



PROJECT REPORT No. OS7

**OILSEED RAPE: SCLEROTINIA
RISK FORECASTING**

MARCH 1994

Price £7.00



OILSEED RAPE: SCLEROTINIA RISK FORECASTING

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This is the final report of a two year project which started in March 1992. The work was carried out by ADAS and funded jointly by the Home-Grown Cereals Authority (Project OS17/1/91 – £15,000) and the Ministry of Agriculture, Fisheries and Food (Project No PD0109 – £7,500).

The Home-Grown Cereals Authority (HGCA) has provided funding for this project but has not conducted the research or written this report. While the authors have worked on the best information available to them, neither HGCA nor the authors shall in any event be liable for any loss, damage or injury howsoever suffered directly or indirectly in relation to the report or the research on which it is based.

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ABSTRACT

Twenty-two "depots" of buried sclerotia of *Sclerotinia sclerotiorum* were established in crops, or individual plots of oilseed rape throughout England in September 1991. The depots were monitored for the production of apothecia from the end of February 1992 until July. The experiment was repeated in 1992 when 25 depots were monitored between March and July 1993.

A detailed examination of meteorological data at six sites in 1992 and 1993 indicated that the initiation of apothecial production was preceded by (i) a dry/drier period of weather and/or (ii) mean daily temperatures (on a weekly basis) starting to rise above 10°C. Germination of sclerotia increased thereafter reaching a peak after a period of wet weather. Apothecial numbers declined during late June to early July when the weather became dry and the mean daily temperatures reached $\geq 15.3^{\circ}\text{C}$ for the week. *Sclerotinia* infection was detected at eight of the sites in 1992 and nine in 1993.

The initiation of germination of sclerotia coincided with flowering, or the presence of fallen petals during pod-ripening, but did not occur at a specific crop development stage. Any scheme for predicting the time of germination of sclerotia and, therefore, ascospore release, could not rely on development stage alone. However, it seems possible that sclerotial germination can be predicted by recording rainfall and temperature data at a site close to the oilseed rape crop. The data can be interpreted simply by examining the rainfall pattern in the weeks preceding the mean daily air temperature, calculated on a weekly basis, reaching 10°C. The remote prediction of the emergence of apothecia can be incorporated readily into forecasting systems which take account of criteria for infection of oilseed rape by *Sclerotinia sclerotiorum*.

OILSEED RAPE : SCLEROTINIA RISK FORECASTING
OBJECTIVE OF RESEARCH

To assess the value of a scheme for predicting outbreaks of sclerotinia stem rot in order to reduce the level of prophylactic fungicide applications.

INTRODUCTION

Sclerotinia stem rot (*Sclerotinia sclerotiorum*) of oilseed rape was, until recently, a disease of minor importance in England and Wales, severe cases mainly being confined to Kent (Romney Marsh), and West Sussex (Chichester Plain). In 1990, the disease was found in only 9% of crops sampled in the ADAS/CSL Pest and Disease Survey. This figure rose to 46% in 1991 (Hardwick 1990, and 1991, ADAS/CSL Pest and Disease Survey, unpublished). Despite this high incidence, the mean severity was low with only 6% of stems affected in England and Wales, the maximum being 16% in Wales. In addition only 9% of crops in the 1991 ADAS survey received a fungicide during flowering.

One hypothesis for the rapid increase in disease incidence in 1991 was that the sclerotial population in the soil of affected crops had increased slowly over a number of years, from small areas of infected plants which had remained unnoticed, and conditions suitable for infection and disease development on a national scale had not previously occurred.

In 1992 the incidence of sclerotinia declined to 28% of crops affected, with 3% of stems affected in England and Wales, the maximum being 8% in the South-West region (Hardwick and Turner, 1992, ADAS/CSL Pest and Disease Survey, unpublished). This decrease in disease was possibly related to the fact that 31% of crops in the 1992 survey received a fungicide spray during or after flowering.

The introduction of a new support system for oilseed rape from the 1992 harvest has led to farmers examining the cost of inputs to the crop, and questioning the need for fungicide treatments. In an effort to rationalise the routine application of fungicides to the oilseed rape crop, ADAS established sclerotial depots throughout England in the autumns of 1991 and 1992. The aim was to monitor apothecial production, thereby identifying crops most likely to be at risk from infection and those that would require treatment.

MATERIALS AND METHODS

Production of sclerotia

Sclerotia from an isolate provided by J R Coley-Smith, University of Hull (isolate J450, obtained from cauliflower seed in Jersey 1983) were produced in flasks in a medium consisting of wheat grain and perlite (Sansford & Coley-Smith, 1992). Flasks were sent to ADAS Plant Pathologists in each of the five MAFF Regions in England.

Burial of sclerotia at depot sites

Prior to determining the optimum position of each depot within the established crop, it was decided to bury the sclerotia in early September within polyester fabric bags which could be easily found when the final locations were selected in February.

Sclerotia were retrieved from the flasks by wet-sieving. Sixty sclerotia were placed on squares of white polyester fabric measuring approximately 10 cm x 10cm. The contents were secured by tying the bag with a small strip of the fabric. Bags were buried immediately after preparation in free-draining plant pots containing soil-less compost, approximately 2cm below the surface. Pots were stored outside by sinking in soil up to the rim.

As soon as the oilseed rape had emerged at the chosen sites, two bags were taken and buried approximately 2cm below the soil surface in an accessible place within the crop and the position marked.

At the end of February, sclerotia were retrieved from the bags and fifty were buried approximately 2cm deep, one per square, in each of two plastic mesh templates placed approximately 20m apart. The mesh was of the type used for fencing, cut to provide 5 x 10 20mm squares. The mesh was fixed in position with tent pegs and a tall cane stood in the ground for future location

Monitoring

Most depots were monitored weekly from the end of February for apothecial production. The total number of sclerotia that germinated at each site was recorded as a percentage, regardless of the number of apothecia produced from each sclerotium (often more than one). Local rainfall data (farm records) or data from the nearest meteorological station were also recorded, as was the developmental growth stage (GS) of the crop.

Meteorological data

Although some farms kept records of rainfall this was not always available on a daily basis. Temperature records were also difficult to obtain. Consequently, for the purposes of interpreting conditions suitable for sclerotial germination, three sites in each year where complete records were kept (Kirton, Boxworth and High Mowthorpe in 1992, and Kirton, Bridgets and High Mowthorpe in 1993), were compared with three where the most complete data were only available from outlying stations. In 1992, Bristol, Wolverhampton, and Owstwick meteorological data were used from Long Ashton, Penkridge and Hull respectively. In 1993, Crowland, Starcross and Church Eaton data were used from Wittering, Exmouth and Walsall.

Data values used in Figures 2 to 13 (pages 14 to 19 and 25 to 30) were calculated for the weeks ending 8 March until 12 July in 1992 and 7 March until 11 July in 1993 using the following equations (E = sum of):

$$\text{Mean daily air temperature per week}^* (\text{°C}) = \frac{E [(\text{daily min} + \text{daily max})/2]}{7}$$

$$\text{Total rain (mm)} = E \text{ daily rainfall per 7 day period}$$

$$\% \text{ Germination} = E \text{ sclerotia germinating from the two grids}$$

* **Referred to hereafter "as mean weekly temperature"**

Flowering period

The flowering period shown in Figures 2 to 13 represents the time between GS 4.1 and 4.9 (first flowers opened on main raceme until all viable buds on main raceme finished flowering). It should be noted that petals were still present after this time whilst pod formation occurred.

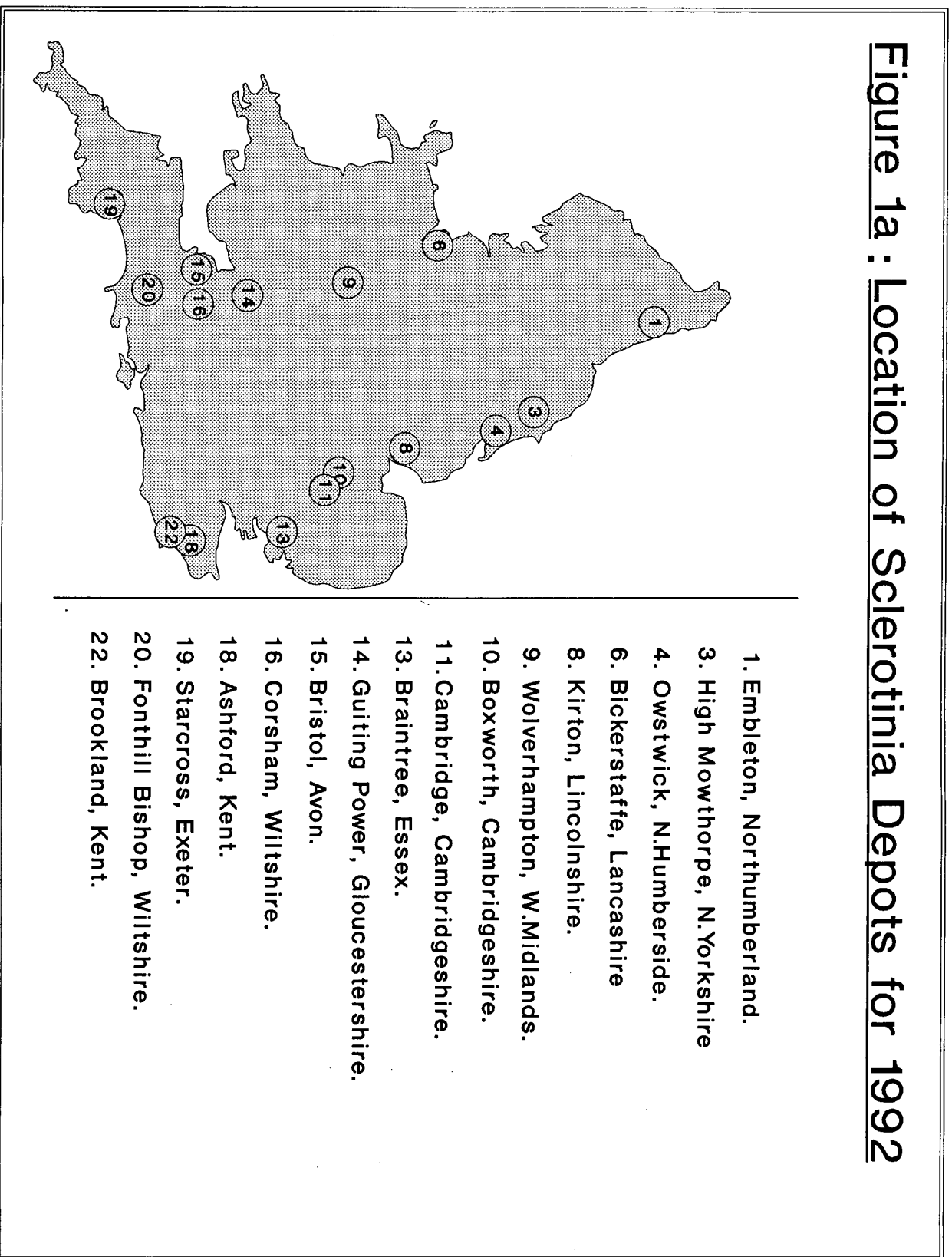
Sites

Twenty-two sites were established in 1992 but the final total from which results were available was 17 (16 winter plus one spring crop). Five sites were lost due to "natural" phenomena; including excavation by foxes, overgrowth by the crop itself, non-establishment and ploughing-out of the crop, and suspected vandalism. Nevertheless, the spread of sites was sufficient to cover most of the oilseed rape growing areas of England. Depots at Kirton, Wolverhampton, Cambridge, Bristol, and Starcross were located off-farm, within specially-drilled plots of oilseed rape.

In 1993, 25 sites were set-up and only one was lost (Bapchild, Kent). Off-farm sites were drilled at Leeds, Kirton, Wolverhampton, Reading and Starcross.

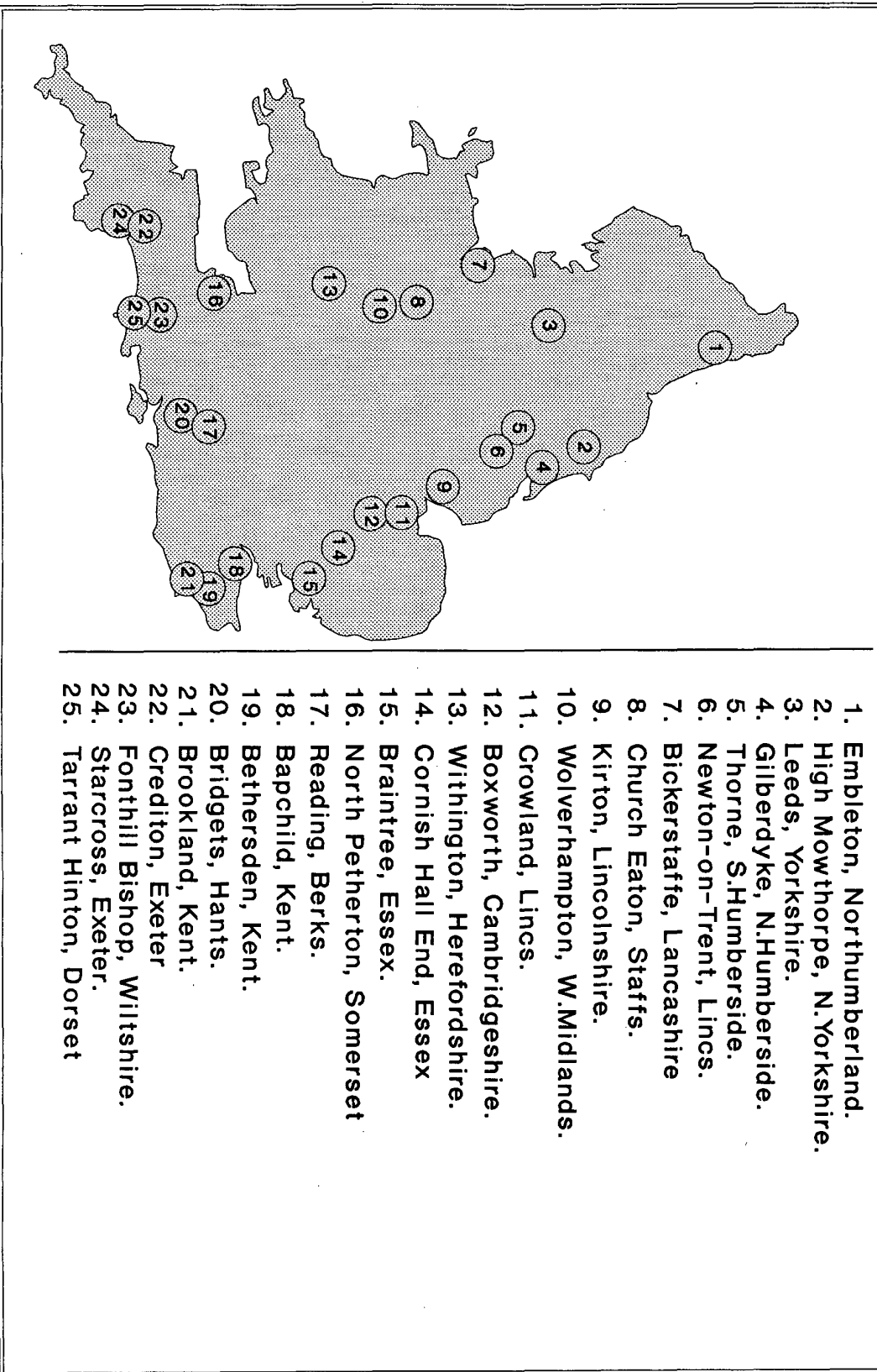
Site locations for depots in 1992 and 1993 are shown in Figures 1a and 1b respectively.

Figure 1a : Location of Sclerotinia Depots for 1992



- 1. Embleton, Northumberland.
- 3. High Mowthorpe, N.Yorkshire
- 4. Owstwick, N.Humberside.
- 6. Bickerstafe, Lancashire
- 8. Kirton, Lincolnshire.
- 9. Wolverhampton, W.Midlands.
- 10. Boxworth, Cambridgeshire.
- 11. Cambridge, Cambridgeshire.
- 13. Braintree, Essex.
- 14. Guiting Power, Gloucestershire.
- 15. Bristol, Avon.
- 16. Corsham, Wiltshire.
- 18. Ashford, Kent.
- 19. Starcross, Exeter.
- 20. Fonthill Bishop, Wiltshire.
- 22. Brookland, Kent.

Figure 1b : Location of Sclerotinia Depots for 1993



Regional germination 1992

In order to compare germination in different areas of the country, sites (identifiable by the numbers allocated in Figure 1a) were grouped into the following regions:-

<u>Region</u>	<u>Sites</u>
North	1, 3, 4, 6, 8, 9, 10, 11
South	13, 14, 15, 16, 18, 19, 20, 22
East	1, 3, 4, 8, 10, 11, 13, 18, 22
West	6, 9, 14, 15, 16, 19, 20
England	All sites listed.

Germination figures (Appendix 1, page 41) were summed and meaned for each category from week ending 19 April until week ending 21 June. Values are presented in Figure 14 (page 32) and Appendix 3 (page 46).

Regional germination 1993

In 1993 the same calculations were made from the following sites (numbers allocated in Figure 1b, sites 17 and 18 excluded due to insufficient data):-

<u>Region</u>	<u>Sites</u>
North	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
South	15, 16, 19, 20, 21, 22, 23, 24, 25
East	1, 2, 4, 5, 6, 9, 11, 12, 14, 15, 19, 20, 21
West	3, 7, 8, 10, 13, 16, 22, 23, 24, 25
England	All sites listed.

Germination figures (Appendix 4, page 47) were summed and meaned for each category from week ending 18 April until week ending 20 June.

Values are presented in Figure 15 (page 34) and Appendix 6 (page 55).

RESULTS

1992 Season

Records of germination and crop development stage for all winter oilseed rape sites are listed in Appendix 1 (page 41).

Sclerotial germination occurred earliest at Kirton (21 April, GS 4.1) with the latest initial records being made at High Mowthorpe (18 May, GS 4.8). Germination occurred at all sites covering all or part of the flowering period. Cambridge was the earliest site to complete germination (9 June, GS 6.4) with the last record being made at High Mowthorpe (29 June, GS 6.1).

Sclerotinia infection of oilseed rape plants in or around the depot was noted at eight of the 16 sites that were monitored (Table 1).

Table 1. Sclerotinia infection at depot sites, 1992

Treatment	Disease present	Disease absent
Fungicide at flowering	Ashford	Bickerstaffe
	Fonthill Bishop	Guiting Power
No fungicide at flowering	Embleton	High Mowthorpe
	Owstwick	Kirton
	Wolverhampton	Cambridge
	Boxworth	Braintree
	Corsham	Bristol
	Brookland	Starcross

The disease developed to affect less than 4% of plants at Ashford and Fonthill Bishop where a fungicide had been applied at petal fall. At Boxworth and Brookland sclerotinia developed to affect 61% and 30% of plants respectively. Results from fungicide trials co-located in the same field as the depots showed good control of sclerotinia from single sprays applied at early petal fall, reducing the disease to less than 6% and zero respectively (Bowerman and Scrace pers. comm.). The level of infection at the four remaining sites that were affected by the disease was low to moderate (up to 12%). No fungicides had been applied at these sites. The

disease was absent at eight sites, two of which had received a fungicide treatment during the flowering period.

In order to relate weather conditions to germination records, six sites selected for in-depth examination are represented graphically in Figures 2 to 7 (pages 14 to 19), and are described below. Rainfall figures for the days immediately preceding the first record of germination for these sites are listed in Appendix 2 (page 44).

The following three sites had on-site weather stations.

Kirton 1992

At Kirton, germination started on 21 April coinciding with early flowering (GS 4.1). At this stage, 50% of plants had up to 10 flowers on the main raceme. The percentage of sclerotia that germinated increased thereafter (Figure 2) reaching a peak on 2 June (21%, GS 6.3) following a week in which 19.8mm of rain fell. Numbers subsequently declined during the week ending 14 June, which was dry, and where the mean weekly temperature reached its maximum at 16.4°C. Thereafter germination decreased, falling to zero by 30 June (GS 6.4).

The weather was dry immediately prior to germination commencing (17-21 April). This was preceded by continuous rainfall (12-16 April) with the maximum for the month falling on 14 April (9.8mm, Appendix 2, page 44). The mean weekly temperature from the beginning of March up to the week that the sclerotia germinated had been less than 10°C, thereafter it remained above 10°C.

There was no evidence of sclerotinia infection at this site (a specially-drilled plot) which was unsprayed.

Boxworth 1992

The pattern of rainfall, temperature, and germination was similar at Boxworth and Kirton. Sclerotia started to germinate slightly later (on 7 May compared to 21 April at Kirton), coinciding with mid-flowering (GS 4.5). The percentage of sclerotia that germinated increased rapidly thereafter (Figure 3) reaching a peak on 5 June (38%, GS 5.9), following a week in which 28.9mm of rain fell. Numbers subsequently declined during the week ending 14 June which had very little precipitation (0.5mm) and where the mean weekly temperature was high at 16.3°C. Nil germination was recorded on 26 June (GS 6.4).

As with Kirton, there was a short period (four days) prior to germination starting, where less than 0.5mm of rain fell per day. This was preceded by low but continuous rainfall with the maximum for the month falling on 27 April (6.9mm, Appendix 2, page 44).

The mean weekly temperature, with the exception of the week ending 26 April, from the beginning of March until the start of germination was less than 10°C. It remained above 10°C thereafter.

The results of a fungicide trial co-located in the same field as the depot showed significant control of sclerotinia stem rot. A range of fungicides applied as single treatments on 15 May significantly ($p=0.05$) reduced the percentage of stems affected, from 61%, to less than 6% (GS 6.9). The crop at the time of the fungicide treatment had 20-25 flowers open and 15-20 pods formed on the main raceme, with the second and third racemes commencing flowering (P Bowerman, pers. comm.).

High Mowthorpe 1992

At High Mowthorpe in North Yorkshire flowering occurred later than at Kirton or Boxworth, and sclerotial germination occurred later than at any other site. The first records of apothecia were made on 18 May coinciding with late flowering (GS 4.8). Sclerotial germination increased thereafter (Figure 4) reaching a peak between 8 and 15 June (29%, GS 5.1 to 5.3). This followed a week in which 15.9mm of rain fell. Numbers subsequently declined during the week ending 28 June which had only 0.2mm of rain, and where the mean weekly temperature had peaked at 15.5°C. Numbers germinating declined to zero on 10 July (GS 6.3).

As with Kirton and Boxworth, a dry period lasting seven days ($<0.5\text{mm/day}$) occurred prior to germination. Rainfall had been low but continuous from 4 to 12 May peaking on 9 May with 4.4mm (maximum for the month). The mean weekly temperature from the beginning of March up until the week prior to germination starting had been less than 10°C. It remained above 10°C thereafter.

Sclerotinia stem rot was not detected in the crop despite the absence of any fungicide treatment.

The sites described below used meteorological data from remote stations.

Bristol 1992

Meteorological data used at this site were taken from Long Ashton, approximately 5 miles south of the depot. The first apothecia were seen on 28 April, one week after flowering started (GS 4.1, 21 April). Germination subsequently increased (Figure 5) reaching a maximum of 22% on 18 May. This followed a week which was dry every day except on 11 May (4.0mm), unlike the three sites with on-site weather stations which were wet (≥ 15.9 mm).

Numbers declined during the week ending 31 May, which was relatively dry (1.5mm only), and where the mean weekly temperature was high at 15.8°C (it peaked at 16.6°C in the previous week). Thereafter germination decreased to zero on 19 June (GS 6.4).

The weather at Long Ashton, in the period from 22-27 April immediately prior to germination, was generally wet. There was, unlike depots where weather was monitored on-site, no dry period immediately preceding germination. The mean weekly temperature from the beginning of March up until two weeks prior to germination commencing had been less than 10°C. It rose to 10.5°C one week before, but then fell until the week ending 17 May during which it rose to 13.5°C and stayed at or above that temperature.

Sclerotinia stem rot was not found at this site (a specially drilled plot at Bristol). The original plant population had been reduced by pigeons, and late volunteers were the only plants present. This may account for the absence of disease symptoms.

Wolverhampton 1992

All meteorological data used at this site were recorded at Penkridge, 9 miles north of the depot. Germination started on 23 April when the oilseed rape was at early flowering (GS 4.2). Sclerotia continued to germinate (Figure 6) with a slight fall in numbers on 25 May following a period (12-22 May) of dry weather. Numbers peaked on 1 June reaching 38% following a very wet week in which 63.4mm of rain fell at Penkridge, and 43mm fell on site in the preceding five days. Thereafter numbers declined in the week ending 14 June which had a high mean weekly temperature of 16.1°C, but which was wet (18.9mm). Germination decreased to zero on 17 June during a dry week.

The weather at Penkridge in the period immediately prior to germination commencing was generally dry with few days on which rain fell. The highest rainfall for the month fell on 14 April (9.0mm) (Appendix 2). The mean weekly temperature from the beginning of March until the week ending 19 April was less than 10°C. It rose to 10.8°C for the week ending 26 April, fell to 9°C the following week, but thereafter remained above 10°C.

The depot, sited in a drilled plot at Wolverhampton, was not treated with a fungicide, and the presence of sclerotinia stem rot was confirmed in a number of plants at the end of the season.

Owstwick 1992

This depot was sited in a farm crop of oilseed rape. Meteorological data were obtained from Hull, 14 miles west. Some rainfall data (weekly totals) were also obtained at the site. Germination records and meteorological data are presented in Figure 7.

Apothecia were first recorded on 5 May soon after flowering began (GS 4.2). Numbers increased very slowly reaching a maximum of 33% on 9 and 16 June at the end of flowering (GS 4.9). Rainfall at Hull in the week ending 7 June was relatively high at 21.9mm (Figure 7) with 21.3mm falling on-site. No further monitoring took place thereafter but it was noted that germination was nil on 15 July.

The rainfall was low for four days prior to germination commencing. This was preceded by low but continuous rainfall, with the second highest rainfall for the month falling on 30 April (6.0mm, Appendix 2, page 44).

The mean weekly temperature, with the exception of the weeks ending 12 and 26 April (10.1 and 10.9°C respectively), from the beginning of March until the start of germination was less than 10°C. It remained above 10°C thereafter.

Six per cent of stems within 2m of the depot were found to be affected by sclerotinia, with 12% in the surrounding crop, which had not been treated with a fungicide.

Figure 2
Kirtton : Sclerotial germination 1992

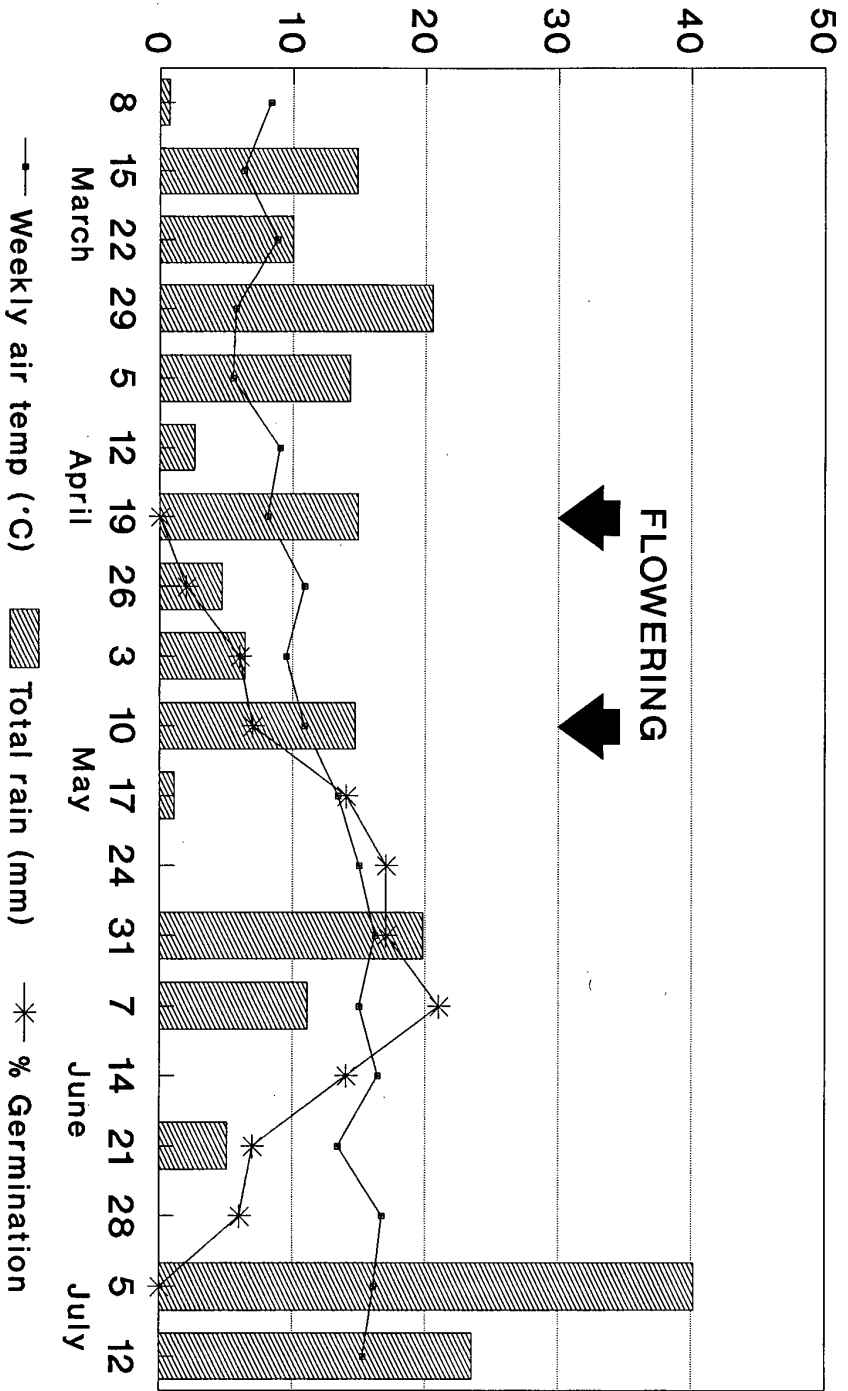


Figure 3
Boxworth : Sclerotial germination 1992

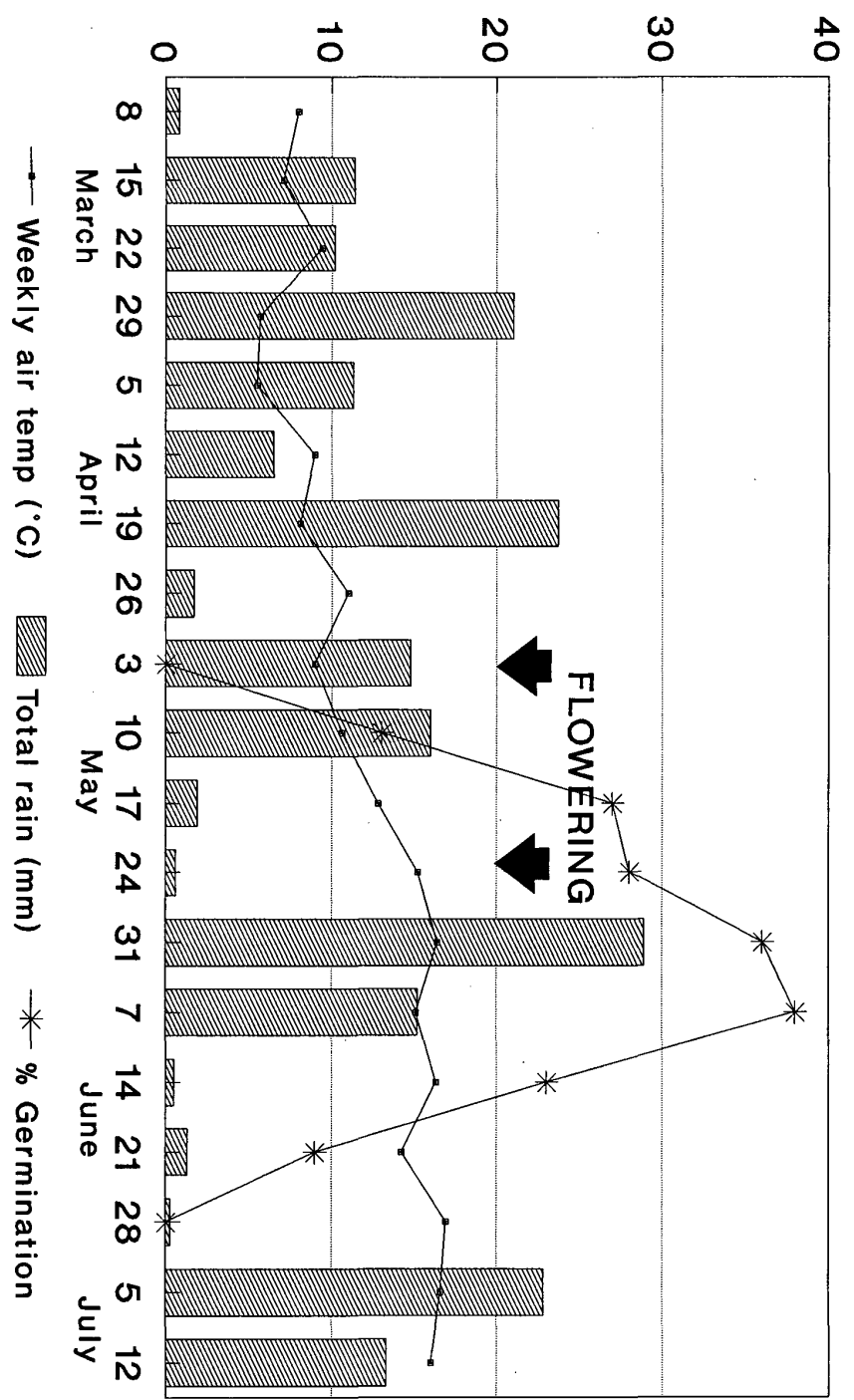


Figure 4
High Mowthorpe : Sclerotial germination 1992

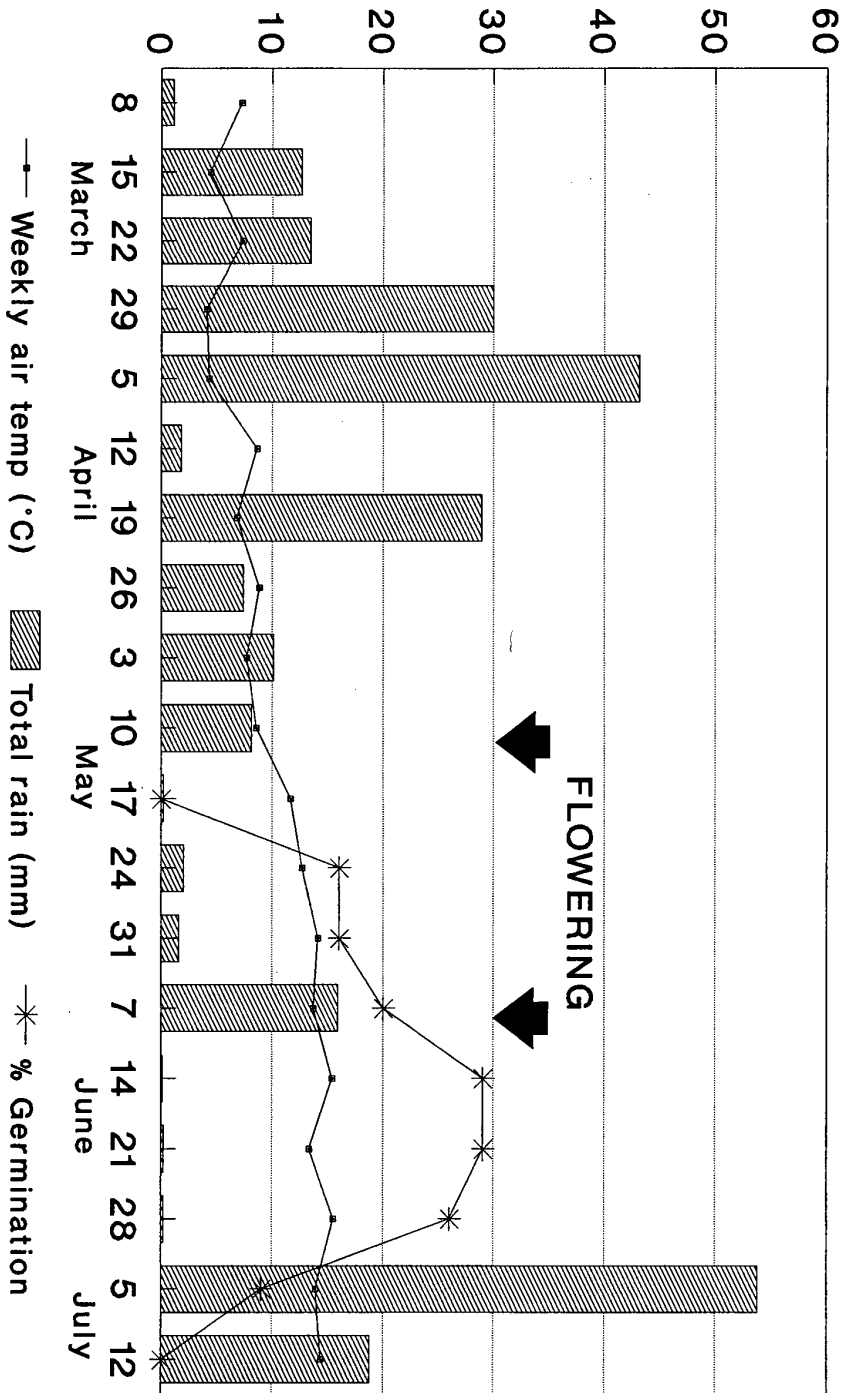
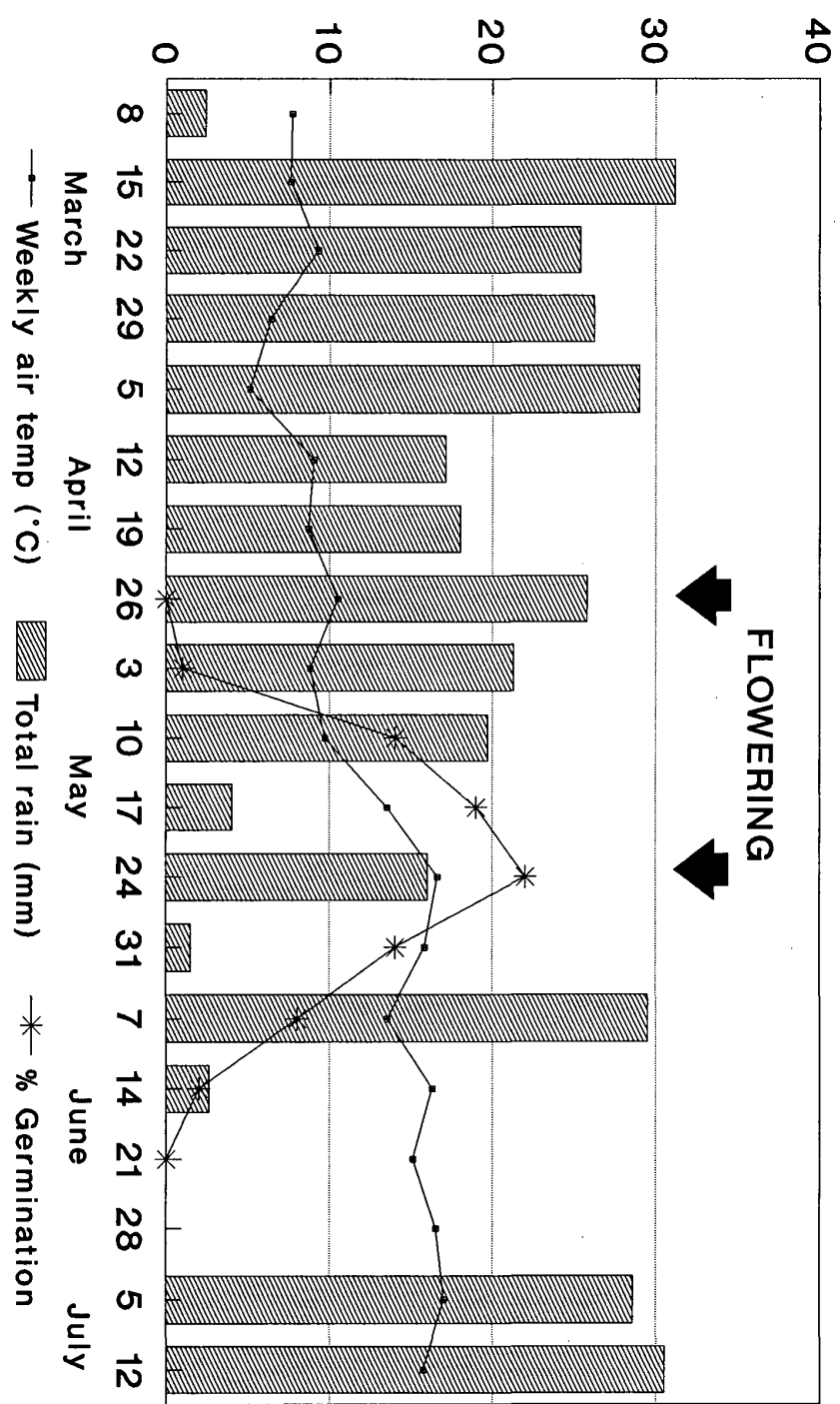
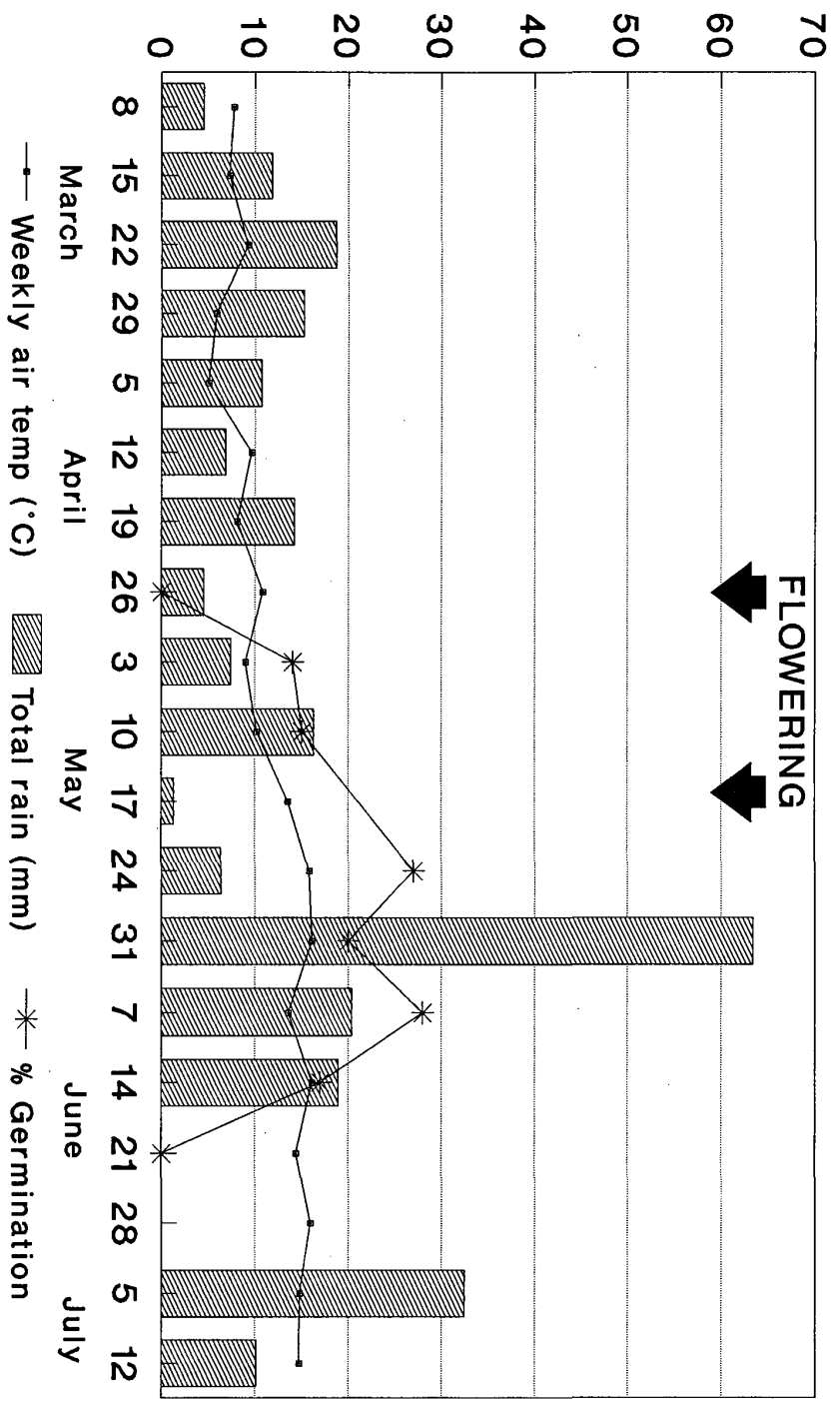


Figure 5
Bristol : Sclerotial germination 1992



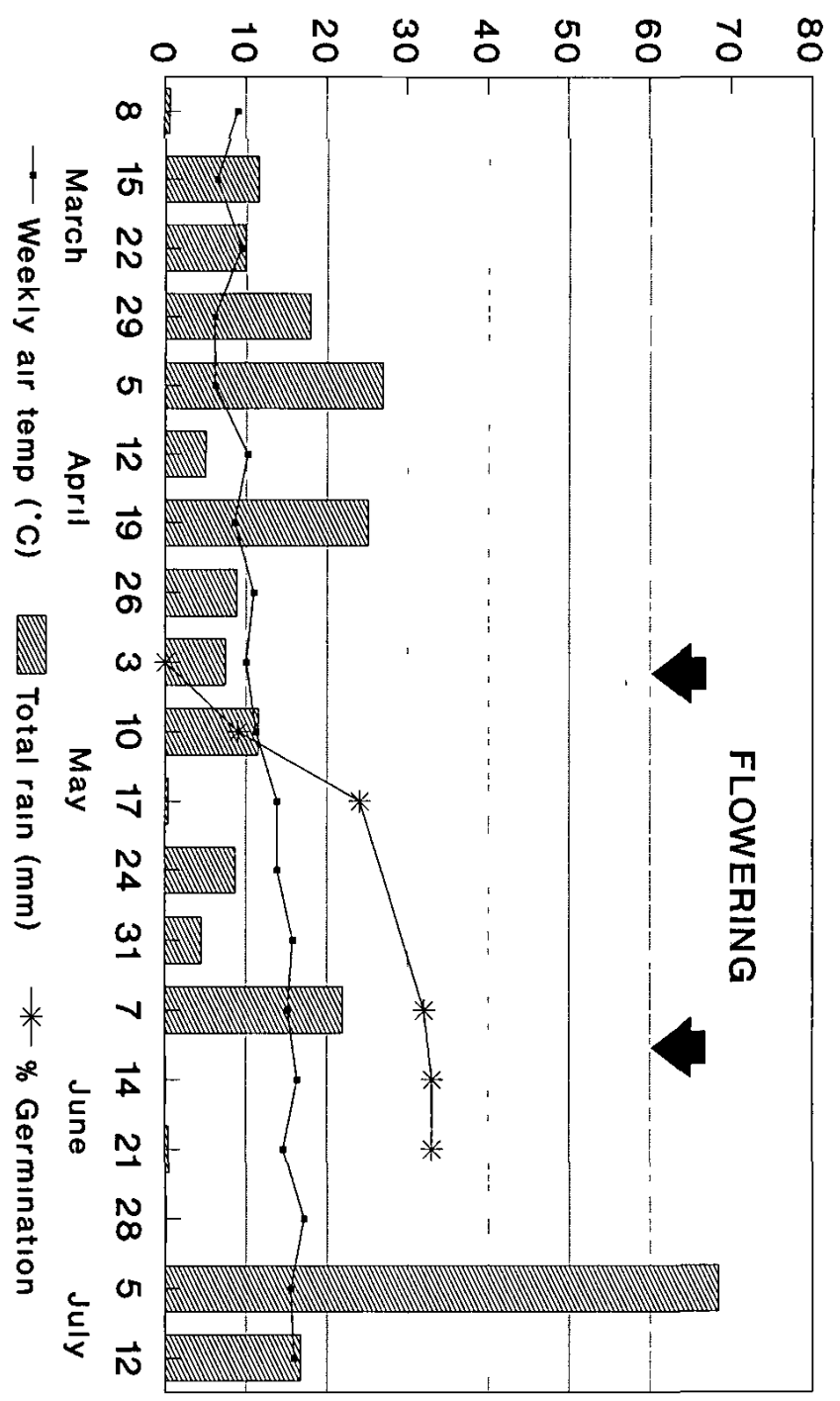
Meteorological data from Long Ashton.

Figure 6
Wolverhampton : Sclerotial germination 1992



Meteorological data from Penkridge.

Figure 7
Owstwick : Sclerotial germination 1992



Meteorological data from Hull.

1993 Season

Records of germination and crop development stage for all sites are listed in Appendix 4 (page 47).

Sclerotial germination occurred earliest at Bethersden (25 March) with the last initial record being made at Reading (7 June, GS 5.1). Crop development was initially slow at the Reading site; plants were still at the rosette stage in mid-April but developed rapidly after a nitrogen application (180 kg N/ha, 16 April). The lack of crop canopy up until this stage is likely to be responsible for the late development of apothecia at this site.

As in 1992, germination of sclerotia occurred at all sites covering all or part of the flowering period (petals were still present at Reading when germination began). Germination was completed first at the Wolverhampton site (17 June, GS 6.3). Sclerotia at many sites continued to germinate in mid-July when monitoring ceased.

Sclerotinia infection of oilseed rape plants in or around the depot was noted at nine of the 24 sites that were monitored (Table 2).

Table 2. Sclerotinia infection at depot sites, 1993

Treatment	Disease present	Disease absent
Fungicide at flowering	Church Eaton North Petherton	High Mowthorpe Bridgets
No fungicide at flowering	Embleton Thorne Newton-on-Trent Crowland Boxworth Braintree Brookland	Leeds Gilberdyke Bickerstaffe Kirtton Wolverhampton Withington Cornish Hall End Reading Bethersden Crediton Fonthill Bishop Starcross Tarrant Hinton

At Church Eaton and North Petherton a fungicide spray was applied during flowering but the disease developed to affect 9 and 1% of plants respectively when assessed at pod-ripening. With the exception of Brookland, the disease developed in the absence of a fungicide treatment to affect less than 2% of plants at pod-ripening. At Brookland, 40% of plants were affected in an untreated area of the field but the application of 1.0 l/ha Ronilan plus 0.5 kg/ha of an mbc fungicide as a tank mixture on 29 April completely controlled the disease in the surrounding crop.

Sclerotinia was not detected at the remaining 15 sites, two of which had received a fungicide treatment during flowering.

As in 1992, six sites were selected for an in-depth examination of results. Apothecial germination in relation to meteorological conditions is represented in Figures 8 to 13 (pages 25 to 30) and are described below. Rainfall figures for the days immediately preceding the first record of germination for these sites are listed in Appendix 5 (page 53).

The following three sites had on-site weather stations.

Kirton 1993

At Kirton, germination started on 20 April coinciding with early flowering (GS 4.1). At this stage 50% of plants were in flower with up to 15 flowers on the main raceme. The percentage of sclerotia that germinated increased thereafter (Figure 8) reaching a peak on 25 May (42%, GS 5.9) following a week in which 19.0 mm of rain fell. Numbers subsequently declined over a period of four weeks. The first week ending 6 June was almost dry (0.7 mm) and the next had the maximum average temperature for the season (16.6°C), thereafter germination dropped to zero on 6 July (GS 6.3).

The weather was dry for seven days immediately prior to germination commencing (13-19 April). This was preceded by continuous rainfall (8-12 April) with the maximum for the month falling on 9 April (18.5 mm, Appendix 5, page 53). The mean weekly temperature from the beginning of March up until the week that the sclerotia germinated had been less than 10°C, thereafter it remained above 10°C.

There was no evidence of sclerotinia infection at this site (a specially-drilled plot) which was unsprayed.

Bridgets 1993

Germination of sclerotia at this site started on 26 April coinciding with full flowering (GS 4.9). Apothecial production increased for a further six weeks (Figure 9) reaching a peak on 7 June (43%, GS 6.3/6.4) following a week in which 18.8 mm of rain fell. Numbers subsequently declined following the maximum mean weekly temperature for the site (16.2°C, week ending 13 June) and reached zero on 28 June (GS 6.6/6.7) after a period of nine dry days (19-27 June).

At the beginning of April the weather was extremely wet with 67.3 mm of rain falling up to the week ending 4 April. The weather subsequently became drier; 25.8 and 2.7 mm fell in the second and third weeks respectively. However, in the week prior to germination commencing, the first three days were dry but then occurred the second highest daily rainfall for the month on the three days prior to the first records of apothecia (Appendix 5, page 53). (It is possible that apothecia were present in the seven days prior to this since the previous record was made on 19 April).

The mean weekly temperature from the beginning of March up until the week prior to germination commencing was less than 10°C. Thereafter it remained above 10°C (except week ending 9 May, 9.6°C).

There was no evidence of sclerotinia infection at this site where a fungicide (Compass @ 3.0 l/ha) was applied at late flowering (5 May, GS 5.5).

High Mowthorpe 1993

The first record of apothecia at this site occurred slightly later than at the previous two sites; 21% of sclerotia had germinated by 5 May coinciding with early flowering (GS 4.2). Numbers peaked on 9 June (74%, GS 5.7) during a week in which 41.8 mm of rain fell (Figure 10). Germination declined from 47% in the week ending 27 June to 8% in the following week coinciding with the maximum weekly air temperature for the site (15.3°C) and nil rainfall. Apothecial numbers continued to decline with 1% of sclerotia showing fruiting bodies on 15 July (GS 6.3).

Prior to germination occurring, less than 2mm rainfall was recorded, between 25 April and 4 May (Appendix 5, page 53). This was preceded by the maximum daily rainfall for the month on 24 April (26.4 mm).

The mean weekly temperature had risen to 10°C in the week prior to germination commencing, although it fell during the next two weeks.

Sclerotinia infection was not detected at this site which received a fungicide treatment at early flowering.

At the following sites meteorological data were obtained from remote stations.

Crowland 1993

Meteorological data used at this site were taken from Wittering, approximately 14 miles south-west of the depot.

Germination commenced on 27 April (GS 4.3, 7%). Peak germination was reached on 24 May (GS 5.8/5.9, 39%), during a week in which 40.6 mm of rain fell (Figure 11).

The first symptoms of sclerotinia stem infection at Crowland were detected in the week ending 30 May. Apothecial numbers declined over two weeks to zero on 7 June (GS 6.1/6.2) following a relatively dry week in which only 1.6 mm of rain fell and during a week in which the mean weekly temperature peaked at 16.7°C.

Low numbers of apothecia emerged on 15 June following a period of continual rain and slightly cooler temperatures but they were only present for a short time and declined to zero by 28 June (GS 6.3).

Prior to the initiation of apothecia the weather was dry for 10 days (13-22 April) with a heavy downpour on 24 April (17.4 mm).

Mean weekly temperatures rose above 10°C in the week prior to the commencement of germination.

Low levels of sclerotinia infection were present at this site (0.6% stems infected) which was not treated with a fungicide during flowering.

Starcross 1993

Meteorological data used at this site were recorded at Exmouth, 2 miles east of the depot.

Apothecia were first detected on 13 April (GS 4.1). Numbers were slow to increase but peaked at 43% on 17 and 26 May (GS 5.9-6.1) following 18 mm of rain in the week ending 16 May. Numbers declined over five weeks to 1% on 29 June (GS 6.6) following a dry week and coinciding with the maximum mean weekly temperature of 18.2°C (Figure 12).

The maximum daily rainfall in April was 23.6mm on 8 April. Subsequently, immediately prior to germination commencing the rainfall was low (11-13 April, 3.3 mm, Appendix 5, page 53). Average temperatures rose to above 10°C during the week that germination commenced.

No fungicides were applied during flowering at this site and no sclerotinia symptoms developed.

Church Eaton

Meteorological data used at this site were recorded at Walsall, 18 miles south-east of the depot.

Apothecia first appeared on 20 April (GS 4.4). Numbers increased to 25% of sclerotia germinating by 18 May (GS 6.1) following a relatively dry week but during a period of increasing rainfall (Figure 13). Germination levels remained the same in the following week which was extremely wet (60.6 mm total rainfall, week ending 30 May). Numbers declined thereafter coinciding with dry weather (0.8 mm week ending 6 June) and high temperatures (16.2°C, mean weekly temperature, week ending 13 June). No germination was recorded on 29 June (GS 6.3).

Rainfall immediately prior to germination commencing was low and intermittent with eight almost dry days between 12 and 19 April; the maximum daily rainfall for the month fell on 8 April (13.6 mm, Appendix 5, page 53). Mean weekly temperatures were less than 10°C between 1 March and 18 April and rose to 10.7°C in the week that germination commenced (week ending 25 April).

Sclerotinia affected 9% of stems at this site which received a fungicide during flowering.

Figure 8
Kirtton : Sclerotial germination 1993

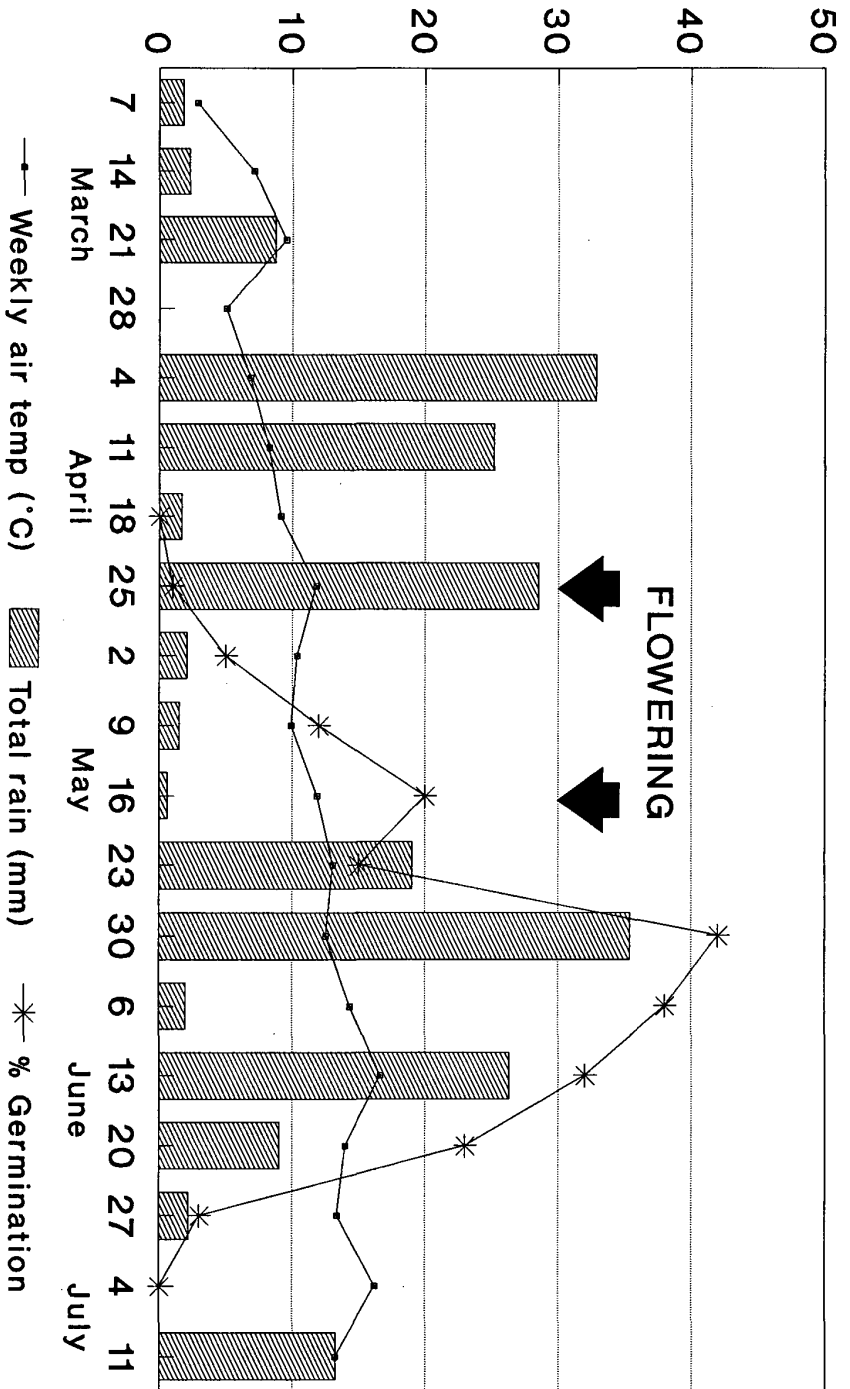


Figure 9
Bridgets : Sclerotial germination 1993

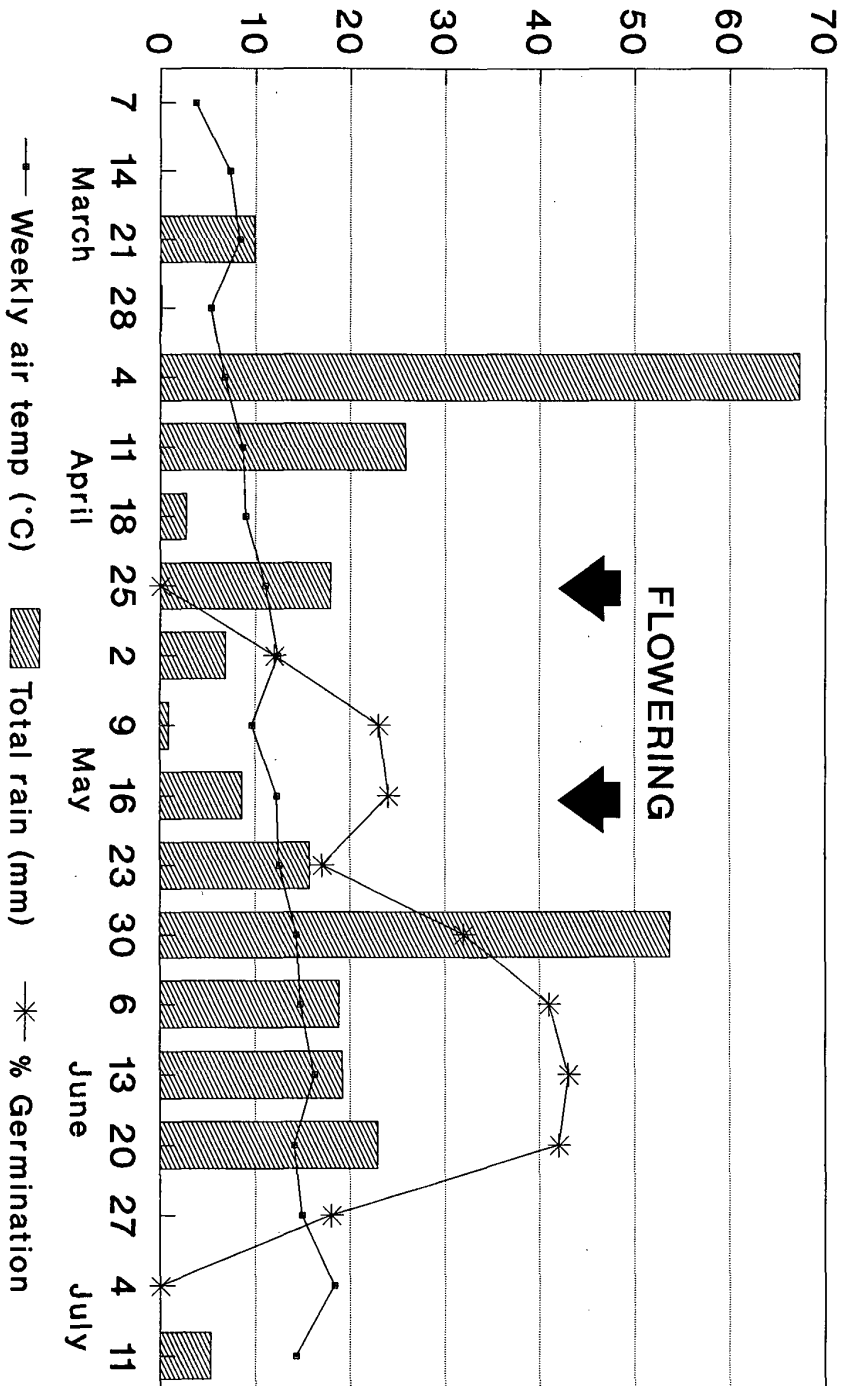


Figure 10
High Mowthorpe : Sclerotial germination 1993

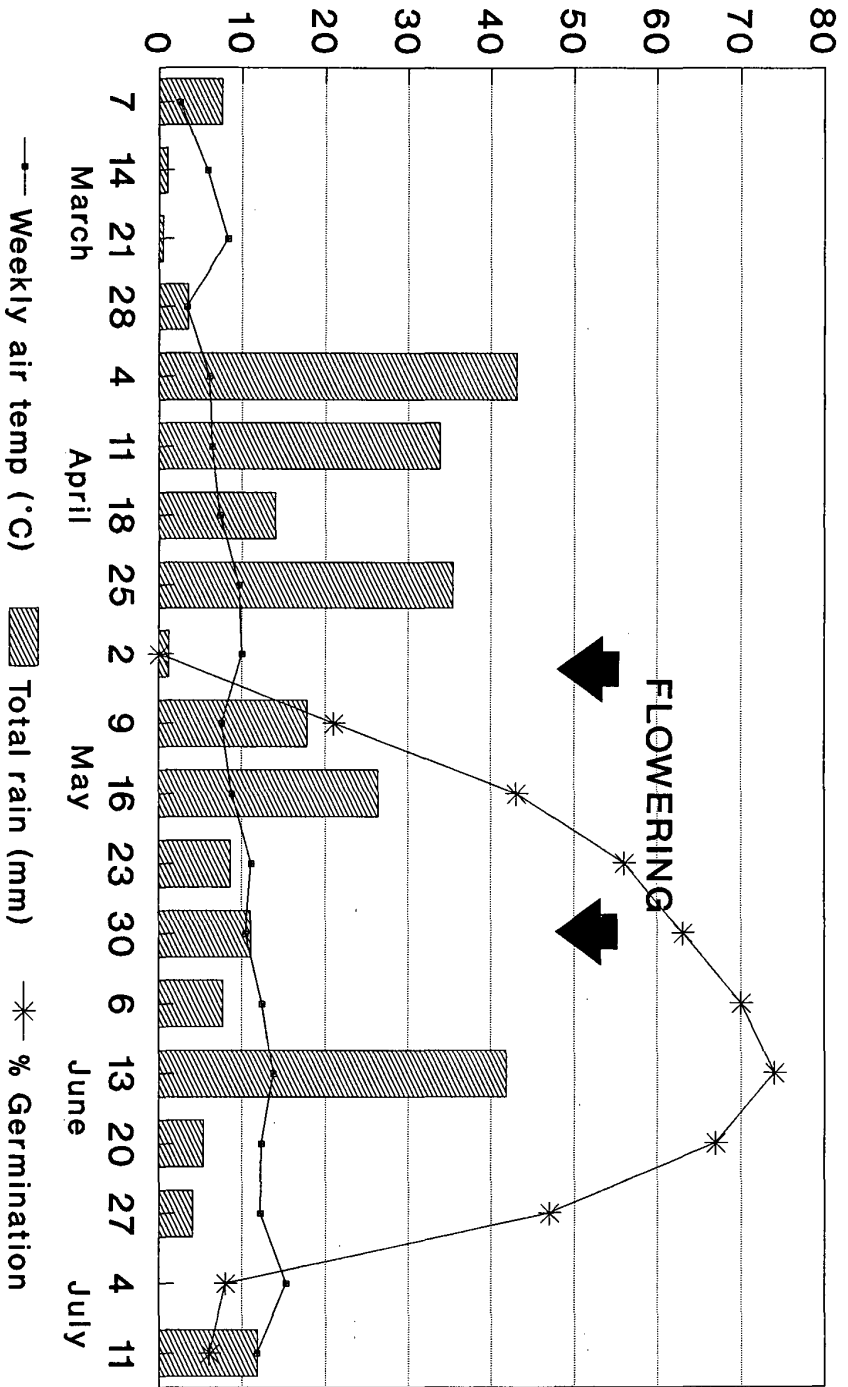
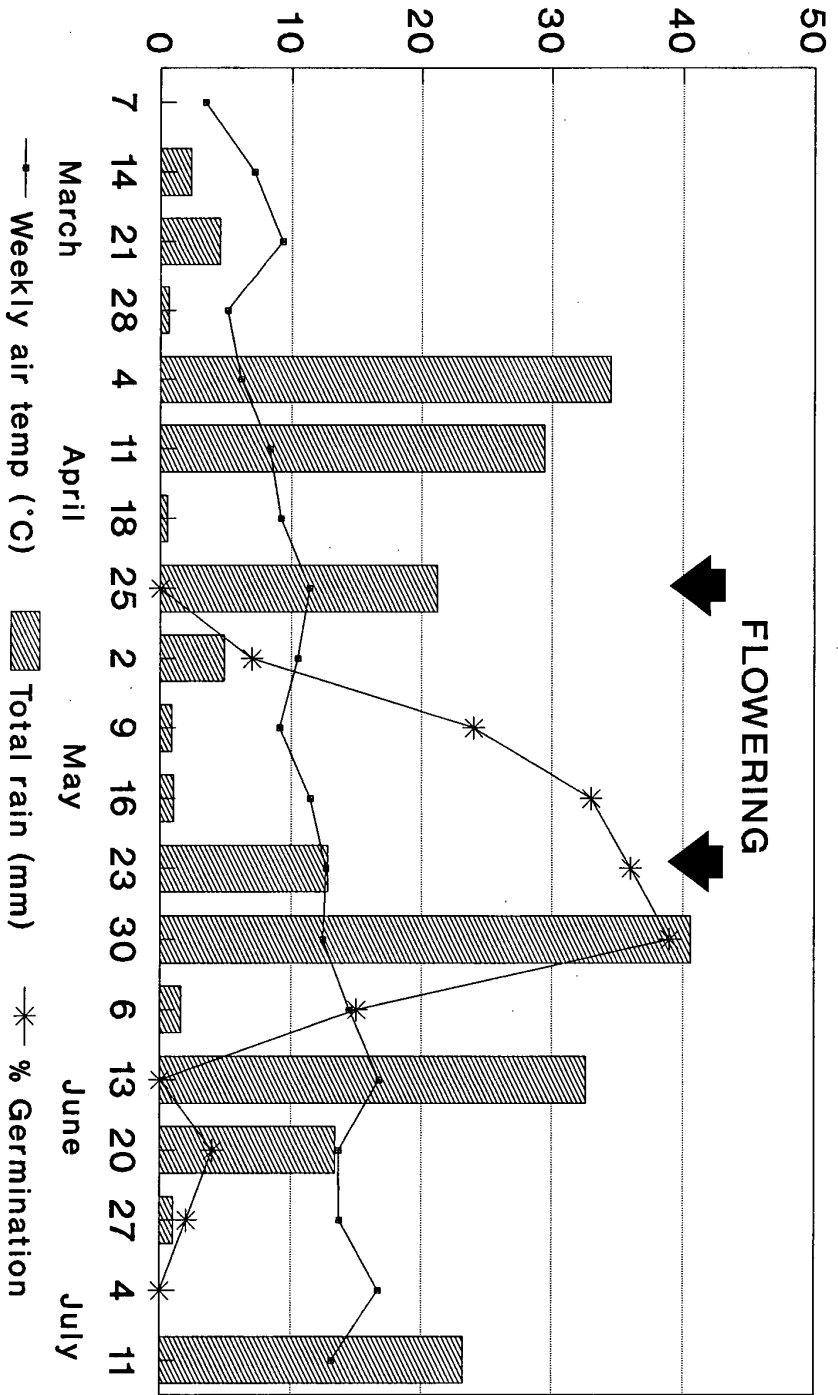
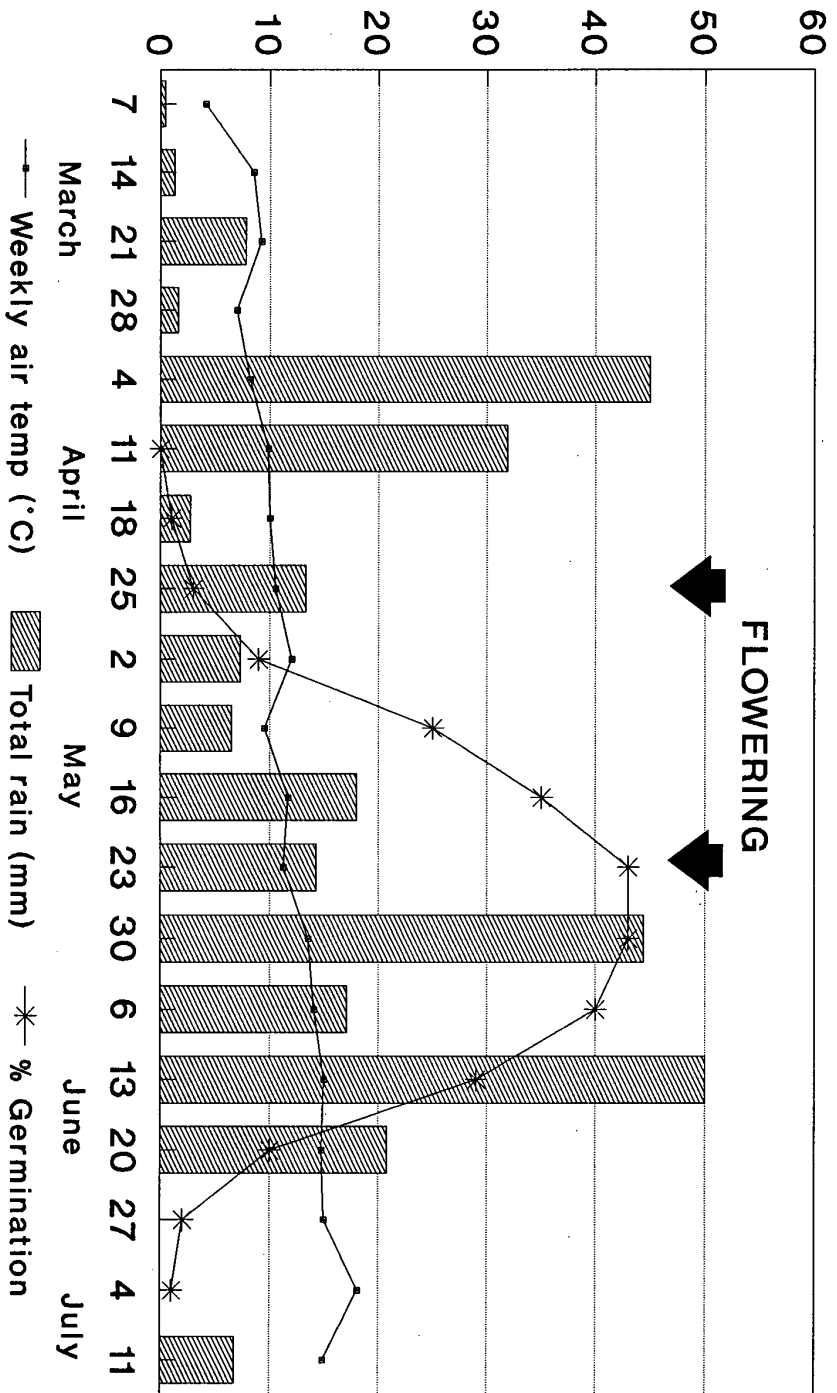


Figure 11
Crowland : Sclerotial germination 1993



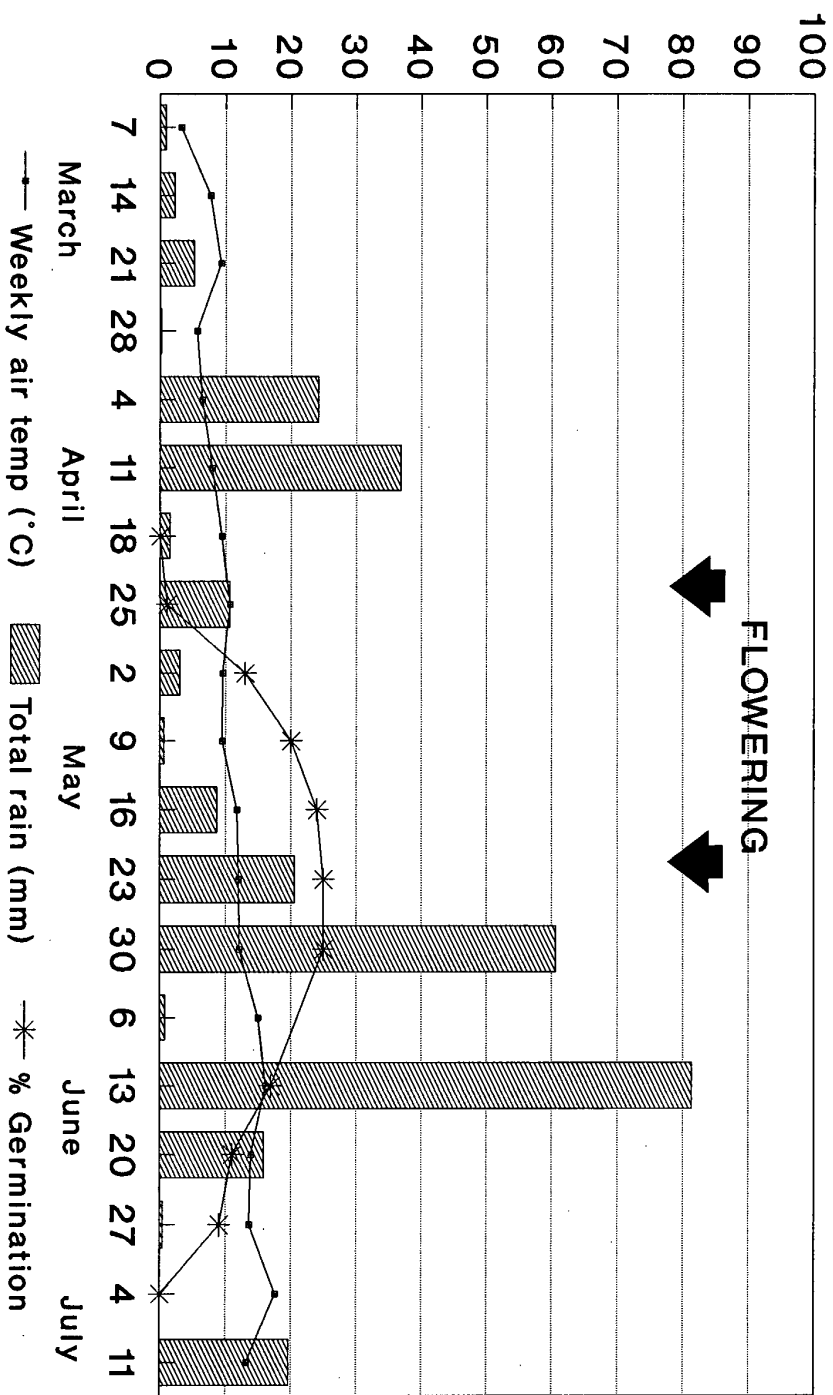
Meteorological data from Wittering.

Figure 12
Starcross : Sclerotial germination 1993



Meteorological data from Exmouth.

Figure 13
Church Eaton : Sclerotial germination 1993



Meteorological data from Walsall

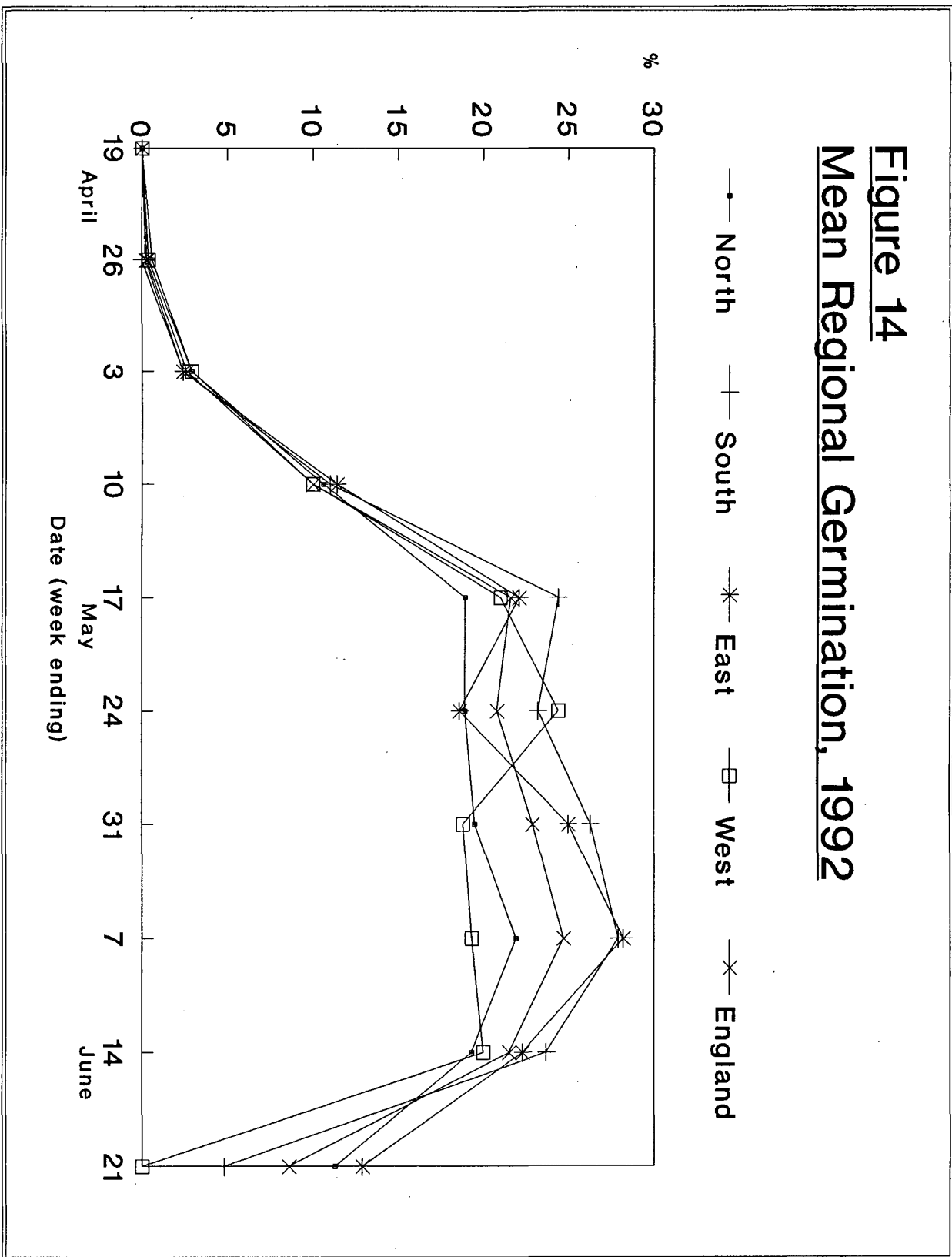
Regional germination 1992

Germination figures for the four regions in England (see Material and Methods) are represented in Figure 14 and listed in Table 3 (Appendix 3, page 46).

Sclerotia at sites in all regions except the south began germinating in the week ending 26 April with those in the south following one week later. There appeared to be very little difference between the regions until the week ending 17 May when the north had the lowest germination value at 18.9% and the south the highest at 24.4%. Germination peaked first in the west in the following week (week ending 24 May, 24.4%). The remaining three regions all peaked during the week ending 7 June, with the south and east attaining 27.9 and 28.2% germination respectively and the north having the lowest maximum value (21.9%).

Thereafter numbers germinating began to decline, with the phase of germination ending first in the west region.

Figure 14
Mean Regional Germination, 1992

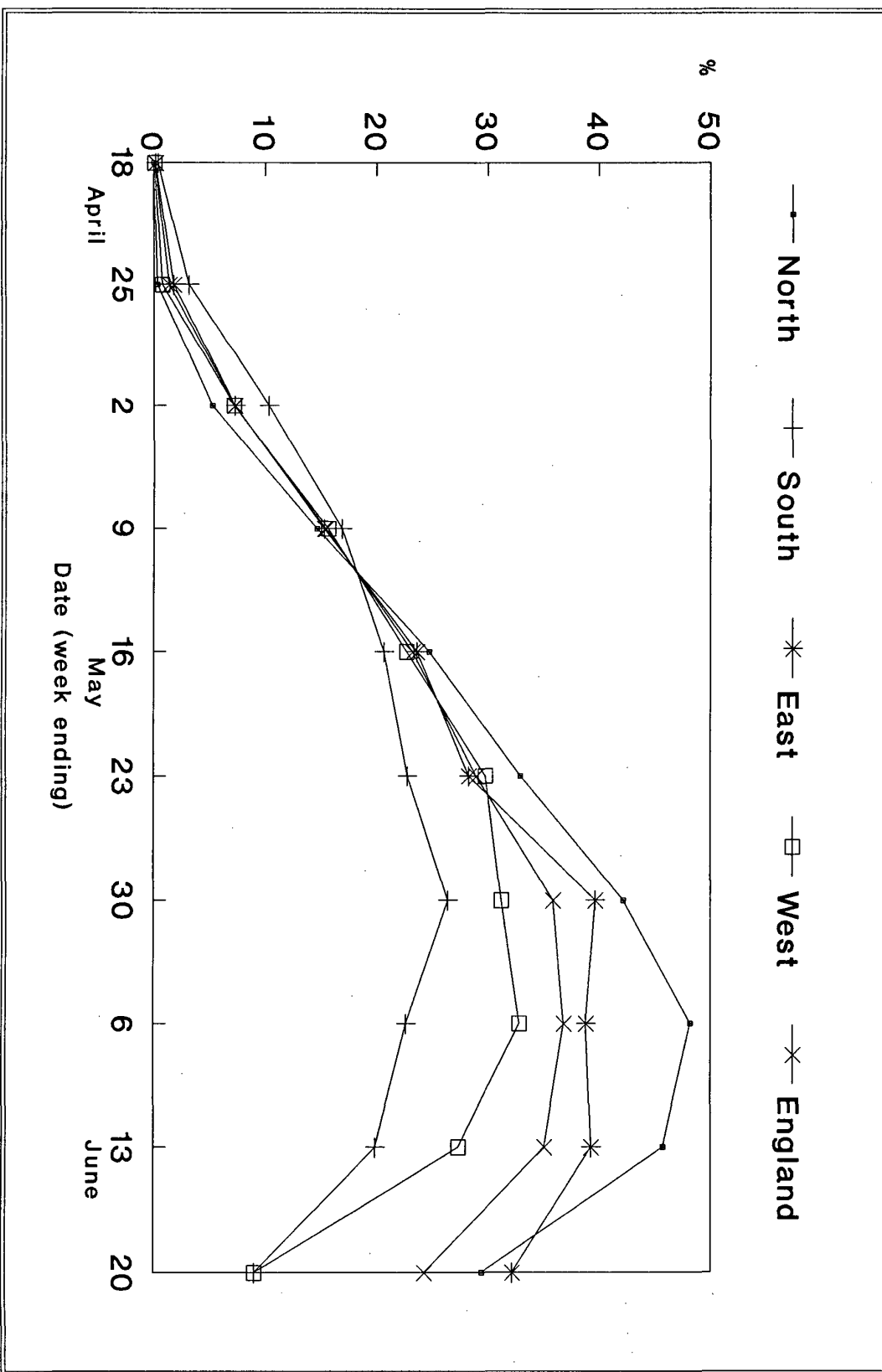


Regional germination 1993

Germination figures for the four regions in England (see Materials and Methods) are represented in Figure 15 and listed in Table 4 (Appendix 6, page 55).

Sclerotia at sites in all regions except the north began germinating in the week ending 18 April with those in the north following one week later. Differences between regions became apparent by the week ending 2 May when the south had the highest figure (10.3%) and the north the lowest (5.3%). Thereafter, sclerotia in the north generally had higher germination figures than the remaining regions, peaking in the week ending 6 June (48.2%). Sclerotial germination in the east peaked in the week ending 30 May at 39.6%, in the west 32.8% week ending 6 June and in the south 26.4% week ending 30 May.

Figure 15
Mean Regional Germination, 1993



DISCUSSION

The objective of this experiment was to evaluate a scheme for predicting outbreaks of sclerotinia in order to reduce the use of prophylactic fungicide applications. This objective was partly fulfilled in the first year of the experiment because results indicated that temperature and rainfall determined when sclerotia of *S. sclerotiorum* were likely to germinate.

Germination appeared to be triggered in the spring by a rise in the mean weekly temperature to above 10°C accompanied by a change in the rainfall pattern from being relatively wet to relatively dry. These results are, in the main, supported by work done by other researchers (see below).

It is known that newly-formed sclerotia require a period of preconditioning prior to germination. This usually requires that sclerotia remain under cool moist conditions (Abawi and Grogan, 1979). None of the depots of sclerotia in this study produced apothecia before the end of March, although some stipes (the stalks upon which apothecia are borne) were detected when the sclerotia were retrieved in February. It has been shown (Willettts and Wong, 1980) that apothecial stipes can be produced between 5 and 25°C but below 10°C and above 20°C apothecial discs fail to form. This was confirmed in the work reported here. However, it is possible for apothecia to be produced in the autumn (Sansford, 1989), and infection can occur at this time (Hardwick *et al.*, 1991, ADAS Oilseed Rape Disease Compendium, unpublished).

Following the preconditioning period it is generally agreed that under field conditions, sclerotia of *S. sclerotiorum* germinate to form apothecia at a temperature optimum of between 10 and 20°C (Lane and Sproston, 1955; Hawthorne, 1976; Saito, 1977). The trend at the 12 sites that were examined in detail appeared to support this since apothecia were not recorded until spring temperatures (weekly mean of daily air temperatures) rose above 10°C.

Kruger (1983) conducted research on the effect of soil temperature (and moisture content) on apothecial development. He found that soil temperatures (at 2 cm depth) of 6-10°C in March or April stimulated sclerotial germination leading to apothecial development in early May. The measurement of air temperature (and rainfall) recorded in the current work, is more easily standardised than that of soil temperature (and moisture content), and will therefore be of more value in any future prediction scheme.

Soil moisture has been shown to be necessary for the production of apothecia by *S. sclerotiorum*. Morrall (1977) showed that apothecia were produced at several soil

moisture potentials between 0 and -7.5 bars, but not below -7.5 bars. Germination at sclerotial depots in this study was usually preceded by a period of wet weather but occurred during dry or drier weather. Soil moisture potentials were not measured.

Once germination had begun, the number of apothecia increased over a number of weeks reaching a peak after a period of heavy rainfall. Apothecial production commenced at the majority of sites between GS 4.1 and 4.9, coinciding with flowering and continuing into the pod ripening stage. Since one of the requirements for sclerotinia infection to occur is an exogenous nutrient supply for the ascospores to germinate (which in oilseed rape is usually the fallen petals), then it seemed likely that the disease would be detected in at least some of the sites. Other conditions required for the germination of ascospores include a high relative humidity (not measured) and an optimum temperature of between 20 and 25°C (Abawi & Grogan, 1979). Although we did not specifically pin-point the time(s) of infection, (which could have occurred on several occasions during the flowering period) we did detect sclerotinia infection at 17 of the 40 winter oilseed rape sites. In addition, observations from fungicide trials co-located with depots at Boxworth and Brookland in 1992, where disease levels in untreated plots were high (61 and 30 % respectively), showed that it was possible to obtain good control by applying a single fungicide spray at petal fall (Bowerman and Scrace, pers. comm.). A similar effect was noted at Brookland in 1993 (Thorpe, pers. comm.).

The final observations made at the depot sites showed that apothecial numbers declined during dry periods coinciding with mean weekly temperatures rising above 15.3°C.

In 1992, no apothecia were detected at any site after the first week in July, which coincided with pod-ripening. Apothecia had been present however during the critical flowering period and served as an indicator that at least one of the requirements for infection had been satisfied. In 1993 apothecia were still present at some sites during the second week in July.

The results showed that where on-site weather data were recorded, the rainfall and temperature requirements for sclerotial germination to commence, reach a maximum, and decline, were the same at all sites. At several of the sites where the weather data were obtained from nearby meteorological stations, some, but not all of the criteria for germination were met.

The initiation of germination coincided with flowering (or the presence of fallen petals during pod-ripening) but did not occur at any one particular growth stage. In any prediction scheme the first stage would be to forecast sclerotial germination. This could not be achieved by monitoring crop growth stage or by the use of off-site weather stations. It could however be done by monitoring temperature and rainfall on-site from early green bud stage (GS 3.3).

In this study additional experimental investigations were made by several ADAS Plant Pathologists in 1992 and 1993, to identify high risk fields by the use of petal culturing, a technique which has been successfully developed in Canada (Turkington *et al.*, 1988). Petals were cultured on an agar medium to determine whether they had been colonised by the ascospores of *S.sclerotiorum*. There appeared to be a good relationship between colonised petals and final disease levels (Davies, Hardwick and Nicholls, pers. comm.).

The depot system has established that monitoring air temperature and rainfall is reliable for predicting the emergence of apothecia. Petal culturing indicates whether ascospores are being released and are present on oilseed rape petals. The next stage in the prediction of infection is to determine whether the petals have adhered to the plant thus allowing the fungus to invade its host. This experiment has determined the first stage in a scheme for the prediction of the timing of fungicide applications against infection of oilseed rape by sclerotinia.

The frequent occurrence of high levels of sclerotinia stem rot no longer appears to be confined to the south-east of England and so it is essential that a reliable forecasting system is produced that will identify fields that would benefit from a fungicide spray, rather than basing advice on previous cropping history and disease incidence alone. By targeting high risk crops this would reduce the cost of production and limit the pesticide pressure on the environment.

ADAS has linked this experiment to new MAFF-funded work on petal culturing in 1993, in an attempt to produce a more definitive risk assessment scheme.

CONCLUSIONS

1. Germination of sclerotia of *S. sclerotiorum* in the spring appears to be preceded by an increase in the mean weekly temperature to $\geq 10^{\circ}\text{C}$, accompanied by a decrease in weekly rainfall.
2. Maximum germination of sclerotia usually follows a week of high rainfall.
3. The production of apothecia declines during dry weather and none are produced when the mean weekly temperature rises above 15.3°C .
4. Meteorological data obtained from on-site weather stations were consistently more accurate in forecasting the germination of sclerotia than data from remote stations.
5. Apothecia were produced during all or part of the flowering period, but no precise crop growth stage at which germination was initiated could be identified.
6. In any forecasting scheme the initiation of sclerotial germination would need to be predicted by the use of an on-site weather station monitoring mean daily air temperatures and rainfall from early green bud (GS 3.3).
7. Future experimentation would aim to confirm the meteorological factors necessary for infection to occur and to obviate the need for the use of live sclerotia as part of any forecasting scheme.

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ACKNOWLEDGEMENTS

I am grateful to those farmers who co-operated in this experiment by allowing ADAS staff to place depots of sclerotia on their land. I would also like to thank the numerous colleagues who set up the depots and monitored them throughout the season.

APPENDIX 1

Sclerotial germination, 1992 sites

Site 1: Embleton, Northumberland

Date	28.4	11.5	18.5	27.5	5.6	16.6	22.6	6.7
Crop GS	-	-	-	4.9	-	-	-	-
% germination	0	4	7	10	15	10	15	10

Site 3: High Mowthorpe, N Yorkshire

Date	11.5	18.5	27.5	1.6	8.6	15.6	22.6	29.6	10.7
Crop GS	4.4	4.8	4.8	4.9	5.1	5.3	5.6	6.1	6.3
% germination	0	16	16	20	29	29	26	9	0

Site 4: Owstwick, N Humberside

Date	28.4	5.5	15.5	2.6	9.6	16.6
Crop GS	4.1	-	-	-	4.9	-
% germination	0	9	24	32	33	33

Site 6: Bickerstaffe, Lancashire

Date	13.4	22.4	27.4	5.5	18.5	3.6	21.6
Crop GS	-	4.1	-	-	-	4.9	-
% germination	0	2	3	10	11	9	0

Site 8: Kirton, Lincolnshire

Date	15.4	21.4	27.4	5.5	12.5	19.5	27.5	2.6	9.6	16.6	23.6	30.6
Crop GS	4.1	4.1	4.4	4.5	5.5	5.4	5.9	6.3	6.3	6.4	6.4	6.4
% germination	0	2	6	7	14	17	17	21	14	7	6	0

Site 9: Wolverhampton, West Midlands

Date	16.4	23.4	29.4	4.5	11.5	18.5	25.5	1.6	8.6	17.6
Crop GS	4.1	4.2	-	-	-	5.2	5.9	-	-	-
% germination	0	1	14	15	20	27	20	28	17	0

Site 10: Boxworth, Cambs

Date	29.4	7.5	14.5	21.5	29.5	5.6	13.6
Crop GS	4.0	4.5	4.7	4.9	5.3	5.9	6.2
% germination	0	13	27	28	36	38	23

Site 11: Cambridge, Cambs

Date	30.4	5.5	12.5	19.5	27.5	2.6	9.6
Crop GS	4.8	5.1	5.6	5.8	5.9	6.3	6.4
% germination	0	31	43	26	18	11	0

Site 13: Braintree, Essex

Date	25.4	2.5	9.5	19.5	26.5	9.6	16.6
Crop GS	4.1	-	-	-	5.9	-	-
% germination	0	4	6	7	15	6	0

Site 14: Guiting Power, Gloucs

Date	29.4	14.5	4.6
Crops GS	4.2-4.9/5.3-5.6	-	6.3
% germination	0	23	19

Site 15: Bristol, Avon

Date	21.4	28.4	7.5	11.5	18.5	29.5	5.6	9.6	19.6
Crop GS	4.1	-	4.8	4.9/5.7	-	5.9	6.2	-	6.4
% germination	0	1	20	19	22	14	8	2	0

Site 16: Corsham, Wilts

Date	24.4	4.5	13.5	29.5	5.6	25.6	9.7
Crop GS	4.1	4.8/5.6	4.9	-	6.2	6.4	6.6
% germination	0	21	31	38	44	8	0

Site 18: Ashford, Kent

Date	24.4	1.5	8.5	17.5	20.5	28.5	4.6	10.6	18.6
Crop GS	-	-	-	5.9	-	-	-	-	-
% germination	0	5	20	30	43	31	48	30	19

Site 19: Starcross, Exeter

Date	21.4	27.4	5.5	12.5	18.5	27.5	1.6	8.6	22.6
Crop GS	-	-	-	-	-	-	-	-	-
% germination	0	2	4	8	8	3	8	6	0

Site 20: Fonthill Bishop, Wilts

Date	30.4	14.5	22.5	9.6	1.7
Crop GS	4.1	-	-	-	6.6
% germination	0	25	54	55	0

Site 22: Brookland, Kent

Date	24.4	1.5	8.5	17.5	21.5	28.5	4.6	10.6	18.6
Crop GS	4.0	-	-	-	5.9	-	-	-	-
% germination	0	7	17	35	5	57	62	49	5

APPENDIX 2

Site 3: Rainfall at High Mowthorpe prior to germination (18 May 1992)

Date (May)	8	9	10	11	12	13	14	15	16	17	18
Rain (mm)	0.6	4.4*	1.2	0.1	tr	0	0	0	0	0	0

*Maximum value for month

Site 4: Rainfall at Owstwick prior to germination (5 May 1992) (Hull figures)

Date (Apr - May)	25	26	27	28	29	30	1	2	3	4	5
Rain (mm)	1.6	1.2	tr	0.7	0.4	6.0*	tr	tr	0	1.5	1.4

*Second highest rainfall for April

Site 8: Rainfall at Kirton prior to germination (21 April 1992)

Date (Apr)	11	12	13	14	15	16	17	18	19	20	21
Rain (mm)	0	0.3	0.4	9.8*	1.5	2.9	0.3	0	0	tr	0

*Maximum value for month

**Site 9: Rainfall at Wolverhampton prior to germination (23 April 1992)
(Penkridge figures)**

Date (Apr)	13	14	15	16	17	18	19	20	21	22	23
Rain (mm)	tr	9.0*	0.8	3.5	0.4	0.3	tr	0.8	0	2.0	0

*Maximum value for month

Site 10: Rainfall at Boxworth prior to germination (7 May 1992)

Date (Apr - May)	27	28	29	30	1	2	3	4	5	6	7
Rain (mm)	6.9*	2.0	0.1	4.7	tr	0.9	tr	0.4	0.4	tr	tr

*Second highest rainfall for April

Site 15: Rainfall at Bristol prior to germination (28 April 1992)

(Long Ashton figures)

Date (Apr)	19	20	21	22	23	24	25	26	27	28
Rain (mm)	0.2	0	0	2.8	0.6	8.2	10.3	3.9	10.5*	0

*Second highest rainfall for month

APPENDIX 3

Table 3: Regional germination values 1992 (Figure 14)

Region	Mean percentage germination for week ending:-									
	19 Apr	26 Apr	3 May	10 May	17 May	24 May	31 May	7 Jun	14 Jun	21 June
North	0	0.6	2.9	10.6	18.9	18.9	19.5	21.9	19.3	11.3
South	0	0	2.4	11.0	24.4	23.2	26.3	27.9	23.7	4.8
East	0	0.2	2.4	11.4	22.1	18.6	25.0	28.2	22.3	12.9
West	0	0.4	2.9	10.0	21.0	24.4	18.8	19.3	20.0	0
England	0	0.3	2.6	10.0	21.6	20.8	22.9	24.7	21.5	8.6

APPENDIX 4

Sclerotial germination, 1993 sites

Site 1: Embleton, Northumberland

Date	26.4	4.5	10.5	17.5	24.5	2.6	7.6	14.6	21.6	28.6	5.7	12.7
Crop GS	4.1	4.4	5.2	5.6	5.8	-	-	6.1	6.2	6.3	6.3	-
% germination	0	1	28	51	60	68	72	75	57	-	-	0

Site 2: High Mowthorpe, North Yorkshire

Date	28.4	5.5	12.5	19.5	26.5	2.6	9.6	16.6	23.6	30.6	7.7	15.7
Crop GS	4.1	4.2	4.4	4.6	5.0	5.4	5.7	5.8	5.9	6.2	6.2	6.3
% germination	0	21	43	56	63	70	74	67	47	8	6	1

Site 3: Leeds, West Yorkshire

Date	26.4	4.5	11.5	19.5	25.5	3.6	9.6	16.6	23.6	30.6	8.7
Crop GS	1.00	1.03	1.05	1.05	2.00	3.3	4.5	4.8/5.3	4.9/5.7	4.9/5.8	6.2
% germination	6	11	22	34	47	54	57	27	10	3	0

Site 4: Gilberdyke, North Humberside

Date	29.4	6.5	13.5	20.5	26.5	3.6	10.6	16.6	24.6	2.7	9.7	16.7
Crop GS	4.3	4.5	5.5	5.7	5.9	5.9/6.1	6.2/6.3	6.3	6.3	6.3	6.4	6.5
% germination	0	22	47	60	73	79	80	77	60	48	32	1

Site 5: Thorne, South Humberside

Date	29.4	6.5	13.5	20.5	26.5	3.6	10.6	16.6	24.6	2.7	9.7	16.7
Crop GS	4.3	4.5	5.5	5.7	5.7/5.9	5.9/6.1	6.2	6.3	6.3	6.3	6.4	6.6
% germination	0	11	26	31	33	57	66	71	58	48	35	15

Site 6: Newton-on-Trent, Lincolnshire

Date	26.4	1.5	11.5	16.5	26.5	1.6
Crop GS	-	-	4.5	4.9	4.9	6.3
% germination	0	1	7	10	12	24

Site 7: Bickerstaffe, Lancashire

Date	14.4	21.4	27.4	4.5	11.5	19.5	24.5	16.6	22.6	28.6	6.7	12.7
Crop GS	3.3	4.1	4.2	-	-	-	-	-	6.3	-	-	-
% germination	0	2	14	6	12	29	13	6	0	0	0	0

Site 8: Church Eaton, Staffordshire

Date	13.4	20.4	27.4	5.5	12.5	18.5	25.5	8.6	15.6
Crop GS	3.3	4.4	4.8	5.8	6.1	6.1	6.2	6.3	6.5
% germination	0	1	13	20	24	25	25	17	11

Site 9: Kirton, Lincolnshire

Date	13.4	20.4	27.4	4.5	11.5	17.5	25.5	2.6
Crop GS	3.6/3.7	4.1	4.2/4.3	4.9	4.9	5.3/5.7	5.9	5.9
% germination	0	1	5	12	20	15	42	38

Site 9: - contd -

Date	7.6	14.6	23.6	29.6
Crop GS	6.1/6.2	6.2/6.3	6.3	6.3
% germination	32	23	3	0

Site 10: Wolverhampton, West Midlands

Date	28.4	5.5	12.5	19.5	28.5	2.6	10.6	17.6	24.6	1.7	16.7
Crop GS	3.9	4.5	4.6	4.9/5.9	6.3	6.3	6.3	6.3	6.4	6.4	6.5
% germination	0	17	22	30	32	28	13	0	0	0	0

Site 11: Crowland, Lincolnshire

Date	20.4	27.4	3.5	10.5	17.5	24.5	2.6	7.6
Crop GS	4.1/4.2	4.3	4.9	4.9/5.3	5.5	5.8/5.9	5.9	6.1/6.2
% germination	0	7	24	33	36	39	15	0

Site 11: - contd -

Date	15.6	21.6	6.7	13.7
Crop GS	6.2/6.3	6.3	6.3/6.4	6.5
% germination	4	2	0	0

Site 12: Boxworth, Cambridgeshire

Date	20.4	29.4	5.5	13.5	21.5	28.5	4.6	11.6
Crop GS	4.3	4.6/5.2	4.9/5.4	4.9/5.7	5.9	6.2	6.2	6.2
% germination	0	1	14	23	42	51	49	46

Site 12: - contd -

Date	18.6	25.6	1.7	11.7
Crop GS	6.3	6.3	6.3	6.4
% germination	25	6	1	1

Site 13: Withington, Herefordshire

Date	22.4	29.4	6.5	13.5	20.5	27.5	4.6	7.6	18.6
Crop GS	4.2	4.4	4.5	4.6	5.5	6.3	6.3	6.3	6.3/6.4
% germination	0	27	39	36	35	28	-	-	0

Site 14: Cornish Hall End, Essex

Date	14.5	21.5	18.6	23.6	30.6	8.7	16.7
Crop GS	4.9/5.7	5.7	6.1	6.2	6.3	6.4	6.7
% germination	0	5	0	0	13	0	0

Site 15: Braintree, Essex

Date	27.4	30.4	3.5	14.5	21.5	29.5	3.6	10.6
Crop GS	4.1/4.3	4.8/5.4	5.5	4.9/5.7	5.7	5.9	5.9/6.2	6.1
% germination	0	15	11	10	20	19	13	8

Site 15: - contd -

Date	18.6	23.6	8.7	12.7
Crop GS	6.1	6.2	6.4	6.6
% germination	0	0	0	0

Site 16: N Petherton, Somerset

Date	27.4	7.5	19.5	27.5	7.6
Crop GS	4.6	4.8	4.9/5.7	5.9/6.3	6.3
% germination	0	14	23	36	31

Site 17: Reading, Berkshire

Date	1.6	7.6	14.6	21.6	28.6
Crop GS	4.7	5.1	-	5.4	5.5
% germination	0	55	66	58	0

Site 18: Bapchild, Kent (Vandalised Site)

Date	8/4	15/4
Crop GS	-	-
% germination	0	2

Site 19: Bethersden, Kent

Date	18.3	25.3	1.4	8.4	15.4	22.4	29.4	6.5	13.5
Crop GS	-	-	-	-	-	-	-	-	-
% germination	0	3	1	0	2	2	5	6	2

Site 19: - contd -

Date	20.5	27.5	3.6	10.6	17.6	24.6	1.7	7.7	14.7
Crop GS	-	-	-	6.3	6.3	6.3	6.4	6.6	6.8
% germination	2	5	2	0	1	3	3	3	3

Site 20: Bridgets EHF, Hampshire

Date	19.4	26.4	3.5	10.5	17.5	24.5	2.6	7.6
Crop GS	4.6	4.9	5.5	5.7	5.7/5.9	5.9	6.3	6.3/6.4
% germination	0	12	23	24	17	32	41	43

Site 20: - contd -

Date	14.6	21.6	28.6	5.7	12.7
Crop GS	6.4/6.5	6.3/6.4	6.6/6.7	6.7/6.8	6.7/6.8
% germination	42	18	0	0	0

Site 21: Brookland, Kent

Date	15.4	22.4	29.4	6.5	13.5	20.5	27.5	3.6
Crop GS	-	-	-	-	-	-	-	-
% germination	0	20	49	47	41	21	19	10

Site 21: - contd -

Date	10.6	17.6	24.6	1.7	7.7	14.7
Crop GS	-	6.3	6.3	6.4	6.5/6.6	6.8/6.9
% germination	11	1	0	0	0	0

Site 22: Crediton, Exeter

Date	27.4	7.5	14.5	22.5	30.5	4.6
Crop GS	4.7	4.9/5.5	4.9/5.7	-	-	6.1
% germination	0	9	30	35	30	29

Site 23: Fonthill Bishop, Wiltshire

Date	3.5	10.5	18.5	28.5	4.6
Crop GS	4.5	4.9	4.9/5.8	-	-
% germination	0	12	27	27	27

Site 24: Starcross, Exeter

Date	5.4	13.4	19.4	26.4	4.5	10.5	17.5	26.5
Crop GS	4.0	4.1	4.3	5.7	5.7	5.7	5.9/6.1	6.1
% germination	0	1	3	9	25	35	43	43

Site 24: - contd -

Date	1.6	8.6	16.6	22.6	29.6
Crop GS	6.2	6.2	6.3/6.4	6.6	6.6
% germination	40	29	10	2	1

Site 25: Tarrant Hinton, Dorset

Date	16.4	30.4	10.5	18.5	3.6	8.6
Crop GS	4.3	4.7	4.9	5.9	6.3	6.3
% germination	0	3	11	17	19	17

APPENDIX 5

Site 2: Rainfall at High Mowthorpe prior to germination (5 May 1993)

Date (Apr- May)	24	25	26	27	28	29	30	1	2	3	4	5
Rain (mm)	26.4*	0.5	tr	0	0	0	0	1.0	tr	tr	0	1.2

*Maximum value for month

**Site 8: Rainfall at Church Eaton prior to germination (20 April 1993)
(Walsall figures)**

Date (Apr)	8	9	10	11	12	13	14	15	16	17	18	19	20
Rain (mm)	13.6*	5.8	3.1	7.5	0	0	0	0	0.5	0.5	0.5	0	0

*Maximum value for month

Site 9: Rainfall at Kirton prior to germination (20 April 1993)

Date (Apr)	9	10	11	12	13	14	15	16	17	18	19	20
Rain (mm)	18.5*	0.6	3.7	1.0	0	0	0	0	0	0.7	0	0

*Maximum value for month

**Site 11: Rainfall at Crowland prior to germination (27 April 1993)
(Wittering figures)**

Date (Apr)	16	17	18	19	20	21	22	23	24	25	26	27
Rain (mm)	0	0.3	0	0	0	0	0	3.8	17.4*	0	3.1	0

*Second highest value for month

Site 20: Rainfall at Bridgets prior to germination (26 April 1993)

Date (Apr)	15	16	17	18	19	20	21	22	23	24	25	26
Rain (mm)	0	1.8	0	0	0	0	0	4.0	11.2*	1.9	0.8	6.9

*Second highest value for month

Site 24: Rainfall at Starcross prior to germination (13 April 1993)

(Exmouth figures)

Date (Apr)	3	4	5	6	7	8	9	10	11	12	13
Rain (mm)	8.3	10.2	0.3	0.7	0	23.6*	tr	5.9	1.3	1.7	0.3

*Maximum value for month

APPENDIX 6

Table 4 - Regional germination values 1993 (Figure 15)

Region	Mean percentage germination for week ending:-									
	18 Apr	25 Apr	2 May	9 May	16 May	23 May	30 May	6 Jun	13 Jun	20 Jun
North	0	0.3	5.3	14.6	24.7	32.9	42.2	48.2	45.7	29.5
South	0.4	3.1	10.3	16.9	20.6	22.8	26.4	22.6	19.9	9.0
East	0.2	1.8	7.3	15.3	23.6	28.3	39.6	38.8	39.3	32.2
West	0.1	0.8	7.2	15.7	22.7	29.8	31.2	32.8	27.3	9.0
England	0.1	1.4	7.3	15.5	23.2	29.0	35.9	36.8	35.1	24.3