-strong, 5=strong, 6=very strong)
- Grain colour (1=light, 2=light-medium, 3=medium, 4=medium-dark, 5=dark)
- Awns (1=full, 2=full-half, 3=half, 4=half-tip, 5=tip)
- Head density (1=dense, 2=dense-medium, 3=medium, 4=medium-lax, 5-lax)
- Glume colour (1=white 2=brown 3=black)

The data on the morphological characteristics are shown in Appendix A.

3.8 Recommendation Status of Varieties Grown

Each year, NSW Agriculture has provided guidance to growers on the varieties that are suitable for growing in that environment at that time. Until 1985, that guidance was in the form of an annual list of Recommended varieties for each region. In more recent years, the list has been of Approved varieties rather than Recommended . The recommendation / approval status of varieties in each shire in each year has been taken from the following sources:

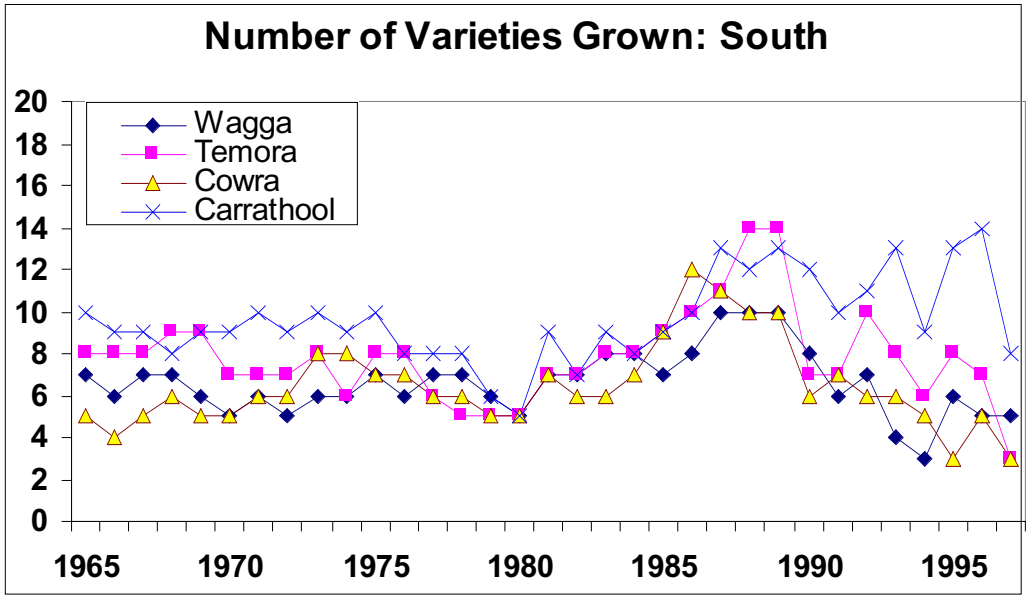
- 1965-1979: Varietal recommendations sourced from NSW Agriculture s *Agricultural Gazette of NSW*.
- 1980-1997: Varietal recommendations and approvals sourced from NSW Agriculture s annual *Winter Cereal Sowing Guide.*

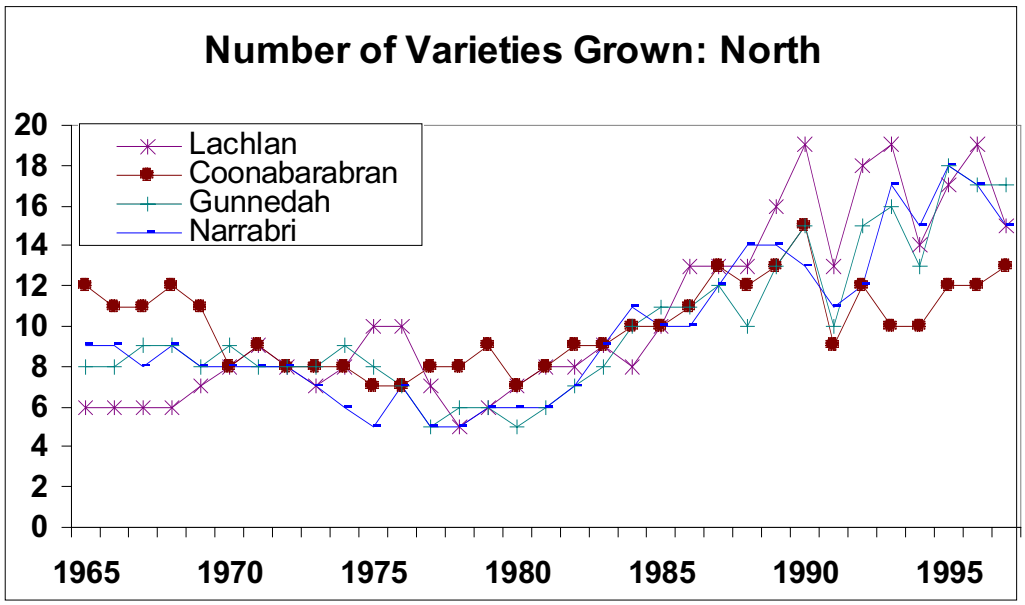
4. Changes Over Time in Variety Share

4.1 Number of Varieties Grown

The number of varieties grown in each shire each year is shown in Figure 4.1. In southern shires, the number of varieties grown each year was relatively steady from the 1960s to the mid-1980s, when the number increased. Since that time, there has been a decline in three of the four southern shires. In the northern shires, the number of varieties grown each year has increased strongly since about 1980.

Figure 4.1: Number of Varieties Grown, by Shire





On average, almost 9 varieties were grown each year in each shire (Table 4.1), two-thirds of which were each grown on less than 10% of the area. However, at different times, between 3 and 19 varieties were grown in one year in a shire. In the southern shires, there was a tendency to grow fewer varieties (average 7.6), compared to the northern shires (average 10.1).

Table 4.1: Number of Varieties Grown in Each Shire

	Total Varieties Grown			Varieties Grown on >10% of area		
	Mean	**Maximum**	**Minimum**	**Mean**	**Maximum**	**Minimum**
Wagga	6.6	10	3	2.8	4	2
Temora	7.8	14	3	2.8	5	1
Cowra	6.5	12	3	2.5	4	1
Carrathool	9.6	14	5	2.9	4	1
- Southern shires	*7.6*	*14*	*3*	*2.8*	*5*	*1*
Lachlan	10.5	19	5	2.7	4	1
Coonabarabran	10.1	15	7	3.2	5	2
Gunnedah	10.0	18	5	3.2	5	1
Narrabri	9.8	18	5	3.4	6	2
- Northern shires	*10.1*	*19*	*5*	*3.1*	*6*	*1*
All shires	**8.9**	**19**	**3**	**3.0**	**6**	**1**

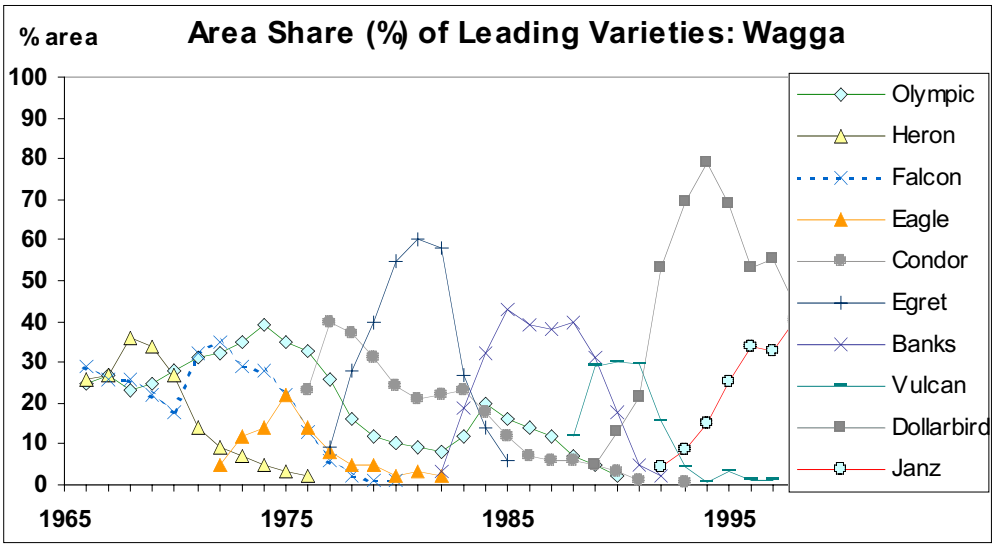
An indication of the balance in the mix of varieties is the number that was grown on 10% or more the area each year. In most shires, there was at least one year in which only one variety was grown on more than 10% of the area. In particular shires, there were years in which up to six varieties had at least a 10% share of the area, with the overall average being three varieties per shire each year. The differences between northern and southern shires were slight, but there was a slight tendency for the southern shires to have fewer varieties with significant share of the area.

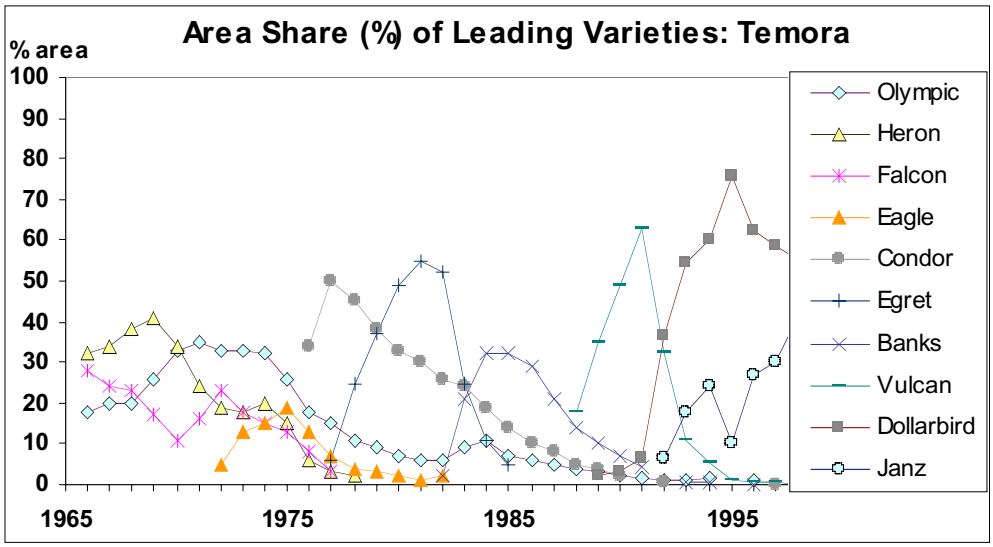
4.2 Variety Area Share Data

At a shire level, the mix of varieties grown in any season is determined by the aggregate of the decisions of all the wheat growers in the shire. Individual wheat growers generally grow more than one variety each year, and they change varieties regularly. In aggregate, then, the area shares of different varieties are constantly changing.

The area shares for each of the eight selected shires for the major varieties (defined as those reaching a maximum of greater than 10% of the area sown) are shown in Figure 4.2. The ever-changing pattern of variety use in each shire throughout the period is evident.

Figure 4.2: Area Share of Major Varieties, by Shire





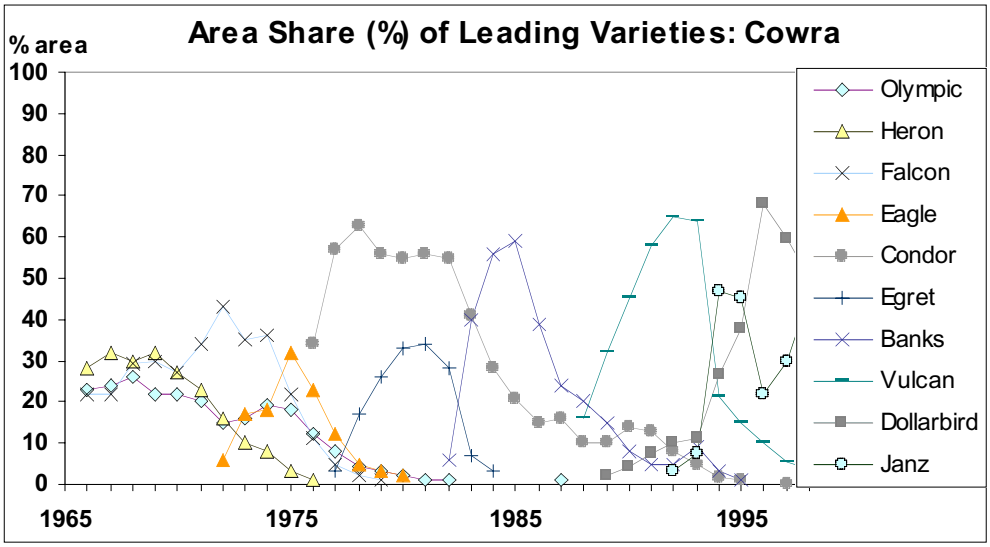
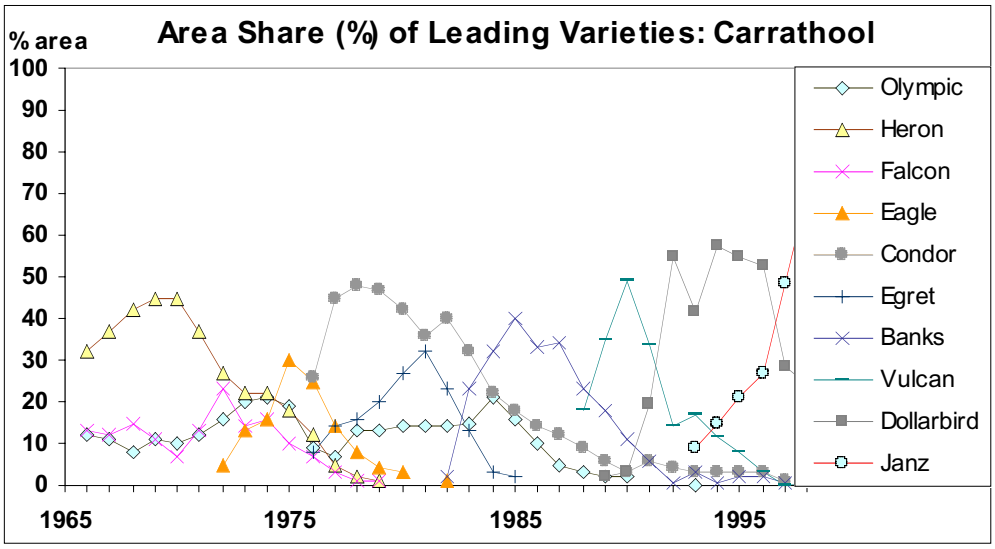
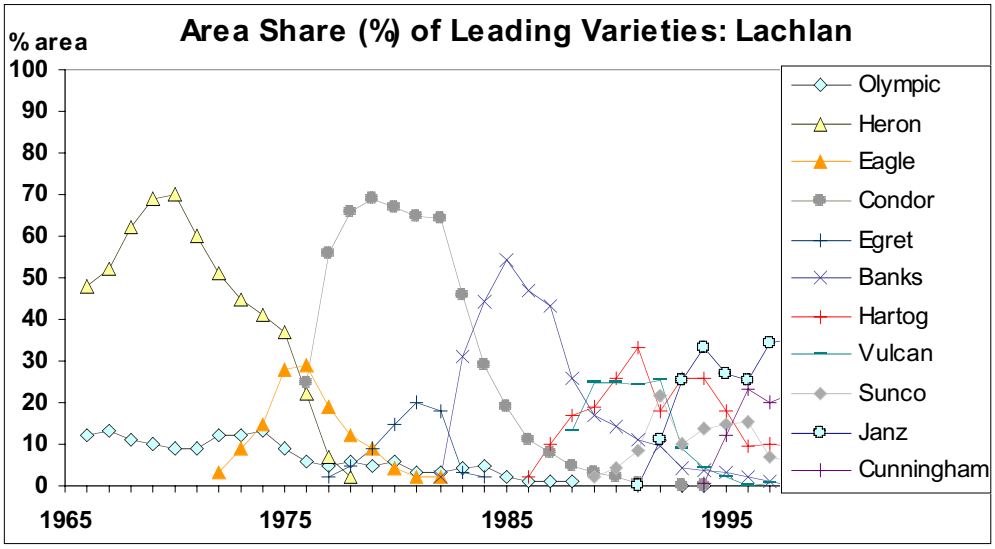


Figure 4.2 (continued): Area Share of Major Varieties, by Shire





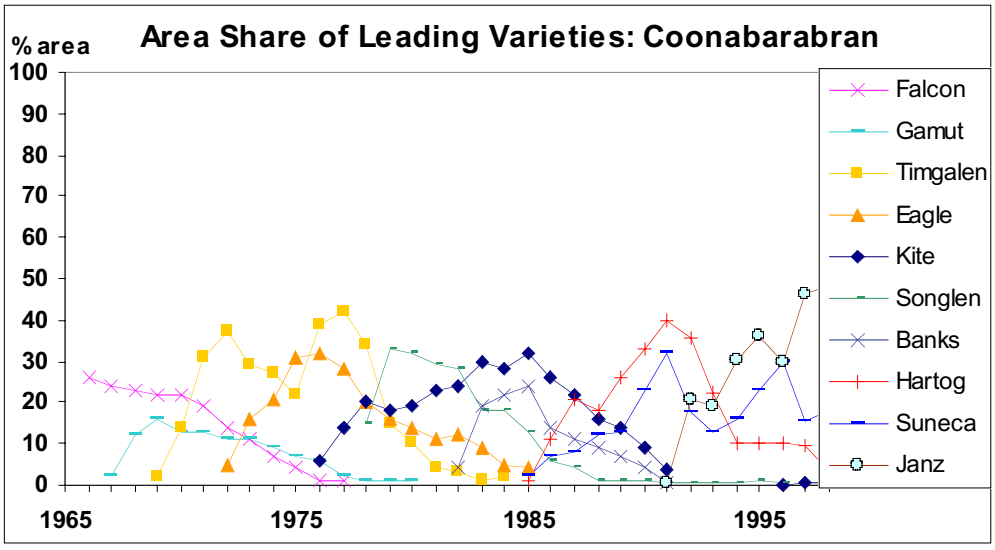
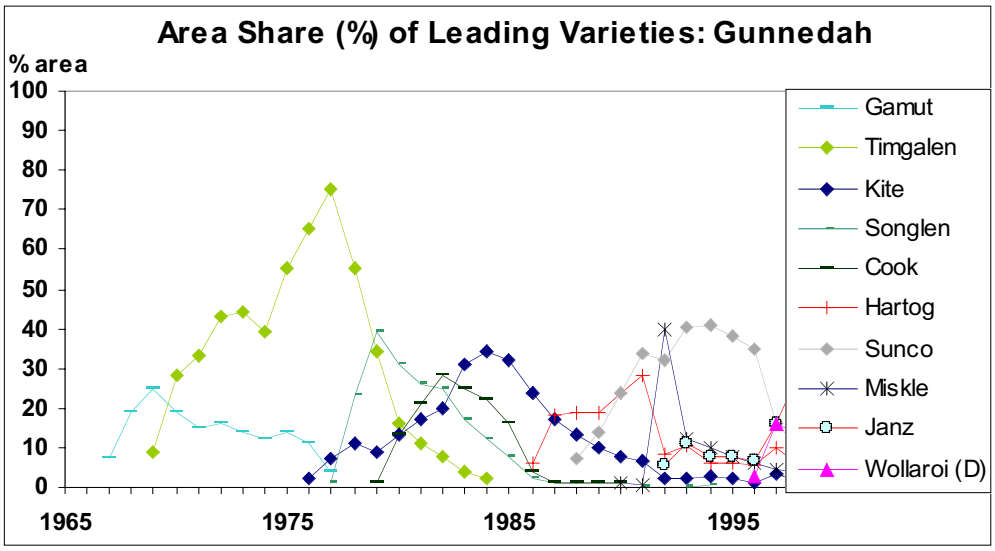
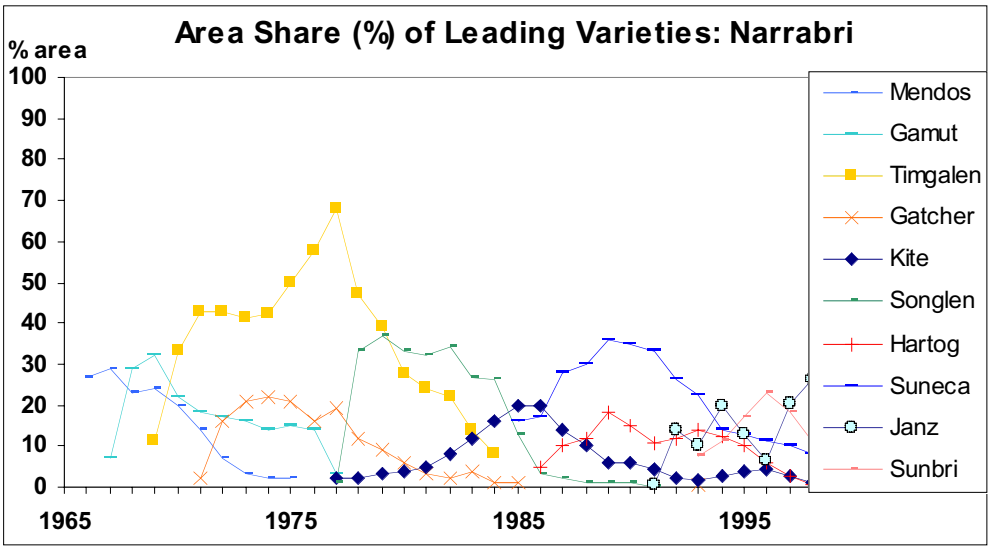


Figure 4.2 (continued): Area Share of Major Varieties, by Shire

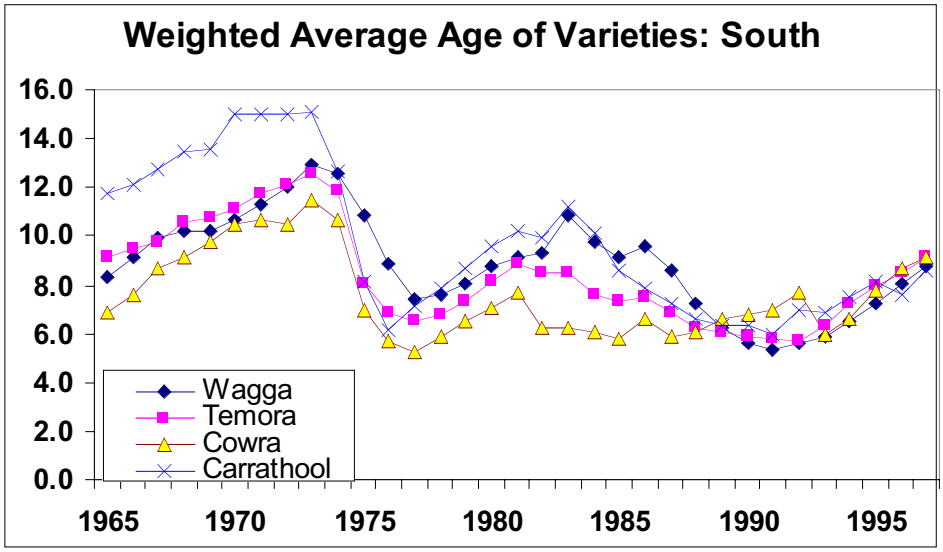


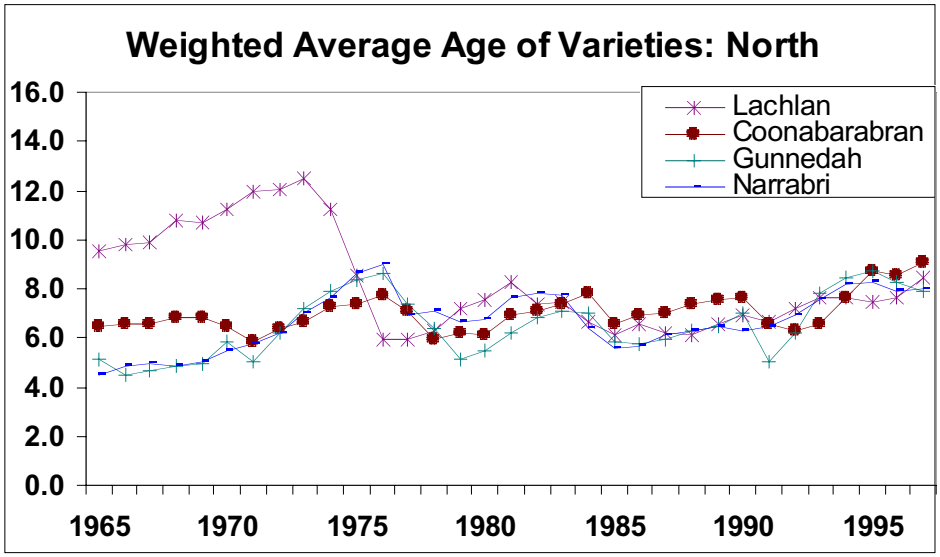


4.3 Rate of Varietal Turnover

The rate of varietal change over time (varietal turnover) can be measured by the Weighted Average Age (WAA) of varieties (Brennan and Byerlee 1991). The higher the WAA, the slower the rate of varietal change. In Figure 4.3, the WAA is shown for each shire. The tendency for the WAA for different shires to move together is evident. This reflects the common degree to which farmers in shires across NSW change varieties as superior varieties become available or as varietal resistance to diseases breaks down across the different environments in the state.

Figure 4.3: Weighted Average Age of Varieties, by Shire





The WAA was 7.9 years overall across all shires (Table 4.2). In the southern shires, the WAA was 8.6 years, compared to 7.1 in the northern shires. However, from the 1970s, there has been a trend towards a more rapid rate of varietal change in the southern shires, and a slight

slowing of varietal change in the north. Nevertheless, the WAA was generally lower in the north than in the south in the 1990s. The five southern-most shires had a significantly lower WAA in 1990s than in 1960s, but the three northern-most shires had an increased WAA.

These rates of varietal turnover are generally faster than a number of regions and countries in the developing world in 1990, where the WAA ranged between 8.0 and 14.7 (Smale and McBride 1996). Brennan and Byerlee (1991) had earlier found an overall average WAA of 7.2 years from 1970-86 across a wide range of countries. It is apparent in Figure 4.3 that the shires had quite different experiences in the 1960s and 1970s, but by the 1990s the WAA for each shire was converging on a common level of 7.0 to 7.5 years.

Table 4.2: Weighted Average Age of Varieties

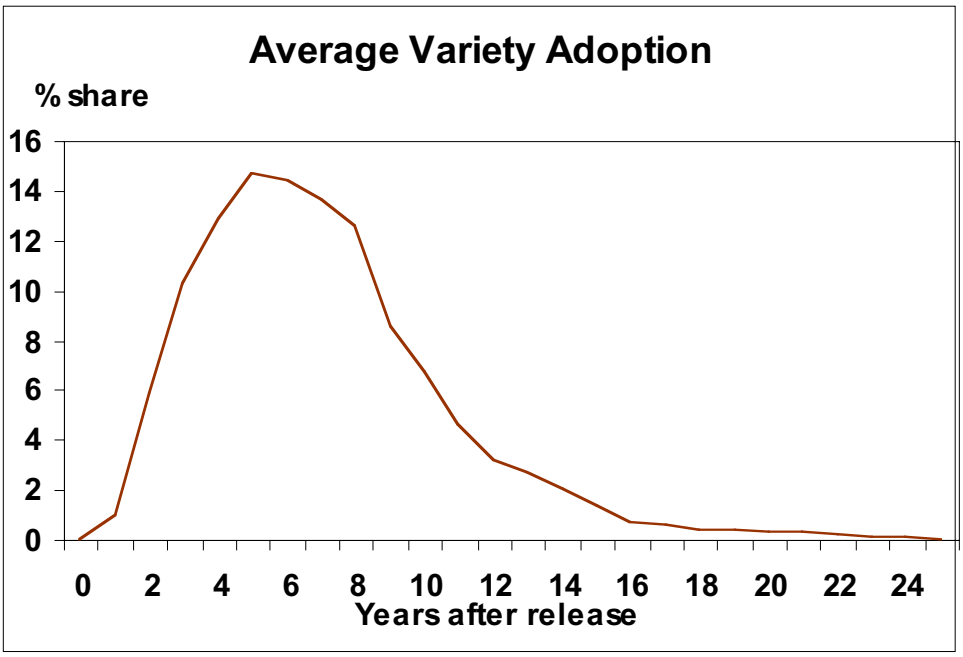
Shire	1960s	1970s	1980s	1990s	Overall
Wagga	9.6	10.2	8.9	6.6	8.8
Temora	9.9	9.5	7.6	7.1	8.4
Cowra	8.4	8.4	6.4	7.4	7.6
Carrathool	12.7	11.1	8.8	7.2	9.7
- Southern shires	*10.2*	*9.8*	*7.9*	*7.1*	*8.6*
Lachlan	10.1	9.3	6.9	7.5	8.2
Coonabarabran	6.7	6.7	7.1	7.6	7.0
Gunnedah	4.8	6.8	6.3	7.4	6.5
Narrabri	4.8	7.0	6.6	7.5	6.7
- Northern shires	*6.6*	*7.5*	*6.7*	*7.5*	*7.1*
All shires	**8.4**	**8.6**	**7.3**	**7.3**	**7.9**

4.4 Average Adoption/Disadoption Patterns of Varieties

Taking an average across all varieties and all shires[1], the average adoption/disadoption pattern is shown in Figure 4.4. The adoption pattern is for variety share to increase to a peak of 15% of the area five years after release, then for share to decline over the following 17 years. Total time to final disadoption of a variety averages 22 years. These results are generally similar to those reported in Brennan (1988) for three shires: Mitchell (part of Wagga), Narraburra (part of Temora) and Waugoola (part of Cowra) over an earlier time period (1950-1983).

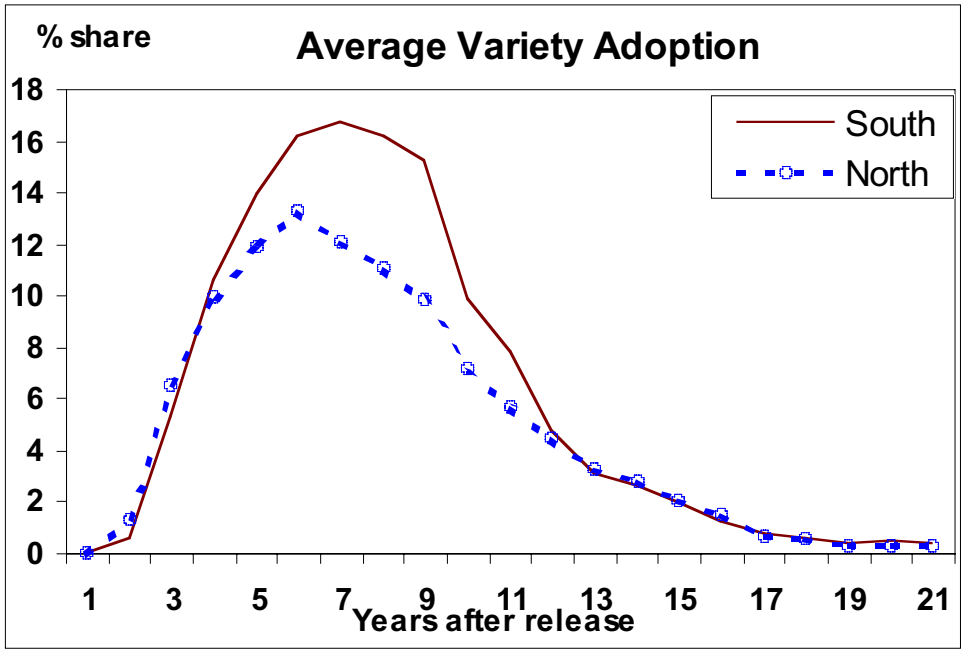
[1] To remove the bias from including unrepresentative varieties such as Bencubbin (released in 1929 and still grown up to 1968) and Olympic (released in 1956 and still grown in the 1980s), both were excluded from the data in estimating this average variety adoption pattern.

Figure 4.4: Average Adoption and Disadoption of Varieties



While the adoption patterns and life of varieties are essentially the same in the north and south of the state (Figure 4.5), the southern shires have a higher peak adoption, reflecting the smaller number of varieties grown (see section 4.1 above).

Figure 4.5: Average Adoption and Disadoption, Southern and Northern Shires

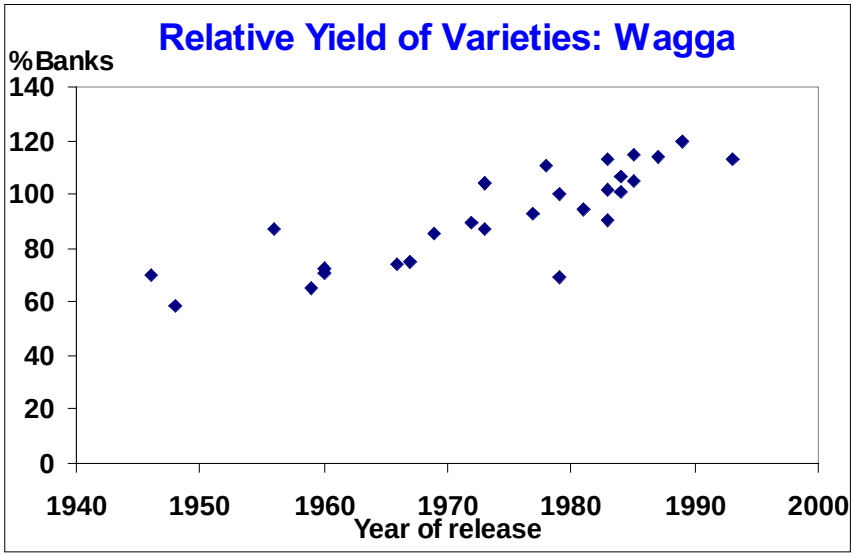


5. Changes Over Time in Yield and Quality of NSW Varieties

5.1 Relative Yields of Varieties

The relative yields (as measured in trials) of the varieties grown in each of the shires over the period are shown in Figure 5.1, in relation to the year of release of the varieties. Clearly, in each shire the yield level of varieties has increased with time. Varieties released in the late 1980s and 1990s show substantial increases in yield than those released in the 1960s, with increases in that time averaging 20%-60%. There are, however, varieties that have not yielded as well as their predecessors in the different shires, so that the progress is erratic at times.

Figure 5.1: Relative Yields of Varieties in Trials, by Year of Release, by Shire



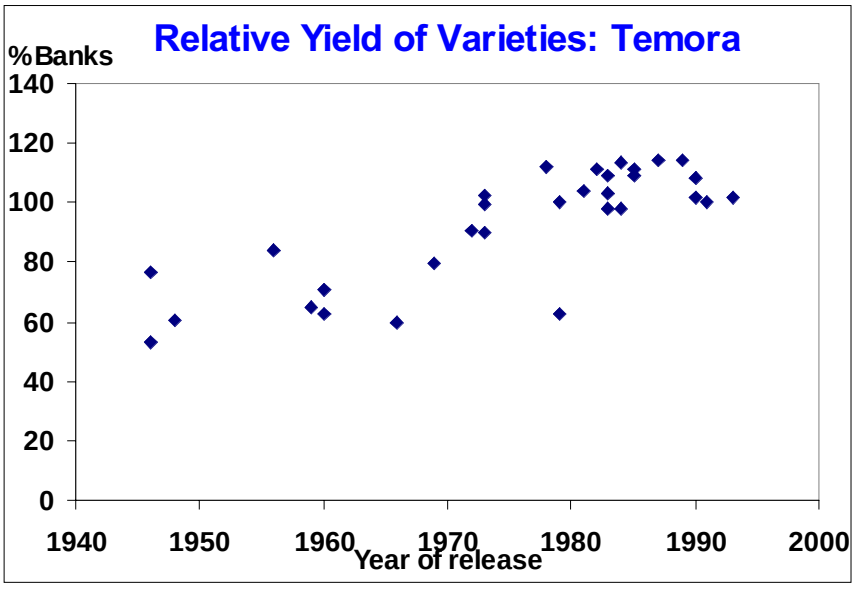
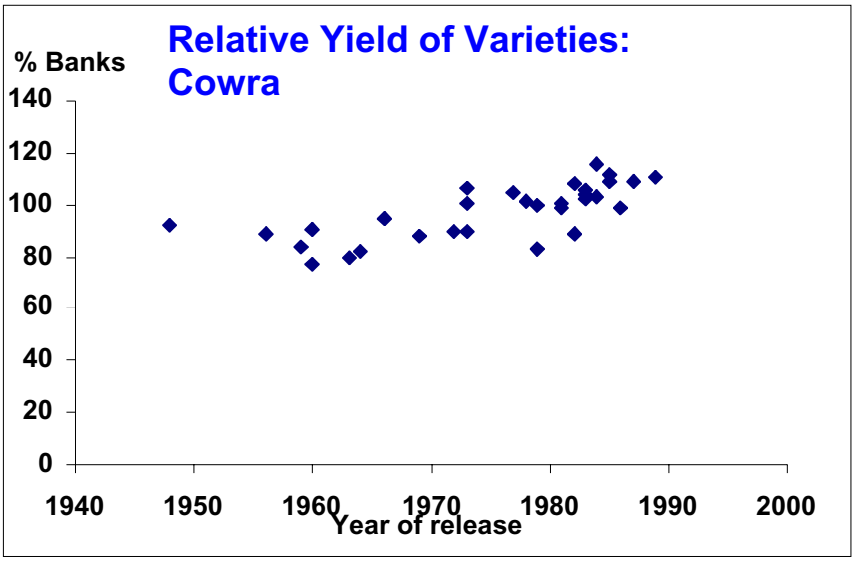
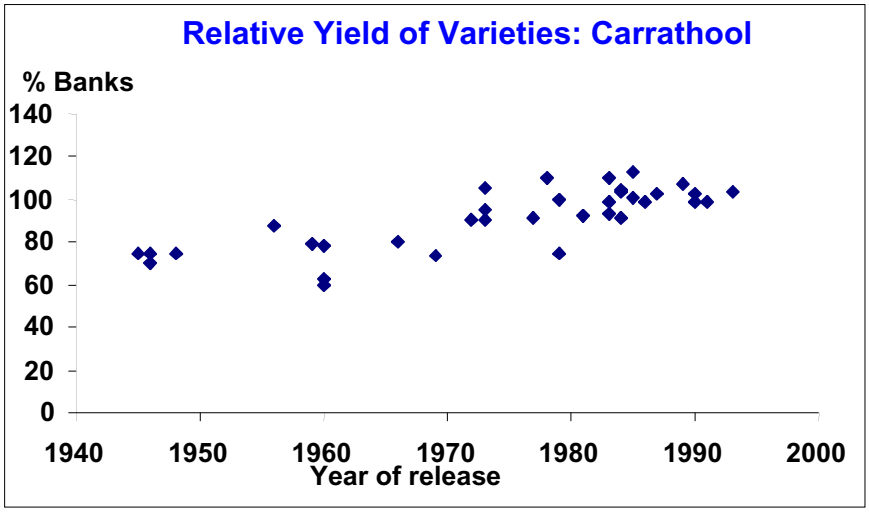


Figure 5.1 (cont d): Relative Yields of Varieties in Trials, by Year of Release, by Shire





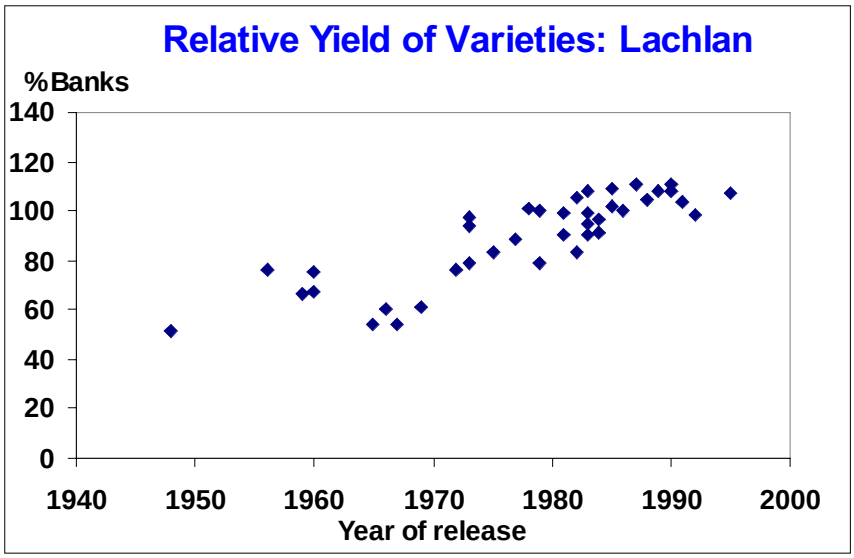
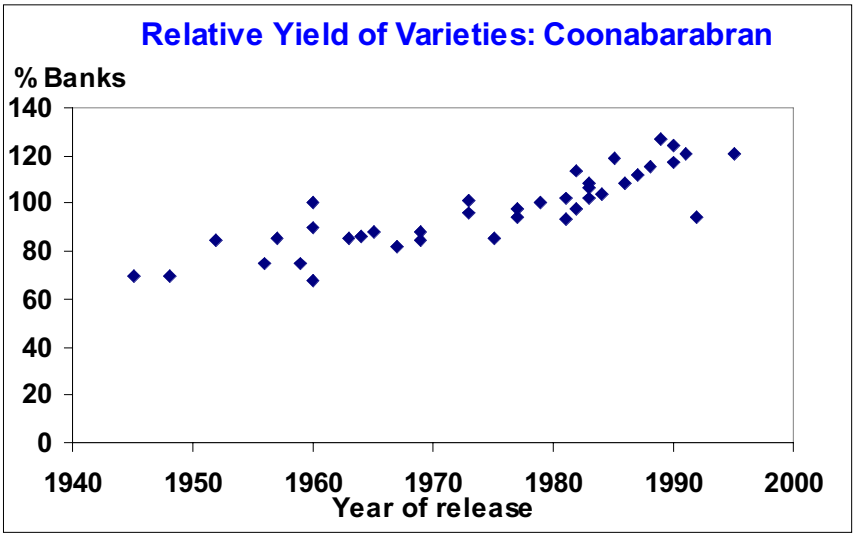
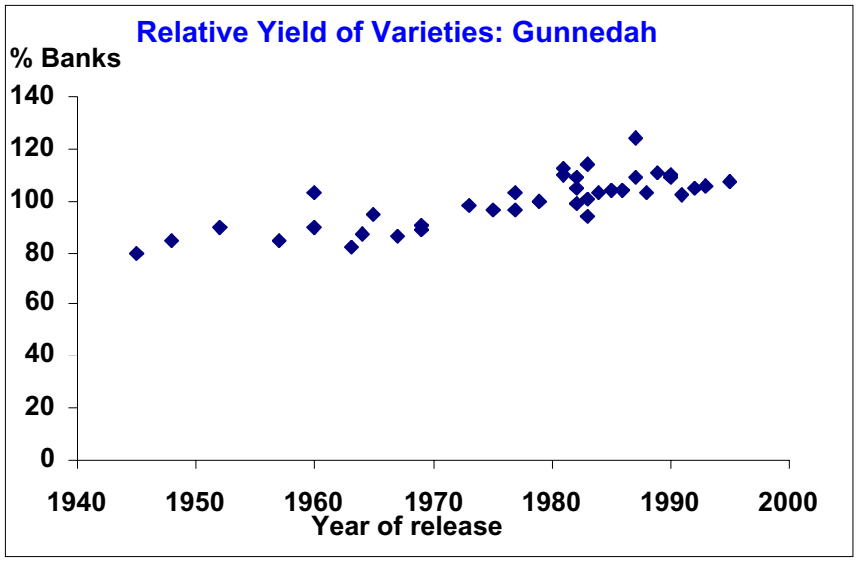
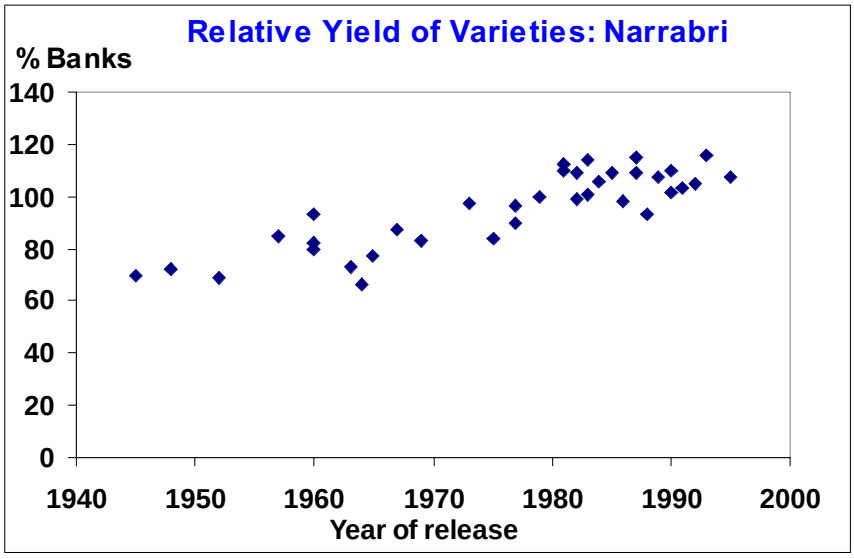


Figure 5.1 (cont d): Relative Yields of Varieties in Trials, by Year of Release, by Shire





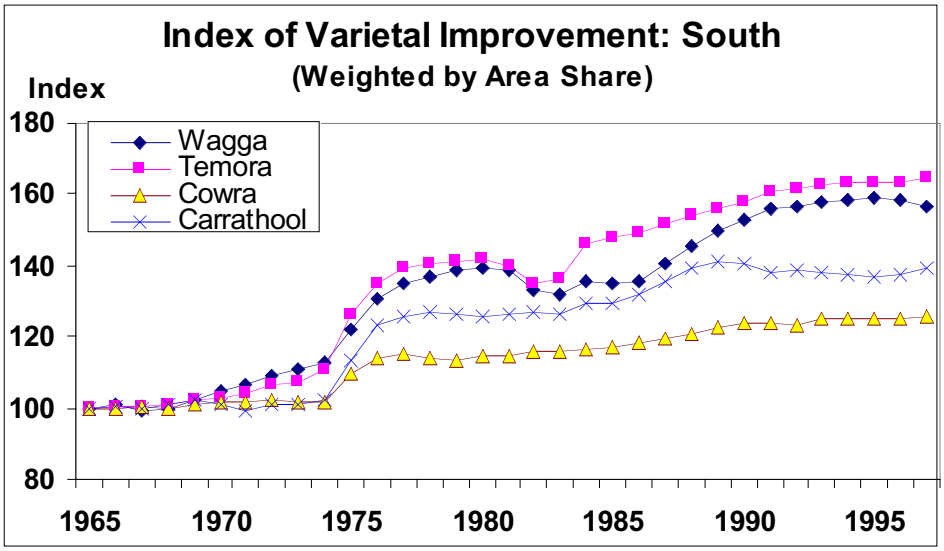


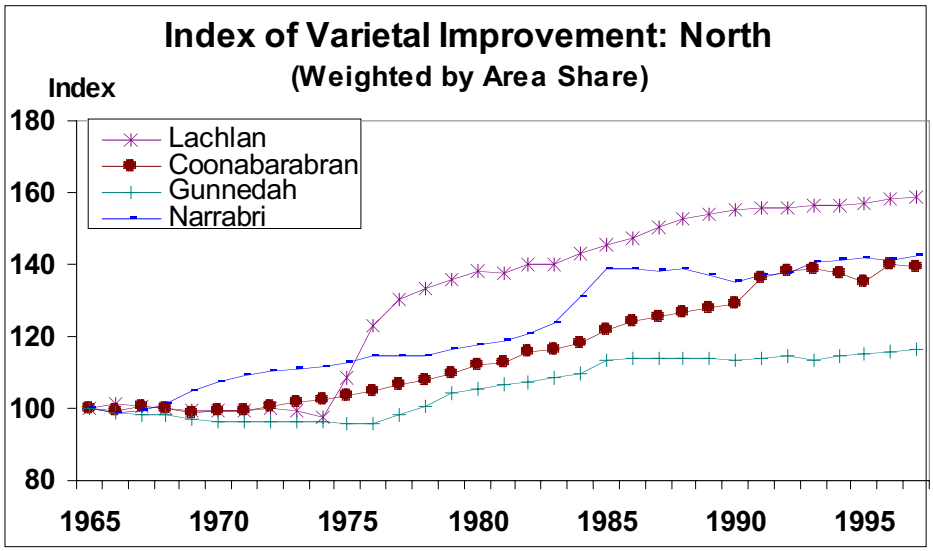
Because some specialty varieties are released from time to time for their quality or particular agronomic characteristics, it is logical that there will be some low-yielding varieties released at times. In addition, the different yield responses in the different environments mean that some varieties that yield relatively well in the higher rainfall areas yield poorly in the drier environments. The varieties shown are all those that have been included in yield trials in each shire, rather than merely those that have been grown in each shire.

5.2 Weighted Index of Varietal Yield Improvement

The Index of Varietal Improvement (Brennan 1984) measures the relative yields, weighted by the area shares of each variety. This index measures the rate of improvement in yields of varieties grown in a particular shire that can be attributed to changes in varieties. The index of varietal yield improvement (with a base of 1965 = 100) is shown for each shire in Figure 5.2.

Figure 5.2: Index of Varetal Yield Improvement, by Shire





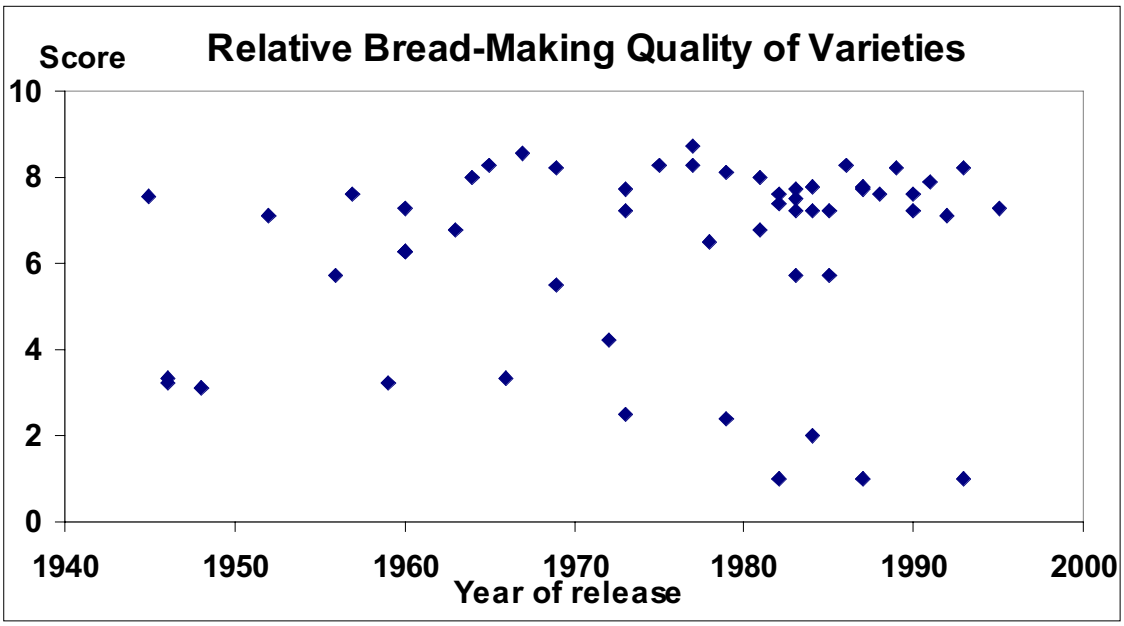
The Indexes of Varietal Yield Improvement show that changes in varieties over the period 1965 to 1997 have brought about increases in wheat yields in all shires. However, there are marked differences between shires in the improvements made in that period. In the southern shires, Temora and Wagga have shown the highest increases over that time, while Cowra has experienced the lowest increase. In the northern shires, Lachlan has shown the highest increase, and Gunnedah the lowest.

In all shires, yield progress was slow or negligible until around 1975, when the semi-dwarf wheats provided a steep jump in yield, especially in the southern shires and Lachlan shire. After the initial surge in these shires, there was a fall in yield in the early 1980s in some shires as the replacement varieties were unable to match the yields of the earlier varieties Condor and especially the lower-quality variety Egret. In the northern shires, the growth in varietal yield from the mid-1970s was generally slower. All shires except Gunnedah and Narrabri have shown steady growth in the Index of Varietal Yield Improvement since 1985. No reason for the lack of recent yield improvement in these two northern shires is apparent.

5.3 Bread-Making Quality of Varieties

The bread-making scores of the quality of each of the varieties is shown in Figure 5.3, by the year of release. These do not vary by shire, as the quality scores are constant across all shires. The scores do not reflect the suitability of quality for other uses such as noodles and flat breads, but the quality requirements for bread-making have been the dominant quality criteria for wheat varieties over the period of analysis. In more recent years, there has been more of an acceptance that specific qualities may be required for some other end-uses.

Figure 5.3: Relative Bread-Making Quality of Varieties, by Year of Release



No clear trend is evident in these data, with the best bread-making scores being similar at the start and the end of the period, and the lowest scores declining over the period. This reflects

the fact that there has been little real increase in the quality *potential*, but that there has been a marked increase in the number of varieties that have achieved bread-making quality close to that of the best varieties. The observations that have low scores in recent decades are the durum varieties and biscuit varieties. Thus, there has been a shift away from all-purpose varieties to separate groupings of bread-making varieties and special-purpose varieties.

5.4 Weighted Index of Varietal Quality Improvement

An Index of Varietal Quality Improvement is derived in the same was as the Index of Varietal Yield Improvement (Brennan 1984), and measures the relative quality over time, weighted by the area shares of each variety. As such, it shows the improvement bread-making quality that is attributable to changes in the varieties grown in each shire. The index is shown in Figure 5.4. The index reveals strong growth in bread-making scores of the varieties grown during the period 1965 to 1997 in southern shires. There was a fall in the index from the late 1970s to the early 1980s, which resulted from the widespread use of the variety Egret, which had poor bread-making quality. In the northern shires, for most of them the increase has been small, since they were already growing varieties suitable for Prime Hard quality from early in the period of analysis. Lachlan shire has shown the most growth in bread-making quality over that period.

5.5 Progress in Yield and Quality

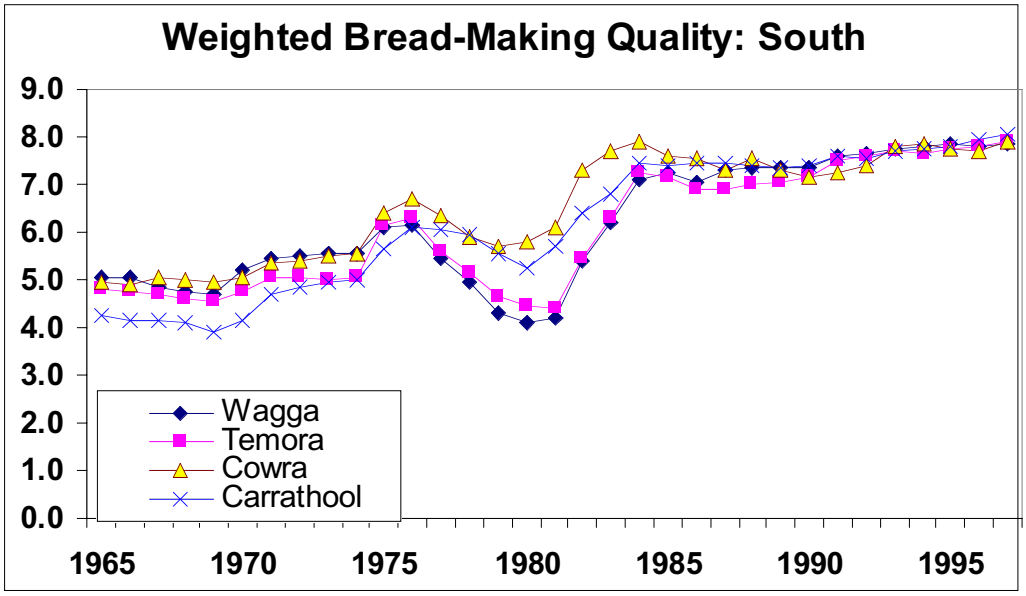
A summary of the progress made in both yield and quality, as measured by the Index of Varietal Yield Improvement and the Index of Varietal Quality Improvement, is shown in Table 5.1. The increase shown over the period 1965 to 1997 was converted to a constant annual rate of increase.

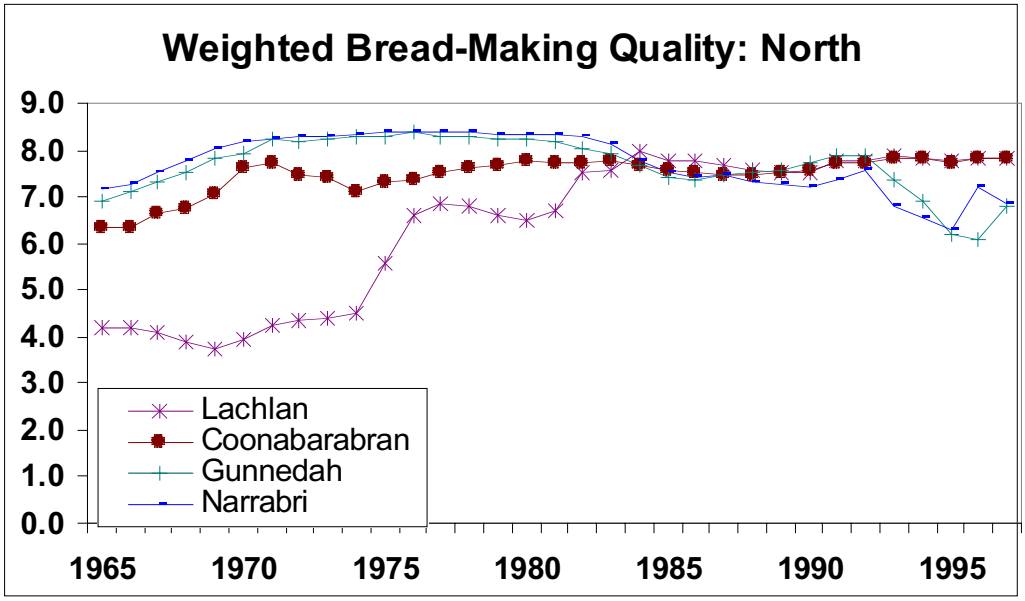
Table 5.1: Average Annual Rates of Varietal Yield and Quality Improvement, by Shire, 1965 to 1997

	Rate of Varietal Yield Improvement *(% per year)*	**Rate of Varietal Quality Improvement** *(% per year)*
Wagga	1.41	1.38
Temora	1.57	1.58
Cowra	0.71	1.49
Carrathool	1.04	2.00
- Southern shires[a]	*1.18*	*1.77*
Lachlan	1.45	1.95
Coonabarabran	1.05	0.66
Gunnedah	0.47	-0.05
Narrabri	1.11	-0.13
- Southern shires[a]	*1.18*	*0.94*
All 8 shires[a]	**1.18**	**1.22**

a Weighted by average area sown in each shire in the 1990s.

Figure 5.4: Index of Varetal Quality Improvement, by Shire





All shires have shown solid rates of yield improvement through varieties, especially Temora, Lachlan and Wagga, which have all had annual rates of increase of 1.4% or above. Coonabarabran, Carrathool and Narrabri have all had rates of improvement of around 1.0% per year. Cowra has been somewhat lower, and Gunnedah has had yield growth through varieties of only 0.5% per year. Across all shires, the weighted average rate of varietal yield improvement (weighted by average area sown in the 1990s) was 1.18% per year. In both the southern and the northern shires the average was also 1.18% per year.

Similarly, all southern shires and Lachlan have had very strong rates of varietal improvement on bread-making quality, an annual rate of 1.38% or above. However, Coonabarabran has had a markedly lower rate of improvement, and Gunnedah and Narrabri have had very small declines over the period. On average, the southern shires had increases of 1.77% per year, while in the northern shires the rate of increase was only 0.94% per year. This difference reflects the fact that the most northern shires already had relatively high bread-making scores at the start of the period, and have found it difficult to make any further improvement. It could also reflect declining soil nitrogen status, as suggested by Hamblin and Kyneur (1993). Across all shires, the average rate of varietal quality improvement (for bread-making) was 1.22% per year, marginally higher than the average rate of varietal yield improvement.

For most shires, however, there has been a combination of both yield and quality improvement over the period at a remarkably high rate, with overall average annual increases of 1.18% in yield and 1.22% in quality across all shires. Southern shires such as Wagga and Temora and the two western-most shires of Carrathool and Lachlan have all shown combinations of yield and quality improvement of over 1.0% per year each. These results show that, especially in those shires, the contribution of the new varieties developed by wheat breeders has been extremely valuable over the past 30 or 40 years.

6. Changes Over Time in Other Characteristics of NSW Varieties

6.1 Variety recommendation/approval status

Each year, NSW Agriculture has provided guidance on the varieties considered best suited for growing in the coming season, on a regional (silo group) basis. In earlier years, the varieties were recommended , but in more recent years the varieties have been approved . Growers are still free to choose to grow other varieties if they choose to do so. Non-recommended or non-approved varieties are normally older varieties that have been removed from the list as being outclassed by superior newer varieties, or are newer varieties that NSW Agriculture considers are less suitable for that particular production environment. Over the full period of the data, the average proportion of the area sown to recommended/approved varieties was 81% of the area (Table 6.1). In southern shires the average was 77% overall, while in the northern shires the average was 85%.

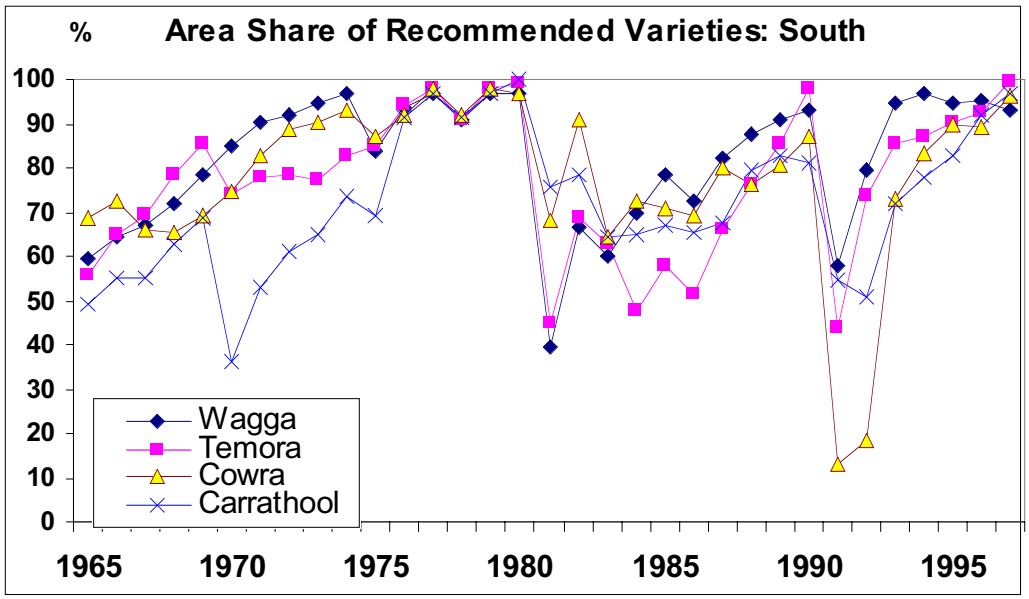
Table 6.1: Percentage of Area Sown to Recommended/Approved Varieties, by Shire

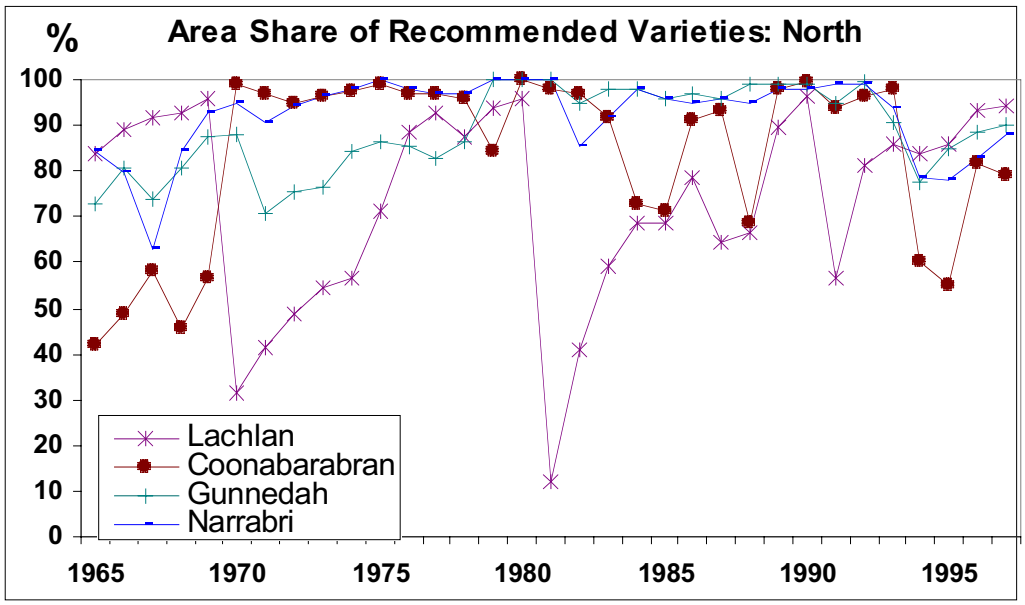
Shire	1960s	1970s	1980s	1990s	Overall
Wagga	68	92	74	88	82
Temora	71	86	66	84	77
Cowra	68	90	77	69	77
Carrathool	58	73	75	76	72
- Southern shires	*66*	*82*	*72*	*79*	*77*
Lachlan	91	67	64	85	74
Coonabarabran	50	96	88	83	83
Gunnedah	79	84	98	91	89
Narrabri	81	97	95	90	92
- Northern shires	*75*	*86*	*86*	*87*	*85*
All shires	**71**	**85**	**80**	**83**	**81**

The recommendation/approval status of the varieties grown in each shire is illustrated in Figure 6.1. In the southern shires, the proportion of the area sown to recommended varieties grew from around 60% in 1965 to 100% in 1980. That largely reflected the fact that the widely grown variety Falcon was not recommended in those shires at that time. The sharp fall in proportion sown to recommended varieties in the early 1980s reflected the removal of Condor and Egret from the recommended list even though they were still widely grown, both in the south and in some northern shires.

In the northern shires, the lower levels of recommended varieties in the 1960s related largely to the phasing out of varieties Glenwari and Bencubbin that were no longer recommended, as well as the fact that Mengavi was widely grown though not recommended. Varieties that continued to be grown after they were taken from the recommended/approval list included Condor and Egret in Lachlan in the early 1980s, Vulcan in Lachlan in the early 1990s and Suneca in Coonabarabran in the mid-1990s. Apart from those varieties, the northern shires tended to conform with the recommendations in the varieties grown.

Figure 6.1: Proportion of Area Sown to Recommended/Approved Varieties, by Shire





6.2 Local origin of varieties

The percentage of the area sown to varieties released from the local breeding program(s) is an indication of the extent to which the varieties grown are developed under local conditions, and a measure of the spillover of research benefits from other regions. For the southern shires, the local breeding program was located at Wagga Wagga (and its adjunct at Temora). For the northern part of NSW, local breeding programs included the Sydney University program at Narrabri, NSW Agriculture s programs at Tamworth and earlier at Glen Innes, and the private hybrid-wheat breeding program based at Tamworth.

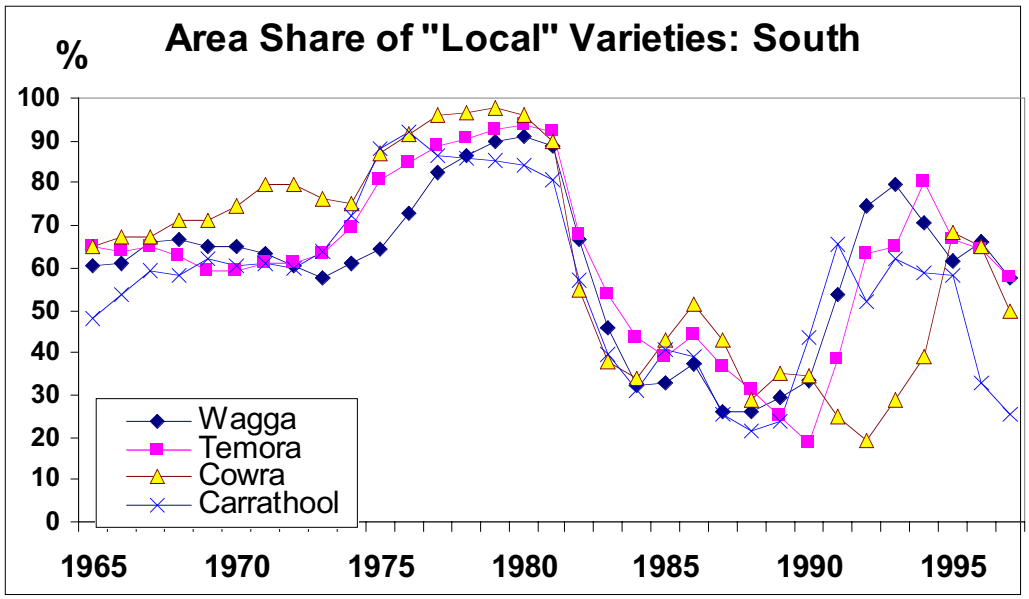
The proportion of the area sown to local varieties moved in cyclical fashion over the period (Table 6.2, Figure 6.2). Until the mid 1970s, around three-quarters of the area in southern shires was sown to local varieties, but that increased to almost 100% with the release of the locally-developed semi-dwarf varieties Condor and Egret. In the early 1980s, however, with the replacement of these varieties with Banks from Queensland, the proportion fell sharply to less than half the area sown. The proportion of local varieties remained low until around 1990 as Banks was replaced largely by Vulcan (from the north). After a rise in the early 1990s, the proportion of the area sown to local varieties then fell again in the late 1990s with the widespread adoption of Janz, developed in Queensland.

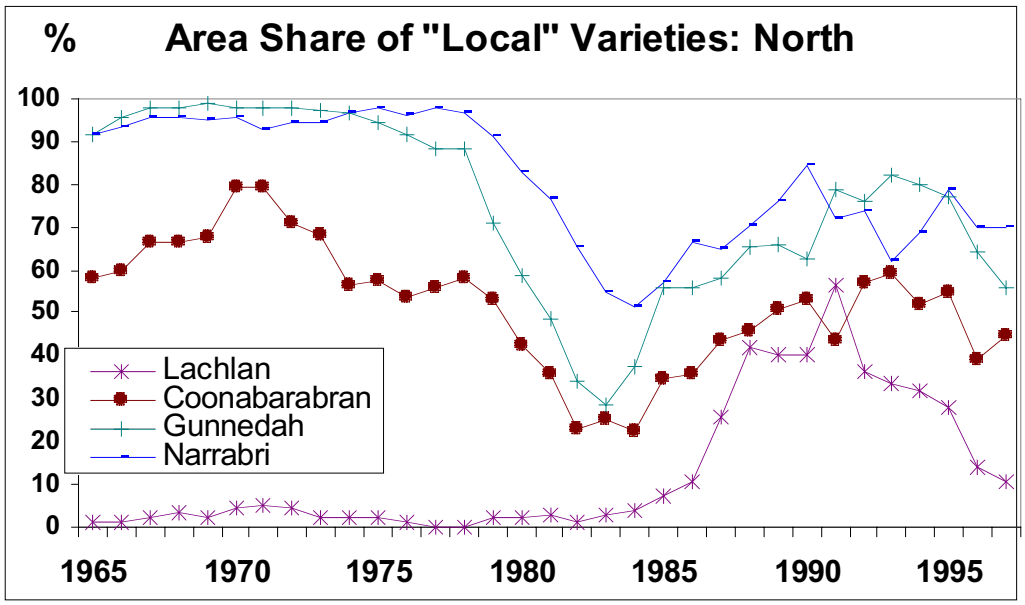
Table 6.2: Area Share of Locally-Released Varieties, by Shire

Shire	1960s	1970s	1980s	1990s	Overall
Wagga	64	70	48	62	61
Temora	63	75	53	57	62
Cowra	68	85	51	41	62
Carrathool	56	76	44	50	57
- Southern shires	*63*	*77*	*49*	*52*	*60*
Lachlan	2	2	14	31	13
Coonabarabran	64	63	36	50	52
Gunnedah	96	92	51	72	75
Narrabri	94	95	67	72	81
- Northern shires	*64*	*63*	*42*	*57*	*55*
All shires	**63**	**70**	**45**	**55**	**58**

In the two most northern shires (Gunnedah and Narrabri), varieties have been overwhelmingly developed locally, with a brief decline in the mid-1980s associated mainly with Kite (developed at Wagga). In Coonabarabran, more of the varieties were derived from outside breeding programs in the 1960s and 1970, mainly southern varieties. The picture is very different for the Lachlan shire. Until about 1980, Lachlan shire had used southern varieties almost exclusively. With the introduction of Banks from Queensland, that shifted, and by the mid-1990s the majority of the varieties grown were from northern breeding programs, either in northern NSW or Queensland. That reflected the capacity to produce Prime Hard quality wheat in the region, which relied on northern varieties. As that marketing policy changed, and the agronomic capacity to produce high-protein wheat was developed, there was a shift away from the varieties bred in the south to those developed in the north. However, apart from Vulcan and Sunco, there was still a strong reliance on Queensland varieties such as Janz, Cunningham and Batavia, so that relatively few were locally developed varieties.

Figure 6.2: Area Share of Varieties Released by Local Breeding Programs





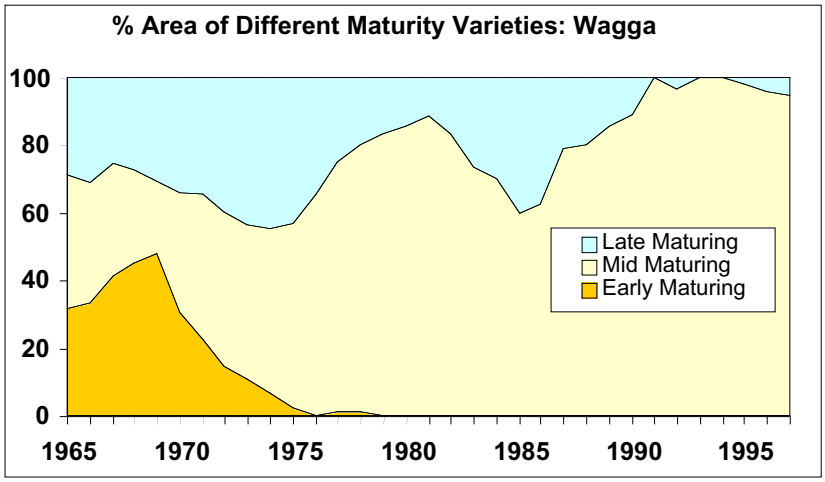
6.3 Maturity of varieties

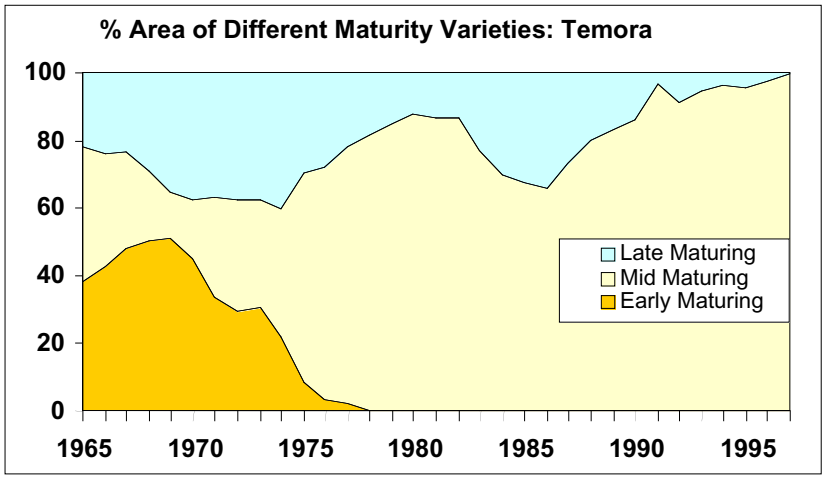
In the agronomic information provided annually by NSW Agriculture, wheat varieties are classified as

- Late maturing (or early-sown)
- Mid-maturing (or main-season), and
- Early-maturing (or late-sown)

Using these classifications, the distribution of the area sown to varieties in each maturity type is shown Figure 6.3. In each of the southern shires, the pattern is very similar. In the 1960s,

Figure 6.3: Changes in Variety Maturity, by Shire





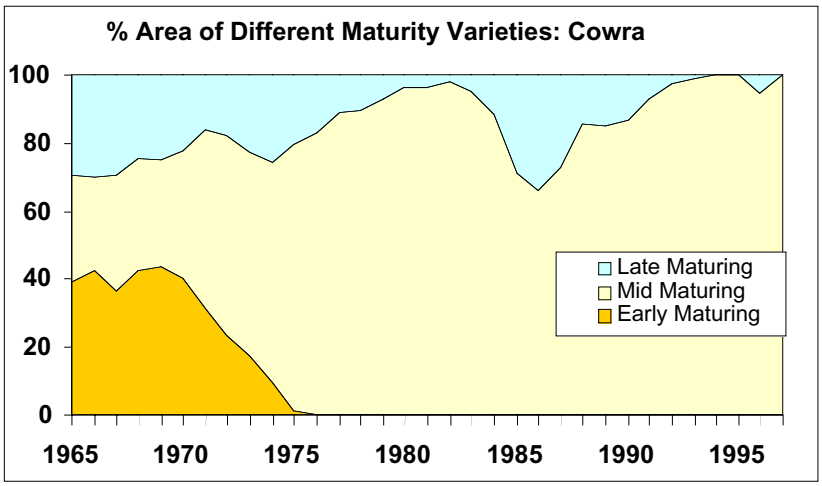
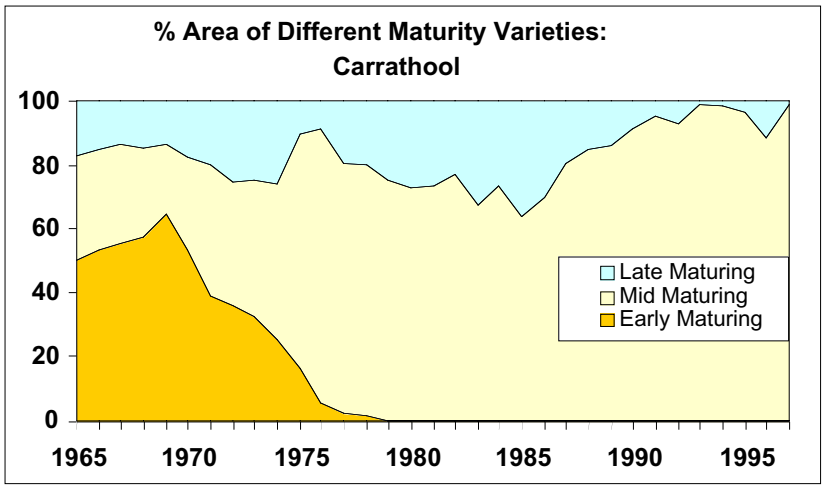
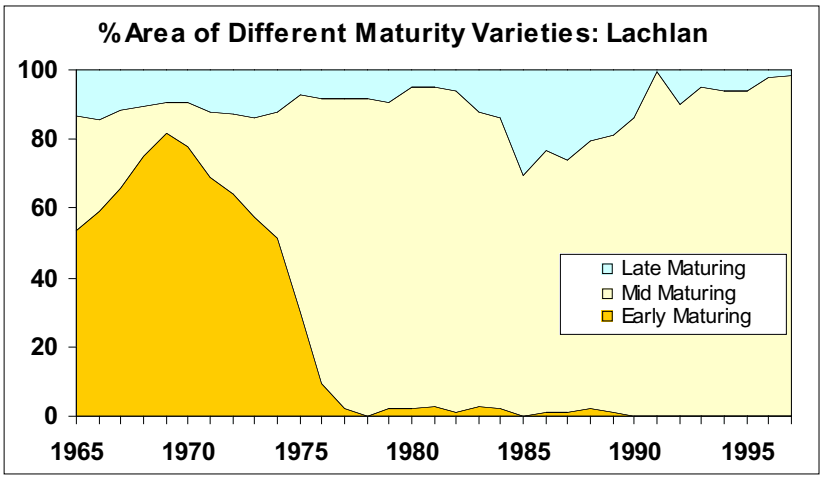


Figure 6.3 (continued): Changes in Variety Maturity, by Shire





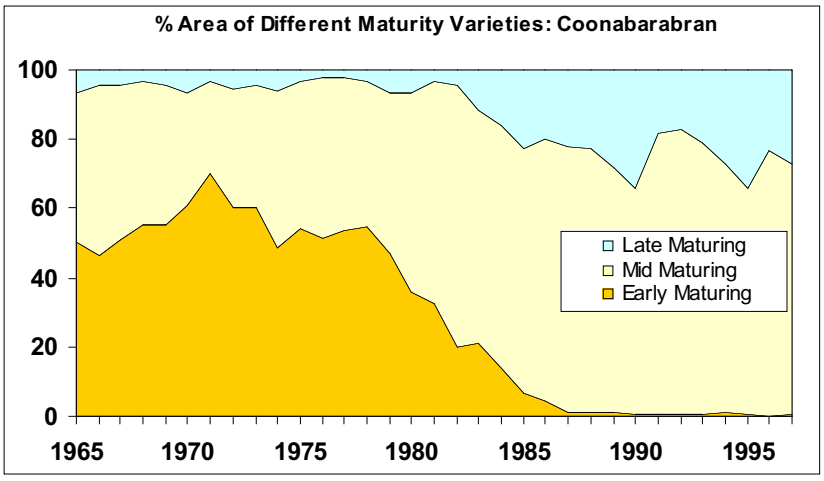
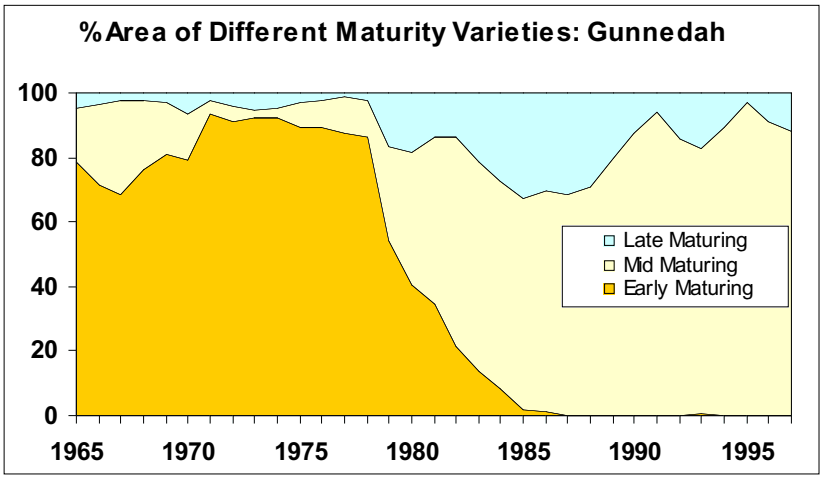
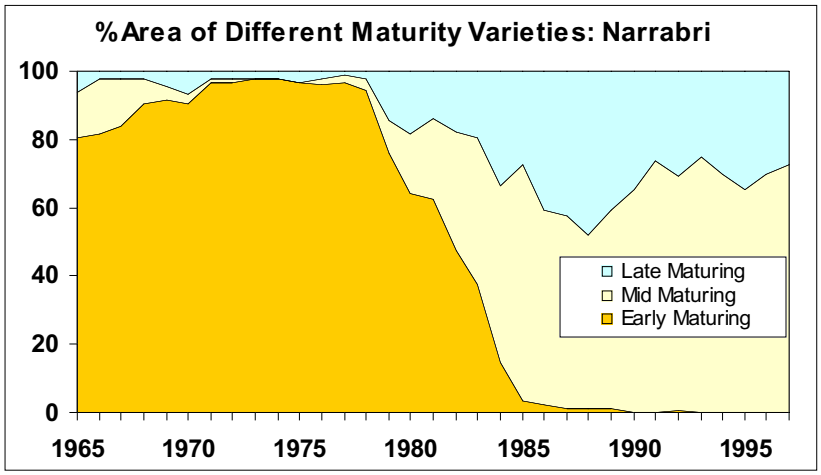


Figure 6.3 (continued): Changes in Variety Maturity, by Shire





there was a relatively even spread of varieties across the three maturity types. By the mid-1970s, there were no early-maturing varieties being grown in any of the four southern shires or in the Lachlan shire. These varieties were replaced by mid-season varieties. From the late 1980s, the proportion of the area sown to late-maturing varieties declined, so that by the end of the period almost all the area was sown to main-season varieties.

In the northern shires, the early-maturing varieties were much more dominant in the 1960s and 1970s. However, by the mid-1980s there were virtually no early-maturing varieties being grown. While late-maturing varieties were generally less important in the north than in the south until the 1980s, they were generally only a significant proportion of the area sown in northern shires by the 1990s.

Growers in the more western shires (Carrathool and Lachlan) were not encouraged to sow late-maturing varieties, because the generally shorter seasons in those areas. Similarly, growers in the more eastern shires (Cowra and Gunnedah) were not encouraged to sow early-maturing varieties (R. Gammie, NSW Agriculture, personal communication).

There are, of course, many other factors involved in the growers choice of sowing time and matching variety type, including the timing of seasonal rainfall, marketing opportunities, changes in farming systems involving alternative crops such as canola or lupins, and varietal disease attributes. In particular, some diseases are encouraged by early sowing, so they would only generally be sown early if adequate disease resistance were available.

This pattern of change of variety maturity over time can also be partly explained by the development in the size of the machinery. In the 1960s, the size of cultivating and sowing machinery constrained the area that could be sown to varieties in a particular maturity group. However, with the development of larger tractors and air-seeders with hugely increased capacity, the ability to sow large areas in a short time increased. As a result, it is now possible for farmers to sow their entire crop area very close to the optimum period for main-season varieties. They no longer need to spread the maturity of the varieties because of the speed at which they can sow the crop.

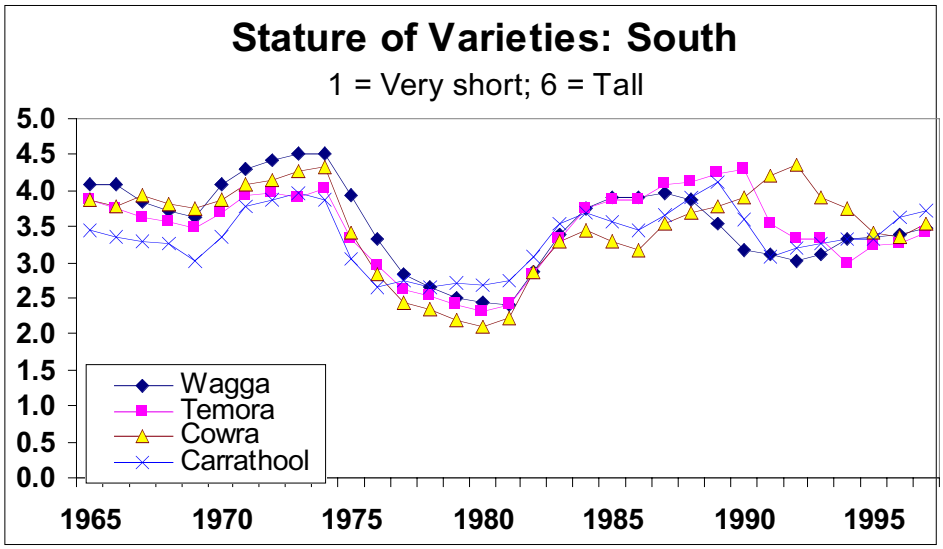
6.4 Other morphological characteristics of varieties

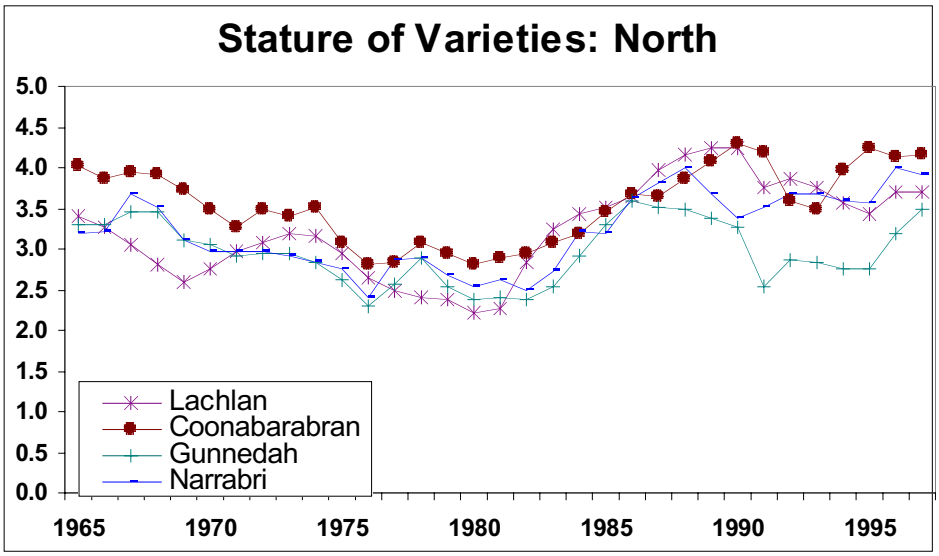
Four morphological characteristics have been tabulated and analysed:

- Stature (1=very short, 2=short, 3= short-medium, 4=medium, 5=medium-tall, 6=tall)
- Straw strength (1=weak, 2=weak-medium, 3=medium, 4=medium-strong, 5=strong, 6=very strong)
- Grain colour (1=light, 2=light-medium, 3=medium, 4=medium-dark, 5=dark)
- Awns (1=full, 2=full-half, 3=half, 4=half-tip, 5=tip)

The data on stature was obtained from the variety registration papers prepared by the breeder of each variety. The changes in stature of the varieties grown, weighted by area share, is shown in Figure 6.4. In the southern shires, there was sharp decline in stature in the mid-1970s, associated with the introduction of the semi-dwarf wheat varieties Condor and Egret , which were adopted very rapidly across the whole region (Brennan and Fox 1995). The reasons for the subsequent increase in stature are unclear, since all varieties grown in NSW from the 1980s onwards have been semi-dwarf varieties. It may the result of breeders modifying what is classified as short or medium as a result of having all semi-dwarfs in their program, so that their concept of medium stature has changed over time.

Figure 6.4: Morphological Characteristics of Varieties Grown, by Shire: Stature

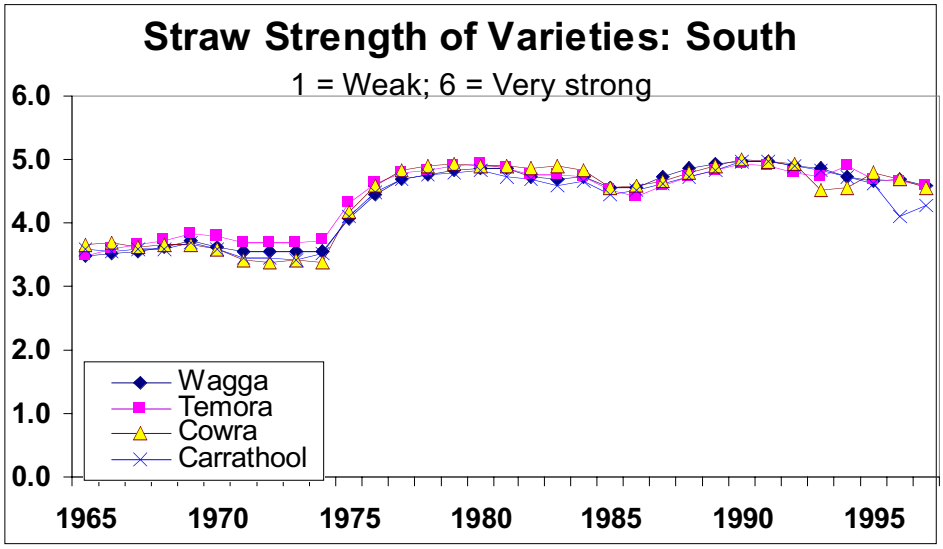


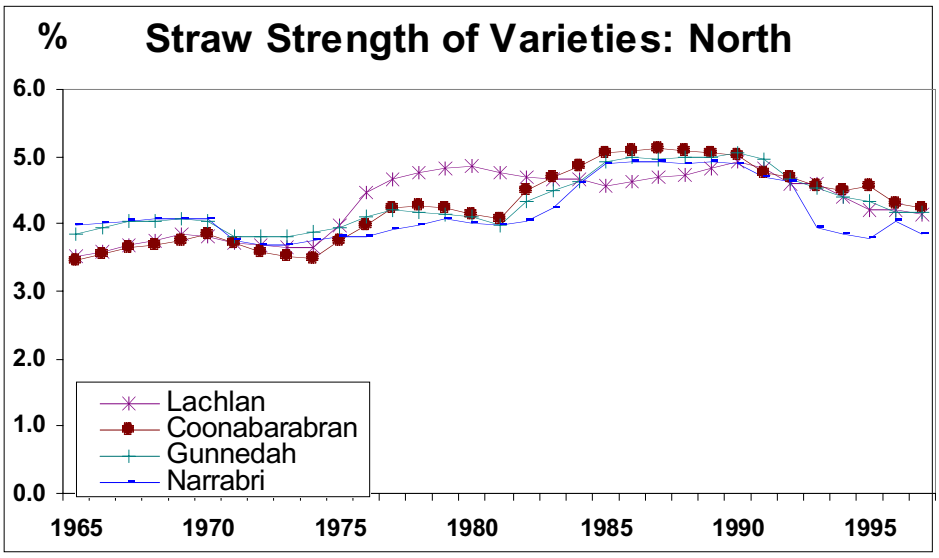


In the northern shires (Figure 6.4), the decline in stature with the introduction of the semi-dwarf varieties was slower than in the south (the adoption of the first semi-dwarfs Kite and Songlen began a little later, and Songlen is not as short as some other early semi-dwarfs). However, the subsequent increase in recorded stature is similar to that in the south.

While the evidence on changes in recorded stature of varieties is somewhat ambivalent, there is no ambiguity about the increase in straw strength from the 1960s to about 1990. In all shires, there has been a considerable increase in straw strength (associated with the use of semi-dwarf wheats, at least initially), followed by a decline in strength in the 1990s (Figure 6.5). There is no clear explanation for the reduction in strength in the more recent years, but it could have important implications for farmers if the decline continues.

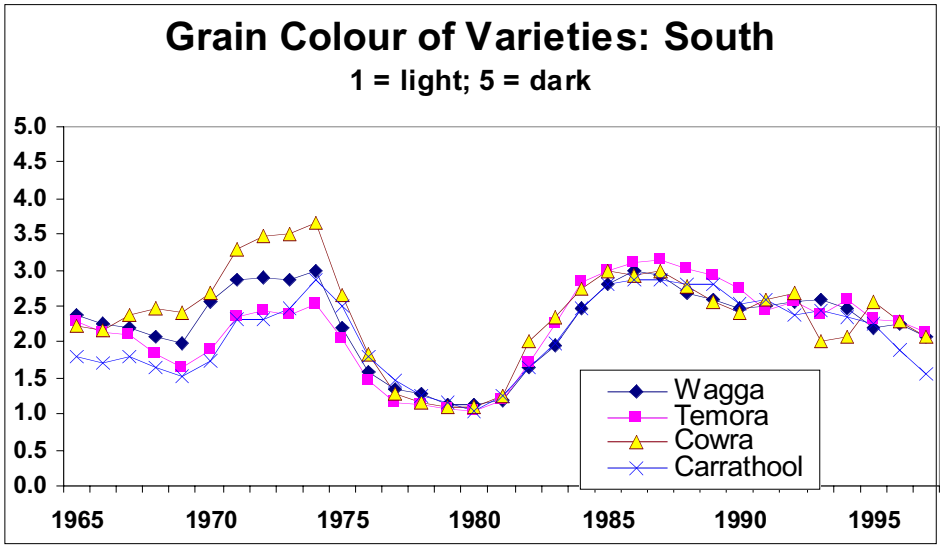
Figure 6.5: Morphological Characteristics of Varieties Grown, by Shire: Straw Strength

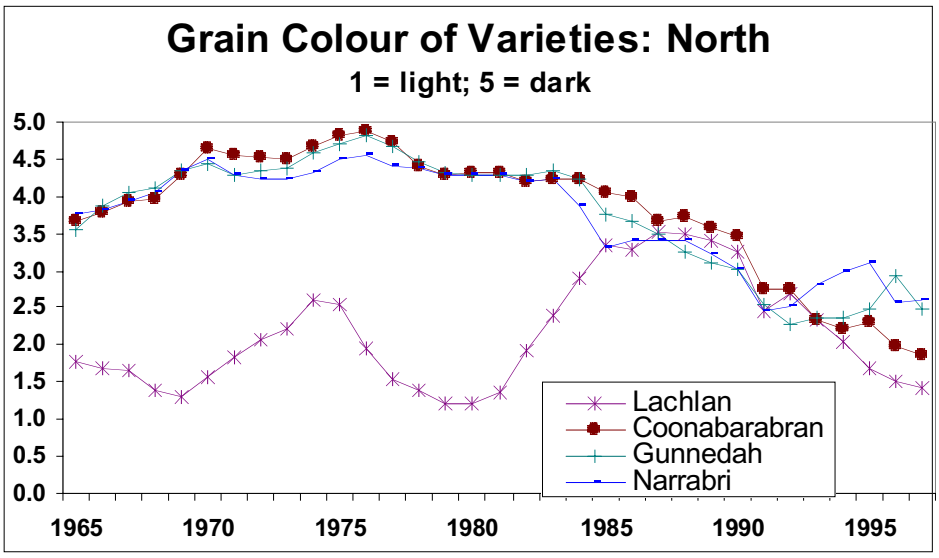




All significant commercial Australian wheats have been white wheats, until a few specialist releases in the 1990s. However, within the white colour, there has been considerable variation in the darkness and lightness of that colour. In the south, the varieties became darker in the early 1970s (Figure 6.6), but then lightened considerably with the introduction of the main semi-dwarf varieties Condor and Egret. As they were gradually replaced in the early 1980s, the weighted average colour became darker, but has declined steadily since about 1985. Lachlan shire has shown a similar pattern to the southern shires, but the other northern shires have shown a very different pattern. In the north, the colour darkened until about 1975, but has declined since that time at a steady rate.

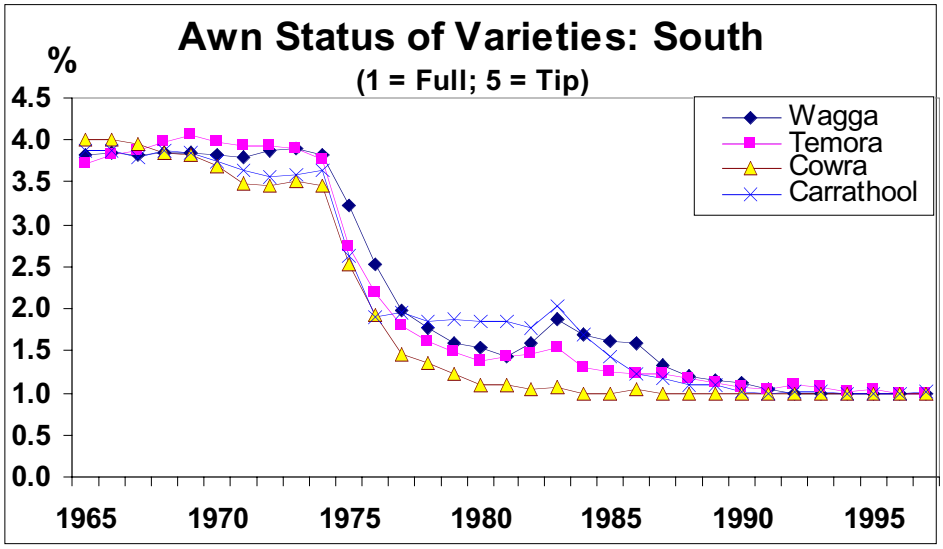
Figure 6.6: Morphological Characteristics of Varieties Grown, by Shire: Grain Colour

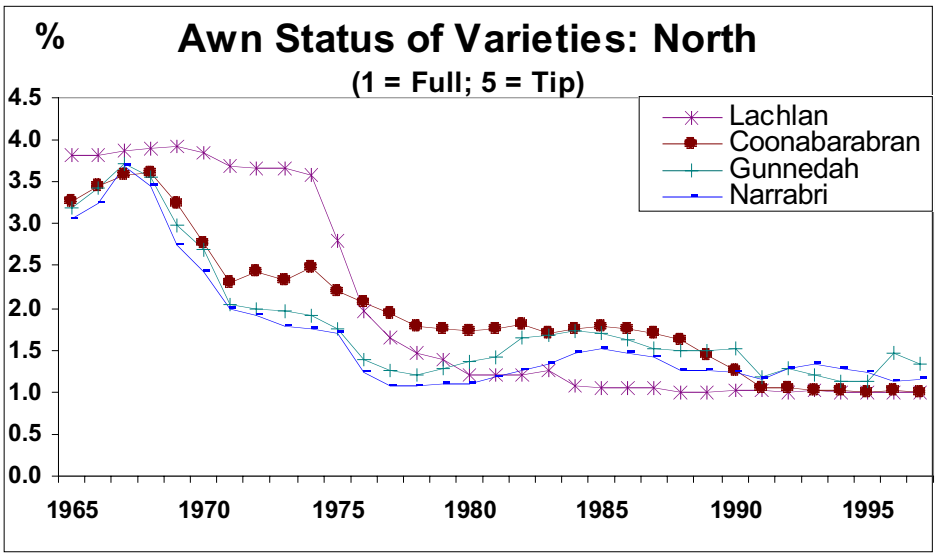




Perhaps the most significant change in the morphology of the wheat varieties grown (apart from their semi-dwarf status) is the increased presence of awns. In the varieties grown in the 1960s, the general situation was a score of 4, which represents half-tip awns (Figure 6.7). By the late 1980s, virtually all varieties grown in southern shires, and most grown in the north were fully awned. By 1997, all southern shires were growing only awned varieties and in the northern shires the only variety not fully awned was a durum variety Wollaroi.

Figure 6.7: Morphological Characteristics of Varieties Grown, by Shire: Awn Status





7. Changes Over Time in Diversity

7.1 Changes in wheat varietal diversity

Genetic diversity is an important determinant of a crop's vulnerability to pests and diseases. One indicator of the diversity within wheat in a region is the mix of varieties grown and the diversity of that mix. While the number of varieties grown each year (section 4) is one indicator of varietal diversity, other more complex indices have been developed (Smale, Meng, Brennan and Hu 1999) to measure the spatial diversity among crop varieties. They include:

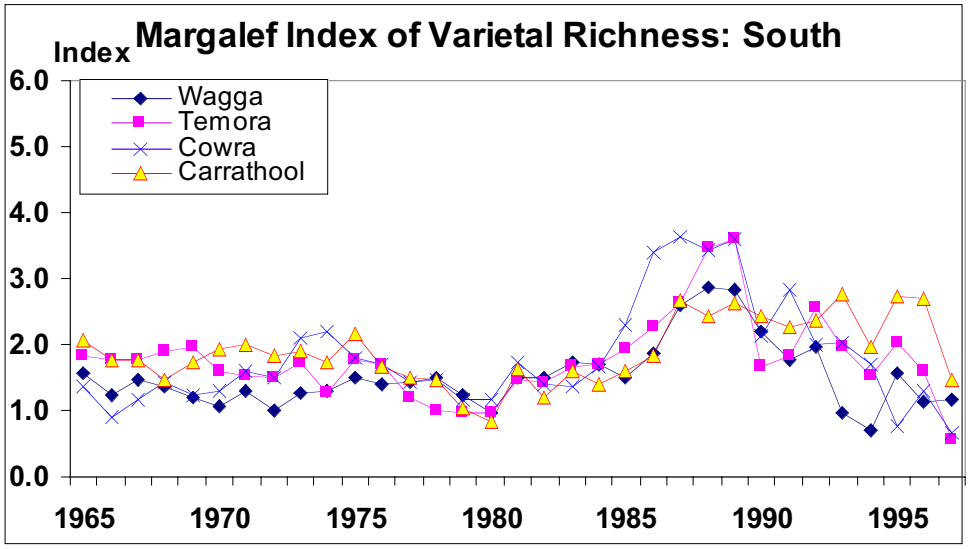
- Margalef index of varietal richness
- Shannon index of varietal richness and evenness

The Margalef index of varietal richness measures the relative richness of the set of varieties in relation to the area sown (the higher the index the greater the relative richness of the set of varieties grown). The changes in the Margalef index for each shire are shown in Figure 7.1. The index changed little in the southern shires between 1965 and the early 1980s. There was a rapid increase in richness in the late 1980s, followed by a strong decline during the 1990s. By 1997, the richness of the variety set in southern NSW was the lowest in the past 35 years.

The picture was similar in the northern shires until the late 1980s, but very different after that time. Except for Coonabarabran, which declined in the 1990s (but not to levels as low as in the 1970s), the northern shires did not show a decline in varietal richness in the 1990s. As a result, most northern shires were growing a more diverse set of varieties in the late 1990s than at any time throughout the previous 35 years.

The Shannon index of varietal richness and evenness combines the richness of the varieties grown with a measure of their relative abundance (the higher the index the richer and more even is the spread of the set of varieties being grown). In the southern shires, the Shannon index fluctuated, but was generally about the same level in the late 1980s as it was in the 1960s (Figure 7.2, Table 7.1). However, there has been a consistent sharp decline in richness and evenness of the variety mix in the 1990s in the southern shires, associated by the dominance of the varieties Janz and Dollarbird across those shires. In the northern shires, again with the exception of Coonabarabran, the general level of the richness and evenness index increased in 1990s, with a move towards a larger and more diverse set of varieties being grown. Some of these differences in the pattern of varietal use between the southern and northern shires that are very evident in Figure 7.2 were also indicated above in Table 4.1.

Figure 7.1: Margalef Index of Varietal Richness, by Shire



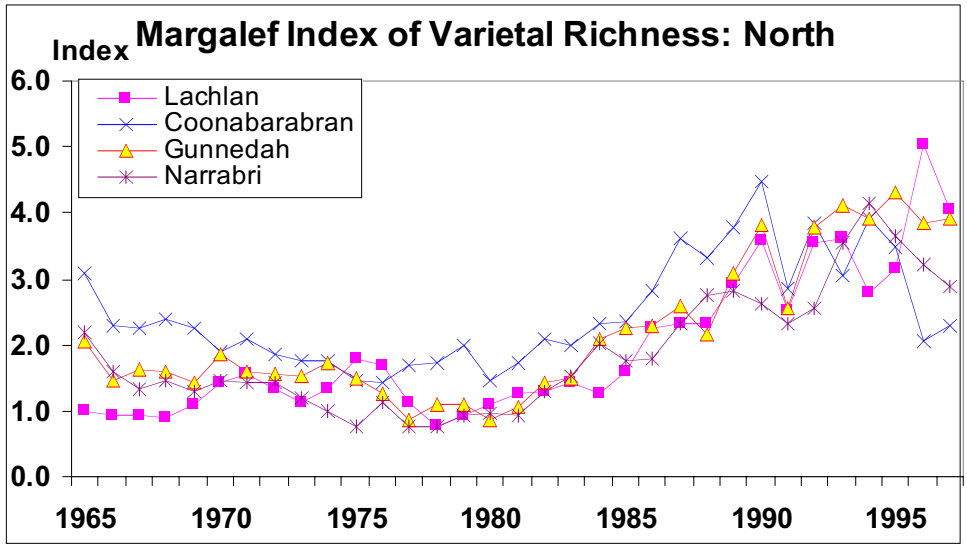
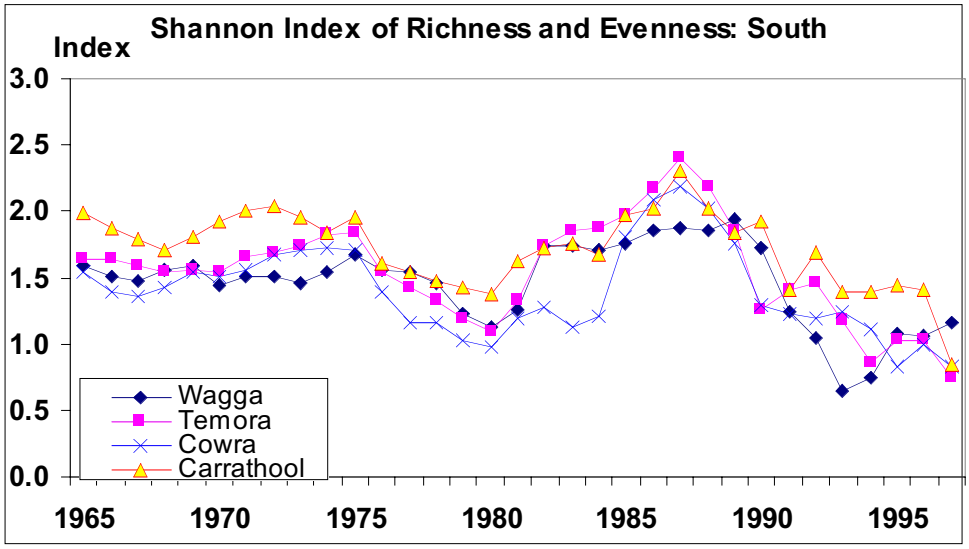


Figure 7.2: Shannon Index of Varietal Richness and Evenness, by Shire



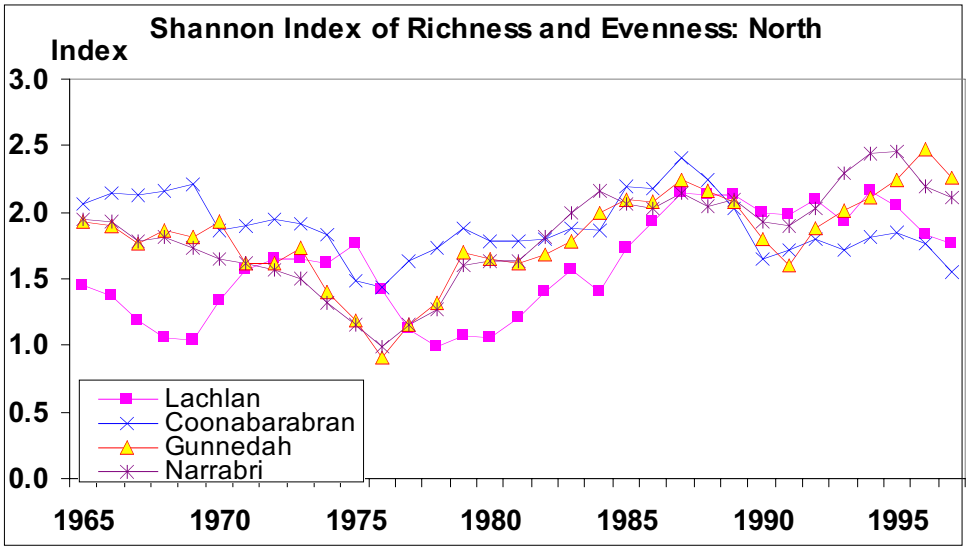


Table 7.1: Changes in Average Varietal Diversity over Time, by Shire
Shannon Index of Varietal Richness and Evenness

Shire	1960s	1970s	1980s	1990s	Overall
Wagga	1.54	1.49	1.69	1.09	1.46
Temora	1.59	1.58	1.85	1.12	1.55
Cowra	1.45	1.46	1.57	1.09	1.40
Carrathool	1.84	1.78	1.83	1.44	1.72
- Southern shires	*1.61*	*1.58*	*1.73*	*1.18*	*1.53*
Lachlan	1.22	1.42	1.67	1.97	1.60
Coonabarabran	2.14	1.76	2.01	1.73	1.89
Gunnedah	1.85	1.46	1.94	2.05	1.81
Narrabri	1.84	1.38	1.96	2.17	1.82
- Northern shires	*1.76*	*1.50*	*1.90*	*1.98*	*1.78*
All shires	**1.68**	**1.54**	**1.81**	**1.58**	**1.65**

The average level of the Shannon index fluctuated in each shire. In the southern shires, the average ranged from around 1.5 to 1.8 in the 1960s and 1970s (Table 7.1). In the 1980s, the average of the index increased in all shires. However, there was a sharp fall in the average levels of the index in the 1990s in all southern shires. In contrast, in three of the northern shires the average of the Shannon index increased to levels of 2.0 or higher. Only in Coonabarabran was there a decline in the 1990s, though it was not as significant as that taking place in the southern shires. In Wagga, Cowra and Temora, however, there was a marked decline in richness and evenness of the varieties being grown in the 1990s.

7.2 Changes in genetic diversity of varieties grown

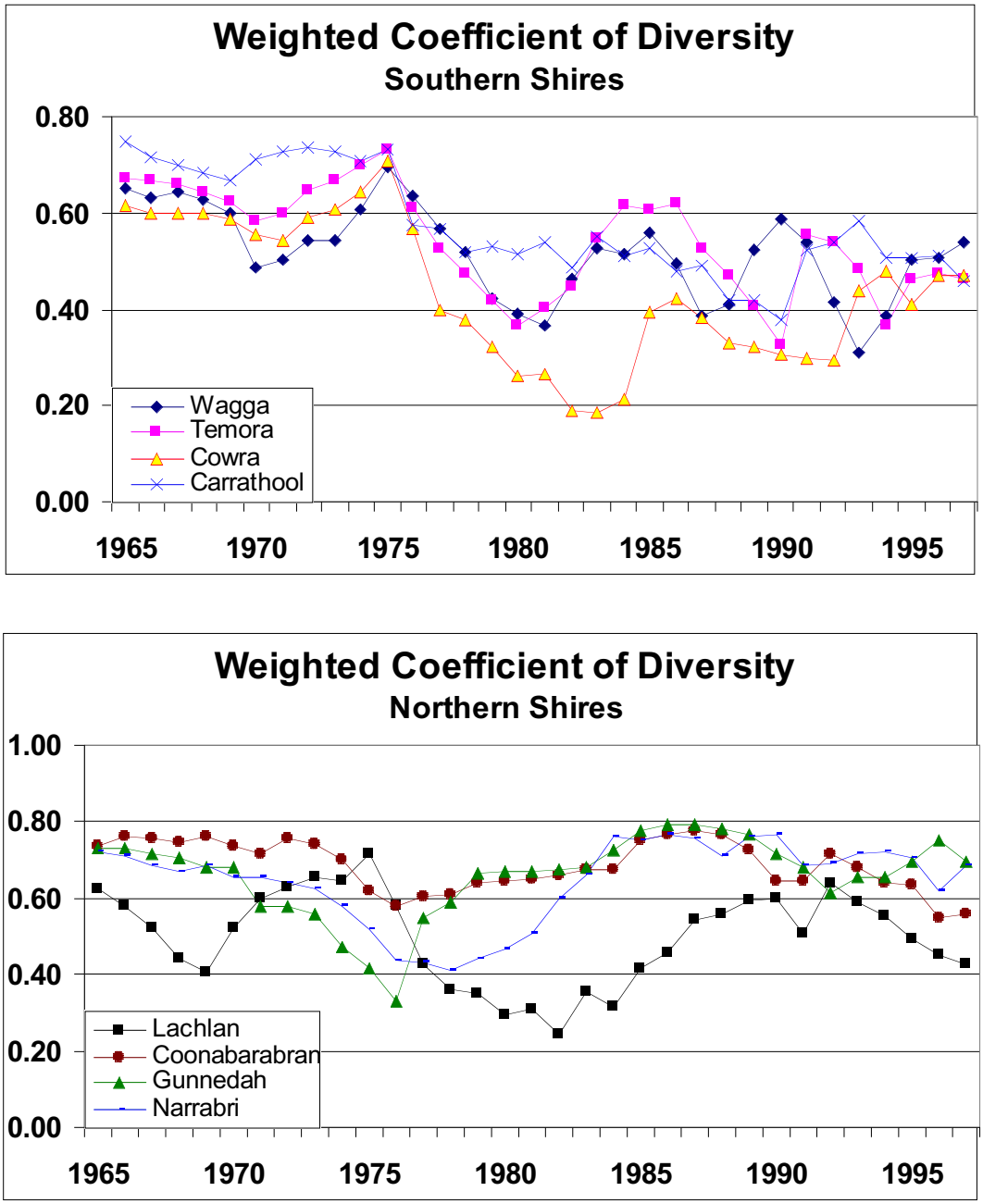
The above measures relate to the mix of varieties that are grown and the changes that have taken place in the varietal mix. However, they do not take account of the relationships between the varieties in their genetic make-up. A more detailed measure of the genetic diversity in the varieties grown is measured by the coefficient of diversity (Cox *et al.* 1985; Souza *et al.* 1994). This measure uses the pedigrees of the varieties to measure the degree of ancestral commonality between varieties, to obtain coefficients of parentage (COPs). When those COPs are weighted by the share of the area sown to each variety, the weighted coefficients of parentage (WCOPs) are derived. From those, the weighted coefficient of diversity (WCOD) is calculated as 1-WCOP. The weighted coefficient of diversity measures the genetic diversity of the mix of varieties being grown in a region in a particular year. Changes over time can indicate the extent to which genetic diversity in farmer s paddocks is being eroded or enhanced over time with the changes in varieties being grown. Changes in the distribution of varieties with different genetic make-ups are reflected in changes in the weighted coefficient of diversity measure.

Brennan and Fox (1995) showed that in the period 1973 to 1993 the diversity at a national level remained high, but this finding varied markedly between States. While there was

significant improvement in diversity in South Australia and Western Australia, there was a narrowing of the genetic base of varieties grown in the eastern States over that period.

At the shire level, the weighted coefficients of diversity reveal a marked decline in the genetic diversity of the varieties that farmers were growing since the mid-1970s in the southern shires (Figure 7.3, Table 7.2). Until 1975, southern shires generally had a WCOD level above 0.6, but after that time all four shires were below that level at almost all times. In the north, all shires apart from Lachlan had WCODs above 0.6 for most of the period. The only times in which they fell below that level were in the 1970s. In the Lachlan shire, the levels were akin to those in the southern shires, with the corresponding decline in the 1990s.

Figure 7.3: Weighted Coefficient of Diversity, by Shire



An examination of the WCODs in each shire by decade (Table 7.2) shows that genetic diversity has reduced significantly in the southern shires. It is noteworthy that in Cowra in the 1980s the mix of varieties as measured by the Shannon index was diverse, but the varieties were sufficiently related as to provide only low levels of genetic diversity at that time.

Table 7.2: Changes in Average Genetic Diversity over Time, by Shire
Weighted Coefficient of Diversity

Shire	**1960s**	**1970s**	**1980s**	**1990s**	**Overall**
Wagga	0.63	0.55	0.46	0.47	0.51
Temora	0.65	0.60	0.50	0.46	0.54
Cowra	0.60	0.53	0.30	0.40	0.43
Carrathool	0.70	0.65	0.49	0.50	0.57
- Southern shires	*0.65*	*0.58*	*0.44*	*0.46*	*0.51*
Lachlan	0.51	0.55	0.41	0.53	0.49
Coonabarabran	0.75	0.67	0.71	0.63	0.68
Gunnedah	0.71	0.54	0.73	0.68	0.66
Narrabri	0.69	0.54	0.67	0.70	0.64
- Northern shires	*0.67*	*0.57*	*0.63*	*0.64*	*0.62*
All shires	**0.66**	**0.58**	**0.53**	**0.55**	**0.57**

Overall, as a group, the shires have had marginally lower average rates of genetic diversity in the 1980s and 1990s than in the previous decades. However, within some shires there has been a more significant decline in genetic diversity. These trends need to be monitored carefully, and actions taken to reverse them if necessary, if the security of wheat production in those shires is to be maintained in the future.

8. Discussion of Results

8.1 Relative Contribution of Varieties and Management to Yield Gains

The data from this study enable an assessment of the relative contribution of changes in varieties to the total yield increases in the eight shires. An assessment of the relative contributions of varieties and other factors such as agronomic practices, management and levels of other inputs is shown in Table 8.1. Average yields in the five-year period to 1969 are compared to average yields in the five-year period to 1997[2]. Across the eight shires, the average increase in that period was 83%, varying from 67% in Wagga to 95% in Carrathool. The increase in the Index of Varietal Yield Improvement (section 5.2) for the same time periods is also shown in the table. On average, the increase in the index from the five years to 1969 to the five years to 1997 was 45%, varying from 17% in Gunnedah to 62% in Temora. The differences between the total yield improvement and the improvement attributable to varieties is due to Other factors such as management and agronomic practices. On that basis, those other factors have accounted for yield increases of 38% in that period.

Table 8.1: Contribution of Varieties and Other Factors to Yield Improvement

	Wheat yields (t/ha)			Index of VYI (1965=100)[a]			% due to	Variety[b]
	5 years to 1969	5 years to 1997	Increase	5 years to 1969	5 years to 1997	Increase	Other	contribution
Wagga	1.55	2.59	67%	100.4	158.0	57%	9%	86%
Temora	1.34	2.55	90%	100.8	163.6	62%	28%	69%
Cowra	1.65	2.88	74%	100.1	125.2	25%	49%	34%
Carrathool	0.89	1.73	95%	100.8	137.7	37%	58%	39%
- Southern shires[c]	*1.16*	*2.14*	*88%*	*100.6*	*145.3*	*44%*	*43%*	*51%*
Lachlan	0.88	1.56	77%	100.2	157.3	57%	20%	74%
Coonabarabran	1.16	2.03	74%	99.8	138.3	39%	36%	52%
Gunnedah	1.31	2.23	71%	98.5	115.0	17%	54%	24%
Narrabri	1.07	2.08	93%	100.8	141.4	40%	53%	43%
- Northern shires[c]	*1.02*	*1.85*	*81%*	*100.1*	*145.2*	*45%*	*36%*	*56%*
Average 8 shires[c]	**1.07**	**1.94**	**83%**	**100.3**	**145.2**	**45%**	**38%**	**54%**

a Index of Varietal Yield Improvement (see section 5.2 above), base 1965=100
b Percentage of total yield improvement due to varieties
c Weighted by area sown in each shire

From this analysis, varietal improvement contributed 45% and management contributed 38% to the 83% increases in yield across these eight shires. That means that varietal improvement contributed approximately 54% of the yield increases, on average across the eight shires. In the southern shires the overall rate of yield improvement was marginally higher than in the northern shires. Interestingly, the increase in the Index of Varietal Yield Improvement was very similar in the north and the south over the period. As a result, the proportion of the gains

[2] Five-year averages are used, rather than individual years, to minimise the impacts of seasonal variation in the shire yields.

due to varieties was 51% in the southern shires and 56% in the northern shires, although the relative contributions varied widely between shires in both the north and south.

Translating those changes to compound annual rates of improvement, overall yields increased by 2.2% per year over the period, 1.2% of which was due to varieties and 1.0% of which was due to other factors.

Such analysis can only be broadly indicative, as it rests on the assumption that there has been no interaction between varieties and the level of other inputs and the /or management practices. However, it does give some interesting information on the extent to which yield improvement is driven by changes in varietal yield and by changes in other factors.

8.2 Value of Varietal Yield Increases

An indication of the value of the yield increases brought about by the improvements in varieties is shown in Table 8.2. The Index of Varietal Yield Improvement (section 5.2) increased by an average of 46% across the shires in the period 1965 to 1997. Given the level of yields in 1965, that increase represented an increase of 0.52 t/ha, on average, ranging from 0.24 t/ha in Gunnedah to 0.90 t/ha in Wagga shire. Valuing that additional yield at a recent average price (fob) of $200 per tonne, the extra yield is valued at $103 per hectare. Thus, if farmers in these shires were still growing varieties that yielded the same as those that they grew in 1965, their incomes would have been an average of $103 per hectare lower in 1997.

Table 8.2: Value of Yield Improvement, 1965 to 1997

	Yield 1965	Increase in yield from varieties[a]	Extra yield	Extra value[b]
	(t/ha)	(%)	(t/ha)	($/ha)
Wagga	1.59	56	0.90	179
Temora	1.38	64	0.89	178
Cowra	1.67	25	0.43	85
Carrathool	0.93	39	0.36	73
- Southern shires[c]	*1.19*	*46*	*0.56*	*113*
Lachlan	0.92	59	0.54	108
Coonabarabran	1.28	40	0.51	101
Gunnedah	1.50	16	0.24	48
Narrabri	1.24	42	0.52	105
- Northern shires[c]	*1.13*	*46*	*0.49*	*98*
Average (8 shires[c])	**1.15**	**46**	**0.52**	**103**

a Measured by the Index of Varietal Yield Improvement (section 5.2 above)
b Based on average price of $200/t (fob)
c Weighted by area sown in each shire

While the overall average was $103/ha, the higher rates of varietal yield improvement found in the southern shires mean that the average for the southern shires was $113, while the average for the northern shires was $98/ha. The higher value in the south reflected the higher average yield levels across those shires.

9. Summary and Conclusions

The comprehensive examination of the wheat varieties grown in the eight selected shires in NSW over the period since 1965 has provided a number of significant findings:

(a) The varieties grown have continually changed, as growers seek to find the most appropriate mix of varieties for their environment given the varieties available.

(b) In each shire, there were approximately 8-10 varieties grown each year, with generally three of those grown on a substantial proportion of the area. The minor varieties were either new varieties in the process of being built up to their peak adoption or older varieties in the stage of being replaced.

(c) In southern shires, there has been a tendency to reduce the number of varieties grown, while in the northern shires the number of varieties grown has increased in the past 30 years.

(d) The rate of turnover of varieties has increased in the southern shires since the 1960s, but has slowed in the northern shires.

(e) The average pattern of adoption and disadoption of varieties shows a rapid increase to a peak share of 15% in the fifth year after release, then a steady disadoption over the following 17 years. On average, the peak adoption level for varieties was higher in the southern shires than in the north, reflecting a marginally less diverse mix of varieties in the south.

(f) The yield levels of varieties increased markedly in all shires during the period since 1965. When the relative yields were weighted by the variety shares, the overall average rate of varietal yield improvement was 1.2% per year throughout the period. The rates of yield improvement were generally the same in the southern shires as in the north.

(g) The bread-making quality of the varieties grown in southern NSW has also increased markedly since the 1960s. In some northern shires, where Prime Hard wheats were already being produced in the 1960s, there has been little change in the overall bread-making quality of the varieties grown. In other shires, especially in the south and central west of NSW, there has been rapid growth in the bread-making quality of the varieties grown. On average, varietal quality has increased at 1.2% per year over the period since 1965, similar to the rate of varietal yield increases.

(h) The progress of breeders in developing the combination of higher-yielding and higher-quality varieties has been notable over the past 30 years or so.

(i) Farmers have generally shown a high level of conformity with NSW Agriculture s list of recommended or approved varieties for each region, with an average of 81% of the area sown to such varieties each year.

(j) Most of the varieties grown in each shire except Lachlan have been released by local breeding programs. However there is a spillover of varieties from the south to the north and vice-versa, as well as from interstate, especially those released in Queensland. The reliance on locally-released varieties has been lower in most shires since about 1980. Lachlan shire,

situated between the northern and southern breeding programs, has used varieties from a range of breeding programs.

(k) There has been a significant shift away from growing varieties with a mix of maturity types to a concentration on mid-maturing varieties since the 1970s.

(l) As well as changing yield and quality of varieties, breeders have brought about a change in the morphological characteristics of the varieties that farmers grow. Varieties have generally become shorter, with stronger straw, a lighter coloured grain and more heavily awned over the period since 1965.

(m) While there was little change in the varietal diversity of the varieties grown in most shires up to the 1980s, there has been some decline in the level of varietal diversity in the 1990s in the southern shires. Within that varietal mix, the underlying genetic diversity has generally declined since the 1980s in some shires, raising some concerns about the capacity to manage crop pests and diseases in the future.

(n) Of the 2.2% per year increase in shire yields since the late 1960s, 1.2% is attributable to varietal change and 1.0% per year is due to other factors such as management and agronomic practices.

(o) If farmers had varieties that only yielded the same as the varieties that were grown in 1965, their income would have been, on average across the eight shires analysed, $103 per hectare lower in 1997.

Overall, then, there have been significant changes in the varieties grown and the characteristics of those varieties. The breeders, by looking to change those characteristics, have brought about significant improvement in both yield and quality of the varieties grown. Growers have responded to the those changes by adopting the higher-yielding and higher-quality varieties from a range of breeding programs, while relying strongly on the Departmental advice on which varieties to grow. Together these changes have led to substantial benefits for NSW wheat growers. However, in some areas, the concentration on a limited number of varieties in recent years has raised some concerns that the genetic base of the varieties grown is becoming narrow and more vulnerable to pests and diseases.

It is clear from the evidence from these data that wheat breeders have provided valuable improvements in varieties for NSW farmers since 1965. The need for those continuing improvements has not diminished in recent years.

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Appendix A: Variety Data

Variety	Release year	Growth habit	Stature	Straw strength	Grain colour	Awns	Head density	Glume colour	Bread making	Early maturing	Mid maturing	Late maturing	Bred in South	Bred in North
Bencubbin	1929	2	6	1	1	1	5	1	4.7	0	1	0	0	0
Gabo	1945	2	4	5	4	3	3	1	7.6	1	0	0	0	1
Insignia	1946	2	2	4	1	4	3	2	3.4	1	0	0	0	0
Pinnacle	1946	2	3	5	1	4	1	2	3.2	0	0	1	0	0
Glenwari	1948	2	4	3	2	5	4	1	3.1	0	1	0	0	0
Spica	1952	2	4	2	4	1	5	1	7.1	1	0	0	0	0
Olympic	1956	2	5	4	1	5	4	1	5.7	0	0	1	0	0
Winglen	1957	2	5	5	5	4	2	1	7.6	0	0	1	0	1
Heron	1959	2	2	4	1	4	4	2	3.3	1	0	0	1	0
Falcon	1960	2	5	3	5	3	2	1	6.3	0	1	0	1	0
Gamenya	1960	2	4	3	3	3	2	1	6.3	1	0	0	0	1
Mengavi	1960	2	3	4	3	3	4	1	7.3	1	0	0	0	1
Festiguay	1963	2	3	4	5	4	2	1	6.8	0	1	0	0	1
Mendos	1964	2	2	5	4	3	4	1	8.0	1	0	0	0	1
Gamut	1965	2	5	4	4	5	5	1	8.3	1	0	0	0	1
Robin	1966	2	2	4	2	3	3	2	3.4	1	0	0	1	0
Timgalen	1967	2	2	4	5	1	3	1	8.6	1	0	0	0	1
Eagle	1969	2	4	3	5	3	5	1	5.5	0	1	0	1	0
Gatcher	1969	2	3	3	3	1	3	1	8.2	1	0	0	0	1
Teal	1972	2	4	5	1	3	3	1	4.2	0	0	1	1	0
Condor	1973	2	2	5	1	1	3	1	7.8	0	1	0	1	0
Egret	1973	2	2	5	1	1	3	1	2.5	0	1	0	1	0
Kite	1973	2	2	6	5	3	5	1	7.2	0	1	0	1	0
Songlen	1975	2	4	4	4	1	2	1	8.3	1	0	0	0	1
Cook	1977	2	2	2	4	1	2	1	8.7	0	1	0	0	0
Shortim	1977	2	1	5	4	1	3	1	8.3	0	0	1	0	1
Millewa	1978	2	5	4	3	1	4	1	6.5	0	1	0	0	0
Avocet	1979	2	2	4	3	1	4	1	2.4	0	1	0	1	0
Banks	1979	2	4	5	3	1	4	1	8.1	0	1	0	0	0
Harrier	1981	1	4	5	5	1	4	1	8.0	0	0	1	1	0
Sunkota	1981	2	4	4	5	1	3	1	6.8	0	0	1	0	1
Hartog	1982	2	5	5	4	1	5	1	7.6	0	1	0	0	0
Kamilaroi(D)	1982	2	2	1	5	1	3	1	1.0	0	1	0	0	1
Suneca	1982	2	5	5	3	1	4	1	7.4	0	0	1	0	1
Osprey	1983	1	3	4	5	1	2	1	7.7	0	0	1	1	0
Quarrion	1983	1	3	4	3	1	4	1	5.7	0	0	1	1	0
Sunstar	1983	2	2	5	1	1	3	1	7.5	0	1	0	0	1
Takari	1983	2	4	5	4	4	4	1	7.2	0	1	0	0	1
Corella	1984	2	5	4	4	1	3	1	2.0	0	1	0	1	0
Sundor	1984	2	4	5	3	1	3	1	7.8	0	1	0	1	1
Sunelg	1984	2	1	5	5	3	4	1	7.2	0	1	0	0	1
Rosella	1985	1	2	5	1	1	3	1	5.7	0	0	1	1	0
Vulcan	1985	2	5	5	3	1	3	1	7.2	0	1	0	0	1
Sunco	1986	2	2	5	1	1	3	1	8.3	0	1	0	0	1
Dollarbird	1987	2	3	5	3	1	3	1	7.7	0	1	0	1	0
Hybr. Meteor	1987	2	5	5	3	5	5	1	7.8	0	1	0	0	1
Yallaroi (D)	1987	1	3	4	5	1	3	1	1.0	0	1	0	0	1
Miskle	1988	2	2	5	3	1	3	1	7.6	0	1	0	0	1
Janz	1989	2	4	4	1	1	3	1	8.2	0	1	0	0	0
Cunningham	1990	2	3	3	1	1	3	1	7.2	0	1	0	0	0
Sunbri	1990	1	4	2	3	1	3	1	7.6	0	0	1	0	1
Batavia	1991	2	4	5	1	1	3	1	7.9	0	1	0	0	0
Sunstate	1992	2	5	5	3	1	3	1	7.1	0	1	0	0	1
Swift	1993	2	4	5	3	1	3	1	8.2	0	1	0	1	0
Wollaroi(D)	1993	1	2	4	5	3	3	1	1.0	0	1	0	0	1
Sunbrook	1995	1	4	2	3	1	3	1	7.3	0	0	1	0	1

Growth Habit (1=winter 2=spring 3=facultative)
Stature (1=very short 2=short 3= short-medium 4=medium 5=med-tall 6=tall)
Straw Strength (1=weak 2=weak-med 3=medium 4=med-strong 5=strong 6=very strong)
Grain Colour (1=light 2=light-med 3=medium 4=med-dark 5=dark)
Awns (1=full 2=full-half 3=half 4=half-tip 5=tip)
Head Density (1=dense 2=dense-med 3=med 4=med-lax 5-lax)
Glume Colour (1=white 2=brown 3=black)

Appendix B: Relative Yields of Varieties[a], by Shire

Variety	Wagga	Temora	Cowra	Carrathool	Lachlan	Coonabarabran	Gunnedah	Narrabri
Bencubbin	51.1	58.4	87.5	74.1	60.7	70.0		
Gabo	54.8	53.3	86.9	75.0	44.7	70.0	80.0	70.0
Insignia	55.8	76.4	82.1	75.0	45.0			
Pinnacle	70.2	53.4	82.6	70.0	30.4			
Glenwari	58.9	60.7	92.4	75.0	51.3	70.0	85.0	72.0
Spica	59.9	46.9	90.0		45.3	84.5	89.8	69.0
Olympic	87.0	83.7	89.1	88.1	76.2	75.0		
Winglen	75.2	72.2	112.6	90.8	93.7	85.0	85.0	85.0
Heron	64.8	64.5	83.9	79.5	66.0	75.0		
Falcon	72.3	70.6	90.9	62.5	75.0	67.8	95.8	93.0
Gamenya	71.1	62.7	77.3	78.4	67.6	100.0	103.5	82.0
Mengavi	60.7	54.2	78.0	60.0	43.7	90.0	90.0	80.0
Festiguay	83.5	74.0	79.8	68.2	46.3	85.7	81.8	73.0
Mendos	82.1		82.0		30.0	86.1	87.0	66.0
Gamut	64.6	52.3	80.5	60.1	53.9	88.1	94.4	76.8
Robin	73.9	59.7	94.5	80.3	59.9	100.7	102.7	103.1
Timgalen	75.1		55.8	61.8	53.9	82.3	86.5	86.8
Eagle	85.7	79.7	87.8	74.0	60.8	88.1	90.2	82.6
Gatcher	78.6	64.1	84.5	67.4	62.3	84.2	88.8	82.6
Teal	89.9	90.4	89.4	90.5	76.4			
Condor	103.9	102.6	106.8	105.1	94.0	96.4	107.9	99.9
Egret	104.4	99.6	89.6	90.9	97.1	88.1		
Kite	87.5	89.6	100.5	94.9	78.8	101.0	97.9	97.1
Songlen					83.6	85.6	96.6	84.1
Cook	93.0	98.1	105.1	91.4	88.4	98.1	102.7	96.6
Shortim			83.9	48.8	69.6	94.1	96.2	89.5
Millewa	110.9	112.2	101.8	109.9	100.6	102.1		
Avocet	68.8	62.6	82.6	74.8	78.6			
Banks	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Harrier	94.6	104.0	98.7	92.1	90.0	101.7	112.0	112.0
Sunkota			96.0	92.5	99.5	93.3	110.0	110.0
Hartog	118.1	111.6	108.1	99.0	105.9	113.9	109.0	109.0
Kamilaroi (D)						104.4	105.0	105.0
Suneca			88.5	95.4	83.0	97.9	99.0	99.0
Osprey	102.1	102.9	105.7	99.3	99.2	108.5	97.0	
Quarrion	90.3	98.2	103.7	92.9	94.5			
Sunstar	112.9	109.2	102.3	109.7	108.3	101.9	114.0	114.0
Takari	79.0	98.6	117.7	87.3	90.6	106.2	101.0	101.0
Corella	106.4	113.2	115.8	105.0	101.4			
Sundor	109.0	109.3	103.2	103.4	96.1	91.3		
Sunelg	100.9	97.8	96.2	91.3	91.3	103.6	103.4	105.4
Rosella	105.0	109.0	111.3	100.4	102.1	110.0	113.2	104.4
Vulcan	114.9	111.3	108.6	112.8	108.7	118.7	103.9	108.8
Sunco		107.9	99.1	98.6	100.5	108.3	103.8	98.0
Dollarbird	114.0	114.5	108.9	102.3	111.0	110.4	104.4	104.4
Hybrid Meteor						112.0	124.2	108.6
Yallaroi (D)							109.0	115.0
Miskle	107.9	109.3	107.8	99.1	104.5	115.0	103.4	92.9
Janz	119.3	114.4	110.9	107.4	108.0	126.5	110.8	107.7
Cunningham	116.1	108.3	105.0	102.3	108.2	117.2	108.6	101.8
Sunbri	99.2	101.4	101.9	98.6	110.4	123.8	109.9	109.9
Batavia	110.1	100.0	100.6	98.9	104.1	120.5	102.2	103.3
Sunstate				107.4	98.6	94.2	104.9	104.9
Swift	113.4	101.6	98.0	103.4	98.3		103.3	104.4
Wollaroi (D)							105.5	115.4
Sunbrook	100.7	105.3	102.0	93.2	106.9	121.0	107.7	107.7

a For convenience, yields are expressed as a percentage of Banks.

See section 3.4 for a detailed explanation of the sources and derivation of the data.

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