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PROJECT REPORT No. 54

NITROGEN AND FUNGICIDE INTERACTIONS IN BREADMAKING WHEAT

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by

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Final report of a 42 month project co-ordinated by Dr. V. W. L. Jordan, IACR-Long Ashton Research Station, Long Ashton, Bristol, BS18 9AF, and involving several research collaborators. The work commenced in February 1988 and was funded by a grant of £191,692 from the Home-Grown Cereals Authority (Project No. 0074/3/87).

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CONTENTS

APPENDIX

Approach I:

Approach II

NOTE: The Report "Across-Site Data Analysis" which relates to the analysis of data in this project may, if required, be obtained from the H-GCA for £5.00 (p and p incl.)

ABSTRACT

This project explored the effects, relationships and interactions underpinning the responses of crops to forms, timing and amounts of nitrogen fertiliser, and disease control strategies on yield, grain and breadmaking quality of "first" winter wheats, and involved two distinct approaches in multi-factorial field experiments.

In the first approach, five rates of nitrogen (50, 100, 150, 200 and 250 kgN/ha) were applied to winter wheat, cv. Avalon, at eight sites in 1988, 1989 and 1990 harvest years, and at two sites cv. Mercia was also included. Three fungicide programmes, based on prochloraz and fenpropimorph, alone and in combination were applied at GS 37 and GS 59.

In the second approach the effects of the main nitrogen top dressing (30, 130 or 230 kgN/ha at GS 31, in mid-April, or 130 kgN/ha in mid-March), late season urea (30kgN/ha solid at GS 37 or 15kgN/ha liquid at GS 37 + GS 55) and late season fungicide (Tilt Turbo at GS 39 + GS 59) were compared at four sites.

Records were made of crop growth, structure, development, disease, grain growth and nitrogen assimilation, yield and components of grain quality; selected samples were tested in each year for breadmaking quality by the Flour Milling and Baking Research Association (FMBRA).

The data were analysed for across-site and year effects by the ADAS Information Services Unit, Cheltenham.

A summary of the overall findings from this study is given below.

1. The effects of nitrogen rates on tiller survival, ear populations and grains/ear were variable and inconsistent over the sites and seasons.

2. Leaf, stem and ear dry matter production and laminar areas and green leaf retention of the topmost two leaves increased as nitrogen rates increased, but yield was negatively related to these factors at some sites in very dry seasons (1989,1990) where moisture was the main limiting factor.

3. There was a higher nitrogen offtake at higher nitrogen levels but there were no consistent differences in the proportion of nitrogen mobilised from stems and flag leaves.

4. The severity of some foliar diseases (brown rust, yellow rust and powdery mildew) increased with increasing nitrogen amounts, whereas effects on septoria were less evident.

5. The 2-spray fungicide programmes (GS 37 + GS 59) gave the selective disease control expected; Corbel being most effective against brown rust and powdery mildew, whereas Sportak gave good control of septoria, and the tank-mix of both fungicides gave the best overall disease control.

6. Yield responses to incremental nitrogen were site and seasonally dependent. In each of the three years, optimum nitrogen at Long Ashton for both cvs Avalon and Mercia was ca. 100 kgN/ha, with yield penalties from 150 kgN/ha and above; similarly for Cirencester in 1989 and 1990. At Morley, Bridgets, Boxworth, Drayton, Newcastle and Aberdeen the nitrogen optima in the first 2 years were ca. 150 kgN/ha, but in 1990 the latter three sites were unresponsive to nitrogen increments (optimum 100kgN/ha).

7. Although there was much site-to-site variation, specific weight was, overall, decreased as nitrogen levels increased, an effect nullified by fungicide disease control.

8. Hagberg Falling Numbers(HFN) increased with increasing increments of nitrogen, to a level above the optimum for grain yield. The 2-spray fungicide programme (Corbel + Sportak) tended to slightly decrease HFN values across the range of nitrogen levels.

9. Grain protein increased linearly at most sites with increased increments of nitrogen, and the overall effect of fungicides was small. However, the amounts required to achieve 11% grain protein varied between sites and seasons, ranging from 50 kgN/ha (Cirencester, 1990) to 250 kgN/ha (Morley, 1990).

10. Sodium dodecyl sulphate(SDS) sedimentation values increased with increased nitrogen, but the increase was not linear. Data also indicated that brown rust had a marked negative influence on SDS values and may therefore affect the quality of grain protein.

11. Where brown rust was controlled with fungicide programmes that contained Corbel yield, specific weight, grain protein and SDS were all increased.

12. There were no consistent effects of incremental nitrogen on flour yield, but flour protein content, flour colour, flour HFN values, loaf volume and loaf score were all improved. Fungicide programmes had no detrimental effects.

Approach II

1. Application of the main nitrogen top dressing in mid-March compared with application in mid-April had a deleterious effect upon almost all parameters measured in this study.

2. There were no consistent crop growth and development responses to urea or fungicides.

3. Nitrogen incremental responses were similar to those found in Approach I, with increased yield as nitrogen increased to 130 kgN/ha, but reductions at the highest nitrogen level (230 kgN/ha). In general, nitrogen improved protein, HFN, and SDS but reduced thousand-grain weight.

4. Late-season fungicide treatment (Tilt Turbo) improved yield at most sites and in most years, on some occasions even in the absence of observable disease, but effects on grain quality parameters were inconsistent.

5. There were no consistent benefits from urea applications in terms of yield or quality parameters. Thus the results of this study do not confirm reports that late-season applications of urea result in increased grain protein.

OBJECTIVES

This collaborative project attempted to provide the Farming Industry with sound scientifically based options for determining nitrogen and fungicide inputs for winter wheat, to optimise breadmaking potential and the production of quality wheat under UK conditions in the current agro-economic climate.

Two separate approaches were adopted, using multi-factorial field experiments on crops of winter wheat, cvs Avalon and Mercia, sown in a "first" wheat after grass or oilseed rape.

Experiments in 1988, 1989 and 1990 harvest years were done at each of the following sites:

Cirencester - Royal Agricultural College

Long Ashton Research Station

Newcastle University

Morley Research Centre

Aberdeen School of Agriculture

Boxworth Experimental Husbandry Farm

Bridgets Experimental Husbandry Farm

Drayton Experimental Husbandry Farm

INTRODUCTION

During the past two decades the UK wheat producer has seen the market transformed from one based on imports to import substitution, particularly of breadmaking wheats, and the export of large quantities of grain surplus to UK requirements. Increasingly the producer must compete on price and produce to the quality standards imposed by these markets.

Nitrogen rates, forms and timings influence both the yield and quality of wheat grain whilst differentially affecting crop susceptibility to disease, and thereby affecting disease control strategies.

Without fertiliser nitrogen, crops often produce only half or less of their potential yield (*Sylvester-Bradley et al, 1982).* Currently, average commercial applications of nitrogen fertiliser to winter wheat are approximately 200 kg/ha *(Chalmers, et al, 1986)* for high yield and of the required protein levels for breadmaking. For milling wheat, a strategy for the use of nitrogen fertiliser must achieve both economic yield and high quality. Application of nitrogen at stem extension should satisfy the physiological needs of the crop, but amounts applied vary. In these situations the efficacy of nitrogen use is in doubt, and the influence of disease on the nitrogen economy of the crop and its impact on grain quality is not fully understood.

The continuing introduction of cultivars of both milling and feed wheats capable of producing high yields has contributed greatly to UK productivity; so too has the control of stem base and foliar diseases by fungicides, which allows the high yield potential to be exploited, with less consideration given to milling quality. However, there are some reports *(Salmon and Cook, 1987; Kettlewell et al, 1987)* that show certain fungicides have an adverse effect on Hagberg Falling Number (HFN), crude protein and sodium dodecyl sulphate (SDS) sedimentation, but that they improve specific weight, flour yield and flour colour.

In the current economic climate and in view of the possible environmental impacts of nitrogen use, what are the implications for yield and quality if nitrogen limitations are imposed? Reducing applied nitrogen amounts below current commercial levels may reduce crop susceptibility to certain diseases and offer economies in fungicide use, but it may also affect yield and quality. To meet market requirements and the increasing demands of intervention standards, it is increasingly important for farmers to manage their wheat to optimise the breadmaking potential.

Previous studies of nitrogen response and the interaction with fungicides *(Jordan et al, 1988; Clare et al, 1990)*, did not encompass the higher levels of nitrogen that farmers are now recommended to use to achieve breadmaking potential.

MATERIALS AND METHODS

Two separate experiments, reported below, were adopted and investigated in a series of multi-factorial field experiments in 1988, 1889 and 1990 cropping years, at eight different sites across the UK (**Table 1**). At each site, crops of winter wheat cv. Avalon, were sown as "first" winter wheats after a non-cereal break crop (grass or oilseed rape) to reduce the risk of take-all and eyespot; at some sites the cv. Mercia was included for comparison.

Table 1. Site Details

Site	Soil Series	Soil Texture
Boxworth EHF	Hanslope	Silty Clay
Bridgets EHF	Andover	Clay Loam
Drayton EHF	Drayton	Clay
Morley RC	Ashley	Sandy Loam
Long Ashton	Holden	Clay Loam
Cirencester	Sherborne	Clay
Newcastle	Hollsworth	Clay Loam
Aberdeen	Tarves	Loam

APPROACH I

Five nitrogen treatments 50, 100, 150, 200, 250 kgN/ha (with a nil nitrogen treatment included at the three EHF sites), were applied as ammonium nitrate. 30 kgN/ha was applied at the start of spring growth (February) with the balance applied as the main application at first node (GS 31) (**Table 2**). Three fungicide programmes (**Table 3**) were chosen for selective control of mildew and rusts, *Septoria* spp. and other possible foliar pathogens and applied on two occasions (GS 37 + GS 59) with unsprayed crops left for comparison. At each site, the 5 x 4 factorial experiment (20 treatment comparisons) was established using plot sizes which ranged from 24m x 6m (Boxworth) to 10m x 2m (Cirencester), and soil samples were taken in autumn 1988 and 1989 for determination of residual N availability in the profiles (**Table 4**).

All other crop husbandry practices (herbicides, insecticides and plant growth regulators) were applied as standard practice according to individual site requirements.

Table 2. Nitrogen Treatments kgN/ha

Treatment	February (GS24)	April (GS31)	Total N
0 (EHF's only)	Nil	Nil	Nil
1.	30	20	50
2.	30	70	100
3.	30	120	150
4.	30	170	200
5.	30	220	250

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Table 3. Fungicide Programmes

Target Disease	GS 37	GS 59
A. Unsprayed	Nil	Nil
B. Mildew/Rust	Corbel (1l/ha)	Corbel (1l/ha)
C. Septoria	Sportak (1l/ha)	Sportak (1l/ha)
D. All Foliar	Corbel+Sportak	Corbel+Sportak

Table 4. Residual Soil Nitrogen (0-90cm)

Site	Total available N in Profile(kgN/ha)	
	1989 crop	1990 crop
Boxworth	58	65
Drayton	68	132
Morley	38	103
Long Ashton	83	104
Cirencester	135	93
Newcastle	31	43

Records were made of crop growth, the incidence and severity of disease, grain growth and nitrogen assimilation. Grain from the harvested areas of each plot was weighed, and samples were cleaned over an aspirated sieve. Moisture content was determined and specific weight recorded. Grain nitrogen content was measured by near-infra-red or Kjeldahl analysis (protein values calculated from %N in dry matter corrected to 14% m.c x 5.7) and HFN and SDS values were determined for each plot. An additional 2 kg sample from each plot was retained, and after the initial analysis of samples was completed, samples from selected treatments were tested for breadmaking quality by the Flour Milling and Baking Research Association (FMBRA).

RESULTS

Crop Growth and Development
(Monitored at Cirencester, Long Ashton, Newcastle and Aberdeen)

The influence of nitrogen amounts on tiller survival and thus ear populations was variable and not consistent over sites, seasons or cultivars in this study; it was only influenced by nitrogen increments in cv. Avalon at Newcastle and Aberdeen in 1988, and at Cirencester in 1989, but not in other years. At Long Ashton, tiller survival was only improved by nitrogen increments in fungicide-treated crops of cv. Mercia in 1989.

Similar results were achieved with grain spikelets/ear. At all four sites there were fewer grains/ear at 50 kgN/ha than at higher levels in 1988, and again at the two northern sites (Newcastle and Aberdeen) in 1989, but there were no significant responses at any site in 1990. Overall, there were no significant or consistent effects on grain growth during grain filling.

In general, ear dry matter production, laminar areas and leaf dry matter production of the flag leaf and leaf 2 for both cvs Avalon and Mercia increased as nitrogen amounts increased. However, green leaf retention responses were more variable, and mainly attributable to seasonal climatic effects.
In sites and years where moisture was not limiting, there was greater green leaf retention at the higher levels of applied nitrogen; however at some sites, especially Cirencester and Long Ashton in the dry years of 1989 and 1990 (see weather data in Appendix), green leaf retention was decreased by the higher levels of nitrogen, as the increased biomass-plants were particularly "stressed" and could not sustain growth as soil moisture was the main limiting factor.

As nitrogen amounts increased, there was a greater uptake of nitrogen into stems, flag leaves and ears, but although there were indications of greater mobilisation of nitrogen away from the flag leaves and stems at 50 kgN/ha there were no consistent differences in the proportion of nitrogen mobilised from stems and leaves.

Disease

The geographical distribution of the sites across the UK was considered sufficient to provide a wide spectrum of disease. The "wet weather" diseases are usually more prevalent and severe in the Northern and South Western sites, with mildew and rusts predominantly prevalent in the Eastern sites. However, during this 3-year study, the last two cropping seasons, 1989 and 1990, were unusually warm and dry with lower than expected levels of *Septoria* spp.

In 1988, *Septoria tritici* was severe at Long Ashton and Cirencester with moderate levels at Morley, Newcastle and Bridgets EHF; powdery mildew was moderate to low at all sites, but levels increased at Bridgets EHF as the season progressed; low levels of brown rust were also recorded at Long Ashton, Morley and Bridgets EHF. The most prevalent diseases at all sites in 1989 were powdery mildew and brown rust, although levels were generally low; yellow rust was also found at some sites. In 1990, brown rust was the most dominant disease at Long Ashton and Morley, and moderate levels of powdery mildew were recorded at Newcastle, but very little disease developed at the other sites.

In general, at sites where sufficient disease was present for comparisons to be made, increasing nitrogen amounts increased the severity of brown rust, powdery mildew and yellow rust, and in the majority of cases *Septoria tritici*. However, in 1988, *S. tritici* was more severe with the lowest nitrogen rate (50 kgN/ha) than on crops with higher amounts of applied nitrogen. Somewhat surprisingly, eyespot developed on the "first" wheats at some sites in 1990, and was more severe at lower nitrogen levels.

The 2-spray fungicide programme (GS 37 + GS 59) of Corbel controlled powdery mildew and brown rust well, and decreased septoria, whereas the 2-spray programme with Sportak alone controlled septoria well but was inneffective against brown rust. The combined tank-mix programme gave the best overall foliar disease control. Although there were no consistent nitrogen / fungicide interactions better disease control with Corbel was achieved at the lower nitrogen levels.

Yield

Comparative yield responses for unsprayed crops (cvs Avalon and Mercia) and those that received the 2-spray tank-mix fungicide programme for each site in 1988, 1989 and 1990 are shown in Appendix A.

Grain yield in 1988 increased significantly ($\underline{P}$=0.05) with increased nitrogen at all sites with the exception of Long Ashton and Cirencester, where increased nitrogen amounts reduced yield. The tank-mix fungicide programme increased yield ($\underline{P}$=0.05) at all sites other than Morley and Newcastle.

In unsprayed crops, grain yield (cv. Avalon) at Long Ashton, Bridgets EHF and Morley did not increase above 100 kgN/ha, whereas at Drayton EHF, Boxworth EHF and Newcastle the optimum nitrogen amount was ca. 150 kgN/ha, and at Cirencester 200 kgN/ha. However, with fungicides the yield across all sites was increased by 15.6% (0.96 t/ha) and the resulting optimum level of nitrogen at Bridgets EHF, Drayton EHF, Morley and Newcastle increased to ca. 200, 200, 150 and 200 kgN/ha respectively.

In 1989, unsprayed crops at Long Ashton, Cirencester, Bridgets EHF and Drayton EHF were unresponsive to additional nitrogen amounts above 50 kgN/ha. With fungicides, the mean yield increased by a further 8.6% (0.58t/ha). The four other sites, Boxworth EHF, Morley, Newcastle and Aberdeen were more responsive to additional increments of nitrogen, and with fungicides the mean yield was increased by 5.4% (0.38 t/ha).

As in the previous year, Long Ashton, Cirencester and Drayton were again unresponsive to nitrogen increments in 1990, with yield optimum for both cvs Avalon and Mercia ca. 100 kgN/ha, and yield penalties from nitrogen amounts of 150 kgN/ha and above at Long Ashton and Cirencester.

In 1990, yields at Newcastle and Aberdeen were also unaffected by nitrogen rates. At Morley, increasing nitrogen amounts up to 150 kgN/ha increased yield, and at Boxworth EHF and Bridgets EHF there were gradual increases in yield up to 200 and 250 kgN/ha, respectively, but no effect of fungicides or interactions.

Thousand Grain Weight

In general, and with both cultivars, thousand grain weight decreased with increasing nitrogen increments. Corbel was the most effective fungicide in this season, and the yield increase with Corbel was greater at the higher nitrogen rates.
At Cirencester thousand grain weight was increased by Sportak in cv. Mercia, in the absence of disease.

Specific Weight

The effect of nitrogen amounts on specific weight was variable, with significant increases in response to additional nitrogen at some sites, and significant decreases at others, and no apparent cultivar interactions. In general, over all sites and seasons the mean effect was for specific weight to slightly decrease as nitrogen levels increased, but where fungicides were applied to control disease, this decrease was no longer evident.

Hagberg Falling Number

HFN values were generally low in 1988 and very high in 1990. In all three years, with the exception of Bridgets EHF in 1988 and 1989, and Cirencester in 1990, HFN values increased significantly ($\underline{P}$ = 0.05) with increasing increments of nitrogen generally to a level which was above the optimum for grain yield. In addition, HFN values tended to be higher in cv. Avalon than in cv. Mercia, with optima at 150 kgN/ha and 200 kgN/ha, respectively in 1990. In 1989, those sites which were unresponsive in grain yield to additional nitrogen were also less responsive in HFN values.

The effect of fungicides on HFN values was variable. In 1988, fungicide treatments that contained Sportak had lower HFN values at Long Ashton, Newcastle and significantly so ($\underline{P}$=0.05) at Morley in 1988, whereas in 1989, Sportak, Corbel and the tank-mix programme increased HFN values, significantly so in cv. Mercia at Cirencester, due presumably to prolonged green leaf retention. However, overall, the effect of the tank-mix fungicide programme was to slightly decrease HFN values across the range of nitrogen levels, significantly ($\underline{P}$ =0.05) at Morley, Long Ashton and Newcastle in 1988, Bridgets EHF in 1989 and Newcastle (cv. Mercia) in 1990.

Grain Protein

In all three years, the mean grain protein content increased linearly at most sites with increasing increments of nitrogen up to the maximum level tested (250 kgN/ha).

The nitrogen levels required to obtain 11% protein with cv. Avalon in 1988 were:- 50 kgN/ha at Long Ashton, 150 kgN/ha at Bridgets and Morley, 200 kgN/ha at Drayton and Newcastle and 250 kgN/ha at Cirencester, and somewhat similar levels at each site were required in 1989:- 100 kgN/ha at Long Ashton and Bridgets, 150 kgN/ha at Morley, and 200 kgN/ha at Cirencester, Drayton and Newcastle.

In 1990, 11% protein was achieved with 50 kgN/ha at Cirencester and Newcastle (cvs Avalon and Mercia), 100 kgN/ha cv. Avalon and 150 kgN/ha cv. Mercia at Long Ashton, whereas at Morley 250 kgN/ha was required to obtain 11% protein.

The overall effect of disease control by fungicides on crude protein was small. However, significant ($\underline{P}$ =0.05) decreases in grain protein following fungicide treatment were found at Morley and Long Ashton in 1988, and significant increases ($\underline{P}$ =0.05) at Bridgets EHF in 1989 and Newcastle in 1990.

Sodium Dodecyl Sulphate (SDS) Sedimentation Volume

At all sites in 1988 and 1989 and at most sites in 1990, there were significantly higher ($\underline{P}$ =0.05) SDS values as the nitrogen rate increased. However, unlike that for crude protein, the increase was not linear with the rate of increase diminishing at the higher nitrogen levels.

The effect of fungicide programmes was small and inconsistent, with a significant reduction ($\underline{P}$= 0.05) at Long Ashton in 1988, but a significant increase ($\underline{P}$ = 0.01) at Bridgets EHF in 1989. At non-disease sites, application of fungicides had no significant effect.

Interestingly, data from Bridgets EHF (**see Table 5**), Long Ashton and Morley in 1989 and 1990 demonstrated that control of brown rust with Corbel gave a significant improvement in SDS values. Brown rust was the most dominant disease at Bridgets EHF in 1989 and meaned over all nitrogen levels, reached 25% of the area of the flag leaf by GS 75. Fungicide programmes that contained Corbel (fenpropimorph) reduced the level to 14% whereas Sportak (prochloraz) gave no control. Brown rust severity on the flag leaves of unsprayed crops increased from 19% to 30% as nitrogen was increased from nil to 250 kgN/ha. Yield, specific weight, grain protein and SDS were all increased when fungicide programmes that contained Corbel were applied.

Table 5. Effect of fungicide programmes on yield, brown rust severity on the flag leaf (%) at GS 75, and grain quality, Bridgets EHF, 1989.

Treatment	Yield (t/ha)	Sp. Wt. (kg/hl)	HFN value	Grain protein(%)	SDS value	Brown rust(%)
Unsprayed	6.58	76.0	365	11.0	58	25
Corbel	7.88	78.7	364	11.5	60	14
Sportak	7.02	76.6	364	10.9	57	28
Corbel+Sport	7.88	79.0	359	11.5	60	14
LSD($\underline{P}$ =0.05)	0.22	0.30	6.4	0.19	1.2	4.6

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APPROACH II

Interactions between nitrogen amounts and timing, late-season urea and fungicide applications.

The effects of the main nitrogen top dressing (30, 130 or 230 kgN/ha at GS 31 - mid-April, or 130 kgN/ha in mid-March), late-season urea (30 kgN solid at GS 37, or 15 kgN/ha liquid at GS 37 + GS 55) and late-season fungicide (unsprayed or Tilt Turbo at GS 39 + GS 59) were compared at four sites:-

Cirencester, cv. Avalon (4 x 2 x 2 factorial = 16 treatments); at Long Ashton (cvs Avalon and Mercia), Morley (cv. Avalon) and Newcastle (cvs Avalon and Mercia) the 130 kgN/ha top dressing and timing treatments were not included in 1989 and 1990.

All sites received an early (February) overall application of nitrogen - 40 kgN/ha, and at GS 32, the experiments were oversprayed with Corbel/Bravo, to delay the onset of severe disease. This treatment was very effective, and at some sites effectively prevented the late-season development of rusts.

Table A. Treatment comparisons used in Approach II

Nitrogen applied (kg/ha)

Total	February	Split March	April	GS37/55*
100	40	-	30	30
200	40	130	-	30
200	40	-	130	30
300	40	-	230	30

* The late application compared
30 kg N/ha as solid urea at GS 37
or 15 kg N/ha as Nufol (spray) at GS 37 plus
15 kg N/ha as Nufol at GS 55.

These comparisons were tested with and without fungicide at GS 39 plus GS 59.

RESULTS

Crop Growth and Development

Overall, there were no consistent urea or fungicide effects on ears/m2 or grains/ear and no nitrogen, fungicide, urea interactions. There were also indications that cv. Mercia had higher ear populations than cv. Avalon; however, this was to some extent compensated by greater grain numbers/ear.
At Cirencester, application of nitrogen in March resulted in lower grain growth (cv. Avalon) from mid July until the end of flowering, compared with April nitrogen.
At Long Ashton, ear dry matter production was greater in 1990 with solid urea at the lower (100kgN/ha) rate, but there were no differences at higher nitrogen rates.
Green leaf area was maintained by increasing the amounts of spring nitrogen, but green leaf retention was reduced by March-applied nitrogen. There were no significant nitrogen, urea or fungicide effects in both cvs Avalon and Mercia.

Disease

Disease development and prevalence differed over the 3-year study. In 1988, *Septoria tritici* was the most prevalent disease and greatest on March-nitrogen crops. Somewhat surprisingly, this disease was more severe at the lower nitrogen level than at the high nitrogen rate. Fungicide treatment reduced disease but urea effects were variable. Urea tended to increase *Septoria tritici* at Cirencester in 1988, and brown rust at Long Ashton in 1989 in cv. Avalon, on the lower nitrogen crops, whereas with cv. Mercia, disease was lower with liquid urea than solid urea at the low nitrogen rate, but the converse true for the higher nitrogen rate.

Yield

Crops given mid-March nitrogen applications had lower yields than those given April-applied nitrogen. With the exception of the Morley site, there were also significant yield reductions at the highest nitrogen rate (230 kgN/ha) in both cvs Avalon and Mercia. Late-season fungicide improved yield at most sites, with the exception of Newcastle, even in the absence of observable disease (Cirencester). There were no consistent interactions between nitrogen, urea or fungicide.

Thousand-grain weight

Thousand-grain weight decreased with increasing nitrogen. March-applied nitrogen also decreased grain weight compared with April nitrogen. Both fungicide and liquid urea increased grain weight in 1988, but there were no other significant effects of fungicide or urea in other years.

Specific Weight

Increasing spring nitrogen reduced specific weight at Morley in 1988, and at Cirencester in 1989, but gave an increase in specific weight at Morley in 1989. March-nitrogen (Cirencester) also gave a reduction in specific weight in 1990.
Application of late-season Tilt Turbo reduced specific weight at Newcastle in 1988, but an increase at Morley (1988), Long Ashton (1989) and Cirencester(1990).
At Morley (1990) solid urea gave higher specific weight than where liquid urea was used, but there were no other urea effects.
There were no significant nitrogen, fungicide or urea interaction effects on specific weight.

Hagberg Falling Number

In general, increasing nitrogen increased HFN value in both cvs Avalon and Mercia, the exception being at Newcastle in 1988 where lodging occurred at the higher nitrogen treatment (230 kgN/ha). Overall, there were no significant effects of fungicide or urea on HFN values, with the exception of Morley in 1990, where fungicide reduced HFN, and at Long Ashton in 1990, where solid urea improved HFN in cv. Avalon, and in cv. Mercia, Tilt Turbo at the higher nitrogen rate decreased HFN values.

Crude Protein Content

Crude protein content increased significantly with increasing nitrogen.
There were no significant effects of fungicide or urea on grain protein at Newcastle and Long Ashton. Similar results were obtained at Cirencester, except that higher crude protein values were obtained with solid urea than with liquid urea only in 1988.
At Morley, Tilt Turbo reduced protein content in 1988, but gave an increase in 1990.
March nitrogen had lower crude protein content than similar amounts of nitrogen applied in April.

Sodium dodecyl sulphate(SDS) sedimentation test

SDS responses were similar to those for grain protein; in general SDS values increased as nitrogen increased. March nitrogen had lower SDS values than April nitrogen, and in general there were no consistent urea or fungicide effects. However, SDS values were decreased by fungicide but improved by solid rather than liquid urea at Morley in 1988.

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Breadmaking Tests

In 1988 and 1989, selected samples were sent to FMBRA for breadmaking tests.

In 1988 only samples from Long Ashton, cv. Avalon, at each level of nitrogen, were analysed. Increasing the amount of nitrogen had little effect on flour yield or flour HFN values, but improved flour colour, flour water absorption and flour protein content. This improvement was translated more effectively into improved breadmaking potential in the Long Fermentation Process (LFP) than the Chorleywood Bread Process (CBP).

Samples from all sites were examined at the 150 kgN/ha level, with and without fungicide treatment.
Specific weight and flour yield were improved by disease control but crude protein, flour grade colour and flour HFN values were little affected. The fungicide treatment gave only a small reduction in loaf volume but reduced loaf score.

In 1989 results again showed no consistent effect of increasing nitrogen level on flour yield. There was a large increase in flour protein content as the level of nitrogen fertiliser was increased from 50 kgN/ha to 250 kgN/ha. However, there was no consistent increase in water absorption despite the large increase in flour protein content. Flour colour and flour HFN values were exceptionally good in 1989, but did show improvement with increasing nitrogen levels. Loaf volume and loaf score also improved as the level of nitrogen increased, with most of the improvement occurring between 50 and 150 kgN/ha. In contrast to 1988, fungicide treatment had no detrimental effect on loaf volume and loaf score.

In 1990, the good harvesting conditions resulted in clean, well-filled grain, and flour colours were exceptionally good with most samples producing negative values. Flour yields and flour HFN values were relatively high, the exceptions being in the lowest nitrogen rates at Morley.

Overall, cv. Avalon, was responsive to nitrogen increments in increased baking performance, but at Newcastle, cv. Mercia, baking performance was rather poor. At the lower nitrogen rate (50kgN/ha), fungicide treatments tended to increase flour HFN values and water absorption but reduced loaf volume and loaf score, whereas at the higher nitrogen rates fungicides treatments that included Corbel improved baking performance, inferring a response to disease control, especially at sites where brown rust was well controlled.

Samples from Approach II (Cirencester and Morley) showed that April nitrogen was more successful than March nitrogen in increasing flour protein content, which was translated into improved breadmaking quality. There were, however, no differences in breadmaking performance between solid and liquid urea and no consistent effects of fungicide treatment.

DISCUSSION

It is usual to obtain a wide range in grain yield responses to nitrogen fertiliser from site to site and season to season *(Sylvester-Bradley* et al, *1982)*. The response in HFN values to increasing nitrogen tends to follow closely that of grain yield *(MacDonald & Vaidyanathan, 1987)*. Similarly in this study, at most sites grain yield and HFN values both show asymptotic responses to increasing nitrogen. However, at Long Ashton and Cirencester increasing spring nitrogen depressed grain yields, especially in 1989, which was attributed mainly to the unusually hot, dry period during grain fill. Previous research *(Annadale* et al, *1984)* has shown that well fertilised wheat used more water than crops grown on poorly fertilised plots; thus available water supply may be exhausted more rapidly resulting in plant stress, and hence grain fill was reduced. Those sites showing large yield responses also gave large responses in HFN values, generally to a nitrogen level above that for optimum yield. The unresponsive sites, presumably well supplied with available soil nitrogen, had a lower optimum for grain yield. HFN values were similarly near optimum at lower fertiliser levels and although not declining, as did grain yield, were little affected by additional nitrogen. It is helpful to those farmers growing breadmaking wheat that grain yield and HFN appear to respond similarly, but this association is not well understood and warrants further study.

Murray and Nunn (1987) found that over the range 0 - 300 kgN/ha the relationship between grain nitrogen and nitrogen fertiliser was asymptotic. Over the more limited range in this study (50 - 250 kgN/ha), the increase in grain protein was generally linear. However, unlike HFN it was not associated with the response of grain yield to nitrogen at that site. *Vaidyanathan* et al, (1987) encountered similar results where no relationship could be established between the amount of nitrogen supplied from the soil and grain nitrogen content. To allow an accurate prediction of the grain nitrogen content from a given amount of fertiliser nitrogen this problem must be resolved.

Nevertheless, it appears that farmers could make substantial savings in certain sites without jeopardizing yields, by exploiting the benefits of residual soil nitrogen from break-crops thereby allowing reductions to be made in the amount of applied nitrogen. This became apparent when classifying the sites used as "responsive" or "unresponsive" to incremental nitrogen. In the "unresponsive" sites, there were higher levels of residual nitrogen (80 - 135 kgN/ha) available in the profiles as determined by soil analysis, than in the "responsive" sites (< 60 kgN/ha) which apparently affected incremental point responses on the dose response curve. In addition, the optimum nitrogen for yield rarely exceeded 150 kgN/ha at any site over the three year study. However, to achieve the required level of grain protein for breadmaking quality, more nitrogen was required at some sites than that providing optimum yield, albeit at some of these sites the grain protein requirements were seasonally dependent.

More research into the contribution of soil nitrogen and the relationship with the nitrogen content of the crop during its growth may allow more precise prediction of the final grain nitrogen content thus allowing nitrogen fertiliser to be applied to achieve that required for breadmaking quality.

Salmon and Cook (1987) reported reductions in HFN value, grain protein and SDS following application of fungicides. Grain protein content tends to be decreased on fungicide-treated crops which retained green leaf area longer and continue to photosynthesise carbohydrate and thus ditute protein. Disease levels in this study were relatively low and as a consequence the grain protein dilution effect might be expected to be small. In 1988, HFN values were markedly reduced with only a small reduction in grain protein and SDS values. This resulted in a slightly reduced loaf volume and loaf score from fungicide treatment. In 1989, an "early harvest", non-disease year the fungicide programmes had no detrimental effects on grain protein and SDS, nor loaf volume and loaf score.

Overall, specific weight was reduced as nitrogen levels increased, but this effect was nullified where fungicides were used to control disease. This may imply a nitrogen/disease interaction whereby the increased foliar disease as a response to higher nitrogen levels is a contributory factor in reducing specific weight.

It is generally assumed that SDS values indicate protein quality and are the most successful parameters for predicting loaf volume; they are also used to "identify" cultivars. However, the data obtained in the course of this project suggests that SDS values can vary considerably according to agronomic practice. The marked effects on SDS values suggest that protein quality may be more varaible, and that brown rust infection, and to some extent powdery mildew, may influence the quality of the grain protein.

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Rosemaund Arable Centre Conference
ADAS Salisbury Crop Centre Conference
ADAS North Wilts Crop Centre Conference
Midland Shires Farmers Technical Conference
Three Counties Show
Crops Conference, East of England Showground
North of England Arable Centre Review Conference

APPENDIX: 1988 CROP: SUMMARY OF YIELD DATA FOR 1988 HARVEST

EXPERIMENT A YIELD(T/HA)

TREATMENT MEAN		LAshton	RAC	Morley	ADASI	ADASII	Newcastle
50N	Nil	8.10	5.75	5.09	4.46	5.78	7.70
	Cor	8.34	6.27	5.55	4.18	6.00	7.18
	Spor	8.72	5.93	5.76	4.48	6.20	8.05
	C/S	8.43	6.05	5.85	4.23	6.22	8.08
mean		8.44	6.00	5.60	4.34	6.04	7.75
6.36							
100N	Nil	8.54	7.00	5.42	5.25	6.10	8.48
	Cor	9.34	7.00	6.07	5.47	6.92	9.33
	Spor	9.52	7.15	6.54	5.47	6.79	9.08
	C/S	9.79	6.96	6.71	5.44	7.24	8.73
mean		9.12	7.03	6.20	5.41	6.76	8.90
7.23							
150N	Nil	8.04	7.26	5.35	5.61	6.04	9.03
	Cor	9.14	7.10	6.05	5.88	7.36	9.38
	Spor	9.02	7.34	6.46	5.80	6.69	9.28
	C/S	9.29	8.09	7.00	6.06	7.69	9.18
mean		8.77	7.45	6.20	5.84	6.94	9.20
7.40							
200N	Nil	7.46	7.70	5.25	5.66	5.86	8.98
	Cor	8.57	7.48	6.26	6.20	7.28	8.88
	Spor	8.56	7.85	6.36	6.00	7.12	8.53
	C/S	8.78	8.18	7.08	6.60	8.06	9.68
mean		8.24	7.80	6.20	6.12	7.08	9.01
7.41							
250N	Nil	7.54	7.67	5.04	5.59	6.19	8.10
	Cor	8.25	8.06	6.45	6.57	7.51	8.25
	Spor	8.41	7.81	5.97	6.07	6.90	8.43
	C/S	8.48	8.74	7.15	6.71	8.02	8.48
mean		8.09	8.07	6.20	6.23	7.16	8.31
7.34							
NIL		7.94	6.25	5.23	5.04	5.70	8.46
CORBEL		8.73	8.02	6.08	5.31	6.58	8.60
SPORTAK		8.85	7.16	6.22	5.22	6.38	8.67
COR/SPOR		8.96	7.64	6.76	5.44	6.95	8.82

R

APPENDIX: 1988 CROP.

HGCA EXPERIMENT A: Yield response (t/ha)

cv. AVALON - unsprayed

Site	50kgN	100kgN	150kgN	200kgN	250kgN
Long Ashton	8.10	8.54	8.04	7.46	7.54
Cirencester	5.75	7.00	7.26	7.70	7.67
Newcastle	7.70	8.48	9.03	8.98	8.10
Morley	5.09	5.42	5.35	5.25	5.04
Bridgets	5.78	6.10	6.04	5.86	6.19
Drayton	4.46	5.25	5.61	5.66	5.59

cv. AVALON - Sprayed (Corbel/Sportak GS 37 + GS 59)

Long Ashton	8.43	9.79	9.29	8.78	8.48
Cirencester	6.05	6.96	8.09	8.18	8.74
Newcastle	8.08	8.73	9.18	9.68	8.48
Morley	5.85	6.71	7.00	7.08	7.15
Bridgets	6.22	7.24	7.69	8.06	8.02
Drayton	4.23	5.44	6.06	6.60	6.71

R

APPENDIX: 1989 CROP.

HGCA EXPERIMENT A: Yield response (t/ha)

cv. AVALON - unsprayed

Site	50kgN	100kgN	150kgN	200kgN	250kgN
Long Ashton	6.29	6.23	6.05	5.41	4.89
Cirencester	6.36	6.23	5.79	5.60	5.60
Newcastle	7.75	8.91	9.46	9.38	9.69
Morley	7.02	8.14	8.15	8.21	8.56
Bridgets	7.08	7.01	6.69	6.38	6.37
Boxworth	7.50	7.79	7.88	7.64	7.17
Drayton	7.36	7.61	7.26	7.39	6.91
Aberdeen	5.80	7.40	7.68	7.53	7.44

cv. AVALON - Sprayed (Corbel/Sportak GS 37 + GS 59)

Long Ashton	6.27	6.41	6.47	6.22	5.81
Cirencester	6.67	6.68	6.30	6.04	5.53
Newcastle	7.91	8.84	9.45	9.69	10.08
Morley	7.23	8.28	8.63	8.42	8.70
Bridgets	7.72	8.28	8.12	8.24	8.34
Boxworth	7.49	8.18	8.29	8.32	8.09
Drayton	7.28	7.51	7.64	7.91	7.01
Aberdeen	6.41	8.03	8.62	7.92	8.07

cv. MERCIA - unsprayed

Long Ashton	8.11	7.33	7.31	6.13	5.89
Cirencester	5.01	4.41	4.21	4.01	3.06
Aberdeen	5.00	6.69	6.72	6.88	6.71

cv. MERCIA - Sprayed (Corbel/Sportak GS 37 + GS 59)

Long Ashton	8.48	8.51	8.48	7.93	6.82
Cirencester	5.81	5.61	5.63	5.16	4.81
Aberdeen	5.20	6.54	6.61	7.19	7.21

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APPENDIX: 1989 CROP.

HGCA EXPERIMENT A: Grain protein (% @ 86% dry matter)

cv. AVALON - unsprayed

Site	50kgN	100kgN	150kgN	200kgN	250kgN
Long Ashton	9.16	10.72	13.58	16.32	17.60
Cirencester	10.34	11.48	13.03	13.44	13.86
Newcastle	8.70	9.74	10.70	12.53	11.92
Morley	8.00	10.08	11.52	12.08	12.32
Bridgets	10.30	10.90	11.20	11.70	12.00
Boxworth	10.20	-	12.20	12.83	13.40
Drayton	8.39	9.24	10.55	10.51	11.85

cv. AVALON - Sprayed (Corbel/Sportak GS37 + GS55)

Long Ashton	9.41	12.41	14.21	16.20	16.61
Cirencester	10.23	11.89	13.03	13.34	14.06
Newcastle	8.61	10.23	10.61	11.66	12.26
Morley	8.24	9.92	11.44	12.40	12.40
Bridgets	11.10	11.50	11.80	11.90	12.00
Boxworth	9.35	-	11.80	13.05	13.57
Drayton	8.69	9.27	9.95	11.04	12.05

cv. MERCIA - unsprayed

Long Ashton	9.42	12.45	12.92	13.87	15.01
Cirencester	10.23	11.36	12.38	12.78	13.29

cv. MERCIA - Sprayed (Corbel/Sportak GS37 + GS55)

Long Ashton	8.59	11.67	13.22	14.61	16.07
Cirencester	10.12	11.25	12.17	12.78	13.50

APPENDIX: 1989 CROP.

HGCA EXPERIMENT A: Hagberg Falling Number (seconds)

cv.AVALON - unsprayed

Site	50kgN	100kgN	150kgN	200kgN	250kgN
Long Ashton	329	349	376	376	363
Cirencester	319	322	341	354	367
Morley	324	382	399	389	389
Bridgets	367	362	370	370	372
Boxworth	251	273	321	335	345
Drayton	304	339	349	361	348
Newcastle	83	173	275	310	300

cv. AVALON - Sprayed (Corbel/Sportak GS37 + GS 55)

Long Ashton	317	356	367	386	367
Cirencester	316	354	354	364	370
Morley	334	376	398	395	392
Bridgets	347	362	364	360	374
Boxworth	249	272	301	331	323
Drayton	305	327	344	356	371
Newcastle	78	153	234	299	317

cv. MERCIA - unsprayed

Long Ashton	302	330	324	330	338
Cirencester	312	312	331	339	330

cv. MERCIA - Sprayed (Corbel/Sportak GS 37 + GS 55)

Long Ashton	307	315	322	319	329
Cirencester	300	293	306	311	312

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APPENDIX: 1990 CROP.

HGCA EXPERIMENT A: Yield response (T/HA)

cv. AVALON - unsprayed

Site	50kgN	100kgN	150kgN	200kgN	250kgN
Long Ashton	6.02	5.72	5.04	4.89	4.62
Cirencester	4.20	4.20	4.07	4.33	3.82
Newcastle	10.73	10.83	10.62	10.71	10.75
Morley	6.86	7.92	8.75	8.82	8.32
Bridgets	6.64	7.31	7.59	7.59	7.45
Drayton	4.80	5.31	5.38	4.94	5.36
Aberdeen	6.93	6.67	6.82	6.83	6.61

cv.AVALON - Sprayed(Corbel/Sportak GS37 + GS59)

Long Ashton	6.99	7.46	7.33	6.78	6.68
Cirencester	4.28	4.20	4.20	4.36	4.37
Newcastle	11.14	11.14	10.92	11.02	11.02
Morley	6.98	8.74	9.25	9.36	9.50
Bridgets	6.10	7.35	7.69	7.69	7.62
Drayton	5.03	5.55	5.00	5.50	5.51
Aberdeen	5.75	5.59	5.80	5.65	5.58

cv. MERCIA - unsprayed

Long Ashton	7.24	7.24	6.65	5.43	5.79
Cirencester	4.07	4.11	4.27	4.03	4.31
Newcastle	9.87	9.69	9.39	9.96	9.41
Aberdeen	2.05	1.90	1.86	1.71	1.69

cv MERCIA - Sprayed

Long Ashton	8.61	9.33	8.85	8.25	8.62
Cirencester	4.27	4.52	4.47	4.39	4.44
Newcastle	11.13	11.47	10.79	11.56	11.07
Aberdeen	2.30	2.22	2.06	2.06	1.95

APPENDIX: 1990 CROP.

HGCA EXPERIMENT A: Grain Protein (% @ 86% dry matter)

cv. AVALON - unsprayed

Site	50kgN	100kgN	150kgN	200kgN	250kgN
Long Ashton	10.26	12.54	13.82	14.39	15.11
Cirencester	11.81	12.75	13.22	13.58	13.46
Newcastle	12.71	12.56	12.71	12.62	12.85
Morley	7.82	8.80	9.90	10.80	11.40
Boxworth	7.20	8.93	10.65	10.94	11.66
Drayton	9.20	10.40	10.80	11.10	11.80

cv.AVALON - Sprayed(Corbel/Sportak GS37 + GS55)

Long Ashton	9.55	11.12	12.83	13.97	14.68
Cirencester	11.33	12.74	13.10	13.58	13.69
Newcastle	12.62	12.68	12.71	13.03	13.21
Morley	7.80	8.90	9.90	10.90	11.70
Boxworth	7.48	9.50	10.51	11.52	12.02
Drayton	9.70	10.30	10.90	11.40	11.80

cv. MERCIA - unsprayed

Long Ashton	10.12	10.40	12.83	13.82	14.11
Cirencester	11.03	12.02	12.46	12.66	12.68
Newcastle	11.05	11.31	11.82	11.62	12.02

cv. MERCIA - Sprayed

Long Ashton	9.55	10.83	11.97	13.40	13.29
Cirencester	10.58	11.80	12.57	12.91	12.55
Newcastle	11.19	11.74	12.24	12.01	12.10

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APPENDIX: 1990 CROP.

HGCA EXPERIMENT A: Hagberg Falling Number (seconds)

cv. AVALON - unsprayed

Site	50kgN	100kgN	150kgN	200kgN	250kgN
Long Ashton	369	368	379	381	373
Cirencester	402	426	404	401	410
Newcastle	422	422	430	425	420
Morley	277	346	380	397	399
Boxworth	338	358	360	385	380
Bridgets	403	420	417	416	429
Drayton	359	359	369	356	376

cv.AVALON - Sprayed(Corbel/Sportak GS37 + GS55)

Long Ashton	357	359	384	382	379
Cirencester	434	403	414	430	422
Newcastle	406	422	422	430	423
Morley	274	370	386	399	395
Boxworth	337	362	372	371	381
Bridgets	400	432	416	425	421
Drayton	361	371	357	392	369

cv. MERCIA - unsprayed

Long Ashton	373	362	370	384	370
Cirencester	393	381	377	390	385
Newcastle	350	356	348	348	363

cv.MERCIA - Sprayed

Long Ashton	360	367	365	368	377
Cirencester	377	384	380	385	376
Newcastle	333	325	333	326	330

APPENDIX II: 1988 CROP

HGCA EXPERIMENT B; SUMMARY OF YIELD DATA FOR 1988 HARVEST
(**CV.AVALON**)

Site	(T/HA) No late fungicide - unsprayed							
	100kgN		200 kgN (Mar)		200kgN		300kgN	
	UL	US	UL	US	UL	US	UL	US
Long Ashton	7.88	8.01	5.60	5.53	5.49	5.71	5.52	5.45
Cirencester	6.39	6.66	7.09	7.40	7.69	7.73	7.44	7.33
Morley	6.72	6.67	6.75	7.14	6.83	7.13	7.00	6.88
Drayton	5.28	5.27	6.17	6.61	6.40	6.57	6.78	6.48
Bridgets	6.80	6.42	6.82	6.52	7.18	7.01	6.85	7.44
Newcastle	8.63	8.78	8.13	8.78	9.03	9.35	8.33	7.80
MEAN	***6.93***	***6.97***	***6.76***	***7.00***	***7.10***	***7.25***	***6.99***	***6.90***

Site	(T/HA) Late fungicide - (Tilt Turbo GS 39+59)							
	100kgN		200 kgN (Mar)		200kgN		300kgN	
	UL	US	UL	US	UL	US	UL	US
Long Ashton	7.58	7.69	6.27	6.24	6.56	6.54	6.25	5.89
Cirencester	6.73	6.46	7.04	7.47	7.92	7.78	8.29	8.41
Morley	7.23	6.95	7.24	7.44	7.77	7.90	8.11	8.02
Drayton	5.27	5.24	6.52	6.57	6.62	6.54	7.01	7.02
Bridgets	6.80	6.85	7.54	7.71	7.64	7.53	8.15	8.15
Newcastle	8.30	9.43	9.15	8.63	9.08	8.90	8.70	8.40
MEAN	***6.99***	***7.10***	***7.29***	***7.34***	***7.60***	***7.53***	***7.75***	***7.65***

APPENDIX II: 1989 CROP

HGCA EXPERIMENT B;

Site	No late fungicide				Late fungicide(Tilt Turbo)			
	100	kgN	300		100	kgN	300	
	UL	US	UL	US	UL	US	UL	US
Long Ashton (cv. Avalon)								
Yield	8.4	8.4	6.3	6.3	7.9	8.2	6.7	6.3
Sp.Wt	49	50	57	54	55	50	58	61
HFN	327	359	380	359	345	339	362	364
Protein	11.1	11.7	17.3	17.6	11.3	11.0	17.7	18.0
Long Ashton (cv.Mercia)								
Yield	9.2	9.0	7.2	7.5	9.0	10.0	8.2	8.2
Sp.Wt	50	47	51	50	49	48	52	51
HFN	327	331	321	319	318	307	326	326
Protein	11.5	12.5	16.0	16.3	11.7	11.7	16.1	16.1
Cirencester (cv.Avalon)								
Yield	6.9	6.5	6.3	5.3	6.8	6.9	5.5	5.6
Sp.Wt	73	73	69	70	73	74	69	70
SDS	58	61	67	67	63	61	67	66
HFN	337	359	374	375	349	332	354	373
Protein	9.6	10.0	12.4	12.4	10.2	9.6	12.4	12.0
Newcastle (cv Avalon)								
Yield	9.7	10.0	10.4	10.7	10.2	9.7	10.5	11.0
Sp.Wt	80	80	80	79	81	79	80	80
HFN	253	210	279	299	248	229	265	292
Protein	9.3	9.7	11.6	12.3	10.0	9.3	11.4	12.2
Morley (cv.Avalon)								
Yield	7.8	7.9	8.7	8.7	7.8	7.7	8.8	8.7
SDS*	62	69	64	70	67	66	67	68
HFN	345	360	389	386	346	354	365	381
Protein	9.6	9.9	12.8	13.1	10.0	9.9	12.9	13.1

APPENDIX II: 1990 CROP

HGCA EXPERIMENT B: Long Ashton and Morley Sites

Site	No late fungicide 100 kgN UL	No late fungicide 100 kgN US	No late fungicide 300 kgN UL	No late fungicide 300 kgN US	Late fungicide (Tilt Turbo) 100 kgN UL	Late fungicide (Tilt Turbo) 100 kgN US	Late fungicide (Tilt Turbo) 300 kgN UL	Late fungicide (Tilt Turbo) 300 kgN US
Long Ashton (cv.Avalon)								
Yield	8.30	8.09	6.95	7.02	8.35	8.19	7.70	7.34
Protein	11.0	11.4	15.3	15.0	11.0	10.8	14.8	15.0
HFN	375	386	380	386	382	382	386	400
Long Ashton (cv.Mercia)								
Yield	9.55	9.09	8.23	7.92	9.87	9.64	9.25	8.92
Protein	10.0	10.3	14.5	14.3	9.8	10.3	14.3	14.3
HFN	363	361	371	384	368	376	368	366
Morley (cv.Avalon)								
Yield	7.40	7.66	8.88	8.92	7.34	7.86	9.20	9.22
Protein	9.4	9.7	12.3	12.1	9.6	9.8	12.5	12.9
HFN	343	350	360	367	402	394	390	403

1990 CROP - CIRENCESTER

HGCA EXPERIMENT B: CV.AVALON INCLUDING NITROGEN TIMING

Overall Mean Treatment Responses

Treatment	Yield(t/ha)	Protein	HFN	Sp. Wt.	SDS
100 kgN	4.38 c	12.28 a	422	76.0 d	70.4
200 kgN(March)	3.06 a	12.64 b	416	72.3 a	70.8
200 kgN	4.42 c	13.24 c	428	74.9 c	69.6
300 kgN	4.12 b	13.28 c	415	73.8 b	69.3
Urea Liquid	4.04 a	12.84	418	73.7 a	70.3
Urea Solid	4.22 b	12.88	422	74.8 b	69.8
Nil Fungicide	4.02 a	12.87	422	73.9 a	69.8
Tilt Turbo	4.24 b	12.85	418	74.6 b	70.3

APPENDIX III: ECONOMIC ASSESSMENT/GROSS MARGINS

In the tables below, gross margins were calculated on data provided from two contrasting sites, Long Ashton and Morley, for 1988 - 90 crops, with £95/ha included for seed, herbicide and PK fertiliser. In addition, although not tested in these experiments, it was felt reasonable to assume that chlormequat would be used at 100 kgN/ha and above, whilst a reduced rate of Terpal would be applied at 200 and 250 kgN/ha. Fungicides and growth regulators were costed at 1990 RRP whilst nitrogen was costed at 30p/kg. Grain was valued at £115/t where protein content was less than 10%, and grain values were progressively increased to a maximum premium of £13/t where protein content exceeded 12% .

LONG ASHTON: cv.AVALON, 1988 CROP.

Fungicide				**Nitrogen level(kgN/ha)**			
GS 37	**GS 65**	**50**	**100**	**150**	**200**	**250**	**Mean**
Nil	Nil	922	963	884	795	790	871
Corbel	Corbel	890	1028	987	899	843	929
Sportak	Sportak	938	1052	996	899	864	950
Cor+Spor	Cor+Spor	864	1048	969	889	835	921
Mean		**904**	**1023**	**959**	**871**	**833**	

LONG ASHTON: cv AVALON, 1989 CROP.

Fungicide				**Nitrogen level(kgN/ha)**			
GS 37	**GS 65**	**50**	**100**	**150**	**200**	**250**	**Mean**
Nil	Nil	608	618	629	532	451	568
Corbel	Corbel	511	666	611	601	436	565
Sportak	Sportak	568	672	653	557	387	567
Cor+Spor	Cor+Spor	531	581	608	561	494	555
Mean		**554**	**634**	**625**	**563**	**442**	

LONG ASHTON: cv.MERCIA, 1989 CROP

Fungicide				**Nitrogen level(kgN/ha)**			
GS 37	**GS 65**	**50**	**100**	**150**	**200**	**250**	**Mean**
Nil	Nil	818	808	791	625	679	744
Corbel	Corbel	751	896	776	676	602	740
Sportak	Sportak	767	886	727	698	608	737
Cor+Spor	Cor+Spor	785	859	865	780	623	782
Mean		**780**	**862**	**790**	**695**	**628**	

LONG ASHTON: cv.AVALON, 1990 CROP

Fungicide GS 37	GS 65	Nitrogen level(kgN/ha) 50	100	150	200	250	Mean
Nil	Nil	607	602	500	466	416	603
Corbel	Corbel	669	726	703	675	610	677
Sportak	Sportak	621	624	576	507	457	557
Cor+Spor	Cor+Spor	614	728	718	633	605	660
Mean		628	670	624	570	522	

LONG ASHTON: cv.MERCIA, 1990 CROP

Fungicide GS 37	GS 65	Nitrogen level(kgN/ha) 50	100	150	200	250	Mean
Nil	Nil	718	739	706	535	566	767
Corbel	Corbel	820	871	886	838	820	847
Sportak	Sportak	757	731	778	676	575	703
Cor+Spor	Cor+Spor	810	915	913	821	853	862
Mean		776	814	821	718	704	

MORLEY : cv.AVALON, MEAN 1988-90 CROPS

Fungicide GS 37	GS 65	Nitrogen level(kgN/ha) 50	100	150	200	250	Mean
Nil	Nil	617	693	764	765	742	716
Corbel	Corbel	616	678	769	802	799	733
Sportak	Sportak	633	710	771	767	758	728
Cor+Spor	Cor+Spor	571	690	785	787	793	725
Mean		609	693	772	780	773	

At Long Ashton, greatest gross margin in 1988, cv.Avalon, was provided by 100kgN/ha, with a gradual reduction in profitability as N amounts increased. In this year, when *Septoria tritici* was most prevalent, Sportak was the most profitable fungicide treatment, but all fungicides were more profitable than unsprayed. In 1989, again greatest gross margins were obtained for both cvs Avalon and Mercia at 100 kgN/ha with substantial penalties from 200 kgN/ha and above. In this relatively low disease year, fungicide treatment (Corbel/Sportak tank mix) was overall only profitable in cv. Mercia. In 1990 gross margin increased up to 100 kgN/ha for cv. Avalon and to 150 kgN/ha for cv. Mercia, with Corbel either alone or in mixture being more profitable than Sportak alone.

In contrast at Morley, and averaged over the 3-year study, the gross margin increased substantially as N amounts increased up to 150 kgN/ha, with a further small increase at 200kgN/ha.

At the lower rates of nitrogen, where eyespot was present but relatively low foliar disease levels, Sportak was the most cost-effective. However, at the higher rates of nitrogen, where yellow and brown rust were more problematical, Corbel was the more important fungicide.

BREADMAKING TESTS: 1989 CROP cv. AVALON (LONG ASHTON) - SPRAYED CORBEL+SPORTAK GS37 + GS 59

TREATMENT KGN/HA	(rep)	SP.WT (kg/hl)	FLOUR YIELD	FLOUR PROTEIN	GRADE COLOUR	FLOUR FN (7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
50	(i)	76.3	76.5	7.6	1.2	224	52.5	1295	15
	(ii)	75.9	76.4	7.1	0.95	214	53.0	1335	17
100	(i)	76.3	76.0	8.0	1.2	244	54.5	1395	24
	(ii)	76.0	77.3	8.7	1.8	260	56.5	1445	27
150	(i)	75.5	75.6	10.0	2.6	224	56.4	1605	36
	(ii)	75.7	75.8	9.4	1.7	252	54.5	1465	29
200	(i)	75.8	76.1	10.8	2.7	274	55.0	1565	40
	(ii)	75.3	75.8	10.8	2.8	250	55.7	1615	40
250	(i)	74.5	76.5	11.3	3.25	287	56.0	1625	43
	(ii)	74.6	75.9	11.3	3.35	210	55.9	1665	39

BREADMAKING TESTS: 1989 CROP cv. AVALON, RECEIVING 150 KGN/HA - ACROSS SITES: COMPARISON BETWEEN UNTREATED CROPS AND THOSE SPRAYED WITH CORBEL+SPORTAK GS37 + GS59

SITE	TREATMENT	SP.WT (kg.hl)	FLOUR YIELD	FLOUR PROTEIN	GRADE COLOUR	FLOUR FN (7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
Newcastle	-sprayed	76.0	75.3	8.8	3.75	237	56.5	1605	28
	-unsprayed	74.8	75.3	8.5	2.45	280	57.0	1565	36
Cirencester	-sprayed	74.2	76.9	8.7	2.30	320	57.0	1085	5
	-unsprayed	70.9	78.1	9.0	2.50	315	57.4	1275	14
Morley	-sprayed	73.4	76.0	9.7	1.90	358	57.0	1535	36
	-unsprayed	70.3	75.7	10.2	2.80	380	57.3	1640	36
Drayton	-sprayed	75.6	76.1	9.4	1.50	205	57.4	1465	24
	-unsprayed	75.6	75.4	9.2	1.30	219	54.4	1405	26
Long Ashton	-sprayed	75.6	75.7	9.7	2.15	238	55.5	1485	30
	-unsprayed	72.8	74.6	10.3	2.00	274	57.0	1585	37

BREADMAKING TESTS: 1989 CROP cv. AVALON (SITE - MORLEY)
EXPERIMENT B; EFFECT OF SOLID AND LIQUID UREA +/- TILT TURBO ON BREADMAKING QUALITY

TREATMENT	SP.WT (kg/hl)	FLOUR YIELD	FLOUR PROTEIN	GRADE COLOUR	FLOUR FN (7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
Urea Liquid	71.5	75.6	10.5	2.05	375	56.5	1585	37
Urea Liquid + Tilt T	72.6	77.2	9.8	1.60	350	57.4	1445	28
Urea Solid	71.5	75.7	10.5	2.00	359	57.2	1535	35
Urea Solid + Tilt T	73.0	75.9	10.2	1.85	346	58.2	1495	31

BREADMAKING TESTS: 1990 CROP cv.AVALON (ACROSS SITES) - UNSPRAYED

KGN/HA	SITE	SP.WT (kg/hl)	FLOUR YIELD	FLOUR PROTEIN	GRADE COLOUR	FLOUR FN (7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
50	Bridgts	77.7	77.0	8.4	-0.7	415	59.2	1265	19
50	Box'th	78.3	72.0	6.1	-2.3	359	53.0	995	0
50	Drayton	78.1	76.1	8.1	-1.3	401	57.4	1240	18
50	Morley	76.9	75.6	7.0	-1.9	250	55.2	1265	20
50	Newcast	80.6	77.0	10.5	-0.6	463	54.6	1400	29
50	RAC	74.3	75.8	11.0	-0.2	518	60.0	1370	32
150	Bridgts	77.5	77.0	10.1	0.0	472	60.0	1355	26
150	Box'th	80.4	77.0	9.2	-1.6	390	58.8	1195	17
150	Drayton	76.6	76.6	9.5	-0.7	433	58.4	1315	22
150	Morley	77.9	77.7	9.1	-1.8	427	60.5	1345	27
150	Newcast	80.9	76.6	10.8	-0.4	471	53.5	1370	23
150	RAC	72.7	75.0	12.3	0.6	507	60.4	1515	37
250	Bridgts	77.7	77.1	11.0	0.2	469	60.4	1425	24
250	Box'th	81.1	78.0	10.0	-1.4	389	59.9	1325	26
250	Drayton	76.2	76.4	10.1	-1.0	401	58.2	1355	28
250	Morley	77.6	78.4	10.8	-0.1	437	60.7	1340	29
250	Newcast	80.9	77.5	10.8	-0.1	442	53.4	1330	22
250	RAC	72.6	75.2	12.4	0.4	524	59.0	1495	32

BREADMAKING TESTS: 1990 CROP cv. AVALON (ACROSS SITES) - SPRAYED CORBEL+SPORTAK GS37 + GS 59

KG/HA	SITE	SP.WT (kg/hl)	FLOUR YIELD	FLOUR PROTEIN	GRADE COLOUR	FLOUR FN (7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
50	Bridgts	77.7	77.0	8.2	-1.0	402	58.0	1225	20
50	Box'th	78.6	76.5	6.2	-2.8	349	54.4	975	0
50	Drayton	77.2	77.0	8.5	-2.0	396	57.2	1265	21
50	Morley	76.3	76.3	7.1	-1.4	280	56.0	1225	15
50	Newcast	80.4	77.3	10.5	-0.4	463	55.5	1400	26
50	RAC	74.3	75.3	10.2	-0.9	484	57.3	1295	21
150	Bridgts	78.1	77.2	10.3	-0.2	470	61.2	1345	27
150	Box'th	80.8	77.7	8.4	-1.5	385	58.0	1145	12
150	Drayton	76.7	77.1	9.4	-1.4	426	59.3	1290	18
150	Morley	76.2	76.6	8.9	-0.8	405	58.9	1315	26
150	Newcast	81.4	78.0	11.0	-0.3	472	54.0	1420	29
150	RAC	73.0	75.6	11.8	0.2	480	58.9	1410	33
250	Bridgts	77.2	77.2	11.1	0.1	438	60.8	1415	31
250	Box'th	81.1	78.0	10.0	-1.3	397	59.3	1325	22
250	Drayton	76.3	77.0	10.2	-1.1	412	59.8	1390	29
250	Morley	76.5	78.0	10.3	-0.2	390	60.3	1315	26
250	Newcast	81.3	76.5	11.2	-0.5	457	54.5	1370	27
250	RAC	73.8	76.3	12.6	0.8	538	61.2	1375	31

BREADMAKING TESTS; 1990 CROP cv. AVALON (SITE - MORLEY) TREATMENT COMPARISONS.

KGN/HA	TREATMENT	SP.WT (kg/hl)	FLOUR YIELD	FLOUR PROTEIN	GRADE COLOUR	FLOUR FN(7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
50	Corbel	76.4	75.6	7.0	-1.9	269	55.7	1245	12
50	Sportak	76.9	76.2	7.1	-1.6	274	56.4	1225	15
50	Cor+Spk	76.3	76.3	7.1	-1.4	280	56.0	1225	15
50	Nil	76.9	75.6	7.0	-1.9	250	55.2	1265	20
100	Corbel	76.1	76.4	7.8	-1.0	362	56.4	1225	15
100	Sportak	76.5	76.7	7.9	-2.3	372	58.8	1315	24
100	Cor+Spk	76.3	76.0	7.7	-1.5	380	56.8	1225	19
100	Nil	78.1	76.5	7.9	-1.2	376	56.5	1235	17
150	Corbel	76.7	76.7	8.9	-0.8	411	59.4	1295	21
150	Sportak	77.0	77.1	9.3	-0.9	412	58.9	1275	20
150	Cor+Spk	76.2	76.6	8.9	-0.8	405	58.9	1315	26
150	Nil	77.9	77.7	9.1	-1.8	427	60.5	1345	27
200	Corbel	76.5	76.5	9.7	-0.6	413	59.0	1355	29
200	Sportak	77.0	77.4	10.0	-1.0	387	57.7	1390	30
200	Cor+Spk	75.8	76.3	9.7	-0.6	400	57.8	1355	28
200	Nil	78.0	77.6	9.9	-1.8	435	60.0	1405	29
250	Corbel	76.1	76.7	10.4	-1.0	435	59.2	1455	32
250	Sportak	77.6	78.3	10.5	-1.4	486	59.8	1385	28
250	Cor+Spk	76.5	78.0	10.3	-0.2	390	60.3	1315	26
250	Nil	77.6	78.4	10.8	-0.1	437	60.7	1340	29

BREADMAKING TESTS: 1990 CROP cv. AVALON (SITE - NEWCASTLE) TREATMENT COMPARISONS.

KGN/HA	TREATMENT	SP.WT (kg/hl)	FLOUR YIELD	FLOUR PROTEIN	GRADE COLOUR	FLOUR FN(7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
50	Corbel	81.9	77.5	10.9	-0.2	461	54.7	1345	25
50	Sportak	81.0	78.2	10.8	-0.3	452	54.5	1370	26
50	Cor+Spk	80.4	77.3	10.5	-0.4	463	55.5	1400	26
50	Nil	80.6	77.0	10.5	-0.6	457	53.6	1370	27
100	Corbel	81.4	77.0	10.7	-0.5	442	53.6	1370	23
100	Sportak	79.2	77.6	10.6	-0.9	481	52.3	1270	15
100	Cor+Spk	80.0	75.5	10.7	-0.9	468	52.5	1350	23
100	Nil	81.1	78.0	10.8	-0.4	463	54.6	1400	29
150	Corbel	80.3	77.2	10.9	-0.7	472	55.0	1420	30
150	Sportak	80.6	78.0	11.0	-0.5	460	53.2	1445	22
150	Cor+Spk	81.4	78.0	11.0	-0.3	472	54.0	1420	29
150	Nil	80.9	76.6	10.8	-0.4	471	53.5	1370	23
200	Corbel	79.0	78.0	11.1	-0.3	484	54.2	1395	22
200	Sportak	80.5	77.9	11.0	-0.4	480	54.1	1395	22
200	Cor+Spk	81.0	77.2	11.1	-0.3	471	53.0	1420	22
200	Nil	80.4	77.6	11.0	-0.4	476	55.5	1345	27
250	Corbel	80.4	77.5	11.3	-0.4	492	53.8	1395	26
250	Sportak	79.6	77.6	11.0	-0.5	460	54.0	1345	18
250	Cor+Spk	81.3	76.5	11.2	-0.5	457	54.5	1370	27
250	Nil	80.9	77.5	10.8	-0.1	442	53.4	1330	22

BREADMAKING TESTS: 1990 CROP cv. MERCIA (SITE - NEWCASTLE) TREATMENT COMPARISONS.

KGN/HA	TREATMENT	SP.WT (kg/hl)	FLOUR YIELD	FLOUR PROTEIN	GRADE COLOUR	FLOUR FN(7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
50	Corbel	78.9	78.3	9.5	-1.2	387	53.0	1245	9
50	Sportak	78.7	77.7	9.1	-1.6	379	51.2	1170	11
50	Cor+Spk	79.3	76.6	9.5	-1.5	345	52.1	1220	14
50	Nil	77.7	76.5	9.2	-1.5	378	50.6	1170	13
100	Corbel	80.0	77.0	10.0	-1.3	387	52.5	1195	9
100	Sportak	79.3	77.6	9.7	-1.1	384	52.4	1220	13
100	Cor+Spk	79.9	76.3	9.9	-1.0	347	54.0	1280	16
100	Nil	78.0	78.0	9.5	-1.3	389	52.3	1240	15
150	Corbel	79.5	77.4	9.9	-1.3	390	52.7	1245	13
150	Sportak	78.7	77.6	9.8	-0.6	400	52.0	1280	15
150	Cor+Spk	79.6	77.0	10.2	-0.7	369	52.5	1270	13
150	Nil	78.4	76.6	9.9	-0.8	405	52.2	1320	19
200	Corbel	78.6	76.0	9.9	-1.6	371	52.0	1320	19
200	Sportak	79.1	77.8	9.9	-1.0	372	53.5	1245	11
200	Cor+Spk	78.9	75.2	10.0	-1.1	379	51.2	1245	15
200	Nil	77.7	77.3	9.7	-0.9	400	51.8	1220	13
250	Corbel	79.8	77.8	10.4	-0.5	361	53.2	1270	18
250	Sportak	78.5	77.5	10.0	-1.0	403	51.9	1210	8
250	Cor+Spk	79.3	77.1	10.3	-0.8	396	53.5	1295	18
250	Nil	78.0	76.5	10.2	-0.6	415	52.0	1280	17

BREADMAKING TESTS: 1990 CROP cv. AVALON - CROPS TO WHICH NO EXTERNAL NITROGEN WAS APPLIED.

KGN/HA	SITE	SP.WT (kg/hl)	FLOUR YIELD	FLOUR PROTEIN	GRADE COLOUR	FLOUR FN(7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
UNSPRAYED									
NIL	Bridgets	77.6	76.8	8.2	-0.9	380	57.0	1285	23
NIL	Boxworth	78.1	76.4	5.6	-2.6	329	53.3	955	0
NIL	Drayton	77.5	76.0	8.2	-1.6	385	56.7	1265	17
NIL	Newcastle	80.8	77.4	10.1	-0.6	433	53.0	1320	17
SPRAYED CORBEL + SPORTAK GS 37 + GS 59									
NIL	Bridgets	78.0	76.7	8.2	-1.1	406	57.0	1285	18
NIL	Boxworth	77.7	76.1	5.6	-3.2	345	52.2	975	0
NIL	Drayton	77.4	76.6	8.1	-1.8	386	55.7	1245	18
NIL	Newcastle	81.2	77.5	10.2	-0.7	447	54.0	1350	19

EXPERIMENT B: Effects of N timing, urea and late-season fungicide

KGN/HA	TIMING	UREA S/L	FUNGIC +/-	SP.WT (kg/hl)	FLOUR YIELD	FLOUR PROTEIN	FLOUR FN(7g)	WATER ABSORP	LOAF VOLUME	LOAF SCORE
Cirencester: cv.Avalon										
200	March	S	+	72.1	75.5	11.4	552	59.5	1445	34
200	March	S	_	71.5	74.7	11.6	460	58.8	1440	32
200	March	L	+	72.0	74.9	11.6	555	60.5	1465	32
200	March	L	_	69.7	74.8	11.6	510	61.0	1430	31
200	April	S	+	72.4	75.5	12.1	523	61.2	1480	36
200	April	S	-	72.8	75.9	12.1	588	62.0	1495	33
200	April	L	+	71.4	75.6	12.0	523	60.5	1470	32
200	April	L	-	73.7	76.2	12.1	588	61.1	1530	35
Morley: cv.Avalon										
200	April	S	+	77.1	76.4	8.1	373	58.4	1250	22
200	April	S	-	77.2	76.5	8.4	422	59.8	1250	21
200	April	L	+	76.9	76.3	7.8	377	59.7	1255	20
200	April	L	-	77.0	76.0	8.0	332	59.3	1270	25

At Cirencester,in general, application of the main nitrogen top dressing in March tended to decrease breadmaking quality parameters compared with April nitrogen. Late-Fungicide treatment (Tilt Turbo) improved Flour Falling Number with March nitrogen but decreased FFN with April nitrogen. Fungicide treatment gave better quality parameters with solid urea than with liquid urea.
At Morley, fungicide treatment decreased FFN with solid urea, anf loaf score with liquid urea.

Rainfall (mm) and Temperature (oC) 1988-90

Long Ashton

Month	Rain 1987/88	Rain 1988/89	Rain 1989/90	Temp 1987/88	Temp 1988/89	Temp 1989/90
Sept	72	86	54	14.4	13.8	14.8
Oct	190	104	107	10.4	11.3	12.3
Nov	79	42	66	7.3	6.0	7.0
Dec	51	20	145	6.2	8.0	5.7
Jan	131	52	143	6.4	6.8	7.4
Feb	71	107	145	5.2	6.7	8.3
March	96	99	18	7.2	8.1	8.5
April	36	85	35	8.6	7.1	8.3
May	55	17	9	12.4	13.8	13.1
June	41	46	80	15.0	14.9	13.7
July	112	38	41	14.8	18.5	17.1
August	116	49	40	15.4	16.7	17.9

Morley

Month	Rain 1987/88	Rain 1988/89	Rain 1989/90	Temp 1987/88	Temp 1988/89	Temp 1989/90
Sept	32	59	15	14.1	13.5	15.3
Oct	127	61	41	10.3	10.7	12.0
Nov	51	38	40	6.6	5.0	6.1
Dec	27	24	106	5.9	6.1	5.0
Jan	108	33	50	5.1	5.3	6.1
Feb	25	42	83	4.3	5.4	7.2
March	82	59	20	5.7	7.6	8.2
April	23	61	47	7.9	6.4	7.9
May	37	10	28	12.0	12.5	11.8
June	17	70	46	13.5	14.0	13.3
July	129	26	23	15.1	17.7	16.1
August	35	27	18	16.2	16.9	18.6

Rainfall (mm) and Temperature (oC) 1988-90.

Cirencester

Month	Rain 1987/88	Rain 1988/89	Rain 1989/90	Temp 1987/88	Temp 1988/89	Temp 1989/90
Sept						
Oct	133	68	132	9.5	10.2	11.4
Nov	99	31	46	5.7	5.2	5.8
Dec	46	19	141	5.1	7.2	5.4
Jan	106	35	94	4.7	5.6	5.2
Feb	67	81	105	3.1	5.3	6.5
March	88	66	12	6.7	7.0	7.4
April	36	82	39	7.7	6.0	7.5
May	31	31	7	11.6	13.4	12.9
June	52	45	13	13.5	14.4	13.3
July	112	19	36	13.5	19.5	17.1
August	74		34	14.7		18.4

Newcastle

Month	Rain 1987/88	Rain 1988/89	Rain 1989/90	Temp 1987/88	Temp 1988/89	Temp 1989/90
Sept		54	14		12.3	12.6
Oct	82	96	45	8.0	9.2	10.6
Nov	65	68	27	5.8	5.1	6.2
Dec	53	26	60	5.5	6.6	3.8
Jan	83	10	55	4.0	6.3	5.4
Feb	23	50	72	4.2	5.0	5.9
March	47	34	16	5.0	5.7	7.0
April	30	49	11	6.6	5.2	7.5
May	66	21	53	9.1	10.3	10.1
June	23	67	49	12.4	12.1	11.4
July	152	5	37	13.5	15.9	14.4
August	66	68	32	14.1	14.9	17.0

SUMMARY OF RESULTS - LONG ASHTON RESEARCH STATION (1988-1990)

LONG ASHTON RESEARCH STATION

HGCA NITROGEN FUNGICIDE INTERACTIONS IN BREADMAKING WHEAT

EXPERIMENT A: SUMMARY OF RESULTS 1988 - 1990

Yield:

In 1988, cv. Avalon, base yield (unsprayed @ 50kgN/ha) was 8.1t/ha; the N optimum for both sprayed and unsprayed crops was 100kgN/ha. All fungicide treatments improved yield.

In 1989, base yield cv.Avalon was 6.29 t/ha, and cv.Mercia was 8.11 t/ha; the N optimum for both cvs Avalon and Mercia was again 100kgN/ha, with yield penalties from applications of 150kgN/ha and above. Highest yield figures were obtained from the combined fungicide programme; there were no nitrogen fungicide interactions.

In 1990, base yields for cvs Avalon and Mercia were 6.02 and 7.24 t/ha, respectively. The optimum for both cvs Avalon and Mercia was again 100kgN/ha. In cv.Avalon the increase in yield with Corbel increased as N rate increased and appeared to counteract the decrease in yield caused by high N amounts. The average yield was highest with the combined fungicide programme. In cv.Mercia, without Corbel, increasing N amounts decreased yield whereas with Corbel, yields were increased., especially in the combined fungicide programme.

Overall and across the 3 years, yield penalties for both cultivars were obtained when N amounts exceeded 100kgN/ha.

Grain Protein:

In 1988, cv. Avalon, grain protein increased linearly as N amount increased, however, a mean level of 11.66% was obtained at the lowest applied N amount (50kgN/ha). Fungicide treatments tended to decrease grain protein.

In 1989, there was a linear increase in grain protein for both cvs Avalon and Mercia as N amount increased, but 100kgN/ha was necessary to provide protein levels above 11.8%. Fungicide effects were not significant.

In 1990, with both cultivars and as in previous years, there was a linear increase in grain protein as N amounts increased, and grain protein was higher on unsprayed crops. In cv.Avalon, 100kgN/ha provided mean grain protein levels of 11.69%, whereas in cv.Mercia at 100kgN/ha grain protein was below 11%, and at 150kgN/ha mean protein level was 12.3%.

Over the 3 year period, but with the exception of cv.Mercia in 1990, all treatments that received at least 100kgN/ha provided grain protein levels in excess of 11.5%.

Hagberg Falling Number:

In 1988, cv. Avalon, Hagberg Falling Numbers were comparatively low (233) and were decreased by low N amounts, and fungicide treatments that contained Sportak. Highest values were obtained in unsprayed crops that received 250kgN/ha.

In 1989, cv. Avalon, HFN increased as N increased up to 200kgN/ha, whereas in cv. Mercia there was a significant increase up to 100kgN/ha but not thereafter. Fungicide effects were not significant.

In 1990, cv. Avalon, HFN increased as N increased up to 150kgN/ha then declined. Corbel alone increased HFN compared with other fungicide treatments. In cv. Mercia, the converse of 1989 was true, HFN increased with increasing N amounts up to 200kgN/ha. Fungicide treatments tended to decrease HFN values, especially those that contained Sportak.

In 1989 and 1990, Hagbergs in both cvs Avalon and Mercia were very high (> 300).

SDS Sedimentation:

In 1989, with both cvs Avalon and Mercia, SDS values increased with N increments up to 150 kgN/ha but at 250 kgN/ha SDS values were decreased: fungicide treatments that contained Corbel also increased SDS values

In 1990, with both cvs Avalon and Mercia there was a linear increase in SDS sedimentation values as N amount increased. In cv. Avalon, SDS was also increased by fungicide treatments that contained Corbel.

Foliar Disease:

In 1988, cv Avalon, Septoria tritici was the most prevalent pathogen, 45-62% leaf 2 area diseased on unsprayed plants, but levels of disease on flag leaves were low. Severity markedly increased between 50 and 100kgN/ha, but not thereafter. Fungicide treatments that contained Sportak substantially decreased disease severity.

In 1989, leaves cv. Avalon had completely senesced by the end of June, with only low amounts of disease on the topmost 2 leaves prior to senescence. S.tritici affected 10 - 15% of leaf 3 areas. In cv. Mercia, S.tritici, powdery mildew and brown rust affected the crop during June, with highest disease amounts on crops that received 200kgN/ha and above. Fungicide treatments that contained Sportak reduced Septoria and those that contained Corbel reduced brown rust and mildew severity.

In 1990, brown rust affected the topmost two leaves cv. Avalon (more severely than cv. Mercia), and low amounts of S.tritici were recorded on leaf 3. Brown rust severity increased at N amounts of 150kgN/ha and above; Corbel gave good control and negated the effects of nitrogen. In cv. Mercia, brown rust, mildew and S.tritici affected the crop, albeit at relatively low amounts (ca 5%). Brown rust severity increased as N amounts increased; and overall mildew was more severe at 250kgN/ha. S.tritici was unresponsive to N amounts. Overall, Corbel gave good control and decreased the N rate disease response.

With both cultivars, there were no major effects or interactions with stem based diseases, although eyespot tended to be more severe at the lower N rates and the incidence of sharp eyespot was greater in cv.Avalon at 150kgN/ha and above.

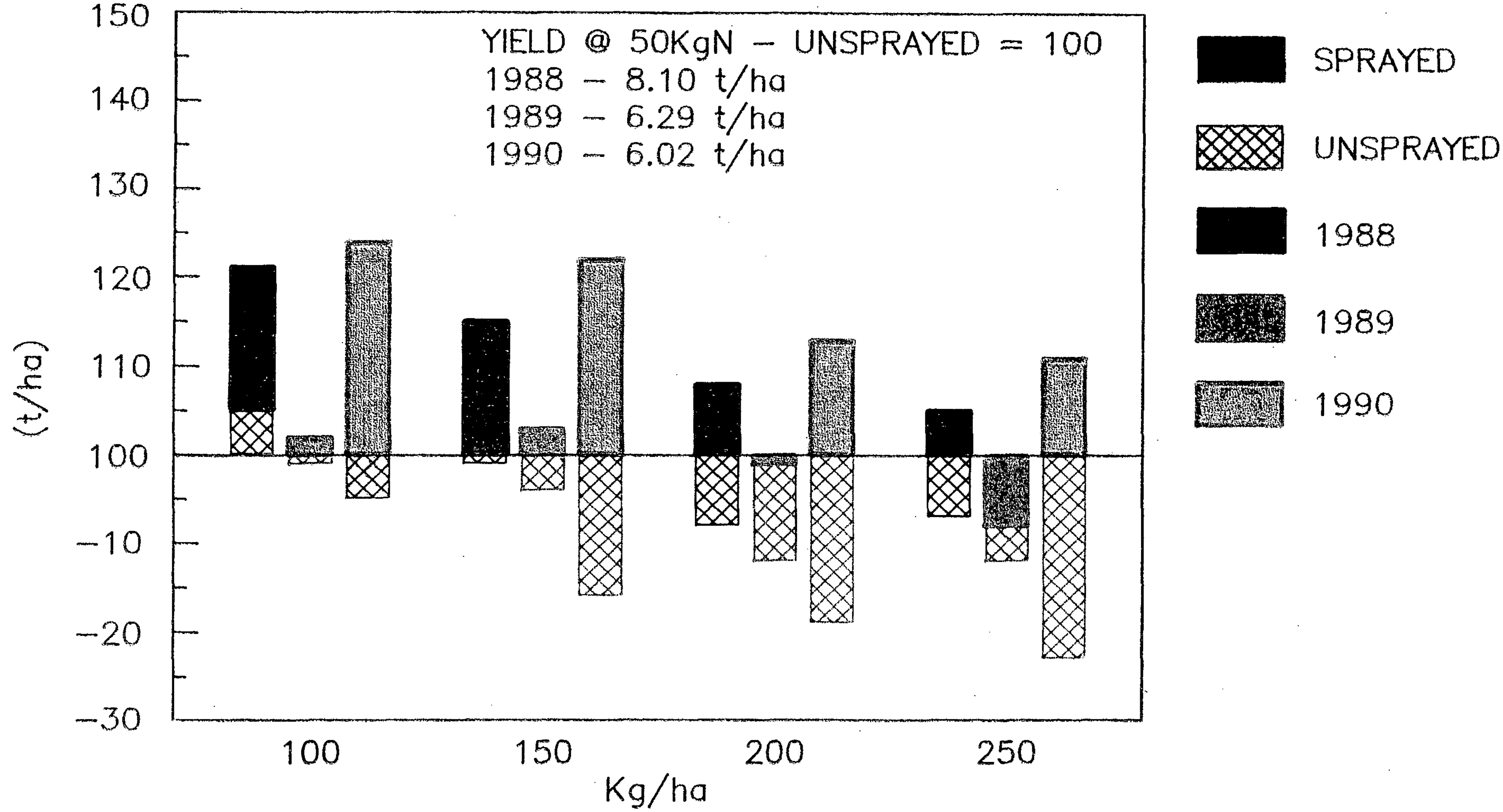
Crop Growth:

In 1988, cv. Avalon grain numbers/ear were increased at 150kgN/ha and above. Leaf size (Flag and leaf 2) was greater at 200kgN/ha than at 50kgN/ha, and high N amounts in combination with fungicide increased green leaf longevity. Ear dry weight was also higher with higher N rates. On selected florets, grain growth was greater with 50 kgN/ha than with 200kgN/ha.

In 1989,cv. Avalon, ear growth rate increased linearly, initially greater at high N, until late-June, when the rate decreased at high N due to premature crop ripening. Flag leaf and leaf 2 size was greater at higher N amounts, but fungicide treatment did not influence dry matter production. On selected florets, grain growth was greater at low N amounts, and at high N fungicide improved grain growth compared with unsprayed.
In cv. Mercia, ear dry matter production increased linearly, except in fungicide treated crops that received high N in which growth rate was much reduced in early July. Dry matter production in the topmost two leaves was greater at high N, but rate of loss was greater in fungicide treated/high N crops in July. Grain growth was greater at low N.

In 1990, in both cvs Avalon and Mercia, ear and flag leaf dry matter production was greater at high N, and unaffected by fungicide treatment.

RESPONSES COMPARED WITH UNSPRAYED @ 50 Kg N
LONG ASHTON cv. AVALON 1988–1990



LONG ASHTON RESEARCH STATION

EXPERIMENT B: SUMMARY OF RESULTS 1988-1990

Yield:

In 1988, cv. Avalon, the crop lodged. Higher yield was obtained with the lower N amount (100kgN/ha) which did not lodge as early or severely. At the higher rates of nitrogen yield was improved with fungicide treatment. There were no other effects or interactions.

In 1989, cv. Avalon, there were only significant effects of N amounts; a yield penalty (22%) was obtained with 300 kgN/ha compared with 100kgN/ha. In cv. Mercia there was a 15% yield penalty from the high N amount, but late season fungicide improved yield by 7%. There were no interactions between N level, urea or fungicide.

In 1990, high N gave a significant yield reduction in both cvs. Avalon (10%) and Mercia (9%). In cv. Mercia, urea increased yield only when applied in liquid form, and decrease in yield with high N was less with fungicide treatment. Yield in the presence of fungicide was higher, an effect unaltered by urea.

Quality Parameters:

In 1988, quality parameters were not taken due to severe crop lodging.

In 1989, high N increased specific weight, Hagberg Falling Numbers and protein in cv. Avalon, and grain protein in cv. Mercia, there were no other major effects.

In 1990, high N improved grain protein and SDS values in both cvs Avalon and Mercia but there were no effects of urea or fungicides. Overall, solid urea improved HFN in cv Avalon, and in cv. Mercia at high N, fungicide (Tilt Turbo) decreased HFN.

Foliar Disease:

In 1988, cv. Avalon, *Septoria tritici* severity was greatest on March nitrogen crops and overall, lower at the highest N amount (300 kgN/ha). There were no other major effects and interactions.

In 1989, cv. Avalon, brown rust and mildew were the most prevalent diseases on the low N crops, and *S. tritici* on high N crops. At low N amounts, brown rust levels were increased by liquid urea. In cv. Mercia, disease was mainly brown rust and mildew. In low N crops, disease was lower with liquid urea than solid, but the converse was true for high N crops.

In 1990, cv. Avalon, *S. tritici* was more severe at the lower N rate when solid urea was applied and at the higher N rate when liquid urea was applied. In cv. Mercia, *S. tritici* levels were lower than with cv. Avalon but on unsprayed crops was more severe when liquid urea was used. Brown rust was more severe at the higher N rate when liquid urea was applied.

Crop Growth:

In 1988, applying the main top dressing in March,increased flag leaf and leaf 2 size and dry matter production until mid-July when a more rapid loss occurred; tiller loss was also greater resulting in fewer ears than with April N. There were no other major treatment effects.

In 1990, cv. Avalon, ear dry matter production was greater with solid urea at 100 kgN/ha, but there wre no differences at 300 kgN/ha. Overall, higher N rate increased biomass production of the topmost two leaves but lowered ear and stem biomass.
In cv. Mercia, leaf dry matter production was greater at higher N, and also ear dry matter production, especially when urea was not used.

SUMMARY OF RESULTS, UNIVERSITY OF NEWCASTLE (1988-90)

Green leaf area

1988 - cv. Avalon. Increasing nitrogen feriliser levels enhanced green leaf area relation. Fungicides did not affect green leaf area.

1989 - cv. Avalon. Increasing nitrogen fertiliser levels enhanced green leaf area retention. Fungicides did not affect green leaf area.

1990 - cv. Avalon. No significant nitrogen or fungicide effect on green leaf area.

1990 - cv. Mercia. Green leaf area retention greater where fungicide treatment included Corbel. No significant nitrogen effect on green leaf area.

Experiment B

Yield

1988 - cv. Avalon. Mid March N applications (130 kg N/ha) had smaller yields than mid April N applications (130 kg N/ha). The lowest yield was obtained from the 230 kg N/ha April treatment. No fungicide or urea effect.

1989 - cv. Mercia. (Main N 30A/230A only). Yield significantly increased with increased N. No significant effect of fungicide or urea.

Thousand grain weight

1988 - cv. Avalon. Thousand grain weight decreased with increased N application. March applied N (130 kg N/ha) had lower thousand grain weight than April applied N (130 kg N/ha). Both fungicide and liquid urea significantly increased thousand grain weight.

1989 - cv. Mercia. (Main N 30A/230A only). No significant effects of N, fungicide, or urea on thousand seed weight.

Specific weight

1988 - cv. Avalon. Increasing N application and fungicide application reduced specific weights. No significant effect of urea on specific weight.

1989 - cv. Mercia. (Main N 30A/230A only). No significant effect of N, fungicide or urea on specific weight.

Hagberg falling number

1988 - cv. Avalon. Hagberg falling number decreased with increasing N, lodging occurred at higher N treatment. No significant effect of fungicide or urea on hagberg falling number.

1989 - cv. Mercia. (Main N 30A/230A only). Hagberg falling number significantly increased with increasing N. No significant effect of fungicide or urea on hagberg falling number.

Crude protein content

1988 - cv. Avalon. Crude protein content significantly increased with increasing N. No significant effect of fungicide or urea on crude protein.

1989 - cv. Mercia (Main N 30A/230A only). Crude protein content significantly increased with increasing N. No significant effect of fungicide or urea on crude protein.

Disease development

1988 - cv. Avalon. Septoria tritici was the most prevalent disease. Levels of infection were low, maximum of 5% infection. Septoria tritici levels were higher in low N crops. Erysiphe graminis (Mildew) was present at trace levels (infection below 1%). No significant effect of fungicide or urea.

1989 - cv. Mercia. (Main N 30A/230Aonly). Disease level very low (average infection below 1%).

Green leaf area

1988 - cv. Avalon. Increasing nitrogen fertiliser and not spraying fungicide enhanced green leaf area retention. No significant effect of urea upon green leaf area.

1989 - cv. Mercia. (Main N 30A/230a only). No significant N, fungicide or urea effect on green leaf area.

UNIVERSITY OF NEWCASTLE UPON TYNE

COCKLE PARK WEATHER

OCTOBER 1987 - SEPTEMBER 1990

MONTHLY RAINFALL
(MM)

	1987-88	1988-89	1989-90
October	82	96	45
November	65	68	27
December	53	26	60
January	83	10	55
February	23	50	72
March	47	34	16
April	30	49	11
May	66	21	53
June	23	67	49
July	152	5	37
August	66	68	32
September	54	14	45

MEAN MONTHLY TEMPERATURE

(°C)

	1987-88	1988-89	1989-90
October	8.0	9.2	10.6
November	5.8	5.1	6.2
December	5.5	6.6	3.8
January	4.0	6.3	5.4
February	4.2	5.0	5.9
March	5.0	5.7	7.0
April	6.6	5.2	7.5
May	9.1	10.3	10.1
June	12.4	12.1	11.4
July	13.5	15.9	14.1
August	14.1	14.9	17.0
September	12.3	12.6	11.5

MONTHLY AVERAGE SMD

(MM)

	1987-88	1988-89	1989-90
October	2.0	0.8	102.3
November	0.7	0.9	74.4
December	0.7	1.1	42.7
January	0.5	2.8	63.8
February.	3.5	2.6	29.7
March	5.1	2.7	33.3
April	4.6	60.5	102.0
May	20.7	35.4	71.9
June	69.7	108.4	179.0
July	15.3	90.9	92.3
August	8.5	99.2	-
September	6.0	99.9	-

SUNSHINE HOURS

	1987-88	1988-89	1989-90
October	68	82	88
November	58	97	74
December	24	50	34
January	61	68	43
February	80	97	69
March	91	116	118
April	114	118	178
May	151	203	181
June	203	89	125
July	137	219	180
August	153	168	166
September	131	106	74

SOIL CHARACTERISTICS 1988-89

Soil series - Hallsworth
Soil texture - Clay loam

NITROGEN AND FUNGICIDE INTERACTIONS IN BREADMAKING WHEAT

HGCA PROJECT NUMBER 0074/01/87

NEWCASTLE UNIVERSITY

APPENDIX 1990 CROP

HGCA EXPERIMENT A: Grain protein response (%) compared with unsprayed crops and 50 kg N/ha - (BGP)

Site	BGP (%)	0kgN	50kgN	100kgN	150kgN	200kgN	250kgN
cv. Avalon - unsprayed							
Newcastle	12.71	92	100	99	100	99	101
cv. Avalon - sprayed (Corbel/Sportak GS37 + GS55)							
Newcastle		96	99	100	100	103	104
cv. Mercia - unsprayed							
Newcastle	- 11.05	99	100	102	107	105	109
cv. Mercia - sprayed (Corbel/Sportak GS37 + GS55)							
Newcastle		103	101	106	111	109	110

HGCA EXPERIMENT A: Hagberg Falling Number response (%) compared with unsprayed crops at 50 kgN/ha - BHFN)

Site	B-HFN	0kgN	50kgN	100kgN	150kgN	200kgN	250kgN
cv. Avalon - unsprayed							
Newcastle	422.75	93	100	100	102	101	99
cv. Avalon - sprayed (Corbel/Sportak GS37 + GS55)							
Newcastle		99	96	100	100	102	100
cv Mercia - unsprayed							
Newcastle	350.00	101	100	102	99	100	104
cv. Mercia - sprayed (Corbel/Sportak GS37 + GS55)							
Newcastle		87	95	93	95	93	94

APPENDIX - H

SUMMARY OF RESULTS, ROYAL AGRICULTURAL COLLEGE (1988-90)

ROYAL AGRICULTURAL COLLEGE

HGCA BREADMAKING WHEAT NXF PROJECT

EXPERIMENT-A 3-Year summary of results

Yield

1988 - Grain yields increased with increasing applied N. Fungicides increased yield above untreated due to high disease pressure, particularly from Septoria tritici infection.

1989 - Depressed grain yields with increased spring-applied nitrogen, attributed to increased water use from higher N input when water was already severely limited. Higher powdery mildew infection on Mercia from increased N input exacerbated the above effect. Yield response to fungicide occurred only by Mercia particularly from a morpholine treatment controlling powdery mildew.

1990 - No significant nitrogen or fungicide effect on yield for Avalon and Mercia. Yields were very low.

Thousand grain weight

1988 - Thousand grain weights were not related to increasing N. Fungicides increased thousand grain weight.

1989 - Increased N fertilisation consistently decreased thousand grain weight - due to poor grain-fill attributed to water shortage. Fungicides increased thousand grain weight only on Mercia, moreso on treatments which controlled powdery mildew (Corbel).

1990 - Increased N fertilisation decreased thousand grain weight - moreso for Avalon than Mercia. Sportak and mixtures increased thousand grain weight on Mercia in the absence of observable disease levels.

Specific weight

1988 - No nitrogen effect on specific weight. Fungicide treatments giving the best disease control gave the highest specific weight.

1989 - There was an inverse relationship between nitrogen input and specific weight for Avalon and Mercia. Lowest N treatments had the greatest specific weight. Fungicides which controlled powdery mildew gave the highest specific weight for Mercia. There was no fungicide effect on specific weight for Avalon.

1990 - Inverse relationship between specific weight and applied spring N for Avalon, with no effect on Mercia. No fungicide effect on specific weight for both varieties.

Hagberg falling number

1988 - Increase in Hagberg falling number with increasing N fertiliser. No fungicide effect.

1989 - Increase in Hagberg falling number with increasing N fertiliser for both varieties. No fungicide effect.

1990 - No consistent effect of N on Hagberg falling number, but values very high. No fungicide effect.

Crude protein content

1988 - Crude protein content increased with every increment of spring-applied N. No fungicide effect.

1989 - Crude protein content increased with every increment of spring-applied N. There was no fungicide effect.

1990 - Crude protein content increased with increasing spring-applied N to 200kg/ha. There was no fungicide effect.

S.D.S sedimentation test

1988 - S.D.S. values increased with increasing spring applied N. There was no fungicide effect.

1989 - S.D.S. values increased with increasing spring applied N. Avalon - no fungicide effect. Mercia - Corbel or Corbel/Sportak had increased S.D.S. values - presumably due to controlling powdery mildew.

1990 - No consistent effect of N on S.D.S. in Avalon or Mercia. No consistent effect of fungicide on S.D.S.

Disease development

1988 - *Septoria tritici* was the major pathogen in this wet season. Surprisingly lower amounts of spring applied N encouraged higher levels of *S. tritici* until late-season. Fungicides reduced *S. tritici* in all cases.

1989 - Very low disease pressure on Avalon. Mercia had a high level of powdery mildew infection. Higher rates of spring applied N encouraged higher levels of powdery mildew. Fungicides significantly reduced powdery mildew infection particularly fenpropimorph.

1990 - Disease levels were very low throughout the season on both Avalon and Mercia.

R

SUMMARY OF RESULTS, ROYAL AGRICULTURAL COLLEGE (1988-90)

ROYAL AGRICULTURAL COLLEGE

HGCA BREADMAKING WHEAT PROJECT

EXPERIMENT B

Yield

1988 - Mid-March nitrogen (N) applications had smaller yields than April applied N. Yield increased with increasing N application at GS31. Control of Septoria tritici with fungicide significantly increased yield.

1989 - There was a decrease in yield with increasing spring applied N. This was attributed to poor grain-fill at higher N levels because of insufficient water available to fill the increased number of grains. March applied N had lower yields than April applied N.

1990 - Yields were low. Trends were similar to those of 1989. There was a fungicide effect in the absence of observable disease.

Thousand grain weight

1988 - Thousand grain weights (tgw) were inconsistent with applied N. Fungicides increased tgw.

1989 - Thousand grain weights were significantly reduced with N increments due to poor grain-fill. March applied N had lower tgw than April applied N. No fungicide or urea effect.

1990 - Results were similar to 1989.

Specific weight

1988 - No N, fungicide or urea effect on specific weight.

1989 - Specific weight was inversely proportional to N input. No difference between March and April applications. No fungicide or urea effect.

1990 - Similar trend to 1989 except March N had significantly lower specific weights. Fungicide increased specific weight.

Hagberg falling number

1988 - The lowest N rate had the lowest Hagberg falling number (HFN). No difference between the other treatments. No difference between March and April N timings. No fungicide or urea effect.

1989 - Similar to 1988, although values were much higher.

1990 - HFN's very high. No significant N,fungicide or urea effect.

Crude protein content

1988 - N application significantly increased crude protein (CP) content. March N had significantly lower crude protein content than similar amounts applied in April. Solid urea application had significantly higher CP values compared to liquid urea - the reason being unclear. No fungicide effect.

1989 - Similar response of CP to N input as 1988 except no difference from timings and no urea effect.

1990 - Again increases in CP to applied spring N. March N had lower CP than April N. No fungicide or urea effect.

Sodium dodecyl sulphate (SDS) sedimentation test

1988 - Values exactly resembled CP values. As applied N increased so did SDS values. March N had lower SDS values to April N. No fungicide or urea effect.

1989 - Only the lowest N level had significantly lower SDS values. No fungicide or urea effect.

1990 - No significant nitrogen, fungicide or urea effect on SDS.

Disease development

1988 - Lower levels of applied N tended to have higher *S. tritici* infection early season. Late season differences were not apparent. March applied N tended to have higher disease levels especially *S. tritici* early-season. Fungicide gives good control of disease levels. Foliar urea application tended to increase *S. tritici* infection.

1989 - Slight infections of S. tritici occurred. Lower N rates tended to have higher infection levels. Fungicide reduced S. tritici levels. There were no urea effects.

1990 - Disease was minimal in this very dry year.

Green leaf area

1988 - Green leaf area (gla) was maintained by increased spring applied N. There was little N - timing effect. Control of disease significantly retained gla. There was little effect of urea upon gla.

1989 - Gla was largely influenced by a hot dry summer. Many early season N effects were rapidly reduced.

1990 - March N had a significantly lower gla than April applied N. This was possibly due to an early vegetative growth increasing water loss from the soil. As the season progressed acute water stress dominated gla. Liquid urea had a lower gla in the absence of scorch. No fungicide effect.