HGCA

PROJECT REPORT No. OS9

IMPROVEMENT OF MANAGEMENT GUIDELINES FOR LINSEED

AUGUST 1994

Price £4.00

PROJECT REPORT No. OS9

IMPROVEMENT OF MANAGEMENT GUIDELINES FOR LINSEED

by

J. B. S. FREER

ADAS Cambridge, Brooklands Avenue, Cambridge CB2 2BL

This is a final report of two projects conducted by ADAS and funded by the Home-Grown Cereals Authority. These were Project No. OS38/3/90 for £34,999 [Linseed: nitrogen and fungicide interactions] and Project No. 0S39/2/90 for £36,665 [Nitrogen requirements for linseed and interaction with varieties and plant growth regulators]. Both projects commenced in April 1991 and lasted for four years.
The work formed part of a programme of research which was partly funded by the European Commission DGVI (CAMAR Scheme Contract No 8001-CT90-0006) and the United Kingdom Ministry of Agriculture Fisheries and Food (ROAME No. AR0109).

Table of contents

Summary

This report summarises the research undertaken by ADAS. Four separate experiments were done during the 1991, 1992 and 1993 seasons at seven sites in England. These consisted of experiments examining methods of establishment (one site for two years), nitrogen requirements and plant growth regulators (seven sites for three years), fungicide programmes (three sites for three years) and harvesting techniques (one site for two years).

The work on establishment has demonstrated that linseed can be sown into a minimally cultivated seedbed that is cheaper to prepare than that traditionally made without a significant increase in seed rate. This work supports earlier work and the recommendation to include a factor for establishment when calculating seed rates. This has been incorporated into an advisory service for growers (ADAS Linseed Sowing Guide).

The experiment on crop nitrogen requirements has demonstrated that linseed will only respond to applied nitrogen if the site has low soil nitrogen reserves. Only five sites of the twenty-one showed a yield response up to 80 kg/ha N. There are therefore cost savings to be made and the crop excels as an environmentally benign addition to the arable rotation. This experiment also examined the role of the plant growth regulator chlormequat, as an input for linseed. Whilst plant height and severity of lodging were reduced, yield increases were less predictable and were not always related to lodging. The experiment demonstrated that chlormequat increased capsule numbers per plant and thus potential yield. The yield increase obtained from the use of chlomequat did not cover its cost and therefore is not recommended as a cost effective input. Lodging remains a problem in linseed; the best defence is to grow it at lower populations (c. 350 plants/^{2}).

The experiment on fungicide programmes showed that disease levels rose as nitrogen levels increased and that a two-spray fungicide programme was required for good control of disease. Yield responses were not closely associated with a particular timing but yield increases in the order of 10-20% were obtainable from programmes containing either a mid-flowering or capsule formation spray making a single spray cost effective. The relative importance of *Alternaria* declined during the three-year period as weather conditions favoured powdery mildew and *Botrytis* to a greater extent (Mercer & Hardwick, 1993).

Harvesting remains the greatest potential problem for producers of linseed. The experiment showed that there was no difference between the harvesting methods used. In dry conditions, the use of a desiccant was unnecessary. However, in more typical, changeable conditions a desiccant, whilst giving no yield benefit, reduces seed moisture and eases harvesting.

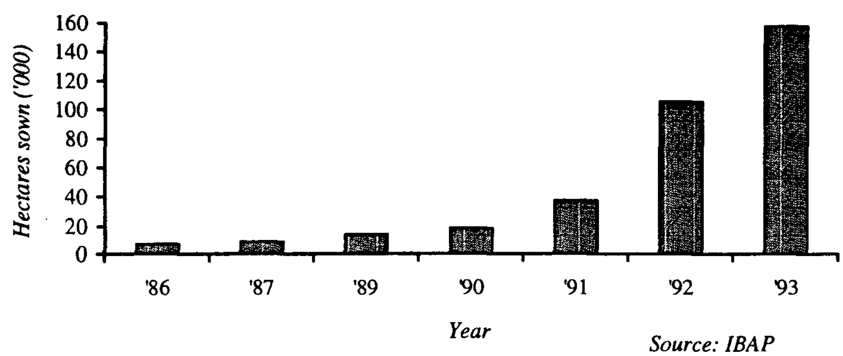
Overall, savings of between £50/ha and £23/ha can be achieved by adopting these findings when comparing 1986 guidelines with those resulting from this work.
This programme of research has been widely disseminated and its findings are already being utilised by linseed producers in England.

Introduction

A four-year programme of research funded jointly by the European Commission DG VI, the United Kingdom Ministry of Agriculture Fisheries and Food's Sugars, Tobacco, Oils and Proteins Division and the Home-Grown Cereals Authority (Oilseeds) levy started in 1991 and was completed in 1994. The objective of the programme was to maximise the production of linseed within the European Union by improving the management guidelines for growers. This was addressed in various ways by the collaborating organisations: ADAS, agronomy/physiology; CETIOM, agronomy/physiology; INRA, plant breeding; Scottish Agricultural College, Auchincruive, disease resistance; and University of Giessen, plant breeding.

The area of linseed grown in the European Union (EU) has increased dramatically in the past decade. The United Kingdom is the largest single producer within the EU. Linseed's popularity has undoubtedly been partly due to the subsidy provided under the old CAP. However, the crop is suited to the modern arable cropping systems in Europe as it fits into farm rotations easily replacing other break crops such as pulses. Under the reformed CAP, linseed does not appear so attractive financially. Despite this, compared with other arable crops, linseed has a low input requirement and has the advantage of being a non-food crop. It is this factor that will ensure that linseed will remain an important break crop in the UK, albeit that part of the acreage will be grown on set-aside land.

Figure 1. UK linseed production 1986 to 1993. Area grown in England and Wales (ha).



This programme of research has served to underpin the crop and provide growers with the information necessary to ensure a continuity of supply within the EU. Its success will be in the longevity of linseed's position in arable rotations as support for the crop declines. This research has demonstrated considerable cost savings which will partially offset this decline in subsidy. Nevertheless, added value for the crop, such as use of its straw for quality fibre production is now necessary for the crop to maintain its foothold in the arable rotation.

Project objectives

The objective of the Project was to maximise production of linseed within the EU by improving management guidelines for growing the crop so as to improve profitability.

This primary objective was being addressed by a number of secondary objectives.

Establishment methods

To examine methods of crop establishment that minimise the costs of establishment and maximise the plant population and seed yield.

Crop nitrogen requirements and plant growth regulators

To provide guidelines for the efficient use of nitrogen by defining the crop's requirements under various soil types and seasons. To examine the rôle of plant growth regulators as a management tool.

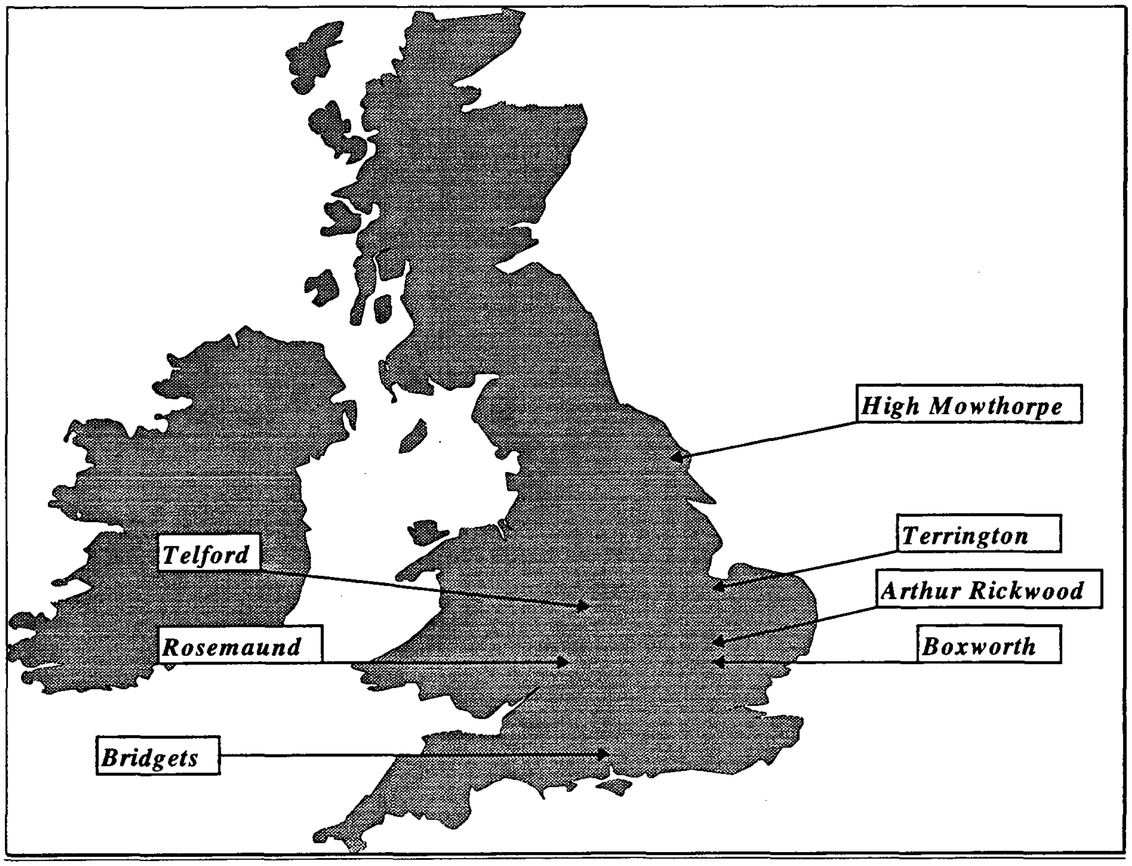
Fungicide programmes
To develop a rational strategy for the use of fungicides on linseed by examining the relationship between disease incidence, nitrogen fertiliser and timing of disease control measures.

Harvesting techniques
To examine methods of harvesting that minimise the cost and maximise the harvested seed yield.

Materials and methods

Four separate experiments were established at a total of seven sites in England (Figure 2). The experiments were situated in commercial crops of linseed and were of a fully randomised design with 3 or 4 replicates. Plot size was 3m x 24m.

Figure 2. Map of British Isles showing location of sites in England, 1991-1993



All operations to the crops were done using commercial machinery unless the particular input was a treatment when specialised equipment was used. This is described in more detail below.

Establishment methods

The experiment was done at Bridgets (silty loam soil over chalk) in 1991 and 1992. Three seedbeds were produced using an increasing degree of cultivation, these were either direct drilling (drill or broadcast onto the trimmed stubble of the previous crop); minimal cultivation (a single pass with a power harrow over the previous crop's stubble in spring prior to drilling); or conventional (plough in the autumn followed by a single pass with a power harrow in spring prior to drilling).

Seed of the variety Blue Chip was sown in order to achieve four populations at 250, 500, 750 or 1000 seeds/m² using the formula below (Freer & Sansome, 1991):

$$\text{Seedrate (kg/ha)} = \text{thousand seed weight} \times \frac{\text{target plants/m}^2}{100} \times \frac{100}{\text{Estd. \%}}$$

(Estd. = expected establishment %)

Establishment was monitored by counting the number of plants at ten points in each plot six weeks after sowing. The experiment was then treated as a standard commercial crop of linseed until harvest. The treatments were fully randomised and replicated four times. The plots were harvested using combine harvesters modified for plot use equipped with electronic data-capture instruments. Samples were collected for dry matter analysis and oil quantity. Oil % assessments were made using the NMR technique (Anon., 1984).

Crop nitrogen requirements and plant growth regulators

The experiment was done at seven sites in England; Arthur Rickwood (peat loam), Boxworth (clay), Bridgets (silty clay loam over chalk), High Mowthorpe (silty clay loam over chalk), Rosemaund (silty loam), Telford (sandy loam) and Terrington (silty loam) in 1991, 1992 and 1993. These seven sites were selected to reflect the typical soil types and regions where linseed is grown within the UK. In 1991 and 1992, five of these sites (Arthur Rickwood, Bridgets, Telford and High Mowthorpe (1991) and Rosemaund (1992)) had the addition of a plant growth regulator treatment. In 1993, this additional treatment was restricted to three sites. At one of these (Arthur Rickwood), a more detailed examination of the physiological effects of the plant growth regulator was made. The experiments were established in commercial crops of linseed where the following crop was one that left low nitrogen residues (ADAS Soil Index 0) (Anon., 1994). The crops were all sown between mid-March and mid-April.

Two varieties, Blue Chip and Norlin (or Blue Chip and Atalante at Rosemaund, Telford and Arthur Rickwood) were sown at seedrates designed to give *c.* 400 plants/m² according to the formula described above.

Soil mineral nitrogen assessments were made by sampling the soil at 0-30, 30-60, and 60-90 cm depths prior to drilling and after harvest.

Nitrogen fertiliser was applied as ammonium nitrate to individual plots either by hand or using specially designed equipment (Skurray Avocet) at rates of nil, 40, 80, 120, 160 or 200 kg/ha N shortly after emergence. On the peaty loam site, rates of nil, 40, 80 and 120 kg/ha N only were applied.

At the sites with the plant growth regulator treatment, chlormequat (as 2.5 l/ha 5C Cycocel) plus non-ionic wetter was applied using Oxford Precision Sprayers at 2.5 l in 200 l/ha of water when the crop was 10 cm or 30 cm high. Measurements of crop height, at ten points per plot, were taken at the time of application and 20-30 days later. Assessments of lodging were made when it occurred and prior to harvest by recording the proportion of each plot affected.

Plots were harvested using combine harvesters modified for plot use equipped with electronic data-capture instruments. Samples were collected for dry matter analysis and oil quantity. Oil percentage assessments were made using the NMR technique.

Fungicide programmes

The experiment was conducted at three sites in England (Bridgets, High Mowthorpe and Rosemaund) in 1991, 1992 and 1993. Plots were established in commercial crops of the variety Antares, with plant populations of *c.*400 plants/m². Nitrogen was applied by hand or machine at three rates nil, 80 or 120 kg/ha. A fungicide programme was imposed on these treatments. This consisted of iprodione plus thiophanate-methyl being applied as 2 l/ha Compass (Rhône-Poulenc) at the following timings or any combination of them: first flower open; mid-flowering; and capsule formation (end of flowering).

An additional spray of fenpropimorph as 2l/ha Corbel (BASF) was applied in 1992 and 1993 at the mid-flowering or capsule formation timing to control powdery mildew. The sprays were applied using Oxford Precision Sprayers.

Disease assessments were made using a % plant affected score (Hardwick, personal communication) at each timing and 3-4 weeks after the last spray. Assessments were made by assessing the diseases present on ten plants per plot. Plots were harvested using combine harvesters modified for plot use equipped with electronic data-capture instruments. Samples were collected for dry matter analysis and oil quantity

Harvesting techniques

The two varieties Antares and Norlin were drilled at Boxworth in 1991 and 1992 to produce plant populations of *c.* 400 plants/m². The plots were treated as commercial crops until harvest when a range of pre- harvest treatments was applied. The varieties were either left untreated and combine harvested or desiccated with diquat (as Reglone (Zeneca) at 2 l/ha in 200 l water plus non-ionic wetter)and combine harvested 7-10 days later; desiccated with glufosinate ammonium (as Challenge (AgrEvo) at 3 l/ha in 200 l water) and combine harvested 7-10 days later; or swathed and picked up with combine harvester 7-10 days later. In addition, in 1991 only, the crops were harvested with a stripper header combine (Hobson, 1986). Oil percentage assessments were made using the NMR technique.

Results

Establishment methods

In 1991, mean population densities of 258, 548, 707 and 864 plants per m² from seed rates of 37, 73, 110 and 145 kg/ha were established (p=0.05). In 1992, mean plant populations of 218, 329, 391 and 464 plants/m² were established from seedrates of 27, 55, 82 and 110 kg/ha seed sown (p=0.05). In 1991, weather conditions were favourable, with adequate soil moisture during the establishment phase. Consequently populations were higher than in 1992, when dry weather, flax flea beetles (*Longitarsus parvulus*) and ground frosts down to -8.4°C all made conditions less favourable. Populations were lowest when the crop was broadcast onto the trimmed stubble but similar when the crop was drilled into seedbeds prepared conventionally or by using minimal cultivation techniques (p=0.05) (Figure 3). The optimum population of *c*. 350 plants/m² (Freer & Sansome, 1991) was obtained from the 55-73 kg/ha seed rate but when direct drilling was employed it had to be increased to 110-145 kg/ha.

Figure 3. Mean plant populations (plants/m²) of linseed obtained from four target populations and three methods of establishment. Bridgets, 1991-1992.

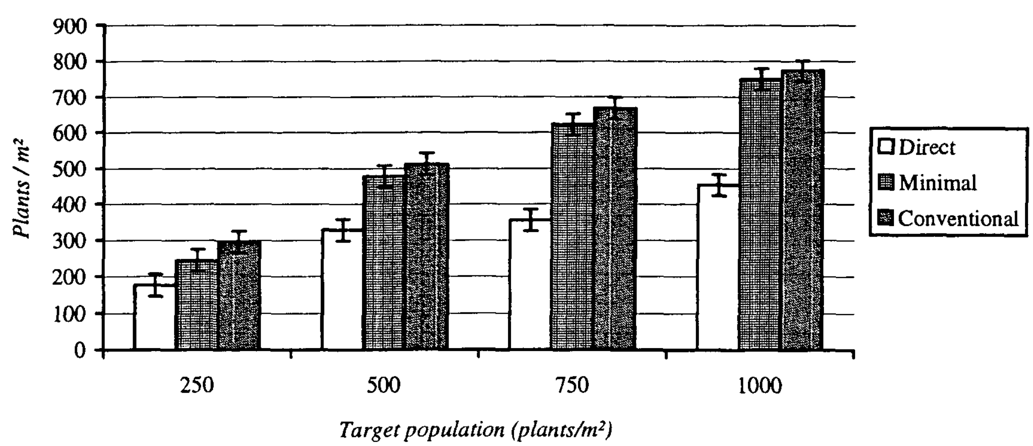
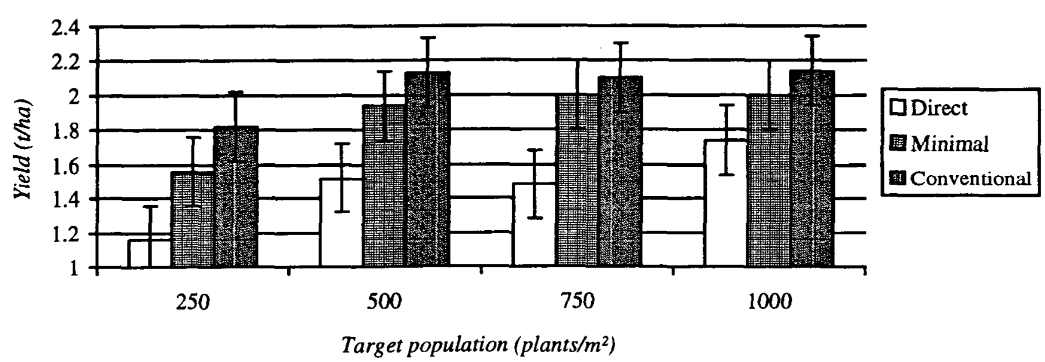


Table 1. **Effect of methods of establishment on the seed yield of linseed (t/ha at 91% DM) variety Blue Chip. Mean of two years, Bridgets, 1991-1992.**

Cultivation method	*Target population(plants/m²) and(seed rate (kg/ha) for {1991} & [1992] in brackets)* 250 {37}[27]	500 {73}[55]	750 {110}[82]	1000 {145}[110]	Mean
			(SED 0.20)		(SED 0.18)
Direct drill	1.92	2.51	2.41	2.66	2.37
Minimal cultivation	2.19	2.63	2.62	2.61	2.52
Conventional	2.50	2.79	2.61	2.74	2.66
			(SED 0.08)		
Mean	2.21	2.64	2.55	2.67	

The seed yield was reduced (p=0.05) by sowing at the lowest rate of 27-37 kg/ha, but there was no yield advantage from sowing more than 55-73 kg/ha (Table 1, Figure 4). There was no difference in yield between the minimum and conventional cultivation methods although these treatments both yielded higher than the direct drilled treatment. There was no treatment effect on oil content of the seed.

Figure 4. **Mean seed yield (t/ha @ 91% DM) of linseed obtained from four target populations and three methods of establishment, Bridgets, 1991-1992.**

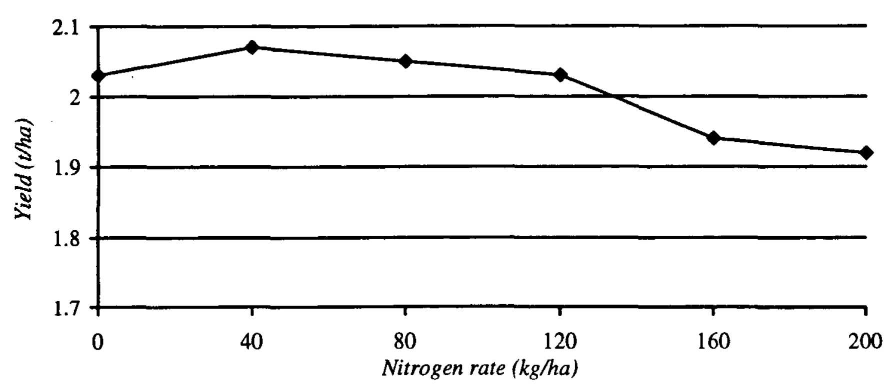


Crop nitrogen requirements

In 1991, there was a high nitrogen residue (up to 350 kg/ha) at most sites due to the previous dry season when little nitrogen was utilised. Consequently, there was no response to nitrogen fertiliser except at two sites where there was a response up to 80 kg/ha (p=0.05). These sites had residual soil mineral nitrogen (SMN) levels of 100 kg/ha or less. Similarly, in 1992, there was no response to nitrogen fertiliser except at sites with low SMN levels, where there was a response up to 40 kg/ha (p=0.05). At some sites, yield was reduced at the higher rates of nitrogen because the crop lodged. In 1993, at all sites, yields were generally low due to the wet season which resulted in all sites lodging to some degree. Only one silty loam site responded to 40 kg/ha (p=0.05). Bad weather at harvest also caused increased seed loss due to shedding and seed sprouting in the capsules; this caused difficulties, partially confounding treatment effects and one site (Arthur Rickwood) was not harvested.

Overall, there was no response at any site in any year to more than 80 kg/ha and in many cases 40 kg/ha was adequate due to the high SMN levels (Figure 5).

Figure 5. Effect of increasing doses of nitrogen fertiliser on the seed yield (t/ha @ 91 % DM) of linseed. Mean of two varieties grown at 19 sites over three seasons (1991, 1992 and 1993).



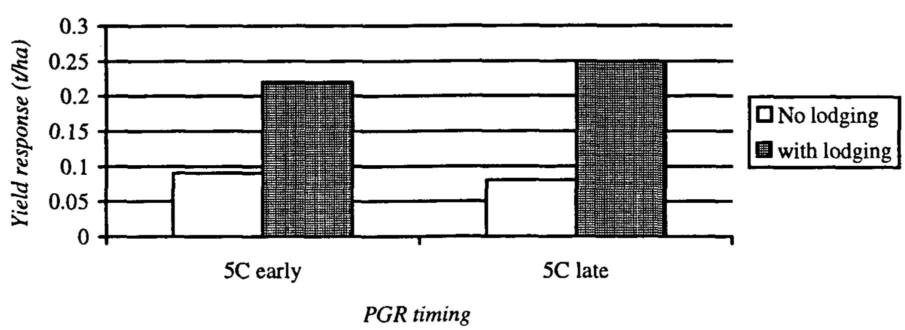
Plant growth regulators

In 1991, the response to chlormequat was variable. Most sites showed an increase in yield of 5-10% when it was applied to Blue Chip. However, one site showed a negative response of over 10%. There was little difference in the level of response between the timings. In general, Atalante responded less than Blue Chip except at one site where lodging occurred. In 1992, the application of chlormequat reduced crop height by 3-11 cm. At three of the four sites lodging occurred; this ranged in severity and Blue Chip lodged more than

Norlin (10-34% in Blue Chip and 10-20% in Norlin). Yield response was closely related to crop lodging. At three of the four sites lodging occurred and at all three, the application of chlormequat reduced the severity of lodging and consequently at two of the three, yield was improved by 0.3-0.5 t/ha. In 1993, application of chlomequat to the varieties Blue Chip and Norlin, resulted in reductions in plant height compared to the untreated of 5-8 cm and 4-12 cm respectively and was similar at both timings of chlormequat application. There were also reductions in lodging compared to the untreated of between 20 and 87% and 0 and 53% respectively. Blue Chip had a greater tendency to lodge than Norlin. The increase in yield from the application of chlormequat was similar for both varieties and ranged from 0.2 to 0.4 t/ha. Although lodging was reduced by the application of chlormequat, it was not sufficient to overcome the loss in yield caused by lodging.

Overall, chlormequat increased yield by between 0.09 and 0.25 t/ha with the larger increase being associated with lodged crops (Figure 6). There was no difference between timings.

Figure 6. Comparison of the yield response obtained from lodged or non-lodged linseed, variety Blue Chip, to chlormequat (as 5C Cycocel) applied early (crop 10 cm high) or late (crop 30 cm high) where the crop. Mean of eight sites, 1991-1993).



At one site in 1993 (Arthur Rickwood), a detailed study was made of the effect of applying chlormequat on the crop's physiology. Blue Chip had a lower plant density, had more branches, was shorter, but more prone to lodging than Norlin. Additional doses of nitrogen fertiliser increased the total above ground dry matter, the number of infertile branches and the number of immature capsules. Chlormequat reduced plant height, lodging, straw dry weight and delayed flowering. The number of fertile and infertile branches, the number of capsules per plant and the percentage of sprouted capsules all increased when chlormequat was applied (Saunders & Freer, 1994). Chlormequat at the later application increased the number of branches per plant, with Blue Chip having a greater number than Norlin; this resulted in more harvestable capsules per plant (total capsules less those still green at the optimum time for harvest) (p=0.05) (Figure 7) and therefore more potential yield. Potential yield was calculated using actual plants/m² at crop maturity, assuming seven seeds per capsule (Freer, 1992c) and thousand seed weights of 6.4g and 8.0g for Norlin and Blue Chip respectively (Anon., 1993). The potential yield of Blue Chip was higher that that of Norlin. Chlormequat increased the potential yield of Norlin when applied early by 0.4 t/ha, the potential yield of Blue Chip increased with both early and late timings by 0.3 t/ha and 0.6 t/ha respectively (p=0.05) (Figure 8). This experiment was not harvested due to adverse weather conditions resulting in complete crop loss due to seed sprouting in the capsules.

Figure 7. Effect of chlormequat as 5C Cycocel on the harvestable capsule number per plant of linseed, Arthur Rickwood, 1993.

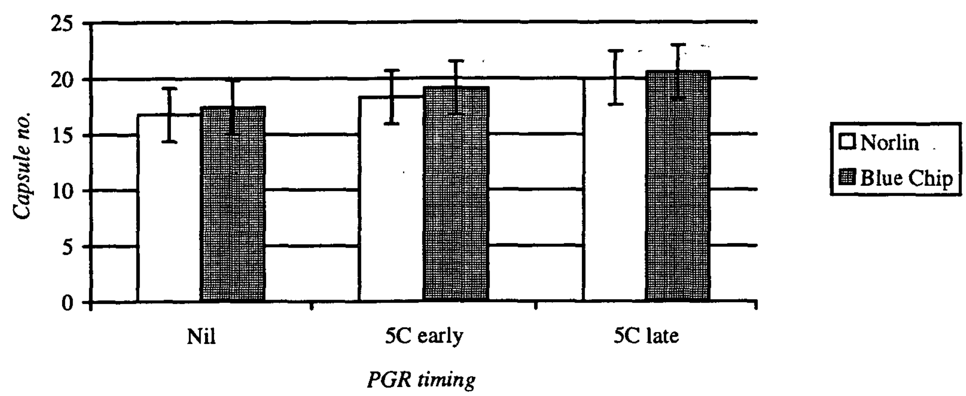
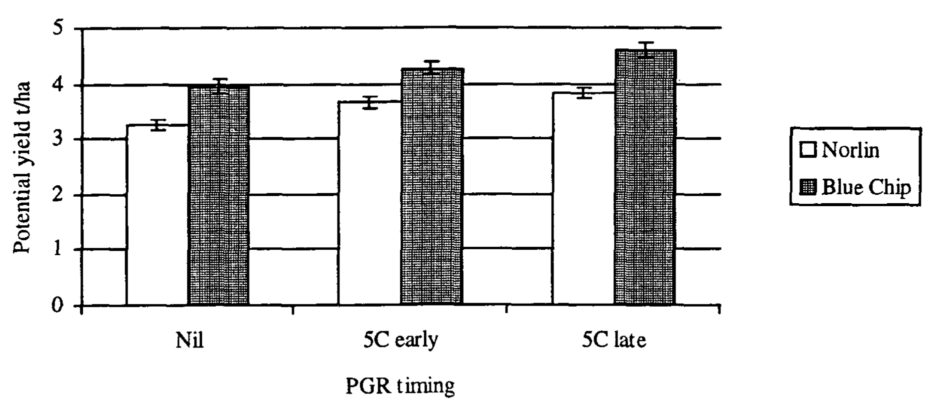


Figure 8. Potential seed yield (t/ha @ 91 % DM) of two linseed varieties treated with chlormequat (as 5C Cycocel) at two timings.



Fungicide programmes

The pattern of disease incidence varied between seasons and the optimum timing for disease control and subsequent yield responses also varied (Mercer *et al.*, 1991). For example at Bridgets in 1993, mildew (*Oidium lini*) appeared on the crop between mid-flowering and capsule formation, consequently superior disease control was obtained from programmes containing the capsule formation timing (Figure 9). In general, it was important to apply a spray when the disease was first seen. However, if this was early in the season there was a danger of the disease re-establishing and a subsequent spray being needed to maintain control. Overall, yield responses were *c.* 7-14 % (Figure 10) over the untreated but this mean hides some larger yield responses such as at Rosemaund in 1991 (Figure 11).

Figure 9. **Powdery mildew infection on 29 August after treatment with iprodione plus thiophanate-methyl compared with untreated control, Bridgets, 1993.**

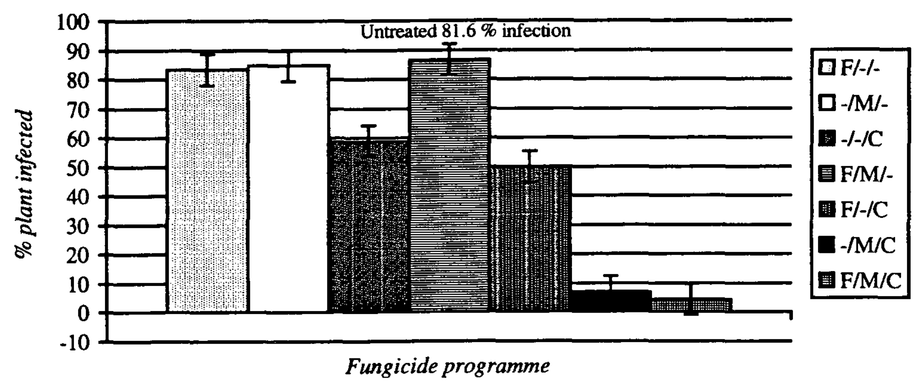


Figure 10. **Seed yield (mean of nine sites) (t/ha @ 91% DM), of linseed after application of fungicide programmes (first flower(f), mid flower(m) and capsule formation (c), 1991-1993.**

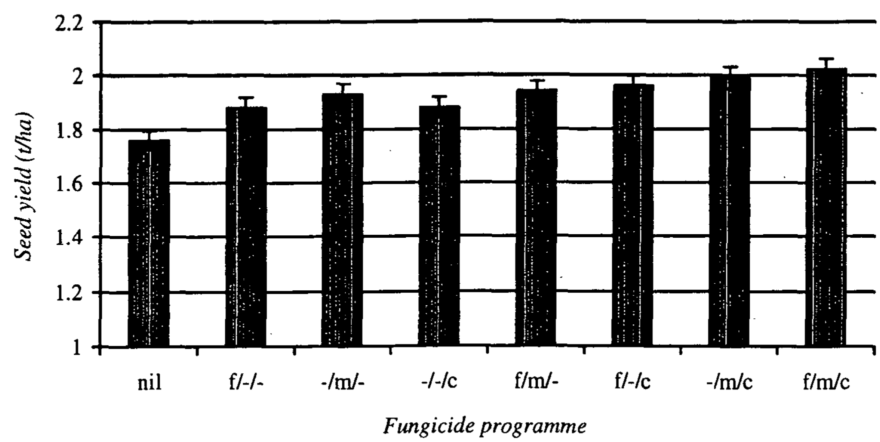
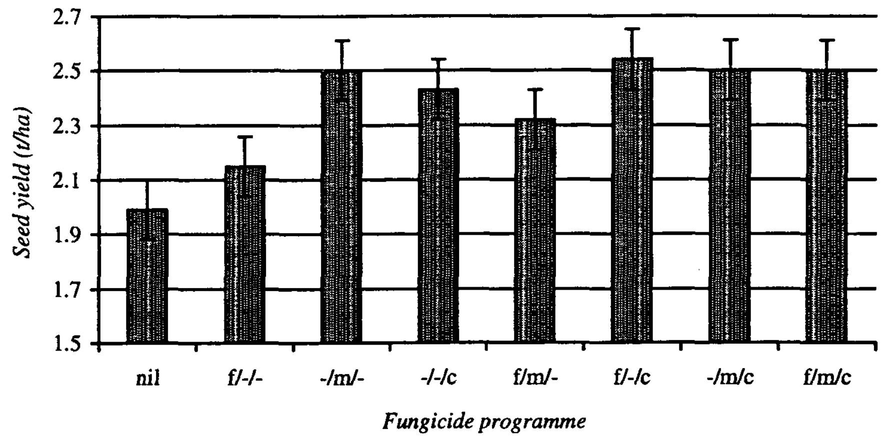


Figure 11. Seed yield (t/ha @ 91% DM), to fungicide programmes applied at either first flower(f), mid-flower(m) or capsule formation (c), Rosemaund, 1991.



In 1991, yield was increased when 80 kg/ha N was applied but there was no additional response to 120 kg/ha. At two sites, responses to fungicide programmes were in the order of 10-15% over the untreated. The most westerly site (Rosemaund) obtained responses of over 20%. Powdery mildew was present at all sites. There was no clear relationship between nitrogen level and disease incidence but disease levels tended to be higher when 80 kg/ha was applied compared with nil.

In 1992, disease levels were low early in the season, but *Botrytis* and *Alternaria* were recorded at levels of 2% and 26% plants affected by the end of the season. (The *Alternaria* was a secondary infection on senescing plants and was considered to be non-pathogenic). Powdery mildew late in the season was the main disease. Untreated plots had between 64% to 99% plants infected by late August. The low levels of *Botrytis* were effectively controlled, particularly by treatments containing the capsule formation timing. The powdery mildew was well controlled at only one site where the infection coincided with the spray timing. However, mildew re-established and by mid-August there was no difference between treatments. There were no differences in yield between the fungicide treatments at any site except one where the fenpropimorph treatment gave a 0.3 t/ha increase. This yield response was confounded by the effect of the chemical on the % lodging. Fenpropimorph reduced lodging (p=0.05) and so it is not possible to determine whether the response was caused by controlling the disease during capsule development or whether it was caused by the reduction in lodging. There was a similar response to nitrogen as in the previous season.

In 1993, infection (*Botrytis* and powdery mildew)occurred late in the season at capsule formation. Consequently, the first two sprays were applied to a crop showing no disease symptoms. Mildew was present when the capsule formation timing was applied. Mildew infection occurring after the first and second fungicide application was not well controlled by the single timings of the fungicide. The capsule formation timing, whilst checking the disease, failed to control it on its own. Control was most effective after the application of a programme including the capsule formation timing. The single spray of fenpropimorph at capsule formation failed to control mildew effectively. There was an increase in yield from the fungicide treatments. This yield increase was greatest when treatments were applied at mid-flowering or capsule formation, either as part of a sequence or as a single application. There was no disease or yield interaction with nitrogen level. The yield response at Rosemaund was partially confounded by poor harvesting conditions.

Harvesting techniques

In 1991, the days prior to application of the pre-harvest treatments and up to harvest were hot, dry and sunny. In contrast the weather in 1992 was changeable during this period. In 1991 moisture content of the seed after swathing was drier than other treatments (p=0.05). In the wet year of 1992 moisture content was higher after both direct combining and swathing (p=0.001) (Figure 12.). Antares out yielded Norlin by 0.7 t/ha and 0.50 t/ha in 1991 and 1992 respectively. The effects of harvesting method on seed yield were inconsistent and there were no differences between methods (Figure 14). Method of harvest did not affect oil content. A greater amount of seed was lost in 1992 and with the variety Norlin. The largest seed losses were associated with swathing compared with direct combined crops.

Figure 12. Effect of harvest method on seed moisture (%) of two varieties of linseed at harvest, Boxworth, 1991 & 1992.
(After Cook & Freer, 1994)

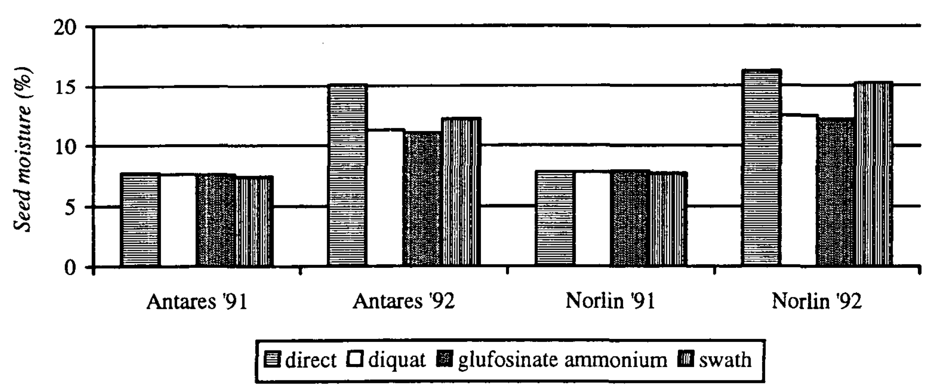


Figure 13. **Effect of harvest method on seed loss due to shedding (plants/m² germinated)from two varieties of linseed, Boxworth, 1991 & 1992.** *(After Cook & Freer, 1994)*

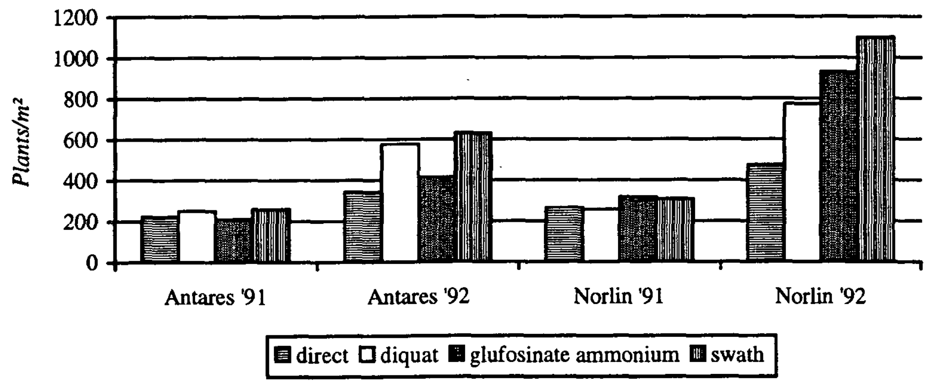
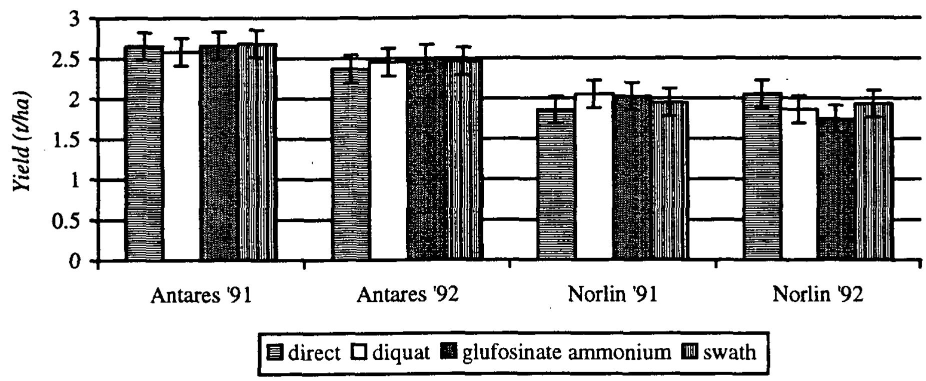


Figure 14. **Seed yield (t/ha @ 91% DM) of two varieties of linseed after pre harvest treatment with desiccants. Boxworth, 1991 & 1992.** *(After Cook & Freer, 1994)*



Discussion

All financial implications discussed below assume a price of £100/t for linseed seed and the profitability of the treatments is based on the margin before the subsidy is added. In this way comparisons can be made despite variations in the level of subsidy between years.

Establishment methods

The costs of establishing linseed can be considerably reduced using the results from this research. The degree of cultivation, certainly on the lighter soils where linseed is traditionally grown can be modified without jeopardising plant establishment. Linseed has a small seed and so requires a firm, fine seed bed to ensure an even and good emergence. These conditions have to be created at the optimum time in the spring; linseed is sensitive to frosts during emergence and to lack of moisture; these phenomena are most likely to affect crops sown either too early or too late. The aim is to obtain a rapid emergence by sowing the seed in a warm moist seed bed. To achieve this, care in the choice and timing of cultivation is necessary. A rapid technique for seed bed preparation is therefore required. Concerns about the environment and more specifically nitrate leaching may make the traditional practice of ploughing in the previous autumn and leaving the ground fallow over winter unacceptable. Equally, the sowing of a cover crop during the autumn to reduce nitrate leaching may delay the sowing of the crop in the spring. Other work has demonstrated that a cover crop does not affect the emergence or seed yield of linseed *per se* (Turley, personal communication) but this experiment did not examine the effect of destruction of the cover crop and the delay this may cause to the optimum time of sowing.

Table 2. Average farmers costs of various cultivation techniques (Nix, 1993).

Cultivation method	Cost of operation(£/ha) (relative to conventional)	Operations
Conventional	£ 74.50 (100)	plough/power harrow/roll/drill
Minimal cultivations	£ 46.00 (62)	power harrow/roll/drill
Direct drill	£ 14.0 (19)	drill

A minimal cultivation system costs 38% less and a direct drill system 81% less than the conventional method of seed bed preparation (Table 2). Taking the cost of seed into account illustrates that large savings can be made.

Table 3. Relative cost of establishing linseed.

Cultivation	Cost of establishment. Mean of two years, variety Blue Chip.			
Cost of seed @ £1.00/kg	250 (32 kg/ha)	500 (64 kg/ha)	750 (96 kg/ha)	1000 (128 kg/ha)
Conventional	£106.5	£138.5	£170.5	£202.5
Minimal cultivation	£78	£110	£142	£174
Direct drill	£46	£78	£110	£142

Plant populations were lower than the optimum (350-400 plant/m^2) when seed rates of 32 kg/ha were used and when direct drilling was employed.
The experiment has demonstrated that in favourable conditions, such as those experienced in spring 1991, linseed can be sown with virtually no seedbed preparation, as long as sufficient compensation is made by drilling more seed (Smith & Freer, 1993). Soil moisture at, and during the critical emergence period is required. In more typical years, such as 1992, there are still considerable savings to be made by reducing the cultivations and these can be made without increasing the seedrate. Overall, savings of *c*.30% in establishment costs could be made by adopting a minimal cultivation system and reducing the seedrate in line with findings from earlier work (Freer & Sansome, 1991) without compromising seed yield. In addition, leaving the ground undisturbed during the winter may have beneficial effects in reducing nitrate leaching. This work was done on a light soil type and so further evaluation is required on more difficult soils. As a direct result of this work and that of Freer & Sansome, the Linseed Sowing Guide service was established for growers. Samples of seed were tested for germination %, seed-borne disease levels and the thousand grain weight measured for seed rate calculation.

Crop nitrogen requirements

This experiment has shown how unresponsive linseed is to nitrogen and the value of conducting a three-year investigation at several sites. Consequently, only crops grown in soils with low soil mineral nitrogen contents (*c*.100 kg at 90 cm depth) are likely to show a response to applied nitrogen fertiliser (five out of 19 sites in this experiment). As little as a 0.01 t/ha increment in seed yield is required to pay for 10 kg/ha of nitrogen fertiliser (ammonium nitrate 34.5% at £108/t). In many cases less than 80 kg/ha N is needed for optimum yield and this experiment has underlined the importance of checking SMN levels because of the danger of predisposing the crop to lodging when applying excess amounts of nitrogen. Savings in fertiliser usage have therefore been identified and this work has also identified linseed as environmentally benign as it has the lowest nitrogen requirement of any (non-leguminous) arable crop. Fertiliser recommendations using these data for the crop are now included in the recently revised MAFF Reference book (Anon., 1994).

Plant growth regulators

This experiment has shown that chlormequat reduces plant height, thus potentially making the plant less prone to lodging if it occurs. Lodging is also more prevalent in crops with a high plant population as taller, thinner stems predispose the plants to lodging. However, if lodging is severe, chlormequat, applied at the recommended dose will reduce the severity but not eliminate the problem. The physiological study has shown that the chemical also has a beneficial effect of the number of capsules per plant. This finding helps to explain those experiments where yield increases were found in the absence of lodging (Freer, 1992a; Freer, 1993a). However, in 18 out of 19 cases the cost of the treatment was not covered by the increase in yield, if and when it occurred. The use of chlormequat for the prevention of lodging in linseed cannot be justified as its use does not provide adequate protection (Freer, 1993c). Other plant growth regulatory compounds may be more effective than chlormequat at controlling lodging. Earlier work has shown that dramatic changes can be made to plant structure (Cook, 1992). At present, the most reliable method of preventing lodging is to sow at the correct rate and restrict the amount of fertiliser applied.

Fungicide programmes

During the three-year period of this experiment, the relative importance of *Alternaria linicola* has declined and that of *Oidium lini* has increased. *Botrytis cinerea* has remained a problem, particularly in wet seasons, often occurring after the crop had lodged. The best disease control has been obtained from a two-spray programme containing a mid-flowering and capsule formation timing. This programme however, is costly and is unlikely to be of commercial use. In most years a single spray will be cost effective when applied between mid-flowering and capsule formation. The precise timing will vary according to season and disease incidence. Further research is now underway to examine spray timing, the epidemiology of powdery mildew and its effect on seed yield and crop maturity.

Harvesting techniques

Time of crop maturity is a more significant factor than the method employed; there is little to chose between the methods of harvesting (Cook & Freer, 1994). The greater risks involved with swathing tend to rule this technique out for most growers. Direct combining is possible in perfect conditions such as those experienced in 1991. Despite there being no yield increase from its use, the majority of growers use a desiccant and of those used, diquat has proved most popular because of its rapid effect. The use of a desiccant, whilst not cost effective in terms of yield increase, provides some insurance at, and eases harvest, particularly if the crop was late sown, is ripening unevenly or contains green weeds. This work supports earlier work done by Ogilvy & Payne, 1991. Desiccating a senescing crop of linseed presents considerable difficulties because of the problem of applying the chemical to the stem target. Harvesting remains the most critical operation with linseed. Seasons such as 1993 serve to highlight the vulnerability of a crop that matures late in the season when the opportunities for good harvesting conditions are diminished. Subsequent work (Froment, 1993) has shown that the timing of desiccant application is important; attempting to speed up the ripening process by applying diquat earlier can result in a yield reduction.

Changes in management guidelines

The variable costs of growing linseed are low compared to other arable crops. However, this project has indicated where further savings can be made which, in view of the decline in subsidy support, could make the difference between growers abandoning the crop completely or continuing to grow it on a reasonable scale.

The typical variable for the crop based on the husbandry practices employed before this work started was *c*.£195/ha (Anon., 1986). Putting the results of this project and related research into practice has brought the variable costs down to *c*.£150/ha (Table 4.) This does not include the potential savings (£28/ha) obtainable by modifying cultivation methods, certainly on lighter land. Overall, by making use of these resultsgrowing costs can be reduced by *c*.£50/ha on light soils, (including cultivations), and £23/ha on heavier soils (where minimal cultivations in the spring may not be appropriate).

Table 4. Comparison of typical inputs 1986 and 1993 for growing linseed. ***(Based on ADAS Gross Margin Budgets)***

Variable costs (£/ha)	1986	1993
Seed (dressed)	90 kg/ha @ £1.00 = 90	64 kg/ha @ £1.00 = 64
Herbicides	Basagran/Vindex @ 39	Ally @ 13
Foliar fungicide	nil	Compass @ 20
Nitrogen	80 kg/ha @ 0.31 = 25	40 kg/ha @ 0.31 = 12
P & K (maintenance)	19	19
Desiccant	Reglone @ 22	Reglone @ 22
Total	**195**	150

Summary of changes recommended as a result of this project to management guidelines for linseed.

- Aim to establish 350-400 plants per m² using a seed rate of *c*.65 kg/ha.
- Consider the use of minimal cultivation techniques to speed up drilling and reduce costs.
- Apply the correct amount of nitrogen fertiliser for the site to avoid lodging.
- Do not apply chlormequat as a routine treatment.
- If powdery mildew is present during late flowering an application of fungicide will be cost effective.
- If the crop is maturing evenly, is weed free and weather conditions are good consider not using a desiccant.

Publication and dissemination

This project has a good record of scientific and popular publications. In addition the results have been widely discussed and promulgated by ADAS consultants and presented at numerous conferences and meetings in England and Wales and in four other EU states. A full report, containing information from the other organisations, will be published by the European Commission during 1994. A further four scientific papers are being prepared by ADAS for publication in 1994 & 1995.

Scientific publications

Cook, S.K. & Freer, J.B.S.(1994). Effects of harvesting methods on yields of linseed varieties. *Tests of Agrochemicals and Cultivars*, **15** (in press).

Freer, J.B.S. (1991). A development stage key for linseed (*Linum usitatissimum*). *Aspects of Applied Biology,* **28**, 33-40.

Freer, J.B.S. (1992a). Effect of nitrogen and plant growths regulators on lodging, seed yield and quality in linseed. *Tests of Agrochemicals and Cultivars*, **13**, *Annals of Applied Biology,* 120, Supplement, 70-71.

Freer, J.B.S. (1993a). Effect of chlormequat on the height, lodging, seed yield and quality of two cultivars of linseed. *Tests of Agrochemicals and Cultivars*, **14**, *Annals of Applied Biology*, 122, Supplement, 102-103.

Freer, J.B.S. (1993b). Linseed husbandry: a UK perspective. *Industrial Crops and Products* **1**, 211-217.

Mercer, P.C. & Hardwick, N.V.(1993). Methods of control of diseases of linseed. *Proceedings Crop Protection in Northern Britain*, 1993, 165-170.

Saunders, P.J. & Freer, J.B.S.(1994). Effects of chlormequat on capsule production and sprouting in two linseed cultivars in an atypically wet season. *Tests of Agrochemicals and Cultivars*, **15** (in press).

Smith, J.M. & Freer, J.B.S.(1993). The effect of methods of cultivation on the establishment and yield of linseed. *Proceedings of the 2nd European Symposium on Industrial Crops and Products*, Italy 1993 (in press).

Popular articles and reports

Freer, J.B.S. (1991). *Research and Development on Linseed.* In: Proceedings of the RASE Conference, **Linseed - A Real Alternative**, January 1991.

Freer, J.B.S., (1992b). *Learning the linseed lore.* **Crops, 10**, (7), 18.

Freer, J.B.S. (1992c). Linseed: Components of yield study. HGCA (Oilseeds) Project Report, No. OS 3. HGCA, London, pp 12.

Freer, J.B.S.(1993c). Linseed husbandry - prevent lodging the cheap way. *HGCA Oilseeds R&D Newsletter*, No. 3, November 1993.

Hardwick, N.V.(1993). Laying in wait for linseed. In *Arable Farming Plus*, March 1993, 26.

Mercer, P.C., Hardwick, N.V., Fitt B.D.L. & Sweet, J.B. (1991). The status of diseases of linseed in the UK. HGCA (Oilseeds) Research Review, No. OS 3. HGCA, London, pp 76.

Major presentations

Royal Agricultural Society of England conference. "Linseed - a real alternative" National Agriculture Centre, Stoneleigh, Warwickshire. 30 January, 1991.

First European Symposium on Industrial Crops and Products. Maastrict, The Netherlands, 25-27 November, 1991.

Association of Applied Biologists conference, Production and protection of Linseed. Cambridge, 16-18 December, 1991.

ADAS National Oilseeds Conference, Harper Adams Agricultural College, Shropshire, 16 July 1992.

References cited in report

Anon. (1984). Determination of the oil content of rapeseed by nuclear magnetic resonance spectrometry. Official Journal of European Communities, No. L328/12, Commission regulation (EEC) No. 3519/84, 14 Dec. 1984.

Anon. (1986). Linseed. Agricultural Development and Advisory Service Pamphlet P2286. MAFF, Alnwick, 4 pp.

Anon. (1994). Fertiliser recommendations for agricultural and horticultural crops (RB 209) 6th edn.. HMSO, London, 34 pp.

Anon. (1993). Varieties of oilseed crops, 1993. Farmers leaflet No. 9. NIAB, Cambridge, 15 pp.

Cook, S.K. (1992). FD 4121A as a growth regulator for linseed. *Tests of Agrochemicals and Cultivars*, **13**, Annals of Applied Biology, 118, Supplement, 66-67.

Cook, S.K. & Freer, J.B.S.(1994). Effects of harvesting methods on yields of linseed varieties. *Tests of Agrochemicals and Cultivars*, **15** (in press).

Freer, J.B.S. & Sansome, G. (1991). The influence of plant population and nitrogen fertility on the seed yield of linseed. *Aspects of Applied Biology,* **28**, 49-53.

Freer, J.B.S. (1992a). Effect of nitrogen and plant growths regulators on lodging, seed yield and quality in linseed. *Tests of Agrochemicals and Cultivars*, **13**, *Annals of Applied Biology,* 120, Supplement, 70-71.

Freer, J.B.S. (1993a). Effect of chlormequat on the height, lodging, seed yield and quality of two cultivars of linseed. *Tests of Agrochemicals and Cultivars*, **14**, *Annals of Applied Biology*, 122, Supplement, 102-103.

Freer, J.B.S.(1993c). Linseed husbandry - prevent lodging the cheap way. *HGCA Oilseeds R&D Newsletter*, No. 3, November 1993.

Froment, M.A.(1993). Effects of desiccants on seed yield and plant dry matter in linseed, *Linum usitatissimum. Tests of Agrochemicals and Cultivars*, **14**, Annals of Applied Biology, 122, Supplement, 100-101.

Hobson, R.N. (1986). *Evaluation and Development of the Grain Stripping Header System 1986.* Div. Note 1443, AFRC Institute of Engineering Research, Silsoe.

Mercer, P.C. & Hardwick, N.V.(1993). Methods of control of diseases of linseed. *Proceedings Crop Protection in Northern Britain*, 1993, 165-170.

Nix, J. (1993). Farm Management Pocketbook, 1994, 24th edn.. Department of Agricultural Economics, Wye College, University of London, Ashford, 213 pp.

Saunders, P.J. & Freer, J.B.S.(1994). Effects of chlormequat on capsule production and sprouting in two linseed cultivars in an atypically wet season. *Tests of Agrochemicals and Cultivars*, **15** (in press).

Ogilvy, S. E. & Payne, J. (1991). The effect of choice and timing of pre-harvest treatments on yield and quality of linseed. *Aspects of Applied Biology,* **28**, 151-154.

Smith, J.M. & Freer, J.B.S.(1993). The effect of methods of cultivation on the establishment and yield of linseed. *Proceedings of the 2nd European Symposium on Industrial Crops and Products*, Italy 1993 (in press).

The following pages provide the data from individual years and sites for information.

Results 1991

Methods of establishment

Overall population densities of 258, 548, 707 and 864 plants per m² from seed rates of 37, 73, 110 and 145 kg/ha were established. Populations were lowest when the crop was broadcast onto the trimmed stubble (352 plants/m²) but similar when the crop was drilled into seedbeds prepared conventionally or by using minimal cultivation techniques (P=0.001). Crop vigour was reduced significantly by sowing at the lowest seedrate and enhanced by the highest (P=0.001). Flowering was significantly extended by drilling at the lowest seedrate and by broadcasting. Method of establishment had no effect on seed yield. Sowing at the lowest seedrate reduced yield significantly but there was no difference between other populations (P=0.001). A plant density of 548 plants/m² was adequate in all situations.

Table 1. Seed yield (t/ha at 91% DM) of linseed cv. Blue Chip, Bridgets 1991

Treatment	Seedrate (kg/ha)				Mean
Cultivation method	37	73	110	145	
			(sed 0.18)		(sed 0.20)
Direct broadcast	1.92	2.51	2.41	2.66	2.37
Minimal cultivation	2.19	2.63	2.62	2.61	2.52
Conventional	2.50	2.79	2.61	2.74	2.66
			(sed 0.08)		
Mean	2.21	2.64	2.55	2.67	

Nitrogen requirements with and without plant growth regulators

There was a high nitrogen residue at most sites due to the previous dry season when little nitrogen was utilised. Consequently there was no response to nitrogen fertiliser except at one chalky loam site where there was a response up to 80 kg/ha (P=0.05).

Table 2. Seed yield response of linseed to nitrogen fertiliser dose. Mean of two varieties at seven sites in England (t/ha at 91 % dry matter) 1991.

Nitrogen dose.	Arthur Rickwood	Telford	Bridgets	Terrington	Boxworth	High M'thorpe	Rosemaund	Mean
0	2.23	2.49	1.75	2.81	2.52	2.1	2.1	2.29
40	2.14	2.57	2.48	2.61	2.54	2.16	2.02	2.36
80	2.14	2.55	2.73	2.76	2.4	2.13	1.82	2.36
120	2.08	2.43	2.77	2.77	2.42	2.22	1.74	2.35
160		2.33	2.71	2.79	2.39	2.19	1.88	2.38
200		2.23	2.79	2.85	2.39	2.22	1.8	2.38
SED	0.120	0.16	0.05					

The response to chlormequat was varied, most sites showed an increase in yield of 5-10% when it was applied to Blue Chip. However, one site showed a negative response of over 10%. There was little difference in the level of response between the timings. In general, Atalante responded less than Blue Chip except at one site where lodging occurred.

Table 2a. **Seed yield response of two varieties of linseed (Atalante and Blue Chip) to chlormequat applied when the crop was at either 10 cm or 30 cm high (t/ha at 91% dry matter).**

Site Treatment	Arthur Rickwood	Bridgets	High Mowthorpe	Telford
Atalante				
Untreated	1.99	2.41	2.02	2.40
10 cm crop height	2.23	2.49	2.11	2.32
30 cm crop height	2.15	2.53	2.14	2.25
Blue Chip				
Untreated	2.17	2.51	2.26	2.41
10 cm crop height	2.18	2.70	2.23	2.57
30 cm crop height	2.14	2.59	2.26	2.65

Fungicide and nitrogen interactions

Yield was greater when 80 kg/ha N was applied but there was no additional response to 120 kg/ha.

Yields increased when a two-fungicide programme was applied. At two sites (HM & BG) responses were in the order of 10-15% over the untreated. The western most site (RM) obtained responses of over 20%. Powdery mildew was present at all sites but control of Botrytis was associated with the greatest yield responses.

Table 3 **Response to applied nitrogen (kg/ha) and fungicide programme (thiophanate methyl plus iprodione at 2 l /ha) of linseed seed yield. Mean of three sites (Bridgets, High Mowthorpe and Rosemaund) in England, 1991. (t/ha at 91% dry matter)**

Nitrogen dose	Fungicide timing	First flower (FF)	Mid flower (MF)	Capsule formation (CF)	FF/MF/_	FF/_/CF	_/MF/CF	FF/MF/CF
0	1.89	1.88	1.98	1.83	2.07	2.13	2.02	2.03
80	2.87	2.96	3.09	2.97	3.10	3.32	3.06	3.17
120	2.92	2.99	3.14	3.03	3.00	3.50	3.11	3.37
				(sed 0.33)				
Mean	2.56	2.61	2.74	2.61	2.72	2.98	2.73	2.86

Methods of harvest

Antares significantly out yielded Norlin. There was no advantage in using a desiccant or in swathing the crop prior to combine harvesting. Using a prototype stripper header increased yield significantly but caution is needed in interpretation due to problems with the machinery which successfully removed the capsules from the stems of the plants but was not designed to thresh the seed from the capsules. This process was done by hand and so the data is not comparable with the other treatments.

Table 4. Effect of methods of harvesting on the seed yield of linseed. Boxworth 1991. (t/ha at 91% dry matter

Treatment	Antares	Norlin	Mean
		(SED 0.2020)	
Direct combine	2.65	1.85	2.25
plus diquat	2.58	2.05	2.32
plus glufosinate methyl	2.66	2.01	2.34

Results 1992

Methods of Establishment

Four distinct plant populations were established from seedrates of 27, 55, 82 and 110 kg/ha seed sown ($P<0.05$). However, establishment % was poorer than expected and the target number of plants was not achieved for any of the seed rates. During the period from 25 March to 12 April ground frosts up to -8.4°C were recorded which are likely to have adversely affected establishment. Plant establishment was not significantly affected by the cultivation method. There was a trend, however, for higher plant densities to establish where the cultivation [Figure 1].

There were no differences in the number of tillers per plant between any of the treatments.

The seed yield was reduced ($P<0.05$) by sowing at the lowest rate of 27 kg/ha. There was no difference in yield between the minimum and conventional cultivation methods. These both yielded higher than the direct drilled treatment [Figure 2]. A mean yield of 1.08 t/ha was obtained overall which is less than half the five-year average yield of 2.4 t/ha. There was no treatment effect on oil content of the seed.

Table 1: **Effect of methods of establishment on the plant population on linseed (number of plants/m² - assessed on 8 June 1992)**

Seedrate (kg/ha) Cultivation method	27	55	82	110	Mean
		(sed ns)		(sed ns)	
Direct drill	173	303	344	397	304
Minimal cultivation	207	312	369	473	340
Conventional	273	373	459	522	407
		(sed 30)			
Mean	218	329	391	464	

Table 2: **Effect of methods of establishment on the seed yield of linseed (t/ha @ 91% DM)**

Seedrate (kg/ha) Cultivation method	27	55	82	110	Mean
		(sed ns)		(sed 0.16)	
Direct drill	0.40	0.52	0.55	0.83	0.57
Minimal cultivation	0.94	1.25	1.38	1.39	1.24
Conventional	1.13	1.46	1.60	1.53	1.43
		(sed 0.08)			
Mean	0.82	1.08	1.17	1.25	

Nitrogen requirements

Due to the previous dry season the soil mineral nitrogen levels were high at all sites. Consequently there was no response to nitrogen fertiliser in 1992 (Figure 3). At some sites yield was reduced at the higher rates of nitrogen because the crop lodged.

At the four sites with the plant growth regulator treatment, whilst there was no response to nitrogen, there were responses to the application of chlormequat (Figure 4).

At ADAS Bridgets, Blue Chip yielded 0.3 t/ha higher than Norlin (P<0.001) but yield was unaffected by either nitrogen dose or the application of chlormequat. No lodging occurred but crop height was reduced by c. 3 cm.

At ADAS Rosemaund, Norlin yielded 0.4 t/ha higher than Blue Chip (P<0.01). Yield was unaffected by either nitrogen dose or chlormequat, however the application of chlormequat did reduce lodging by 10% in Blue Chip (70% lodging in untreated) and 11% in Norlin (30% lodging in untreated). Crop height was reduced by c. 6 cm.

At Admaston Crop Centre, Norlin yielded 0.2 t/ha higher than Blue Chip (P<0.05). Nitrogen dose reduced yield if more than 80 kg/ha was applied (P<0.05). The application of chlormequat increased yield if applied at the 30 cm timing by 0.5 t/ha in Blue Chip and 0.4 t/ha in Norlin. Crop height was reduced by 11 cm and 7 cm respectively. Lodging was reduced by 34% in Blue Chip (74% in untreated) and by 19% in Norlin (43% in untreated).

At ADAS Arthur Rickwood, there was no difference between varieties and no benefit from applications of nitrogen. Chlormequat increased seed yield by 0.3 t/ha and 0.4 t/ha for Norlin and Blue Chip respectively. Lodging was reduced by 10% in Norlin (untreated 15%) and 35% in Blue Chip (untreated 85%) when chlormequat was applied at the 10 cm stage. Height was reduced by c. 6 cm by chlormequat at either timing.

Differences between varieties ranged from nil to 0.4 t/ha. Blue Chip gave the higher yield in the absence of lodging but Norlin produced the highest yield when crops lodged. High residual amounts of nitrogen in the soil due to the previous dry season resulted in no response to applied nitrogen. At one site yields declined when more than 80 kg/ha N was applied. The application of chlormequat reduced crop height by 3-11 cm. At three of the four sites lodging occurred; this ranged in severity and Blue Chip lodged more than Norlin (10-34% in Blue Chip and 10-20% in Norlin).
Yield response was closely related to crop lodging. At three of the four sites lodging occurred and at all three the application of chlormequat reduced the severity of the lodging and consequently at two of the three, yield was improved.

Table 3: Effect of nitrogen fertiliser dose on the seed yield of linseed (t/ha at 91% DM)

Soil type	Nitrogen Dose						
	0	40	80	120	160	200	SED
Organic	2.08	1.94	1.94	2.01	-	-	0.120
Sandy loam	1.76	1.65	1.53	1.47	1.43	1.31	0.201
Chalky loam	1.76	1.80	1.77	1.81	1.80	1.78	0.075
Silty loam	1.06	1.04	0.97	1.00	1.00	1.01	0.049
Clay	2.35	2.17	2.15	2.21	2.35	2.25	0.058
Chalky loam	2.19	2.37	2.58	2.46	2.42	2.62	0.162
Silty loam	2.71	2.83	2.76	2.82	2.77	2.89	0.030
Mean	1.99	1.97	1.96	1.97	1.68	1.69	

Disease and Nitrogen Interactions

Disease levels were low early in the season and Botrytis and Alternaria being recorded at levels of 2% and 26% plants affected. (The Alternaria was a secondary infection on senescing plants and was considered to be non pathogenic.) Powdery mildew late in the season was the main disease. Untreated plots had between 64%, 99% and 95% plants infected on 24, 2 and 19 August at each site respectively. The low levels of Botrytis were effectively controlled, particularly by treatments containing the capsule formation timing. The powdery mildew was well controlled at only one site where the infection coincided with the spray timing. However, mildew re-established and by 19 August there was no difference between treatments.

There were no differences in yield between the fungicide treatments at any site except one where the fenpropimorph treatment gave a 0.3 t/ha increase. This yield response was confounded by the effect of the chemical on the % lodging. Fenpropimorph reduced lodging ($P<0.05$) and so it is difficult to say whether the response was caused by controlling the disease during capsule development or whether it was caused by the reduction in lodging. There was no interaction with nitrogen level (Figure 5).

Table 4: Effect of a fungicide programme on the seed yield of linseed (t/ha at 91% DM)

Timing of iprodione	Site Bridgets	High Mowthorpe	Rosemaund
SED	0.17	0.16	0.067
Untreated	1.25	2.43	1.12
First flower only	1.40	2.54	1.23
Mid-flower only	1.45	2.59	1.01
Capsule formation only	1.39	2.31	1.09
First flower + mid flower	1.57	2.54	1.07
First flower + Capsule form	1.45	2.47	1.17
Mid-flower + Capsule form	1.39	2.52	1.17
First + Mid + Capsule form	1.28	2.56	0.96
Corbel at mid-flower	1.31	2.30	1.38

Harvesting

Flowering commenced on 3 and 10 July for Antares and Norlin respectively and ended on 25 July. Plant populations on the 20 May were 316 and 239 plants/m² for Antares and Norlin respectively. The weather on the days prior to application of pre-harvest treatments and the period up to harvest was changeable. There was no lodging in either variety at harvest.

Table 5: Yield of seed (t/ha) at 91% DM)

Harvesting method	Antares	Norlin	Mean
		(sed 0.096)	(sed 0.068)
Direct combine	2.37	2.05	2.21
Reglone	2.45	1.86	2.16
Challenge	2.50	1.74	2.12
Swath	2.46	1.93	2.20
		(sed 0.048)	
Mean	2.45	1.89	

Table 6: Oil content of seed (% at 91% DM)

Harvesting method	Antares	Norlin	Mean
		(sed 0.44)	(sed 0.31)
Direct combine	38.9	37.6	38.2
Reglone	39.0	38.1	38.5
Challenge	39.5	38.2	38.9
Swath	38.5	37.2	37.9
		(sed 0.22)	
	39.0	37.8	

Oil content was significantly (P<0.001) higher in the variety Antares. Oil content was lower (P<0.05) when harvested after swathing than after treatment with Reglone or Challenge.

Table 7: Seed losses (m^2)

Harvesting method	Antares	Norlin	Mean
Direct combine	343	475	409
Reglone	576	774	675
Challenge	416	931	674
Swath	631	1100	866
Mean	491	820	

Norlin lost seed to a significantly (P<0.001) greater extent than Antares. Seed loss was significantly (P<0.001) higher where the seed had been harvested after swathing.

Seed losses were greater in Norlin probably due to it being an earlier maturing variety than Antares. As the swathing was done at too late a growth stage this accounts for the higher seed losses in this treatment (Figure 6).

Results 1993

Nitrogen requirements

There was no response *(p=0.05)* to nitrogen fertiliser in 1993 (Table 1, Figure 1). At all sites, yields were generally low due to the wet season which resulted in the crops at all sites lodging to some degree. Bad weather at harvest also caused increased seed loss due to shedding and seed sprouting in the capsules.

At the three sites with the plant growth regulator treatment, whilst there was no response to nitrogen, there were responses to the application of chlormequat in terms of reduced plant height and lodging (Figure 2) and increased seed yield which may have been caused by the increase in capsule numbers per plant which accompanied the reduction in plant height.

At ADAS Bridgets, application of chlomequat (as New 5C Cycocel) to the varieties Blue Chip and Norlin, resulted in reductions in plant height compared to the untreated of 4.9 cm and 3.6 cm respectively when assessed on 23 July and was similar at both timings of chlormequat application. There were also reductions in lodging compared to the untreated of 20% and 0.3% respectively when assessed on 1 September. Blue Chip had a greater tendency to lodge than Norlin. Lodging increased with increasing nitrogen doses in both varieties. The increase in yield from the application of chlormequat was similar for both varieties at 0.2 t/ha. Although lodging was reduced by the application of chlormequat, it was not sufficient to overcome the loss in yield caused by lodging.

At ADAS Rosemaund, application of chlomequat (as New 5C Cycocel) to the varieties Blue Chip and Atalante, resulted in reductions in plant height compared to the untreated of 7.3 cm and 12.1 cm respectively at the early timing but only 7.5 cm and 7.3 cm at the later timing. Reductions in lodging compared to the untreated were in the order of 42% and 20% respectively when assessed on 19 July. Blue Chip had a greater tendency to lodge than Atalante but was more responsive to the plant growth regulator. Lodging increased with increasing nitrogen doses in both varieties. The increase in yield from the application of chlormequat was confined to Blue Chip at 0.4 t/ha.

At ADAS Arthur Rickwood, application of chlomequat (as New 5C Cycocel) to the varieties Blue Chip and Norlin, resulted in reductions in plant height compared to the untreated of 7.8 cm and 7.1 cm respectively and was similar at both timings of chlormequat application. Reductions in lodging compared to the untreated (87% and 53% respectively) were in the order of 13% and 2% respectively when assessed on 19 July. Blue Chip had a greater tendency to lodge than Norlin. Lodging increased with increasing nitrogen doses in Blue Chip. Chlormequat at either application date increased the number of branches per plant with Blue Chip having a greater number than Norlin; this resulted in more capsules per plant and therefore more potential yield. This experiment was not harvested due to adverse weather conditions resulting in complete crop loss.

Table 1. **Effect of nitrogen fertiliser dose on the seed yield of linseed (t/ha @ 91% DM)**

Soil type	Nitrogen Dose (kg/ha)						
	0	40	80	120	160	200	Mean
Chalky loam	2.46	2.76	2.73	2.66	2.64	2.60	2.64
Silty loam	1.64	1.32	1.31	1.29	1.30	1.14	1.33
Clay	1.77	1.54	1.50	1.31	1.45	1.28	1.48
Chalky loam	1.88	1.94	1.60	1.49	1.31	1.36	1.60
Silty loam	1.72	1.96	2.09	2.12	2.09	2.07	2.01
Mean	1.89	1.90	1.85	1.77	1.76	1.69	

Disease and Nitrogen Interactions

Disease infection occurred late in the season at capsule formation. Consequently, the first two sprays were applied to a crop showing no disease symptoms(Table 2). Mildew was present when the latest timing was applied. Mildew infection occurring after the first and second fungicide application was not well controlled by the single timings of the fungicide. The capsule formation timing, whilst checking the disease, failed to control it on its own. Control was most effective after the application of a programme including the capsule formation timing. At one site (Rosemaund), disease pressure was so great that control was poor even from the three-spray programme. The single spray of Corbel at capsule formation failed to control mildew effectively.

Table 2. **Mildew infection (% plant surface infected) in linseed after treatment with Compass and Corbel.**

Timing of iprodione + thiophanate methyl	Bridgets	Site High Mowthorpe	Rosemaund
SED	9.24	1.45	9.20
Untreated	81.6	26.1	97.4
First flower only	83.3	25.9	87.1
Mid-flower only	84.7	23.4	87.1
Capsule formation only	58.9	17.9	90.5
First flower + mid flower	86.7	23.4	78.5
First flower + Capsule formation	50.0	10.1	80.8
Mid-flower + Capsule formation	7.2	10.2	79.9
First + Mid + Capsule formation	4.4	6.8	58.1
Corbel at capsule formation	75.0	21	91.0

There was an increase in yield from the fungicide treatments (Table 3). This increase was greatest when treatments were applied at mid-flowering or capsule formation, either as part of a sequence or as a single application. The yield response at Rosemaund was partially confounded by poor harvesting conditions.

Table 3. **Effect of a fungicide programme on the seed yield of linseed (t/ha at 91% DM)**

Timing of iprodione + thiophanate methyl	Site Bridgets	High Mowthorpe	Rosemaund
	(SED 0.066)	(SED 0.102)	(SED 0.067)
Untreated	1.05	2.98	0.71
First flower only	1.23	2.96	0.85
Mid-flower only	1.42	3.09	0.74
Capsule formation only	1.27	3.01	0.77
First flower + mid flower	1.45	3.17	0.93
First flower + Capsule formation	1.45	3.20	0.79
Mid-flower + Capsule formation	1.50	3.24	0.82
First + Mid + Capsule formation	1.47	3.37	0.83
Corbel at capsule formation	1.15	2.99	1.05