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Optimum number of regional trials for selection of wheat varieties in northern grain region

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Abstract

The major purpose of any testing program is to establish repeatable differences between cultivars in a given environment but cultivars rarely perform consistently across the range of environments in which they are tested. Plant breeders recognise that the nature of genetic material and the environments in which it is tested are such that there is a lot of uncertainty involved in the selection of superior varieties.

Economists have not been closely involved with the cultivar selection process and only recently has there been much interest taken by economists in the costs and management of breeding programs (Brennan *et al.* 1998).

This paper tries to estimate long term variable costs of conducting regional variety trials and to determine the optimal number of trials for south Queensland and northern New South Wales graingrowing regions.

Introduction

Brennan *et al.* (1998) noted that the assessment of potential new cultivars of cereal crops involves a comparison of their characteristics (for example, yield, disease resistance, milling qualities) with those of standard cultivars in field experiments. These field experiments are usually grown at a number of sites and, over a number of years of intensive testing, the cultivars that have attributes required by farmers for commercial production are gradually selected from a range of genetic material. This selection process usually proceeds in stages with large numbers of entries of variable material at the start of the process and fewer lines with more consistent characteristics in the later stages.

The major purpose of the testing program is to establish repeatable differences between cultivars in a given environment but cultivars rarely perform consistently across the range of environments in which they are tested. Plant breeders recognise that the nature of genetic material and the environments in which it is tested are such that there is a lot of uncertainty involved in the selection of superior varieties. It is therefore largely a question of judging between uncertain quantities to determine which potential new cultivars are genuinely superior to the standards or commonly grown varieties (Brennan *et al.* 1998). However, cultivars respond in unique ways to the environment in which they are grown, and their ranking is seldom consistent between locations or across the years in which they are tested.

Various methods of spatial and temporal testing have been devised to obtain statistical estimates of the GxE interactions that are involved and to capture their impact on the selection of superior cultivars. This research has largely quantified the technical implications and allowed researchers to develop estimates of the error structures associated with their experimental designs. However, the cost implications of this work on breeding and selection strategies have not been fully explored. They have not been exploited to the extent possible in the management of field testing programs. Managers of varietal testing programs must address questions about where, how often and in what numbers should new genetic material be tested in the process of selecting superior cultivars for commercial production. Economists have not been closely involved with the cultivar selection process and only recently (eg Brennan 1986, Kingwell 1987, Brennan and Murray 1989, Brennan *et al.* 1998) has there been much interest taken by economists in the costs and management of breeding programs.

This paper tries to estimate long term variable costs of conducting individual trials and to determine the optimal number of trials for south Queensland and northern New South Wales graingrowing regions.

Selection trials in Queensland

The selection process for wheat varieties in Queensland is based on three stages: preliminary, strain, and regional variety trials (J. Shepherd, *pers.comm.*, June 1998). Individual cultivars included in Stage 1 and Stage 2 trials are repeated (they are included in those trials twice before discarding or progressing to the next stage). The objective of the current exercise was to calculate the least cost way of carrying out the number of trials needed to minimise the sum of actual trial costs and cost of Type I and II errors for yield but it has been observed that the main cause of loss of varieties from the program has been due to quality factors.

Table 1: Approximate number of entries in stage trials, Queensland

Stage	Starting number	Approximate number selected
Preliminary (i)	1 500	300-400
(ii)	300	100
Strain (i)	1 000*	120-150
(ii)	120	18-20
Regional (i)	18	6
(ii)	6	4
(iii)	4	2

Footnote: * 10 single plant selections are taken from the 100 “varieties” that come through the preliminary stage trials which makes the number of individuals going into the strain trials up to 1 000.

The total number of plots involved in this exercise varies from year to year but the current south Queensland program requires about 25 000 plots per year and 10 000 for Central Queensland. The Queensland wheat breeding program is based on making variety selections within three maturity groups: quick, intermediate and slow, with one of the three plant breeders at Leslie Research Institute (QWRI) responsible for each section of the program. In a recent year which can be used as a typical example, there were 1 910 entries into preliminary stage trials, 650 entries in strain trials, and 64 in regional variety trials, allocated among the maturity groups as shown in the following table.

Table 2: Entries and location of selection trials for a typical season

Type of trial	Entries	Location of trials
Preliminary stage (single rep.)		
Slow	890	3 SQ, 2 CQ
Intermediate	470)
Quick	550) 2 SQ, 1CQ
Total	1 910	8 trials
Strain (2 reps)		
Slow	210)
Intermediate	340)
Quick	100) 4 SQ, 2 CQ trials
Total	650	6 trials
Regional variety trials (3 reps.)		
Slow (4 standards)	24)
Intermed. (4 stds)	24)
Quick (4 standards)	16) 15 SQ, 8 CQ
Total	64	18 trials

The plant breeding staff intend to increase the number of entries in this program to 3 000 over the next few years as a consequence of reducing the size of plots in the regional variety trials from 13 to 8 metres in length. Selected varieties are usually kept in the regional variety trials

for a total of 5 years to give growers an opportunity to see and compare them with the existing standard varieties.

Details of 1998 trials as a basis for estimating cost structure

Actual planting details for 1998 trials are included in the following tables as a basis for estimating cost structure.

Table 3: 1998 trial plantings, South Queensland

Site	Planting dates	Plots planted	Type of trial			Comments
			Prelimin.	Strain	Regional	
1. Lundavra	12 May	1 490				
	28 May	140	900	450	280	
2. Billa Billa	13 May	140				
	29 May	900	550	200	280	
3. Moonie	13 May	140				
	4 June	400	0	0	320	400 plots replanted
4. Inglestone	13 May	140				
	27 May	1 550	500	910	280	
5. Dulacca	21 May	120				
	22 May	660	0	450	280	
6. Wallumbilla	21 May	140				
	2 June	140	0	0	280	
7. Roma	22 May	400				
	26 May	1 400				
	9 June	1 600				
	10 June	200	900	420	280	Includes plots for quality as well as regional varieties
8. Meandarra	27 May	140				
	3 June	850	550	200	240	
9. Culara	28 May	140				
	3 June	400	0	240	280	
10. Murra Cul Cul	28 May	300				
	5 June	2 120	0	0	280	
11. Haystack	2 June	300	0	0	280	
12. Bungunya	4 June	1 500	500	710	280	
13. Jimbour (Kents)	5 June	140				
	15 June	2 780	0	0	280	
14. Purrinuan	5 June	280				
	11 June	230	0	230	280	
15. Macalister	11 June	1 600	890	420	280	
16. Jimbour (Little)	12 June	710	0	710	710	
17. Gatton College	25 May	2 520	0	0	0	All GEP
Total		21 230				

The total number of plots planted this year was over 21 000. Totals are not always the sum of preliminary, strain and regional plots since there might be other plots, eg. barley, oats selection, quality and germplasm enhancement plots included in some trials.

Central Queensland

The 1998 program in Central Queensland comprises a series of 9 trials, a number of which were solely regional variety trials. Some of the trials are carried out in conjunction with other experimental work, for example barley selection trials, and the nature of the environment means that two or even more planting dates are required to accommodate the range of maturity dates within the genetic material. The objective is to plant the different maturing lines in such a way that they all mature at the same time for convenient harvesting. This is not always possible in central Queensland which makes the trials more expensive to service.

The following table sets out trial location, type of trial, and plot numbers for the central Queensland series for 1998.

Table 4: Location of Central Queensland trials for 1998

Location	Type of trial			Other plots	Total
	Preliminary	Strain	Regional		
Kilcumin	550 (quick)	200 (quick)	192 (quick)	S28 (fertiliser)	970
Capella			192 (Q, I, S)	28 (fertiliser)	220
Gindie	890 (slow)	420 (slow)	192 (Q, I, S)	28 (fertiliser) 60 (barley, R) 280 (barley, S)	1 870
Fernlees	890 (slow) 470 (inter.)	420 (slow) 680 (inter.)	192 (Q, I, S)	60 (barley, R) 2 630 (UQ, GEP)	5 342
Orion			192 (Q, I, S)		192
Bauhinia			192 (Q, I, S)	28 (fertiliser) 60 (barley, R)	280
Theodore			192 (Q, I, S)		192
Dauringa		680 (inter.)	192 (Q, I, S)		872
Biloela R.S.		200 (quick)	192 (Q, I, S)	60 (barley, R) 280 (barley, S) 180 barley select 72 (barley, rust)	985
Total					10 731

Cost estimates

Plant breeding staff in south and central Queensland were asked to keep detailed diaries of time spent planting, maintaining and harvesting trails in 1998 so that variable costs of the trial program could be determined. We were particularly interested in costs that changed as the number of trials, and the number of entries in them, increased.

South Queensland

On the basis of a spreadsheet analysis prepared for each current trial, the following cost structure is estimated for trials in the south Queensland wheatgrowing zone. It should be

noted that these are long term variable costs, that is those items of expenditures that could possibly be saved if these trials were not carried out. They therefore include an estimate of the cost of staff time involved in servicing these trials, tractor and header operating costs, travelling costs to trial sites and overnight accommodation, as well as fertilisers, chemicals, and any other expenses that are directly attributable to the conduct of these trials. The overhead costs for the plant breeding staff and general activities associated with the plant breeding program have not been allocated. The balance of staff time when not actually working on specific trials, the fixed costs associated with facilities and equipment used for plant breeding work, and supporting research services used by the program have not been considered. There are some notes about some of these costs for the Queensland program are available from the authors.

Table 5: Variable cost estimates for each wheat selection trial in south Queensland

Location	Type of trials				Variable Cost estimate	Notes
	Prelim. plots	Strain plots	Regional plots	Total plots		
Lundavra	900	450	280	1 630	7 826	
Inglestone	500	910	280	1 690	6 203	
Bungunya	500	710	280	1 500	5 901	
Macalister	890	420	280	1 600	6 068	
Billa Billa	550	200	280	1 040	5 143	
Meandarra	550	200	240	990	5 678	
Roma	900	420	280	3 480	11 553	Incl. 1 880 plots
Dulacca	0	450	280	780	4 797	for quality trials
Culara	0	240	280	540	4 761	
Pirrinuan	0	230	280	510	3 130	
Jimbour (Little)	0	710	0	710	2 981	
Wallumbilla	0	0	280	280	4 101	
Haystack	0	0	280	300	3 827	
Moonie	0	0	320	400	4 147	
Jimbour(Kents)	0	0	280	2 780	10 184	Incl. 2 640 GEP
Murra Cul Cul	0	0	280	2 420	7 780	Incl. 2 120 GEP
Gatton College	0	0	0	2 520	7 317	All GEP plots

For costing purposes, the trials have been grouped according to whether they contained entries from all three stages (preliminary, strain, or regional), whether they included both strain and regional lines, or were simply regional trials. While the combined trials were the most expensive to conduct on average, (trials with all three stages accounted for \$5 000 up to \$6 000 in variable costs in most cases), the cost per plot was considerably lower than for trials where only regional material is tested. This is clearly the most costly stage in the testing program and should always be combined with other stage trials if possible. A large part of the costs associated with field trial work is the cost of actually getting the staff to the trial site. If they can service a larger number of plots while they are there, then the cost of servicing these trials on a \$ per plot basis is relatively less.

These data can be used to estimate the impact on total variable costs of varying the number of trials that are conducted. To the required combination of preliminary and strain trials, as well as trials associated with the Germplasm Enhancement Program, it is possible to add a

variable number of regional stage trials and the effect of doing this on the program cost structure is shown in the following graph.

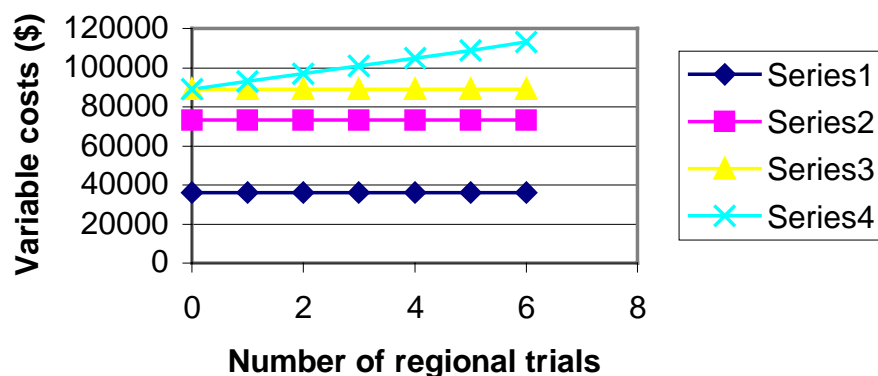


Figure 1: Variation in south Queensland trial costs against number of regional stage trials

Series 1 = combined preliminary, strain and regional trials at 6 locations; Series 2 = regional trials including germplasm enhancement material; Series 3 = combined strain and regional trials; Series 4 = total variable cost estimate

Central Queensland costs

On the basis of spreadsheet calculations, the following cost structure is estimated for the Central Queensland selection trial program.

Table 6: Variable costs for trials in Central Queensland

Location	Type of trials				Estimated cost	Notes
	Prelim. plots	Strain plots	Regional plots	Total plots		
Kilcumin	550	200	192	970	\$10 200	
Gindie	890	420	192	1 870	10 500	Also incl. barley
Fernlees	1 360	1 100	192	5 342	16 800	2 630 GEP plots
Dauringa		680	192	872	9 100	
Biloela RS		200	192	985	9 300	Also incl. barley
Capella			192	192	5 300	
Orion			192	220	4 100	
Bauhinia			192	280	6 100	Also incl. barley
Theodore			192	192	5 000	

It is again noted from this table that the conduct of regional trials on their own is relatively more expensive than including them with other stages at fewer sites. If the number of lines at the preliminary and strain stage is to be increased, then it would be cost effective to put them at sites that already have regional and/or strain trials.

From the point of view of cost savings, it might also be possible to consider relocating the GEP material or the barley variety work to other sites rather than concentrating it all at one or two of the existing sites. Practical considerations, such as evenness of the site and assistance from the farmer cooperator, are obviously important factors in making decisions about where these trials are situated.

The impact of varying the number of trials conducted in central Queensland is shown in the following figure. The number of regional trials has been varied from five which is the minimum number regarded as technically acceptable to met the needs of the program up to nine.

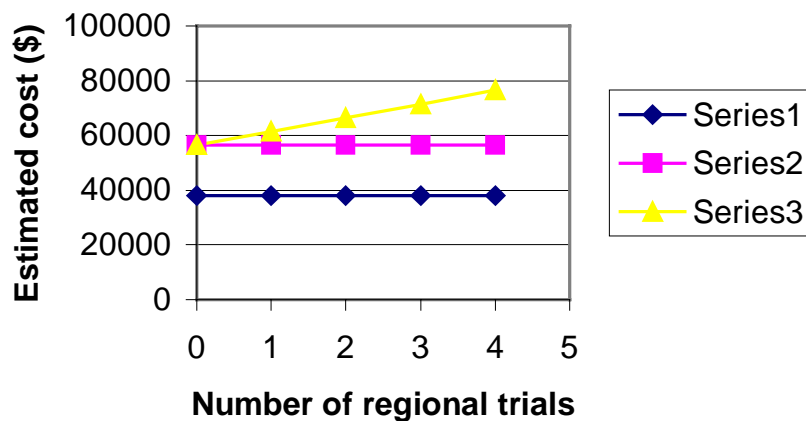


Figure 2: Variation in variable costs due to change in number of regional trials, Central Queensland. Series 1 = cost of combined preliminary, strain and regional trials; Series 2 = cost of combined strain and regional trials; and Series 3 = total cost of all trials including a variable number of regional trials.

The majority of costs, by far, are associated with the preliminary and strain trials in the selection program. As the number of regional trials increases, the costs are presented as increasing linearly although as more trials are included in the trial program, and the distance to trial sites increases, then costs might be expected to rise in a non-linear fashion.

New south Wales: Selection trials conducted by University of Sydney, Plant Breeding Institute, Narrabri

A summary of the system for selecting new wheat varieties in northern New South Wales, based on discussions with Frank Ellison, University of Sydney, Plant Breeding Insititue, Narrabri (September 1998) is presented in Table 7.

Table 7: Stage activities in PBI program for northern New South Wales

Stage	Summary of activities
First stage	1 000 rust-resistant single plant lines from Usydney breeding program tested each year (for quality, milling performance, and dough characteristics) to provide 700 entries to this stage. Planted in spatially analysible single replicate trials (20% controls)

	Planted at three sites (eg. North Star, Narrabri, Gilgandra) 300 lines proceed to next stage
Second stage	300 entries Planted at five sites (eg. Walgett and Spring Ridge added to previous three sites). 100 lines proceed to third stage.
Third stage	100 entries Planted at 10 sites (five new sites in addition to five already used for earlier stages). Unreplicated 1.8 x 6m plots 20 of best lines proceed to NSW Agriculture regional variety trial program.

NSW Agriculture has traditionally carried out yield testing of advanced lines from a number of sources. Since NSW Agriculture no longer has a bread wheat breeding program for the northern region, they are currently testing about 20 lines from PBI, 20 lines from QWRI and 10 lines from Hybrid Wheat Australia in spatially analysible 2-replicate S3 trials at a number of sites throughout the northern New South Wales graingrowing region.

PBI program costs

Individual spreadsheets were also prepared for trials conducted by University of Sydney, Plant Breeding Institute staff. Again the approach has been to present the data in a form that allows the cost changes to be observed as the number of trials is changed. In this case, the activities from two organisations have to be combined (Plant Breeding Institute and NSW Agriculture to obtain a complete picture of the cost relationships in the northern section of the NSW wheatgrowing area. Table 8 summarises the data from Plant Breeding Institute trials.

Table 8: Summary of PBI program trials and costs

Trial location	Type of trial			Total number of plots	Cost estimate
	S1 entries	S2 entries	S3 entries		
Combined S1, S2 and S3 trials (Narrabri, North Star, Gilgandra)	700	300	100	1 300	17 349
	700	300	100	1 300	28 273
	700	300	100	1 300	30 090
Combined S2 and S3 trials (Walgett, Moree)	0	300	100	600	18 996
	0	300	100	600	15 272
Stage 3 trials: Spring Ridge Myall Vale	0	0	100	300	8 347
	0	0	100	300	7 319

In addition to the 10 trials conducted by University of Sydney, NSW Agriculture also carries out a number of S3 trials in the northern NSW zone with Crop Evaluation Unit staff based at Narrabri, Gunnedah, Condoblin, and Coonamble sites. In 1998, nine of these sites were planted before 15 May and another nine planted after 15 May. Only limited information is available at this time to cost the NSW Agriculture trial activities but it can probably be assumed that they have a similar cost structure to the regional trials conducted in Queensland. Trials where only regional varieties are tested appear to cost about \$4 000 per site in variable costs in south Queensland and \$5 000 to \$6 000 per site in Central Queensland. The NSW Agriculture program costs were based on the lower Queensland estimate and allowed the cost curve for northern NSW to be calculated as the number of regional trials was varied.

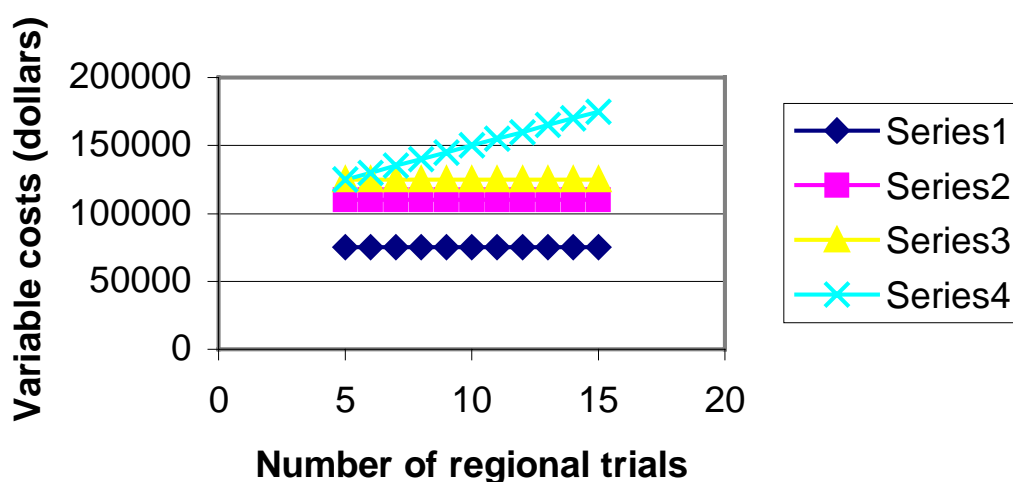


Figure 3: Effect of number of trials on variable costs in northern NSW. Series 1 = cost of combined S1, S2 and S3 trials conducted by University of Sydney; Series 2 = cost of combined S2 and S3 trials; Series 3 = cost of University of Sydney S3 trials; Series 4 = total variable cost estimate including the cost of a number of NSW Agriculture S3 trials.

In the past, there was no coordination between the University of Sydney program and the NSW Agriculture activities but there is some coordination now and more could be possible. For instance, the PBI team could contain their activities to an area reasonably close to their base at Narrabri if the NSW Agriculture staff at some of the centres such as Gunnedah, Condoblin, Coonamble, could be used to plant S2 and S3 trials in those areas to support the University of Sydney program. It is presumed that NSW Agriculture would continue to operate from Narrabri because of the need to carry out evaluation activities for other crops in that area.

Benefits of cultivar testing

The benefits of cultivar testing can be listed as the benefits that the farmers obtain from growing a new variety rather than a former single variety or group of varieties. This benefit may be expressed as higher yields or reduced losses due to disease, higher prices due to better quality, or reduced growing costs. Total benefits in any year depend on the area of the new cultivar sown, the marginal increase in yield or quality parameters for the new variety over the displaced variety, the price obtained, and any change in the cost of growing the new cultivar compared with the one it replaced.

The net benefits from a variety selection program are therefore the difference between the total gross benefits arising from the release of new varieties less total trial costs as well as the opportunity cost of errors made during the selection process. These errors could be principally of two types: the errors when a cultivar is released but its true yield is inferior to or no better than existing varieties; or when a cultivar is not released even though its true yield is superior to that of existing cultivars. The value of these opportunity costs depends on the contribution of individual varieties to the graingrowing economy of the northern region.

Value of wheat production in northern region

Data on the value of wheat production in south and central Queensland and northern New South Wales were recently assembled by Murray Davis (Davis 1998). The relevant statistical information for the 10-year period, 1986-87 to 1996/97 is produced in the following tables.

Table 9: Value of wheat production in northern region, 1986-7 to 1996-7

Area	Central Queensland			South Queensland			Northern New South Wales		
	Area planted ('000ha)	Production ('000 t)	Yield (t/ha)	Area planted ('000ha)	Production ('000 t)	Yield (t/ha)	Area planted ('000ha)	Production ('000t)	Yield (t/ha)
1986/87	180.0	224.0	1.24	659.0	665.0	1.01			
1987/88	163.0	257.0	1.58	503.0	481.0	0.96	1 212.0	1 729.0	1.43
1988/89	200.0	429.0	2.15	640.0	1 283.0	2.00	1 184.0	1 949.0	1.65
1989/90	215.0	420.0	1.95	664.0	971.0	1.46	1 095.0	1 561.5	1.43
1990/91	376.0	704.0	1.87	737.0	1 374.0	1.86	1 090.6	2 046.5	1.88
1991/92	87.0	89.0	1.02	395.0	256.0	0.65	755.4	842.8	1.12
1992/93	185.0	176.0	0.95	463.0	552.0	1.19	796.6	1305.8	1.64
1993/94	107.5	133.7	1.24	447.4	419.9	0.94	961.9	2 462.0	2.51
1994/95	77.6	54.2	0.70	322.8	170.2	0.53	580.6	221.8	0.38
1995/96	103.2	59.8	0.58	522.7	459.0	0.88	1 243.8	2 045.4	1.64
1996/97	191.1	309.9	1.62	827.5	1 797.9	2.17	1 809.4	4 597.1	2.54
Average	171.4	259.7	1.36	561.9	766.3	1.24	1 074.9	1 876.1	1.62

Brennan and Murray (1998) ["Economic importance of wheat diseases in Australia", NSW Agriculture, Wagga Wagga, 48 pp] estimated the unit value of wheat production in the northern region at \$199 per tonne. Using this figure, the area has a gross value of production which averaged \$580 million per year over the past 10 years although production in the area is highly variable and fluctuated from a low level of 357 000 tonnes in 1995/95 to over 6.7 million tonnes in the best of the past 10 years, 1996/97.

Adoption of new varieties in Queensland

Brennan and Fox (1995) listed the varieties in the following table as released by the Queensland wheat breeding program between 1974 and 1993. The series was extended by more recent information (Brennan, P. 1998. "Review of Northern wheat improvement program) to the present time.

Table 10: Varieties released by Queensland wheat breeding program

Variety	Year of release
Oxley	1974
Cook	1977
Banks	1979
Hartog	1982
Flinders	1982
Bass	1983
King	1983
Torres	1983
Vasco	1985
Diaz	1986
Perouse	1989
Janz	1989
Cunningham	1990
Batavia	1991
Houtman	1992
Tasman	1993
Pelsart	1993
Rowan	1993
Leichhardt	1995
Arnhem	1996
Mawson	1996
Kennedy	1998
Baxter	1998

From the data presented in the table, it is revealed that there were 13 new varieties released in the past nine years, a rate of about 1.5 per year or three new varieties each two years.

Australian Prime Hard wheat (APH) is the major grade of wheat exported from Queensland. Most deliveries to other grades are Prime Hard varieties which have not met AWB receival standards, often because they did not reach the minimum protein requirement. The main APH varieties in Queensland, in order of receival volume currently are Hartog, Cunningham, Batavia, Sunco, and Janz (Mills and Sheppard, 1998). Detailed information listing all of the currently grown varieties in Queensland in order of popularity has been provided on a confidential basis by the AWB.

Because of climatic conditions in Queensland wheat growing areas and the consequent variability in the time of planting, there is a need to have a range of varieties in each maturity category. This adds to the cost of the plant breeding program and reduces the value of any single variety. In each year, a proportion of slow, intermediate and quick maturing varieties are grown, depending on weather conditions and other factors. The current recommendations for south and central Queensland are set out in the following table.

Table 11: Variety recommendations by maturity date, South and Central Queensland

Maturity group	South Queensland	Central Queensland
Slow maturity	Sunvale Batavia Sunlin	Batavia
Intermediate maturity	Meteor Cunningham Pelsart Janz Sunco	Janz Rowan Sunco Cunningham Houtman Meteor Sunvale Sunlin
Quick maturity	Hartog Rowan Tasman Sunstate Leichhardt Arnhem Mercury	Hartog Sunstate Tasman Leichhardt Arnhem Mercury

Source: DPI Wheat varieties for Queensland 1998

In the absence of more detailed data, it has been assumed that each popular variety stays on the farmer's list of choices for about 12 years. During six of those years, the area planted to the variety increases and then declines as it is replaced by a newer, higher yielding variety or one with other desirable characteristics such as disease resistance.

Adoption of new varieties in northern New South Wales

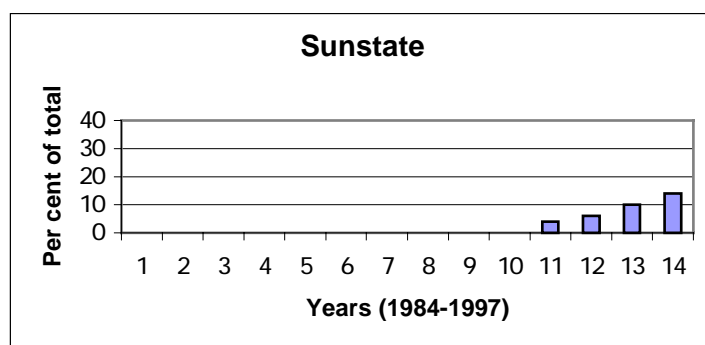
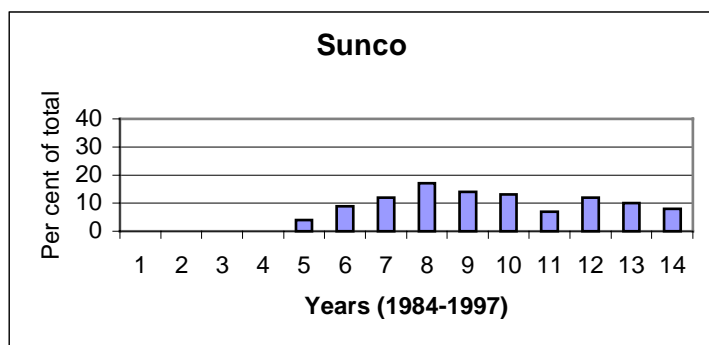
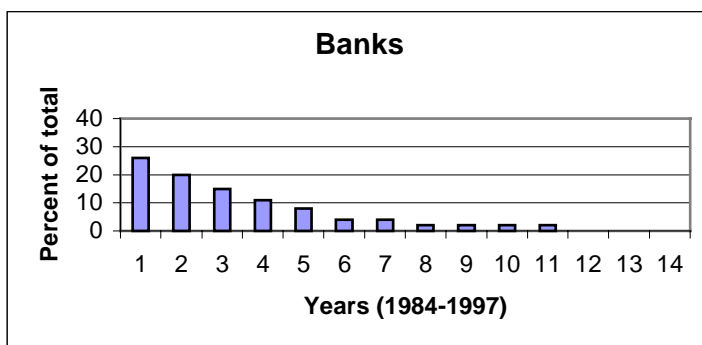
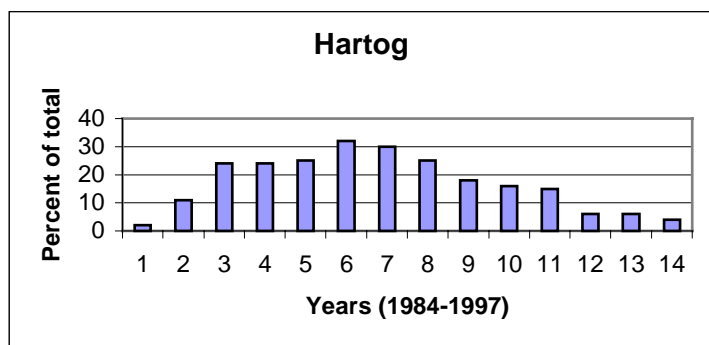
Information on wheat varieties grown in northern New South Wales since 1984 is presented in the following table.

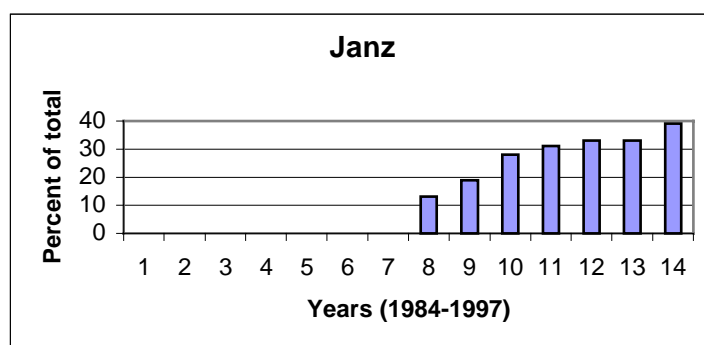
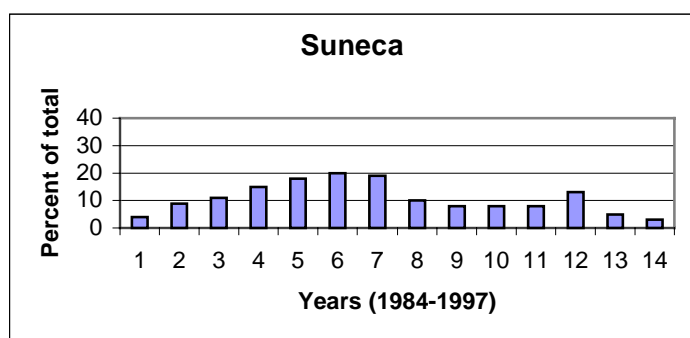
The most popular varieties in northern New South Wales over the past 15 years have included Banks, Hartog, Sunco, Suneca, and Janz. They appear to reach a peak of about 30% of the total plantings (although Janz comprised nearly 40% of the plantings in northern New South Wales in 1997) and remain as significant varieties for about 12 to 14 years. Some adoption profiles for the most popular varieties are shown in the following figures.

Table 12: Northern NSW wheat varieties (1984-1997)

Variety	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984
Batavia	3	5	3											
Cunningham	6	8	9	12	2									
Hartog	4	6	6	15	16	18	25	30	32	25	24	24	11	2
Janz	39	33	33	31	28	19	13							
Kamilaroi	4				2									
Miskle	1	3	3	5	7	9	5	1						
Sunbri	2	6	6	3	4	5								
Sunbrook	4													
Sunco	8	10	12	7	13	14	17	12	9	4				
Suneca	3	5	13	8	6	8	10	19	20	18	15	11	9	4
Sunland	1	1												
Sunmist	2	2	1											
Sunstate	14	10	6	4										
Sunvale	3	1												
Wallaroi	1													
Dollarbird		1	1	4	3	3	2	1						
Banks				2	2	2	2	4	4	8	11	15	20	26
Sunelg				2	2	2	3	2	3	2	2			
Sunkota				3	3	3	3	7	9	12	11	11	13	9
Kite					2	3	3	3	3	6	8	10	12	15
Vulcan					3	7	8	8	7	5				
Resella						1		2	2					
Sunstar							2	3	3	5	6	8	8	1
Osprey								2	2	3	4	3	3	
Harrier										1	1	2	3	6
Takara										2	2	3	3	
Condor											1	2	3	5
Cook											1	3	5	12
Songlen											1	2	4	11
Gatcher													2	2
Eagle														2
Shortim														3

Source: Wheat Varieties in New South Wales 1973-1977, Australian Institute of Agricultural Science Occasional Paper No. 107





The rate of release of new varieties in northern New South Wales over the past 10 years has been such that about one new variety each year reached a significant proportion of the total planting (>1 percent). The following table shows information about the release dates of recent new varieties.

Table 13: Rate of release of new varieties in New South Wales

Date of first significant production	Variety
1988	Sunco
1989	Rosella
1990	Miscle, Dollarbird
1991	Janz
1992	Sunbri
1993	Cunningham
1994	Sunstate
1995	Batavia, Sunmist
1996	Sunland, Sunvale
1997	Sunbrook, Wallaroi

However, not all of these were successful in commercial production. While there were 15 varieties that achieved more than 1 percent of the planted area in the 10 years 1988 to 1997, over 60 percent of the wheat grown in northern New South Wales consisted of three varieties in 1997, Janz (39%), Sunco (8% and apparently declining), and Sunstate (with 14%).

Value of a new variety

To estimate the value of a new variety, some assumptions need to be made about the yield increase expected, the increase in area grown of the new variety (rate of adoption), and the window of opportunity before the new variety will itself be replaced. On the basis of release rates that apply for Queensland and NSW where new varieties are released at fairly frequent intervals, their value can be assessed in terms of the increased yield that will be achieved by growers during the relatively short period before that variety itself is replaced.

To estimate the advantage from a new variety, perhaps the case of Janz replacing Hartog in northern New South Wales might be considered. Data from Table 12 show that Hartog represented 2% of plantings in 1984, reached 30% in 1990, and then declined, but it still comprised 4% of plantings in 1997. Janz was first included in the statistics in 1991, at 19% of the total area, rising to 39% by 1997. The introduction of Sunco (in 1988) and Sunstate (1994) is also of interest. It seems that new varieties which might eventually make up a

significant proportion of the wheat crop in northern New South Wales are released at 3-5 yearly intervals.

The majority of wheat in northern New South Wales appears to be grown as “Main season” wheat. While yield information on Early sown (before 15 May) and Main season (sown after 14 May) varieties is presented in Gammie (1997), a comparison with Table 12 shows that only about 6 percent of the area was planted to early season varieties in 1997. It therefore seems acceptable to assess varieties as “Main season” varieties with the appropriate assumptions made about the maximum area that it might occupy. There is also an opportunity to identify and value minor varieties, suitable for niche growing conditions, for example, early planting, but with such a small amount of wheat being planted at this time of year in northern New South Wales, there seems little reason to do so.

On the basis of release rates that apply for northern NSW, new varieties that make up a significant proportion of the wheat crop are released at 3-5 yearly intervals. Their value can be based on the increased yield that will be achieved by growers during the period before that variety itself is replaced. Three different rates of adoption have therefore been chosen to reflect what has happened recently with wheat varieties in northern NSW: a slow linear adoption rate (2, 4, 6, 8, 10, 12, 14% of the area grown over a period of 7 years); a rapid linear adoption rate (2, 8, 14, 20, 26, 32% over 6 years); and an exponential adoption rate (2, 4, 8, 16, 32, 32% again over 6 years). On the basis of these assumptions, it has been estimated that a new wheat variety in the northern region of New South Wales could be worth an extra \$3.3 to \$12.6 million when the value of extra yield is discounted to present day values. The calculations made on the basis of these assumptions are presented in the following table.

Table 14: Estimated value of a new wheat variety in northern New South Wales zone (\$m NPV discounted, 8%)

Adoption rate assumptions	Yield increase 2.50%	Yield increase 5.0%
Slow linear adoption rate	3.35	6.70
Fast linear adoption rate	6.30	12.61
Exponential adoption rate	5.69	11.38

On the basis of similar assumptions, it has been estimated that a new wheat variety in the south and central Queensland regions could be worth anything between \$3.3 to \$12.6 million extra to the industry when the value of extra yield they make possible is discounted to present day values. Some of the assumptions needed to make these calculations are included in Tables 15.

Table 15: Value of new variety in central Queensland (\$ million NPV, discounted at 8%)

Adoption rate	2.5% yield increase	5.0% yield increase
Slow linear adoption	\$0.457	0.721
Rapid linear adoption	0.861	1.723
Exponential adoption rate	0.777	1.555

Table 16: Value of new variety in south Queensland (\$ million NPV, discounted at 8%)

Adoption rate	2.5% yield increase	5.0% yield increase
Slow linear adoption	1.060	2.120
Rapid linear adoption	2.533	5.066
Exponential adoption rate	2.386	4.573

Decision errors

Because variety selection decisions are made with limited data, the possibility of decision errors cannot be avoided. Two types of decision error, type I and type II, need to be considered. A type I error is involved when a new cultivar is released but its true yield is worse than a currently grown commercial variety. With a type II error, a superior cultivar has not been identified during the selection process and therefore has not been made available to growers. In each case, growers have suffered a loss of potential income. They may have been induced into growing a new cultivar whose performance was worse than an existing variety but these losses are not particularly serious. The cost of changing a wheat variety does not incur a substantial extra cost although that may change in the future with a more commercial orientation driving the marketing of new varieties. Growers tend to abandon quickly those new varieties that do not perform up to their expectations, especially if they have other choices to fall back on. The income foregone because the selection program did not find a potentially high-yielding variety is much more serious but there is a degree of uncertainty about them. This uncertainty is reduced as more trials are undertaken but the cost of doing the trial work increases, even though the number of entries at this stage is relatively small. The optimum number of variety selection trials is thus a balance between the increasing real cost of doing more trials and collecting more statistical information from each of them and the opportunity cost of making errors which declines as the number of trials is increased. This results in a broadly U-shaped curve from which the optimum number of trials, indicated by the lowest point on the curve, can be determined (See Brennan *et al.* 1998 and Brennan's notes (March 1997).

Brennan *et al.* (1998) defined the critical percentage difference (CPD) as the difference in yield that must be observed between the new cultivar and the standard variety if the new cultivar is to be selected and released for commercial production. They chose a CPD of zero which means that a new cultivar would be released if its observed yield was equal to or greater than that of a standard variety. Brennan *et al.* (1998) also defined "acceptance probabilities" ρ based on methods proposed by Henderson (1975), Patterson *et al.* (1977) and Cullis *et al.* (1996b). This is the probability of accepting a new cultivar for release on the basis that its true (unknown) yield is greater than that of the standard variety by some stated percentage difference in yield. The probability of committing a non-release error is therefore $1 - \rho$ for the same stated percentage difference in yield. As Brennan *et al.* (1998) point out, the probability of committing a release error, the probability that a new cultivar is released even though its true yield is less than that of the standard variety by a given percentage, is the same as the non-release error ($1 - \rho$) when the CPD is zero.

These acceptance probabilities are a function of several factors which Brennan *et al.* (1998) spell out in some detail. Each acceptance probability is a value uniquely associated with a particular set of conditions. Where the difference between the true yield of the new variety and the one it replaces is large, the chance of committing a non-release error is low. The

variance of the means for the respective cultivars in a series of trials is affected by number of sites, years of testing, and replication in trials, and the lower the trial variance, the less chance there is of committing non-release errors. The size of the CPD will also affect the acceptance probabilities. The higher the CPD, the lower the acceptance probability. The level of significance used to discriminate between cultivars also affects these probabilities. The lower the level of significance, the higher the chance of making non-release errors.

Estimates of these acceptance probabilities were made following the procedure outlined by Cullis *et al.* 1996. The acceptance probability α is the probability of accepting a new line when the true difference between it and one or more standard lines, expressed as a percentage of the general mean, is at least D (the critical percentage difference). For experiments conducted with r replicates at m locations over n years, the variance of a fixed line mean ϕ can be expressed by the following equation

$$\phi = \frac{\sigma_e^2}{rmn} + \frac{\sigma_{gly}^2}{mn} + \frac{\sigma_{gy}^2}{n} + \frac{\sigma_{gl}^2}{m}$$

The variance of a predicted line value, v , is

$$v = \phi / (1 + \phi / \sigma_g^2).$$

The variance of the difference between two line predictions, expressed as a percentage of the general mean for the set of trials μ is $2v(100/\mu)^2$. If $\underline{\delta}$ is an estimate of δ , the true percentage difference between two lines, (2.5% or 5.0% for example), then the distribution of $\underline{\delta}$ is

$$\underline{\delta} \sim N \left\{ \delta, \frac{2v(100)^2}{\mu} \right\}$$

If D is the critical percentage difference that must be exceeded by $\underline{\delta}$ for the new line to be accepted, the acceptance probability α is defined as $P(\underline{\delta} > D)$. That is

$$\alpha = P \left(z > \frac{D - \delta}{\sqrt{2v(100/\mu)}} \right)$$

These equations have all been implemented in an EXCEL spreadsheet using the values generated from a combined analysis of large numbers of trial results in each of the three sub-regions.

Table 17: Estimates of variance components

Parameter values	South Qld regional trials (intermed / slow maturity)	South Qld regional trials, (quick maturity)	Central Q regional trials, (intermed ./ slow maturity)	Central Q regional trials, (quick maturity)	University of Sydney trials	NSW Agric. "core" trials
σ_e^2	0.034	0.032	0.034	0.032	0.166	0.034
σ_{gly}^2	0.050	0.040	0.017	0.035	0.157	0.091

σ_{gy}^2	0.010	0.013	0.016	0.009	0.019	0.031
σ_{gl}^2	0.006	0.007	0.002	0.002	0.015	0.006
σ_g^2	0.026	0.016	0.055	0.016	0.024	0.033
μ	2.72	2.45	2.81	2.64	3.23	2.79

Source: DeLacy (1998)

The point can be made here that this work has highlights the general consistency of variance components across programs. There are some exceptions however and this means that attention has to be paid to the conduct of the trial program to keep the variance components within acceptable limits.

Acceptance probabilities have been calculated for each sub-program, south Queensland, (quick and medium/slow series), central Queensland (quick and medium/slow series) as well as northern zone of New South Wales. In the latter case, it required some amalgamation of University of Sydney and NSW Agriculture data since the optimum number of trials is based on the notion of integration and sharing of information (and resources) between the two programs.

For these calculations, we set D , the critical percentage difference that must be exceeded by the true mean of a new line for it to be accepted, at 0 which means that a new line will be selected if its yield is as great or greater than the yield of standards in the trial. The number of replicates r , the number of years or testing n , and number of testing sites m have been set at appropriate levels. The number of replicates has been set to 3, the number of years of testing to 2, and the number of trials varied in the spreadsheet in order to calculate the optimum number.

Acceptance probabilities for the south Queensland and northern New South Wales regions are shown in the following figures.

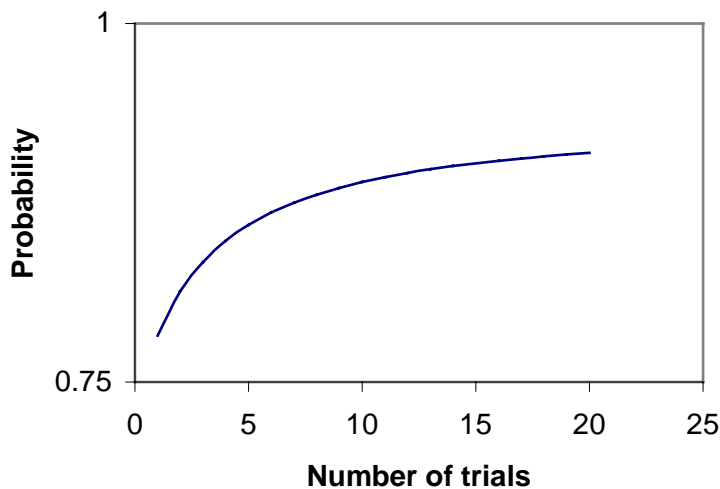


Figure 4: Acceptance probabilities for wheat variety trials in northern NSW

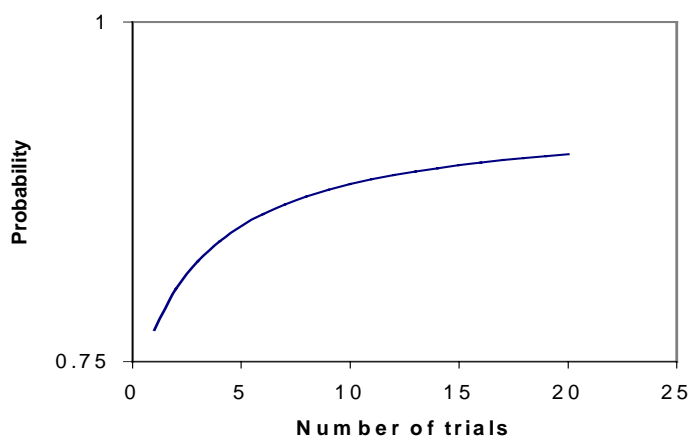


Figure 5: Acceptance probabilities for wheat trials (medium/slow varieties) in south Queensland

The probability of a non-release error is $1 - \alpha$, the probability that a variety will be selected for commercial production. As described previously, this depends on the variance components for genotypes, genotype x year, genotype x line, and genotype x year x line interactions resulting from the trial program. It also depends on the general mean yield in the trial series, number of replicates, years of testing, and number of trial sites. When multiplied by the value to the wheat industry of an individual variety, this probability provides an estimate of the cost of making Type II errors in the selection program. This is the income foregone by not selecting a variety that would have had a yield equal to or better than the standard variety. For the northern graingrowing industry, these error costs are substantial and actually overshadow the costs incurred in doing the trial work. They are so large because of the significant value of the wheat produced in the northern graingrowing region and the important contribution made to it from individual varieties.

From combining the costs of carrying out the selection program with the potential costs of errors in decisions, it is possible to derive an indication of the optimum number of trials to be conducted. While the costs of carrying out an increasing number of trials is estimated to rise linearly (at least) while the cost of making errors declines asymptotically, an optimum number of trials can be identified where the combination of true costs and opportunity costs are minimised. This is shown in the following figures. The combined cost of developing a new variety, and the income potentially foregone from doing insufficient trial work to identify a superior variety, for a range in the number of regional trials (S3 trials in NSW) carried out. In the NSW case, these start at 5, the minimum number of regional trials currently conducted under the University of Sydney plant breeding program. The rest of these regional trials are carried out by NSW Agriculture Crop Evaluation Unit which is located at various centres in the northern New South Wales wheatgrowing area. The combined cost curve has a broad flat section that begins about 15 regional trials. The reduction in Type II errors at this point appears to just about balance the increase in variable costs as the number of trials increases above 15. Trial costs have not been projected beyond 20, which is considered about the limit of reliability of the cost data. In the absence of other data, the costs for doing this work have been based on the cost of doing similar trials by the QDPI in south Queensland.

The significant thing about this analysis is the important role that the error costs play in determining the optimum number of trials. It is not the cost of actually doing the trial work that is so important as the structure of the variance components and their influence on the acceptance probabilities and the opportunity cost of making errors in selection.

The cost curves to minimise the combined costs of carrying out research work and the errors in failing to identify superior varieties do not appear to have a sharp minimum but are relatively flat over a substantial range. Therefore while the minimum number of trials might be about eighteen in each region, there was not much difference in cost between 15 and 20 trials. It is worth noting that trial costs are relatively less significant than the opportunity costs of errors in failing to select better performing varieties. Even though the cost of errors declines as the number of trials increases, over the range of interest, the rate of decline is fairly flat while the cost of trials is increasing at least at a linear rate.

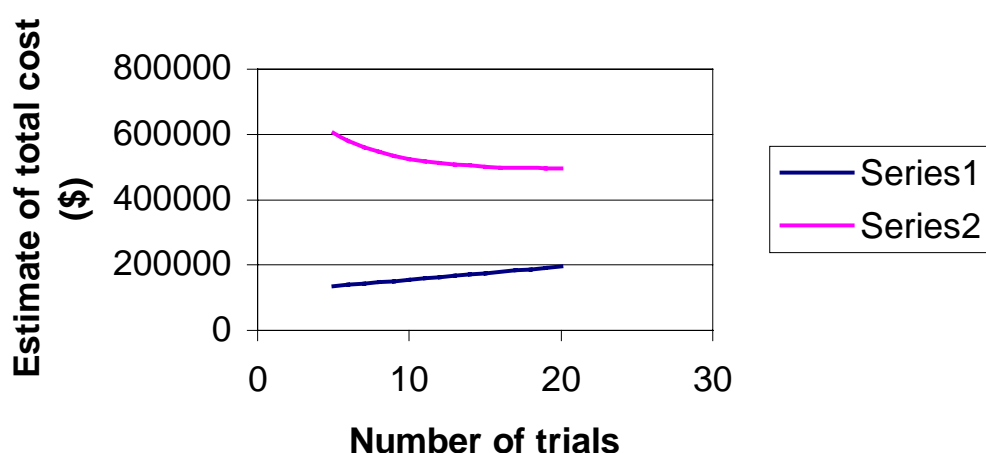


Figure 5: Optimum number of regional variety trials for northern NSW

The optimum number of trials in New South Wales is significantly less than has been conducted in the past although current practice is to carry out a number of trials close to the optimum.

In south Queensland, the program has been running for a number of years with the number of trials believed to be about optimal for that region while further investigation of the situation in central Queensland is needed.

An important issue that has not been addressed is the potential cost of lost trials and the safeguards that might be implemented to deal with that situation. To what extent are extra trials built into the program to compensate for trials that might be lost and not harvested for various reasons.

The present analysis has been structured to determine the optimum number of breeders trials on a cost minimisation basis but there is need for further evaluation of the breeding program from the point of view of determining whether it is achieving maximum benefits for the industry and other stakeholders. Rather than view the exercise in terms of determining the optimum number of trials as the number that minimises cost, it may be more useful to view it as a process by which the benefits from plant breeding can be maximised. This may require an increasing investment in trial work. The other aspect worth investigating is to change the

balance between early and late stage trials in the selection program. This would have implications for both the variance components of the analysis as well as the costs.

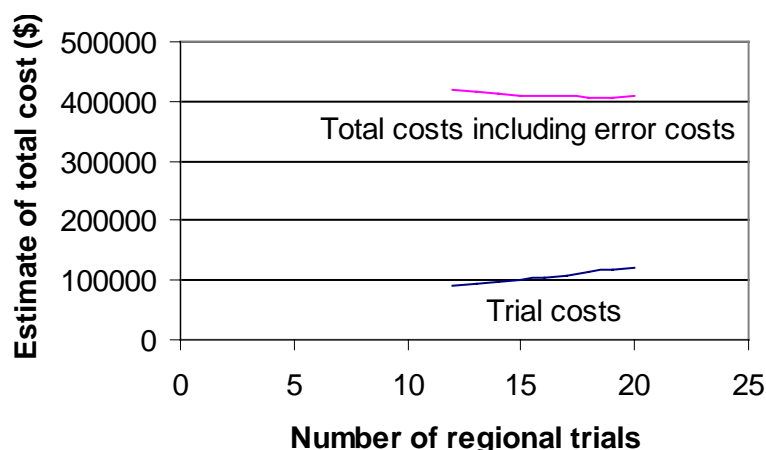


Figure 6: Optimum number of regional trials to minimise costs for south Queensland region

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Appendix I

Overhead costs for Queensland DPI wheat breeding program

Staff costs

Queensland Wheat Research Institute plant breeding staff include John Shepherd (who is responsible for the intermediate maturity group, Paul Brennan (quick maturing group) and Phil Banks (slow maturing group). Two technicians are attached to each of the intermediate maturing and quick maturing groups, Wayne C. and James H. work with John S. on the intermediate group, Paul Brennan has two technicians working on the quick maturing group, as well as Martin ?? who is mainly used on glasshouse work but who may be called on for about one month to assist at harvest time. Phil Banks does not have an allocated technician for the slow maturity program.

Estimated salary rates for these staff are given below. All salary costs are net of on-costs which can be estimated to be 25% (????) of base salary.

Paul Brennan

John Sheppard \$48 000

Phil Banks

Technicians

Wayne C. \$32 000

James H. \$27 000

????????? \$40 000

????????? \$33 000 (two technicians working with Pual Brennan)

Martin ? \$28 000 (mainly glasshouse work. 1 month at harvest.)

Quality group

David Martin, Principal chemist, \$50 000

Bruce Stewart, cereal chemist \$45 000.

3 technicians \$30 000 each

It was estimated that 80% of the costs of this group should be allocated to the wheat program.

At harvest time, they may include extra casual labour in their team.

Biometrical analysis

Probably involves use of a biometrician for one month. Annual salary cost \$45 000

David Butler (GRDC funded database). Allocate 1 month, annual salary cost, \$52 000 per year.

Support services

There is also some support to the program provided by David Wildermuth and John Thompson. We can probably assume that these costs will not change with changes in the number of regional variety trials conducted.

Australian Crop Accreditation System (ACAS)

This appears to be a national quality control system to ensure that breeders material is evaluated properly. ACAS is apparently establishing protocols to ensure that things are done properly and that the data collected and used to decide on acceptable varieties are of acceptable quality. How will ACAS activities impact on the costs of carrying out the QDPI program? Do the existing procedures meet its requirements or will there be extra costs, at the selection end of the program, to meet them.

Operation times

Approximate times for operations at each trial site (given by John Shepherd) Tractor hours (for costs) do not agree with the labour utilisation figures. Tractor hours may perhaps be 0.5 of the total time input.

	Time per trial	Time per plot
Planting		
Unload and set up to apply fertiliser	0.5 h	
Put in trip lines across paddock	0.5-0.75 h	
Planting, 1 hour per box , includes Getting seed, fertiliser, etc (0.75 to 1.0 h to plant 360 plots)		0.166 minute
Planting bulk at end of each trial	0.5 h	
Wash down equipment	0.5 hr	
Travel to next site	(see notes on record sheets)	

These operations are carried out with 3 people (JS, WC, and JH), 1 tractor driver and two other operators.

[In regard to planting time: this means that by my calculations the planter is travelling at something in excess of 2.88 km per hour to achieve this. Is this reasonable? Remember that the planter has to stop for seed and fertiliser.]

Overnight accommodation (based on 1998 figures): 8 overnights for 3 people (24 nights accommodation) Standard rates? Or actual accommodation costs??

Other operations carried out during the course of these trials include:

GPS readings 1.5 h per site (2 people)
(Do these inspections involve overnight stays?)

Spray with herbicide, depending on site.

(Try to avoid if possible. Spray about one-third of trials.)

Cost of herbicides: MCPA lve, Puma, Ally, Glean, Starane, estimated at \$2 000 per year.

Overnight stays, total of 4

Fertiliser costs

Both urea and Starter Z are applied to trials, usually broadcast at the rate of 120 kg urea and 40 kg/ha of Starter Z (35 kg in JS notes) applied with seed at planting. Does this require an additional tractor operation to broadcast the urea?

Cost of fertiliser:

Urea (46% N) price from Grow Force Aust. Ltd, Dalby, \$16.45 per 40 kg bag, ie. 80c per kg N. Cost for 120 kg per ha is \$96.

Starter Z (zinc coated P), 9.4.5 N, 20.5% P, and 2.2% Zn.

(Cost estimate from Grow Force for Tech Feed 830 (11.6N, 16.7 P, 6.4 S, and 1.7 Zn or Tech Feed 801 (zinc coated di-ammonium phosphate) 9.7 N, 21.1 P, 2.1 S, and 1.7 Zn was \$33.10 per 50 kg bag. Cost for 40 kg per ha is \$26.50.

A couple of trials in 1998 seemed to have different application rates, eg. Lundavra and Dulacca 60 kg urea, Billa Billa 90 kg urea. (At Roma, the wheat trial received 120 kg urea while no urea was applied to the barley plots.)

All wheat trials should receive the standard 120 kg urea and 40 kg Starter Z per hectare.

Urea is dropped on soil surface at planting and worked in with planter. No additional operation required to spread urea.

JS estimates the total cost of fertiliser for the program trials at \$3 500 per year.

Other inspection trips as appropriate (should include 2 per site by JS (or one of the other breeders). What is the time estimate for this?

Overnight stays for trial inspections: John Shepherd 15

Paul Brennan 5

Phil Banks, 5

(Remember, there is a need to inspect Central Queensland trials as well.

Travel times to trial sites from Toowoomba

Lundavra	3.0 h
Dulacca	3.0 h
Roma	3.0-4.0 h
Haystack	2.0 h
Dalby	1.0 h
Macalister	1.5 h
Jimbour	1.5 h