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RYE AND TRITICALE IN THE UK

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RYE AND TRITICALE IN THE UK

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1. ABSTRACT

Rye is an ancient cereal and, worldwide, is second only to wheat as the grain most commonly used for the production of bread; in the UK it is mainly used for crispbread production. Triticale, a relatively new hybrid of wheat and rye was introduced to UK farmers in the early 1980's and is used mainly as a component of animal feed.

The area of each crop grown in the UK currently represents approximately 0.2% of the total cereal area of 4 million hectares but there is scope for an increase in production. For rye, this is mainly dependent on achieving grain of sufficiently high Hagberg Falling Number (HFN) to replace imported grain. With triticale, improved continuity of supply to satisfy the demand from animal feed compounders is all that appears to be necessary.

Rye and triticale, being crops of minor national importance, have attracted only limited funding for research into their husbandry requirements.

This review brings together the results of trials published and unpublished, conducted on the husbandry of both crops throughout the UK since the mid 1970's. Comparisons with other cereal species are also made and recommendations are given for crop husbandry and future work.

1.1 Rye

Rye tends to be tall and prone to lodging. Currently, four cultivars are most likely to be available for commercial production in the UK: Animo, Merkator, Halo and Sentinel. All are acceptable for crisp bread production. In trials, only Sentinel appeared to offer significant yield advantages over the older cultivar Animo. All were shorter than Animo but equally susceptible to lodging.

Although some commercial organisations recommend seedrates in excess of 185 kg/ha, ADAS experiments demonstrated that high seedrates aggravated lodging and reduced yield; seedrates of 50 kg/ha produced 0.5 t/ha greater yield than 150 kg/ha. It is suggested that 100 kg/ha provides adequate insurance for poor establishment and overwinter plant loss and should be used for all but the poorest seedbed conditions.

Rye is less susceptible than wheat, barley and triticale to attack by the take-all fungus Gaeumannomyces graminis. Experiments have shown that in that part of the rotation at risk from take-all, it may benefit relatively more than other cereal species from early sowing which in turn can substantially reduce the risk of nitrogen leaching.

Application of autumn nitrogen did not affect yield but increased early lodging and is not recommended. Spring nitrogen application reduced HFN in both the presence and absence of lodging. The optimum level of nitrogen for yield was dependent on lodging risk but even with sequential PGR application, there was evidence that 100 kg/ha N was optimum on N Index 0, light soils.

Chlormequat applied at GS31 did not always reduce the amount of lodging at harvest but in most experiments it increased yields. Later applications of mepiquat chloride plus ethephon (Terpal) or ethephon (Cerone) tended to produce marked reductions in crop height and lodging and similar or greater yield responses than chlormequat.

There was insufficient evidence to demonstrate any potential benefits of sequential applications of chlormequat, followed by Terpal or Cerone.

Although rye is susceptible to a range of foliar diseases and the stem-base disease eyespot (Pseudocercosporella herpotrichoides), it is speculated that the need to control late attacks of foliar diseases is less than in wheat. In experiments between 1978 and 1981, fungicide controlled mildew but did not affect yield. By contrast, control of Rhynchosporium secalis and eyespot increased yields by 0.6 to 1.0 t/ha. In experiments currently in progress, control of mildew has produced yield increases of more than 1.0 t/ha.

HFN is an important determinant of grain quality which may be affected by pre- and post-maturity alpha-amylase activity. In experiments, reductions in HFN occurred when harvest was delayed following a rainfall event which increased grain moisture content. The results suggest that there may be advantage in harvesting early (at 20% moisture content) and drying the grain.

On light soils prone to drought, when grown as a second or third cereal, rye produced similar or much better yields than winter barley. It also produced better yields than triticale and substantially out-yielded winter wheat. Take-all was considered to be mainly responsible for the differences in yield between species but early development in rye probably makes it less drought susceptible. It was observed that small cost savings in nitrogen and fungicide applications were partially eroded by the need to use PGR's. Thus, any economic advantages of growing rye are most likely to be related to the yield and premium paid for grain quality.

It is recommended that further studies are carried out on HFN, cultivars, seedrates, sowing dates, nitrogen, growth regulating mechanisms, disease control, rotations, water relations and nitrogen leaching.

1.2 Triticale

Following the introduction of several cultivars with a disappointing performance into the UK in the early 1980's, newer cultivars of triticale are now available giving improved yields and more consistent quality. In trials between 1985 and 1988, the overall yields of Lasko, Salvo, Cumulus, Purdy and Polo were not significantly different. Differences in field characters, disease resistance and grain quality were apparent, particularly notable being the better straw strength of Salvo, Cumulus and Purdy.

Experiments on light soils produced no yield response to seedrates in excess of 60 kg/ha. However, variation in mean grain weight was noted within and between cultivars and it may be best to use seedrates based on a number rather than a weight of seed per unit area; a realistic target to aim for would be 200-250 plants/m^2 established.

On light soils, there was a consistent advantage to sowing in the second half of September compared with October and November. Early sowings tended to increase grains/m^2, mean grain weight, dry matter accumulation and straw height. Like wheat, but in contrast to rye and barley, lodging of triticale was aggravated by early sowing. On heavier, more fertile soils, a yield reduction occurred when sowing was delayed until early December but there were no differences between September and October sowings. Sowing should take place in the second half of September on light soils or where winter growth was likely to be limited, and from October onwards on fertile soils.

Despite wide variation in response to spring nitrogen, the mean optimum level of nitrogen for Lasko and Salvo was 120-160 kg/ha on N Index 0 mineral soils. Limited data suggest that 40 kg/ha N is sufficient on peat soils or more fertile mineral soils. Successive nitrogen increments decreased mean grain weight and specific weight and increased crop height, lodging, grains/m^2 and grain nitrogen content. Other results demonstrated the importance of applying a proportion of the total spring nitrogen in early March as an insurance against poor uptake in April during dry weather. No information is available on the effects of autumn nitrogen but it is suggested that there is no underlying physiological mechanism justifying its use and it should be avoided on grounds of nitrogen leaching.

In ADAS experiments, chlormequat at GS30/31, or mepiquat chloride plus ethephon (Terpal) or ethephon (Cerone) at GS37/39 increased yields of Lasko by an average 0.6, 0.7 and 0.2 t/ha respectively; Terpal or Cerone following chlormequat both increased yields by approximately 1.0 t/ha. In IACR experiments, chlormequat had variable effects on lodging control in Lasko, only increasing yields when lodging was prevalent. Single applications of Cerone increased yields by 0.4 to 0.5 t/ha irrespective of lodging but when lodging was severe in a vigorous crop, sequential and double rate applications of chlormequat followed by Cerone gave yield responses in excess of 2.0 t/ha. Although some growth regulator treatments produced significant effects on yield components, the effects were not consistent. In most experiments, trends in height reduction and lodging control were similar to trends in yield promotion. However, not all the yield increases could be ascribed to lodging control; yields were sometimes increased in the absence of lodging. Furthermore, as in rye, there was some evidence to suggest that cultivars may respond differently to treatments with growth regulators irrespective of their resistance to lodging.

The yield response of triticale to a programme of fungicides was generally less than 5% and uneconomic whereas in wheat, the response averaged 12% (up to 34% in one experiment). However, substantial yield increases of over 0.7 t/ha were occasionally obtained by applying a programme of fungicide sprays even when disease was absent or at low levels. The main diseases reported to affect triticale were eyespot, Septoria nodorum and yellow rust (Puccinia striiformis). Resistance to take-all differed within a few hexaploid cultivars but was generally intermediate between wheat and rye and similar to barley. Differences also occurred between cultivars in their resistance to cereal cyst nematode (Heterodera avenae) and ergot (Claviceps purpurea).

As with rye, there is a shortage of herbicides recommended for post crop emergence grass weed control in triticale.

The design of some experiments did not always allow valid comparisons of cereal species. However, valid comparisons were made in two series of experiments conducted in second and third cereal situations between 1986 and 1988. When good commercial husbandry practice was applied to each species on medium to light soils, triticale was normally higher yielding than wheat but lower yielding than barley. In the presence of a low-input regime on light soil, yields of triticale were markedly higher than those of wheat and similar to barley. On heavy soils, triticale was out-yielded by barley but not wheat. Take-all undoubtedly influenced yields in these experiments. Despite potential savings in fungicide costs, yield is the most important factor in growing triticale profitably.

It is recommended that further studies are carried out on cultivars, seedrates, growth regulating mechanisims, disease control and water relations.

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2. ABBREVIATIONS

ADAS	Agricultural Development and Advisory Service
EC	European Community
EHF	Experimental Husbandry Farm
HFN	Hagberg Falling Number
HGCA	Home-Grown Cereals Authority
IACR	Institute of Arable Crops Research
IPSR	Institute of Plant Science Research
LARS	Long Ashton Research Station
LSD	Least Significant Difference
MRC	Morley Research Centre
NAS	Norfolk Agricultural Station (recently re-named Morley Research Centre)
NIAB	National Institute of Agricultural Botany
NSA	Nitrate Sensitive Area
PBI	Plant Breeding Institute
RES	Rothamsted Experimental Station
SAC	Scottish Agricultural College
UK	United Kingdom
WPBS	Welsh Plant Breeding Station

3. INTRODUCTION

The aim of this paper is to review Research and Development work on rye and triticale which has been conducted in the United Kingdom (UK) in order to formulate husbandry requirements and draw comparisons, where possible, with the major cereal species in terms of yield, quality, disease susceptibility and profitability. Areas where current information is inadequate are also identified.

Despite links in their breeding the two species have diverse histories and uses and some brief comment is worthwhile.

3.1 Rye

3.1.1 Origin and areas of production

Rye (Secale cereale L.) is second only to wheat as the grain used most commonly for the production of bread worldwide (Bushuk, 1976). Because of the extreme hardiness of the rye plant and its ability to grow in sandy soils of low fertility, rye can be grown in areas that are generally not suitable for other cereals. The greatest production is in the cool temperate zones of the world with the Soviet Union being the leading producer, followed by Poland and Germany (Janick et al., 1974).

Although rye was brought into cultivation later than wheat, its primary centre of origin appears to be similar to that of wheat, namely in South-Western Asia (Deodikar, 1963) and it is considered to have moved into Northern Europe during the first millennium BC. Most of the cultivated rye is of the diploid type. In relation to major cereals such as wheat, the number of cultivars grown is low. Rye is a cross-pollinated crop. It is extremely difficult to keep cultivars pure and considerably less effort has been expended in breeding compared to most other temperate small grain cereals.

The area of rye grown in the UK decreased from approximately 28,000 hectares in 1953 to only 4,000 hectares in the late 1960's (Anon., 1970). Thereafter, there was a small increase but the area remained relatively constant and was recorded as 7,354 hectares in 1988 (Anon., 1988a). This represents less than 0.2% of the total UK cereal area (approximately 4 million hectares) and categorises rye as a cereal of minor national importance in relation to other cereals such as wheat or barley. It is grown mainly in East, Central and Southern areas of England frequently on soils which are prone to drought.

3.1.2 Uses and markets

The most important use of rye grain in the UK is in crispbread production (G.L. Jones, ADAS, Cambridge, pers. comm.), which utilises over half the total UK production which was 32,000 tonnes in 1986 (Anon., 1988b).

Manufacturers of crispbread prefer to use a 50:50 balance between imported (mainly from Denmark and Spain with some from France) and home-grown grain in order to safeguard supplies. The poor quality of the UK crop in some years has further encouraged these main processors to maintain this significant import insurance. More consistent high quality produce from the UK would obviously encourage a reduction in imports.

Following recent increases in the popularity and consumption of health foods, a small but increasing amount of rye grain is used in British style granular wheat bread. Other uses for human consumption include rye flour production and as a sauce thickener (G.L. Jones, pers. comm).

The HFN of rye grain is a particularly important aspect of quality in relation to milling and baking terms. The grain is inherently susceptible to high alpha-amylase activity and low HFN.

Crispbread manufacturers require rye grain with an HFN preferably greater than 125 but will accept grain above 90 HFN. In reality, it is the sugar content which determines the suitability of the grain for crispbread manufacture; too much causes the crispbread to bubble during the baking process (M.D. Clark, Ryvita Co. Ltd., Poole, pers. comm.). However, the HFN gives a rough indication of the likely sugar content and is the chosen measure of quality initially, because it can be determined relatively easily and quickly.

Rye grain which is unsuitable for human consumption can be used as an animal feed. Although its nutritive value is comparable with wheat, as a feedstuff, palatability problems and growth-inhibiting factors associated with rye have restricted its use. The compounds causing the feeding problem have not been positively identified; the pentosans, trypsin inhibitors and alkylresorcinols have been suggested. However, the structure of the endosperm cell walls, which is markedly different in rye, wheat and triticale grains, may be responsible for the low accessibility of rye nutrients to the action of digestive enzymes (Rakowska et al., 1988).

3.2 Triticale

3.2.1 Origin and areas of production

Triticale is a 'man-made' cereal with only a short history. Its name reflects its breeding which is a hybrid between wheat (genus Triticum) and rye (genus Secale). Rye crossed with breadwheat (Triticum aestivum) produces octoploid triticales and rye crossed with durum wheat (Triticum durum) produces hexaploid triticales. At present, most of the triticales grown are of the latter derivation (Mann, 1985).

Wheat and rye were first crossed in 1875 by a Scottish botanist, Stephen Wilson but the results were disappointing (Smith, 1983). The plants were sterile because the two parents contained different numbers of chromosomes. In 1937, Pierre Givaudon of France found that treating seedlings with colchicine caused a doubling of the chromosomes and potentially fertile plants. This discovery opened the door for the development of triticale from a laboratory curiosity into a potential food crop.

In the mid 1950's, Dr J G O'Mara of Iowa State University, successfully applied Givaudon's technique to a hybrid of rye and durum wheat and produced hexaploid triticale which then became the subject of large-scale seed production. By 1974, American researchers had bred vastly improved cultivars attaining yields up to nearly 10 t/ha, comparable with the best wheats (Smith, 1983). Its production has spread to many parts of the world from the United States of America to the Soviet Union, China, South America and Europe, including the UK. Approximately 7,680 hectares of triticale were grown by UK farmers in 1989 (Anon., 1989a).

3.2.2 Uses and markets

Triticale, being a cross between rye and wheat, is considered potentially to have the combined qualities of both parents. Like rye, it is hardier than wheat and may be cultivated successfully in harsh environments. It also has good disease resistance, particularly to powdery mildew (*Erysiphe graminis*).

Triticale and wheat contain similar grain protein levels but triticale contains a larger proportion of lysine, which is relatively deficient in most cereal proteins (Smith, 1983).

In the UK, triticale has not gained wide acceptance for human consumption and is largely used as an animal feed. Soon after its introduction into the UK in the early 1980's, triticale was regarded with suspicion by feed compounders and was difficult to market. This was largely due to wide variations in protein content of farm-produced grain, coupled with poor continuity of supplies as a result of the relatively small area grown.

More recently, improved cultivars have reduced the variation in protein and compounders' interest is returning but there still remains the local problems of continuity of supply (C.G. Green, Semundo Ltd., Cambridge, pers. comm.).

Unlike rye and the major cereals, there is no EC intervention support for triticale.

3.3 Previous research

Rye and triticale have attracted only limited funding for research into their husbandry requirements. Indeed, some suggestions for the husbandry of rye, for example sowing date and seedrate, are often conflicting and frequently appear to be based on arbitrary past practice.

Although triticale has attracted slightly more funding than rye, the grower has had to rely to some degree on enlightened guess work for its husbandry.

4. RESEARCH AND DEVELOPMENT

4.1 Cultivars

Plant breeding has done much to enhance yields of the major cereals. Silvey (1986) estimated that in the 36-year period 1947-1983, the adoption of new cultivars contributed 45% and 38% to yield improvements in wheat and barley respectively.

The fact that rye and triticale are of minor national importance is reflected in the limited number of cultivars available and in the non-availability of rye cultivars bred in the UK.

There are no National List requirements for rye or triticale and hence no statutory performance testing (Furber, 1986). However, NIAB co-ordinated a trial series based at NIAB centres, EHF's and commercial farms in conjunction with ADAS.

4.1.1 Rye

Six cultivars are currently available for commercial production in the UK. Four of these, Animo (which has been widely grown in the UK since 1977), Halo, Merkator and Sentinel, are most widely available (Anon., 1989b) and their relative yields and field characters are shown in Tables 1 and 2.

Table 1. Yield of grain as % of Animo, straw height (cm) and lodging (%) of rye cultivars (mean 1985-88).

Cultivar	Yield as % of Animo (6.11 t/ha)	Straw height (cm)	Lodging (%)
Sentinel	107	133	48
Halo	105	137	49*
Merkator	102	136	52
Animo	100	149	48

* = adjusted means

Source: NIAB, Cambridge

Table 2. Grain specific weight in kg/hl (mean 1986-88) and grain protein as % in dry matter of rye cultivars (mean 1986-87)

Cultivar	Specific weight (kg/hl)	Protein (%)
Sentinel	73.5	11.2
Halo	73.3	11.8
Merkator	74.3	11.8
Animo	72.7	12.9

Source: NIAB, Cambridge

All of the cultivars have rather long, weak straw and similar maturity although Halo, Merkator, and Sentinel had slightly shorter straw than Animo (Anon., 1989b). Differences in yield of less than 6% were not significant, so Sentinel was the only cultivar to significantly out-yield Animo, the oldest cultivar on the List. Animo had the lowest grain specific weight but the highest protein content.

Two other cultivars grown commercially but not tested in NIAB trials are Danko from Germany and Admiral from the Netherlands. Their performance and characteristics are similar to those of the cultivars described above (G.C. Mann, pers. comm.).

There is currently no comparative information available on the relative differences in HFN between cultivars. However, one leading crispbread manufacturer will accept any of the cultivars mentioned, provided the HFN and normal criteria are met (M.D. Clark, Ryvita Co. Ltd., Poole, pers. comm.).

4.1.2 Triticale

During the early 1980's, triticale cultivars bred at the PBI, Cambridge were released for commercial use. Supplies of seed were limited and in order to meet farmer demand, some seed companies imported and marketed cultivars such as Aquarius, Bokolo and Grace. The performance of these cultivars in relation to modern cultivars and those bred at the PBI was extremely disappointing (Anon., 1985) and some farmers became discouraged from further attempts at growing triticale.

Newer cultivars of triticale are now available giving improved yields and more consistent quality. However, as with rye, few are available for commercial production. Their relative yields and some characteristics are shown in Tables 3 & 4. The experiments were conducted on up to eight light to medium textured soils in East, Central and Southern England.

Table 3. Yield of grain as % of Lasko and Salvo (mean 1984-88), straw height (cm) and lodging (%) of triticale cultivars (mean 1985-88).

Cultivar	Yield as % of Lasko and Salvo from all trials	Yield as % of Lasko and Salvo from light soils only	Straw height (cm) all trials	Lodging (%) all trials
	(6.54 t/ha)	(5.96 t/ha)		
Lasko	100	102	113	41
Salvo	100	98	104	18
Cumulus	103	102	117	13
Purdy	104	103	112	(16)
Polo	104	105	121	(49)

( ) = limited data

Source: NIAB, Cambridge

Table 4. Grain specific weight (kg/hl) and grain protein % in dry matter of triticale cultivars (mean 1986-88).

Cultivar	Specific weight (kg/hl)	Protein (%)
Lasko	68.9	13.9
Salvo	66.5	13.1
Cumulus	66.6	13.3
Purdy	66.8	12.7
Polo	69.5	12.9

Source: NIAB, Cambridge

Yield differences less than 6% between cultivars over all trials and less than 10% between cultivars on light soils were not statistically significant. Thus, yield differences between cultivars are not significant. However, the cultivars demonstrated relatively large differences in field characters. These ranged from Polo having long, weak straw to Salvo having medium-height straw of above average strength. Lasko and Polo produced the best grain specific weight and Lasko the greatest protein content.

The NIAB (Anon., 1989b) have also published limited data on disease ratings for these cultivars from two years of inoculated trials (Table 5).

Table 5. Disease resistance ratings expressed on a 1-9 scale (1 = very susceptible; 9 = highly resistant) of triticale cultivars in inoculated trials.

Cultivar	Yellow rust	*Septoria nodorum*	Eyespot
Lasko	5	(4)	(3)
Salvo	(5)	(5)	(6)
Cumulus	(6)	(5)	(6)
Polo	(5)	(5)	(3)
Purdy	7	(6)	(7)

( ) = limited data   Source: NIAB, Cambridge

Varieties are still virtually immune to mildew and although no brown rust or *Septora tritici* were observed in trials, this does not rule out the possibility of these diseases occurring.

4.2 Seedrate

As with other cereals, wide variations in rye and triticale seedrates may be tolerated without affecting yield. Both crops are most likely to be grown on light soils where seedbeds are relatively easy to achieve and there is good seed/soil contact. Assuming the seed is viable, the resulting germination should be high.

4.2.1 Rye

Some trade organisations recommend seedrates in excess of 185 kg/ha. However, it is common practice for growers to sow approximately 125 kg/ha. The mean grain weight of rye seed is 33 g per 1000 grains. Thus, seedrates of 185 kg/ha would represent about 560 seeds/m^2.

Seedrates reduced to 125 kg/ha would still represent about 380 seeds/m^2, almost equivalent to the 400 seeds/m^2 recommendation for sowing winter barley when establishment conditions are poor (Anon., 1984).

Experiments on seedrates for rye grain production were carried out on loamy sand at Gleadthorpe EHF in Nottinghamshire between 1979 and 1981. The rye cv. Dominant, was sown in late September (Table 6).

Table 6. Effect of seedrate on the grain yield (t/ha at 85% DM) of rye in 1979, 1980 and 1981.

	Seedrate (kg/ha)					
Year	50	100	150	200	250	LSD (5%)
1979	-	5.9	6.0	5.8	-	0.28
1980	5.2	-	4.5	-	3.9	0.39
1981	4.0	-	3.7	-	3.7	0.47

Source: ADAS, Gleadthorpe EHF

In 1979, in the absence of lodging, seedrate had no significant effect on yield. In 1980 and 1981 lodging occurred. It was aggravated by the seedrate increments and the greatest yields were achieved from the lowest seedrate (50 kg/ha), albeit not significantly so in 1981. Differential nitrogen and growth regulator treatments were also included in these experiments. However, irrespective of their use, the lowest seedrates gave the greatest yield. It was concluded that, although crops grown at low seedrates were often taller than those sown at high rates, they lodged less because they were stiffer strawed.

4.2.2 Triticale

Seedrate recommendations for triticale range between 125 to 185 kg/ha or "as for wheat".

Seedrates between 20 and 200 kg/ha in 20 kg increments were compared by ADAS on loamy sand soil at Gleadthorpe EHF in the years 1983 to 1985. A selection WTCB 134 was used in 1983 and cv. Lasko in 1984 and 1985. The effect of seedrate on yield of grain, plant population and yield components was assessed (Table 7).

Table 7. Effect of seedrate on the grain yield (t/ha at 85% DM), spring plant population/m^2, ear population/m^2, number of grains/ear and 1000 grain weight (g at 85% DM) of triticale (mean 1983-85).

Seedrate (kg/ha)	Seedrate (seeds/m^2)	Yield (t/ha)	Spring plant population/m^2	Ear population/m^2	Grains/ ear	TGW (g)
20	56	4.7	78	355	55	40
40	111	5.0	111	399	51	39
60	167	5.2	150	438	49	38
80	222	5.1	176	459	45	37
100	278	5.1	197	499	45	36
120	333	5.2	207	485	42	37
140	389	5.1	244	520	40	36
160	444	5.1	270	568	40	36
180	499	5.1	305	569	40	36
200	555	5.1	363	594	39	35
LSD (5%)		0.24	36.4	53.0	3.4	1.3

Source: ADAS, Gleadthorpe EHF

As expected, spring plant population and ear population were positively correlated with seedrate increments; grains per ear and 1000 grain weight were negatively correlated. Yields increased with each seedrate increment up to 60 kg/ha (167 seeds/m^2) but not thereafter. Significant yield increases from seedrates above 60 kg/ha were not obtained in any of the years. There was no significant yield increase in 1984 and 1985 above 40 kg/ha.

Similar effects were also observed in an experiment conducted by Semundo Ltd. at the Guinness Barley Research Station, Wiltshire in 1981, using the cultivar Lasko (D.M. Miles, Semundo Ltd., Warminster, pers. comm.). Four equal seedrate increments between 60 and 240 kg/ha (165 and 660 seeds/m^2) were compared. There was no yield advantage by increasing the seedrate above 60 kg/ha.

In both the ADAS and Semundo experiments, it was also observed that seedrate increments reduced crop height but increased lodging. Similar, albeit non-significant effects occurred when two seedrates were compared by the PBI at Cambridge and Icklingham (R.S. Gregory, IPSR, Norwich, pers. comm.). Although these results imply that low seedrates of 60 kg/ha may be used for triticale without adversely affecting yield, it is important to consider other factors which may influence the amount of seed which should be sown. Triticale is often sown on heavier soils than those on which the experiments were conducted. Thus, an increase in seedrate might be necessary to allow for reduced establishment in poorer or coarser seedbeds. Also, large differences in mean seed weight can occur within and between cultivars. For example, seed supplied for testing in the NIAB/ADAS cultivar trials at Gleadthorpe in 1983 and 1984 varied according to cultivar between 32 g and 53 g per 1000 grains (McDonald, 1984). Assuming that these traits still occur in cultivars it may be prudent for growers to make appropriate adjustments to triticale seedrates and to sow on the basis of seed number rather than weight. A realistic target might be to aim for 200 - 250 plants per m^2 at the end of the winter as in wheat or barley. However, on light soils in particular, a lower target could be considered which would serve to reduce seed costs and minimise the risk of lodging.

4.3 Sowing date

Theoretically, the earlier a crop is sown, the more radiation it intercepts, the greater the dry matter production (Gallagher & Biscoe, 1978; Monteith & Elston, 1983) and therefore the greater the yield potential (Biscoe, 1979; McLaren, 1981).

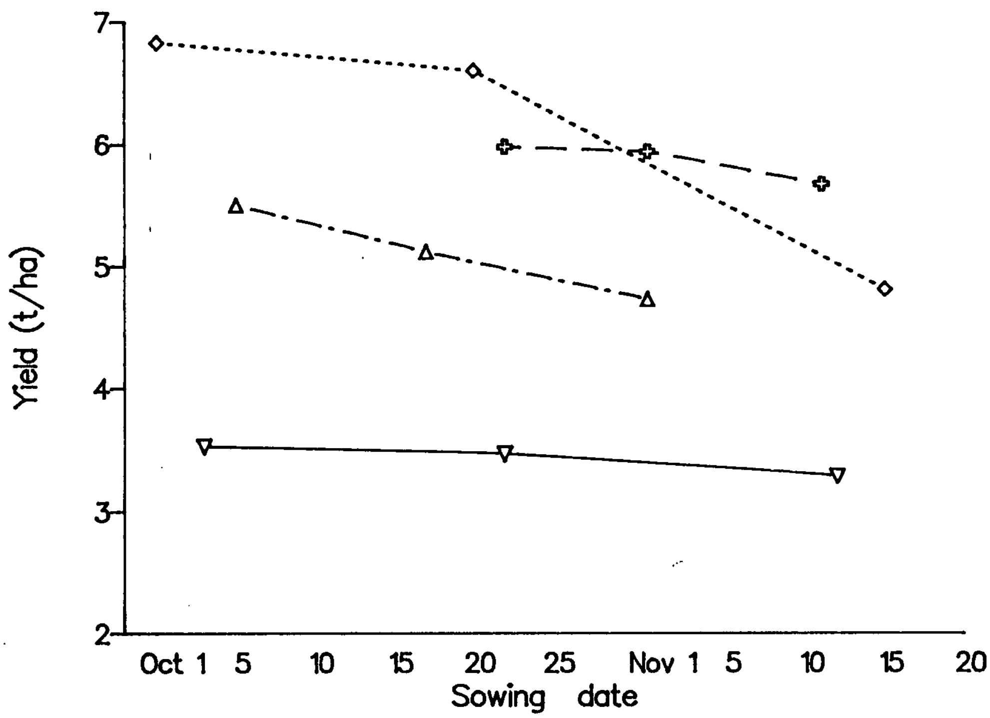
Root development in early-sown crops also tends to be further and faster (Barraclough & Leigh, 1984) and maturity is advanced (McDonald, 1987), thus helping to avoid the effects of drought conditions which often prevail on very light soils.

The potential benefits of early sowing may be eroded by increased susceptibility to lodging and disease, especially eyespot (Pseudocercosporella herpotrichoides) and take-all (Gaeumannomyces graminis) (Fielder, 1988). Rye and triticale are considered to be less susceptible to take-all and may therefore be more suitable than other cereals for early sowing.

4.3.1 Rye

In each of the years 1976 to 1979, rye (cv. Dominant) was sown at Gleadthorpe EHF on three dates. The aim was to sow in early October, mid-October and late October/early November. The precise sowing dates were not always achieved due to inclement weather and poor seedbed conditions. The range of sowing dates and yields are summarised in Fig. 1.

Each year there was a yield reduction, albeit not always statistically significant, when sowing was delayed. Overall, the reduction was greatest at the latest sowings. Unfortunately, not all of the sowing dates were early enough to test current commercial practice which is to sow rye before other winter cereals. Frequently, this occurs in early September in many parts of Eastern England.



Source: ADAS, Gleadthorpe EHF

Figure 1: Yield response of rye to sowing dates in Autumn ▽, 1976; ✚, 1977; ◇, 1978; △, 1979.

Work started at Gleadthorpe EHF, in autumn 1988, indicated that lodging risk in rye increases with later sowing date (Table 8); thus, rye would appear to resemble winter barley rather than winter wheat in this respect (Fielder, 1988). Yield decreased linearly when sowing was carried out after 21 September (Table 8) and was strongly correlated (P=0.01) with the increase in lodging. Grain specific weight (average of 75 kg/hl) and HFN (average of 289) were not affected by sowing date in this experiment.

Table 8. Lodging (%) and grain yield (t/ha at 85% DM) of rye (cv. Halo) sown at 125 kg/ha on five sowing dates in autumn 1988.

	Sowing date					
	7 Sept	21 Sept	4 Oct	18 Oct	1 Nov	LSD (5%)
Lodging (1 August 1989)	0	0	10	27	40	14.9
Yield	6.6	7.0	6.6	6.3	6.0	0.45

Source: ADAS, Gleadthorpe EHF

4.3.2 <u>Triticale</u>

In each of the three years 1983 - 1985, an experiment was conducted by ADAS on loamy sand at Gleadthorpe EHF with the aim of comparing triticale sown in the second half of September with late October. In 1983, the later sowing was delayed because of bad weather and took place in early November. In 1983, a low yielding triticale selection WTCB 134 was used; in 1984 and 1985, cv. Lasko was used.

In all three years, there was a significant yield advantage from sowing in September rather than late October/early November and the mean advantage was 0.5 t/ha (Table 9). Although, overall, there was a trend for the early sowing to increase the number of grains per unit area and the mean grain weight, the effects were not consistent each year. Above-ground dry matter accumulation and straw height were always greater in the earlier sowings. Early lodging occurred in 1985 and was notably worse on the taller, September-sown crops. Potential benefits from the enhanced dry matter yield may therefore not have been realised resulting in the smallest yield increase.

Table 9. Effect of sowing date on the grain yield (t/ha at 85% DM) of triticale in 1983, 1984 & 1985.

Year	Sowing date: Mid/late September	Sowing date: Late October/ early November	LSD (5%)
1983	4.7	3.9	0.44
1984	5.8	5.2	0.16
1985	6.1	5.9	0.16
Mean	5.5	5.0	0.33

Source: ADAS, Gleadthorpe EHF

These yield advantages from early sowing on light soil were confirmed in an experiment conducted by the PBI in Suffolk in 1983 (R.S. Gregory, IPSR, Norwich, pers. comm.) where triticale sown on 15 September produced a yield of 5.5 t/ha, 1.4 t/ha greater than from sowing on 1 October. During the same year, three sowings were also compared on a heavier sandy clay loam at the PBI. Similar yields of 8.2 and 8.5 t/ha were achieved from sowing on 17 September and 26 October respectively. When the sowing was delayed until 6 December, the yield was reduced to 6.9 t/ha.

The above results do not constitute a comprehensive assessment of sowing dates for triticale. However, it can be broadly concluded that on fertile soil, where the crop is likely to make a lot of winter growth, triticale should be sown after the beginning of October onwards. Earlier sowings may give similar yields but greater inputs are required and the crop may be more difficult to manage. On land where winter growth is likely to be limited and on less fertile, particularly sandy soil, the crop should be sown from mid-September onwards.

4.4 Nitrogen

In the absence of lodging, the extent to which rye or triticale require fertiliser nitrogen largely depends on three things:

i <u>The potential of the crop to grow.</u>

High yielding crops take up large amounts of nitrogen; grain contains about four times as much nitrogen as straw or root and accounts for most of the nitrogen uptake. This is particularly pronounced where grain is required to have large protein concentrations.

In experiments, the optimum grain yield of the crop unrestricted by nitrogen usually occurs at, or just above, the largest amount of fertiliser N that does not cause lodging.

ii <u>The capacity of the soil to provide nitrogen in available forms.</u>

Soil nitrogen commonly provides half the crop's requirements but this is highly dependent on the organic matter content of the soil and the recent history of the field. Some crops need no fertiliser N.

In experiments, the capacity of the soil to provide nitrogen is indicated by the crop N uptake without applied N.

iii <u>The efficiency with which the crop recovers nitrogen from soil and from fertiliser.</u>

This is highly variable but causes of variation are poorly understood or difficult to anticipate and, in current advice, no attempt is made to predict recovery. Considerable uncertainty is thus inherent in advice on nitrogen use.

However, it is of particular concern that, compared to other cereals, nitrogen predisposes rye and triticale to more severe and earlier lodging. If lodging occurs before the end of grain filling, the yield potential of the crop is reduced, N uptake may be curtailed and the efficiency of nitrogen recovery is poor. The earlier the lodging, the greater will be these effects. It is, therefore, crucial that experimental data are interpreted in the light of the dates and extents of lodging.

4.4.1 Rye - effect of nitrogen on yield

In relation to other cereals, there is a dearth of information relating to the nitrogen requirement of rye. However, on sandy soils or shallow soils over chalk or limestone, it is recommended (Anon., 1988c) that a total of 125 kg/ha nitrogen is applied to rye and, by analogy with the requirements of wheat and barley, none of it should be applied in the autumn but all in the spring. Trade advice sometimes conflicts with this, as rates of nitrogen up to 165 kg/ha plus an extra 25 kg/ha in the autumn may be recommended (M.N. Pertwee, Pertwee Holdings Ltd., Colchester, pers. comm.).

4.4.1.1 Autumn nitrogen

The effects of applying up to 40 kg/ha nitrogen to rye in the autumn were measured at Gleadthorpe EHF in 1979 and 1980. The seed cv. Dominant, was sown at the end of September/early October into a loamy medium sand soil. There was no significant yield response to autumn nitrogen in either year but in the second year it substantially increased early lodging after heavy showers of rain in June (Table 10).

Table 10. Yield of grain (t/ha at 85% DM) and lodging (%) on 18 June 1980 (in brackets), following applications of autumn applied nitrogen to rye grown as a second cereal.

	Autumn nitrogen (kg/ha)			
Year	0	20	40	LSD (5%)
1979	5.5	5.6	5.6	0.21
1980	2.7 (36)	-	3.0 (68)	0.44

Source: ADAS, Gleadthorpe EHF

4.4.1.2 Spring nitrogen

Rates of spring nitrogen were also compared in experiments at Gleadthorpe EHF. Initially, two rates were tested, the nitrogen usually being applied in one application between the end of March and mid April. The yield results are shown in Table 11.

Table 11. Grain yield (t/ha at 85% DM) of rye grown with different histories of previous cropping at two rates of spring applied nitrogen.

Year	Cultivars	Previous cropping	Nitrogen (kg/ha) 65	125	LSD (5%)
1974	Dominant	2 year ley	5.8	6.3	0.42
1976	Dominant	2 year ley	2.5	2.3	0.55
1977	Dominant	Cereal	3.8	4.3	0.31
1978	Dominant	Cereal	5.2	5.9	0.69
1978	Animo	Cereal	5.4	6.0	0.69

Source: ADAS, Gleadthorpe EHF

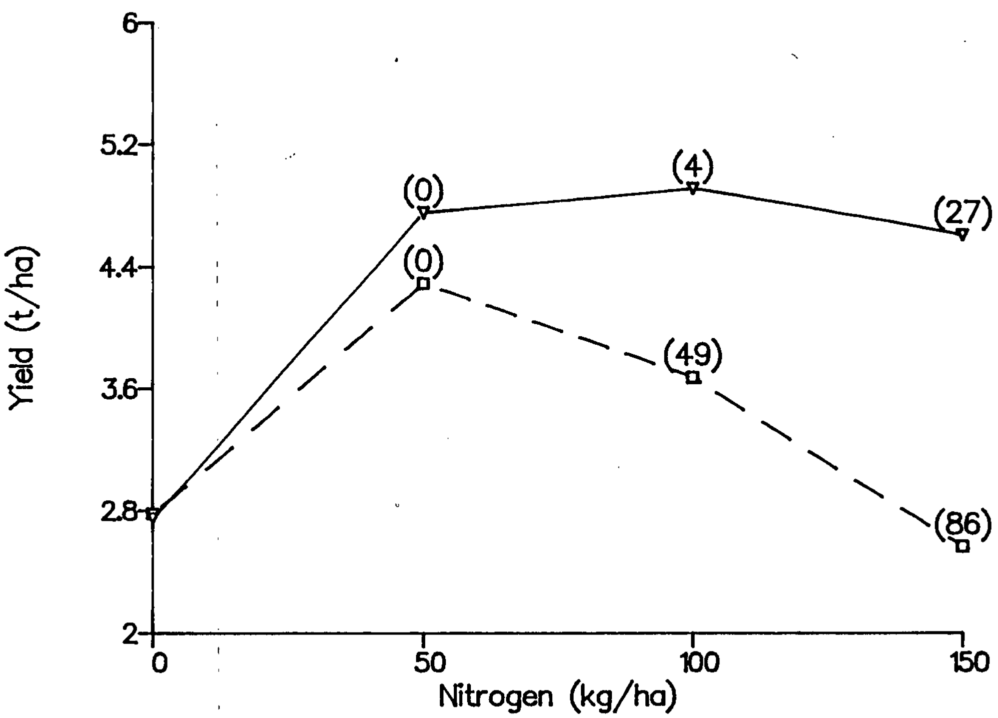
Irrespective of previous cropping, in three of the four years, there was a positive yield response, albeit not always statistically significant, when the nitrogen was increased as shown in Table 11. In 1976, yields were reduced by a severe drought and there was no response to the extra nitrogen.

Between 1979 and 1981 experiments at Gleadthorpe included higher nitrogen level comparisons. Where lodging was prevalent and no growth regulators were used, the nitrogen optima were extremely variable and ranged between 0 and 90 kg/ha (Table 12, Fig. 2). Higher rates of nitrogen sometimes caused severe early lodging. Use of a growth regulator reduced lodging and appeared to increase the optima but there was no yield increase above 100 kg/ha (Figs 2 & 3).

Table 12. Grain yield (t/ha at 85% DM) of rye grown without PGR, at different levels of spring applied nitrogen, after cereals, 1979 and 1980.

Nitrogen (kg/ha)	1979		1980	
0	-		2.6	
60	5.2		2.9	
90	5.9		2.6	
120	5.6		2.9	Severe lodging
150	5.8	Lodging	3.0	
180	5.4		3.0	
LSD (5%)	0.28		0.70	

Source: ADAS, Gleadthorpe EHF

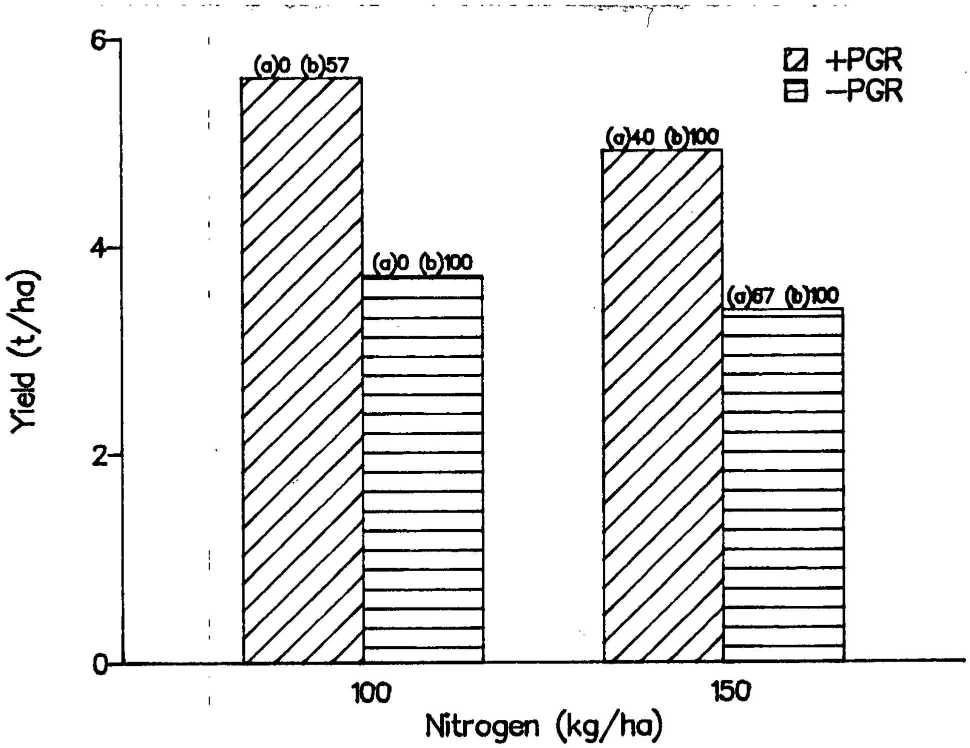


Source: ADAS, Gleadthorpe EHF

Figure 2: Effect of nitrogen rate on grain yield and lodging % at harvest (in brackets) of rye grown, ▽ , with, and □ , without PGR, after cereals in 1981.

A range of nitrogen timings was also included in the experiments at Gleadthorpe EHF and affected yields in 1979 (data not presented). Split applications of nitrogen, half at Zadoks decimal growth stage

(GS) (Zadoks et al., 1974) 25 (Feb/March) plus half at GS31 (April), tended to produce higher yields than when all the nitrogen was applied as a single dressing at GS25 or GS31. Early spring (GS25) nitrogen increased vegetative growth which aggravated lodging. Unfortunately none of the treatments included applications at GS30. At Gleadthorpe EHF, delaying all the nitrogen until late GS30 in winter barley depressed yields but the use of an early split avoided this loss (Harris et al., 1987). The main benefit of applying part of the nitrogen dressing during tillering was to ensure that the crop had some nitrogen available if the main dressing was delayed. This may also be true for rye.



Source: ADAS, Gleadthorpe EHF

Figure 3: Effect of nitrogen on grain yield and lodging % on (a) 18 June and (b) at harvest of rye grown with and without plant growth regulator in 1980.

A more recent multi-site experiment was carried out by ADAS between 1986 and 1988. The experiment was primarily aimed at comparing triticale with wheat and barley at several nitrogen levels. Rye was included in the site at Gleadthorpe EHF. The nitrogen was applied as 40 kg/ha early to mid-March with the remainder in April (GS30/31). A full growth regulator regime of chlormequat at GS30/31 followed by Terpal at GS37 was used. The rye grain yields and lodging are shown in Table 13.

Table 13. Grain yield (t/ha at 85% DM) and lodging (%) at harvest, of rye (cv. Animo) grown as a second cereal at four levels of nitrogen with a full PGR regime.

	Nitrogen (kg/ha)				
Year	80	120	160	200	LSD (5%)
1986	7.1 (0)	7.2 (3)	8.1 (10)	8.0 (13)	1.09
1987	6.2 (0)	6.5 (0)	6.5 (3)	6.4 (33)	0.73
1988	6.8 (79)	6.5 (93)	6.1 (95)	5.5 (98)	0.92

Source: ADAS, Gleadthorpe EHF

In this experiment, yields were greater than those realised in the earlier experiments. However, although greatest yields were achieved, respectively, at 160 and 120 kg/ha N in 1986 and 1987 when lodging was at relatively low levels, there was considerable variability within the results, making it impossible to calculate an optimum level with any confidence.

In 1988, in the presence of severe early lodging, yields tended to decline with each nitrogen increment.

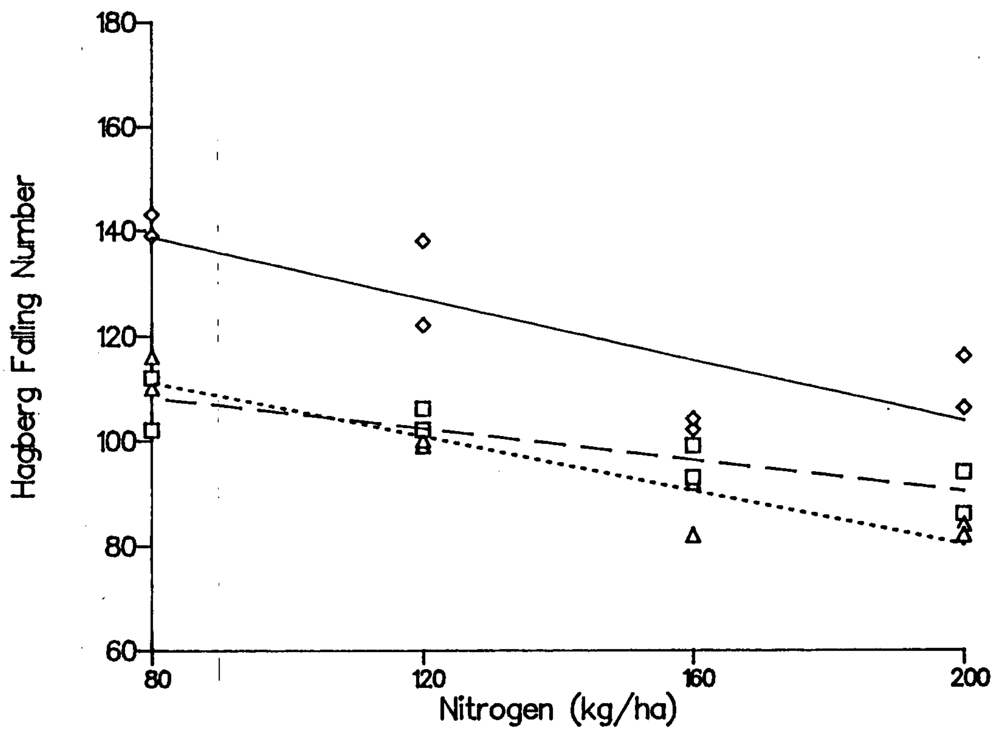
4.4.2 Rye - effect of nitrogen on quality

One of the main objectives in growing rye is to produce grain with a high HFN which is suitable for milling and baking. In some wheat experiments, increasing the nitrogen up to or above the optimum level for yield has produced positive responses in HFN (McDonald & Vaidyanathan, 1987). It is widely accepted that excessive nitrogen applications contribute to lodging, which in turn may reduce grain quality, including HFN.

It is also accepted that grain protein is enhanced by high levels of applied nitrogen (Murray & Nunn, 1987). While this quality aspect is important in milling wheat it is of little concern in milling rye.

The effect of nitrogen on the HFN of rye grain was measured in the experiment referred to in Table 13.

Nitrogen increments reduced the grain HFN (P=0.05) and the decline commenced at the lowest level of nitrogen (Fig. 4). Although the slopes of the response varied, similar trends occurred each year, irrespective of the amount of lodging. Unlike that sometimes found in wheat, there was no indication of any HFN response to nitrogen above the amount required for optimum yield.



Source: ADAS, Gleadthorpe EHF

Figure 4: Relationship between the HFN of rye grain (cv. Animo) and spring- applied nitrogen in ◇, 1986; □, 1987; Δ, 1988.

It is difficult to provide an explanation for this phenomenon. There did not appear to be a direct correlation with lodging or dry matter of the grain at harvest, nor were there signs of grain sprouting.

Gale et al. (1983) reported that some cultivars of wheat were prone to produce pre-germination alpha-amylases in immature grain before the onset of dormancy and without visible signs of germination. They also noticed that the syndrome was exacerbated by slow grain drying before harvest. Rye is also susceptible to producing pre-maturity alpha-amylase (J.E. Flintham, IPSR, Norwich, pers. comm.). It is possible that the nitrogen increments extended or delayed the ripening period (this was not identified) and caused a reduction in HFN. Factors affecting HFN require identification in order that they may be manipulated where possible to improve grain quality.

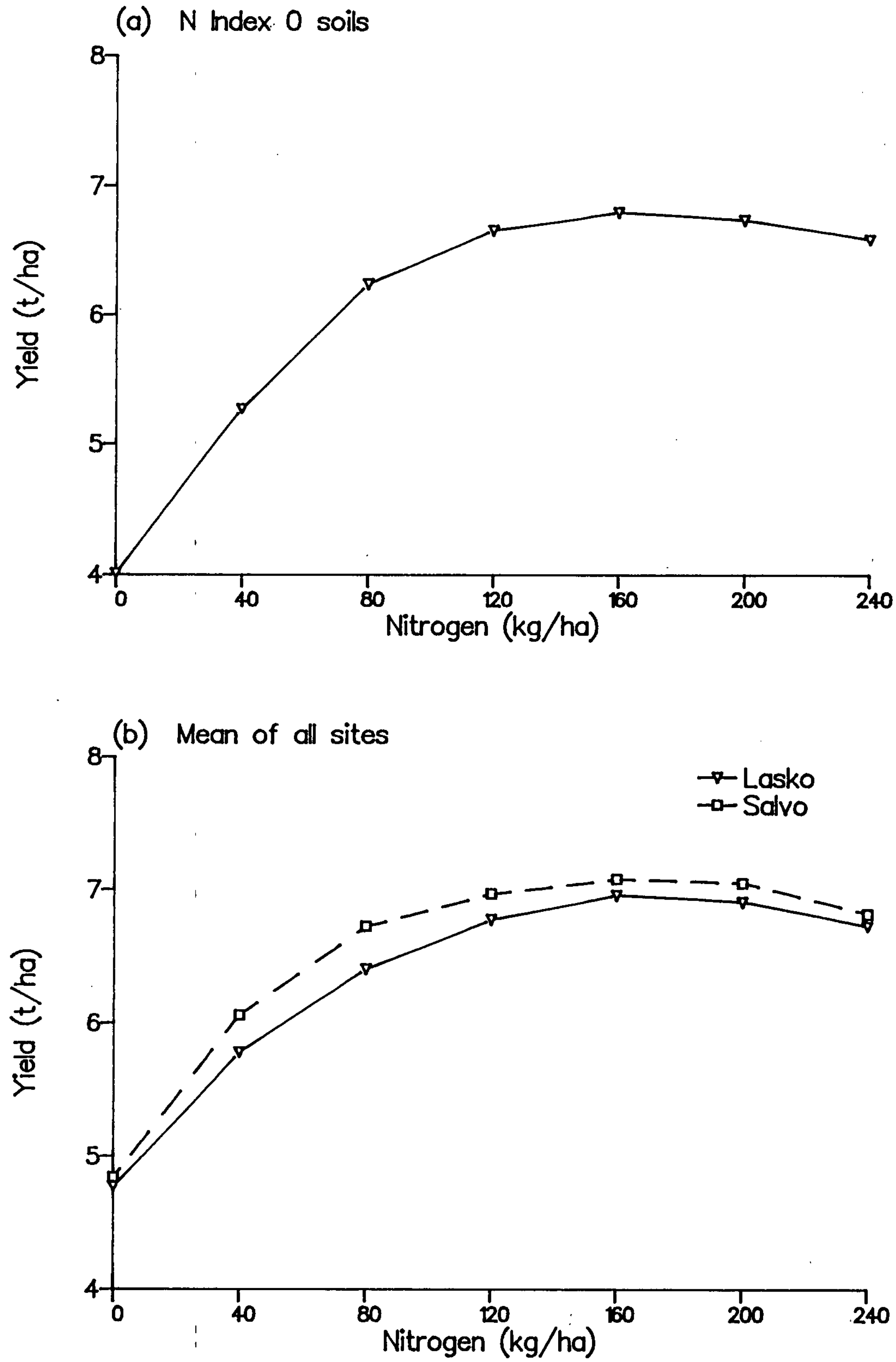
4.4.3 Triticale

Although spring-applied nitrogen treatments have been included in several experiments conducted on triticale, none of the experiments has examined the use of autumn nitrogen. However, it is assumed that, as in rye and the major cereals, it is unlikely to affect yield and might aggravate lodging.

4.4.3.1 Spring nitrogen rate

Between 1984 and 1986, a co-ordinated experiment was conducted by ADAS to assess the optimum level of spring-applied nitrogen for grain yield of triticale (Aquilina, 1987). Two cultivars, Lasko and Salvo, were included in the trials to enable the possible cultivar interaction with nitrogen rates to be assessed. Seven nitrogen rates were applied to both cultivars, ranging from 0 to 240 kg/ha in 40 kg/ha increments.

The experiment was conducted on 6 sites in 1984, 7 sites in 1985 and 5 sites in 1986. The sites were located on a wide range of soil types because, although triticale was thought to be suited to lighter or more marginal soils, there was also interest in its potential on the heavier soils.



Source: ADAS, National

Figure 5: Grain yield response of triticale (cv's Lasko and Salvo) to nitrogen (mean 1984-86) on (a) N Index 0 sites and (b) all sites.

Sowing dates ranged from September to mid-October. The growth regulator chlormequat was applied at GS31 at all sites. Fungicides were used as and when necessary. Small variations in the time of nitrogen application occurred between sites and years but within the range of March/April and all of it by GS30/31. The responses to nitrogen on mineral soils are summarised in Figs 5 (a) & (b).

At an assumed fertiliser cost ratio of 3 kg grain weight per kg N applied, nitrogen optima varied from 0 to 200 kg/ha N on Nitrogen Index 0 sites. The differences were not specifically related to soil type. However, optima on the majority of Index 0 sites ranged between 120 and 200 kg/ha N; the mean over cultivars, sites and years was between 120 and 160 kg/ha (Fig. 5 a).

Despite the use of chlormequat, lodging frequently occurred at nitrogen levels in excess of 120 kg/ha. It tended to be worse in Lasko and on fertile soils. Nitrogen increments decreased grain specific weight and mean grain weight but increased grain protein.

The data summarising Index 0 sites do not include results obtained on loamy peat soil at Arthur Rickwood EHF with an Index 0 status. There, the approximate nitrogen optima were nil in 1984 and 80 kg/ha in 1985. Tests were also made on more fertile soils. On Nitrogen Index 1 soils at Arthur Rickwood EHF in 1986 and Rosemaund EHF (silt loam) in 1985, and Index 2 soil at Rosemaund in 1984, the nitrogen optima were approximately 40 kg/ha.

There was no significant interaction between nitrogen rate and cultivar. However, although their nitrogen requirements were similar, at low levels of nitrogen, the slope of the response curve was slightly steeper with Salvo than with Lasko (Fig. 5 b).

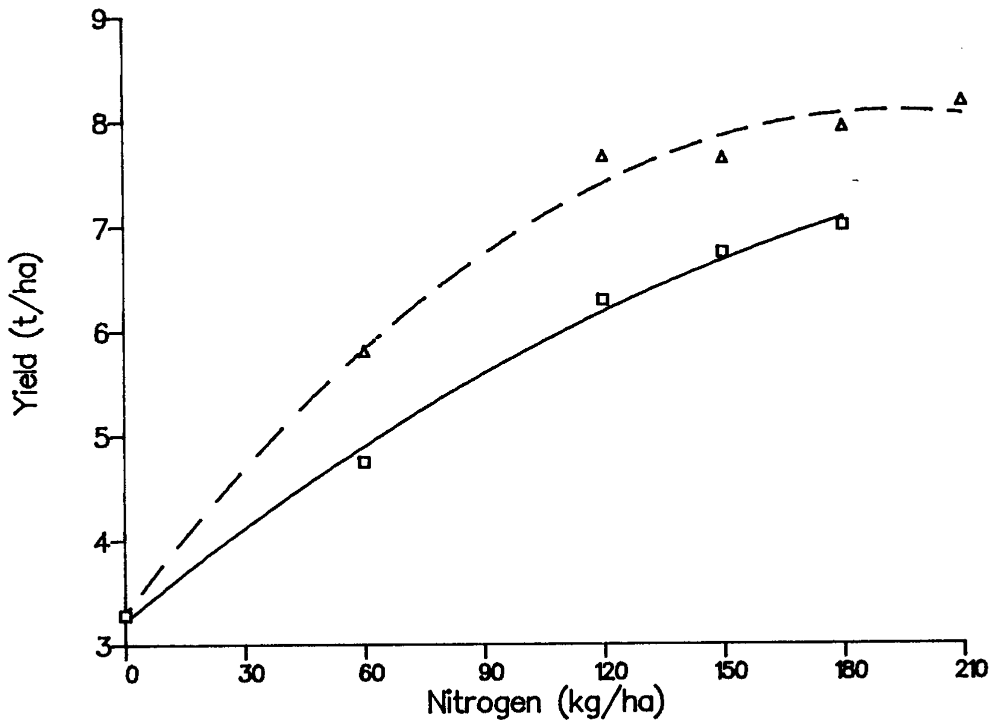
Nitrogen rate experiments were also conducted by Semundo Ltd. each year between 1980 and 1985 on upper chalk soils in Wiltshire (D.M. Miles, pers. comm.). As in the ADAS experiments, the nitrogen optima were variable, ranging from 125 kg/ha to 200 kg/ha; the mean over the years was approximately 160 kg/ha N. The nitrogen increments also tended to increase crop height, lodging, grains/ear, ears/m^2 and grain nitrogen content, and reduce mean grain weight. Other experiments were conducted at the NAS (M. Nuttall, pers. comm.), the West of Scotland College of Agriculture (G.P. Whytock, pers. comm.) and the PBI (R.S. Gregory, pers. comm.). The short-term nature of these experiments or lack of treatments preclude confident assessments of nitrogen optima. However, in general they lend support to the results and observations obtained by ADAS and Semundo Ltd.

4.4.3.2 Spring nitrogen timing

In 1983 and 1984, on N Index 0 soils, Semundo Ltd. compared all the nitrogen applied in April with a split application of 60 kg/ha in late February/early March and the remainder in April. Up to 6 levels of nitrogen from 0 to 210 kg/ha were used.

In 1983, splitting the nitrogen had no significant effect on yield and the optimum total level was approximately 90 kg/ha. The following year, yields increased with each increment of nitrogen up to approximately 190 kg/ha (Fig. 6). In this situation, splitting the application increased the yield by approximately 1 t/ha irrespective of total nitrogen application. It also markedly increased crop height.

These large responses can be attributed to there being virtually no rainfall in the area during April 1984 thus preventing the efficient use of the April-applied nitrogen. However, the results also highlight the importance of splitting the nitrogen; while it may not always give a yield response, it should provide some insurance against yield loss particularly in dry springs.



Source: Semundo Ltd., Wiltshire

Figure 6: Effect of nitrogen rate and timing (□ , single application on 18 April; △ , 60 kg/ha N on 9 March plus the remainder on 18 April) on the grain yield of triticale in 1984.

4.5 Plant growth regulators

Biomass accumulation in cereals is an important determinant of grain yield (Green, 1984). However, when attempting to maximise dry-matter production, a taller crop more prone to lodging may result (Boothroyd & Clare, 1984). The propensity of a crop to lodge is not solely governed by its height. Other factors such as strength of the soil surface, rooting pattern, crown depth, stem thickness, resistance of the crop canopy to air movement and weather are interrelated and may also affect lodging (Sylvester-Bradley & Scott, 1990). Although many contemporary triticale cultivars contain a dwarfing gene and are shorter than rye, both crops are very tall relative to wheat and barley (McDonald, 1984) and are prone to lodging. They may, therefore, be considered ideal crops upon which to use lodging suppressants. Failure to control lodging is likely to reduce grain yield and quality and substantially increase harvest duration.

Three chemicals are available for lodging control in cereal crops: chlormequat, mepiquat chloride and ethephon (Table 14). Commonly referred to as PGR's, all have growth retarding properties; chlormequat and mepiquat chloride inhibit the production of gibberellins (Caldicott & Lindley, 1964; Cartwright & Waddington, 1981) by blocking the conversion of mevalonic acid to kaurene, the precursor of gibberellic acids (Boothroyd & Clare, 1984); ethephon generates the production of ethylene (Child et al., 1983). All PGR's will be referred to by their product names (Table 14).

Table 14. PGR's referred to in this review - product names, chemical names and active ingredients per litre of product.

Product	Chemical	Active ingredient/ litre of product
Cycocel (various)	chlormequat (2-chlorethyl trimethyl ammonium cloride)	644 g
Terpal	mepiquat chloride plus ethephon (2-chloroethyl phosphonic acid)	305 g 155 g
Cerone	ethephon	480 g
Ethrel C	ethephon	480 g

4.5.1 Rye

Between 1979 and 1981, PGR treatments were included in experiments at Gleadthorpe EHF. The treatments varied in each of the three years which prevents an overall analysis of the data. However, several effects were observed as follows.

In 1979, 2 l/ha Terpal or 2 l/ha Ethrel C were applied as a single or split application at growth stages ranging from GS31-49. Overall, both PGR's tended to reduce crop height but there was no lodging and no significant yield response. In 1980, 2 l/ha Terpal or 2 l/ha Cerone were applied at GS45. They both reduced crop height, delayed the onset of lodging and significantly increased yield (Table 15).

Table 15. Grain yield (t/ha at 85% DM), crop height score* and lodging % on 18 June (GS73) and lodging (%) at harvest of rye (cv. Dominant) following applications of Terpal or Cerone at GS45 in 1980.

PGR	Yield (t/ha)	Crop height score*	Lodging on 18 June (%)	Lodging at harvest (%)
Nil	3.4	6.3	53	100
Terpal (2 l/ha)	5.0	4.6	0	88
Cerone (2 l/ha)	5.3	3.8	0	78
LSD (5%)	0.39	0.56	4.1	9.4

Source: ADAS, Gleadthorpe EHF

* Crop height score 2 = approximately 1.4 m
7 = approximately 1.9 m

In 1981 (data not presented), only Cerone was applied at GS45 using a lower rate of 1.5 l/ha. It reduced lodging at harvest from 34% to 8% and increased the yield from 3.3 to 4.2 t/ha. However, no significant effects on crop height were observed.

Experiments conducted by ADAS on light soil in Suffolk during 1980 and 1982 supported the Gleadthorpe EHF results. Terpal at GS37/39 and Cerone at GS37/49 greatly reduced lodging and increased yields (Table 16).

Cycocel applied at GS31 was also compared in the Suffolk experiments between 1978 and 1982 (Table 16). Although it did not always reduce the amount of lodging at harvest, it increased yields in each of the four years by an average 0.6 t/ha. It compared well in yield terms in 1980 with single later applications of Cerone or Terpal but less well in 1982. There was insufficient evidence to demonstrate any potential benefits of sequential applications of Cycocel followed by Terpal or Cerone.

Table 16. Grain yield responses (t/ha at 85% DM) of rye crops treated with different PGR regimes compared to untreated yields, and lodging (%) (in brackets), 1978, 1979, 1980 and 1982.

	1978 (cv. Dominant)	1979 (cv. Dominant)	1980 (cv. Dominant)	1982 (cv. Animo)
Untreated yield (t/ha)	2.9 (40)	3.7 (43)	5.0 (90)	5.6 (50)
Cycocel at GS31	+0.8	+0.5 (10)	+0.5 (80)	+0.4 (50)
Terpal at GS37/39	-	-	+0.5 (15)	+0.9 (0)
Cerone at GS37/49	-	-	+0.3 (10)	+0.7 (0)
Cycocel then Terpal	-	-	-	+1.1 (0)
Cycocel then Cerone	-	-	-	+0.6 (0)

Source: ADAS, Suffolk

A further five replicated experiments on the effect of Cerone on winter rye were conducted by Union Carbide UK Limited in Suffolk between 1982 and 1984 (D.S. Tyrrell, Embetec Crop Protection, Harrogate, pers. comm). The treatments were applied between GS42 and 49. As in the ADAS experiments, the effects of the treatments varied between years and sites. However, further confirmation was produced of the ability of Cerone to reduce lodging and increase yields of rye (Table 17, a & b). Cerone produced other effects although they were not always consistent. Most notable were that grains per ear, mean grain weight and grain specific weight tended to be improved. Straw height was significantly reduced and negatively correlated with increasing application rates of the growth regulator (Table 17, a & b). Rye remained extremely tolerant to Cerone at 4.0 l/ha even when the soil moisture deficit was high and the crop showed stress symptoms of rolled leaves. Overall, however, the optimum application rate of Cerone appeared to be approximately 1.0 l/ha which is the rate currently recommended.

Cycocel at 2.5 l/ha was also included in two of the Union Carbide experiments in 1982. Its only significant effect was to produce an 8% yield increase in one of the experiments and in contrast with the ADAS results, in yield benefit terms it was considerably less effective than Cerone.

Table 17. Yield of grain (t/ha at 85% DM), straw height (cm), fertile tillers/m^2, grains/ear, 1000 grain weight (g) and grain specific weight (kg/hl) expressed as a percentage of untreated, and lodging (%) prior to harvest, of rye, following (a) an application of Cerone at GS42/49; mean of 2 sites (cv. Dominant) in 1982, 2 sites (cv. Animo) in 1983 and 1 site (cv. Animo) in 1984 and (b) increasing applications of Cerone at GS47/49; mean of 2 sites (cv. Dominant) in 1982.

(a)

	Yield (t/ha)	Height (cm)	Lodging (%)	Ears /m^2	Grains /ear	1000 grain weight (g)	Specific weight (kg/hl)
Untreated	4.9	157	76	449	59	30	68
Cerone (1.0 l/ha)	113	93	23	101	105	105	102

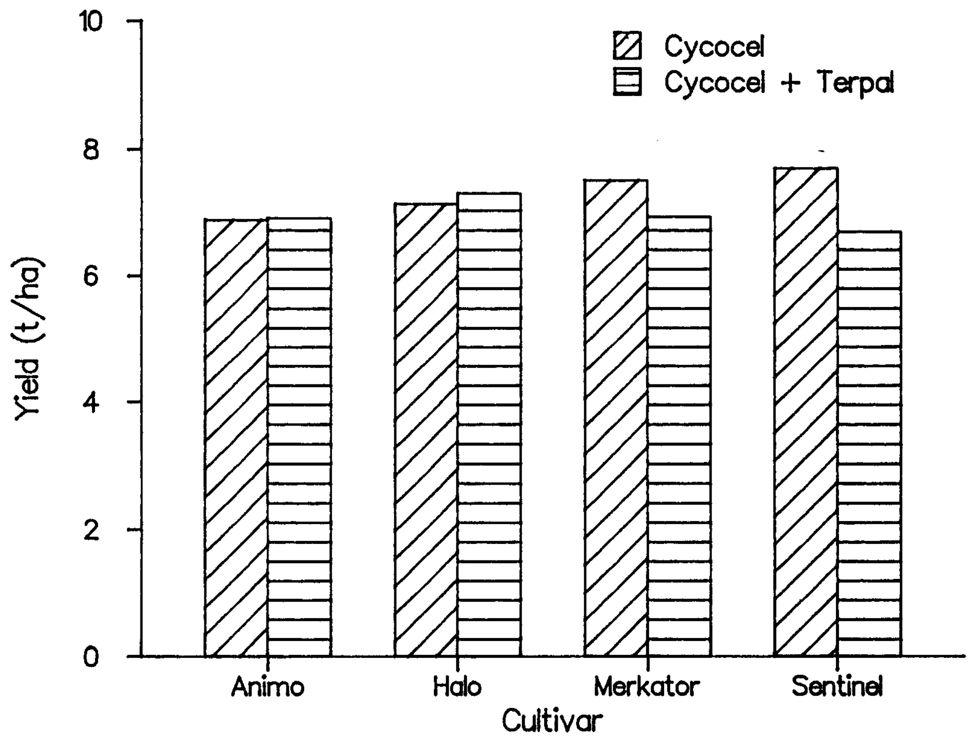
(b)

	Yield (t/ha)	Height (cm)	Lodging (%)	Ears /m^2	Grains /ear	1000 grain weight (g)	Specific weight (kg/hl)
Untreated	4.2	148	99	426	57	31	68
Cerone 1.0 l/ha	120	91	2.9	106	112	108	103
Cerone 1.25 l/ha	117	90	1.8	101	115	108	103
Cerone 1.5 l/ha	119	89	0.4	102	111	108	104
Cerone 2.0 l/ha	118	88	0	107	107	107	103
Cerone 3.0 l/ha	119	86	0	108	105	106	103
Cerone 4.0 l/ha	118	84	0	101	103	107	103

Source: Embetec, Harrogate

In all the above growth regulator experiments, the cultivars used were either Dominant or Animo and there was no evidence that they responded differently.

Commencing in 1987, four cultivars of rye (Animo, Halo, Merkator and Sentinel) have been grown using two PGR regimes at Gleadthorpe EHF. The experiment has been conducted by ADAS in collaboration with NIAB as part of the Recommended List series of experiments. The PGR regimes have been 2.5 l/ha Cycocel at GS30/31 compared with Cycocel at GS30/31 followed by Terpal at GS37. In 1988, severe lodging occurred, yields were low and there was no significant response to the sequential PGR regime. In the previous year, there was no lodging and under severe drought stress the application of Terpal reduced the yield of Sentinel from 7.8 to 6.8 t/ha (Fig. 7). The



Source: ADAS, Gleadthorpe EHF

Figure 7: Effect of an application of Terpal at GS37 on the grain yield of four cultivars of rye subjected to drought stress in 1987.

yield of Merkator was reduced from 7.5 to 6.9 t/ha, albeit non-significantly, whereas the yields of Animo and Halo were unaffected. These interim results suggest that differences in sensitivity between cultivars to PGR may occur. The work is continuing.

4.5.2 Triticale

4.5.2.1 ADAS experiments

A co-ordinated experiment from 1984 to 1986 compared applications of 2.5 l/ha Cycocel at GS30/31 with 2 l/ha Terpal at GS37-39 and 1 l/ha Cerone at GS37-39 (Table 18).

Table 18. Mean grain yield responses (t/ha at 85% DM) compared to untreated yields of triticale (cv. Lasko) following applications of PGR's in 1984, 1985 and 1986.

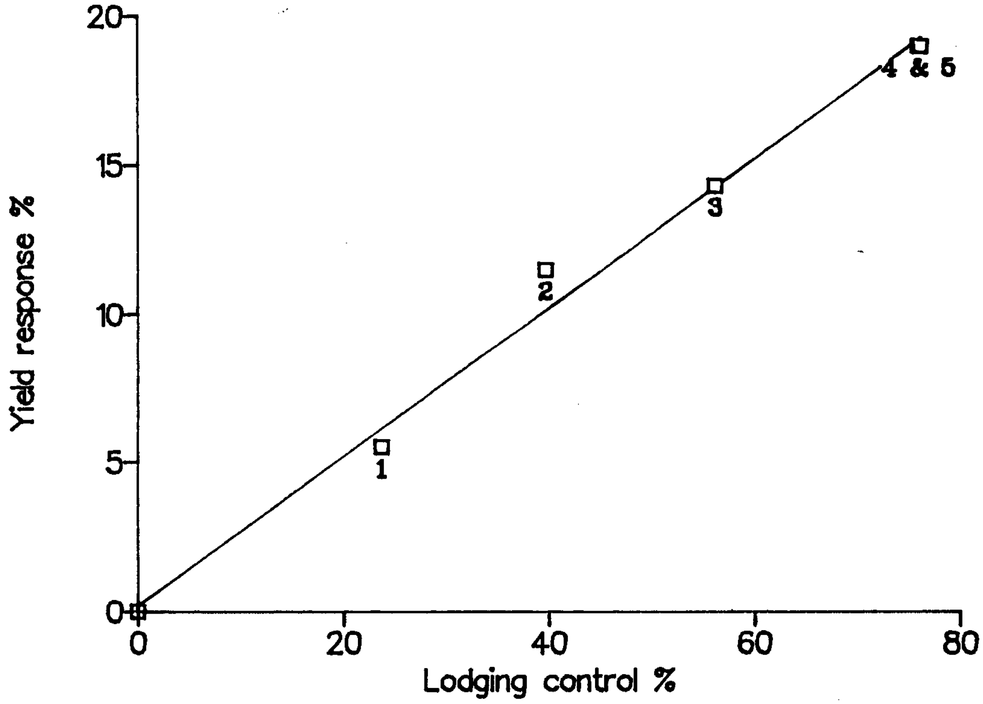
	1984	1985	1986
No. of sites	3	3	2
Untreated yield (t/ha)	6.2	5.8	8.0
Cycocel	+0.8	+0.7	+0.2
Terpal	+0.7	+1.0	+0.3
Cerone	+0.3	+0.4	0
Cycocel then Terpal	+1.1	+1.6	+0.4
Cycocel then Cerone	+1.1	+1.7	+0.4
LSD (5%)	0.58	0.44	0.49

Source: ADAS, National

Despite seasonal differences in the size of the responses, a pattern was evident. Cycocel and Terpal alone produced similar responses while Cerone alone had only approximately half the effect. A two-spray combination of Cycocel followed by Terpal, or Cycocel followed by Cerone proved to be similar and produced the greatest yield responses.

In addition to the above treatments, half-rate, sequential, applications of Cycocel or Terpal were compared for two years at Rosemaund EHF; the yield increases were no better than from single full-rate applications (data not presented). On another site in the West Midlands, when Cycocel at GS31 was followed by half-rate Terpal or Cerone at GS37/39, lodging control was reduced and the average yield increase declined by approximately 25%.

From this series of experiments, a good relationship was established between the control of lodging and grain yield response (Fig. 8). The two-spray programmes tended to be additive in effect and achieved the best results.



Source: ADAS, National

Figure 8: Percent yield response of triticale (cv. Lasko) related to the control of lodging following various PGR applications (1 = Cerone GS37/39; 2 = Cycocel GS30/31; 3 = Terpal GS37/39; 4 = Cycocel then Terpal; 5 = Cycocel then Cerone), 1984 & 1985. Mean of six sites.

Internode lengths were measured on one of the sites in 1985 (Table 19). Two-spray combinations of Cycocel followed by Terpal or Cerone had the greatest shortening effect from ground level to the third node but actually increased the length between the fourth node and the ear. Single applications of Cycocel or Terpal had a slightly smaller effect on the lower internodes, a similar effect between nodes three and four and no significant effect between the fourth node and ear. A single application of Cerone had the least effect, producing only a small shortening of the intermediate internodes.

These results are similar to those reported for winter barley by Boothroyd & Clare (1984) in which the greatest shortening effect occurred on that internode elongating most rapidly at, or shortly after the time of PGR application and that the stem length between the final internode and the ear could show greater elongation than the untreated.

Table 19. Effect of PGR applications on the internode lengths (cm) of triticale (cv. Lasko) in 1985.

	Internode					
	ground-1	1-2	2-3	3-4	4-ear	total ground-ear
Untreated	7	17	22	28	35	109
Cycocel	5	13	19	25	35	97
Terpal	6	14	18	25	37	100
Cerone	7	16	21	27	33	104
Cycocel then Terpal	4	11	16	25	41	97
Cycocel then Cerone	4	11	17	25	40	97
LSD (5%)	1.1	0.8	0.7	1.2	2.6	3.4

Source: ADAS, West Midlands

Components of yield were also measured on some of the ADAS sites (data not presented). While on occasions the individual yield components of cv. Lasko were significantly affected by the treatments, the results were confounded by lodging and were not always consistent over sites and years. Over the three years, treatments containing Cycocel or Terpal increased the number of fertile tillers on two out of six sites. Cycocel reduced the mean grain weight on three of eight sites; Terpal also reduced it on one site but along with Cerone, increased it on another site. The number of grains per ear was only measured on three sites and was not significantly influenced by any of the treatments. These effects are similar to those more clearly established in winter barley and winter wheat (Boothroyd & Clare, 1984).

Autumn and spring applications of Cycocel were included during a Nottingham University and Gleadthorpe EHF collaborative study between 1983 and 1985 (Table 20). The experiments further demonstrated the potential for Cycocel to reduce lodging in triticale and increase yields. As expected, spring applications were more effective at reducing lodging and increasing yields than those applied in the autumn.

Table 20. Grain yield responses (t/ha at 85% DM) of triticale following applications of Cycocel compared to untreated yields and lodging (%) at harvest in 1983 (cv. WTCB 134), 1984 and 1985 (cv. Lasko).

	1983	1984	1985
Untreated yield (t/ha)	6.2 (0)	4.3 (61)	4.1 (90)
Cycocel - Autumn	-	+0.8 (52)	+0.4 (70)
Cycocel - Spring	+0.4 (0)	+1.6 (26)	+1.1 (21)
Half-rate Cycocel - Spring	+0.4 (0)	+1.2 (36)	-
LSD (5%)	0.11	0.57	0.40

Source: Nottingham University and
ADAS, Gleadthorpe EHF

Most noteworthy is that there was no lodging in the first year of this experiment (Table 20) yet an application of Cycocel at GS30 increased the yield of triticale by 0.4 t/ha but did not influence the yields of wheat and barley in adjacent experiments. Growth regulators may increase grain yields of cereals in the absence of lodging from modifications to growth or development (Boothroyd & Clare, 1984). However, applications of Cycocel usually lead to a reduction in mean grain weight (Humphries et al., 1965; El-Sharkawy et al., 1973; Gill et al., 1974). For wheat crops, reduced mean grain weight may completely offset Cycocel-induced increases in numbers of grains such that yield, in the absence of lodging, is unchanged (Nuttall, 1979). In the first year of the Nottingham University and Gleadthorpe EHF collaborative study, when there was no lodging, Green et al. (1984) found that while for wheat, increases in number of grains were usually offset by reductions in mean grain weight, for triticale this latter variable seemed more stable and the yield improvement of 0.4 t/ha was obtained.

It is also of concern whether all cultivars of triticale will respond to the use of PGR's in a similar manner. In 1984, at a single site in the West Midlands, five cultivars of triticale were grown with and without Terpal applied at GS38 (Table 21).

Lodging occurred in all cultivars grown without Terpal. However, the amount was negligible in Salvo and Torrs and the yields of these cultivars were unaffected by Terpal. Conversely, lodging in Lasko and Newton was more severe. Terpal reduced lodging and produced substantial yield increases. These results confirm the importance of controlling lodging in some weak-strawed cultivars.

Table 21. Grain yield (t/ha at 85% DM) and lodging (%) on 31 July (in brackets) following an application of Terpal at GS38 to five triticale cultivars in 1984.

	Nil		Terpal
Grace	5.3 (88)		+0.1 (31)
Lasko	6.1 (62)		+1.1 (17)
Newton	6.5 (39)		+1.3 (0)
Salvo	7.0 (6)		+0.1 (0)
Torrs	6.3 (9)		+0.1 (6)
LSD (5%)		0.64	

Source: ADAS, West Midlands.

However, not all the weak-strawed cultivars responded in the same manner. Lodging was worst in Grace and although the application of Terpal reduced it significantly, there was no effect on yield. This phenomenon is difficult to explain except that Terpal had a negative influence on the 1000 grain weight of Grace only, reducing it from 44.8 g to 40.2 g.

Further evidence of differential responses of triticale cultivars to Terpal occurred at Gleadthorpe EHF during 1987 in the absence of lodging (Table 22). When Terpal was applied at GS39 following an overall spray of Cycocel at GS30/31, there was no significant effect on the yields of Lasko or Salvo but the yield of Cumulus was decreased by 0.9 t/ha. Moisture stress may have contributed to this effect but it is also possible as with rye cv. Sentinel (Fig. 7), that certain triticale cultivars such as Grace and Cumulus are more dependent on export of assimilates to ear which is adversely influenced by ethylene.

Table 22. Effect on grain yield (t/ha at 85% DM) in the absence of lodging of Terpal applied at GS39 to three triticale cultivars following an overall application of Cycocel at GS30/31 in 1987.

	Cycocel	Cycocel, then Terpal
Cumulus	5.0	-0.9
Lasko	5.0	+0.2
Salvo	4.2	+0.5
LSD (5%)	0.66	

Source: ADAS, Gleadthorpe EHF

Lasko has been described previously as being responsive to applications of Cycocel and this was also true at Boxworth EHF when it was grown in 1984 only and suffered from lodging. However, Salvo was grown at Boxworth in 1984 and 1985 and it was generally unresponsive to Cycocel, irrespective of the presence or virtual absence of lodging. Conversely, single applications of Terpal at GS37 or Cerone at GS44/47 produced similar and best yields even when lodging control was improved by an earlier application of Cycocel preceding the Terpal or Cerone. Part of these yield increases was attributed to increases in the number of grains per ear and more particularly to increases in mean grain weight.

A more recent experiment which began in 1987 on peat soils at Arthur Rickwood EHF is comparing single applications of Cycocel and sequential applications of Cycocel followed by Terpal on winter wheat and three cultivars of triticale. Interim data have further confirmed that PGR's, particularly sequential applications, can produce useful reductions in lodging and that yield improvements are most likely to be obtained from cultivars more susceptible to lodging such as Lasko.

4.5.2.2 Long Ashton Research Station experiments

Experiments were carried out in 1985 at two contrasting sites which enabled the comparison of responses to PGR treatment in crops of different vigour (R.D. Child, LARS, pers. comm.). The sites were at Long Ashton, where deep, moist soils ensured vigorous growth in crops much disposed to lodging and at Eastleach, Gloucestershire where the Cotswold brash is shallow, less water retentive and grows less vigorous, shorter crops which are less disposed to lodging. Glasshouse experiments with pot-grown plants were carried out at Long Ashton to examine effects of Cerone on dry-weight production and partitioning. All the experiments were carried out with cultivar Lasko.

The field experiments were designed to examine the effects of single (GS30 and GS32) and sequential, multiple applications (GS30 + 32 and GS30+32+37) of Cycocel at 1.75 l/ha with and without a single treatment of Cerone at GS59 in 1985 and GS49 in 1986. In 1985, a double rate of Cycocel (3.5 l/ha) was included at GS30. In the glasshouse experiments, plants were sprayed with Cerone at GS37.

Responses to treatment depended on whether lodging originated either at the base of the stem or in the upper two internodes (brackling). The former situation was characterised by complete collapse of the stem which resulted in the crop flattening. In the case of brackling, the crop leaned but did not collapse on the ground.

Table 23. Effects of PGR applications on lodging* (stem-base collapse) in triticale (cv. Lasko) at Long Ashton and Eastleach in 1985.

Cycocel	Long Ashton Cerone -	Long Ashton Cerone +	Eastleach Cerone -	Eastleach Cerone +
Nil	7.2	6.7	9.0	7.8
GS30	6.2	5.7	7.3	3.8
GS32	7.0	5.3	8.2	5.7
GS30+32	7.2	3.5	5.3	3.3
GS30+32+37	6.0	3.0	5.3	1.7
2 x GS30	6.2	4.0	7.3	3.7
LSD (5%)	2.06		2.58	

* Lodging score indicates proportion of plot affected on a 1-10 scale (1 = no lodging; 10 = whole plot affected, flat).

When lodging occurred (as in 1985), sustained control of stem extension was essential in order to reduce lodging susceptibility (Table 23). A single application of Cycocel at GS30 or GS32 had no significant or lasting effect on lodging and there was no advantage in doubling the recommended rate. In the more vigorous crop at Long Ashton, multiple applications of Cycocel did not increase resistance to lodging; in the less vigorous crop at Eastleach, significant reductions were recorded. Sequential applications of Cycocel and Cerone greatly reduced lodging at both sites.

When brackling occurred (as in 1986), it was reduced by sequential applications of Cycocel at GS30 + 32 at Long Ashton (Table 24). It was almost eliminated at both sites by treatment with Cerone.

Table 24. Effects of PGR applications on brackling* (bending in the upper internodes) in triticale (cv. Lasko) at Long Ashton and Eastleach in 1986.

Cycocel	Long Ashton Cerone -	+	Eastleach Cerone -	+
Nil	6.2	1.3	1.9	1.1
GS30	5.8	0.3	2.0	0.4
GS32	6.2	0	1.9	1.0
GS30+32	3.8	0	1.9	0.4
GS30+32+37	4.2	0	1.7	0.1
LSD (5%)	1.62		0.58	

* Brackling score indicates proportion of plot affected on a 0-10 scale (0 = no lodging; 10 = whole plot affected, flat).

Yield responses to treatment with Cycocel related closely to the degree of lodging control in 1985 at both sites (Table 25).

Table 25. Effect of PGR applications on grain yield (t/ha at 85% DM) of triticale (cv. Lasko) at Long Ashton and Eastleach in 1985.

Cycocel	Long Ashton Cerone -	+	Eastleach Cerone -	+
Nil	5.9 (t/ha)	+0.4	4.6 (t/ha)	+0.4
GS30	+0.9	+1.2	+0.9	+1.9
GS32	+0.4	+0.9	+0.6	+1.1
GS30+32	+1.0	+2.1	+1.4	+1.5
GS30+32+37	+1.0	+2.4	+1.1	+1.8
2 x GS30	+0.9	+2.2	+1.0	+1.3
LSD (5%)	0.76		0.78	

Further yield improvements, which were not always significant, were recorded in response to Cerone, particularly at Long Ashton.

When there was no stem-base lodging, as in the 1986 crop, yield was unaffected by Cycocel treatment (data not shown). However, Cerone produced an overall yield increase of approximately 0.5 t/ha at both sites.

Cerone increased mean grain weight at both sites when applied alone or in combination with Cycocel in 1986; there was a similar trend in 1985. The proportion of seed in the largest sieving category (>2.8 mm) was reduced by Cycocel. In the glasshouse experiments, total dry weight production and harvest index were unaffected by Cerone.

4.5.2.3 Semundo experiments

Several experiments employing PGR treatments were conducted by Semundo Ltd. on upper chalk soils in Wiltshire between 1980 and 1985 (D.M. Miles, pers. comm.). The main findings in these experiments are summarised below (data not presented).

In 1980, 3.5 l/ha Cycocel at GS30 had no effect on the yield of Lasko but reduced crop height, decreased mean grain weight and increased grains per ear and ears per m^2.

Bettaquat, Helestone, Halloween (Cycocel containing products), Cycocel, Cerone and Terpal had no effect on the yields of Lasko in 1982. Fungicide (propiconazole + carbendazim) combined with Cycocel at GS30 reduced crop height and lodging but also had no effect on the yield of Lasko.

In 1983, Cycocel and Terpal appeared to reduce the yield of Salvo but Cerone increased the yield of Lasko.

Recommended rates of Cycocel and Terpal reduced crop height but had no significant effect on the individual yields of Lasko, Salvo or CHD 461/77 in 1984. Overall, however, yields were reduced by Cycocel followed by Cerone.

In 1985, Terpal at GS32 and Cerone at GS45-49 was used with various rates and timings of Cycocel. A single application of 1 l/ha Cerone produced the highest yields in two experiments for Lasko and Salvo. However, treatments containing Cycocel and Terpal also produced significant yield improvements but no pattern of response relating to the timing or application rate of the growth regulators was apparent. A single application of Cerone in two other experiments on Lasko and Salvo produced no significant yield response. Over all of the 1985 experiments, Lasko appeared slightly more responsive than Salvo.

In relation to experiments carried out by other researchers, triticale in the Semundo trials appeared less responsive in yield terms to applications of PGR's. On the upper chalk soils in Wiltshire, the incidence of lodging in cereals is normally low. This was the case in the Semundo experiments and probably accounts for the lower, or lack of, response (D.M. Miles, pers. comm.).

4.5.2.4 Other experiments

At the NAS in 1984, Cycocel at GS30-31 increased the yield of Lasko in the absence of lodging but Terpal at GS37 had no significant effect (M. Nuttall, NAS, pers. comm.). Both growth regulators, particularly Terpal, increased the numbers of fertile tillers and reduced straw length. They equally reduced mean grain weight and nitrogen content of the grain.

Similar effects on the mean grain weight of Lasko occurred in Aberdeenshire (Naylor, 1987) but although grain nitrogen content was also reduced by early applications of Cycocel, it was increased by late applications at GS47. Furthermore, Naylor (pers. comm.) observed in two experiments (when there was no lodging) that Cycocel consistently increased the number of grains per ear in Lasko. While this was generally offset by lower mean grain weights, in one of the experiments, a greater number of ears was produced by Cycocel which combined to produce a yield increase. Conversely, in the same year, none of the yield components of Salvo was affected.

Finally, in the absence of lodging in 1983, BASF plc (J.S. Taylor, pers. comm.) recorded a significant straw height reduction in both Lasko and Salvo following the use of Cycocel or Terpal but yield improvements only occurred in Lasko.

In conclusion, it is clear that the level of lodging in triticale presents a widespread problem to growing the crop in most areas. Any future that may exist for triticale, particularly weaker-strawed cultivars such as Lasko, will partially depend on the efficacy of PGR's in preventing lodging. Cycocel and Terpal seem useful in this respect. While two-spray programmes of Cycocel followed by Cerone or Terpal, usually give extremely efficient lodging control, the cost of such applications may sometimes prove to be uneconomic if lodging is minimal.

4.6 Disease control

Diseases caused by either viruses or fungi are recognised as major causes of yield loss in cereals (Sylvester-Bradley & Scott, 1990). Most leaf and stem diseases can be controlled by fungicide applications and over a 9-year period Cook & Thomas (1990) reported substantial yield responses to fungicide programmes in winter wheat (Table 26).

Table 26. Mean yield response (t/ha at 85% DM) to fungicide programmes in ADAS winter wheat experiments from 1979 to 1987.

Programme	Yield response (t/ha)
GS39	+0.6
GS31+39	+0.8
GS31+39+59	+1.1

However, that such responses can occur in wheat does not necessarily imply that rye and triticale will respond similarly.

4.6.1 Rye

There are three important diseases of rye; eyespot (*Pseudocercosporella herpotrichoides*), mildew (*Erysiphe graminis*) and brown rust (Puccinia recondita) (D.J. Yarham, ADAS, Cambridge, pers. comm.). Rhynchosporium secalis and Septoria secalis have been recorded but are rarely severe (D.J. Yarham, ADAS, Cambridge, pers. comm.). Rye is also considered to be more susceptible to ergot (Claviceps purpurea) than, for example, barley and wheat. Although it cannot be controlled by fungicide, it is noteworthy that contamination of harvested grain is rare (M.D. Clark, pers. comm.).

Fungicides can delay the senescence of wheat (Priestley & Bayles, 1982) and, when applied in late season, have been shown to increase yields when disease pressure has been high (Cook & Yarham, 1985). Physiologically, rye differs considerably from wheat (Bushuk, 1976). In rye, between heading and anthesis, a large amount of assimilate was found to be stored in the stem which, at late stages, was withdrawn into the grain; ear and flag leaf photosynthesis represented only a small source of assimilate supply to the grain. Thus, the value of prolonging green leaf may be less than in wheat. It can, therefore, be speculated that rye may be less affected by late season attacks of foliar disease than, for example, wheat.

Furthermore, it is also known (Gooding et al., 1987; Stevens et al., 1988) that prolonging green leaf in wheat by using fungicides is sometimes negatively associated with grain HFN. This may be equally true for rye.

There is minimal information on the response of rye to the tactical use of fungicides and much of what is known is now out of date with the continued development of newer chemicals.

4.6.1.1 Seed treatments

In general, rye suffers less from seed-borne diseases than do other cereals. Thus, while seed treatment of wheat (primarily against bunt, Tilletia caries) and of barley (primarily against leaf stripe, Pyrenophora graminea) has long been standard practice, rye seed is usually untreated.

Treatment against stripe smut (Urocystis occulta) was recommended as long ago as the 1940's (Dillon Weston & Taylor, 1943) but this advice went generally unheeded. Indeed, since that time, stripe smut has only been recorded on five or six occasions in the UK, the last being in 1977 when the disease was found on three crops of cv. Rheidol in south Norfolk (D. J. Yarham, pers. comm.).

A potentially more serious seed-borne disease is the seedling blight caused by Fusarium spp. (in particular by F. nivale). Though not uncommon, this disease seldom causes serious yield losses; occasionally, however, it can so decimate a crop that re-drilling is necessary.

In 1978/79, seed treatment with triadimenol + fuberidazole (Baytan) or organomercury was compared with untreated seed. Their effect on plant emergence and Fusarium infection was monitored at eight sites by ADAS for Bayer UK Ltd. (Table 27).

Table 27. Effect of seed treatment on Fusarium infection and emergence of rye. Mean of eight sites, 1978/79.

	% plants infected by Fusarium	Emergence plants/m^2
Untreated	10.5	36.7
Organomercury	5.7	39.8
`Baytan'	2.0	38.8

Source: Bayer UK Ltd.

Seed treatment for Fusarium spp. is most likely to be cost-effective following seasons when wet weather before harvest favours seed infection, and cool wet conditions after sowing favour disease development.

The activity of Baytan against the disease is due primarily to the presence of fuberidazole in the formulation. Since fuberidazole is an MBC fungicide, the recent widespread occurrence of MBC-resistant strains of Fusarium nivale (Locke et al., 1987), is likely to reduce the effectiveness of this material.

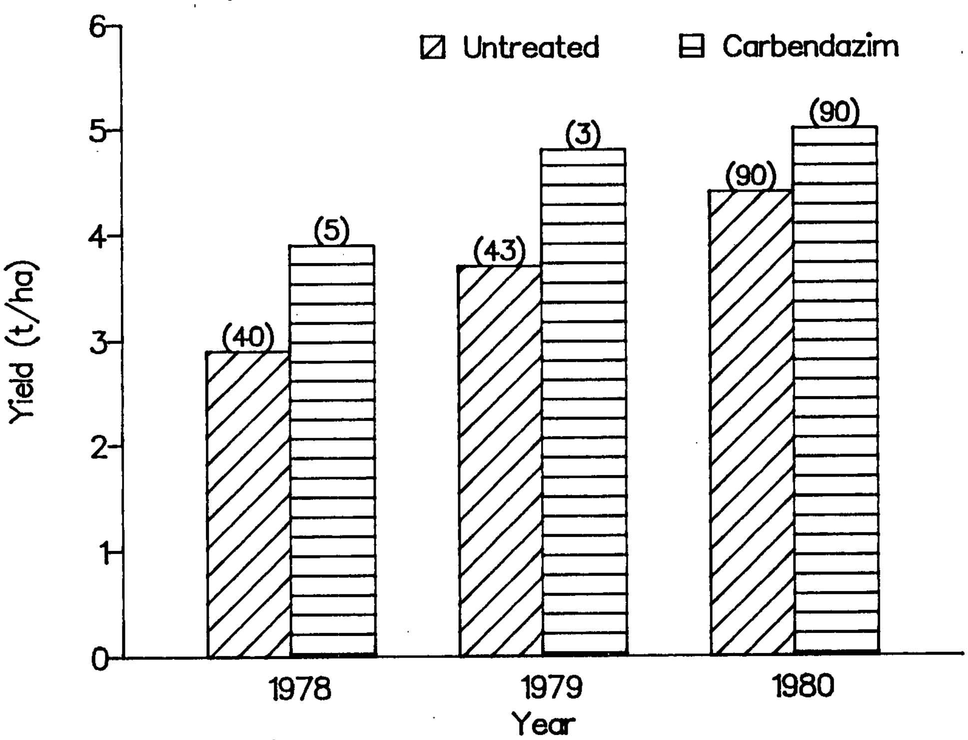
Bayer UK Ltd. (R.E. Simons, pers. comm.) also reported reductions in mildew and brown rust during late March 1984 following the use of Baytan as a seed treatment when compared with organomercury.

4.6.1.2 Foliar treatments

In replicated trials between 1978 and 1981, ADAS monitored the effects of triadimefon (Bayleton) on winter rye in Suffolk. In 1978, there was virtually no disease and no response to an application in the spring. In 1979, Bayleton was applied in the autumn to control a small amount of mildew; there was no effect on yield. In 1981, it was applied at a range of growth stages between GS26 and 49. Despite causing a reduction in mildew on leaf 3 from over 25% to nil, there was no yield response; the crop was observed to `grow away from the disease'.

ADAS also monitored the effects of carbendazim (Bavistin) applied to rye at GS31 in replicated trials between 1978 and 1980 (Fig. 9). In 1978 and 1979, yield increases of 1.0 t/ha were achieved by reducing eyespot, which in turn reduced lodging. An attack of Rhynchosporium which occurred in the 1979 experiment, in late April, was also controlled by carbendazim. In 1980, carbendazim had no overall effect on lodging but yields were increased by 0.6 t/ha.

The eyespot fungus occurs in two strains, wheat and rye (Scott et al., 1975; Julian & Lucas, 1990). Based on pathogenicity, both strains affect wheat and barley but the rye strain additionally affects rye. There is a high level of MBC resistance in the rye strain (King & Griffin, 1985) and although not tested it is likely that there would be a high level of resistance in any eyespot found on rye. The ADAS experiments were conducted before resistance became prevalent. Thus, the responses to carbendazim obtained in these experiments are probably no longer relevant in commercial practice (Griffin & King, 1985).



Source: ADAS, Suffolk

Figure 9: Effect of an application of carbendazim at GS31 on the grain yield and lodging % (in brackets) of rye in 1978, 1979 & 1980.

It is noteworthy that ADAS started a new experiment in 1988/89 at Gleadthorpe EHF (Table 28) and in Norfolk, to investigate the effect of foliar and stem-base diseases on grain quality and yield in modern cultivars of winter rye.

At the Norfolk site, brown rust was the only disease of any significance. It was seen as early as mid-April but it remained at low levels (mean 3.5% on leaf 2 at GS74); Merkator and Sentinel were more affected than Animo or Halo. Although the disease was reduced by all the fungicide programmes, none of the cultivars showed a yield improvement (data not presented).

Table 28. Effect of fungicide programmes on mildew (% leaf 4 at GS69) and grain yield response (t/ha at 85% DM) in 1989. Mean of four cultivars, Animo, Halo, Merkator and Sentinel.

Treatment at GS 31	37	39	Yield response (t/ha)	Mildew (% leaf 4)
Nil	Nil	Nil	5.2	27
SA+C	Nil	Tilt	+1.1	1
Nil	Nil	T. Turbo	+0.7	13
SA+C	Nil	T. Turbo	+1.2	1
Nil	SA+C	Nil	+1.0	4
LSD (5%)			0.21	5.6

Source: ADAS, Gleadthorpe EHF

SA+C = Prochloraz + carbendazim plus fenpropimorph (Sportak Alpha plus Corbel)
T. Turbo = propiconazole + tridemorph (Tilt Turbo)

At Gleadthorpe EHF, high levels of mildew had developed by mid-March and continued to spread throughout the summer. Low levels of brown rust and Septoria tritici developed after flag leaf emergence on the lower leaves. Stem-base disease was insignificant. All treatments gave some control of mildew which was positively correlated with increases in yield; all cultivars responded similarly. There was no significant advantage from two-spray programmes compared to a single spray of Sportak Alpha + Corbel at GS37. However, a single spray of Tilt Turbo was inferior. All treatments gave control of the low levels of brown rust.

4.6.1.3 Take-all

With the exception of oats, rye is less susceptible than other cereals to attacks by the take-all fungus Gaeumannomyces graminis but severe attacks have been noted in a few crops after an application of lime (Gair et al., 1978). Recent experiments (Hollins et al., 1986; Hollins & Scott, 1990; T. W. Hollins, PBI, Cambridge, pers. comm.; R. J. Gutteridge, RES, Harpenden, pers. comm.; ADAS Gleadthorpe EHF) have confirmed the relative resistance of rye to take-all and associated yield benefits compared to other cereal species, particularly on light soils.

Hollins and Scott (1990) have demonstrated that take-all isolates obtained from diseased cereal roots collected throughout the UK, varied from those infecting seedlings of wheat substantially and rye slightly (N-isolates), to those infecting both wheat and rye substantially (R-adapted isolates). The isolates could not be divided into two distinct groups based on pathogenicity to wheat or rye and all were morphologically similar to G. graminis var. tritici. R-adapted isolates were obtained from all areas sampled throughout the UK. They did not predominate on a particular host species and occurred together with N-isolates in a single field. Hollins (pers. comm.) also found that isolates identified as R-adapted on seedlings showed adaption to adult field grown rye in terms of disease frequency and yield loss. However, in spite of this adaption, rye was still relatively resistant (see Table 32, page 61). The exploitation of this resistance gives rye a useful role in the rotation on light soils. However, as a carrier or host for take-all, it is not a break-crop, and winter wheat after rye grown for grain or early grazing should be avoided.

4.6.2 Triticale

It is widely considered that one of the main attractions of growing triticale is its greater resistance to disease and therefore, a potentially lower fungicide requirement relative to other cereals.

Furber (1986) reported that triticale was resistant to barley yellow mosaic virus and virtually immune to mildew. The crop also appears to have good resistance to brown rust and Septoria tritici (G.C. Mann, pers. comm.). It appears to have less resistance to Septoria nodorum, eyespot and yellow rust (Puccinia striiformis) and, as in the major cereals, differences in the varietal sensitivity have been recorded (see Cultivars - page 16). Workers at the PBI (Hollins & Scott, 1985) found resistance to sharp eyespot (Rhizoctonia cerealis) to be good in the cultivars tested and equal to the resistant wheat cultivar, Gawain.

It is not surprising, therefore, that with this assumed high level of disease resistance, relatively few experiments have been conducted to examine the response of triticale to fungicides.

In seven NIAB and ADAS/NIAB trials in 1984, a prophylactic fungicide regime of prochloraz + carbendazim plus fenpropimorph (Sportak Alpha plus Corbel) at GS31, triadimefon + captafol (Bayleton CF) at GS39 and carbendazim plus fenpropimorph plus chlorothalonil (Bavistin plus Corbel plus Bravo) at GS59 was applied to wheat (cv. Norman) and 10 triticale cultivars. The average response of the cultivars Lasko and Salvo was 3% and not significantly different from the untreated (Mann, 1985).

Naylor & Su (1988a) confirmed disease resistance of triticale (cv. Salvo) compared to wheat (cv. Norman). In a cool damp growing season in which mildew was present at high inoculum levels in wheat it did not develop in triticale. Although similar proportions of triticale and wheat plants showed symptoms of eyespot, this disease only seemed to develop to levels that interfered with standing power of the wheat (Naylor & Su, 1988b).

In contrast, Scott & Hollins (1985) found that the triticale cultivars Salvo and Lasko were as severely infected with eyespot as the susceptible wheat cultivar Armada, when inoculated with isolates of <u>P. herpotrichoides</u> adapted to rye. They also found significant differences in susceptibility between triticale cultivars; the triticale cultivars Warren and Torrs were infected only to the same degree as the wheat cultivar VPM I which has resistance from <u>Aegilops ventricosa</u>.

At the NAS in 1984, triticale and wheat were sprayed with propiconazole + carbendazim (Hispor) at GS31, propiconazole (Tilt) at GS37 and Bayleton CF at GS58 (Table 29).

In the absence of disease control, the wheat was severely infected by mildew and Septoria, and produced yields much lower than those of triticale. Fungicides did not significantly increase the yield of triticale whereas they substantially increased the yield of wheat to

Table 29. Grain yield (t/ha at 85% DM) of triticale (cv. Lasko) and wheat (cv. Norman) grown with and without fungicides

	Yield of grain (t/ha at 85% DM)	
	Triticale	Wheat
Without fungicide	6.7	5.9
With fungicide	6.9	7.9
Yield response	+0.2	+2.0
LSD (5%)	0.21	

Source: NAS, Morley

above that of triticale. In this experiment, the yields of triticale increased with each increment of nitrogen up to 220 kg/ha when fungicides were applied. Without fungicide, there was a response up to 180 kg/ha but yields tended to decline at 220 kg/ha N. It is possible that hormonal effects of the fungicides may have prolonged leaf area duration thus allowing an increase in the nitrogen optimum. Alternatively, without fungicides, the response to nitrogen may simply have been diminished by unrecorded disease.

Semundo Ltd. conducted fungicide experiments in 1984 and 1985 in Wiltshire. In 1985, the yields of Lasko, but not Salvo, were increased from 7.0 to 7.5 t/ha by applying a combination of triadimenol + fuberidazole (Baytan) seed treatment, triadimefon + carbendazim (Bayleton BM) at GS32 and Tilt Turbo at GS61. There was a small, albeit non-significant, trend in both Lasko and Salvo for increased response to fungicides at high/above-optimum nitrogen levels.

In another experiment, Baytan seed treatment increased the yield of Lasko, but not Salvo, from 6.1 to 7.4 t/ha. However, in the same year, Rosko (a sister line of Lasko), and Lasko in the previous year, were unaffected by Baytan or triadimefon (Bayleton). Disease data are not available and no explanation for these responses can be provided.

At Rosemaund EHF in 1984, a fungicide programme of Tilt at GS32 and Bayleton CF at GS39 and GS59 applied to Lasko and Salvo, increased tiller density, mean grain weight and specific weight. It reduced the number of grains per ear (perhaps as a consequence of the higher tiller population). Lodging was increased by the fungicides, probably aggravated by increased biomass weighted with rain during wet weather. Within the context of no foliar disease, a substantial yield increase of 0.7 t/ha was recorded, meaned over both cultivars.

During 1984 and 1985, the effects of different fungicide programmes, comprising Sportak Alpha at GS30/31 (1984/1985 respectively) and sprays of Bayleton CF at GS39, and approximately GS59 were compared by ADAS on a crop of triticale (cv. Lasko) (Table 30). In 1984, low levels of eyespot and a trace of Septoria nodorum were found in the experiment. However, the crop remained remarkably disease free throughout the season and following an overall spray at GS30, subsequent fungicide applications did not affect yield.

Table 30. Grain yield response (t/ha at 85% DM) of triticale (cv. Lasko) following fungicide applications in 1984 and 1985.

	1984	1985
Untreated	-	5.5 (t/ha)
GS30/31	7.3 (t/ha)	+0.3
GS39	-	+0.2
GS59	-	+0.2
GS30/31+39	+0.1	+0.6
GS30/31+59	-0.1	+0.6
GS39+59	-	+0.8
GS30/31+39+59	0.0	+1.0
LSD (5%)	0.51	0.33

Source: ADAS, Cambridge

In the following year, levels of foliar disease remained relatively low throughout the season. Septoria nodorum was present at a level of less than 10% on leaf 2 at the time of the main disease assessment (GS75). Eyespot levels were above the threshold suggested for winter wheat (20% tillers infected) by the time of the first disease assessment (19 April). Although results were variable, treatment at GS31 provided some control of eyespot. This effect was most marked when no further treatments were applied.

Surprisingly, yield responses to some of the treatments were quite large (Table 30). Although not significantly better than the control, the GS31 treatment was the best and most cost-effective of the single sprays. Two sprays gave better responses than single sprays but there was little to choose between application times. The best overall response was to a three-spray programme (+1.0 t/ha) which is comparable to the long-term average in wheat.

4.6.2.1 Take-all

Triticale appears to be partially resistant to take-all. Trials conducted at the PBI (Hollins et al. , 1986) between 1977 and 1984 showed that triticale was intermediate in resistance between wheat (susceptible) and rye (resistant). Octoploid triticale was slightly more susceptible than hexaploid triticale. There was little evidence of consistent variation in resistance among wheat or rye cultivars but a few hexaploid triticale cultivars varied in resistance. The use of triticale was suggested as an immediately available means of introducing take-all resistance into cereals.

Triticale was also found to have intermediate resistance to take-all between rye and wheat at RES and Woburn (R. J. Gutteridge, pers. comm.), and Gleadthorpe EHF between 1986 and 1988. However, winter barley was also grown in these experiments and by harvest, it appeared similarly affected to triticale. The Rothamsted and Woburn results are summarised in Table 31.

At Gleadthorpe EHF, visual symptoms of take-all (whiteheads) at harvest were always worst in wheat, then triticale, then winter barley; none was observed in rye.

Variations in the ability of take-all isolates to affect wheat and rye seedlings have been described on page 56. Hollins (pers. comm.) also found that N-isolates of take-all affect the yield of wheat, triticale and rye in decreasing order of severity related to the amount of disease they cause on roots, triticale being approximately intermediate between wheat and rye (Table 32). R-adapted isolates do not apparently jeopardise the moderate resistance of triticale.

Table 31. Take-all index* determined during June and July on wheat, barley, triticale and rye grown at Rothamsted and Woburn. Means of high and low input systems, 1986-88.

	Rothamsted		Woburn	
	June	July	June	July
W. wheat (Avalon)	106	181	148	216
W. barley (Panda)	84	127	82	122
Triticale (Lasko)	76	106	66	130
Triticale (Status)	79	95	58	128
Rye (Dominant)	38	41	21	60

Source: IACR (RES)

* Take-all index is a measure of take-all infection weighted according to the severity of the infection ie. $\frac{(a + 2b + 3c)}{T} 100$

Where: a = number of plants with slight take-all
b = number of plants with moderate take-all
c = number of plants with severe take-all
T = total number of plants assessed

Table 32. Take-all index (Hollins *et al.*, 1986) and yield loss % in wheat, triticale and rye infected by N- and R-isolates. Mean of four years, 1982-85.

	Take-all index	Yield loss (%)
N-isolates		
Wheat	73	35
Triticale	43	20
Rye	5	1
R-isolates		
Wheat	73	30
Triticale	42	18
Rye	18	10

Source: PBI, Cambridge

4.6.2.2 Ergot

As in rye (page 51), it is widely considered that ergot is a potential threat to triticale production. It is known that cultivars differ in susceptibility and it is possible to use screening techniques in breeding programmes (Gregory et al., 1984). In practice, ergot contamination in crops of triticale appears to be rare (M. J. Furber, pers. comm.).

4.7 Weed control

Herbicide screening for cereals is normally undertaken by chemical manufacturers. Rye and triticale have attracted relatively little attention in this respect in the UK. There has been no work done on the effect of weed populations on rye and triticale. However, in order to help satisfy a demand for information on crop safety, particularly in triticale, workers at the PBI (Gregory et al., 1984), ADAS, Harper Adams Agricultural College and the West of Scotland Agricultural College conducted various experiments and observations in the early to mid 1980's. Herbicides which were available for other cereals were applied mainly to triticale; in some cases rye and wheat were included. The results are not presented because in themselves they do not constitute recommendations and they are now out-dated by the introduction of new herbicides and cultivars and new label recommendations and regulations controlling the use of pesticides.

As for wheat, certain cultivars of rye and triticale have sometimes been damaged by herbicides which have shown no phytotoxic effects on other cereal cultivars. Thus, there may be considerable dangers in using some herbicides, which are already approved for the major cereals, on rye and triticale under off-label approval arrangements. Fortunately, the number of herbicides which have label approvals for rye and/or triticale has increased and is shown in Table 33. Their use on these crops is frequently restricted to named cultivars or special times of application and they should not be used without due reference to manufacturers' label information.

Table 33. Herbicides and groups of weeds* which they control, approved under the Control of Pesticides Regulations 1986, for use on rye and/or triticale in 1990.

	Weeds controlled			Rye	Triticale
bromoxynil + clopyralid	BL				√
bromoxynil + fluroxypyr + ioxynil	BL			√	√
bromoxynil + ioxynil	BL			√	√
bromoxynil + ioxynil + mecoprop	BL			√	√
chlorotoluron	BL	G			√
clopyralid + fluroxypyr + ioxynil	BL				√
clopyralid + mecoprop	BL			√	√
2,4-D	BL			√	
dicamba + MCPA + mecoprop	BL			√	
difenzoquat			WO	√	√
flamprop-M-isopropyl			WO	√	√
fluroxypyr	BL			√	√
isoproturon	BL	G	WO	√	√
isoproturon + isoxaben	BL	G		√	√
isoxaben	BL			√	√
linuron + trifluralin	BL	G			√
MCPA	BL			√	
mecoprop	BL				√
methabenzthiazuron	BL	G		√	√
metoxuron	BL	G			√
pendimethalin	BL	G	WO	√	√
terbutryn	BL	G		√	√
tri-allate		G	WO	√	√
trifluralin		G		√	√

Source: Anon. (1990)

* √ = Approved
BL = broad-leaved
G = graminaceous
WO = wild oats

In conclusion, it is considered that for most situations, except where controlling graminaceous weeds after crop emergence, there is an adequate range of herbicides approved and that no further work (outside of that by chemical manufacturers) is justified.

4.8 Pest control

There is a dearth of evidence to support the value of using insecticides on rye and triticale. However, insect pests such as the aphid vectors of barley yellow dwarf virus (BYDV), wheat bulb fly (Delia coarctata), frit fly (Oscinella frit) and cereal yellow fly (Opomyza sp.) have been observed in both rye and triticale crops and it is usually assumed that the criteria for, and benefits from their control, will be analagous to those in wheat. Despite there being very few label recommendations for the use of insecticides on either crop, both rye and triticale may be treated with products approved for use on wheat and/or barley within the Food and Environment Protection Act 1985 (FEPA) regulations for off-label uses of pesticides (Anon, 1989c).

In 1985, ADAS examined the susceptibility of a range of cereal species to wheat bulb fly and measured the effects of an intensive, three-spray programme of fonofos, chlorfenvinphos and omethoate applied between 28 December 1984 and 14 March 1985 (Table 34). The response to the spray-programme was poor; on average, wheat bulb fly larval invasion of plants was only halved. This was attributed to a delayed and extended period of wheat bulb fly egg-hatch. However, the trial did confirm that both rye and triticale are suitable hosts for wheat bulb fly.

Table 34. Percentage of plants, with and without a three-spray insecticide programme, invaded by wheat bulb fly larvae on 9 April 1985.

	Untreated	Treated
Winter barley - cv. Halcyon	42	22
Winter wheat - cv. Norman	37	18
Rye - cv. Rheidol	42	9
Triticale - cv. Lasko	38	19
Triticale - cv. Aquarius	25	17

Source: ADAS, Cambridge

In order to obtain information on damage by leatherjackets to winter cereals, the insecticide chlorpyrifos was applied at monthly intervals to plots of triticale in 1987 and 1988 (Table 35).

Table 35. Effect of chlorpyrifos sprays, for leatherjacket control, on the grain yield (t/ha at 85% DM) of triticale (cv. Lasko) in 1987 and 1988.

	1987 (Tipula paludosa)	1988 (Nephrotoma maculata)
Untreated	5.0	6.7
Chlorpyrifos in:		
Dec	5.5	-
Jan	5.3	-
Feb	5.3	6.6
Mar	5.6	6.9
Dec + Mar	5.3	-
Feb + Mar	-	6.6
LSD (5%)	0.45	0.48

Source: ADAS, Northumberland & Staffordshire

Each year, the population of leatherjackets was approximately 80/m^2 in January, well above the present ADAS threshold of 30/m^2 for control on winter cereals in late winter/early spring. All treatments gave over 80% control of leatherjackets, except that applied in March 1988 which had no effect. The species present in 1988 was Nephrotoma maculata. It had pupated in April which suggested that its potential for feeding damage in spring was less than for the usually more abundant T. paludosa. This may partly explain why, in 1988, yields were unaffected whereas, in 1987, all treatments tended to increase yields, although they were only significantly greater following single sprays in December and March. No other work on insecticides has been reported.

Work at the WPBS (Cook et al., 1985) showed that triticale cultivars differed widely in their susceptibility to cereal nematode (Heterodera avenae). Triticale cv. Warren was susceptible to both common UK pathotypes A and C; cv. Lasko was susceptible to A but resistant to C; cv. Salvo was resistant to both, and was the most resistant cultivar in all tests. Resistance in triticale is of significance since the crop is frequently grown on light land which is relatively prone to infection although the pest is now of minor status.

4.9 Harvest date

4.9.1 Rye

Rye grain has a strong tendency to sprout in warm, wet climates. During sprouting, the activity of alpha-amylase can increase to the extent that the flour cannot be used for bread production (Bushuk, 1976). Rye is also susceptible to producing pre-maturity alpha-amylase (J. E. Flintham, pers. comm.) which adversely affects HFN (Gale & Flintham, 1988).

The importance of HFN has previously been stated (pages 9 & 10); grain with an HFN of less than 90 may be unacceptable for baking and attract only the lowest prices as an animal feed. Harvest date may therefore be an important criterion.

Table 36. Effect of harvest date on HFN and moisture content (%) of rye grain in 1987 & 1988.

1987	HFN	%MC	1988	HFN	%MC
11 August	165	29	11 August	157	22
14 August	167	27	12 August	114	27
17 August	174	18	15 August	101	21
20 August	159	18	17 August	107	19
24 August	113	28	19 August	103	18
27 August	79	27	22 August	106	20
			24 August	86	19
			26 August	85	16
			30 August	71	24
			1 Sept	62	-
LSD (5%)	18.3			31.3	

Source: ADAS, Gleadthorpe EHF

In 1987 and 1988, replicated plots of rye (cv. Merkator) were harvested by hand on successive dates at Gleadthorpe EHF. The grain was removed from the ears in a bench thresher and then dried in an oven at 50°C to 14% moisture content. The HFN's of the grain and corresponding moisture contents at harvest are shown in Table 36.

There were significant reductions in HFN in both years when harvest was delayed. The reductions tended to occur after periods of rainfall which increased grain moisture content. It was obvious in this experiment that the penalty for delaying harvest was large. During periods of unsettled weather, there may be advantages in harvesting early at high moisture contents and drying the grain, in order to reduce the risks of obtaining low HFN's and low prices.

4.9.2 Triticale

HFN is not a determinant of quality in triticale because the grain is mainly used as an animal feed. Thus, timely harvest in triticale is unlikely to be as important as it is in rye.

However, like rye, there is a tendency for triticale to lodge and for the grain to sprout in the ear following maturity. In wet seasons in particular, although it may be preferable to harvest triticale after rye, there may be benefits in harvesting it before feed wheat. Observations at Gleadthorpe EHF, showed that if the three crops were sown on the same day in the autumn they would mature at approximately the same time. No work has been done on sequential harvesting of triticale.

4.10 Comparison of rye and triticale with other cereal species

4.10.1 Rye

Between 1972 and 1979, winter rye (cv. Dominant) was compared with a range of cereal species, triticale, winter wheat, winter oats and winter and spring barley grown as first or second cereals on loamy sand at Gleadthorpe EHF. Cultivars changed and not all species were compared every year. However, irrespective of previous cropping, in six out of seven years, rye produced the greatest yields; 1979 was the exception.

Marked improvements in cultivars and husbandry techniques, particularly in relation to the major cereals, have taken place since these experiments were conducted and there must be doubt as to the continuing relevance of the results.

More recently, triticale cultivar trials conducted in the 1980's by NIAB, ADAS and Semundo Ltd. sometimes included rye and wheat comparisons. Rye yields were variable, tending to be best on the lighter soils. However, these trials often received husbandry most appropriate to triticale which may have adversely affected the yields of rye and wheat.

Between 1986 and 1988, species comparisons were conducted on clay loam soil at Rothamsted and sandy soil at Woburn (R. J. Gutteridge, pers. comm.). Wheat, barley, rye and triticale were grown as third cereals under high and low input systems of husbandry (Table 37). The `high input' systems provided 40 kg/ha N in February and 160 kg/ha N in April with a full fungicide, insecticide and growth regulator programme. The `low input' system provided only 120 kg/ha N in April. Take-all was prevalent on both sites but was more severe with the low input system; rye was the least affected.

Table 37. Grain yield (t/ha at 85% DM) of rye, wheat, barley and triticale grown as third cereals under low and high input systems of husbandry at Rothamsted and Woburn. Mean 1986-88.

	Rothamsted		Woburn	
	Low input	High input	Low input	High input
Rye - cv. Dominant	6.5	7.1	6.4	7.2
W. wheat - cv. Avalon	6.2	7.0	3.4	5.1
W. barley - cv. Panda	6.7	8.8	4.8	6.2
Triticale - cv. Lasko	6.2	7.5	5.0	5.3
Triticale - cv. Status	6.2	6.8	4.5	5.1

Source: IACR (RES)

On heavier Rothamsted soil, Panda winter barley produced the highest yields irrespective of husbandry regime but it only marginally out-yielded rye at the low level of input. On the light Woburn soil, Dominant rye substantially out-yielded all species irrespective of input (Table 37).

Species comparisons as second cereals were also conducted by ADAS on loamy sand soil at Gleadthorpe EHF during the same period. Rye was compared with wheat, barley and triticale (Table 38).

All crops received four levels of nitrogen split between 40 kg/ha in early March and the remainder at GS30/31. Other husbandry inputs were given to each crop based on good commercial practice. These included additional growth regulator sprays on the rye and triticale.

Table 38. Grain yield (t/ha at 85% DM) of rye, wheat, barley and triticale grown as second cereals receiving four rates of N fertiliser. Mean 1986-88.

	Nitrogen (kg/ha) 80	120	160	200	Mean
Rye - cv. Animo	6.7	6.7	6.9	6.6	6.7
W. wheat - cv. Galahad	4.5	5.6	5.9	6.0	5.5
W. barley - cv. Igri	6.4	6.9	7.3	7.4	7.0
Triticale - cv. Lasko	5.5	6.5	6.4	6.3	6.2
LSD (5%)			0.99		0.49

Source: ADAS, Gleadthorpe EHF

Overall, there was no significant difference between the yields of rye and barley but both out-yielded triticale and wheat. Responses to nitrogen varied each year and there was no conclusive evidence of different nitrogen requirements. There was however, a non-significant trend for the yields of rye and triticale (because of greater susceptibility to lodging) to decline at the highest levels of nitrogen, whereas the yields of wheat and barley continued to increase.

It is interesting to speculate why wheat performed badly and conversely why rye and barley performed well. Undoubtedly, take-all was responsible for large yield reductions in wheat. However, winter barley was also affected by take-all but did not show such severe symptoms in the field. A commonly held view is that rye and triticale are deep rooting and exploit more soil moisture thus making them less prone to the effects of drought. When a visual inspection of the soil profile was made immediately post harvest at Gleadthorpe EHF in 1988, there was no evidence to suggest that the final rooting depth was greater in rye than in wheat, barley or triticale. However, above ground, it was observed that the species developed at different rates. For example, rye was first to reach ear emergence, followed in turn by barley, then triticale then wheat. Although these comparative differences did not continue through to harvest (barley was first to mature), species which develop early may be at less risk from drought and the exacerbating effects of take-all which tend to increase progressively during the spring and summer.

It is also possible that rye actually benefits from a more highly developed root system. Starzycki (1976) reported that rye roots take up water and nutrient very efficiently and that rye uses 20-30% less water per unit of dry matter formation than wheat. Such a mechanism of drought resistance, if it continues in new cultivars, could prove particularly beneficial in future, should forecasts of global warming and increased risk of drought in the UK hold true.

The efficiency of winter rye to extract residual soil N and reduce over-winter losses caused by leaching was demonstrated, albeit without comparisons with other cereals, at Gleadthorpe EHF during the winter 1988/89 (M. Shepherd, ADAS, Gleadthorpe EHF, pers. comm.) (Table 39).

Table 39. Effect of cropping on over-winter (November 1988 to April 1989) leaching losses of nitrogen below 90 cm following a previous winter cereal crop on loamy medium sand.

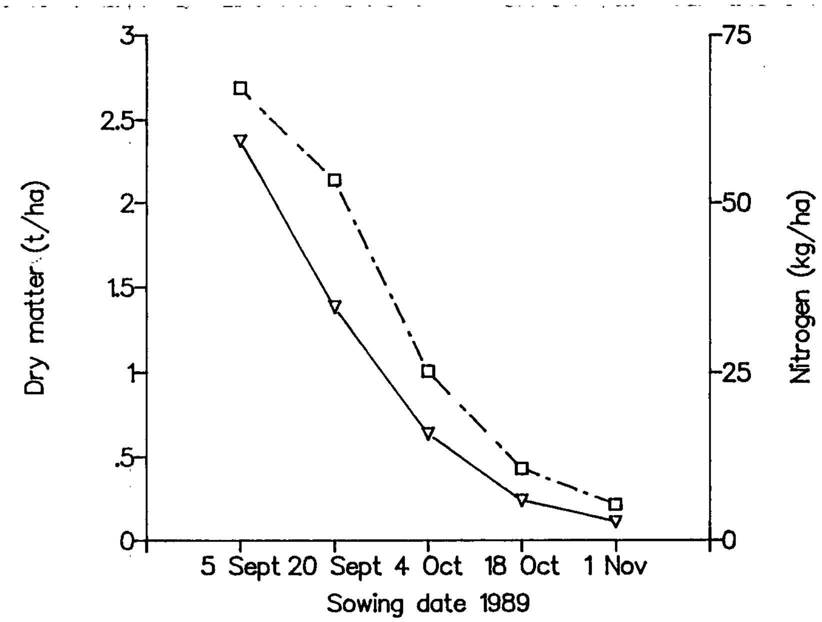
	Drainage (mm)	Mean mg N /litre drainage	Leached N (kg/ha)	Crop uptake in March (kg/ha N)
Fallow	150	21	32	0
Forage rape (sown 16 August)	110	9	10	22
Rye (sown 19 September)	110	3.5	3.5	50

Source: ADAS, Gleadthorpe EHF

Not only was rye more efficient than forage rape in extracting residual soil N (drainage was the same for both crops), the mean nitrogen content of the drainage water from November to April was less than one third of the maximum concentration (11.3 mg N/litre) recommended by the EC in drinking water. Thus, the additional potential value of rye as an autumn/winter cover crop to reduce nitrogen pollution should be considered.

It was also noted that although the forage rape was sown approximately one month earlier than the rye, it grew poorly compared to the rye and this may have affected its ability to extract nitrogen. In an experiment at Gleadthorpe EHF, commencing autumn 1989, nitrogen off-take in rye was positively correlated with dry-matter production which was reduced by each delay in sowing (Fig. 10).

Thus, it is considered that in order to obtain greatest efficiency in reducing leaching losses, very early sowing is important and rye might be better suited than other cereals for this purpose; lodging may decrease in rye (Table 8) compared to wheat (Fielder, 1988) and triticale (page 22); rye is least affected by take-all (page 55) which is aggravated by early sowing (Fielder, 1988); rye is ideally suited to being grown on very light soils which are in themselves most prone to leaching.



Source: ADAS, Gleadthorpe EHF

Figure 10: Effect of sowing date on ▽ , dry matter production and □ , N off-take of rye on 31 January 1990.

4.10.1.1 Financial aspects

The costs of growing rye are probably not too dissimilar from those of other winter cereals. Small potential savings in cost with benefits to the environment by reducing nitrogen and fungicide inputs compared to other cereals, are likely to be partially eroded by the need for increased growth regulator usage. Thus the cost benefits of growing rye will be largely related to its yield and the premium paid for grain quality. It is noteworthy that over the three years between 1986 and 1988 on loamy sand at Gleadthorpe EHF, rye was the most profitable crop when compared with wheat, barley and triticale in second cereal situations.

4.10.2 Triticale

Comparisons between triticale and other cereals, particularly wheat, have been carried out by several researchers since the early 1980's. One of the first papers to be published was written by Ford et al. (1984). In two experiments on good arable soils, they found that in the absence of inter-plot competition (the shading effects of tall cultivars grown adjacent to short cultivars), lodging and differential disease incidence, wheat produced similar or better yields than triticale. In a third experiment on loamy sand, triticale out-yielded wheat. However, disease control was not fully effective in this experiment and it was suggested that the yield advantage of triticale may have been exaggerated. Unfortunately, this phenomenon might have occurred in many experiments, especially where overall husbandry treatments were given. Husbandry requirements such as disease control, nitrogen and growth regulators will vary between species. Over, or in particular under, application may have a deleterious effect on yield. This is especially true of disease control in winter wheat and it is demonstrated by work done at Bridgets EHF (Table 40).

Table 40. Grain yields (t/ha at 85% DM) and husbandry details of triticale and wheat grown in cultivar testing trials. Mean 1985-89.

Husbandry	Triticale cultivar trials (Mean of Lasko and Salvo)	Winter wheat Recommended List trials (Trial mean)	
	7.1	6.5	8.7
Fungicide	Single spray (GS31)	Nil	Full programme
PGR	Cycocel (GS31)	Nil	Nil
Nitrogen (kg/ha)	180	240	240

Source: NIAB, South Region (Bridgets EHF)

It can be seen that with the above husbandry inputs triticale out-yielded wheat grown without fungicides but it could not compete successfully when the wheat received a full fungicide programme.

The crops were grown in relatively fertile situations as second cereals after grass on chalky clay loam where reasonable to good yields of wheat would be expected. However, Furber (1986) noted (unreplicated data) that on the same farm, triticale out-yielded wheat by 1 t/ha when both were grown on a continuous cereal site with fertiliser and fungicide management most likely to favour wheat. Thus, as was shown by Ford et al. (1984), triticale may be more suited to less fertile situations but in order to obtain valid comparisons with other species, it is important to use data from replicated experiments where the potential yield is not limited by arbitrary husbandry decisions imposed by the experimenter.

Valid, replicated comparisons, were made when triticale was compared with winter wheat and winter barley on nine medium to light soil sites by ADAS between 1986 and 1988. The sites were second or subsequent cereals on fields in the South West Region and at Bridgets, Gleadthorpe and High Mowthorpe EHF's. Each crop was managed according to good husbandry practice, current at the time, but yield potential may still have been limited. Wheat and barley usually received more fungicide but triticale more growth regulators. Up-to-date cultivars were used which were considered popular with the local farming communities. These were mainly Lasko (triticale), Galahad (winter wheat) and Igri (winter barley), although out of the nine sites, Salvo (triticale) was grown once and Brock (winter wheat) and Marinka (winter barley) twice. Each crop was grown with at least three different levels of nitrogen (Table 41).

Irrespective of the level of nitrogen applied, over all sites and years, winter barley was highest yielding, wheat lowest and triticale intermediate. Examination of individual site data showed that out of the nine comparisons, triticale was significantly out-yielded by wheat only twice and barley three times. Conversely, triticale out-yielded wheat five times but barley only twice. Unlike that found by Ford et al. (1984), there was no indication that the performance of triticale in relation to the other species was improved on the lighter soils.

Table 41. Mean grain yield (t/ha at 85% DM) of triticale, winter wheat and winter barley grown as second or subsequent cereals on nine medium to light soil sites between 1986 and 1988.

	Nitrogen (kg/ha)			
	120	160	200	Mean
Triticale	5.8	6.0	6.1	6.0
Wheat	5.3	5.6	5.8	5.6
Barley	6.2	6.5	6.6	6.5
LSD (5%)		0.62		0.36

When rye was included at Gleadthorpe EHF it also out-yielded triticale (Table 38).

Crop responses to nitrogen varied between sites but surprisingly there was no consistent evidence that triticale, wheat and barley had different nitrogen requirements. Take-all was observed on some sites, especially at Gleadthorpe EHF and was undoubtedly, partly responsible for the relatively poor performance of wheat. It was also seen in the other crops, and although not as severe as in wheat, crop stunting and whiteheads appeared worse in triticale than in barley. Speculation in relation to rooting depth, maturity, drought and take-all is discussed in the previous section on rye (pages 69 & 70).

Results produced by other workers at RES and Woburn lend support to those produced by ADAS (R. J. Gutteridge, pers. comm.). Their experiments and results have also been previously described in the section on rye (page 68, Table 37). Only on the light soil at Woburn with a low input of management did triticale produce yields equivalent to or marginally better than barley. On the heavier Rothamsted soils or where high inputs were given, barley was highest yielding. However, triticale produced similar or much better yields than wheat, particularly when only low inputs were given at Woburn.

Other workers in England have described yield benefits from triticale compared to wheat (Semundo Ltd; ADAS, Arthur Rickwood EHF; R. C. Anslow, Harper Adams Agricultural College). The better results have usually been obtained on lighter soils or in take-all situations.

Workers in Scotland (G. P. Whytock, SAC, Auchincruive; N.M. Fisher, SAC, Edinburgh; K. Walker, School of Agriculture, The University, Aberdeen) have also commented on some satisfactory performances of triticale in relation to wheat. However, good results appear to have only been obtained on the lightest soils and because of late maturity particularly in relation to barley, triticale is not widely recommended.

It could be argued that many of these species comparison experiments have been carried out where some aspect of agronomy, site or season has seriously limited yield. At Rosemaund EHF, adjacent experiments on triticale and wheat, made in the same field, show a clear yield advantage in favour of winter wheat (Table 42).

Table 42. Grain yield (t/ha at 85% DM) of triticale and winter wheat grown in adjacent experiments in 1984, 1985 and 1986.

Year	Triticale	Winter wheat
1984	8.8	11.5
1985	6.6	9.3
1986	8.7	9.9

The most favourable season on record, was 1984 indicating that at these higher levels of yield, wheat is better adapted to exploit the favourable aspects of site and season. It could, therefore, be argued that in terms of physiology, wheat is the better ideotype.

4.10.2.1 Financial aspects

Cereal gross margins are based on the difference between yield multiplied by the price and the variable costs, such as seed, pesticides and fertilisers. It is important to note that triticale is mainly used as an animal feed and would, therefore, command feed grain prices probably similar to, or slightly lower than those of wheat (McDonald, 1988). Because triticale has good resistance to leaf diseases use of fungicides is likely to be lower than on wheat or barley. However, these savings may be partly offset by the greater need to use PGR's and by slightly higher seed costs. Experiment results do not suggest major savings in nitrogen costs. Thus, the variable costs of growing the species are similar and the choice of whether to grow wheat, barley or triticale for animal feed is probably largely yield dependent.

4.11 Husbandry - conclusions and guidelines

4.11.1 Rye

Soils and rotational position

Rye can be particularly successful on light, drought-prone soils which frequently produce poor yields of wheat or barley. Its excellent tolerance of take-all make it ideally suited to being grown as a second or subsequent cereal but field observations suggest that it should not be considered as a break crop. It should not be grown on fertile soils which are conducive to lodging nor in regions where the sale of grain for milling may be difficult.

Cultivar

Choice of cultivar may be determined by reference to the NIAB Recommended Varieties of Cereals List (NIAB Farmers Leaflet No. 8.).

There is no information on the Lists concerning the relative differences between cultivars but all are currently acceptable for milling providing normal quality criteria are met.

Seedrate

Compared to other cereals, the average 1000 grain weight of rye is low (approximately 33 g) and this should be considered when determining seedrate. On light soils, where there is good seed/soil contact, experiments showed no benefits from increasing the seedrate above the lowest level tested, 50 kg/ha (150 seeds/m^2). The crop is extremely winter hardy and should incur minimum plant loss. Thus, rates of 300 seeds/m^2 (approximately 100 kg/ha) or less should produce adequate plant populations and ground cover for all but the very poorest conditions. Excessive seedrates contribute to crop lodging.

Sowing date

Early sowings of rye in September are recommended for highest yields and resistance to lodging. Take-all infection in the major cereals is frequently aggravated by early sowings; rye is unlikely to be affected because of its excellent resistance. The ability of the crop to reduce nitrogen leaching losses will also be improved by early sowing.

Nitrogen

Autumn-applied N

Autumn nitrogen should not normally be applied. It is unlikely to affect yield and may aggravate lodging and leaching losses.

Spring-applied N

There is little evidence that current rye cultivars will respond in yield terms to more than 100 kg/ha of applied nitrogen in N Index 0 situations, even if a full PGR programme is used. In experiments lodging could almost be guaranteed at nitrogen rates in excess of 120 kg/ha. HFN was reduced by nitrogen increments irrespective of the presence or absence of lodging. Although not fully tested, it is recommended that the nitrogen is split between up to 40 kg/ha in early/mid-March and the remainder at late GS30 as an insurance against poor uptake which might occur in dry springs if the nitrogen is applied as a single dressing at GS30.

Plant growth regulators

In rye, substantial benefits to lodging control and yield have been achieved by applications of Cycocel, Cerone or Terpal. Due to limited experiment results, potential benefits from two-spray programmes of Cycocel at GS30/31 followed later by Cerone or Terpal have not been proved. Nevertheless, it is suggested that when conditions for growth are good, two-spray programmes are used in order to reduce the risk of lodging.

Fungicides

The most important diseases of rye are eyespot, mildew and brown rust. Economic yield increases can be obtained by controlling these diseases, particularly during stem extension. However, due to the sporadic incidence of disease outbreaks, a managed disease control approach is recommended rather than prophylactic treatments. Most rye strains of eyespot are resistant to MBC fungicides.

Herbicides

Although there is a wide range of herbicides for rye, label recommendations sometimes restrict their use to certain cultivars, such as Animo or Dominant and to certain times of application. This is particularly important in relation to black-grass (Alopecurus myosuroides) control for which herbicide label recommendations are usually restricted to pre-crop emergence application only. The choice and timing of herbicides for broad-leaved weed control are numerous and should present few problems.

Insecticides

Rye appears to be susceptible to many of the pests which attack wheat. Despite a lack of supporting experimental evidence, it is currently suggested that pest control in rye should be exercised in accordance with measures used on wheat, within the bounds of off-label approval.

4.11.2 Triticale

Soils and rotational position

Triticale is best suited to light/medium soils and to being grown as a second or subsequent cereal where take-all may occur. In such situations, triticale is likely to out-yield winter wheat but less likely to out-yield winter barley. When inputs of nitrogen and fungicide are restricted, it may also out-yield winter barley grown with lower inputs.

Cultivar

As with rye, choice of cultivar may be determined by reference to the Recommended Varieties of Cereals List (NIAB Farmers Leaflet No. 8.).

Seedrate

High seedrates are likely to aggravate lodging. Experiments mainly using cv. Lasko, showed no yield advantage from sowing more than approximately 170 seeds/m^2 (60 kg/ha) into good seedbeds on light soils. However, in order to establish an adequate plant population under a wider range of soils and poorer conditions, higher rates of up to 350 seeds/m^2 may be needed. Assuming a 1000 grain weight of 40 g (variations may occur according to cultivar) this represents a maximum seedrate of 140 kg/ha.

Sowing date

Triticale should be sown from mid-September on infertile or light soils. On fertile soils, sowing should take place from early October. Sowing too early may aggravate take-all and crop lodging and create a greater need for PGR inputs.

Nitrogen

Autumn-applied N

Under normal conditions, applications of nitrogen in the autumn will not influence yield but may aggravate lodging and increase the risk of nitrate pollution by leaching.

Spring-applied N

On sandy or shallow soils, in N Index 0 situations, it is recommended that 120 to 160 kg/ha nitrogen is applied and that it is split between 40 kg/ha N in early to mid-March followed by the remainder at GS30. On peat soils, or mineral soils with a relatively high residual N status, a total application of 40 kg/ha N will probably be sufficient.

Plant growth regulators

Lodging control is usually necessary in triticale, especially in the weaker-strawed cultivars. Cycocel at GS30/31 may give reasonable, inexpensive control and additionally may sometimes increase yields of cultivars such as Lasko by manipulating yield components. Experiments have shown that improved lodging control, albeit at greater cost, may be achieved by a sequential application of Cycocel as suggested above, followed by either Cerone or Terpal at flag leaf emergence.

Fungicides

Currently grown cultivars have excellent resistance to mildew and Septoria tritici and good resistance to brown rust. They have less resistance to eyespot, yellow rust and Septoria nodorum. Large responses to prophylactic fungicide treatments are uncommon and are unlikely to be economic. Thus, a carefully managed fungicide programme is recommended; frequently, a single treatment to control eyespot, if required, may be all that is necessary.

Herbicides

Comments as for rye (page 78).

Insecticide

Comments as for rye (page 79).

5. RECOMMENDATIONS FOR FURTHER STUDY

5.1 Rye

Recommendations for further study on rye fall into two main categories:-

a. Investigations aimed at improving not only yield but also grain quality and milling potential. Such improvements would encourage greater use of home-grown grain and correspondingly reduce imports.

b. Investigations aimed at evaluating the agronomic value of the crop. For example, the ability of rye to tolerate take-all and drought and minimise nitrogen leaching may enhance its value in certain rotational situations.

5.1.1 Hagberg Falling Number (Very High Priority)

HFN is a major determinant of rye grain quality and is of utmost concern to producers and processors. Despite its importance, the review indicates that HFN has been measured in only a small minority of experiments. The crop is susceptible to pre- and post-maturity alpha-amylase activity and limited data suggest that reduction in HFN can be reduced by early harvesting. Further work is necessary to provide a greater understanding of the effects of cultivar, weather conditions, grain moisture content and harvest date on changes in alpha-amylase activity and HFN in rye.

Nitrogen applications appear to reduce HFN. The effects of other husbandry inputs such as fungicides and PGR's are not known. Thus, it is also recommended that HFN is measured in as many future experiments as possible.

5.1.2 Cultivars (Very High Priority)

It is essential that rye cultivars continue to be tested in order to produce a Descriptive List. There are, however, indications that rye cultivars differ in their sensitivity and requirements for PGR's; this may also be true for fungicides. Thus, it is recommended that two experiments are conducted, each on three light soils sites in rye-growing areas:

a. Cultivars x ± fungicides with overall PGR applications to minimise lodging.

b. Cultivars x PGR programmes (Nil, Cycocel, Cycocel + Cerone) with an overall fungicide programme to minimise disease.

5.1.3 Seedrates (High Priority)

Limited experimental evidence suggests that there are benefits in terms of lodging control and yield from using low seedrates. Relatively high seedrates are frequently recommended by seed suppliers without apparent justification. A series of simple experiments comparing seedrates from 20 to 200 kg/ha could resolve this situation.

5.1.4 Sowing date (High Priority)

There is a dearth of information relating to sowing dates for rye. A single-site experiment was started at Gleadthorpe EHF in autumn 1988 to compare sowing dates from early September to early November. The addition of three sites in rye-growing areas in Eastern and Southern England to cover a wider range of climatic conditions is recommended in order to give greater confidence in the results. Consideration should be given to adopting similar experimental methods to those being discussed for the major cereal species.

5.1.5 Nitrogen (High Priority)

Rye is frequently grown on light, free-draining soils which are particularly prone to nitrate leaching. Previous research suggests that the nitrogen requirement of rye is less than that required for the major cereals. However, experiments have produced extremely variable results and were often conducted without modern lodging control techniques. A new series of experiments is therefore recommended to study timings and rates of spring nitrogen application. Priority should be given to comparing timings between early March and late GS30. Zero nitrogen treatments must be included in order to allow response curves to be drawn and full growth regulator programmes must be used to give best possible lodging control, essential at high nitrogen applications.

5.1.6 Growth regulating mechanisms (Very High Priority)

Very high priority recommendations for further study on PGR's are included under cultivars (5.1.2). However, the mechanisms by which PGR's affect rye are also of concern. Prior to anthesis, large amounts of assimilate are stored in the stems of rye which are later re-translocated into the grain. Excessive shortening of the stem may lead to a reduction of assimilate for grain filling. This requires further clarification, as incorrect use of PGR's could nullify this physiological advantage of rye compared to other cereal species.

5.1.7 Disease control (High Priority)

A new experiment was started by ADAS in autumn 1988 on two sites to investigate the effect of foliar and stem base disease on rye cultivars. Initial results have shown that disease infection has tended to be site specific. An increase in the number of sites to at least five is recommended to encompass a full range of diseases and provide a greater and more rapid measure of confidence in the results.

5.1.8 Rotations (Very High Priority)

The relative resistance of rye to take-all makes the crop ideally suited to being grown in such situations. It is of concern, however, that it has sometimes been considered to be a break crop. Information is required on the effects on yield and take-all, of single and multiple crops of rye and in comparative and succeeding crops of wheat.

5.1.9 Water relations (Very High Priority)

Rye undoubtedly performs well on drought-prone soils and this may be of increasing importance if current forecasts of global warming and water shortage become a reality. It is not known whether the crop's tolerance of drought, relative to other cereals, is due to a lower water requirement, more efficient water extraction or simply earlier development which may avoid drought. It is recommended, therefore, that studies are carried out under crop shelters in order to clarify these points.

5.1.10 Nitrogen leaching (Very High Priority)

Rye has shown considerable potential, especially when sown early, to extract residual nitrogen from the soil during the autumn and winter and minimise nitrogen leaching. The crop may, therefore, have particular relevance as a `cover crop' in Nitrate Sensitive Areas (NSA's). It is not known how effective rye is relative to other cereals. Thus, it is recommended that rye, triticale, wheat and barley are sown at monthly intervals from 20 August to November on light soils with a view to measuring nitrogen off-take, leaching and yield.

5.2 Triticale

As with rye, husbandry research conducted on triticale is minimal compared to that done on the major cereals. This is not only a reflection of the national importance of triticale but also because it is a "new" crop. However, unlike rye, triticale is used mainly as an animal feed and therefore its market potential is not governed by such stringent grain quality parameters. Thus, knowledge required to grow a crop of triticale is mainly related to husbandry inputs which simply produce high yields of grain at a reasonable cost. Several of these husbandry aspects have been resolved by recent research but the newness of the crop dictates that some work is still outstanding and necessary.

5.2.1 Cultivars (Very High Priority)

New cultivars are being introduced and it is essential that their performance continues to be tested on a range of soil types. As with rye, there are indications that triticale cultivars differ in their sensitivity and requirements for PGR's. It is, therefore, recommended that cultivars are tested with three PGR programmes, Nil, Cycocel and Cycocel + Terpal.

Consideration should be given to developing prediction methods and linking them with work being considered on the major cereals.

5.2.2 Seedrates (Medium Priority)

There is uncertainty regarding triticale seedrate requirements for the heavier/coarser soils. High seedrates, particularly on heavier soils, are likely to predispose the crop to early lodging. Conversely, high seedrates may be desirable on coarse soils in order to obtain adequate plant populations. This should be investigated in a series of simple experiments on the heavier soils, by comparing seedrates from 20 to 240 kg/ha.

5.2.3 Growth regulating mechanisms (Very High Priority)

There is undoubtedly a strong relationship between height reduction, lodging control and yield promotion. However, the effect of PGR's on lodging do not account for all the increases in yield nor the effects on grain size of triticale in field experiments. Limited data suggest that these phenomena cannot be fully ascribed to changes in dry weight production or partitioning within the plant. It is possible that changes in canopy structure improve recovery by the combine during harvesting. It is also possible that the effects of PGR treatment on stem length may vary with tiller position in the crown. Further work is necessary to clarify these points.

Consideration should be given to adapting proposals for R & D being developed on wheat and barley.

5.2.4 Disease control (Medium Priority)

Although experiments have demonstrated that triticale is less responsive to fungicides than wheat, nevertheless surprisingly large economic yield responses have occurred by controlling relatively low disease infestations. Furthermore, any marked increase in triticale production may evolve new pathogens which affect triticale and render the crop more responsive to the use of fungicides. It is recommended that, at present, work is undertaken on at least three sites to evaluate the need for and response to, fungicides which control eyespot, Septoria nodorum and yellow rust.

5.2.5 Water relations (High Priority)

That triticale is deep rooting and drought tolerant, appears to be largely based in conjecture. It is possible that rate of crop development and take-all resistance have overriding influences. More information is needed on rooting and water relations in triticale compared to other cereal species.

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