HGCA

PROJECT REPORT No. 167

COMPARISON OF WINTER WHEAT PROFITABILITY USING 3-PASS, 5-PASS AND 7-PASS PRODUCTION SYSTEMS

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by

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ABSTRACT

Minimum Pass Husbandry is a technique which has the objective of reducing the number of passes made through the cereal crop without reducing the crop's profitability.

In this three year project this objective was tested in the winter wheat crop at six locations in the UK. To test the concept six trials compared the performance of winter wheat under three management regimes which differed in the number of passes made through the crop with nitrogen and agrochemicals. 3, 5 and 7 pass management systems were applied to two varieties, Hunter and Brigadier, at four different seedrates and two different sowing dates.

The yield results from the project illustrated that adopting fewer passes through the wheat crop reduced the yield of the crop. Averaged over all treatments and sites the yield penalty for adopting 3 pass management compared to a more conventional 7 pass system was recorded as 0.52 t/ha. Despite the lower yield of the minimum pass approach, there were savings in input costs as the number of passes was reduced. If grain was priced at £75/tonne and application cost applied at £5/ha per pass, it was shown that the 3 pass technique was as profitable or more profitable on three out of four occasions, using the yield data from the project (actual figure 76%). Since a yield penalty was suffered as a result of adopting fewer passes through the crop, it is acknowledged that the benefits of minimum pass husbandry are most likely to occur at low grain prices where application costs are a serious consideration. This is usually where land blocks are being farmed at some distance from the main farming enterprise.

The project illustrated that the success of adopting fewer passes through the crop was influenced by the variety's resistance to disease but that this characteristic was most manifest when the crop was later sown. As the concept depends on a single fungicide and nitrogen application there was also evidence to suggest that the technique was most applicable in drier regions of the country where expected responses to fungicides were lower. However, the introduction of the longer lasting Strobilurins should help strengthen the one spray strategy in the future.

In order to fully utilise the nitrogen from a single application in the minimal pass technique there was evidence to indicate that earlier timings should be adopted to avoid drought uptake restriction. In addition, there was also some grounds to suggest the technique may be better suited to more fertile 1st wheat situations or generally more fertile soils.

The maximum yield penalty associated with the 3 pass technique over the three years occurred when a massive grain aphid infestation created a 2 - 3 t/ha yield advantage for the 7 pass control treatment which incorporated an aphidicide.

The data generated over the three years of the project should give growers greater confidence in the selection of winter wheat crops suitable for minimum pass husbandry approaches. The technique, however, remains most suitable for scattered farming systems where growers carry out the husbandry using one set of farm machinery. In addition, the technique is particularly pertinent when grain prices are low - £80/tonne or below - as they are currently.

1.0 INTRODUCTION TO MINIMUM PASS HUSBANDRY

1.1 Objectives of project

The objective of this three year project was to determine whether it is possible to reduce the number of passes made through the winter wheat crop with nitrogen fertiliser and agrochemicals, without reducing the profitability of the crop. In working towards this objective the project varied variety, seedrate, drilling date and geographic location in order to assess in which situations a grower is most likely to be successful with this technique.

1.2 Economic justification

The primary stimulus for the work on Minimum Pass Husbandry was the CAP (Common Agricultural Policy) reforms of 1992. In these reforms cereal growers would have subsidies removed from the grain, allowing prices to fall to "world price". To compensate for lower grain prices, growers would receive an area aid subsidy instead. The response by many cereal growers to these reforms was to look at ways of reducing overhead costs by taking on more land. Larger farming units were formed without taking on extra labour, contractors being employed at peak periods. As many arable farmers saw larger farm structures as the means of reducing unit cost per tonne of production, competition increased for farming contracts on arable land. As a consequence of this competition many cereal growers took on land that was some distance from the main farming enterprise, in some cases 20 - 30 miles distant. Despite these more scattered farming enterprises, fertilising and spraying was still carried out with the same machinery from the main farm. It was with these scattered arable farming enterprises in mind that the concept of Minimum Pass Husbandry was born.

Through the course of the project grain prices went from £110/tonne in 1995 to £80/tonne in 1997. In many ways the fall in grain price has increased the interest in the results of the project as the relevance of this technique increases as grain price falls (see Section 5.1), especially for those growers operating on several scattered land blocks.

1.3 Technical justification

Although perhaps slightly less important, the second justification for pursuing Minimum Pass Husbandry has been the improvement in agrochemical technology. Fairly obviously, there is little point in pursuing fewer passes through the crop if the consequence is a large reduction in yield. However, even compared to ten years ago, agrochemicals are significantly superior, allowing greater protection from disease and weed infestation from a single application.

In terms of fungicide technology, the introduction of Cyproconazole in 1992, Tebuconazole in 1993 and Epoxiconazole in 1994 were all significant improvements in disease control, compared to the previously used chemicals. Consequently, a single flag leaf application of Epoxiconazole (Opus) could be expected to secure a much larger proportion of the yield created by a full 3 spray fungicide programme than would have been achieved with fungicides ten years ago. In addition, the 1997 introduction of the Strobilurins with their

In addition, the 1997 introduction of the Strobilurins with their properties of greater persistence has further strengthened the case for one pass disease control.

Minimum pass weed control has been facilitated by the introduction of the two residual herbicides, Pendimethalin (Stomp) and Diflufenican (supplied in combination with other active ingredients such as IPU eg Panther) which, even from low doses in the autumn, have given total weed control in many situations.

Another factor which has helped shape the minimum pass approach is a greater appreciation of agronomic principles, in particular the control of lodging. ARC experiments in 1992 illustrated PGR application had less influence over keeping the crop standing than reducing crop biomass by reducing seeding rates. In addition, the application of an early fertiliser dose in February/March could be detrimental to yield and standing power in fertile 1^{st} wheat situations.

Such results have helped to establish systems of cereal management which could potentially reduce the number of passes through the wheat crop from 10 to 3 for the purposes of this experiment.

Thus, in conclusion, advances in agrochemical technology combined with other agronomic findings on crop structure gave rise to the possibility of growing winter wheat with fewer passes. This project would determine whether such a reduction in the number of passes could be carried out without reducing profitability.

1.4 Environmental perception

Whilst Minimum Pass Husbandry may not always involve reducing the quantity of agrochemical applied to the crop, the reality is fewer visits to the field. Sometimes this will lead to a genuine environmental advantage eg avoidance of early nitrogen fertiliser. However, in an era where perception is as important as fact, Minimum Pass Husbandry should have a good environmental image in the eyes of the public since there will be less use of the tramlines for spraying and fertilising. Clearly, set against the frequent low dose techniques which form an alternative strategy for lowering input costs, it is easier to understand why minimum pass would be viewed as a more environmentally friendly approach even though, in reality, the amount of active ingredient being applied may be similar.

2.0 EXPERIMENTAL PROCEDURES

2.1 Experimental variables

Each of the 6 trial sites in the project worked with 4 experimental variables. These were:

i. Varieties
ii. Seedrates
iii. Drilling dates
iv. Number of passes through the crop (management level)

i Varieties: 2

Hunter : High yielding variety with good disease resistance
Brigadier : Higher yielding lower disease resistance ratings

This variable would expose whether variety disease resistance influenced the potential success of Minimum Pass Husbandry.

ii Seedrates: 4

Different seedrates create different plant structures and canopy formations. These different structures have a profound influence on the need for agronomic inputs eg PGRs.

The four seed rates:

English Sites	Approximate Cost (£/ha)	Scottish Site	Approximate cost (£/ha)
150 seeds/m^2	17 - 18	250 seeds/m^2	28 - 29
250 seeds/m^2	28 - 29	350 seeds/m^2	39 - 40
350 seeds/m^2	39 - 40	450 seeds/m^2	50 - 51
450 seeds/m^2	50 - 51	550 seeds/m^2	61 - 62

iii Drilling dates: 2

Again, as with seedrates, drilling date of wheat can greatly influence the need for inputs and thus potentially the need to pass through the crop.

Early Drilling	Late Drilling
Target date	Target date
25 September - 5 October	25 October - 4 November

Aiming at a four week interval between sowings.

The exact drilling dates for each trial in the project can be found with yield results in Section 3.0.

iv Number of passes through the crop

Each of the combinations of variety, seedrate and drilling date were then subjected to three levels of management input, 3 passes, 5 passes and 7 passes through the crop.

Treatment Timing	3 Pass	5 Pass	7 Pass
Autumn/ Early Spring	Herbicide with optional insecticide	Herbicide with optional insecticide	Herbicide with optional insecticide
GS23	-	1st nitrogen	1st Nitrogen
GS30	-	-	Plant growth regulators + extra herbicide if required
GS30 - 31	Total Nitrogen	Main Nitrogen	Main Nitrogen
GS32	-	1st Fungicide + extra herbicide if required	1st Fungicide
GS39	Fungicide + extra herbicide if required	2nd Fungicide	2nd Fungicide
GS59 - 69	-	-	3rd Fungicide with optional insecticide

Notes on management levels:

- All levels of management received the same level of nitrogen fertiliser, 3 passes receiving a single dose.
- The protocol does not rigidly specify project choice for specific trial sites. Site managers have the ability to tank mix other agrochemicals at the specified timings eg under 3 passes a herbicide could be mixed with the flag leaf fungicide, provided a tank mix recommendation existed.
- The only products and rates that are specified are the flag leaf fungicides which must be based upon either Epoxiconazole or Tebuconazole at ¾ rate plus chlorothalonil or morpholine.

2.2 Experimental design and geographic spread of trial sites

The trials were replicated three times and randomised in management blocks, taking account of the different harvest dates and practical ability to apply inputs in blocks.

Statistical analysis of the project was provided by BioSS (Biomathematics and Statistics Scotland), based at the University of Edinburgh. Experimental trial design for the project was also provided in the 1997 season to make statistical analyses easier. A typical experimental design for the project is outlined below.

Typical experimental design (1997 season)

Rep 1	DD1 5 Pass	DD1 3 pass	DD1 7 Pass	DD2 3 Pass	DD2 7 Pass	DD2 5 Pass
Rep 2	DD2 7 Pass	DD2 5 Pass	DD2 3 Pass	DD1 5 Pass	DD1 3 Pass	DD1 7 Pass
Rep 3	DD2 7 Pass	DD2 3 Pass	DD2 5 Pass	DD1 3 Pass	DD1 7 Pass	DD1 5 Pass

Varieties and seedrates were randomised within each management block to simplify the practical application of inputs.

The project was carried out at six trial sites in the UK:

1 **ARC Andover, Hampshire**
Soil type: Andover 1
Shallow calcareous soil over chalk
Altitude: 80 m

2 **ARC Biggleswade, Bedfordshire**
Soil type: Hanslope
Chalky boulder clay
Altitude: 40 m

3 **ARC Caythorpe, Lincolnshire**
Soil type: Elmton 1
Brashy, calcareous loam over limestone
Altitude: 60 m

4 **ARC Cirencester, Gloucestershire**
Soil type: Sherborne
Cotswold brash clayey soil over limestone
Altitude: 110 m

5 **ARC Wye, Kent**
Soil type: Coombe 2
Fertile brickearth soil 1995 - 1996
Gault clay brown soil 1997
Altitude: 90 m

6 **SA Burrelton, Perthshire**
Soil type: Sandy loam
Altitude: 90 m

ARC : Arable Research Centres
SA: Scottish Agronomy

2.3 Field measurements and assessments

Whilst this report concentrates on the yield and economic results, the following field measurements and assessments were also recorded.

i. Establishment

ii. Disease Assessments
GS32 % leaf cover Leaf 3
GS39 % leaf cover Leaf 3
GS75 % leaf cover Leaf 2 or 3 (depending on disease)
Whiteheads/m^2 GS75 if difference apparent

iii. % Lodging

iv. Ears Number/m^2

v. Weed Population Assessments
Prior to Application
At GS30

vi. Grain Sampling Assessments
Specific weight (kg/hl)
Protein and Hagberg on 350 seeds/m^2 only (450 seeds/m^2 in Scotland)

vii. Yield (t/ha) corrected to (15% moisture)

3.0 YIELD RESULTS

3.1 Individual trial site results 1995 - 1997 (3 year means)

The following sections outline the 3 year yield means for each trial site in the project. Yields are expressed in t/ha corrected to 15% moisture.

DD1 Drilling Date 1 early sown crop
DD2 Drilling Date 2 later sown crop

3.1.1 ARC Andover site, Hampshire

2 Year Yield Mean (t/ha) 1995-1996 Management Level and Drilling Date

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2	Mean DD1	Mean DD2
Hunter	**150**	8.29	7.89	8.78	7.78	9.06	8.31	**8.71**	**7.99**
	250	9.08	8.30	9.02	8.23	9.53	8.93	**9.21**	**8.49**
	350	9.08	8.47	9.11	8.72	9.61	9.18	**9.27**	**8.79**
	450	9.26	8.55	9.18	8.70	9.79	9.06	**9.41**	**8.77**
	Mean	**8.93**	**8.30**	**9.02**	**8.36**	**9.50**	**8.87**		
Brigadier	**150**	9.13	7.90	9.23	8.07	9.58	8.64	**9.31**	**8.20**
	250	9.39	8.42	9.42	8.48	9.87	9.00	**9.56**	**8.63**
	350	9.70	8.65	9.51	8.80	10.05	9.41	**9.75**	**8.95**
	450	9.75	9.01	9.69	8.95	10.13	9.67	**9.86**	**9.21**
	Mean	**9.41**	**8.32**	**9.39**	**8.45**	**9.83**	**9.02**		

LSD: Sowdate/Seedrate - 0.56 t/ha
LSD: Passes/Sowdate/Variety - 0.69 t/ha
LSD: Passes/Sowdate/Variety/Seedrate - 1.38 t/ha
DDI: Drilling date 1 DD2: Drilling date 2

Mean Difference in Yield between 3 Pass and 7 Pass Systems (1995 - 1996)

Hunter	DD1	0.57 t/ha	Advantage 7 pass
	DD2	0.57 t/ha	Advantage 7 pass
Brigadier	DD1	0.42 t/ha	Advantage 7 pass
	DD2	0.70 t/ha	Advantage 7 pass

There was a significant linear trend for yield to increase with increasing numbers of passes, though the advantage of 7 pass systems over 5 pass is much more significant than the advantage of 5 pass over 3 pass. 3 pass was least successful (significant) relative to 7 pass with late sown Brigadier, a recurring feature through the trial series.

Seedrate did not interact with the number of passes.

Brigadier was higher yielding than Hunter, but this was most marked when the two varieties were sown early. Optimum seedrates for **yield** were 350 or 450 seeds/m^2 irrespective of drilling date.

In conclusion, 7 pass management systems out yielded 3 pass by an average of 0.56 t/ha, but individually it was late sown Brigadier that was most penalised by moving to a 3 pass system, the difference in yield then being 0.70 t/ha.

Effect of Pass number and Drilling date - individual trials (1995 and 1996)

The following data examines the effect of drilling date, variety and number of passes in both trial years. Data presented is a mean of the 4 seedrates.

1995 Yield data t/ha (Mean of 4 seedrates)

	Management Level and Drilling date					
Variety	**3 Passes**		**5 Passes**		**7 Passes**	
	DD1 29 Sep	**DD2 24 Oct**	**DD1 29 Sep**	**DD2 24 Oct**	**DD1 29 Sep**	**DD2 24 Oct**
Hunter	8.78	9.13	8.95	9.19	9.22	9.42
Brigadier	9.35	9.17	9.36	9.55	9.71	9.81

1996 Yield data t/ha (Mean of 4 seedrates)

	Management Level and Drilling date					
Variety	**3 Passes**		**5 Passes**		**7 Passes**	
	DD1 5 Oct	**DD2 31 Oct**	**DD1 5 Oct**	**DD2 31 Oct**	**DD1 5 Oct**	**DD2 31 Oct**
Hunter	9.08	7.47	9.09	7.53	9.77	8.32
Brigadier	9.63	7.81	9.57	7.60	10.10	8.55

Correlation between 2 trials was 0.285

1997 Yield data t/ha (Mean of 4 seedrates)

Severe wheat bulb fly infestation made the establishment of the later sowings very variable. As a consequence this section of the trial was discontinued in early summer.

Data from the early sowing (which was also affected by the problem, but to a much lesser extent) is presented below. Trial sown on 1 October.

Variety	Seeds/m²	3 Passes	5 passes	7 passes
		Management Level		
Hunter	150	5.16	4.67	6.66
	250	5.97	6.06	7.42
	350	6.60	6.61	7.38
	450	7.44	6.51	7.75
	Mean	**6.29**	**5.96**	**7.30**
Brigadier	150	5.03	5.11	6.37
	250	6.57	5.67	6.83
	350	7.05	6.40	7.88
	450	7.19	6.97	7.81
	Mean	**6.46**	**6.04**	**7.22**

Examining the data from all three years it is apparent that there was little difference in yield between 3 and 5 pass systems, but significant advantages moving to 7 pass. With the exception of 1997 where wheat bulb fly was an obvious factor, there was no interaction between seedrate and the number of passes. In 1997, minimal pass systems were strongly penalised at low seedrates.

3.1.2 ARC Biggleswade site, Bedfordshire

2 Year Mean t/ha 1995 - 1996

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2	Mean DD1	Mean DD2
Hunter	**150**	8.09	5.86	8.97	6.60	9.93	7.47	9.00	6.64
	250	8.53	7.03	8.97	7.03	10.33	8.13	9.28	7.40
	350	8.86	7.40	9.19	8.00	10.57	8.86	9.54	8.09
	450	8.75	7.78	9.62	8.11	10.39	8.66	9.59	8.18
	Mean	**8.56**	**7.02**	**9.19**	**7.44**	**10.31**	**8.28**	-	-
Brigadier	**150**	8.60	6.20	8.77	6.26	10.00	7.72	9.12	6.73
	250	8.86	6.93	9.41	7.55	10.41	8.42	9.56	7.63
	350	9.25	7.46	9.56	7.79	10.41	8.87	9.74	8.04
	450	9.31	7.49	9.64	8.55	10.44	9.03	9.80	8.96
	Mean	**9.01**	**7.02**	**9.35**	**7.54**	**10.32**	**8.51**	-	-

LSD: Sowdate/Seedrate - 0.76 t/ha
LSD: Passes/Sowdate/Variety - 0.93 t/ha
LSD: Passes/Sowdate/Variety/Seedrate - 1.86 t/ha

Mean Difference in Yield between 3 Pass and 7 Pass Systems (1995 - 1996)

Hunter	DD1	1.75 t/ha	Advantage 7 pass
	DD2	1.26 t/ha	Advantage 7 pass
Brigadier	DD1	1.31 t/ha	Advantage 7 pass
	DD2	1.49 t/ha	Advantage 7 pass

The Biggleswade site produced the clearest advantages to the conventional 7 pass management systems. In 1995 the advantage to 7 pass system was attributed to two factors, aphid control which was critical at this site in 1995 and split nitrogen to avoid restrictions applying to a single main dose (as in the case with 3 pass). In 1996 lack of aphid control with minimum pass treatments was not a factor but restricted nitrogen uptake at main dose timings still favoured the split applications.

Neither year produced any data to indicate that the success of minimum pass husbandry was influenced by either variety or seedrate.

In conclusion it is at this site that there has been the greatest yield penalty moving to minimum pass husbandry, primarily because the 1995 data was so strongly influenced by effect of aphid control in the conventional 7 pass system.

Effect of Pass number and Drilling date - individual trials (1995 - 1996)

In order to examine the influence of individual years in the two year yield mean, the following data looks at the effect of drilling date and number of passes in each trial for the two year period. To simplify the figures, seedrates have been meaned as there was no interaction between passes and seedrate.

1995 Yield data t/ha (Mean of 4 seedrates) Management Level and Drilling date

Variety	**3 passes**		**5 Passes**		**7 Passes**	
	DD1	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**
	28 Sep	**24 Oct**	**28 Sep**	**24 Oct**	**28 Sep**	**24 Oct**
Hunter	8.11	7.42	8.93	8.20	10.89	9.46
Brigadier	8.69	7.37	9.10	7.99	10.99	9.88

1996 Yield data t/ha Management Level and Drilling date

Variety	3 passes		5 Passes		7 Passes	
	DD1	DD2	DD1	DD2	DD1	DD2
	29 Sep	30 Oct	29 Sep	30 Oct	29 Sep	30 Oct
Hunter	9.00	6.61	9.44	6.67	9.71	7.09
Brigadier	9.32	6.67	9.59	7.08	9.64	7.14

Correlation between the 2 trials is = 0.547

1997 Yield data t/ha (Mean of 4 Seedrates)

Due to the extreme autumn drought in parts of East Anglia, the 1996/97 trial did not emerge until late November irrespective of drilling date. This overall effect was made worse due to a very heavy infestation of wheat bulb fly. As a consequence no data was generated from Biggleswade site in 1997.

The data from 1995 illustrates the huge yield benefits of aphid control during grain fill period. Advantages of 2.5 - 3.0 t/ha for 7 pass system were reduced to a more typical 0.3 - 0.7 t/ha in 1996.

In 3 years of experimentation at 6 sites, it is the 1995 Biggleswade trial that gave the greatest yield disadvantage when adopting minimum pass husbandry.

3.1.3 ARC Caythorpe site, Lincolnshire

3 Year Yield Mean (t/ha) 1995-1997

		Management Level and Drilling Date							
Variety	**Seedrate**	**3 Passes**		**5 Passes**		**7 Passes**		**Mean**	
	(seeds/m2)	**DD1**	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**
Hunter	**150**	6.90	5.80	7.40	6.03	7.65	5.89	**7.32**	**5.91**
	250	7.09	6.01	7.69	6.57	7.91	6.14	**7.56**	**6.24**
	350	7.26	6.27	7.75	6.82	7.93	6.64	**7.65**	**6.58**
	450	7.24	6.11	7.70	6.68	7.98	6.49	**7.64**	**6.43**
	Mean	**7.12**	**6.05**	**7.64**	**6.53**	**7.87**	**6.29**		
Brigadier	**150**	6.67	5.10	7.32	5.66	7.52	5.69	**7.17**	**5.48**
	250	6.99	5.75	7.58	6.21	7.93	5.83	**7.50**	**5.93**
	350	7.19	6.12	7.64	6.35	8.07	6.43	**7.63**	**6.30**
	450	7.41	6.03	7.70	6.27	7.96	6.33	**7.69**	**6.21**
	Mean	**7.06**	**5.75**	**7.56**	**6.12**	**7.87**	**6.07**		

LSD: Sowdate/Seedrate - 0.27 t/ha
LSD: Passes/Sowdate/Variety - 0.33 t/ha
LSD: Passes/Sowdate/Variety/Seedrate - 0.66 t/ha
DDI: Drilling date 1 DD2: Drilling date 2

Mean Difference in Yield between 3 Pass and 7 Pass Systems (1995 - 1997)

Hunter	DD1	0.75 t/ha	Advantage 7 pass
	DD2	0.24 t/ha	Advantage 7 pass
Brigadier	DD1	0.81 t/ha	Advantage 7 pass
	DD2	0.32 t/ha	Advantage 7 pass

7 pass control treatments significantly out yielded 3 pass techniques looking at the 3 year yield means of the experiment. However, there was a significant interaction between pass and sowing date ($p = 0.007$) which indicated that the minimum pass approach was much more successful at the late sowing. The benefit to the minimum pass approach at the later sowing was manifest in two ways. Firstly, the highest yields with the late drilled crops came from the 5 pass approach not 7 pass (which was the case with the early sowings). Secondly, the difference in yield between 3 and 7 pass techniques was reduced to less than a third of a tonne. Overall, however, irrespective of number of passes, later sowings at Caythorpe were on average 1.4 t/ha lower yielding over the three year period, a factor linked to the drought-prone nature of this soil.

Altering the seedrate or variety did not show any interaction with the number of passes at this site. As a consequence, there was no evidence that minimum pass husbandry was more successful with a more disease resistant variety or thinner crop structure. This site was not subject to lodging in any of the three years of the project.

There was little difference in the yield of either Brigadier or Hunter at seedrates between 250 seeds /m^2 and 450 seeds/m^2 when sown early. However, at later sowings 250 seeds/m^2 became significantly inferior.

Effect of Pass number and Drilling date - individual trials (1995 - 1997)

In order to examine the influence of individual years in the three year yield mean, the following data looks at the effect of drilling date and number of passes in each trial for the three year period. To simplify the figures, seedrates have been meaned as there was no interaction between passes and seedrate.

1995 Yield data t/ha (Mean of 4 seedrates)

	Management Level and Drilling date					
Variety	**3 passes**		**5 Passes**		**7 Passes**	
	DD1	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**
Hunter	7.03	6.40	7.50	7.01	8.31	7.00
Brigadier	6.71	5.76	7.54	6.40	8.20	6.37

Correlation with the three year mean = 0.912

1996 Yield data t/ha

Variety	Management Level and Drilling date					
	3 passes		**5 Passes**		**7 Passes**	
	DD1	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**
Hunter	7.83	6.83	8.32	7.41	8.15	6.41
Brigadier	7.88	6.77	7.99	7.11	8.34	6.54

Correlation with the three year mean = 0.915

1997 Yield data t/ha

Variety	Management Level and Drilling date					
	3 passes		**5 Passes**		**7 Passes**	
	DD1	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**
Hunter	6.52	4.92	7.09	5.17	7.15	5.47
Brigadier	6.60	4.73	7.16	4.87	7.08	5.30

Correlation with the three year mean = 0.962

The greatest advantage of the 7 pass technique was observed in 1995 when the single dose nitrogen of the 3 pass technique resulted in considerably less ears/m^2 owing to drought conditions in April effecting its uptake. There was little or no evidence at this site to suggest that minimum pass was more successful with either the disease resistant variety or lower seedrates although the advantage of the 7 pass management over 3 pass was clearly eroded at the later drilling date in all three years.

3.1.4 ARC Cirencester site, Gloucestershire

3 Year yield mean (t/ha) 1995 - 1997

Variety	**Seedrate**	**3 Passes**		**5 Passes**		**7 Passes**		**Mean**	
	(seeds/m2)	**DD1**	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**
Hunter	**150**	8.01	6.68	8.14	6.46	8.13	6.63	**8.09**	**6.59**
	250	8.12	7.26	8.33	6.99	8.36	7.09	**8.27**	**7.11**
	350	8.40	7.57	8.21	7.41	8.39	7.45	**8.33**	**7.48**
	450	8.62	7.75	8.20	7.49	8.63	7.77	**8.48**	**7.67**
	Mean	**8.29**	**7.32**	**8.22**	**7.09**	**8.38**	**7.24**		
Brigadier	**150**	7.88	6.38	8.07	6.42	8.04	6.99	**8.00**	**6.60**
	250	8.10	6.91	8.50	7.05	8.52	7.11	**8.37**	**7.02**
	350	8.53	7.33	8.58	6.99	8.96	7.78	**8.69**	**7.37**
	450	8.49	7.06	8.51	7.44	8.58	7.67	**8.53**	**7.39**
	Mean	**8.25**	**6.92**	**8.42**	**6.98**	**8.53**	**7.39**		

LSD: Sowdate/Seedrate - 0.44 t/ha
LSD: Passes/Sowdate/Variety - 0.53 t/ha
LSD: Passes/Sowdate/Variety/Seedrate - 1.07 t/ha
DDI: Drilling date 1 DD2: Drilling date 2

Mean Difference in Yield between 3 Pass and 7 Pass Systems (1995 - 1997)

Hunter	DD1	0.09 t/ha	Advantage 7 pass
	DD2	0.02 t/ha	Advantage 7 pass
Brigadier	DD1	0.28 t/ha	Advantage 7 pass
	DD2	0.47 t/ha	Advantage 7 pass

Earlier sowing was significantly higher yielding ($p<0.001$) than later sowing. However, there was no significant difference in yield between passes with either variety or sowing date. Although not significant, Brigadier did display a slightly greater yield advantage from the 7 pass control treatment compared to Hunter, much against expectation this advantage was most manifest at the later drilling date.

There was no evidence that there was an interaction between number of passes and seedrate, thus lower seedrates did not make minimum pass husbandry any more or less successful. There was, however, no lodging in any of the three years of the experiment, a factor which may have exposed the value of lower seedrates in the absence of PGRs.

In conclusion, the three year yield mean exposed only small differences between 3, 5 and 7 pass systems in overall yield. However, there was an indication that higher disease levels evident in Brigadier resulted in a greater advantage to the three fungicides of the 7 pass system.

Effect of Pass number and Drilling date - individual trials (1995 - 1997)

The following data examines the effect of drilling date, variety and number of passes in each trial in the three year period. As there were no interactions between pass and seedrate, the data presented is a mean yield of 4 seedrates.

1995 Yield data t/ha (Mean of 4 seedrates)

	Management level and Drilling date					
	3 Passes		**5 Passes**		**7 Passes**	
	29 Sept	**27 Oct**	**29 Sept**	**27 Oct**	**29 Sept**	**27 Oct**
Hunter	7.15	6.95	7.65	6.49	8.22	7.48
Brigadier	6.85	6.44	7.87	6.63	8.43	7.71

Correlation with the 3 year mean: 0.765

1996 Yield data t/ha (Mean of 4 seedrates)

	Management level and Drilling date					
	3 Passes		**5 Passes**		**7 Passes**	
	3 Oct	**2 Nov**	**3 Oct**	**2 Nov**	**3 Oct**	**2 Nov**
Hunter	7.79	6.73	6.81	6.38	6.44	5.45
Brigadier	7.63	6.37	6.85	5.98	6.60	5.27

Correlation with the 3 year mean: 0.641

1997 Yield data t/ha (Mean of 4 seedrates)

	Management level and Drilling date					
	3 Passes		**5 Passes**		**7 Passes**	
	2 Oct	**14 Nov**	**2 Oct**	**14 Nov**	**2 Oct**	**14 Nov**
Hunter	9.92	8.27	10.22	8.40	10.48	8.78
Brigadier	10.28	7.96	10.53	8.32	10.54	9.19

Correlation with the 3 year mean: 0.953

Nitrogen timing and the effects of drought have played a significant role in the results from the Cirencester centre. The single main dose Nitrogen application significantly penalised the success of the 3 pass system in 1995, compared to the 5 and 7 pass system. In 1996 the timing of the single nitrogen dose in the 3 pass system was brought forward from late April to early April, a move designed to compensate for the lack of early nitrogen. This change of timing resulted in 3 pass being higher yielding than both 5 and 7 pass systems. The latter employed a two split approach to nitrogen.

Higher disease pressure in 1997 clearly exposed the yield benefits of the late season fungicide in the 7 pass system. However, these benefits were more manifest with the later sown crop where the flag leaf emergence and grain fill periods coincided more with the wetter weather pattern.

3.1.5 ARC Wye site, Kent

3 Year yield mean (t/ha) 1995 - 1997

Variety	**Seedrate**	**3 Passes**		**5 Passes**		**7 Passes**		**Mean**	
	(seeds/m2)	**DD1**	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**
Hunter	**150**	8.72	7.95	8.72	8.03	9.00	8.12	**8.81**	**8.03**
	250	8.90	8.34	8.76	8.62	9.13	8.56	**8.93**	**8.51**
	350	9.07	8.58	8.87	8.67	9.20	8.80	**9.05**	**8.68**
	450	9.00	8.67	8.86	8.86	9.21	8.97	**9.02**	**8.83**
	Mean	**8.92**	**8.39**	**8.80**	**8.55**	**9.14**	**8.61**		
Brigadier	**150**	9.29	8.00	9.36	7.94	9.56	8.31	**9.40**	**8.08**
	250	9.54	8.57	9.36	8.38	9.81	9.01	**9.57**	**8.65**
	350	9.31	8.59	9.46	8.41	9.73	9.04	**9.50**	**8.68**
	450	9.50	8.49	9.54	8.67	9.73	9.06	**9.59**	**8.74**
	Mean	**9.41**	**8.41**	**9.43**	**8.35**	**9.71**	**8.86**		

LSD: Sowdate/Seedrate - 0.31 t/ha
LSD: Passes/Sowdate/Variety - 0.37 t/ha
LSD: Passes/Sowdate/Variety/Seedrate - 0.75 t/ha
DD1: Drilling date 1 DD2: Drilling date 2

Mean Difference in Yield between 3 Pass and 7 Pass Systems (1995 - 1997)

Hunter	DD1	0.22 t/ha	Advantage 7 Pass
	DD2	0.22 t/ha	Advantage 7 Pass
Brigadier	DD1	0.30 t/ha	Advantage 7 Pass
	DD2	0.45 t/ha	Advantage 7 Pass

There was a significant sowing date x variety interaction ($p < 0.001$), with both varieties yielding similarly at the later sowing but Brigadier being superior at the earlier sowing date. In terms of seedrate, this more fertile soil produced little difference in yield between 150/m^2 and 450 seeds/m^2 at the earlier sowing, although 150 seeds/m^2 was significantly inferior to higher seedrates at the second sowing date.

Taking the mean of all seedrates, varieties and sowing dates, 7 pass management systems were significantly higher yielding than 3 and 5 pass systems. However, overall yield differences were small, 3 pass - 8.78 t/ha, 5 - 8.78 t/ha and 7 pass 9.08 t/ha. Looking at individual varieties, the greatest advantage to 7 pass over 3 pass was seen with Brigadier sown late, especially with the late disease pressure in 1997 which was more damaging to the later sown crops.

The number of passes showed no interaction with seedrate in the three years of the trial.

In conclusion, overall there was only a small yield advantage to operating 7 passes through the crop as compared to 3 passes over the three years - mean 0.3 t/ha - all treatments all years. Other than late sown Brigadier, none of the treatment variables looked to have a significant effect on the success or otherwise of the minimum pass approach.

Effect of Pass number and Drilling date - individual trials (1995 - 1997)

The following data examines the effect of drilling date, variety and number of passes in each trial in the three year period. Data presented is a mean yield of 4 seedrates.

1995 Yield data t/ha (Mean of 4 seedrates)

	Management level and Drilling date					
	3 Passes		**5 Passes**		**7 Passes**	
	5 Oct	**3 Nov**	**5 Oct**	**3 Nov**	**5 Oct**	**3 Nov**
Hunter	9.60	9.48	9.40	9.70	9.49	9.32
Brigadier	9.75	9.45	9.66	9.54	9.89	9.50

Correlation with the 3 year mean: 0.691

1996 Yield data t/ha (Mean of 4 seedrates)

	Management level and Drilling date					
	3 Passes		**5 Passes**		**7 Passes**	
	29 Sept	**31 Oct**	**29 Sept**	**31 Oct**	**29 Sept**	**31 Oct**
Hunter	9.34	9.31	9.32	9.54	9.98	9.72
Brigadier	10.44	9.53	10.55	9.53	10.78	9.90

Correlation with the 3 year mean: 0.888

1997 Yield data t/ha (Mean of 4 seedrates)

	Management level and Drilling date					
	3 Passes		**5 Passes**		**7 Passes**	
	6 Oct	**15 Nov**	**6 Oct**	**15 Nov**	**6 Oct**	**15 Nov**
Hunter	7.83	6.38	7.69	6.34	7.93	6.80
Brigadier	8.03	6.26	8.08	6.00	8.46	7.17

Correlation with the 3 year mean: 0.942

With the exception of Brigadier in the more disease prone year of 1997, the individual trials from the three years indicate little difference in yield between the three different levels of management. With higher disease pressure in 1997 the higher fungicide input of the 7 pass approach, (particularly the ear wash element), has begun to pay dividends over the single flag leaf approach of the 3 pass. Interestingly, the higher fungicide input has been more beneficial with later sown crops, particularly on Brigadier. This correlates with disease assessments which illustrated greater differences in disease level between 3 and 7 pass when crops were late sown. The reason for this (which is contrary to most expectations) is the fact that more of the ear emergence and grain fill period of the later sown crop coincided with the wetter weather and Yellow Rust infection in June and July.

3.1.6 Scottish Agronomy Burrelton site - Perthshire

3 Year yield mean (t/ha) 1995 - 1997 **NB: the trial site was at Milnathort, Kinross in 1995**

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2	Mean DD1	Mean DD2
Hunter	**250**	8.79	7.79	9.25	8.14	9.03	8.16	**9.02**	**8.03**
	350	8.96	8.23	9.51	8.40	9.27	8.56	**9.25**	**8.40**
	450	9.20	8.28	9.33	8.30	9.36	8.35	**9.30**	**8.31**
	550	8.95	8.24	9.35	8.47	9.53	8.72	**9.28**	**8.48**
	Mean	**8.98**	**8.14**	**9.36**	**8.33**	**9.30**	**8.45**		
Brigadier	**250**	8.66	6.85	8.97	7.38	9.21	7.61	**8.95**	**7.28**
	350	8.94	7.30	9.23	7.74	9.25	7.74	**9.14**	**7.59**
	450	9.26	7.42	9.12	7.86	9.32	7.97	**9.23**	**7.75**
	550	9.13	7.87	9.16	8.14	9.38	8.29	**9.22**	**8.10**
	Mean	**9.00**	**7.36**	**9.12**	**7.78**	**9.29**	**7.90**		

LSD: Sowdate/Seedrate - 0.33 t/ha
LSD: Passes/Sowdate/Variety - 0.40 t/ha
LSD: Passes/Sowdate/Variety/Seedrate - 0.81 t/ha

Mean Difference in Yield between 3 Pass and 7 Pass Systems (1995 - 1997)

Hunter	DD1	0.32 t/ha	Advantage 7 pass
	DD2	0.31 t/ha	Advantage 7 pass
Brigadier	DD1	0.29 t/ha	Advantage 7 pass
	DD2	0.54 t/ha	Advantage 7 pass

Meaning all treatments/varieties, there was a linear increase in yield ($p<0.001$) as the number of passes increased. However, again the overall differences were small, 7.74 t/ha 3 pass versus 8.18 t/ha 7 pass.

There was no interaction between number of passes and sowing date, indicating in the three years little difference in the relative success of minimum pass husbandry according to sowing date. A feature which also showed up at Cirencester and Wye was the greater advantage of the 7 pass system on late sown Brigadier rather than early sown Brigadier.

There was no influence of seedrate on the success of the three different management systems, a feature common to all six trial sites.

There was a variety sowing date interaction which illustrated Brigadier to be inferior to Hunter at the later sowing date but equal to Hunter at the earlier sowing date.

Seedrates, which were set in a range 100 seeds/m^2 higher than the English sites, produced optimum yields for both varieties at 450 seeds/m^2 sown early, and 550 seeds/m^2 sown late. Overall, the yield differences between 250 - 550 seeds/m^2 were small (approximately 0.25 t/ha) although 250 seeds/m^2 became statistically inferior with later sowings.

Effect of Pass number and Drilling date - individual trials 1995 - 1997

The following data examines the effect of drilling date, variety and number of passes in each trial in the three year period. Data presented is the mean of the four seedrates.

1995 Yield data t/ha (Mean of 4 seedrates)

	Management level and Drilling date					
	3 Passes		**5 Passes**		**7 Passes**	
	3 Oct	**2 Nov**	**3 Oct**	**2 Nov**	**3 Oct**	**2 Nov**
Hunter	9.44	9.59	10.53	9.55	10.49	9.74
Brigadier	10.23	9.32	10.44	9.62	10.49	9.51

Correlation with the 3 year mean: 0.806

1996 Yield data t/ha (Mean of 4 seedrates)

	Management level and Drilling date					
	3 Passes		**5 Passes**		**7 Passes**	
	10 Oct	**2 Nov**	**10 Oct**	**2 Nov**	**10 Oct**	**2 Nov**
Hunter	9.74	8.50	9.72	8.77	9.62	8.47
Brigadier	9.28	8.03	9.47	8.55	9.45	8.49

Correlation with the 3 year mean: 0.933

1997 Yield data t/ha (Mean of 4 seedrates)

	Management level and Drilling date					
	3 Passes		**5 Passes**		**7 Passes**	
	10 Oct	**11 Nov**	**10 Oct**	**11 Nov**	**10 Oct**	**11 Nov**
Hunter	7.74	6.32	7.83	6.67	7.79	7.14
Brigadier	7.48	4.73	7.46	5.17	7.93	5.71

Correlation with the 3 year mean: 0.943

In the 1995 and 1996 trials there was little yield advantage going beyond the 5 pass system, irrespective of variety or drilling date. In 1997 the 7 pass system did perform significantly better than the 3 pass system, especially on the late sown crops. As with other trial sites this was due to higher disease levels in the later sown crops, particularly Mildew. Again, the benefit of 3 spray fungicide programmes in the 7 pass system were not as apparent in the early sowing where disease levels were considerably lower. Overall, in 1997 as would be expected, Brigadier gave the clearest indication of 7 pass advantage over 5 and 3 pass.

3.2 Overall Yield Results 1995 (all sites)

The following four sections of the Report examine the yield results of all trial sites meaned together. Firstly, Sections 3.2 - 3.4 examine the results from individual years in order to assess the seasonal variation during the project.

1995 Yield Data t/ha Mean of 6 sites

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Hunter	**150**	8.01	7.39	8.53	7.67	9.06	8.13
	250	8.24	8.12	8.71	8.20	9.33	8.57
	350	8.45	8.40	8.91	8.70	9.54	9.08
	450	8.59	8.52	8.93	8.68	9.66	9.04
	Mean	**8.32**	**8.10**	**8.77**	**8.31**	**9.40**	**8.70**
Brigadier	**150**	8.01	7.10	8.56	7.44	9.29	8.18
	250	8.45	7.86	8.86	8.23	9.60	8.62
	350	8.79	8.20	9.12	8.39	9.79	9.11
	450	8.87	8.18	9.24	8.80	9.71	9.12
	Mean	**8.53**	**7.84**	**8.95**	**8.22**	**9.60**	**8.76**

LSD: Sowing date/Seedrate - 0.28 t/ha
LSD: Passes/Sowing date/Variety - 0.34 t/ha
LSD: Passes/Sowing date/Variety/Seedrate - 0.67 t/ha

Mean Difference in Yield between 3, 5 and 7 Pass Systems 1995 (all sites)

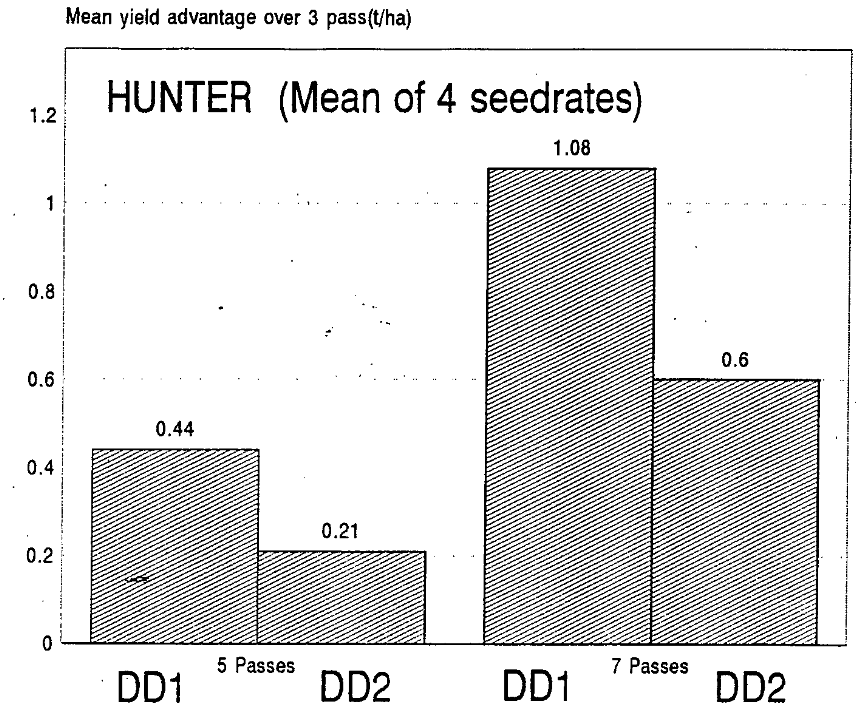
The mean yield advantage of 5 and 7 passes over 3 passes is illustrated graphically (Figure i).

1995 data indicated a clear yield advantage to management systems with a higher number of passes, the differences between 3, 5 and 7 passes being highly significant ($p<0.001$).

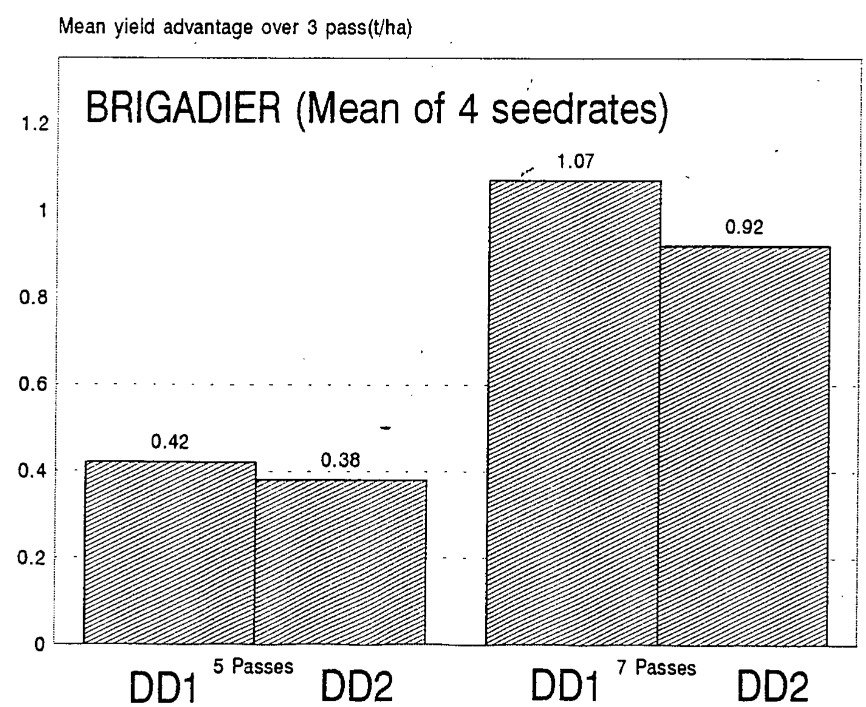
With early sowings there was no evidence that minimum pass husbandry ie 3 and 5 passes was more or less successful with the disease resistant variety, Hunter. However, there was an interaction between pass and sowing date ($p = 0.067$ not quite significant) which clearly illustrated that, at the later sowing date, minimum pass husbandry was relatively more successful with the disease resistant variety, Hunter.

Figure (i)

MEAN YIELD ADVANTAGE OF 5 and 7 PASSES OVER 3 PASSES
1995 (Mean of all sites)



MEAN YIELD ADVANTAGE OF 5 and 7 PASSES OVER 3 PASSES
1995 (Mean of all sites)



There was no interaction between seedrate and number of passes in 1995, indicating that seedrate adjustment was not a factor in making minimum pass husbandry more successful.

Overall the large difference in yield between 3 and 7 pass systems in 1995 was heavily influenced by the Biggleswade result where the very high grain aphid populations created a 2.5 - 3.0 t/ha difference between 3 and 7 pass. This contrasts to the Wye site where yield difference ranged from 0 - 0.1 t/ha. Over the three years of the project it is the Biggleswade result in 1995 that has shown the greatest yield penalty to minimum pass husbandry. The influence of this result on the 1995 data can be more clearly demonstrated if a 5 site mean excluding Biggleswade is considered.

Yield advantage of 7 Pass over 3 Pass 1995

6 site mean (including Biggleswade)

Hunter	DD1	1.08 t/ha	Advantage 7 pass
	DD2	0.60 t/ha	Advantage 7 pass
Brigadier	DD1	1.07 t/ha	Advantage 7 pass
	DD2	0.92 t/ha	Advantage 7 pass

5 site mean (excluding Biggleswade)

Hunter	DD1	0.74 t/ha	Advantage 7 pass
	DD2	0.31 t/ha	Advantage 7 pass
Brigadier	DD1	0.82 t/ha	Advantage 7 pass
	DD2	0.61 t/ha	Advantage 7 pass

In conclusion, 1995 data demonstrated a large variation in the success of minimum pass husbandry. At all but one site reducing the number of passes through the crop resulted in lower yields. However, the extent of the yield penalty varied enormously between sites. In most situations the yield penalty was rarely more than 0.75 t/ha, the exception being Biggleswade where a massive grain aphid infestation resulted in a yield penalty of 2 - 3 t/ha, depending on sowing date.

3.3 Overall yield results 1996 (all sites)

1996 Yield Data t/ha Mean of 6 sites

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Hunter	**150**	8.29	7.06	8.50	7.16	8.66	7.10
	250	8.75	7.38	8.78	7.63	8.93	7.51
	350	8.95	7.76	8.83	7.88	9.04	7.79
	450	9.02	7.92	8.91	7.96	9.06	7.74
	Mean	**8.75**	**7.53**	**8.75**	**7.66**	**8.92**	**7.53**
Brigadier	**150**	8.83	7.12	8.80	7.23	8.90	7.26
	250	8.86	7.35	9.09	7.53	9.15	7.44
	350	9.14	7.71	9.03	7.80	9.32	7.83
	450	9.26	7.42	9.03	7.83	9.24	7.89
	Mean	**9.02**	**7.48**	**8.99**	**7.59**	**9.15**	**7.60**

LSD: Sowing date/Seedrate - 0.26 t/ha
LSD: Passes/Sowing date/Variety - 0.32 t/ha
LSD: Passes/Sowing date/Variety/Seedrate - 0.65 t/ha

Mean difference in yield between 3, 5 and 7 pass systems 1996 (all sites)

Removing the variable of seedrate the following bar graphs (Figure ii) illustrate the mean yield advantage of 5 and 7 pass over 3 pass systems. Of the three years of the project 1996 was the only year (looking at a six site mean) when there was no significant difference between the number of passes. Consequently, 1996 was the most successful season for minimum pass husbandry techniques as there was little yield penalty adopting 3 passes compared to the conventional 7 pass system. For Hunter the yield difference between 3 and 7 pass measured a maximum of 0.17 t/ha whereas with Brigadier the maximum difference was 0.13 t/ha.

Although the differences were small there was evidence that the yield benefit of 7 pass over 3 pass was manifest at the early sowing with Hunter but not at the later sowing. This tendency for 3 passes to be more successful at the later sowing was not manifest with the more disease susceptible variety, Brigadier. Thus overall interaction of variety, sowing date and number of passes was very similar to the yield differences observed in 1995.

Again, as in 1995, there was no interaction between seedrate and number of passes, indicating that seedrate adjustment was not a factor in making minimum pass husbandry more successful. However, there was no lodging in any of the 1996 trials, a factor which might have created bigger differences.

Unlike 1995, when there was one site that gave an enormous benefit to the conventional 7 pass system ie Biggleswade, 1996 had far smaller differences between 3 and 7 passes. In fact, the Cirencester site displayed significant yield advantages to 3 pass over 5 and 7 pass in 1996, a result which was purely the effect of bringing forward the timing of the single nitrogen dose. The 200 kg/ha N main dose in the 3 pass system was applied on 12 April compared to 25 April for the main dose on the split nitrogen approach of the 5 and 7 pass system.

Whilst the 1996 season was clearly more successful in terms of minimum pass husbandry, it is clear that the large benefits of 3 pass over 7 pass at the Cirencester have distorted the six site national mean.

Mean Difference in Yield between 3 Pass and 7 Pass Systems

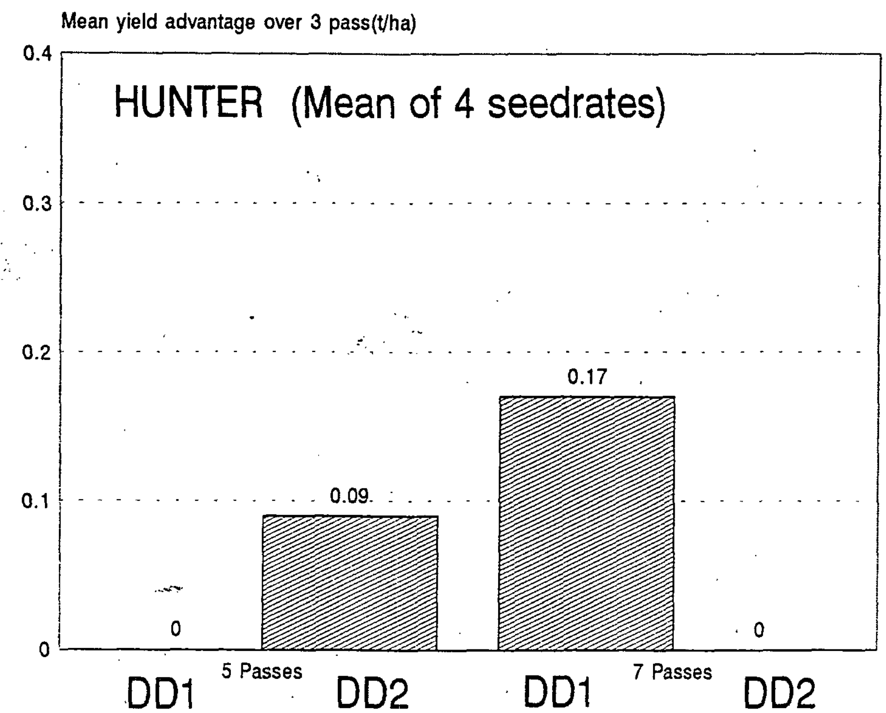
Hunter	DD1	0.47 t/ha	Advantage 7 pass
	DD2	0.26 t/ha	Advantage 7 pass
Brigadier	DD1	0.36 t/ha	Advantage 7 pass
	DD2	0.37 t/ha	Advantage 7 pass

Looking at aspects other than the number of passes, 1996 data clearly illustrated the higher yield or early sowings. In addition, it again revealed that the superiority of Brigadier over Hunter was only manifest at the early sowing, with little difference in yield at the later sowing date (p 0.054).

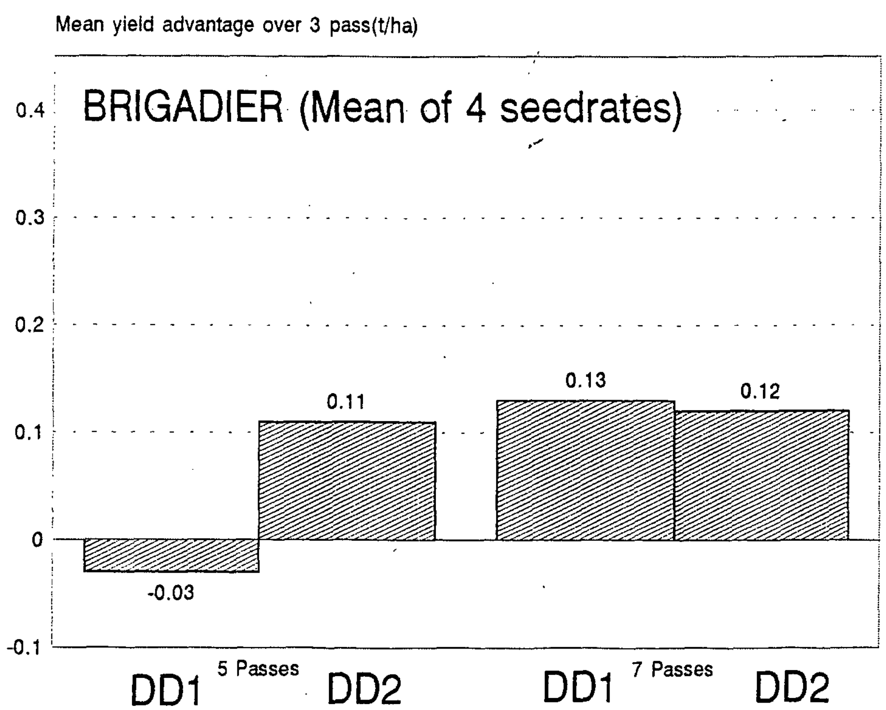
In general, yield increased with seedrate to 350 seeds/m^2 after which there was little improvement. Noticeably in Kent, though, differences between seedrates were very small.

Figure (ii)

MEAN YIELD ADVANTAGE OF 5 and 7 PASSES OVER 3 PASSES
1996 (Mean of all sites)



MEAN YIELD ADVANTAGE OF 5 and 7 PASSES OVER 3 PASSES
1996 (Mean of all sites)



3.4 Overall yield results 1997 (all sites)

In 1997 the Biggleswade trial site failed. Therefore the overall means cover only five sites, not six as in previous years.

1997 Yield Data t/ha Mean of 5 sites

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Hunter	**150**	7.13	5.49	7.26	5.36	7.90	5.76
	250	7.59	6.13	7.84	6.29	8.18	6.54
	350	7.83	6.36	7.96	6.62	8.13	6.96
	450	7.99	6.28	7.89	6.60	8.26	7.05
	Mean	**7.63**	**6.07**	**7.74**	**6.22**	**8.12**	**6.58**
Brigadier	**150**	7.26	5.15	7.46	5.10	7.79	6.14
	250	7.81	5.57	7.77	5.81	8.26	6.45
	350	7.86	5.71	8.07	5.80	8.44	6.64
	450	8.10	5.78	8.11	6.16	8.40	6.76
	Mean	**7.76**	**5.55**	**7.85**	**5.71**	**8.22**	**6.50**

LSD: Sowing date/Seedrate - 0.22 t/ha
LSD: Passes/Sowing date/Variety - 0.27 t/ha
LSD: Passes/Sowing date/Variety/Seedrate - 0.54 t/ha

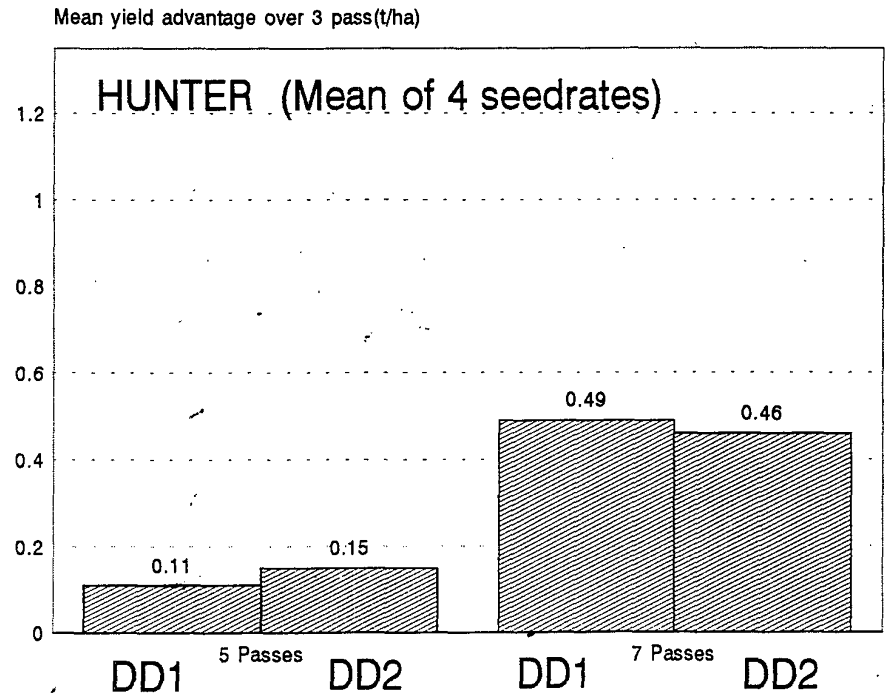
NB Means have been adjusted to take account of the missing yield values from Andover late sown.

1997 data indicated a significant ($p<0.004$) curved response to an increased number of passes with both varieties. In other words, yield increased with the number of passes but the advantage of 7 pass over 5 pass was much more manifest than the advantage of 5 pass over 3 pass. This advantage of 7 pass relates to the 7 pass management system being the only treatment to incorporate an ear wash fungicide. Normally the impact of the ear wash or T3 fungicide is relatively small, however 1997 produced exceptional levels of late season disease. What was particularly apparent was that these high levels of disease had a greater impact on the later sown crops, particularly the more disease susceptible variety, Brigadier. Early sown, the advantage of 7 pass over 3 pass was relatively modest at 0.49 or 0.56 t/ha, with little indication that variety susceptibility was a factor.

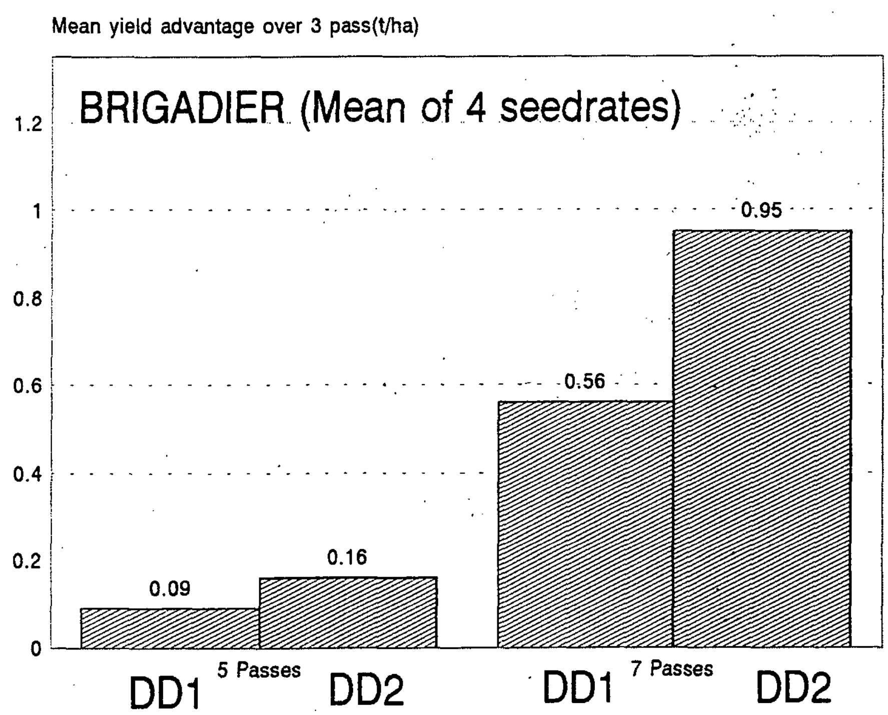
Incorporation of split nitrogen timing and a GS32 fungicide with the 5 pass system had minimal effects on yield in 1997.

Figure (iii)

MEAN YIELD ADVANTAGE OF 5 and 7 PASSES OVER 3 PASSES
1997 (Mean of all sites)



MEAN YIELD ADVANTAGE OF 5 and 7 PASSES OVER 3 PASSES
1997 (Mean of all sites)



3.5 Overall 3 year mean yield for the Experiment

The following data looks at the mean yields for all sites in all three years.

1995 - 1997 Yield Data t/ha 3 year mean (all sites)

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Hunter	150	8.02	6.88	8.38	6.99	8.69	7.24
	250	8.37	7.43	8.63	7.59	8.94	7.75
	350	8.56	7.73	8.73	7.96	9.05	8.15
	450	8.64	7.82	8.75	7.98	9.12	8.14
	Mean	**8.40**	**7.47**	**8.62**	**7.63**	**8.95**	**7.82**
Brigadier	150	8.28	6.71	8.53	6.88	8.86	7.41
	250	8.52	7.18	8.81	7.44	9.19	7.72
	350	8.74	7.51	8.93	7.60	9.31	8.10
	450	8.88	7.50	8.95	7.86	9.24	8.15
	Mean	**8.61**	**7.23**	**8.81**	**7.45**	**9.15**	**7.85**

LSD: Sowing date/Seedrate - 0.17 t/ha
LSD: Passes/Sowing date/Variety - 0.21 t/ha
LSD: Passes/Sowing date/Variety/Seedrate - 0.42 t/ha

Mean Difference in Yield between 3, 5 and 7 Pass Systems 1995 - 1997

Over the three years of the project higher yields came from a greater number of passes through the crop. This advantage of more passes is expressed in terms of yield in the following graphs (figure iv). As there was no interaction between number of passes and seedrate, yield differences are presented as a mean of four seedrates. Taking the yield data from the three years and 17 individual sites indicated a significant increase ($p<0.001$) in yield as the number of passes through the crop increased. Looking at a mean of all treatments over the three years, 3 pass gave a yield of 7.92 t/ha, 5 pass 8.13 t/ha and 7 pass 8.44 t/ha. Thus the overall yield penalty of moving from a conventional 7 pass management system to a 3 pass minimum pass husbandry approach was approximately 0.5 t/ha.

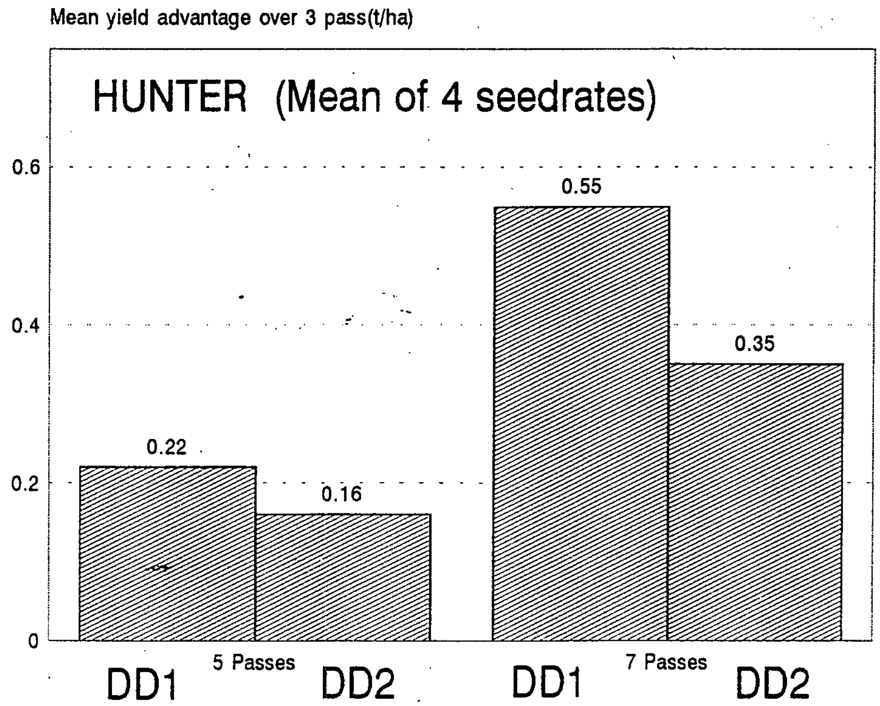
With early sown crops which were significantly higher yielding there was no evidence to suggest that variety resistance or seedrate had any bearing on the performance of minimum pass husbandry. Therefore the difference between 3, 5 and 7 pass management systems was the same irrespective of variety or seedrate.

There was evidence to suggest that later sowing improved the relative performance of the minimum pass system but only with the more disease resistant variety, Hunter. With Brigadier the indications were that sowing date did not affect the relative yield differences between 3, 5 and 7 passes.

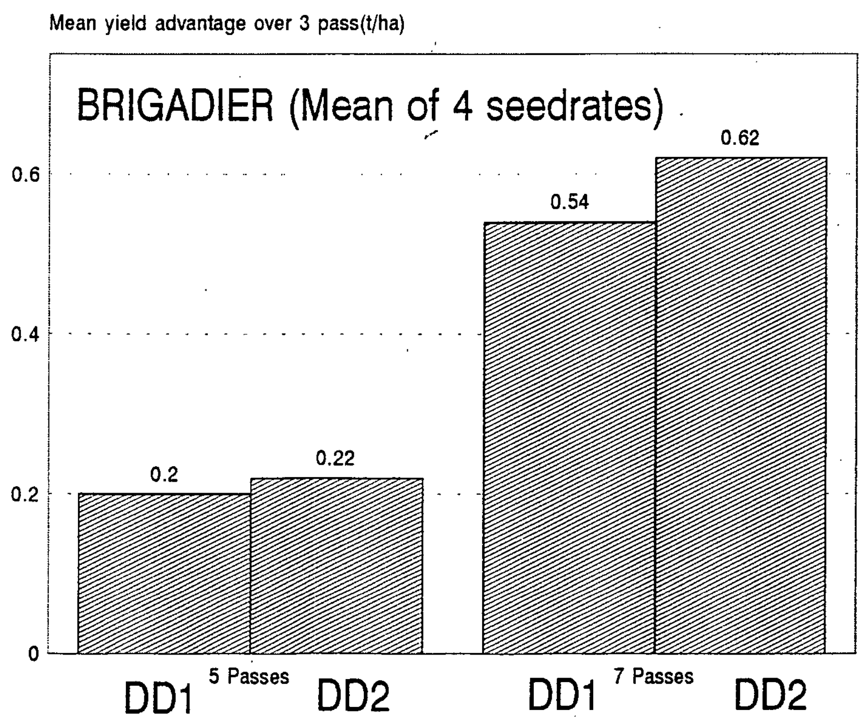
For discussion on why 7 pass was superior to 3 pass see Section 5.0.

Figure (iv)

MEAN YIELD ADVANTAGE OF 5 and 7 PASSES OVER 3 PASSES
1995 - 1997 (Mean of all sites, all years)



MEAN YIELD ADVANTAGE OF 5 and 7 PASSES OVER 3 PASSES
1995 - 1997 (Mean of all sites, all years)



3.6 Crop structure and disease assessments in relation to yield

This experiment was primarily set up as a management trial, examining how large differences in overall management affects the yield and profitability of the winter wheat crop. Since the different management treatments differed by more than one variable it was not possible to determine which factors within a 3, 5 and 7 pass system created the yield differences that were apparent in the yield results.

However, by examining key trials within the projects, one can clearly see that crop structure and disease assessments did relate very strongly to yield differences in some circumstances.

3.6.1 Disease control

The minimum pass husbandry approach depends on fewer fungicide applications, with the 3 pass system being dependent on a single flag leaf fungicide for disease control. Through the course of the project the 7 pass conventional management system depended upon a 3 spray fungicide programme, with reduced rates (typically ¼ - ½ rates) employed at the T1 timing - GS32 and ear wash timing T3 - GS59-69.

This difference in the management treatments between 1 and 3 fungicide sprays did not create large differences in disease levels in the first two years of the project. This was primarily due to the lower disease levels experienced in the 1995 and 1996 seasons. However, it was apparent that in almost all cases there was visual difference in disease levels when comparing 3 and 7 passes, particularly on leaf 2 and 3 in the canopy. The advantage of 7 pass treatments over 3 pass was most apparent in the wetter south west of the country where wheat crops historically suffer from higher levels of Septoria tritici. As one might expect, this difference in disease levels was most obvious in Brigadier. For example, the following table compares 3 and 7 pass treatments on Brigadier from Hampshire and Kent in 1996. The assessments revealed smaller differences between 3 and 7 pass in the drier south east, especially on the more disease susceptible variety, Brigadier.

% Septoria tritici infection (leaf 2) on Brigadier early sown (3 v 7 passes) compared between Hampshire and Kent 1996

% Septoria infection GS75-80	**ARC Hampshire**		**ARC Kent**	
Seedrate (seeds/m^2)	**3 Pass**	**7 Pass**	**3 Pass**	**7 Pass**
150	7.7	0	1.3	0.7
250	6.3	0.3	1.2	0.7
350	4.7	0.4	1.0	1.0
450	10.7	1.7	1.2	1.0
Mean level of infection	**7.35**	**0.6**	**1.2**	**0.85**
April rainfall(mm)	48mm		6mm	
Mean Yield t/ha	9.63	10.10	10.44	10.73

Septoria infection assessed 5 July - Hampshire, 4 July - Kent.

Whilst it is not possible to conclude that the greater difference in disease levels in Hampshire explains the greater differences in yield, it was clear through the course of the project that wherever the growth stage period GS31 (1st node) to GS37 (flag leaf emerging) was subject to low levels of rainfall, visual differences in disease levels between 3 and 7 passes were generally small.

With the advent of better eradicant Triazoles such as Opus - Epoxiconazole, ARC has found that the value of the T1 and T3 fungicides has been diminished if these superior products are applied at flag leaf (T2).

Thus, since most of the trials in the project employed either Opus or Folicur (Tebuconazole) on the flag leaf, ARC were not surprised to find small differences between 3 and 7 passes.

Overall, therefore, for 1995 and 1996 there was only a small amount of evidence to indicate that disease control was inferior with the minimum pass husbandry approach. Where differences in disease levels were most manifest in the two years was in wetter regions of the country where Septoria tritici developed on 3 pass treatments in Brigadier.

1997 produced a season with much higher levels of disease. Septoria tritici, Yellow Rust and Mildew were features of the trials.

A common feature of this high disease pressure was that it occurred later in the season in June. Consequently, the yield results and disease assessments from the 1997 season illustrate that it was the later drilling dates that most expressed the differences between the one fungicide approach of the 3 pass and the three fungicides of the 7 pass.

This exposed much greater differences in disease between the 3 and 7 pass systems as the 7 pass system incorporated an ear wash fungicide application. The greater difference in disease levels between the 3 and 7 pass systems was clearly illustrated at the Hampshire site in 1997.

ARC Hampshire 1997

% Septoria tritici infection (leaf 2) on early sown (1 October) Brigadier and Hunter, comparing 3 and 7 pass

Disease assessed GS75-80

	% Septoria tritici leaf 2 Management System		
	3 passes	**5 passes**	**7 passes**
Hunter	26	31	12
Brigadier	59	47	23

Disease assessed 10 July. Mean of 4 seedrates.

Looking at the above assessment it is clear that the disease resistance of the variety became much more of a factor if the variety was to be a suitable candidate for minimum pass husbandry in 1997. Note that the effect of adding a GS32 fungicide with the 5 pass approach had little effect in terms of reducing disease levels. However adding an ear wash fungicide with the 7 pass approach had a substantial effect at reducing disease levels because its timing better coincided with the peak of disease pressure.

One of the variables in the project which it was thought would reduce disease pressure and thus enhance the success of minimum pass was later sowing. The 1997 results actually served to illustrate the complete reverse with Brigadier, since the yield differential between 3 and 7 pass was actually greater sown late than sown early. Averaged across all sites the difference between 3 and 7 passes was 0.95t/ha with late sown Brigadier. However with early sown Brigadier, the difference averaged only 0.56t/ha. The primary reason for this was that the late season disease peak created greater disease when crops were sown late. The following tables clearly illustrate this difference in disease development between early and late sown crops.

Scottish Agronomy - Burrelton Perthshire 1997

% Disease Infection - 20 June
Mil = % Mildew infection
Sep = % Septoria infection

Variety/Seedrate (seeds/m²)		**3 Pass**		**7 Pass**	
		% Mil	**% Sep**	**% Mil**	**% Sep**
Drilling date 1-10 October					
Hunter	**250**	1.3	1	0	0.7
	350	2.0	1.3	0	0.7
	450	2.0	1.7	T	0.7
	550	3.7	2	T	0.7
Brigadier	**250**	1.3	1.3	1.7	1
	350	2	1.3	2.7	1.3
	450	2.7	2	3	1.3
	550	4.7	2.7	3	1.3
Drilling date 2 - 9 November					
Hunter	**250**	2.7	0.3	1.3	T
	350	4.0	1.0	1.3	0.7
	450	4.3	0.7	3.3	0.7
	550	9.3	0.3	5	0.7
Brigadier	**250**	10	1.3	18	1.7
	350	15	2.3	16	1.3
	450	21	1.7	13	1.3
	550	21	3.0	18	1.3

3.6.2 Crop Structure Assessments

With 3 pass treatments in the project nitrogen for the crops' requirements was provided as a single dose, applied GS30/31. This compared to the 2 split nitrogen regime of the 5 and 7 pass techniques where the total nitrogen dose was split, with 40 - 80 kg/ha N being applied at the late tillering stage and the remainder applied at GS30/31.

In two, possibly three, sites in 1995 and 1996 it would appear that this difference in nitrogen approach could have been largely responsible for the relative yield difference between 3 and 7 pass systems Where main dose timings coincided with very dry conditions there was evidence that the single nitrogen application of the 3 pass system was severely penalised by restricted uptake, relative to 5 and 7 pass systems that had the "insurance" of an early tillering dose. This restriction in nitrogen uptake manifested itself with a reduction in ear number in the 3 pass management crops.

From the assessments there was some evidence that the greatest differences in ear number between 3 and 7 pass systems occurred where the crop was in the least fertile situations.

For example, taking the ear counts for 1995 for the trials at the Caythorpe and Wye sites, the main dose applications were subject to drought conditions at both sites yet it was only at the Caythorpe site that ear numbers were noticeably higher with the 7 pass management system.

ARC Wye 1995/Caythorpe 1995
Ears/m^2 recorded at harvest

Variety/Seedrate	**Ears/m^2**			
	Wye		**Caythorpe**	
	3 Pass	**7 Pass**	**3 Pass**	**7 Pass**
Brigadier - Early sown				
150 seeds/m^2	487	471	442	596
250 seeds/m^2	499	432	445	512
350 seeds/m^2	525	439	480	574
450 seeds/m^2	487	416	514	560
Mean	**500**	**440**	**470**	**561**
Yield t/ha	**9.75**	**9.89**	**6.71**	**8.20**
Hunter - Early sown				
150 seeds/m^2	441	353	440	562
250 seeds/m^2	449	359	414	498
350 seeds/m^2	352	388	482	480
450 seeds/m^2	481	452	472	518
Mean	**431**	**388**	**452**	**515**
Yield t/ha	**9.60**	**9.49**	**7.03**	**8.31**

- On the more fertile brickearth site at Wye where the crop followed vining peas there were smaller differences in ear number between 3 and 7 pass systems in favour of 3 pass. Thus the single dose v split approach to nitrogen appeared to have little influence on crop structure at this site. If anything, 3 passes gave greater ear number.

- At the Caythorpe site, on brash soil, where the wheat crop was a 2nd cereal following spring barley, there was considerably less soil fertility. In this situation the split nitrogen approach of the 7 pass system lead to a significant increase in ear number relative to the single nitrogen dose of the 3 pass system.

Thus there was some evidence that minimum pass techniques embracing a single dose of nitrogen were more prone to crop canopies with lower ear numbers. However, this effect was most manifest where soil fertility was very low, either by virtue of soil type or previous crop or both.

It was noticeable, comparing yield performance of Caythorpe and Kent sites in 1995, that this nitrogen timing effect on ear number created large differences in yield at the Caythorpe site. In addition, since disease levels were so low at this site, it is easier to be confident that this nitrogen timing effect created a large element of the yield differences between the 3 and 7 pass management.

In the majority of trials carried out in the project, the yield differences between management systems have been relatively small. As differences in yield between managements could have been due to more than one variable, this Section of the report has restricted its attention to assessments where yield differences between 3, 5 and 7 passes have been at their greatest. In some of these cases it can be illustrated from assessments that crop structure and disease control differences help explain the yield results.

3.7 Influence on grain quality

3.7.1 Specific Weights

As ARC has found in previous experiments, the yield differences associated with different husbandry treatments tend to correlate quite strongly with the specific weight differences. Thus, if a trial displayed a larger yield difference between 3, 5 and 7 pass management systems, then specific weight differences would be correspondingly greater. If there was a small difference in yield between different management systems, then the specific weight differences were correspondingly smaller.

The following tables illustrate these trends with reference to the ARC Cirencester Centre, where 3 pass management gave inferior yields to 7 pass in 1995 and 1997 but was superior to 7 pass in 1996. These yield trends are particularly well correlated to the specific weights for Brigadier.

ARC Cirencester Specific Weight kg/hl 1995 - 1997

1995

Variety	Seedrate (seeds/m^2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2	Mean DD1	Mean DD2
Hunter	**150**	73.6	71.7	77.8	71.2	74.7	71.0	**75.4**	**71.3**
	250	74.5	72.6	78.2	74.7	75.0	72.2	**75.9**	**73.2**
	350	75.7	73.9	78.8	74.1	76.4	73.5	**76.9**	**73.8**
	450	76.4	73.6	78.4	75.7	76.0	73.3	**76.9**	**74.2**
	Mean	**75.1**	**73.0**	**78.3**	**73.9**	**75.5**	**72.5**		
Brigadier	**150**	73.7	70.3	76.6	73.2	73.7	71.5	**74.6**	**71.7**
	250	72.7	71.4	76.9	72.8	76.2	72.2	**75.2**	**72.1**
	350	74.2	71.8	77.3	74.3	77.0	73.3	**76.2**	**73.1**
	450	75.2	74.1	77.9	74.3	77.8	72.9	**77.0**	**73.7**
	Mean	**73.9**	**71.9**	**77.2**	**73.7**	**76.2**	**72.5**		

Highest specific weights were seen with the 5 pass treatment. There was a trend throughout for the higher seed rates to give better specific weights but the most marked effect was that of drilling date. The September sown plots consistently showed a higher specific weight, between 2 and 4 kg/hl over the October sown plots.

1996

Variety	Seedrate (seeds/m^2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2	Mean DD1	Mean DD2
Hunter	**150**	73.5	71.5	70.9	67.9	73.6	70.9	**72.7**	**70.1**
	250	71.5	71.2	70.2	70.3	72.0	71.5	**71.3**	**71.0**
	350	72.8	71.3	69.7	69.5	71.4	71.2	**71.3**	**70.7**
	450	70.1	70.8	71.4	70.5	70.8	70.5	**70.8**	**70.6**
	Mean	**72.0**	**71.2**	**70.6**	**70.0**	**72.0**	**71.0**		
Brigadier	**150**	75.8	73.5	75.4	71.8	74.3	72.1	**75.2**	**72.5**
	250	77.0	74.2	72.6	71.8	70.2	71.1	**73.4**	**72.4**
	350	74.2	73.9	75.3	73.5	74.4	71.1	**74.6**	**72.8**
	450	74.2	74.3	73.4	73.4	72.5	71.3	**73.4**	**73.0**
	Mean	**75.3**	**74.0**	**74.2**	**72.6**	**72.9**	**71.4**		

Specific weights were higher for the early sowing over the late sowing, higher for Brigadier than for Hunter, and there was a tendency for higher specific weights to be associated with lower seed rates. In terms of management level, Brigadier produced better specific weights with 3 passes than with 5 or 7. Hunter, however, showed no clear relationship between specific weight and management level.

1997

Variety	Seedrate (seeds/m²)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2	Mean DD1	Mean DD2
Hunter	**150**	75.9	72.0	77.6	74.8	76.1	72.5	**76.5**	**73.1**
	250	75.9	72.1	77.9	74.8	77.1	74.1	**77.0**	**73.6**
	350	76.4	72.8	77.7	74.2	77.1	73.3	**77.1**	**73.4**
	450	76.4	73.0	77.9	74.8	77.0	74.4	**77.1**	**74.1**
	Mean	**76.2**	**72.5**	**77.8**	**74.7**	**76.8**	**73.6**		
Brigadier	**150**	77.0	72.7	77.6	72.8	77.5	72.7	**77.4**	**72.7**
	250	74.5	74.7	78.0	74.3	77.5	73.3	**76.7**	**74.0**
	350	77.0	73.2	77.9	74.9	77.7	76.0	**77.5**	**74.7**
	450	74.2	74.2	77.6	74.1	77.8	74.0	**76.5**	**74.1**
	Mean	**75.7**	**73.7**	**77.8**	**74.0**	**77.6**	**74.0**	**77.0**	**73.9**

Drilling date showed the clearest effect on specific weight, consistently higher with the earlier sowing. For both varieties, the seed rates had little effect on specific weight with the earlier sowing but, when sown late, specific weight increased with seed rate. Hunter produced the best specific weight with 5 passes, at both drilling dates. Brigadier produced best specific weight with either 5 or 7 passes, both of which were better in this respect than 3 passes.

Overall, specific weight of the grain has generally mirrored the yield rank order and differences. In general, differences in specific weight due to the number of passes have been most manifest with the more disease susceptible variety, Brigadier.

4.0 ECONOMIC RESULTS

The following three sections of the report look at how the yield results of the project translated into gross margin, remembering that the variable costs of the minimum pass systems are lower than the conventional 7 pass management systems. Sections 4.1 and 4.2 examine purely gross margin analysis, with Section 4.3 looking at how these margins are affected by the deduction of application costs.

The full details relating to trial inputs and costings can be found in Section 6.1

4.1 Gross Margin Results - individual sites (3 year means)

4.1.1 ARC Andover Gross Margins 1995 - 1996

Third year results have been omitted because of failure of late sowing.

Gross margins have been calculated on the basis of £75/tonne. Whilst full details can be found in Section 6.1, the mean variable cost difference between the three management systems was as follows (figures taken at 350 seeds/m^2).

Variable costs ARC Andover at 350 seeds/m^2

	3 Pass £/ha	5 Pass £/ha	7 Pass £/ha
Hunter	178	192	210
Brigadier	184	197	215

Small differences between Hunter and Brigadier were due to different seed sizes causing different seed costs.

Applying the mean, 2 year yields and 2 year variable costs gave the following gross margins at £75/tonne.

2 Year Gross Margin (£/ha) 1995 - 1996 (ARC Andover)

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Hunter	**150**	465	459	488	437	491	459
	250	514	479	496	460	516	495
	350	503	481	492	487	511	503
	450	506	477	487	475	514	484
	Mean	**497**	**474**	**491**	**465**	**508**	**485**
Brigadier	**150**	525	457	519	456	528	481
	250	533	484	522	475	537	496
	350	544	489	516	487	539	515
	450	536	504	518	486	533	522
	Mean	**535**	**484**	**519**	**476**	**534**	**504**

Figures presented do not include arable aid payments.

The yield advantage of the 5 and 7 pass systems has been offset by the higher variable costs associated with these systems. As seedrate was not an interactive factor with number of passes, the following mean gross margins give an overview of the impact of number of passes.

	Gross margin £/ha 3 Passes	5 Passes	7 Passes
DD1			
Hunter	497	491	**508**
Brigadier	**535**	519	534
DD2			
Hunter	474	465	**485**
Brigadier	484	476	**504**

7 pass-treated Hunter gave a gross margin £11/ha greater than 3 pass. 5 pass was least profitable but overall differences were small between the profitability of different managements (less than £20/ha).

With Brigadier early sown, 3 pass gave £1/ha advantage over the conventional 7 pass system. Later sown, the 7 pass gross margin was £20/ha superior to 3 pass. Again the 5 pass systems were least profitable.

4.1.2 ARC Biggleswade Gross Margins 1995 - 1996 (2 year mean)

Typical variable cost differences for the Biggleswade site over the two years 1995 and 1996 were as follows:

Variable cost ARC Biggleswade at 350 seeds/m^2 (2 year mean)

	3 Pass £/ha	5 Pass £/ha	7 Pass £/ha
Hunter	203	220	239
Brigadier	203	220	239

2 Year Gross Margin (£/ha) 1995 - 1996 (ARC Biggleswade)

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Hunter	**150**	429	262	477	299	530	346
	250	450	337	465	319	548	383
	350	462	353	470	381	554	426
	450	442	370	490	377	529	399
	Mean	**446**	**330**	**475**	**344**	**540**	**389**
Brigadier	**150**	467	287	461	273	535	364
	250	474	329	497	358	554	405
	350	491	357	497	364	542	426
	450	484	347	491	409	532	426
	Mean	**479**	**330**	**487**	**351**	**541**	**405**

Gross margin £/ha

	3 Passes	5 Passes	7 Passes
DD1			
Hunter	446	475	**540**
Brigadier	479	487	**541**
DD2			
Hunter	330	344	**389**
Brigadier	330	351	**405**

The two year gross margins for the Biggleswade site are strongly influenced by the 1995 results when the conventional 7 pass approach had a 2 - 3 t/ha advantage over the 3 pass experimental treatment owing to the enormous effect of grain aphid control. The result is a mean gross margin advantage over the two years of £59- £92/ha to the 7 pass treatment. However, this disguises the fact that in 1996 there was no difference in gross margins between 3 and 7 passes.

Largely due to the 1995 results, it was at this site that the minimum pass husbandry systems performed most poorly, with small savings in input costs unable to make up for the huge loss of yield owing to grain aphid infestation.

4.1.3 ARC Caythorpe Gross Margins 1995 - 1997 (3 year mean)

Gross margin figures were calculated on the basis of the three year yield mean and three year mean variable costs. Typical variable cost differences were as follows:

Variable costs ARC Caythorpe at 350 seeds/m^2 (mean of 4 seedrates)

	3 Pass £/ha	**5 Pass £/ha**	**7 Pass £/ha**
Hunter	166	191	204
Brigadier	170	195	208

3 Year Gross Margin (£/ha) 1995 - 1997 (ARC Caythorpe)

Variety	**Seedrate (seeds/m2)**	**3 Passes DD1**	**3 Passes DD2**	**5 Passes DD1**	**5 Passes DD2**	**7 Passes DD1**	**7 Passes DD2**
Hunter	**150**	373	290	385	282	391	259
	250	376	295	396	312	400	268
	350	379	305	390	321	391	295
	450	367	282	376	300	385	273
	Mean	**374**	**293**	**387**	**304**	**392**	**274**
Brigadier	**150**	353	236	377	253	379	242
	250	366	273	385	282	399	241
	350	370	290	378	281	398	275
	450	375	271	371	264	378	256
	Mean	**366**	**268**	**378**	**270**	**389**	**254**

Again at this site, as with Andover, the yield advantage of 5 and 7 passes has been eroded by the higher variable costs. Looking at gross margin meaning seedrates gave the following results:

	Gross margin £/ha 3 Passes	**5 Passes**	**7 Passes**
DD1			
Hunter	374	387	**392**
Brigadier	366	378	**389**
DD2			
Hunter	293	**304**	274
Brigadier	268	**270**	254

Early sown 7 pass techniques outgross margined 3 pass techniques by £18/ha or £23/ha, depending on variety. At the later sowing 3 pass was more profitable than 7 pass but the outright best gross margins were produced by 5 pass.

4.1.4 ARC Cirencester Gross Margins 1995 - 1997 (3 year mean)

Typical variable cost differences for the Cirencester site were as follows:

Variable costs ARC Cirencester at 350 seeds/m² (3 year mean)

	3 Pass £/ha	5 Pass £/ha	7 Pass £/ha
Hunter	182	197	211
Brigadier	185	200	215

3 Year Gross Margin (£/ha) @ £75/tonne (ARC Cirencester)

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Hunter	**150**	439	340	434	308	418	306
	250	438	373	438	338	426	330
	350	448	385	419	359	418	347
	450	454	389	407	354	425	361
	Mean	**445**	**372**	**425**	**340**	**422**	**336**
Brigadier	**150**	428	316	427	304	410	332
	250	434	345	449	340	436	330
	350	454	364	443	324	457	369
	450	440	333	427	347	418	349
	Mean	**439**	**340**	**437**	**329**	**430**	**345**

The small yield advantage to an increased number of passes was not great enough to pay for the extra inputs. Thus with both varieties at the two drilling dates 3 pass gave higher gross margins than 5 and 7 pass systems (except 7 pass late drilled Brigadier).

	Gross margin £/ha 3 Passes	5 Passes	7 Passes
DD1			
Hunter	**445**	425	422
Brigadier	**439**	437	430
DD2			
Hunter	**372**	340	336
Brigadier	340	329	**345**

3 pass minimum pass systems produced £9/ha or £23/ha better gross margins than 7 pass when crops were early sown.

The advantages of 3 pass systems were more apparent at the later sowing but only with the disease resistant variety, Hunter, registering an advantage of £36/ha over 7 pass. With Brigadier late sown, the conventional 7 pass system gave a gross margin £5/ha greater than 3 pass.

4.1.5 ARC Wye Gross Margins 1995 - 1997 (3 year mean)

Typical variable cost differences for the Wye site over the three years were as follows:

Variable costs ARC Wye at 350 seeds/m^2 (3 year mean)

	3 Pass £/ha	5 Pass £/ha	7 Pass £/ha
Hunter	188	207	229
Brigadier	195	214	236

3 Year Gross Margin (£/ha) 1995 - 1997 (ARC Wye)

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Hunter	**150**	486	432	467	419	466	403
	250	490	452	460	454	465	426
	350	493	460	459	447	461	434
	450	477	456	448	452	451	437
	Mean	**487**	**450**	**459**	**443**	**461**	**425**
Brigadier	**150**	526	433	512	410	505	415
	250	533	464	500	431	511	455
	350	504	453	496	421	493	445
	450	506	434	490	428	481	435
	Mean	**517**	**446**	**500**	**423**	**498**	**438**

Again, the small yield advantages conferred by the 7 pass management systems were nullified by the extra costs associated with their higher input system.

	Gross margin £/ha 3 Passes	5 Passes	7 Passes
DD1			
Hunter	**487**	459	461
Brigadier	**517**	500	498
DD2			
Hunter	**450**	443	425
Brigadier	**446**	423	438

3 pass management systems produced higher gross margins than both 5 and 7 pass. The advantage of minimum pass husbandry ie 3 pass over the conventional 7 pass system, varied between £8 - £25/ha.

The Wye site, of the six trial locations, produced the best results from which one could justify minimum pass husbandry as a technique to be adopted.

4.1.6 SA Burrelton Gross Margins 1995 - 1997 (3 year mean)

Typical variable cost differences over the three years for the Perthshire site were as follows. Please note that the first year of the experiment was carried out at Milnathort, Kinross.

Variable costs SA Burrelton at 350 seeds/m^2 (3 year mean)

	3 Pass £/ha	5 Pass £/ha	7 Pass £/ha
Hunter	187	200	217
Brigadier	187	200	217

3 Year Gross Margin (£/ha) 1995 - 1997 (SA Burrelton)

Variety	Seedrate	3 Passes		5 Passes		7 Passes	
	(seeds/m2)	DD1	DD2	DD1	DD2	DD1	DD2
Hunter	**250**	494	419	515	432	482	417
	350	496	441	524	441	489	436
	450	503	434	499	422	485	409
	550	473	420	490	424	487	426
	Mean	**492**	**429**	**507**	**430**	**486**	**422**
Brigadier	**250**	485	349	494	375	496	376
	350	495	372	503	391	488	375
	450	508	370	484	389	482	381
	550	487	392	476	399	476	394
	Mean	**494**	**371**	**489**	**389**	**486**	**382**

The Scottish site displayed similar gross margin trends to the five English sites, with the yield advantage of the conventional 7 pass system being erased by higher input costs.

	Gross margin £/ha		
	3 Passes	**5 Passes**	**7 Passes**
DD1			
Hunter	492	**507**	486
Brigadier	**494**	489	486
DD2			
Hunter	429	**430**	422
Brigadier	371	**389**	382

5 pass management systems produced the optimum gross margin in three of four situations outlined, 3 pass being the best for Brigadier early sown. It should be emphasised, however, that less than £20/ha covers the different management systems at this site.

4.2 Gross margin based on 3 year yield mean (all sites)

The following table takes the overall yield matrix generated over three years from 17 individual experiments, and uses it to generate a gross margin. Grain is valued at £75/tonne and the variable costs adopted are also a mean of the three years and 17 individual trials.

Gross Margin £/ha (based on 6 site - 3 year yield mean) Grain @ £75/tonne

Variety	**Seedrate (seeds/m2)**	**3 Passes DD1**	**3 Passes DD2**	**5 Passes DD1**	**5 Passes DD2**	**7 Passes DD1**	**7 Passes DD2**
Hunter	**150**	439	358	449	349	455	351
	250	455	389	457	384	463	378
	350	458	401	454	401	461	398
	450	454	397	444	391	455	386
	Mean	**451**	**386**	**451**	**381**	**458**	**378**
Brigadier	**150**	457	344	459	339	466	362
	250	464	368	468	370	479	374
	350	468	381	465	370	477	390
	450	467	368	455	378	460	383
	Mean	**464**	**365**	**462**	**364**	**470**	**377**

Looking at the gross margins produced by the "master yield matrix" from the experiment, the most obvious feature is the similarity of the figures for all three management levels.

Hunter early sown	£7/ha covers the gross margins of 3, 5 and 7 passes with 7 pass superior to 3 and 5 pass
Hunter late sown	£15/ha covers the gross margin of the three levels of management. 3 pass superior to 7 pass by £8/ha and £15/ha superior compared to 5 pass

Brigadier early sown	£8/ha covering 3, 5 and 7 pass management. 7 pass superior to 3 pass by £6/ha
Brigadier late sown	£13/ha covering 3, 5 and 7 pass, 7 pass being superior to 3 pass by £12/ha

Thus the yield advantage of the conventional 7 pass management technique which was apparent throughout the three years of the project was cancelled out to a large extent by the cost of the extra inputs which were used to generate the yield increase in the first place.

However, the concept of minimum pass husbandry does not only rest on input cost savings. It is equally a saving in application costs which may be increased when land blocks are separated by large distances. The next section takes the gross margins and adjusts them to take account of the differential applications costs involved.

The following table represents the actual mean of site gross margins from the project. Differences between gross margins are again very small.

Mean of Site Gross Margins 1995 - 1997 (all sites)

Variety	Seedrate (seeds/m2)	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Hunter	150	448	367	461	363	463	365
	250	461	396	463	387	474	390
	350	465	403	455	403	470	402
	450	453	399	450	397	465	397
	Mean	**456**	**391**	**457**	**387**	**468**	**388**
Brigadier	**150**	464	346	465	345	475	368
	250	472	378	476	379	487	384
	350	478	387	469	378	485	402
	450	471	380	462	389	470	397
	Mean	**471**	**373**	**468**	**373**	**479**	**388**

4.3 Margins after deduction of application costs 1995 - 1997 (all sites)

As the concept of minimum pass husbandry gives a saving in application costs, the following margin table illustrates the three year mean margin after the deduction of variable costs and application costs. For the purposes of this Section, the margins for the different seedrates have been meaned.

Each application pass has been costed at £5/ha (£2/acre), a figure frequently used to represent typical "farmer costs". Whilst a higher figure could be chosen, it was felt that the cost of application should be linked to a farmer's cost rather than a contractor. However, with large distances between land blocks, it would be easy to justify higher figures being inserted. Thus in the following calculations application costs were £15/ha 3 pass, £25/ha 5 pass and £35/ha 7 pass.

Margin £/ha after variable and application cost deduction 1995 - 1997 (all sites)

cv Hunter (mean of 4 seedrates) disease resistant variety

Trial Site/Drilling date		Management level 3 Pass	5 Pass	7 Pass
ARC Andover	Early Sowing	**482**	466	473
	Later Sowing	**459**	440	450
ARC Biggleswade	Early Sowing	431	450	**505**
	Later Sowing	315	319	**354**
ARC Caythorpe	Early Sowing	359	**362**	357
	Later Sowing	278	**279**	239
ARC Cirencester	Early Sowing	**430**	400	387
	Later Sowing	**357**	315	301
ARC Wye	Early Sowing	**472**	434	426
	Later Sowing	**435**	418	390
SA Burrelton	Early Sowing	477	**482**	451
	Later Sowing	**414**	405	387

cv Brigadier(mean of 4 seedrates) disease susceptible variety

Trial Site/Drilling date		Management level 3 Pass	5 Pass	7 Pass
ARC Andover	Early Sowing	**520**	494	499
	Later Sowing	**469**	451	**469**
ARC Biggleswade	Early Sowing	464	462	**506**
	Later Sowing	315	326	**370**
ARC Caythorpe	Early Sowing	351	353	**354**
	Later Sowing	**253**	245	219
ARC Cirencester	Early Sowing	**424**	412	395
	Later Sowing	**325**	304	310
ARC Wye	Early Sowing	**502**	475	463
	Later Sowing	**431**	398	403
SA Burrelton	Early Sowing	**479**	464	451
	Later Sowing	356	**364**	347

The above table of figures represents gross margins presented in Sections 4.1.1 - 4.1.6, with application costs deducted.

If it is assumed that each variety/drilling date combination represents one comparison it is possible to calculate the success rate of the minimum approach compared to the conventional 7 pass management system. Thus Brigadier sown late at Andover gives one comparison of 3 and 7 pass over the period the project was running. In all, the previous table gives 24 comparisons of 3, 5 and 7 pass.

% of occasions that 3 Pass management margins were equal to or superior to 7 Pass (based on 24 three year mean comparisons)

All sites

Without application costs @ £75/tonne	With application costs @ £75/tonne
56%	76%

Applying application costs to the results of the project increased the success of minimum pass husbandry from 56% to 76% comparing margins against the conventional 7 pass control. This increase in superiority of the 3 pass system was a manifestation of the small differences in gross margin between 3 and 7 passes. That is why the £20/ha difference in application costs ie 4 extra passes of the 7 pass at £5/ha had a significant effect on profitability.

5.0 DISCUSSION AND CONCLUSIONS

5.1 Effect of grain price and application costs

Examining the trial results as a whole, it is clear that adopting a reduced number of passes through winter wheat has reduced the yield of the crop. Averaging all treatments and all trials over the three years of the experiment created yield differences between management treatments as follows:

3 Pass Minimum Pass Husbandry Treatment	5 Pass	7 Pass Conventional Control Treatment
7.92 t/ha	8.13 t/ha	8.44 t/ha

The yield decreased in a linear relationship with the reduced number of passes.

However, in terms of profitability the objective of the project was upheld at £75/tonne for the grain, the extra yield created by the 5 and 7 pass management systems was equally counterbalanced by the extra input costs of these more intensive systems. Thus in terms of gross margin, 3 pass management systems outperformed the conventional 7 pass systems on 56% of occasions (Section 4.3).

As a concept, minimum pass husbandry is most applicable where the grower is faced with higher application costs owing to the distant location of the land, for example. The results from this project illustrate that if a fairly modest application cost of £5/ha per application was applied then, due to a saving of £20/ha (4 passes at £5/ha), the success rate of minimum pass husbandry versus the conventional 7 pass control could be increased to 76% from 56%. In other words, using the yield results from this project with grain at £75/tonne and application costs of £5/ha per pass, a 3 pass management system for growing winter wheat was more profitable than a conventional 7 pass system on three out of four occasions.

It is clear from the results that since 3 pass techniques created a yield penalty, grain price versus input costs are an important component of the gross margin advantage of the minimal pass technique. If the grain price rises, it can be shown that success rate of the conventional 7 pass management system increases as the extra grain associated with this technique becomes more valuable relative to the input costs.

In conclusion, the project has illustrated that provided grain prices are low (£75/tonne applied in this case) and application costs are included, the concept of minimum pass husbandry can be as profitable as conventional management systems.

5.2 Interaction of minimum pass husbandry with cultivar, seedrate and drilling date

Having upheld the objective of the project (ie to farm winter wheat with fewer passes through the crop without reducing its profitability), this Section of the discussion considers in which situations a grower is most likely to be successful with the technique of minimal passes.

The project was set up with a number of "inbuilt" variables - two varieties of differing disease resistance, differing seedrates and two sowing dates. These experimental variables were incorporated into the experiment to examine whether minimum pass husbandry was more or less successful when these variables were adjusted.

Influence of cultivar

Since minimum pass husbandry depends on fewer fungicide applications, it was thought that more disease resistant varieties might be more suitable candidates. In the experiment Hunter was incorporated as a variety that was more disease resistant, particularly with regard to *Septoria tritici*, and Brigadier, the variety that was disease susceptible - Mildew, *Septoria tritici* and Yellow Rust.

The results of the project illustrated that when crops were sown conventionally - late September/early October - variety resistance had little influence on the yield differences between the 3, 5 and 7 pass management systems. Thus, looking at three years of trials (all sites), the 7 pass yield advantage over 3 pass was 0.54 t/ha with Brigadier, and 0.55 t/ha with Hunter when sown early.

Where there was clear indication that growing Hunter improved the relative success of the minimum pass technique was when crops were late sown. In this situation Brigadier illustrated a yield penalty of 0.62 t/ha to adopting 3 pass management compared to 0.35 t/ha with Hunter. Thus the greater disease resistance of Hunter and hence suitability for minimal pass husbandry was most apparent relative to the susceptible variety when the crop was sown late. This disease resistance factor was particularly important in 1997 when the peak of disease pressure affected later sown crops more severely than early sown crops. In 1997 the yield penalty of adopting 3 pass compared to 7 pass with late sown Brigadier averaged 0.95 t/ha compared to just 0.46 t/ha with Hunter.

Therefore, disease resistance of the variety is a characteristic which creates better opportunities for minimum pass husbandry to be successful, although in this three year project it was only manifest at the later sowing date.

Influence of seedrate

Only in one of the 17 trials making up the trial series was there a significant interaction between seedrate and the success of minimum pass. Overall, the yield results illustrated that seedrate adjustment had little influence on the yield difference between the three different management approaches.

At the start of the project it was felt that since plant growth regulators are restricted to the flag leaf timing with the 3 pass approach, greater emphasis would need to be placed on thinner crop structures in order to prevent lodging risk. Throughout the course of the experiment 3 and 5 passes were never treated with PGRs which may be regarded atypical. However, none of the trials were subject to lodging differences.

The lack of lodging, due in some trials to the stiffer straw of Brigadier and Hunter, did not enable the project to test the theory that 3 passes would be penalised less at lower seedrates in the absence of growth regulators. Instead, in most trials the optimum seedrate for the conventional 7 pass management was the same as the 3 pass. However, the exact seedrate did vary considerably depending on trials location and sowing date.

Although the 3 pass technique still allows for a plant growth regulator to be applied in tank mixture with the flag leaf fungicide, in reality this would not be particularly advantageous. Firstly, this later timing precludes the use of chlormequat which is the cheapest, most common form of plant growth regulation. Secondly, tank mixtures incorporating products such as Terpal, Upgrade and Cerone contain the active ingredient ethephon which, whilst being very effective as a PGR, can increase the risk of scorch if mixed with high rates of fungicide at the same time. In addition these later season PGRs are more expensive.

Thus in conclusion, it would be far more practical to consider stiffer strawed varieties when considering candidates for minimum pass husbandry. With these varieties, given the right conditions, PGRs may not be required. Remember that whilst not demonstrated in the results of this project, overly thick seedrates create thick crop canopies which can be much more lodging prone, particularly on fertile soils. It should also be restated that in 1st wheat situations where soil nitrogen reserves tend to be higher in early spring, tillering doses of nitrogen in late February/early March can exacerbate the lodging pressure in some crops. With the 3 pass minimal pass treatment, early spring nitrogen is avoided thus there is less danger of nitrogen fertiliser creating lodging and therefore less emphasis on PGRs as inputs.

Influence of sowing date

The most marked influence of sowing date was that the late drilled crops in the project were significantly lower yielding in all but three individual trials (ARC Andover 1995, ARC Kent 1995 and 1996). Noticeably, all three exceptions being in the south of the country where higher winter temperatures enabled greater compensation from the late sowing date. Overall for the three years averaging all treatments, early sowings (late September/early October) produced a yield of 8.75 t/ha compared to 7.57 t/ha with later sowings (late October/mid November). This mean yield penalty of 1.18 t/ha was at its lowest at the Kent location where over three years the difference was reduced to 0.70 t/ha.

In terms of interaction with the number of passes, it was clear that with Brigadier, delaying the sowing date in order to make the crop more suitable for fewer passes, did not work. The yield differential between 3 pass and 7 pass management approaches actually increased when Brigadier was sown late, though this overall effect was much influenced by the higher disease pressure of the 1997 season. As already explained, later sowings did favour the use of Hunter as a candidate for minimum pass since the yield advantage of more passes was effectively halved at the later sowing.

Though it has less bearing on the interaction with minimum pass, it was also noticeable from the project that the yield advantage of Brigadier over Hunter was only apparent at the early sowing even with the higher input 7 pass systems.

Influence of other factors

Through the course of the project a number of factors did appear as variables which would influence the success of fewer passes through the crop. The following section discusses some of these factors although it should be emphasised that because of the complex nature of the project, this discussion is based on observations rather than specific side by side comparisons.

Soil fertility and rotation position

Since fewer passes through the crop restricts the number of nitrogen applications, there was some evidence that the 3 pass technique (which depends on a single nitrogen dose at main dose timing) was more successful at trial sites where there was little need for early spring nitrogen. Thus on the fertile brickearth soils in Kent, early spring nitrogen (late February/early March) frequently creates small yield penalties of 2 - 3%, particularly in 1st wheat situations. Therefore at this site over the three years the crop displayed less need for early nitrogen, and had an overall lower requirement for nitrogen (140 kg/ha N in 1995 - 96 compared to 200 kg/ha N elsewhere). The lower overall requirement for nitrogen also makes it more practical to apply the total nitrogen requirement in a single dose. It was noticeable from assessments of ear numbers that the 3 pass technique produced slightly higher ear numbers than 7 pass at the Kent site.

This contrasted sharply with the ARC Caythorpe location where the three years of the trial were carried out in a 2nd cereal situation on a more drought prone, brashy soil. In this less fertile situation the early nitrogen of the 7 pass system created crop canopies with much greater ear numbers which subsequently yielded considerably more than the 3 pass approach.

Consequently, minimum pass husbandry was consistently inferior to conventional 7 pass systems over the three years at the Caythorpe site. At other locations where the trials were always in 1st wheat situations, the yield differential between 3 and 7 pass was more inconsistent, with 3 pass yields almost equalling 7 passes at some site in some season.

Thus more fertile cropping situations or soil types may enable the grower to pursue fewer nitrogen applications more easily, therefore making them more suitable for minimal pass techniques.

Main dose timing

Another factor which penalised the success of minimum pass treatments in the project was the timing of the single dose of nitrogen. At Cirencester and Caythorpe in 1995 the single nitrogen dose of the 3 pass techniques was subject to restricted uptake owing to drought.

With the 5 and 7 pass approaches the early nitrogen doses of 40 kg/ha N provided "drought insurance" which the 3 pass technique never benefited from. Whilst it can only be proven with circumstantial evidence, if the timing of single dose had been brought forward to early April - GS30 (pseudostem erect) instead of GS31 (1^{st} node) it can only have enhanced the performance of the 3 pass technique. In the 1996 Cirencester trial this approach of bringing forward the single nitrogen application relative to the main dose timings on the split approach was implemented. As a consequence of this changed timing the 1996 yield rankings gave 3 pass treatments significantly higher yields than either 5 or 7 pass treatments. Thus the single Nitrogen dose timing in the 3 pass system had a much greater bearing on yield than any of the inputs and the split nitrogen approach of the 5 and 7 pass systems.

Therefore, if the grower restricts the number of nitrogen passes to a single dose then bringing forward the timing of that single dose relative to main dose applications with multiple passes could be advantageous. This is very important on lighter less fertile soils. It would still however be preferable not to apply to the crop before 1 April for fear of leaching losses.

Grain aphid infestation

Through the course of the project the greatest yield penalty to result from adopting minimum pass husbandry occurred in Biggleswade in 1995. In this trial the yield penalty from adopting a 3 pass technique was 2 - 3 tonnes/ha. This drop in yield was almost entirely due to a massive infestation of grain aphid which was controlled by an aphidicide under the 7 pass conventional regime.

To date this trial has created the greatest detriment from adopting a reduced number of passes. As a consequence of this result, grain aphid infestations would necessitate an extra pass.

Geographic location and disease pressure

With the correct management there appeared to be little evidence that minimum pass husbandry could not be adopted in any region of the country. However, though disease pressure was not particularly great over the 1995 and 1996 seasons, it was evident that the wetter west of the country created bigger differences in *Septoria tritici* levels between 3 and 7 pass management systems. As the minimum pass technique depends on a single flag leaf fungicide, it would be sensible to suggest that unless the variety is very disease resistant there is a greater chance of being successful with this technique in regions of the country where expected response to fungicides is small.

Therefore, where wetter weather creates regions where response to *Septoria tritici* control is much greater than the national average, this would be a less suitable scenario for the adoption of minimum pass husbandry.

In conclusion, the project has illustrated that it can be equally profitable to farm winter wheat with fewer passes down the tramlines, provided grain prices are low and application costs are included. The skill of the grower is recognising which crops are most suitable for the technique. As was made clear in the introduction, the technique is going to be particularly pertinent to those growers with a number of farming land blocks which are separated by a considerable distance but farmed with one set of machinery.

Although this experiment was set up around a "3 pass system" it would be wrong to think of minimum pass husbandry as a 3 pass management system. More correctly, it would be better to plan variety, seedrate and field choice to minimise the number of passes, and then monitor the crop at the key timings where passes were to be omitted. Thus, for example, if because of acute grain aphid infestation the planned 3 pass approach was inappropriate, it would become a 4 pass management system. Thus minimum pass husbandry should be thought of as having a minimum number of passes eg 3 passes which is flexible enough to cater for changes in status of the crop.

5.3 Further work

Having proven that the consequences for yield potential in adopting minimum pass husbandry are not as great as anticipated, ARC wish to develop the experimental work further. There are two aspects to the work that need to be explored:

i. A refinement of 3 and 4 pass techniques which incorporate the latest Strobilurin fungicide technology.

ii. The minimum pass husbandry philosophy needs to be integrated with lower cost establishment systems.

There is no doubt that the introduction of the Strobilurin fungicides should enhance the ability of the grower to farm winter wheat with a single fungicide application. If the longer lasting protection of the Strobilurins was combined with acknowledged eradication properties of the best Triazoles, a single mixture of both of these products must offer better disease control than a single spray based purely on Triazoles and Morpholines. In addition, an early optimum timing of the single spray mixture might allow more opportunities for tank mixtures with PGRs and herbicides.

At £75/tonne and below for cereals, there is an urgent need to drive down the cost per unit tonne of production. ARC foresees the next logical step to be the combination of lower cost establishment techniques with subsequent savings in the number of passes down the tramline. **This is planned to be the next phase of the project**.

Acknowledgement

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6.0 APPENDIX

6.1 Crop Input and Costings

6.1.1 ARC Andover, Hampshire

1995 Andover Trial

Management Level	Date of Application	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Nitrogen (kg/ha)							
1st dose GS23	10 March	-	-	40	40	40	40
2nd dose GS30/31	14 April	200	200	160	160	160	160
Fungicides							
Genie(0.2)+Bravo(0.5) GS32	28 April	-	-	✓	✓	✓	✓
Epic(0.75)+Tern(0.5) GS39	22 May	✓	✓	✓	✓	✓	✓
E Impact(0.62) GS69	20 June	-	-	-	-	✓	✓
Herbicides							
Stomp(1.6)+IPU(3.0)	2 November	✓	-	✓	-	✓	-
HBN(1.5)+IPU(1.0)	4 April	-	✓	-	✓	-	✓
PGR							
Chlormequat 5C(2.5) GS30/31	19 April	-	-	-	-	✓	✓
Insecticides							
Sumi Alpha(160 ml)	2 November	Tank mix	-	Tank mix	-	Tank mix	-
Aphox(280 g)	20 June	-	-	-	-	Tank mix	✓
Total nitrogen and agrochemical variable cost £/ha		**129**	**119**	**142**	**132**	**165**	**155**

1996 Andover Trial

Management Level	Date of Application	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Nitrogen (kg/ha)							
1st N Dose GS24	6 March	-	-	40	40	40	40
2nd N Dose GS30 - 31	11 April	200	200	160	160	160	160
Fungicides							
GS32 Genie(0.2)+Bravo(0.5)	13 May	-	-	✓	✓	✓	✓
GS39 Opus(0.75)+Tern(0.25)+ Bravo(0.75)	2 June	✓	✓	✓	✓	✓	✓
GS65 Legion(2.5)	24 June	-	-	-	-	✓	✓
Herbicides							
IPU(4.0)+Panther(1.0)	3 November	✓	-	✓	-	✓	-
PGR							
Brevis (Chlormequat) (2.25)	9 April	-	-	-	-	✓	-
	29 April	-	-	-	-	-	✓
Insecticides							
Decis 200 ml/ha (Tank mixed with herbicide)	3 November	✓	✓	✓	✓	✓	✓
Aphox 280 g/ha (Tank mixed with ear wash fungicide)	24 June	-	-	-	-	✓	✓
Total nitrogen and agrochemical variable cost £/ha		**154**	**116**	**168**	**130**	**191**	**153**

1997 Andover Trial

Management Level

	Date of Application	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Nitrogen (kg/ha)							
1st dose	11 March	-		50		50	
Main dose	3 April	225		175		175	
Fungicides							
GS32 1/3 Alto(0.27)+ ¼ Bravo (0.5)	30 April	-		✓		✓	
GS39 ¾ Folicur(0.75)+ ¼ Tern(0.25)+Bravo(0.5)	23 May	✓		✓		✓	
GS69 ¼ Folicur(0.25)	17 June	-		-		✓	
Herbicides							
½ Panther(1.0)+IPU(1.0)	16 Nov	✓		✓		✓	
Ally 30 g/ha (Tank mixed with fungicide)	23 May	✓		✓		✓	
PGR							
Brevis (Chlormequat) (2.25)	10 April	-		-		✓	
Insecticides							
Sumi Alpha(165 ml/ha) (Tank mixed with herbicides)	16 Nov	✓		✓		✓	
Aphox(280 g/ha) (Tank mixed with fungicides)	17 June	-		-		✓	
Total nitrogen and agrochemical variable cost £/ha		**145**		**157**		**168**	

6.1.2 ARC Biggleswade, Bedfordshire

1995 Biggleswade Trial

Management Level	Date of Application	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Nitrogen (kg/ha)							
1st N dose GS25	16 March	-	-	60	60	60	60
2nd N dose GS30/31	13 April	200	200	140	140	140	140
Fungicides							
GS32 Genie(0.2)+Bravo(0.5)	28 April	-	-	✓	✓	✓	✓
GS39 Folicur(0.75)+ Tern(0.25)	15 May	✓		✓		✓	
GS39 Folicur(0.75)+ Tern(0.25)	25 May		✓		✓		✓
GS69 E Impact (0.625)	14 June	-	-	-	-	✓	
GS69 E Impact (0.625)	23 June	-	-	-	-	-	✓
Herbicides							
Panther(2.0)	18 Nov	✓	✓	✓	✓	✓	✓
Wildcat (1.5)	15 May	✓		✓		✓	
Wildcat (1.5)	25 May		✓		✓		✓
PGR							
GS30 Chlormequat 5 C (2.5)	23 March	-	-	-	-	✓	-
GS30 Chlormequat 5 C (2.5)	10 April	-	-	-	-	-	✓
Insecticides							
Decis(200 ml)	18 November	tank mix	tank mix	tank mix	tank mix	tank mix	tank mix
Aphox(280 g/ha)	14 June	-	-	-	-	✓	
Aphox(280 g/ha)	23 June	-	-	-	-	-	✓
Total nitrogen and agrochemical variable cost £/ha		**125**	**122**	**145**	**142**	**168**	**165**

1996 Biggleswade Trial

Management Level

	Date of Application	3 Passes		5 Passes		7 Passes	
		DD1	DD2	DD1	DD2	DD1	DD2
Nitrogen (kg/ha)							
1st N dose GS25	13 March	-	-	40	40	40	40
2nd N dose GS30- 31	16 April	200	200	160	160	160	160
Fungicides							
GS32 Punch C(0.4)+ Corbel(0.5)	DD1 25 April DD2 5 May	-	-	✓	✓	✓	✓
GS39 Folicur(0.75)+ Bravo(1.0)	DD1 2 June DD2 6 June	✓	✓	✓	✓	✓	✓
GS69 Folicur(0.25)	18 June	-	-	-	-	✓	✓
Herbicides							
Autumn Kite(5.0)	3 November	✓	✓	✓	✓	✓	✓
PGR							
5 C (2.5)	DD1 4 April	-	-	-	-	✓	-
	DD2 25 April	-	-	-	-	-	✓
Insecticides							
No insecticides applied							
Total nitrogen and agrochemical variable cost £/ha		**118**	**118**	**141**	**141**	**153**	**153**

1997 Biggleswade Trial

Trial discontinued.

6.1.3 ARC Caythorpe, Lincolnshire

1995 Caythorpe Trial

Management Level	Date of Application	3 Passes		5 Passes		7 Passes	
		DD1	DD2	DD1	DD2	DD1	DD2
Nitrogen (kg/ha)							
1st N dose GS23	10 March	-	-	80	80	80	80
2nd N dose GS30/31	19 April	205	205	125	125	125	125
Fungicides							
GS32 Pointer(0.6)+Patrol(0.5)	27 April	-	-	✓	✓	✓	✓
GS39 Folicur(0.75)+Bravo(1.0)	23 May	✓	✓	✓	✓	✓	✓
GS59 E Impact(0.625)	22 June	-	-	-	-	✓	✓
Herbicides							
Panther(2.0)	2 November	✓	✓	✓	✓	✓	✓
PGR							
GS30 Chlormequat 5 C (2.5)	23 March	-	-	-	-	✓	✓
Insecticides							
Toppel 250 ml/ha (Tank mixed with herbicide)	2 November	✓	✓	✓	✓	✓	✓
Total nitrogen and agrochemical variable cost £/ha		**121**	**121**	**145**	**145**	**158**	**158**

1996 Caythorpe Trial

Management Level	Date of Application	3 Passes DD1	DD2	5 Passes DD1	DD2	7 Passes DD1	DD2
Nitrogen (kg/ha)							
1st N Dose	15 March	-	-	40	40	40	40
2nd N Dose	16 April	200	200	160	160	160	160
Fungicides							
GS32 Tilt(0.5)+Tern(0.5)	7 May	-	-	✓	✓	✓	✓
GS39 Epic(0.75)+Tern(0.5)	3 June	✓	✓	✓	✓	✓	✓
GS59 Folicur (0.25)	24 June	-	-	-	-	✓	✓
Herbicides							
Panther(2.0)	15 November	✓	✓	✓	✓	✓	✓
PGR							
Chlormequat(2.5)	25 April	-	-	-	-	✓	✓
Insecticides							
Toppel 250 ml/ha (Tank mixed with herbicide)	15 November	✓	✓	✓	✓	✓	✓
Total nitrogen and agrochemical variable cost £/ha		**131**		**154**		**167**	

1997 Caythorpe Trial

Management Level	Date of Application	3 Passes		5 Passes		7 Passes	
		DD1	DD2	DD1	DD2	DD1	DD2
Nitrogen (kg/ha)							
1st N dose GS24	14 March	-		50		50	
2nd N dose GS31	14 April	200		150		150	
Fungicides							
GS32 Silvacur(0.5)+ Corbel(0.5)	1 May	-		✓		✓	
GS39 Silvacur(0.75)+ Patrol(0.5)	20 May	✓		✓		✓	
GS69 Folicur(0.25)	1 July	-		-		✓	
Herbicides							
Panther(2.0)+IPU(3.1)	16 December	✓		✓		✓	
PGR							
Cycocel(2.5)	1 April	-		-		✓	
Insecticides							
None applied							
Total nitrogen and agrochemical variable cost		**108**		**135**		**148**	

6.1.4 ARC Cirencester, Gloucestershire

1995 Cirencester Trial

Management Level	**Date of Application**	**3 Passes**		**5 Passes**		**7 Passes**	
		DD1	**DD2**	**DD1**	**DD2**	**DD1**	**DD2**
Nitrogen (kg/ha)							
1st N dose GS23	13 March	-	-	50	50	50	50
2nd N dose GS31	28 April	200	200	150	150	150	150
Fungicides							
GS32 Genie(0.2)+ Bombardier(0.5)	2 May	-	-	✓	✓	✓	✓
GS39 Epic(0.75)+Bravo(1.0)	DD1 22 May DD2 26 May	✓	✓	✓	✓	✓	✓
GS59 E Impact (0.63)	21 June	-	-	-	-	✓	✓
Herbicides							
IPU(3.0) Encore(3.0)	17 November	✓	✓	✓	✓	✓	✓
PGR							
5 C Cycocel (2.5)	DD1 11 April DD2 28 April	-	-	-	-	✓	✓
Insecticides							
Ambush C(0.25)	17 November	✓*	✓	✓	✓	✓	✓
Total nitrogen and agrochemical variable cost £/ha		**128**	**128**	**141**	**141**	**154**	**154**

* Tank mixed with herbicide

1996 Cirencester Trial

Management Level	Date of Application	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Nitrogen (kg/ha)							
1^{st} N dose GS23	6 March	-		50		50	
2^{nd} N dose GS31	DD1 6 March DD2 25 April	200		150		150	
Fungicides							
Halo(1.33)	30 April	-		✓		✓	
Folicur(0.75)+Bravo(1.0)	4 June	✓		✓		✓	
Folicur(0.25)	24 June	-		-		✓	
Herbicides							
Panther(2.0)	15 Dec	✓		✓		✓	
Ally(30 g)	DD1 30 April DD2 4 June	-		✓		✓	
Starane (0.5)	4 June	✓		✓		✓	
PGR							
Cycocel (2.5)	DD1 11 April DD2 23 April	-		-		✓	
Insecticides							
Hallmark(0.1)	24 June	-		-		✓	
Total nitrogen and agrochemical variable cost £/ha		**159**		**173**		**192**	

1997 Cirencester Trial

Management Level

	Date of Application	3 Passes DD1	DD2	5 Passes DD1	DD2	7 Passes DD1	DD2
Nitrogen (kg/ha)							
1st N dose GS22	5 March	-		50		50	
2nd N dose GS31	21 April	200		150		150	
Fungicides							
Impact Exel(1.5)	23 April			✓		✓	
Opus(0.75)+Tern(0.25)	DD1 23 May DD2 29 May	✓		✓		✓	
Folicur(0.25)	24 June					✓	
Herbicides							
Panther(2.0)+IPU(3.0)	23 October	✓		✓		✓	
PGR							
Cycocel(2.5)	DD1 8 April DD2 30 April					✓	
Insecticides							
Cyperkill(0.25)	23 October	✓*		✓		✓	
Total nitrogen and agrochemical variable cost £/ha		**140**		**158**		**171**	

* Tank mixed with Herbicide

6.1.5 ARC Wye, Kent

1995 Wye Trial

Management Level	Date of Application	3 Passes DD1	DD2	5 Passes DD1	DD2	7 Passes DD1	DD2
Nitrogen (kg/ha)							
1st N dose GS25	15 March	-	-	40	40	40	40
2nd N dose GS30/31	12 April	140	140	100	100	100	100
Fungicides							
GS32 Genie(0.2)+Bravo(0.5)+ Tern(0.33)	27 April	-	-	✓	✓	✓	✓
GS39 Epic(0.75)+Tern(0.5)	18 May	✓	✓	✓	✓	✓	✓
GS69 E Impact(0.625)	14 June	-	-	-	-	✓	✓
Herbicides							
Javelin Gold(3.0)+IPU(1.0)	4 November	✓	✓	✓	✓	✓	✓
PGR							
GS31 Chlormequat 5 C(2.5)	20 April	-	-	-	-	✓	✓
Insecticides							
Sumi Alpha(165 ml/ha)	4 November	Tank mix	-	Tank mix	-	Tank mix	-
Aphox(280 g/ha)	14 June	-	-	-	-	✓	✓
Total nitrogen and agrochemical variable cost £/ha		**125**	**122**	**145**	**142**	**168**	**165**

1996 Wye Trial

Management Level

	Date of Application	3 Passes DD1	DD2	5 Passes DD1	DD2	7 Passes DD1	DD2
Nitrogen (kg/ha)							
1st N dose	25 March	-	-	40	40	40	40
Main N dose	16 April	140	140	100	100	100	100
Fungicides							
GS32 Genie(0.2)+Tern(0.25)+ Bravo(0.5)	1 May	-	-	✓	✓	✓	✓
GS39 Folicur(0.75)+Tern(0.5)	30 May						
GS69 ½ Legion (2.5)	20 June	-	-	-	-	✓	✓
Herbicides							
Panther(2.0)+IPU(3.0)+ CMPP(1.0)	31 Oct or 12 Dec	✓	✓	✓	✓	✓	✓
Ally(30 g/ha)+Starane(0.6) (Tank mixed with Fungicide)	30 May	✓	✓	✓	✓	✓	✓
PGR							
Brevis(2.25)	25 April	-	-	-	-	✓	✓
Insecticides							
Decis(200 ml/ha) (Tank mixed with Herbicide)	31 Oct	✓	✓	✓	✓	✓	✓
Aphox(280 g/ha) (Tank mixed with Fungicide)	20 June	-	-	-	-	✓	✓
Total nitrogen and agrochemical variable cost £/ha		**177**	**173**	**198**	**194**	**221**	**217**

1997 Wye Trial

Management Level

	Date of Application	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Nitrogen (kg/ha)							
1st N dose	6 March	-	-	40	40	40	40
Main N dose	8 April	200	200	160	160	160	160
Fungicides							
GS32 1/3 Alto(0.27)+ ¼ Tern(0.25)	30 April	-	-	✓	✓	✓	✓
GS39 ¾ Opus(0.75)+ ¼ Tern(0.25)+1/4 Bravo(0.5)	14 May	✓	✓	✓	✓	✓	✓
GS69 ¼ Folicur(0.25)	18 June	-	-	-	-	✓	✓
Herbicides							
½ Panther(1.0)+ IPU(4.0)	15 Nov	✓	✓	✓	✓	✓	✓
Starane 2(0.7) (Tank mixed with flag fungicide)	14 May	✓	✓	✓	✓	✓	✓
PGR							
Brevis (Chlormequat)	DD1 3 April	-	-	-	-	✓	✓
	DD2 30 April	-	-	-	-	✓	✓
Insecticides							
Sumi Alpha(165 ml/ha) (Tank mixed)	15 Nov	✓	-	✓	-	✓	-
Aphox (280 g/ha)	18 June	-	-	-	-	✓	✓
Total nitrogen and agrochemical variable cost £/ha							

6.1.6 Scottish Agronomy sites (Kinross and Perthshire)

1995 Milnathort, Kinross Trial

Management Level	Date of Application	3 Passes DD1	3 Passes DD2	5 Passes DD1	5 Passes DD2	7 Passes DD1	7 Passes DD2
Nitrogen (kg/ha)							
1st N dose GS23	3 March	-	-	63	63	63	63
2nd N dose GS31	24 April	213	213	150	150	150	150
Fungicides							
GS32 Genie(0.2)+Patrol(0.25)	20 May	-	-	✓	✓	✓	✓
GS39 Epic(0.75)+Bravo(1.0)	7 June	✓	✓	✓	✓	✓	✓
GS59 E Impact(0.63)	7 July	-	-	-	-	✓	✓
Herbicides							
Panther(1.0)+Treflan (1.5)	28 November	✓	✓	✓	✓	✓	✓
Harmony M(75 g/ha)	7 June	✓	✓	-	-	-	-
Harmony M (50 g/ha)	DD1 20 May DD2 26 May	-	-	✓	✓	✓	✓
PGR							
3 C(2.0)	12 May	-	-	-	-	✓	✓
Insecticides							
Aphox(140 g/ha)	7 July	-	-	-	-	✓	✓
Total nitrogen and agrochemical variable cost £/ha		**143**	**143**	**152**	**152**	**172**	**172**

1996 Lawton Burrelton, Perthshire Trial

Management Level	Date of Application	3 Passes		5 Passes		7 Passes	
		DD1	DD2	DD1	DD2	DD1	DD2
Nitrogen (kg/ha)							
1st N dose GS23	4 March	-		63		63	
2nd N dose GS31	10 May	200		137		137	
Fungicides							
GS32 Genie(0.2)+Patrol(0.25)	20 May	-		✓		✓	
GS39 Folicur(0.75)+Patrol(0.5)	12 June	✓		✓		✓	
GS59 E Impact(0.63)	3 July	-		-		✓	
Herbicides							
Harmony M(60 g/ha)	27 April	✓		✓		✓	
Starane(0.75)	12 June	✓		✓		✓	
PGR							
3 C Cycocel (2.3)	8 May	-		-		✓	
Insecticides							
None applied							
Total nitrogen and agrochemical variable cost £/ha		**135**		**151**		**166**	

1997 Lawton Burrelton Trial

Management Level	Date of Application	3 Passes		5 Passes		7 Passes	
		DD1	DD2	DD1	DD2	DD1	DD2
Nitrogen (kg/ha)							
1st N dose GS23	26 March	0		63		63	
2nd N dose GS31	30 April	200		137		137	
Fungicides							
GS32 Genie(0.2)+Patrol(0.25)	14 May	-		✓		✓	
GS39 Folicur(0.75)+Patrol(0.5)	29 May	✓		✓		✓	
GS59 E Impact(0.63)	27 June	-		-		✓	
Herbicides							
Harmony M(60 g/ha)	7 April	✓		✓		✓	
Starane(0.6)	14 May	✓		✓		✓	
(Tank mixed with Fungicide)							
PGR							
3 C Cycocel (2.3)	7 May	-		-		✓	
Insecticides							
None applied							
Total nitrogen and agrochemical variable cost £/ha		**135**		**151**		**166**	

SEED COSTS

Although it varied slightly from season to season, typical seed costs applied to the trial results were as follows:

150 seeds/m^2	£15 - £18/ha (depending on seed size)
250 seeds/m^2	£25 - £30/ha
350 seeds/m^2	£35 - £42/ha
450 seeds/m^2	£45 - £54/ha
550 seeds/m^2 (Scotland only)	£55 - £66/ha

Small variations in seed cost between seasons were due to different TGW of the different seed stocks.

6.2 Cropping Details of the Trial Sites

Trial Site	Year	Previous Crop	Trial Site Status	Soil Type
ARC Andover Hampshire	1995	Rotational setaside	1st wheat	Andover series 343 h chalk soil
	1996	Rotational setaside	1st wheat	Andover series 343 h chalk soil
	1997	Rotational setaside	1st wheat	Andover series 343 h chalk soil
ARC Biggleswade Bedfordshire	1995	Winter oilseed rape	1st wheat	Hanslope 411 Chalky boulder
	1996	Winter oilseed rape	1st wheat	"
ARC Caythorpe Lincolnshire	1995	Spring Barley	2nd cereal	Elmton 1 343a brashy loam
	1996	Spring Barley	2nd cereal	"
	1997	Spring Barley	2nd cereal	"
ARC Cirencester Gloucestershire	1995	Winter oilseed rape	1st wheat	Sherborne 343 Brash soil
	1996	Winter oilseed rape	1st wheat	Sherborne 343 brash soil
	1997	Winter oilseed rape	1st wheat	Heavier brash soil than 95/96
ARC Wye Kent	1995	Vining peas	1st wheat	Coombe 2 Chalky fine Loamy soil 511 g
	1996	Vining peas	1st wheat	
	1997	Winter oilseed rape	1st wheat	Gault clay
Scottish Agronomy Kinross/ Perthshire	1995 (Kinross)	Turnip S. OSR	1st wheat	Sandy loam
	1996 (Perthshire)	Potatoes	1st wheat	Sandy loam
	1997 (Perthshire	Potatoes	1st wheat	Sandy loam