Development of *Sclerotinia* Stem Rot on Cultivars of Oilseed Rape

by

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ABSTRACT

Methods were devised to produce a constant supply of apothecia and ascospores of *Sclerotinia sclerotiorum* under controlled conditions, to collect ascospores and to store them. The effects of temperature, relative humidity and light on the discharge and germination of the ascospores were investigated.

Eight field trials of winter oilseed rape cultivars were conducted at three sites over three years which aimed to determine the susceptibility of 31 cultivars to stem rot. Field performance of these cultivars varied with year and site suggesting that the differences recorded were likely to be associated with agronomic and environmental factors rather than genetically based differences in susceptibility. There was no evidence of resistance to *Sclerotinia* stem rot in the current cultivars and lines of oilseed rape.

Basic epidemiological data were recorded from these cultivar trials but other field trials explored further the epidemiology of stem rot.

The survival of sclerotia was affected by depth of burial and soil type. The number of apothecia produced from sclerotia was influenced by depth of burial, source of the sclerotia and applications of nitrogen. Numbers of apothecia under crops of oilseed rape were variable even within one site. Maximum numbers of ascospores were trapped between 14.00 + 16.00 h and could sometimes be related to numbers of apothecia and/or to amounts of stem rot.

Infection occurred only in the presence of a dead petal. Its role was shown not to be as a nutrient supply per se but rather to provide a base for mycelial inoculum. Adhesion of petals to stems during periods of maximum ascospore production appeared to be critical for infection. Such

periods need to be predicted if sprays to control stem rot are to be applied economically.

Fungal extension in the stem was often considerable and resulted in lodging, yield loss (both seed weight and oil content) and finally formation of sclerotia in or on stem and roots. Varying numbers of sclerotia were returned to the soil. Monitoring of this reservoir could help assess the risk of stem rot in an oilseed rape crop.

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Dedicated, with love, to my husband, Nicholas Mitchell.

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INTRODUCTION

With the increase of hectarage in the United Kingdom cultivated to winter oilseed rape, various disease problems have arisen. Indications of possible diseases have been ascertained from the countries of the EEC and Canada already cropping winter oilseed rape. *Sclerotinia sclerotiorum*, the causal organism of stem rot, is recognised as the second most important pathogen on the continent. Preliminary observations in the U.K. in 1980, showed local occurrences of the pathogen on breeders trials of new cultivars. The situation was acknowledged as being potentially dangerous as *S. sclerotiorum* is a soil borne fungus and once present in the soil could seriously limit oilseed rape production.

Nothing was known in the U.K. about the ability of the fungus to infect existing cultivars, candidate cultivars or breeding lines; its variability as a pathogen or the levels of resistance that might be present in oilseed rape.

The aims of the research were therefore to devise a practical method for determining cultivar resistance/susceptibility in both the glasshouse and the field, and to determine the nature of any resistance; screen a wide range of cultivars entered for U.K. National and Recommended Lists, to establish a disease rating; investigate pathogen variability with respect to its host range and implications for crop rotations; and to investigate more fundamental aspects of the epidemiology of the disease in the U.K.

Plate i : Symptoms of *Sclerotinia sclerotiorum* on winter oilseed rape.



Plate ii : Sutton Scotney, 1982: Pod browning resulting from stem infections by *Sclerotinia sclerotiorum* on cultivar Jet Neuf.



SECTION 1

PRODUCTION OF APOTHECIA AND ASCOSPORES BY ISOLATES OF *SCLEROTINIA SCLEROTIORUM*

1.1 Introduction and Relevant Literature

1.1.1. Taxonomy and nomenclature

The fungus now known as *Sclerotinia sclerotiorum* was first described as *Peziza sclerotiorum* by Libert (1837). When Fuckel (1870) described the genus *Sclerotinia* he transferred this species to it with the name *Sclerotinia libertiana*. However this binomial was inconsistent with the International Rules of Botanical Nomenclature and Wakefield (1924) cited G.E. Massee as the proper authority (*S. sclerotiorum* (Lib.) Massee) as he had used that binomial in 1895. However, since de Bary used the same binomial as early as 1884 (de Bary, 1884) he should be cited as the proper authority for this fungus. *Sclerotinia sclerotiorum* (Lib.) de Bary was designated as the type species of *Sclerotinia* in the reappraisals of this genus and related fungi by Whetzel (1945), by Korf & Dumont (1972) and by Buchwald & Neergaard (1973, 1976). Two other names are commonly encountered in the taxonomic literature, *Sclerotinia trifoliorum* Erikss. and *S. minor* Jagger. The former was described by Eriksson (1880) as the pathogen of clover stem rot and the latter was used by Jagger (1920) for isolates with small sclerotia from lettuce, celery and other crops in New York State. These two pathogens were considered by Smith (1900) to be identical with *Sclerotinia libertiana* (*S. sclerotiorum*).

Other, apparently less important species of *Sclerotinia* have been identified including: *S. intermedia* Ramsay; *S. serica* Keay; *S. sativa* Drayton & Groves; *S. trifoliorum* Erikss. var. *fabae* Keay and *S. tuberosa* (Hedus. ex Mérat) Feld.

The three species, *S. sclerotiorum*, *S. trifoliorum* and *S. minor* have been extensively studied because of their wide distribution and great economic importance (Willetts & Wong, 1980). However, there has been considerable discussion on their status as species. Smith (1900) considered *S. trifoliorum* and isolates with small sclerotia (*S. minor* Jagger) to be identical with *S. sclerotiorum* as did Purdy (1955), Walker (1969), Morrall *et al.* (1972), Price & Colhoun (1975) and Mordue & Holliday (1976).

The criteria on which the three species were delimited were size of sclerotia, asci and ascospores, time of apothecial development in the field and host range (Jagger, 1920; Whetzel, 1945; Buchwald & Neergaard, 1973). Many of these criteria have subsequently been questioned. Thus although *S. minor* has been reported mainly on forage legumes, other hosts including vegetable legumes have been recorded and in reviewing these and other data Wong & Willetts (1980) concluded that host association was not a reliable criterion for determining the three species. Similarly, after reviewing the earlier literature Purdy (1955) pointed out that the size ranges for sclerotia of the three species overlapped. There was a continuous gradation in the diameter of sclerotia from those of *S. minor* (0.25 to 5 mm) to the larger ones of *S. trifoliorum* (0.3 to 10 mm) and *S. sclerotiorum* (1 to 30 mm). Nor could the asci or ascospores of the three species be clearly distinguished. Purdy (1955) also showed that measurements of sclerotia, asci and ascospores obtained by Ramsay (1924) for *S. intermedia* and by Drayton & Groves (1943) for *S. sativa* were within the range given by other workers for *S. sclerotiorum*, *S. trifoliorum* and *S. minor*. In view of this variability he concluded that the size of these structures had little value for delineating the three species.

However, other characteristics are available. Wong & Willetts (1973) used polyacrylamide gel electrophoresis to study 15 isolates, four

identified as *S. minor*, four as *S. trifoliorum* and seven as *S. sclerotiorum*. On the basis of the electrophoretic patterns for soluble proteins, aromatic esterase, acid phosphatase, glucose-6-phosphate dehydrogenase (NADP-linked), NADP dehydrogenase and malate dehydrogenase (NAD) the isolates could be seperated into three distinct groups with only small intergroup differences. The grouping agreed with their previous findings on sclerotial ontogenesis (Willetts & Wong, 1971) and was supported by further studies on mycelial interaction (Wong & Willetts, 1975a) and cytology (Wong & Willetts, 1975b) using isolates from a wider range of crops. They concluded that the three groups corresponded to three distinct species, *S. minor*, *S. trifoliorum* and *S. sclerotiorum*.

1.1.2. Geographic distribution and economic importance

Although widely distributed, *S. sclerotiorum*, *S. trifoliorum* and *S. minor* are most common in temperate regions (Reichert, 1958) rather than hot, dry areas. *S. sclerotiorum* has been reported from many countries (Purdy, 1979) and thus potentially could have a large impact as a pathogen. Crop losses attributable to *S. sclerotiorum* vary considerably but in some regions may result in appreciable financial loss. For example, Lumsden *et al.* (1975) reported a 20% loss in a Nebraska dry bean crop in 1973 resulting in $12 million loss. However, most reports tend to be based upon estimated ranges of disease incidence (Poole, 1922; Ogawa *et al.*, 1965; Macum *et al.*, 1977; Purdy, 1979).

1.1.3. Host range

S. sclerotiorum has a wide host range. In the review by Purdy (1979) it is listed as occurring on 361 species distributed in 64 plant families. The main hosts occur in the families Solanaceae, Cruciferae, Umbelliferae, Compositae, Chenopodiaceae and Leguminosae (Willetts & Wong,

1980) and amongst crops the fungus is most important on vegetable and oil-seed species. There is no clear evidence of physiological specialization although some hosts appear particularly susceptible to some isolates. Thus Price & Colhoun (1975) tested 19 isolates on 11 host species and found tomato (cv Orange Sunrise) the most susceptible. Generally, *S. sclerotiorum* appears to be amongst the most omnivorous and successful of plant pathogens.

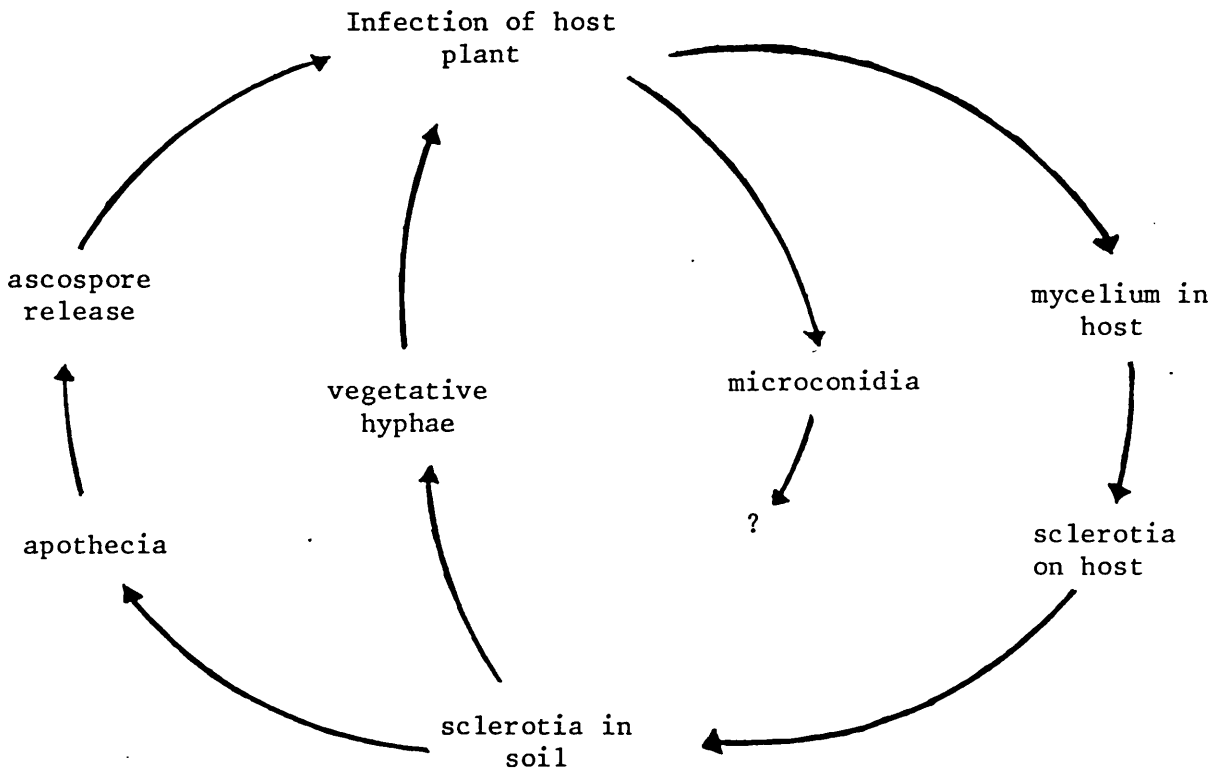
1.1.4. Life cycle of *S. sclerotiorum*

The basic life cycle of *S. sclerotiorum* is shown in Fig. 1. Infection of susceptible hosts is initiated either by mycelium, originating from sclerotia in soil or from neighbouring plants, or by ascospores produced in apothecia. Under favourable environmental conditions the fungus rapidly invades the host tissues and appears as a white cotton-like mycelium on the host surface and within cavities in the plant. Later small compact bodies (sclerotia) develop within the mycelium. These blacken as they mature and are the means by which the fungus perennates. They usually fall to the ground as the crop is harvested and become incorporated into the soil during cultivation. Occasionally they become buried in plant debris. Sclerotia can remain dormant for many years (Brown & Butler, 1936; Coley-Smith & Cooke, 1971). They produce apothecia (carpogenic germination) usually only after a period of 'conditioning' but may produce vegetative mycelium at any time.

1.1.5. Germination of sclerotia

When sclerotia are incubated on distilled water (Purdy, 1958), moist sand or sponge (Saito, 1977) individual hyphae emerge through the sclerotial rind. On nutrient media this type of germination (myceliogenic germination) can result in the formation of small secondary sclerotia (Steadman & Nickerson, 1975). With isolates that normally form small

Figure 1 : Lifecycle of *Sclerotinia* spp.



sclerotia (usually referred to as *S. minor*) secondary sclerotia may be produced on some substrates directly from the sclerotium itself (Williams & Western, 1975b; Adams & Tate, 1976). These arise as bulges from the sclerotium which enlarge and finally rupture, releasing a plug or dense mass of mycelium visible to the naked eye.

In the field, sclerotia more often germinate to form apothecia (carpogenic germination). These are most readily produced in moderately cool climates, optimally at 10-20°C (Lane & Sproston, 1955; Hawthorne, 1976; Saito, 1977) and when soil moisture is adequate (Walker, 1969), that is, above -7.5 bars (Morrall, 1977). Drying of sclerotia greatly delays the production of apothecia and may inhibit it completely (Abawi & Grogan, 1975). Other factors are important at certain stages of development. Thus, light appears necessary for the differentiation of the apothecial stipes into disks (Henson, 1935) while Honda & Yunoki (1977) report that only light below 390 nm is effective. Various aspects of apothecial genesis, ascospore production and cellular structures of apothecia, asci and ascospores are given in the publications of Tu & Colotelo (1973), Jones (1974), Kosasih & Willetts (1975) and Saito (1977).

Other investigations have been more concerned with the practical problem of producing apothecia to obtain ascospores for experiments. Various methods have been evolved but most do not ensure that apothecia are produced within a defined time. Some researchers have used sclerotia collected from the field and have kept these in sterile distilled water (Bedi, 1956; Grogan & Abawi, 1975; Abawi *et al.*, 1975; Hunter *et al.*, 1982), moist sand (Grogan & Abawi, 1975), moist vermiculite (Schwartz & Steadman, 1978), non-sterile tap water agar (Sutton & Deverall, 1983) or soil (Jones & Gray, 1973; Morrall, 1977; Thompson & Kondra, 1983). Treatments of the sclerotia before transfer to these substrates have included air-drying and

storage at 4°C (Jones & Gray, 1973), storage at 4°C for a minimum of 2 months (Thompson & Kondra, 1983) and burial in glasshouse soil for 97 days (Schwartz & Steadman, 1978). Otherwise, the incubation temperature, where reported, has been 15° (Morrall, 1977) or 20°C (Jones & Gray, 1973; Sutton & Deverall, 1983). Apothecia formed at 2-6 weeks (Jones & Gray, 1973), 3-4 weeks (Sutton & Deverall, 1983), 4 weeks (Morrall, 1977), 4-8 weeks (Thompson & Kondra, 1983) or 7-8 weeks (Grogan & Abawi, 1975).

Apothecia produced on sterile natural substrates such as autoclaved celery, carrots and wheat (Grogan & Abawi, 1975), wheat bran (Honda & Yunoki, 1977) and corn-meal/sand (Singh & Singh, 1979) or on defined media such as PDA (Purdy, 1955; Henderson, 1962; Kosasih & Willetts, 1975; Tariq & Jefferies, 1984) have been used in similar attempts to induce apothecia. These also have involved a transfer from the nutrient medium to water agar (Henson & Valleau, 1940; Henderson, 1962; Kosasih & Willetts, 1975; Tariq & Jefferies, 1984), distilled water (Purdy, 1955), moist sand (Singh & Singh, 1979) or soil (Honda & Yunoki, 1977). In most instances the production of sclerotia was erratic and varied from 4 weeks to 7 months.

Various methods have also been used to collect ascospores from apothecia. These include attaching apothecia to the inner face of a petri dish lid with the disk facing sterile distilled water (Abawi *et al.*, 1975), sterile coverslips (Grogan & Abawi, 1975) or the empty base (Sutton & Deverall, 1983) or placing mature apothecia in trenches cut in water agar and inverting over millipore filters on the petri dish lid (Schwartz & Steadman, 1978). Ascospores collected in water have also been retrieved on millipore filters (Hunter *et al.*, 1982; Thompson & Kondra, 1983).

1.2 General Materials and Methods

1.2.1. Fungal isolates

Isolates of *Sclerotinia sclerotiorum* were obtained from as wide a host range as possible, mainly through the National Institute of Agricultural Botany (NIAB) and the Agricultural Development and Advisory Service (ADAS). These are listed in Table 1, along with two *S. trifoliorum* isolates.

The isolates were received as colonies on agar, sclerotia or diseased material. Mycelial plugs (5 mm) were transferred from young colonies to plates of potato dextrose agar (PDA) or glucose-asparagine-yeast agar (GAY). Mature sclerotia were removed from older colonies, surface-sterilized in 10% sodium hypochlorite (c. 1% available chlorine) for 1 min and washed three times in sterile distilled water before plating on PDA or GAY. When only sclerotia were received they were surface-sterilized for 3 min but otherwise were treated similarly. Diseased material (usually stems) was either plated directly onto GAY e.g. JN1, or surface-sterilized for 1 min and washed before being cut into 2 cm pieces and placed onto GAY or PDA. Colonies were subcultured after 4 days until pure cultures were obtained; thereafter sclerotia were transferred every 3 weeks to GAY.

A total of 40 isolates were obtained using these techniques during the 3 years.

1.2.2. Media

The following media were used in various experiments and their descriptions can be found in "*The Plant Pathologist's Pocketbook*" (PPP) Second Edition, CMI, England unless otherwise stated.

Table 1 : Isolates of *Sclerotinia sclerotiorum* and *S. trifoliorum*(*) obtained for this study.

Host and cultivars (where known)	Year collected	Origin (area and/or collector)	Isolate code
	(a) Cultivated crops		
1. Winter oilseed rape (*Brassica napus* var. *oleifera* L.) cv. Jet Neuf	1982	Sutton Scotney, Hants.; S.J. Mylchreest	JN1
	1982	Chichester, W. Sussex; Dr. J. Davies, ADAS	JN2
	1982	Stow Longe, Cambs.; Dr. P. Gladders, ADAS	JN4
	1982	Tilney St. Lawrence, Cambs.; Dr. P. Gladders, ADAS	JN5
	1982	Bridgets EHF, Hants.; Dr. E.J. Evans, ADAS	JN6
	1982	Winchester, Hants.; Dr. E.J. Evans, ADAS	JN7
	1982	S. Acre, Norfolk; Dr. P. Gladders, ADAS	JN8
	1982	Foulness Island, Essex; Dr. P. Gladders, ADAS	JN9
	1984	Fulbourn, Cambs.; Dr. P. Gladders, ADAS	JN10
cv. Rafal	1981	Bridgets, EHF, Hants.; Dr. E.J. Evans, ADAS	R1
	1983	Roxburghshire, Scot.; Dr. T. Brokenshire, ESCA	RG1
	1983	Perth, Scot.; Dr. T. Brokenshire, ESCA	R2
cv. Norli	1983	Roxburghshire, Scot.; Dr. T. Brokenshire, ESCA	N1
cv. Vigor	1982	Dr. C. Knight, NIAB	V1
2. Winter field beans (*Vicia faba* L.) cv. Maris Beagle	1982	Dr. P. Gladders, ADAS	FB1
cv. Throws	1984	Sible Hedingham, Essex; Dr. P. Gladders, ADAS	B2
	1984	Sible Hedingham, Essex; Dr. P. Gladders, ADAS	B3
	1984	Hertford End, Essex; Dr. P. Gladders, ADAS	B4
	1984	Haverhill, Suffolk Dr. P. Gladders, ADAS	B5
3. Brussel Sprouts (*Brassica oleracea* var. *bullata* s. var. *gemmifera* L.)	1983	Elgin, Scot.; Dr. M. Munro, NSCA	BRUS
4. Cabbage (*Brassica oleracea* L.)	1976	R. Coulter, Manchester	RC802
5. Celery (*Apium graveolens* L.)	1982	Beeston, Beds.; Dr. P. Gladders, ADAS	C3887
6. Chrysanthemum (*Chrysanthemum morifolium* L.)	1976	Dr. K. Price, Manchester	SS3

Table 1 : Continued.

Host and cultivars (where known)	Year collected	Origin (area and/or collector)	Isolate code
	1983	Reading, Berks.; E. Framingham, ADAS	CHRY
7. Clover (*Trifolium pratense* L.)	1981	Dr. M. Doherty, NIAB	St 1*
cv. Deben (red)	1982	Bantam, Norfolk; Dr. P. Gladders, ADAS	St 2*
(*Trifolium repens* L.) cv. Menna (white)	1984	Woodbridge, Suffolk; Dr. P. Gladders, ADAS	1195
8. Cucumber (*Cucumis sativus* L.)	1983	Reading, Berks.; E. Framingham, ADAS	Cuc
9. Lettuce (*Lactuca sativa* L.)	1982	Foxash, Essex; Dr. P. Gladders, ADAS	L2E
	1982	Wyboston, Essex; Dr. P. Gladders, ADAS	L4776
10. Parsley (*Petroselinum crispum* (Mill) Nym.)	1982	Hemblington, Norfolk; Dr. P. Gladders, ADAS	P5005
11. Peas (*Pisum sativum* L.)	1983	Laurencekirk, Scot.; Dr. D. Jones, Macaulay Institute	PR1
cv. Avola	1983	Fife, Scot.; Dr. T. Brokenshire, ESCA	PA1
12. Potato (*Solanum tuberosum* L.)	1982	Whalsey, Shetlands; Dr. D. Jones, Macaulay Institute	PW1
13. Soybean (*Glycine max*)	1982	Brazil; M. Epperlan, U.C.; London	SOY
14. Sunflower (*Helianthus annuus* L.)	1976	Dr. K. Price, Manchester	SS2
	(b) Wild hosts		
15. *Heracleum sphondylium* L. (Hogweed)	1983	Roxburghshire, Scot.; Dr. T. Brokenshire, ESCA	HO1
16. *Raphanus raphanistrum* L. (Wild radish)	1983	Silwood Park, Ascot; S.J. Mylchreest	RAD
17. *Trifolium repens* L. (Clover)	1983	Silwood Park, Ascot; S.J. Mylchreest	CLOV
18. *Capsella bursa-pastoris* (L.) Medicus (Shepherds purse)	1983	Silwood Park, Ascot; S.J. Mylchreest	SP

Breadcrumb and Prunejuice Medium

Commercial (Hovis plc) brown breadcrumbs

Prunejuice (from an "off-the-shelf" can of prunes)

Distilled water

A layer (1 cm) of brown breadcrumbs (Hovis) in a 250 ml conical flask was moistened with about 40 ml of a 1:1 (v/v) mixture of distilled water and prunejuice. Flasks were autoclaved at 121°C for 15 min (W.S. Suliman, 1983).

Glucose, Asparagine and Yeast Agar (GAY)

Trevethick & Cooke, (1973).

Malt Extract Agar

PPP p. 396. (Conservation)

Oatmeal Sand Medium

A mixture of 196 g sand and 4 g oats (Scotts Porridge Oats) in a 500 ml conical flask was wetted with about 15 ml distilled. The mixture was then autoclaved at 121°C for 1 h.

Potato Dextrose Agar

PPP p. 397.

Potato Sucrose Agar

PPP p. 397.

Rape Leaf Extract Agar

Fresh mature rape leaves (100 g) were blended in 1 l distilled water, filtered through muslin and the filtrate readjusted to the original volume. Agar (15 g) was added and the medium autoclaved at 121°C for 15 min.

Soil Extract Agar

A mixture of 1 kg soil and 1 l distilled water was steamed for 30 min, left to stand overnight and then filtered. Dextrose (1 g), yeast

extract 0.1 g, KH_2PO_4 (0.2 g) were added to the filtrate which was adjusted to 1 l and pH7. Twenty grams of agar were added before autoclaving at 121° for 15 min.

V-8 Agar

PPP p. 398.

Water Agar (Tap or Distilled)

PPP p. 395.

Wheat Grain Medium

A mixture of 25 g wheat grain (cv. Armada) and 60 ml distilled water was placed in 250 ml flasks and autoclaved at 121°C for 20 min.

1.3 Production of Apothecia

1.3.1. Preliminary experiments with *Sclerotinia sclerotiorum* isolate R1 from oilseed rape

(a) Mycelial growth on various media

Six replicate plates of PDA, PSA, GAY, V8 and MA were each inoculated centrally with a mycelial disk (5 mm) cut from the edge of a 3-day-old colony. Plates were incubated at 20°C in constant light. The following were recorded: two colony diameters at right angles at 2, 4 and 6 days after inoculation, number of days to reach the edge of the petri dish, time taken for sclerotia to form and mature and the number of sclerotia per plate.

Growth was initially more rapid on V8 and MA (Table 2) but by 6 days all colonies had reached the edge of the petri dish. Sclerotia initials formed first and matured most rapidly on MA but more were produced on GAY agar than any other medium. This medium was therefore used in many of the subsequent experiments with *S. sclerotiorum*.

(b) Growth at different temperatures

Six plates of GAY agar, inoculated centrally with a 5 mm mycelial disk, were incubated at 5°, 10°, 15°, 20°, 25° and 30°C with constant light. The times taken for mycelial growth to reach the edge of the petri dish, for sclerotia to form and mature were recorded and mature sclerotia were counted. The length and width of six sclerotia from each treatment were measured on graph paper under a binocular microscope (x 20).

Mycelial growth, initiation and maturation of sclerotia, and the production of sclerotia were optimal at 20°C (Table 3). The longest sclerotia were formed at 5°C and the shortest and thinnest at 30°C.

Table 2 : Growth of *Sclerotinia sclerotiorum*, isolate R1 on various media at 20°C.

Parameter measured	Medium				
	PDA	PSA	GAY	V8	MA
Mean colony diameter (mm)					
2 days	31.3 a	32.0 ab	34.8 ab	65.8 c	69.2 d
4 days	60.7 a	64.7 b	79.7 c	89.7 d	90.0 d
6 days		Growth to petri dish edge			
Mean No. days to					
sclerotial initials	7.5 ab	7.0 ab	7.0 ab	8.2 b	5.3 a
mature sclerotia	10.2 c	9.7 bc	9.3 b	11.5 d	7.5 a
Mean No. sclerotia/plate	4.8 a	18.8 bc	29.8 c	11.8 ab	17.0 ab

Values along one line with no letter in common are significantly different at $\underline{P} = 0.05$ (Duncan's multiple range test). They are the means of six replicates. The agar media were potato dextrose (PDA), potato sucrose (PSA), glucose-asparagine-yeast (GAY), V8 juice (V8) and malt (MA).

Table 3 : Growth of *Sclerotinia sclerotiorum*, isolate R1 on glucose-asparagine-yeast agar at different temperatures.

Parameter measured	Temperature (°C)					
	5	10	15	20	25	30
Mean No. days for mycelium to cover plate	14.7 e	9.0 d	6.7 b	6.0 a	5.7 a	7.7 c
Mean No. days to						
sclerotial initials	23.5 f	12.5 d	8.7 b	7.0 a	11.3 c	21.2 e
mature sclerotia	29.2 e	20.8 d	11.0 b	9.3 a	13.8 c	21.2 d
Mean No. sclerotia/plate	3.5 a	19.8 b	24.3 c	29.8 d	16.5 b	4.8 a
Mean dimensions (mm) of sclerotia - length	6.9 d	6.1 c	5.9 c	5.7 c	5.1 b	3.7 a
- width	3.5 b	3.1 b	3.3 b	3.8 b	3.4 b	2.4 a

Values along one line with no letter in common are significantly different at $\underline{P}$ = 0.05 (Duncan's multiple range test). They are the means of six replicates.

(c) Growth in different light regimes

Different light regimes were applied to replicate plates of GAY agar centrally inoculated with a mycelial disk. The plates were incubated at 20°C in continuous light, 14 h light/10 h dark or continuous darkness.

No marked differences were detected in the time for mycelial growth to cover the plate, sclerotial formation or the total numbers of sclerotia produced per plate.

1.3.2. Variability of isolates

There were two experiments. The first experiment examined the variation in size of sclerotia of 29 isolates of *S. sclerotiorum* and one of *S. trifoliorum* produced after 4 weeks on GAY agar at 20°C. The lengths and widths of 100 mature sclerotia of each isolate were measured as in 1.3.1.(b). A value for 'roundness' of the sclerotia was calculated by dividing the length by the width.

There was considerable variation in the size of sclerotia of any one isolate (Appendix 4). When the values for length and roundness (length/width) were analyzed and the mean values ranked, no consistent clear cut differences between isolates or groups of isolates were apparent (Table 4).

The second experiment examined the cultural characteristics and production of sclerotia of 18 isolates of *S. sclerotiorum* and one of *S. trifoliorum* when grown on GAY agar at 20°C. Again no distinct groups of isolates could be distinguished (Table 5).

1.3.3. Production of apothecia from sclerotia

(a) Development of a technique to induce apothecia

The following 15 experiments detail the development of a

Table 4 : Ranking of 29 isolates of *Solerotinia scerotiorum* and one of *S. trifoliorum** by length (mm) and roundness (length/width) of sclerotia.

Rank based on								
Mean length of sclerotia			Roundness of sclerotia		
	(a)	(b)			(a)	(b)
FB1	2.082	0.06	PR1	1.215	1.06
JN5	2.924	0.14	FB1	1.216	
SP	2.959	1.37	JN4	1.240	
C3887	3.026	1.4	PW1	1.257	
JN4	3.167	1.81	HO1	1.264	
JN8	3.308	1.78	RC802	1.268	
L4776	3.322		P5005	1.269	
L2E	3.331	1.94	SP	1.291	
JN6	3.353		SS3	1.291	
RC802	3.359		JN5	1.298	
RAD	3.371		V1	1.308	
SS3	3.405		C3887	1.308	
CHRY	3.493		JN6	1.315	0.85
V1	3.57	0.95	PA1	1.317	
JN9	3.583	0.9	JN8	1.319	
St.1*	3.633		JN7	1.35	0.85
HO1	3.695	1.10	JN1	1.359	0.86
R1	3.795		R1	1.371	
JN1	3.941	0.86	L4776	1.374	
CLOV	3.972		L2E	1.383	
SOY	4.003		SOY	1.383	
JN7	4.041		RAD	1.387	
B2	4.068		BRUS	1.397	
SS2	4.230	0.39	JN9	1.40	0.26
PR1	4.567	1.54	B2	1.424	
CUC	4.861		CHRY	1.426	
BRUS	5.001		St.1*	1.437	0.16
PA1	5.153		CUC	1.469	
P5005	5.188	0.3	CLOV	1.508	0.1
PW1	5.597		SS2	1.557	

	SS	MS	F
Treatments	1672.22	57.66	32.8***
Residual	5069.61	1.76	
Total	6741.82		

	SS	MS	F
	19.00	0.66	5.76***
	325.91	0.11	
	344.91		

Table 5 : Growth and production of sclerotia by 18 isolates of *Sclerotinia sclerotiorum* and one of *S. trifoliorum*.

Isolate code	Mean No. days to cover plate	Mean No. sclerotia/plate	Distribution of sclerotia on plate
JN1	5	38.7	Edge
JN4	4	61.0	1 cm in from the edge
JN5	3	33.3	Edge
JN6	3	51.0	Edge
JN7	3	65.0	Edge
JN8	4	52.0	Scattered over the plate
JN9	3	42.3	Edge
R1	5	46.0	1 cm in from the edge
V1	3	47.7	Edge
FB1	6	100.0	Scattered over the plate
C3887	4	52.0	1 cm in from the edge
L2E	4	55.0	Edge and in the centre
L4776	4	39.0	1 cm in from the edge & centre
P5005	3	20.0	Edge
RC802	3	50.0	Scattered over the plate
SS2	3	36.0	Edge
SS3	3	18.0	Scattered over the plate
PW1	3	17.0	Edge and the centre
*S. trif.*1	4	125.0	Scattered over the plate

Values are the mean of three replicate plates.

technique to induce apothecia consistently from sclerotia grown on culture media. Isolates R1 and JN1 were used mainly and isolates SS2, JN2 and *S. trif.*1 occasionally. Sclerotia were produced at 20°C on several media (PDA, PSA, GAY, oatmeal-sand, prunejuice-breadcrumbs and soil extract agar) in case one medium did not provide the potential for carpogenic germination.

Experiment 1. Sclerotia of JN1 and R1 were produced on PSA and GAY and samples (25 sclerotia) were placed individually in bags (5 x 5 cm) of terylene net which had been boiled in distilled water for 20 min prior to use. These bags were either laid on or just buried in washed and dried fine silver sand (A.B. & Sons Ltd., Croydon) in white plastic punnets (10 x 9.5 cm, 4.5 cm deep). Each punnett was maintained at 50%, 70% or 100% saturation by adding water every 2 days to keep its weight constant. The punnets were distributed in incubators at 10°, 15° and 20°C so that there were four replicates of each isolate-position-moisture-temperature combination (total of 36 treatments).

After 12 weeks, sclerotia of both isolates either placed on or beneath the surface of sand at 70% and 100% saturation at 20°C had germinated to form mycelium which covered the surface of the sand sparsely. Although the experiment was continued for 6 months no mycelium was observed in the other treatments nor were any apothecia formed in any treatment.

Experiment 2. Isolates JN1 and *S. trif.*1 were grown on GAY, wheat grain and breadcrumbs + prunejuice until mature sclerotia were produced. These were removed and dried at room temperature (22° ± 2°C). By setting up cultures each week, samples of sclerotia were obtained which had dried for periods ranging from one to 8 weeks. A sample of freshly-harvested sclerotia was also included. Each of these nine samples was

divided into two subsamples, one of which was given a cold treatment (48 h in a deep freeze at -15°C), the other was left at room temperature. Sclerotia were then placed either on wet filter paper (Whatman No.7) or cotton wool in round plastic containers with lids (No.11 dishes, A.W. Gregory Ltd., Glynde St., London). These containers were incubated at room temperature. Sclerotia were kept damp by spraying every few days with distilled water and were examined over 8 months for mycelial germination and production of apothecia. There were three replicates of 30 sclerotia for each of the 216 treatments.

There was no indication of apothecial formation with isolate JN1 (Table 6). Most sclerotia germinated to mycelium but this was difficult to detect on cotton wool. Sclerotia of *S. trif.*1 produced on GAY and wheat grain, air dried for 4-8 weeks and then given a cold treatment formed apothecial stipes,but these did not differentiate further. No type of germination was observed in the other treatments.

This experiment was later repeated using sclerotia of *S. sclerotiorum* collected from a field of oilseed rape (JN2), but these germinated to form mycelium only.

Experiment 3. Freshly harvested sclerotia of isolate JN1 produced on GAY, breadcrumbs and prunejuice, oatmeal/sand and wheatgrain were placed in a deep freeze (-15°C) for 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 21 or 28 days. Following the cold treatment, 30 sclerotia (in three replicate dishes) were placed on damp filter paper in plastic round dishes at 10°, 15° or 20°C. The filter paper was kept damp by spraying every few days with distilled water and sclerotia were examined daily.

All the sclerotia produced mycelium, irrespective of the treatment, after one month of incubation.

Experiment 4. Sclerotia of isolate JN1 were grown and cold-

Table 6 : The effect of air drying and cold treatment on carpogenic germination (Experiment 2).

Number of weeks air dried	48 hours cold treatment	Source of sclerotia											
		JN1						*S. trif.*1					
		GAY		Wheat		Bread		GAY		Wheat		Bread	
		FP	CW	FP	CW	FP	CW	FP	CW	FP	CW	FP	CW
0	NO	M	M	M	x	M	x	x	x	x	x	x	x
	YES	M	x	M	x	M	x	x	x	x	x	x	x
1	NO	M	x	M	x	M	x	x	x	x	x	x	x
	YES	M	x	M	x	M	x	x	x	x	x	x	x
2	NO	M	x	M	x	M	x	x	x	x	x	x	x
	YES	M	x	M	x	M	x	x	x	x	x	x	x
3	NO	M	x	M	x	M	x	x	x	x	x	x	x
	YES	M	x	M	x	M	x	x	x	x	x	x	x
4	NO	M	x	M	x	M	x	x	x	x	x	x	x
	YES	M	x	M	x	M	x	S(21)	S(22)	S(2)	S(5)	x	x
5	NO	M	x	M	x	M	x	x	x	x	x	x	x
	YES	M	M	M	M	M	M	S(41)	S(30)	S(22)	S(20)	x	x
6	NO	M	x	M	x	M	x	x	x	x	x	x	x
	YES	M	M	M	M	M	M	S(43)	S(52)	S(50)	S(32)	x	x
7	NO	M	x	M	x	M	x	x	x	x	x	x	x
	YES	M	M	M	M	M	M	S(42)	S(45)	S(41)	S(30)	x	x
8	NO	x	x	x	x	x	x	x	x	x	x	x	x
	YES	M	M	M	M	M	M	S(37)	S(35)	S(42)	S(50)	x	x

Table 6 : Continued.

FP = Filter paper

CW = Cotton wool

M = Mycelial germination

S = Stipe production (number is total from 90 sclerotia)

x = No germination

treated as in Experiment 3 but they were incubated at 10°, 15° or 20°C on tap water agar in glass petri dishes and screw-capped glass vials (8 cm). Sclerotia at 10° did not germinate; those at 15° and 20°C produced mycelium. Although the experiment was maintained for 8 months, no apothecia were produced.

Experiment 5. Sclerotia from 4-week-old cultures of isolate JN1 on GAY, breadcrumbs and prunejuice and wheatgrain, were placed on tap water agar, in sterile tap water and in sterile distilled water in glass petri dishes which were incubated at 10°, 15° or 20°C. There were three replicates of 30 sclerotia for each of the 27 treatments.

Sclerotia germinated to form mycelium in all treatments, but no apothecia were produced after 8 months.

Experiment 6. This experiment examined the effects of different types of damage to the outer layers (rind) of the sclerotia. Mature sclerotia harvested from cultures of JN1 on GAY and wheat grain were treated in one of the following ways:

i) the rind was peeled off completely revealing the white medulla;

ii) 1 mm was cut off from one end of the sclerotium, revealing the white medulla and bordered by the rind;

iii) the rind was scored with a scalpel down the length of the sclerotium on the top and bottom surfaces;

iv) the sclerotium was shaken in carborundum powder for 3 min and washed with sterile distilled water;

v) the sclerotium rind was rubbed on all surfaces with a file.

Samples of the treated sclerotia and undamaged sclerotia (control) were placed on damp filter paper in plastic (No.11)

dishes and on tap water agar in petri dishes. These were incubated at 10°, 15° or 20°C. There were three replicates of 20 sclerotia for each of the 72 treatments.

Sclerotia damaged by carborundum powder (iv) or filing (v) did not germinate at all. Others germinated to varying extents, but formed only mycelium over the 20 weeks of the experiment. Where the white medulla had been exposed, the sclerotia rind had reformed and blackened.

Experiment 7. Failure to produce apothecia of any isolate from oilseed rape prompted this experiment with three isolates of *S. sclerotiorum* from other hosts. Isolates RC802 (Cabbage), SS2 (Sunflower) and SS3 (Chrysanthemum) were grown on GAY, wheatgrain and breadcrumbs and prunejuice. After 30 days, mature sclerotia were removed and incubated in tap water agar or sterile distilled water, in petri dishes and on moist washed silver sand in transparent, plastic "sandwich" boxes (17.5 x 11.5 x 5 cm, Stewart Plastics) and incubated at 10°, 15° or 20°C. There were 30 sclerotia in each box or petri dish for each treatment combination.

A total of 30 apothecia were produced after 28 weeks from the sclerotia of the cabbage isolate incubated at 15°C on wet sand. No apothecia were detected from the other isolates and the only sclerotia that germinated were those grown on breadcrumbs and prunejuice.

Experiment 8. Sclerotia of isolate JN1, produced on GAY and wheatgrain, were placed in 100 ml plastic beakers which were then covered with muslin tied under the lip securely. Cold tap water was run continuously over the sclerotia for 6, 12, 24, 36 or 48 h. They were then spread out on damp filter paper in petri dishes and incubated at 10°, 15° or 20°C for 28 weeks, during which time they were kept moist by spraying twice a week with distilled water. There were three replicates each of 30

sclerotia per treatment.

All sclerotia germinated to form mycelium; none formed apothecia.

Experiment 9. Experiments 2-6 and 8 were repeated but the treated sclerotia in each case were placed into the No.11 dishes with a 2.5 cm depth of moistened John Innes No.1 (A.B. & Sons Ltd., Shirley, Croydon) or moistened Sutton Scotney, Hampshire soil (Clay Loam). The dishes were then incubated as before and kept moist by spraying twice a week with distilled water.

No apothecia were observed.

Experiment 10. Isolate JN1 was grown at 20°C for 4 weeks on soil-extract agar prepared from soil collected at Sutton Scotney. The harvested sclerotia were then placed in petri dishes containing damp filter paper, tap water agar or John Innes No.1 compost. Plates were incubated for 28 weeks at 15°C but no apothecia were formed. When the experiment was repeated using sclerotia grown on rape leaf extract agar again no apothecia formed.

Experiment 11. Sclerotia of isolates JN1 and SS2, produced on GAY, were buried in moist soil at 2 cm depth in pots (8 x 6.7 x 6.7 cm) which were then kept either in the laboratory or outside. There were four replicate pots of 20 sclerotia for each treatment.

After 4 months (May-August) the sclerotia were removed and placed on moist filter paper in petri dishes which were kept in the laboratory. After 20 weeks, 25% of the sclerotia of isolate SS2 formed stipes but these did not develop further. No stipes formed from sclerotia of JN1.

Experiment 12. Sclerotia of JN2 (stored at 4°C after collection), JN1 and R1 (from GAY and wheatgrain) were placed at a depth of 2 cm in 10

cm plant pots containing John Innes No.3 in a greenhouse at 17°C with a 14 h photoperiod. The sclerotia were then oversown with barley (cv. Golden Promise) or oilseed rape (cv. Jet Neuf). Each pot contained 50 sclerotia of one isolate. Six pots of each isolate were prepared, three were sown with barley, three with oilseed rape and these were watered every 2-3 days.

No apothecia were produced in any treatment after 16 weeks.

Experiment 13. Roots were collected from 4-week-old oilseed rape plants (cv. Jet Neuf) grown in moist silver sand watered with Long Ashton Solution (Hewitt, 1962). Excised roots were surface sterilised in 10% NaClO (1% available Cl) for 2-3 min, washed in sterile distilled water and then placed into 250 ml conical flasks containing sterile distilled water. The roots were incubated in the dark at 20°C for 10 days.

The exudates were bulked, concentrated to about half volume using a rotary evaporator and sterilized by filtering through a 0.2 µm millipore filter.

Sclerotia of JN1, SS2 (produced on GAY and wheat-grain) and JN2 were placed into 100 ml conical flasks containing 50 ml of the root exudate or into No.11 dishes containing John Innes No.1 moistened with the exudate. These were then incubated at 10°, 15° or 20°C. The soil was kept moist with the exudate.

No apothecia were produced in either the flasks or the dishes but mycelium was observed in the flasks after 10 days incubation.

Experiment 14. Sclerotia of JN1 and R1, produced on GAY and wheatgrain,were placed in plastic petri dishes on damp filter paper or water agar. There were 20 sclerotia per dish and three replicates per

treatment. Plates were irradiated with near UV (black light) using Phillips Fluorescent Light Tubes at a distance of approximately 35 cm for various times :30 min and 1, 4, 8, 12, 24, 48, 72, 96, 120 and 144 h. Treated sclerotia were then incubated at 10°, 15° or 20°C and kept moist by spraying with distilled water.

Although sclerotia were subsequently kept for 6 months at room temperature (22° ± 2°C) neither apothecia nor mycelia were produced.

Experiment 15. Isolate JN1 was grown on GAY and on wheatgrain at 20°C for 4 weeks when many sclerotia had formed and matured. Sclerotia were removed from GAY and some from the wheatgrain and were placed separately in plastic petri dishes. These plates and the flasks of wheatgrain still with some sclerotia were then kept at 4°C for periods ranging from one week to 8 weeks. After the designated period, sclerotia (removed from adhering wheatgrain, where necessary) were placed either on damp filter paper in No.11 dishes or 1 cm deep in John Innes No.1 in plastic 'sandwich' boxes. The dishes and boxes were then incubated at 10°, 15°, 20°C or room temperature. Sclerotia were kept moist by spraying with distilled water periodically. There were four replicates of 50 sclerotia for each treatment.

Sclerotia kept in wheatgrain medium at 4°C for more than 3 weeks and then placed in potting compost began to produce stipes after 6 weeks at 10° and after 15 weeks at 15°C. Many stipes appeared but no apothecia developed and eventually the stipes changed from light to dark brown.

Subsequently when stipes appeared, the boxes and dishes were placed under near UV for a 14 h exposure every 24 h at 22°C. Within 5 days, swellings appeared at the tips of the stipes and these finally

developed into flat apothecial disks. Ascospores were produced and when the lids of the containers were removed, 'puffing' of the spores could be seen. Stipes placed at higher temperatures did not develop further.

No apothecia formed from sclerotia kept at 4°C for less than 3 weeks irrespective of subsequent treatment, nor were any apothecia formed when sclerotia from both media were subsequently incubated at 20° or room temperature (near 20°C) following cold periods ranging from 3 to 8 weeks. Sclerotia from GAY also failed to produce apothecia at 15°C.

The numbers of apothecia produced in the remaining treatments are summarized in Table 7. This indicates that most apothecia were produced by sclerotia grown on wheatgrain following a cold treatment in this medium for 4 weeks (Plate 1 & 2).

This particular treatment was repeated successfully and was adopted for subsequent experiments, using the following procedure:

i) sterile wheatgrain (cv. Armada) in 250 ml flasks was inoculated with *S. sclerotiorum* and kept at 25°C for 3 weeks;

ii) flasks were transferred to 4°C and incubated for 4 weeks;

iii) sclerotia were removed from the wheatgrain and placed c 1 cm deep in John Innes No.1 in transparent, plastic dishes (with lids) which were incubated at 10°C;

iv) when a large number of stipes appeared the containers were put under near UV (black light) at room temperature.

This technique produced apothecia in approximately 15 weeks. It has been repeated by Dr. P. Newman (PBI; pers. comm.), Mr. T. McHale (Liverpool Poly.; pers. comm.) and Dr. J.M.L. Davies (ADAS; pers. comm.).

Table 7 : Production of apothecia from sclerotia of *Sclerotinia sclerotiorum* (isolate JN1) grown on GAY or wheat grain (Experiment 15).

Source of sclerotia		Incubation		Weeks at 4°C					
		Temp.	Medium	3	4	5	6	7	8
GAY		10°	Filter paper	0	13	13	14	12	12
			J.I. no. 1	19	102	84	69	35	37
Wheat grain	R	10°	Filter paper	0	9	11	9	10	3
	W			0	26	24	19	12	4
Wheat grain	R	10°	J.I. no. 1	14	172	194	74	47	32
	W			208	679	321	124	121	138
Wheat grain	R	15°	J.I. no. 1	3	107	34	21	21	15
	W			32	238	64	44	17	16

Each value is the total number from four replicates of 50 sclerotia. Sclerotia were removed from GAY before the cold treatment and from wheat both before (R) and after (W) the cold treatment. Incubation refers to the treatments after this cold period.

Plate 1 : Apothecia produced from culture grown sclerotia of isolate JN1.

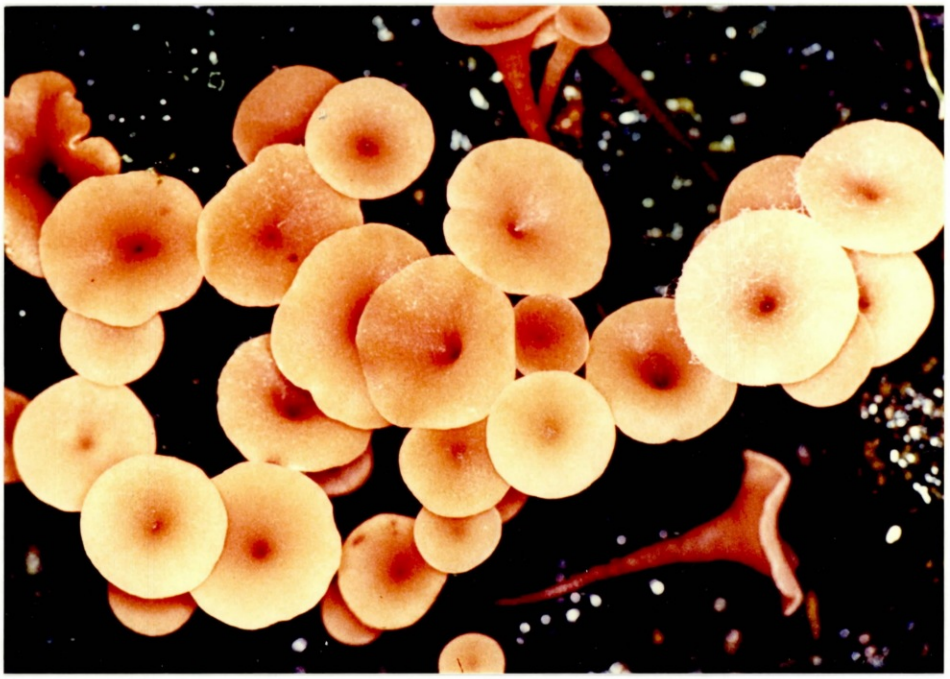
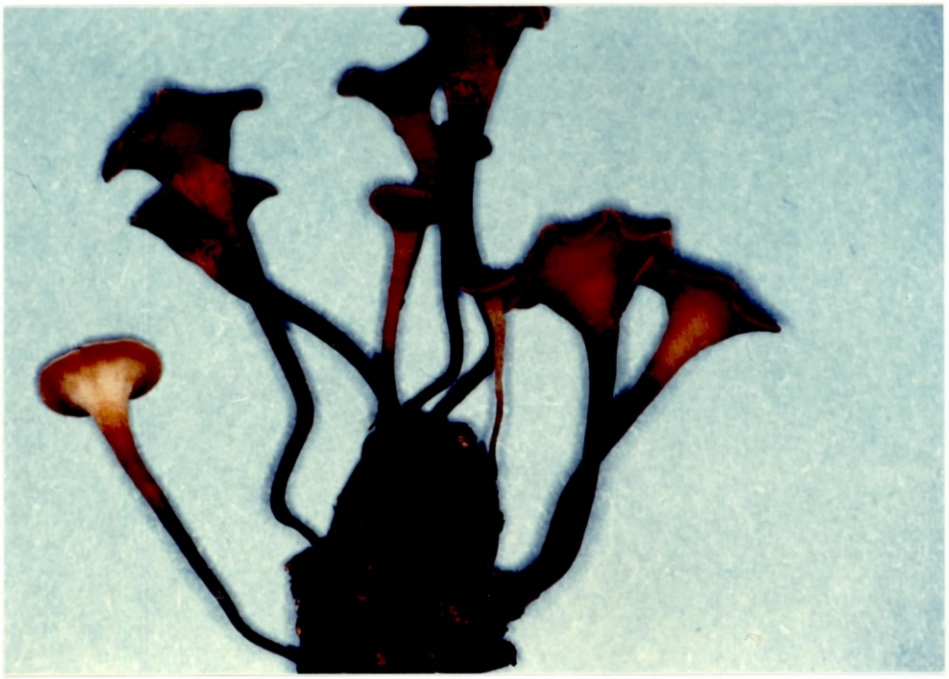


Plate 2 : Apothecia on one culture produced sclerotium of JN1.



(b) Effect of fluctuating temperatures on production of apothecia

Under natural conditions sclerotia buried in soil or on the soil surface are subjected to fluctuating temperatures. In the following experiment sclerotia were kept at different temperature regimes and the effects on subsequent production of apothecia were monitored.

Plates of GAY were each inoculated centrally with a 5 mm mycelial disk of isolate JN1. Each plate was sealed with masking tape to prevent drying of the agar and was then incubated at 20°C for 3 weeks when sclerotia were mature.

At this stage the plates were divided in two series, A and B. Plates were subjected to two different temperatures for 16 h and 8 h periods (series A) or 20 h and 4 h periods (series B) per day as indicated in Table 8. After 4 weeks at these regimes, sclerotia were transferred to No.11 dishes containing John Innes No.1 and incubated at 10°C. Numbers of apothecia were counted after stipes had been subjected to near UV.

The temperature of the 16 h (series A) or 20 h (series B) period in each 24 h cycle had more affect on the numbers of apothecia produced (Table 8). Most apothecia formed when sclerotia were kept for these periods at 5°C. Fewer apothecia developed from sclerotia kept at 10°C and none at all from sclerotia kept at 15° and 20°C during these periods.

In a series of comparable controls, only sclerotia kept continuously at 5°C subsequently produced apothecia but the number per 100 sclerotia (136) was greater than that obtained with any two-temperature regime.

(c) Production of apothecia by different isolates

The production of apothecia from sclerotia of isolates

Table 8 : Numbers of apothecia formed from 100 sclerotia previously incubated for 4 weeks at different temperature regimes.

Series A

Sclerotia incubated at 8 h/day at	Sclerotia incubated 16 h/day at			
	5	10	15	20°C
5	-	22.1	0	0
10	30.5	-	0	0
15	20.0	0	-	0
20	3.9	6.4	0	-
Totals/100 Sclerotia	54.4	28.5	0	0

Series B

Sclerotia incubated at 4 h/day at	Sclerotia incubated 20 h/day at			
	5	10	15	20°C
5	-	3.4	0	0
10	8.2	-	0	0
15	0	3.5	-	0
20	31.6	29.0	0	-
Totals/100 Sclerotia	39.8	35.9	0	0

was examined using the standard technique. Most isolates of *S. sclerotiorum* produced apothecia but an isolate of *S. trifoliorum* did not. Isolates varied in the time they took to produce stipes at 10^{o} and in the final numbers of apothecia formed (Table 9).

Associations between numbers of apothecia produced and size of sclerotia, as indicated by sclerotium length and 'roundness' (p. 30) were examined by the non-parametric Spearman rank correlation coefficient (Table 10). These tests did not show any significant relationship between sclerotial size and production of apothecia.

Table 9 : Production of apothecia from sclerotia of different isolates of *Sclerotinia sclerotiorum*.

Host	Isolate code	Weeks at 10° to form stipes	Days under NUV to form apothecia	No. apothecia per 40 sclerotia*
Oilseed rape	JN1	6	5	92
	JN2	8	5	70
	JN4	9	5	62
	JN5	8	5	54
	JN6	6	5	57
	JN7	7	5	63
	JN8	7	5	44
	JN9	10	5	31
	JN10	10	5	14
	R1	10	5	81
	RG1	8	5	9
	R2	9	5	36
	N1	11	5	14
	V1	10	5	47
Winter field beans	FB1	9	5	41
	B2	11	5	44
	B3	13	5	26
	B4	16	5	31
Brussel Sprouts	BRUS	9	5	56
Cabbage	RC802	13	5	29
Celery	C3887	10	5	24
Chrysanthemum	SS3	17	5	9
	CHRY	14	5	26
Cucumber	CUC	11	5	34
Lettuce	L2E	12	5	43
	L4776	12	5	32

Table 9 : Continued.

Host	Isolate code	Weeks at 10° to form stipes	Days under NUV to form apothecia	No. apothecia per 40 sclerotia*
Parsley	P5005	14	5	35
Peas	PR1	15	5	27
	PA1	17	5	12
Potato	PW1	20	5	39
Soybean	SOY	8	5	34
Sunflower	SS2	10	5	15
Hogweed	HO1	11	5	62
Wild radish	RAD	8	5	80
Clover	CLOV	11	5	88
Shepherds purse	SP	13	5	67

*Discharge of ascospores was observed for all isolates producing apothecia.

Table 10 : Test* for the association between apothecial numbers and sclerotial length and roundness of 30 isolates.

Isolate	Ranking		
	Apothecia	Length	Roundness
JN1	1	19	17
JN4	7.5	5	3
JN5	11	2	10
JN6	9	9	13
JN7	6	22	16
JN8	13.5	6	15
JN9	22	15	24
R1	3	18	18
V1	12	14	11
FB1	16	1	2
B2	13.5	23	25
Soybean	19.5	21	21
SS2	27	24	30
SS3	29	12	9
Chry	25	13	26
Cuc	19.5	26	28
RC802	23	10	6
L2E	15	8	20
L4776	21	7	19
P5005	18	29	7
PW1	17	30	4
PA1	28	28	14
PR1	24	25	1
HO1	7.5	17	5
Brus	10	27	23
Rad	4	11	22
Clov	2	20	29
SP	5	3	8
S. trif. 1	30	16	27
C3887	26	4	12

$$r_s = \left| - \frac{6 \times \Sigma d^2}{(n-1)\ n\ (n+1)} \right.$$

$$t = r_s \sqrt{\frac{n-2}{1-r_s^2}}$$

	$r_s = 0.122$	$r_s = 0.063$
	$t = 0.69$	$t = 0.34$
with 28 df	$\underline{p} < 0.2$	$\underline{p} < 0.2$
	NS	NS

*Spearman rank correlation coefficient (Siegal, 1956)

1.4 Experiment with Ascospores

1.4.1. Collection of ascospores

Several methods of collecting ascospores from apothecia were tested.

(a) Individual sclerotia with one or more apothecia were removed from the soil and transferred to a trench cut in a plate of 1% water agar. The plates were then inverted over a 50 mm diameter millipore filter (type AA 0.45 µm) fastened to the lid and incubated at 20°C with constant light. Spore release was continuous and filters were changed daily. The deposited ascospores were removed from the filter with a camel-hair brush and suspended in a small amount of sterile distilled water. The concentration of ascospores was then adjusted to the required amount. Ascospores were transferred onto agar pieces by placing the filters (plus collected ascospores) directly onto the agar. However, this did not allow easy adjustment of the ascospore concentration.

(b) Apothecia (with stipes removed) were fixed to the lids of petri dishes with the hymenial layer facing the base of the dish. Ascospores were deposited on different surfaces - the dry base of the dish, 1% water agar in the base or as a film on a microscope slide or a millipore filter. Deposits on agar were useful for inoculum because segments could be cut from the agar but this allowed no standardization of the numbers of ascospores. Deposition of ascospores into FAA fixative* in the petri base was useful for counts of ascospores produced and for measuring ascospores because the fixative inhibited germination.

(c) With both of the above methods apothecia tended to dry out fairly rapidly so an attempt was made to collect ascospores directly from apothecia in situ in plastic 'sandwich' boxes or No.11 dishes. As soon as the lids of these were removed a glass funnel (12 cm diameter) was inverted

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*FAA = formaldehyde - acetic acid - alcohol fixative

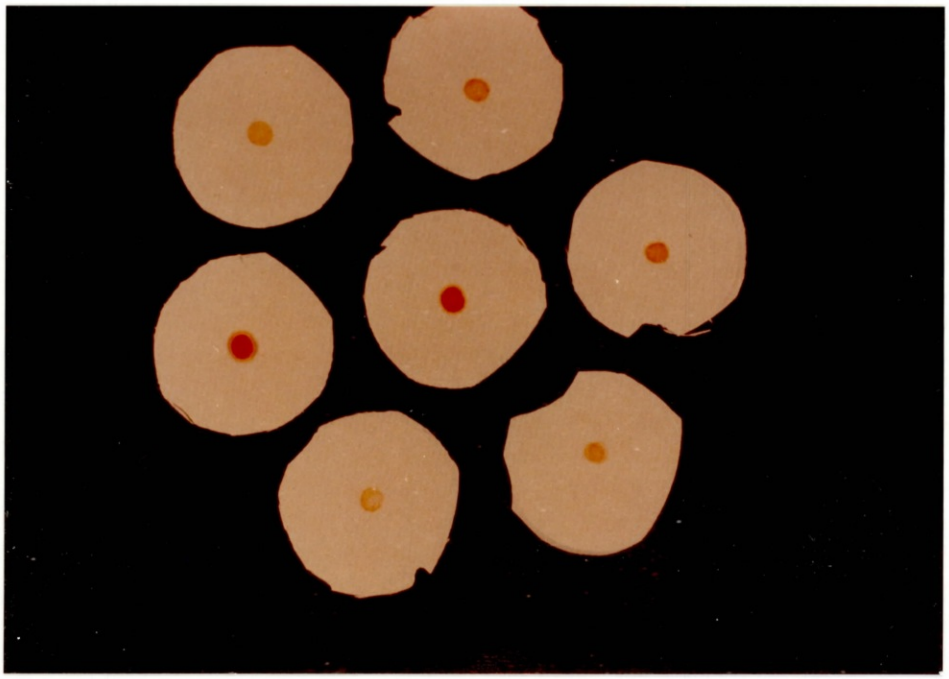
over the apothecia. This funnel was connected to a vacuum pump via a water trap. Ascospores collected in the trap were subsequently removed by filtration on a millipore membrane filter (type AA, 0.5 µm, 5 cm diameter). Filters were dried overnight at c. 20°C with low humidity. Ascospores could be stored on these filters and suspensions prepared by washing when required. Relatively low amounts of spores, spread over the filter surface were trapped by this method.

A modification of the above technique proved the most useful way of collecting spores. Immediately after removing the lids of containers, a funnel was inverted over the apothecia. This funnel had a millipore filter container (Servinex 25), filled with a type AA filter (0.5 µm, 2.5 cm diameter), fixed in the neck with masking tape. Spores were impacted on the filter by suction from a pump (c. 5 p.s.i.). Aggregated spores were readily seen as yellow spots on the filter (Plate 3). The filters could be stored or the spores removed by submerging filters in sterile distilled water.

1.4.2. Storage of ascospores

Membrane filters with wet collected ascospores (the water trap method), were placed in standard 8 cm screw-capped vials. Half of the vials contained calcium chloride chips covered with muslin to prevent direct contact with the spores. Vials were stored in the laboratory (22 ± 2°C), in a refrigerator (4 ± 1°C) and in a deep freeze (-19°C). Filters were sampled after 1, 2, 4, 8 and 12 months and submerged in sterile distilled water. Ascospores were removed with a camel-hair brush and the resulting suspension was spread over the surface of GAY plates which were incubated at room temperature. The percentage germination of spores was calculated by counting at least 100 spores either after 8 h (0, 1 and 2 month samples) or after 16 h incubation (4, 8 and 12 month samples). Two

Plate 3 : Ascospores collected on millipore filters.



replicate samples were examined.

A similar experiment used spores collected on dry membrane filters (method (c)). These were stored in plastic petri dishes in a desiccator containing $CaCl_2$ placed in a refrigerator at 4°C. Viability tests on ascospores were made after 1, 2, 4, 8 and 12 months. At least 200 spores were counted in each sample from three replicates.

Wet collected ascospores survived longest in the presence of a dessicant at all three temperature regimes (Table 11). Spores survived longer in the deep freeze than at room temperature or 4°C, although their viability decreased by half. Survival at room temperature was poor, even with a dessicant.

Dry collected ascospores survived better at 4°C than wet collected spores and retained their vaibility for 4 months. Their ability to germinate then declined markedly (Table 12).

1.4.3. Ascospore measurements

Apothecia of isolate JN1 were attached to the lids of petri dishes with vaseline and the dish lids were then lightly swabbed with FAA to hasten spore release. Ascospores were collected in droplets of water on microscope slides directly below apothecia, and 25 spores from each of three apothecia were measured after 2 h; at x 150 magnification.

Mean ascospore length was 11.6 µm, (range 8-13 µm) this is within the limits for *S. sclerotiorum* given by Mordue & Holliday (1976).

1.4.4. Effect of temperature, relative humidity and light on the discharge and germination of ascospores

(a) Ascospore discharge

A factorial experiment was set up to investigate ascospore discharge at 5°, 10°, 15° and 20°C at relative humidities of 100, 97, 92.8,

Table 11 : Mean percentage germination of wet collected ascospores stored at different temperatures with (D) or without (ND) a desiccant ($Ca\ Cl_2$).

Storage temp. (°C)	Desiccant (D) or not (ND)	Months of storage				
		1	2	4	8	12
22 ± 2	D	68.5	72.5	43.5	19.5	26.5
	ND	0	0	0	0	0
4 ± 1	D	100	92	86.5	46	40.5
	ND	25.5	18	0	0	0
-19	D	100	99	90	73	41
	ND	82.5	86.5	76.5	69	22.5

Each value is the mean of two replicates. In a test of a sample before storing 100% of the spores germinated.

Table 12 : Mean percentage germination of dry collected ascospores at $4^{o}C$.

Months of storage	% Germination (mean of three replicates)
0	100
1	100
2	97.6
4	92
8	56.6
12	31.3

Each value is the mean of three replicates.

85.2, 73.4, 62.4, 44.3, 33.8, 16.9, 1.7 and 0%; both in the light and the dark.

Freshly formed mature apothecia (isolate JN1) of similar size (6 mm) were selected and excised. They were then fixed onto the underside of the lids of No.11 dishes with vaseline, so that the ascospores were discharged downwards. Within each dish, there was the base of a plastic petri dish containing either 10 ml glycerol solution or water, above which a glass slide was supported with a glass "T-piece". Each apothecium was placed on the lid so that spores discharged into a drop of sterile distilled water on the microscope slide.

The required humidities were obtained by varying the concentration of the glycerol solution (Johnson, 1940). Immediately after the insertion of apothecia the dishes were placed in an illuminated incubator at one of the designated temperatures. Dishes in the 'dark' treatment were wrapped in black polythene. There were three dishes for each treatment.

Ascospores were allowed to deposit for 4 h. The lids were then removed rapidly to prevent further spore deposition through 'puffing'. A drop of Tween 40 was added to each drop and the number of ascospores was estimated using an Improved Neubauer Haemocytometer.

Relative humidity and temperature clearly had marked effects on ascospore deposition (Table 13). Overall, deposition was greatest at 92.8% r.h. and 15^{o}C. Generally more ascospores were deposited in the light than in the dark but the magnitude of the difference varied with temperature.

No spores were deposited at 0 and 1.7% r.h. and very few at 16.9%. An analysis of variance, omiting these values indicated highly significant effects ($\underline{P} < 0.001$) of temperature, relative humidity and

Table 13 : Effect of temperature, relative humidity and light on deposition of ascospores.

% r.h.	Thousands of ascospores deposited								
	4°		10°		15°		20°		
	L*	D	L	D	L	D	L	D	
100	24.4	23.1	99.7	86.8	195.6	132.5	159.9	60.9	782.9
97	27.1	24.7	103.1	86.9	234.5	139.3	184.7	94.5	894.8
92.8	28.5	26.4	117.4	87.4	293.2	147.6	264.2	200.3	1165.0
85.2	17.3	16.7	92.3	63.1	205.5	101.1	200.2	193.1	889.3
73.4	9.2	7.9	64.1	24.8	83.2	64.3	82.1	80.7	416.3
62.4	2.2	2.4	40.3	11.6	69.2	52.1	74.5	62.3	314.6
44.3	1.4	0.9	7.3	2.5	60.4	42.1	9.2	7.1	130.9
33.8	0.9	0.1	0.3	0.3	9.9	7.6	8.8	2.1	30.0
16.9	0.7	0.1	0.1	0	0.8	0.2	0.8	0	2.7
1.7	0	0	0	0	0	0	0	0	0
0.0	0	0	0	0	0	0	0	0	0
	117.5	102.3	524.6	363.4	1152.3	686.8	984.4	701.0	
	214		888		1839.1		1685.4		

* Incubated in light (L) or darkness (D)

Analysis of variance	df	SS	MS	F	
Temp.	3	352.5	117.5	5.3	***
r.h.	7	501.2	71.6	3.2	***
Light	1	42.6	42.6	1.9	ns
Temp. x r.h.	21	177.3	8.4	0.4	ns
Temp. x Light	3	21.3	7.1	0.3	ns
Light x r.h.	7	21.8	3.1	0.1	ns
Temp. x Light x r.h.	21	45.3	2.2	0.1	ns
Error	126	2801.5	22.2		

light and a significant temperature x light interaction, which are apparent from the margin totals of Table 13.

(b) Germination

Microscope slides coated with a thin layer of 1% water agar were placed below apothecia of isolate JN1 attached to lids of No.11 dishes so that three separate spore prints were deposited in 4 h. Each slide was then placed in a closed plastic box on damp filter paper and incubated at 5^{o}, 10^{o}, 15^{o}, 20^{o} or 25^{o}C with or without light. After 6 h, a drop of cotton blue-lactophenol was placed onto each print to arrest germination.

Germination was assessed from counts of ascospores within five fields at x 150 in each print, giving a total of at least 500 ascospores. The lengths of 25 germ tubes were also measured in each print.

No germination occurred at 5^{o}C in either the light or the dark.

Both germination and germ tube growth were better in the dark than in the light (Table 14). Temperatures between 10^{o} and 25^{o}C had little effect on germination overall but did effect germ tube growth, although individual analysis of variances were significant (Appendix VII and VIII).

A factorial analysis on % germination and germ tube length were both significant ($P < 0.001$) for the temperature x light interaction (Table 15).

Table 14 : Effects of temperature and light on germination and germ tube growth of ascospores.

Temperature °C	Mean % germination ± S.E.(a)		Mean germ tube length (µm) ± S.E.(b)	
	Light	Dark	Light	Dark
10	15.45 ± 0.53 a	63.91 ± 0.99 c	10.8 ± 0.20 a	34.8 ± 1.93 ab
15	20.17 ± 0.37 b	65.53 ± 1.27 d	17.04 ± 0.57 b	39.3 ± 2.76 bc
20	26.67 ± 0.68 c	58.10 ± 1.41 b	24.44 ± 0.50 c	45.8 ± 3.94 c
25	33.29 ± 0.87 d	54.68 ± 0.85 a	29.6 ± 0.89 d	30.2 ± 2.13 a

(a) Mean % germination is angular transformed (arcsin $\sqrt{\%}$) of 15 replicate counts.

(b) Mean is based upon 25 replicates.

(c) Values with no letter in common are significantly different using Duncans multiple range test (P = 0.05) for each treatment of light and dark.

Table 15 : Factorial analysis of the effect of temperature and light on the germination and germ tube growth of ascospores.

i) % germination

°C	L	D	
10	15	64	79
15	20	66	86
20	27	58	85
25	33	54	87
	95	242	337

ii) Germ tube length

°C	L	D	
10	11	35	46
15	17	39	56
20	24	46	70
25	30	30	60
	82	150	232

Anovar

(i)	df	SS	MS	F	
Temperature	3	3792.09	1264.03	14.42	***
Light	1	4686.01	4686.01	53.48	***
Temp x Light	3	37114.18	12371.39	141.18	***
Error	17	1489.76	87.63		

(ii)	df	SS	MS	F	
Temperature	3	2022.88	674.29	0.35	ns
Light	1	2166.21	2166.21	1.12	ns
Temp x Light	3	59817.95	19939.32	10.30	***
Error	17	32898.09	1935.18		

SECTION 2

FIELD TRIALS OF WINTER OILSEED RAPE CULTIVARS 1981-4

2.1 Introduction and Relevant Literature

2.1.1. Oilseed rape

Rapeseed is the collective term used for Brassica crops grown for the oil in their seed. There are three species: *Brasicca napus* L. spp *oleifera* L. (swede rape or oilseed rape) grown throughout much of Europe, *B. campestris* L. spp *oleifera* L. (turnip rape or oil turnip) favoured by Canada (Thompson & Kondra, 1983) and Sweden because of its hardiness and *B. juncea* (L.) Gzem & Coss. (mustard), mainly grown in India and China. Both turnip and swede rape have winter and spring sown forms, the winter cultivars being generally higher yielding. Canadian production is almost entirely from spring sown cultivars.

Winter cultivars of oilseed rape contain most oil. They are predominantly grown throughout Europe because the European Economic Community (E.E.C.) requires a minimum level of 40% oil content for the full intervention price. The oil, generally about 42% by weight of the seed, is used for industrial purposes or as edible oil in the production of margarine and cooking fats. For the latter, oil with low erucic acid is required since there is some evidence that experimental animals fed on oil high in erucic acid developed heart lesions (Aaes-Jorgensen, 1972; Parkes, 1974). Although this has been questioned (Parkes, 1975), new cultivars of oilseeds have been developed - originally in Canada - with an erucic acid content as low as 2%, compared to nearly 45% in existing cultivars. Recent E.E.C. legislation requires low levels of erucic acid and the change over within the community to low erucic acid cultivars has been very rapid.

Rapeseed meal, approximately 57% of the seed weight, is incorporated into compound animal feeds at a rate not exceeding 10%. This restriction is because the glucosinolates which it contains can induce thyroid problems in cattle (Josefsson, 1972). Although the glucosinolates can be inactivated by processing methods, these are costly and not entirely effective. Breeding programmes have been established to develop rapeseed low in both erucic acid and glucosinolates - the "double-zero" cultivars. These cultivars are available and under trial in the U.K.

2.1.2. The E.E.C.

Within the E.E.C., France, W. Germany, the U.K. and Denmark are the main producers of rapeseed. There have been increases in the area grown in all four countries over the past 20 years, due primarily to the stimulus given by the E.E.C.'s Common Agricultural Policy (C.A.P.).

The objective of the C.A.P. for oilseeds is to encourage production and so decrease the need to import oils, fats and animal feed (Bell, 1975). The policy protects E.E.C. oilseed crushers and supports financially, seed grown within the E.E.C. Internal support arrangements apply to the two oilseeds most widely grown in the community - rapeseed and sunflower seed. Intervention prices are set just below the target price and are the minimum price at which processors are allowed to purchase from the grower. Prices are adjusted each year in line with production costs and theoretically at least, market demand. This support for the oilseed rape market is likely to be maintained until 1989 (Gardner, 1984). Without price support, nutritional, physiological and harvesting problems would have controlled the production of oilseed rape. Its recent history clearly shows that arable farming is mainly governed by financial incentives rather than well established biological and rotational principles. In order to maintain orderly trading relations with major

world food producers, it has been suggested that the annual output of rapeseed from the E.E.C. should not exceed 3.3 m tonnes during the next 5 years. A co-responsibility levy to restrict the level of support, if production exceeds the average of the three previous seasons, is already in force.

2.1.3. Oilseed rape in the U.K.

Although rape is considered a relatively new crop in the U.K., it was first introduced by Dutch engineers in the 19th Century who came to drain the Fens and needed rape oil to keep their wind pumps working. The crop was re-established in the 1960's by United Oilseed Producers - a farmer-owned marketing organisation based in Wiltshire.

Until the mid 1970's the low hectarage of rape in the U.K. was grown mainly in the south; in the Berkshire, Hampshire and Wiltshire area. Since 1972, when Britain joined the E.E.C., the area sown with oilseed rape has increased exponentially, largely due to its guaranteed price and value as a break crop for cereals, particularly one that can be followed by wheat. The area of cultivation has spread mainly to the north and east, throughout the main cereal growing areas (Table 16).

This rapid spread based on two cultivars - Jet Neuf and Rafal has affected the diversity of arable farming,with fewer species and families of crop plants being sown in rotations. The additional production has been from land formally used for spring cereals, sugar beet and grass.

Average yields have remained in the region of 2.0-2.5 t/ha, although a potential of 7.5 to 8.5 t/ha has been predicted from detailed physiological studies (Daniels *et al.*, 1982).

Table 16 : Production of oilseed rape in England.

	1968	1973	1978	1982	1983	1984
Total (thousand ha)	6.4	13.5	64.0	172.6	217.6	261.3
Regional contribution (% of total)						
North	0.3	0.35	0.76	2.6	3.4	
Yorkshire/Humber	2.5	3.6	11.9	17.6	18.0	
North West	0.07	0.05	0.14	0.44	0.6	
East Midlands	16.7	19.8	29.9	30.0	29.8	
West Midlands	5.1	2.2	4.1	5.0	5.5	
East Anglia	10.1	12.8	16.2	16.2	15.0	
South East	47.7	50.0	32.2	25.2	24.5	
South West	17.5	11.2	4.8	3.0	3.2	

From Bunting (1984)

2.1.4. Stem rot and oilseed rape

The first record of *S. sclerotiorum* on winter oilseed rape in England was in 1973, with 5% plants infected in one crop. Similar amounts were noted in the same area in 1974. In 1977, two crops in the West Midlands and Yorkshire were slightly infected. In 1978, the disease was reported in only one spring rape crop in Kent. One East Midland crop in 1979 was infected, while in both 1979 and 1980 a low incidence was recorded in most crops examined in Berkshire, Hampshire and Oxfordshire. In 1981, the disease was reported in the Eastern region, with low levels recorded from most other areas excluding the South West Region, Kent and Sussex. In 1982, the disease was more widely spread with reports from most areas, except the South West Region. Severe outbreaks were rare - only four out of 204 crops examined were recorded with 20% or more plants infected (Evans *et al.*, 1984). A few crops were infected in 1983. In 1984 symptoms were reported for the first time in January (in crops in Kent and Sussex and three crops in the Eastern Counties) (Jellis *et al.*, 1984).

Few crops in the U.K. have been severely infected to date and the incidence of stem rot has generally been low. However in West Germany, France, Denmark and Canada, stem rot is a major disease of oilseed rape (Krüger, 1980; Scheibert-Böhm *et al.*, 1981; Regnault, 1984; Jenson & Buchwaldt, 1983; Dueck *et al.*, 1983).

2.1.5. Susceptibility of oilseed rape cultivars

Before 1981-82, the susceptibility of winter oilseed rape cultivars had not been investigated in the U.K. Reports from other countries have only appeared in publications since 1979 (Renard & Brun, 1979; Thompson & Kondra, 1983; Jenson & Buchwaldt, 1983; Krüger & Stoltenberg, 1983) in France, Canada, Denmark and W. Germany respectively. These were all under field conditions but artificial inoculation in the form of

mycelium, was used in some experiments rather than natural inoculum in the form of ascospores. Other methods of artificial inoculation of oilseed rape have been described (Anon., 1981; Scheibert-Böhm *et al.*, 1981; Brun *et al.*, 1983) but there is to date, no standard procedure.

The lack of information on the U.K. cultivars both those Recommended (Anon., 1983) and those under the National Institute of Agricultural Botany (NIAB) National List Trials, prompted an investigation to screen for disease resistance under both field conditions and in the greenhouse.

2.2 Description of the Trials

During each of three seasons (1981-82, 1982-83, 1983-84), the susceptibility of winter oilseed rape cultivars was examined in trials at three sites - Four Counties Farm, Sutton Scotney, Hampshire; Silwood Park, Ascot, Berkshire and NIAB Headquarters, Cambridge. In each trial, the 16 cultivars which were in at least their second year of National List Trials by NIAB, were grown so that the range of cultivars changed slightly from year to year. Overall a total of 31 different cultivars were grown in eight trials. These are listed in Table 17. Over the 3 years, five cultivars were common to all eight trials.

2.2.1. Sutton Scotney

(a) 1981-82

The trial was sited on land previously planted to peas which had been slightly infected with *S. sclerotiorum*. Seed, dressed with iprodione, was sown on 28 August 1981 by NIAB staff using an Oyjord drill at a rate of 6-8 kg/ha with 18 cm row spacing. Post-emergence herbicides were applied in autumn (Kerb 50W) and spring (Benazoluz). The trial was fertilised with N:P:K (50:70:70 kg/ha) in the seed bed with a spring top dressing of 200 kg/ha.

There were four replicate plots (each c. 40 x 20 m) of each cultivar in a randomised block design (Appendix IX). Each cultivar was drilled in a 1.75 m wide band with a small break (c. 0.25 m) before the next, and the whole trial was surrounded by guard rows of cv. Jet Neuf.

The trial was combined direct without desiccation on July 17, 1982. The ground was circular rotovated, straight rotovated and then ploughed down before the following trials. The crop residues were not burnt.

Table 17 : Winter oilseed rape cultivars grown in trials 1981-84.

1981-82	1982-83	1983-84
Jet Neuf	Jet Neuf	Jet Neuf
Rafal	Rafal	Rafal
Bienvenu	Bienvenu	Bienvenu
Fiona	Fiona	Fiona
Korina	Korina	Korina
Norli	Norli	Diander
Lingot	Lingot	E82/2 - Falk
Elvira	Elvira	79/95 - Mikado
Vigor	Belinda	Belinda
Ledark	Di7/81 - Brittander	Jem
Perle	Di8/81 - Chrysander	Semu 10/82 - Carola
St 1/80a	Di9/81 - Diander	Semu 20/82 - Barbara
Semu 13/79	D111/80 - Pamela	Pamela
Jupiter	JN332 - Duo-Darmor	Darmor
DSVWRE11 - Lirama	JN404 - Tandam	DSVWRG30 - Liradonna
Valdor	DSVWRE24 - Lirabella	Lirabella
	+ DORAL (SILWOOD)	+ DORAL (SILWOOD)
	+ PERLE (NIAB)	

(b) 1982-83

The trial was sown on 8 September 1982 on land occupied by Block I of the 1981-82 trial. There was one block only of 16 cultivars, each in a plot 20 x 2 m and separated from its neighbour by a 0.25 m access path (Table 18). The trial was surrounded by a 2 m border of cv. Jet Neuf and was netted to prevent pest damage. The seedbed was fertilised, N:P:K (40:60:60), followed by a spring dressing on 26 March 1983 of nitrogen at the rate of 200 kg/ha using TN34 (Thames Nitrogen Co. Ltd., Ferry Lane Works, Rainham, Essex - ammonium nitrate with a total N of 34.5% - 17.25% nitric nitrogen and 17.25% ammoniacal nitrogen).

A spring herbicide ("Weed Out", May and Baker) was applied at stem extension as Couch grass was a problem. Plots were harvested on 13 July 1983.

(c) 1983-84

The trial was sown on 25 August 1983 in an area previously covered by Block IV in the 1981-82 trial and then planted to barley in 1982-83. The layout (Table 18) and management of the trial were otherwise similar to the 1982-83 trial. Herbicide (Kerb 50W) was applied in the autumn and the spring nitrogen dressing on 22 March 1984. Plots were harvested on 17 July 1984.

All three trials at Sutton Scotney relied on natural inoculum of *S. sclerotiorum*. The soil was classed as Clay Loam (6.3% coarse sand; 44.6% fine sand; 16.3% silt and 32.8% Clay) using the New Jersey Scale.

2.2.2. Silwood Park

(a) 1982-83

The trial tested 17 cultivars, sixteen from the National

Table 18 : Cultivar plan for Sutton Scotney 1982-83 and 1983-84.

Plot	1982-83	1983-84
1	Pamela	Bienvenu
2	Korina	Rafal
3	Lirabella	Carola
4	Jet Neuf	Darmor
5	Norli	Pamela
6	Belinda	Mikado
7	Brittander	Lirabella
8	Elvira	Diander
9	Rafal	Korina
10	Darmor	Jet Neuf
11	Fiona	Falk
12	Diander	Liradonna
13	Tandem	Barbara
14	Lingot	Fiona
15	Bienvenu	Belinda
16	Chrysander	Jem

List plus Doral, claimed by Krüger & Stoltenberg (1983) to have low susceptibility to stem rot. A single plot (3 x 3 m) of each cultivar formed a square enclosing a central circular plot of cv. Jet Neuf (Figure 2). Plots were sown on 2 September 1982 using a small hand drill (Whitwood Seed Drill, Dashwood, London, England) with 18 cm row spacing and a seed rate of 6-8 kg/ha. The seed bed received N:P:K (40:60:60 kg/ha) and a post emergence herbicide (Kerb 50W) was applied.

As the land had no previous crop of oilseed rape or history of *Sclerotinia*, plots were inoculated with sclerotia of *S. sclerotiorum*. Mature sclerotia were removed from 28-day-old cultures of isolate JN1 on wheat grain and were placed in small (c. 6 x 6 cm) bags of terylene net, 20 sclerotia per bag. Five bags were placed, c. 1 cm deep in each plot on 16 September 1982, one centrally and four equidistant on the plot diagonals to give, overall, 100 sclerotia per 9 m^2.

A spring dressing of nitrogen (200 kg/ha) TN34 was applied on 26 March 1983. Plots were harvested when plants had reached growth stage 4.4, so the date varied with cultivar from 8 July to 18 July 1983.

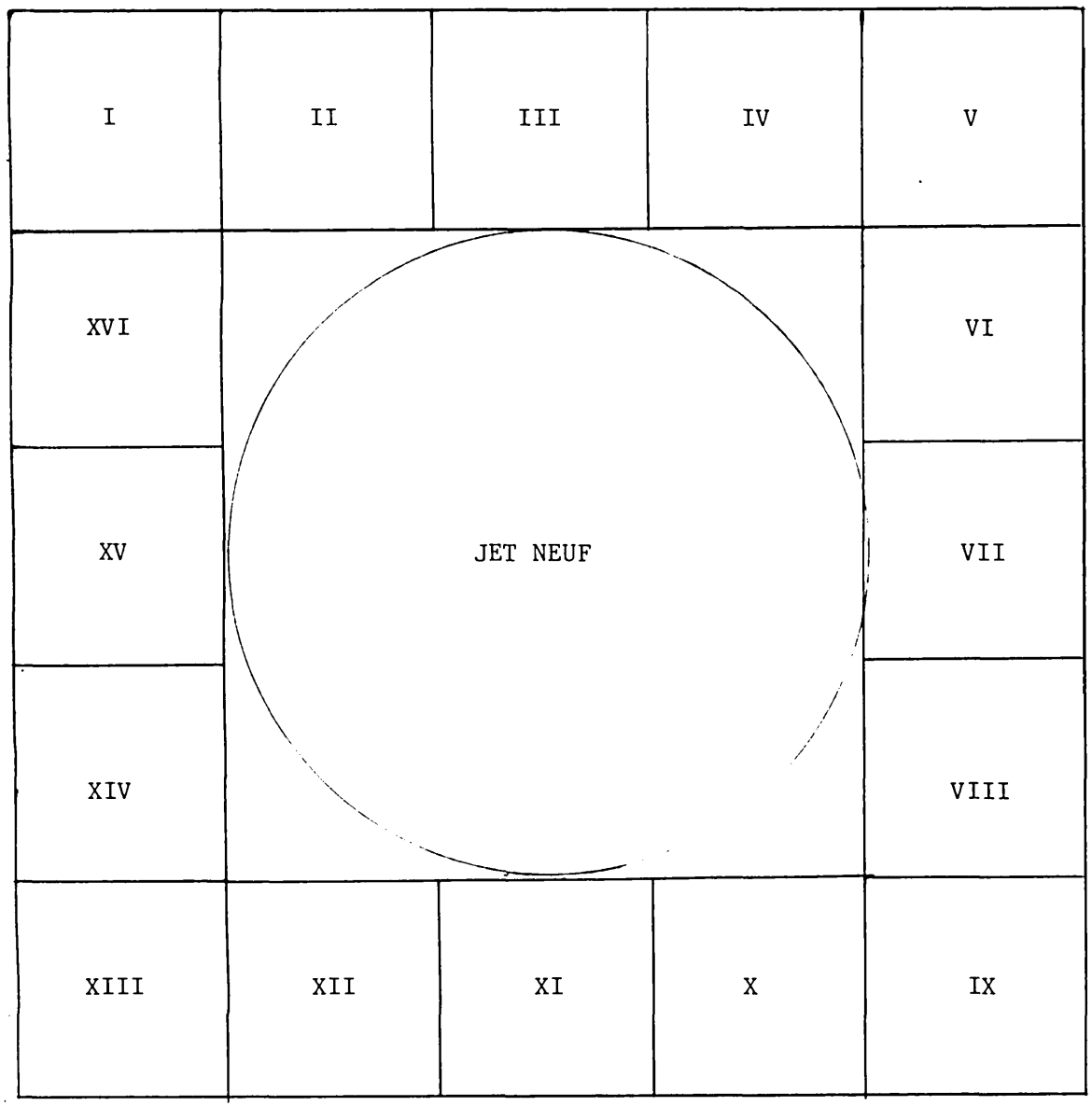
The whole trial was netted throughout to prevent bird damage.

The soil at Silwood is classified as Bagshot Sand.

(b) 1983-84

The layout of the trial was the same as in 1982-83, though the selection of cultivars differed. Plots were sown on a different area of the experimental ground on 26 August 1983 and bags containing sclerotia as in 1982-83 were buried in plots on 9 September 1983. The spring nitrogen dressing was split due to early growth following the mild winter, half being applied on 24 February 1984 and half on 20 March 1984 to give overall a rate of 200 kg/ha. Nitrochalk was used (I.C.I. plc. Agricultural

Figure 2 : Layout of winter oilseed rape cultivar trial at Silwood Park.



Plot	Cultivar 1982-83	1983-84
I	Fiona	Diander
II	Belinda	Doral
III	Norli	Liradonna
IV	Brittander	Jem
V	Lirabella	Belinda
VI	Pamela	Korina
VII	Elvira	Bienvenu
VIII	Bienvenu	Rafal
IX	Lingot	Fiona
X	Diander	Falk
XI	Doral	Lirabella
XII	Darmor	Mikado
XIII	Korina	Carola
XIV	Chrysander	Pamela
XV	Rafal	Barbara
XVI	Tandem	Darmor

Division, P.O. Box 1, Billingham, Cleveland - calcium ammonium nitrate with a total nitrogen of 26% from ammoniacal N -13% and nitric nitrogen -13%). Harvesting was not done on this trial due to low infection levels.

2.2.3. NIAB, Cambridge

(a) 1981-82

Sixteen cultivars were tested in a randomized block design with four replicates on the site of a tunnel from which the polythene had been removed but with facilities for overhead irrigation. Plots (two rows of 2 m) were sown by hand on 17 September and plants were thinned on 22 October 1981 (Appendix X). Sclerotia of *S. sclerotiorum* were placed close to plant stems on the soil surface on 5 November and 1 December 1981 and again on 19 and 21 January 1982. On each occasion four to five sclerotia were used per 2 m row. For the first two inoculations the isolate, from an unknown oilseed rape cultivar, was grown on PDA under NUV. Later inoculations used sclerotia of R1 produced on carrots in a damp chamber.

Plots were harvested on 23-25 June 1982.

(b) 1982-83

The experimental design of 1981-82 was used but with 16 cultivars plus cv. Perle (Appendix XI). These were sown by hand on 15 September 1982, thinned on 7 October and inoculated with sclerotia on 8 October 1982 using isolate JN1 grown on wheat grain at 25°C for 28 days. Approximately 30 sclerotia per row were buried c. 1 cm deep in the trial.

Plots were irrigated from above every morning from the beginning of April to the end of May if no rain had fallen overnight.

Plots were harvested on 19-20 July 1983.

(c) 1983-84

This trial was also of similar design to the previous two trials on this site. Plots were sown on 10 September 1983, thinned on 12 October and incoulated with sclerotia of JN1 on 13 October 1983. (Appendix XII shows the layout of the trial). Plots were irrigated where necessary between April-June and harvested on 23-24th July 1984.

2.2.4. Final assessment of stem rot in field trials

A high incidence of stem rot in the 1981-82 trial at Sutton Scotney provided an opportunity to evaluate different ways of assessing disease each based on the presence or absence of infection. Four methods were tried:

(i) the percentage of brown racemes in each plot was estimated by eye;

(ii) percentage diseased plants was based on 20 plants at random in each plot;

(iii) the number of diseased plants were counted in two 1 m quadrats;

(iv) a 2.5 m bamboo cane was inserted across the rows at ground level in two or three places at random along the plot and the percentage of plants infected was based on a minimum sample of 50 plants touching the cane.

Results obtained by the four methods are compared in Table 19. Method (i) was unsatisfactory since premature browning caused by disease could not always be distinguished readily from natural ripening and methods (ii) and (iii) caused damage to the plot, although method (iii) appeared to give a good estimate of disease. Method (iv) gave similar results to method (iii) and was quicker and easier, so it was adopted for subsequent assessments at Sutton Scotney and Silwood Park.

At Cambridge every plant was assessed for presence or absence of lesions.

Table 19 : Percentage incidence of stem rot at Sutton Scotney (June, 1982) as determined by four methods.

Cultivar	Method*			
	(i) Brown racemes	(ii) 20 random plants	(iii) Two quadrats	(iv) Plants touching cane
Lingot	2.9	4.1	2	5
Lirama	5.9	5.5	5	10
Bienvenu	41.9	42.1	9	20
Jupiter	6.4	11.9	4	0
Korina	28.8	34.4	14	40
Vigor	19.2	14.6	6	10
Elvira	21.5	20.8	9	15
Semu 13/79	5.1	10.2	7	5
Fiona	26.6	27.3	13	15
Perle	4.1	1.8	5	0
Norli	9.1	7.0	2	10
Rafal	11.1	18.9	3	5
Jet Neuf	39.1	46.4	18	45
St 1/80a	8.9	11.3	5	10
Valdor	19.3	25.0	11	20
Ledark	1.8	9.5	2	0

*For details see text.

2.3 Results from the Trials

2.3.1. Disease incidence

The incidence of stem rot in the eight trials from 1981-84 is summarized in Table 20. The amounts of disease varied considerably between sites and from year to year. There was a high incidence of stem rot in trials at Sutton Scotney 1981-82 and Silwood 1982-83, moderate amounts in the trials at Cambridge in 1982-83 and 1983-84 and rather little disease in the remaining four trials (Sutton Scotney 1982-83 and 1983-84, Silwood 1983-84 and Cambridge 1981-82). Where disease incidence was moderate or high differences between cultivars were also apparent. These features were examined in more detail.

Data from trials with replicate plots where disease incidence was moderate or high (Sutton Scotney 1981-82, Cambridge 1982-83 and 1983-84) were examined by analyses of variance on transformed data. These indicated significant differences between cultivars in each of the three trials (Table 21; Appendix XIII, XIV and XV).

Next, the data of Table 20 (transformed to $\sqrt{x + 0.5}$) were used to determine differences between sites in each of the three seasons. Analyses of variance showed that the difference in disease incidence between sites was highly significant ($P \leq 0.001$) but that between cultivars was not, suggesting a low degree of agreement between the behaviour of cultivars at the three sites (Table 22; Appendix XVI). This latter feature was examined further by two non-parametric tests on the ranked values shown in Table 23, using Spearman's test of rank correlation for the 1981-82 data and the Kendall coefficient of concordance for the 1982-83 and 1983-84 data (Siegal, 1956). These tests (Table 24; Appendix XVII) confirmed that there was no significant measure of agreement between the ranking of cultivars at the various sites.

Table 20 : Incidence of stem rot in trials with winter oilseed rape cultivars, 1981-84.

Cultivar	% plants with stem rot							
	Sutton Scotney			Silwood		Cambridge		
	1981-82	1982-83	1983-84	1982-83	1983-84	1981-82	1982-83	1983-84
Elvira	47.6	4		40		0.5	51.8	
Jet Neuf	67.9	30	3.9	70	4	1.3	38.6	13.8
Bienvenu	53.2	12	10.3	38	2	0	46.4	20.2
Jupiter	39.6					0.4		
Korina	53.3	4	8.3	12	6	0.9	39.9	22.0
Lirama	27.1					2.2		
Perle	25.3					0		
Semu 13/79	45.7					0.4		
St 1/80a	44.0					0.9		
Vigor	36.7					1.2		
Norli	32.0	8		60		1.3	36.3	
Rafal	40.3	8	9.4	38	2	0.5	44.4	14.8
Fiona	54.8	4	1.9	46	4	0	31.4	15.4
Ledark	31.4					0.4		
Lingot	21.5	4		44		5.4	47.0	
Valdor	33.3					1.2		
Belinda		4	1.9	90	6		24.9	17.5
Brittander		6		60			30.7	
Lirabella		8	0	64	4		35.8	18.3
Pamela		2	1.8	34	2		31.0	14.8
Diander		8	5.7	26	2		37.1	28.3
Darmor		0	3.8	26	0		32.7	10.6
Doral				36	6			
Chrysander		6		10			18.4	
Tandem		0		18			27.0	
Carola			5.6		2			14.7
Mikado			3.6		2			10.0
Falk			5.5		0			18.4
Liradonna			5.9		6			15.7
Barbara			0		4			10.5
Jem			2.0		4			17.1

Data for the 1981-82 trial at Sutton Scotney and all trials at Cambridge are the means of four replicate plots; other data are from single plots of each cultivar.

Table 21 : Analyses of stem rot incidence amongst cultivars grown in replicated trials.

		Sutton Scotney 1981-82	Cambridge 1982-83	Cambridge 1983-84
F-value:	Cultivar	5.92***	2.0 *	2.78***
	Blocks	5.29**	7.79***	2.37
Error:	Mean square	38.9	57.8	20.4
	D.f.	45	45	45

Ranking of cultivars (in descending order from least to highest incidence)

(Sutton 1981-82)		(Cambridge 1982-83)		(Cambridge 1983-84)	
Lingot	a	Chrysander	a	Darmor	a
Perle	ab	Belinda	ab	Diander	ab
Lirama	ab	Tandem	abc	Mikado	ab
Norli	abc	Pamela	abc	Falk	abc
Ledark	abc	Brittander	abcd	Bienvenu	abc
Valdor	abc	Fiona	abcd	Korina	abc
Jupiter	bcd	Darmor	abcd	Pamela	abc
Vigor	bcd	Norli	abcd	Rafal	abc
Rafal	bcd	Lirabella	abcd	Liradonna	abc
St 1/80a	cd	Diander	abcd	Lirabella	abc
Semu 13/79	cd	Jet Neuf	abcd	Belinda	abc
Elvira	cd	Korina	bcd	Jem	bcd
Bienvenu	de	Rafal	bcd	Fiona	cd
Korina	de	Bienvenu	bcd	Jet Neuf	cd
Fiona	de	Lingot	cd	Barbara	cd
Jet Neuf	e	Elvira	d	Carola	d

*, **, ***, denote F-values significant at $P \leq 0.05$, 0.01 and 0.001 respectively.

Values with no letter in common are significantly different ($\underline{P} = 0.05$).

Table 22 : Summary analyses of stem rot incidence between sites during three seasons.

Season	Sites	F-value		Error	
		Sites	Cultivar	Mean square	D.f.
1981-82	Sutton Scotney, Cambridge	285.4***	0.49	0.76	15
1982-83	Sutton Scotney, Silwood Park, Cambridge	48.2***	1.47	1.57	30
1983-84	Sutton Scotney, Silwood Park, Cambridge	56.6***	0.77	0.43	30

*** F-values significant at $P \leq 0.001$

Table 23 : Ranking of winter oilseed rape cultivars in relation to incidence of stem rot in field trials, 1981-84.

Cultivar	Sutton Scotney			Silwood		Cambridge		
	1981-82	1982-83	1983-84	1982-83	1983-84	1981-82	1982-83	1983-84
Elvira	12	6		10		7	16	
Jet Neuf	16	16	9	16	11	14	11	4
Bienvenu	13	15	16	8.5	5.5	2	14	14
Jupiter	7					5		
Korina	14	6	14	2	15.5	9	12	15
Lirama	3					15		
Perle	2					2		
Semu 13/79	11					5		
St 1/80a	10					10		
Vigor	8					12		
Norli	5	12.5		13.5		13	9	
Rafal	9	12.5	15	8.5	5.5	7	13	7
Fiona	15	6	4.5	12	11	2	6	8
Ledark	4					5		
Lingot	1	6		11		16	15	
Valdor	6					11		
Belinda		6	4.5	17	15.5		2	11
Brittander		9.5		13.5			4	
Lirabella		12.5	1.5	15	11		8	12
Pamela		3	3	6	5.5		5	6
Diander		12.5	12	4.5	5.5		10	16
Darmor		1.5	8	4.5	1.5		7	3
Doral				7	15.5			
Chrysander		9.5		1			1	
Tandem		1.5		3			3	
Carola			11		5.5			5
Mikado			7		5.5			1
Falk			10		1.5			13
Liradonna			13		15.5			9
Barbara			1.5		11			2
Jem			6		11			10

(a) Cultivars are ranked from least (1) to highest (17) incidence of stem rot.

(b) The mean rank is given for those cultivars with the same disease incidence.

Table 24 : Tests of association between ranking of cultivars by stem rot incidence at different sites.

Season	Sites	Test of association	D.f.	Parameter and value
1981-82	Sutton Scotney, Cambridge	Spearman rank correlation	14	r_s = -0.29 t = 1.13 n.s.
1982-83	Sutton Scotney, Silwood, Cambridge	Kendall coefficient of concordance	15	W = 0.52 X^2 = 23.35 n.s.
1983-84	Sutton Scotney, Silwood, Cambridge	Kendall coefficient of concordance	15	W = 0.463 X^2 = 20.84 n.s.

Further analyses examined differences in disease incidence between years at each of the three sites. The data from Sutton Scotney and Cambridge were limited to five cultivars (Jet Neuf, Fiona, Korina, Bienvenu and Rafal) and from Silwood 10 cultivars (the previous five plus Belinda, Lirabella, Pamela, Diander and Darmer). These analyses showed a highly significant difference ($P \leq 0.001$) in disease incidence between years (Table 25; Appendix XVIII) but, again, little agreement between the ranking of cultivars at any one site in these years (Table 26; Appendix XVIX).

Finally, the mean disease incidence (transformed to $\sqrt{x + 0.5}$) on the five cultivars common to all eight trials was examined by an anlysis of variance. This showed a highly significant difference ($P = 0.01$) between trials, but not between cultivars (Table 27). However it was clear from this analysis that the two currently Recommended Cultivars (Anon., 1983) - Jet Neuf and Bienvenu - had the highest disease incidence with mean values of 28.7% and 22.8% respectively.

2.3.2. Factors influencing disease incidence

Section 2.3.1. dealt with the overall differences in incidence of stem rot amongst cultivars in trials from 1981 to 1984 as indicated by final disease assessments. This section considers further these cultivar differences in relation to production of apothecia, counts of airborne ascospores and development of the oilseed rape, especially flowering.

(a) Trials at Sutton Scotney

Production of apothecia. Apothecia were not seen in the 1981-82 trial, but in the two subsequent trials, quadrats (0.5 x 0.5 m) were marked out in plots of each cultivar, and the numbers of apothecia appearing within these quadrats were counted about every 7 days. A total of 18 quadrats were placed in the trial - one in each cultivar and one midway down the two

Table 25 : Summary analyses of stem rot incidence between seasons for three sites.

Site	Seasons	F-value		Error	
		Season	Cultivar	Mean square	D.f.
Cambridge	1981-82, 1982-83, 1983-84	72.3***	0.88	0.61	8
Sutton Scotney	1981-82, 1982-83, 1983-84	36.9***	1.22	0.91	8
Silwood	1982-83, 1983-84	79.8***	1.54	1.35	9

*** F-values significant at $P \leq 0.001$

Table 26 : Tests of association between ranking of cultivars by stem rot incidence at the same site in different seasons.

Site	Seasons	Test of association	D.f.	Parameter and value
Cambridge	1981-82, 1982-83, 1983-84	Kendall coefficient of concordance	4	$W = 0.277$ $X^2 = 3.32$ n.s.
Sutton Scotney	1981-82, 1982-83, 1983-84	Kendall coefficient of concordance	4	$W = 0.254$ $X^2 = 3.03$ n.s.
Silwood	1982-83, 1983-84	Spearman rank correlation	9	$r_s = 0.184$ $t = 0.562$ n.s.

Table 27 : Analysis of stem rot incidence on five winter oilseed rape cultivars in eight trials during 1981-84.

Cultivar	Mean stem rot incidence (as $\sqrt{x + 0.5}$) at							
	Sutton Scotney			Silwood		Cambridge		
	1981-82	1982-83	1983-84	1982-83	1983-84	1981-82	1982-83	1983-84
Jet Neuf	8.26	5.5	2.04	8.38	2.06	1.25	6.23	3.71
Bienvenu	7.32	3.5	3.25	6.19	1.5	0.5	6.83	4.52
Korina	7.32	2.06	2.92	3.15	2.5	1.07	6.34	4.72
Rafal	6.37	2.87	3.11	6.19	1.5	0.87	6.68	3.88
Fiona	7.42	2.06	1.47	6.8	2.06	0.5	5.63	3.96

Anovar

Factor	d.f.	SS	MS	F	
Cultivar	4	4.90	1.23	1.40	n.s.
Year/site	7	191.2	27.31	31.15	***
Error	28	24.56	0.88		
Total	39	220.66			

end plots - to give a total area of 4.5 m^2 surveyed in 1982-83. In 1983-84, quadrats were placed at both ends of each cultivar plot to give a total area of 8 m^2 surveyed.

The numbers of apothecia recorded in these quadrats during the two seasons are shown in Tables 28 and 29. In 1983 apothecia were first seen on 11 May and were recorded in the following 5 weeks, though by 15 June they were found only in the quadrat within the plot of Bienvenu. Maximum production was recorded on 25 May, with a mean of 6.9 apothecia/m^2. There was considerable variation in the numbers produced within each plot and in the periods during which apothecia were present. These features are indicated in the last column of Table 28. As individual apothecia were not removed after counting nor otherwise marked these values are the total numbers of 'apothecial weeks'.

In 1984 apothecia appeared later than in 1983, being seen first on 23 May. Peak production occurred on 6 June, and with a mean of 13.1 apothecia/m^2 was greater than in 1983. No apothecia were recorded after 27 June. Again, there was considerable variation in the production of apothecia within individual quadrats.

Counts of airborne ascospores. The number of airborne ascospores above the plots was estimated using rod spore traps (Jenkyn, 1974). One trap was placed centrally in a plot so that the sticky trap surface was just above the racemes. Traps were exposed for weekly periods. Ascospores were counted over the whole of the detached Sellotape strip and the number of ascospores/mm^2 was calculated.

In 1981-82, spore traps were placed only in plots of Jet Neuf so that there were four within the whole trial. In 1982-83, traps were placed in alternate plots; these were planted with Korina, Jet Neuf, Belinda, Elvira, Darmor, Diander, Lingot and

Table 28 : Production of apothecia at Sutton Scotney, 1983.

Cultivar quadrat	Numbers of apothecia in quadrats on						Total No. 'apothecial weeks'
	May			June			
	11	18	25	1	8	15	
Pamela	0	0	2	2	2	0	6
Korina	0	0	0	0	0	0	0
Lirabella	0	0	0	0	0	0	0
Jet Neuf	1	4	3	2	0	0	10
Norli	1	3	2	1	1	0	8
Belinda	1	4	4	5	0	0	14
Brittander	0	0	1	1	0	0	2
Elvira	3	4	3	1	1	0	12
Rafal	0	2	4	3	3	0	12
Darmor	3	3	2	2	3	0	13
Fiona	1	2	1	1	0	0	5
Diander	1	1	3	1	1	0	7
Tandem	2	2	0	0	0	0	4
Lingot	2	2	2	1	1	0	8
Bienvenu	2	2	2	2	2	2	12
Chrysander	1	1	0	0	0	0	2
Pamela (mid-plot)	0	0	0	0	0	0	0
Chrysander (mid-plot)	1	0	0	2	0	0	3
Mean No. apothecia per m^2	4.2	6.7	6.9	5.7	3.3	0.4	

Table 29 : Production of apothecia at Sutton Scotney, 1984

Cultivar quadrat	Numbers of apothecia in quadrats on						Total No. 'apothecial weeks'
	May		June				
	23	30	6	13	20	27	
Bienvenu	0	6	8	5	2	0	21
Rafal	0	1	6	11	0	0	18
Carola	0	2	5	4	2	0	13
Darmor	0	0	5	7	1	0	13
Pamela	1	10	17	8	5	0	41
Mikado	4	9	5	19	4	0	41
Lirabella	0	2	2	2	0	0	6
Diander	0	0	4	4	0	3	11
Korina	0	0	0	2	0	0	2
Jet Neuf	0	1	15	5	0	0	21
Falk	1	8	15	3	2	3	32
Liradonna	0	0	2	2	2	0	6
Barbara	0	0	11	4	2	0	17
Fiona	0	0	1	2	1	0	4
Belinda	0	0	1	2	0	0	3
Jem	0	4	8	0	1	0	13
Mean No. apothecia per m^2	0.4	3.0	6.6	5.0	1.4	0.4	

Chrysander. A similar distribution of traps in 1983-84, involved plots planted with Bienvenu, Carola, Pamela, Lirabella, Korina, Falk, Barbara and Belinda.

In each of the 3 years, ascospores were first trapped near the beginning of May and the maximum number was recorded at the end of this month (Table 30), despite the obvious difference in the peaks of apothecia production in 1983 and 1984. In 1982 the total numbers of ascospores caught in each of the four traps within plots of Jet Neuf were remarkably similar (Table 31). In both 1983 and 1984 there was considerable variation in the numbers of ascospores caught in each trap. For the 1984 data, the regression of total ascospores trapped on the corresponding values for 'apothecial weeks' was significant at $\underline{P} = 0.05$, suggesting that the numbers of ascospores were directly related to the production of apothecia within the same plots. With the 1983 data, no significant relationship was obtained ($\underline{P} > 0.1$).

Growth and flowering of the oilseed rape. In 1981-82, flowering was recorded by M.J. Furber (NIAB, South Regional Trials Officer, Bridget E.H.F.) using a scale of 0-18 to describe flowering (9 - the midway point was full flowering and 18 - the end, with complete pod set). In 1982-83 and 1983-84, the percentage cover of the leaves by petals was estimated using a key devised originally for cereal rusts (Figure 3; Peterson *et al.*, 1948), to indicate the extent of petal fall and thus possible infection sites for ascospores. In 1984 growth stages were also recorded from April to harvesting, using the key shown on p. 99.

The cultivars in each trial reached full flower at different times. This is clearly illustrated by the 1982 data (Table 32). In this trial several groups could be distinguished. Lingot and Bienvenu flowered earlier and Lirama and Perle

Table 30 : Numbers of ascospores caught per week on rod spore traps in field trials at Sutton Scotney.

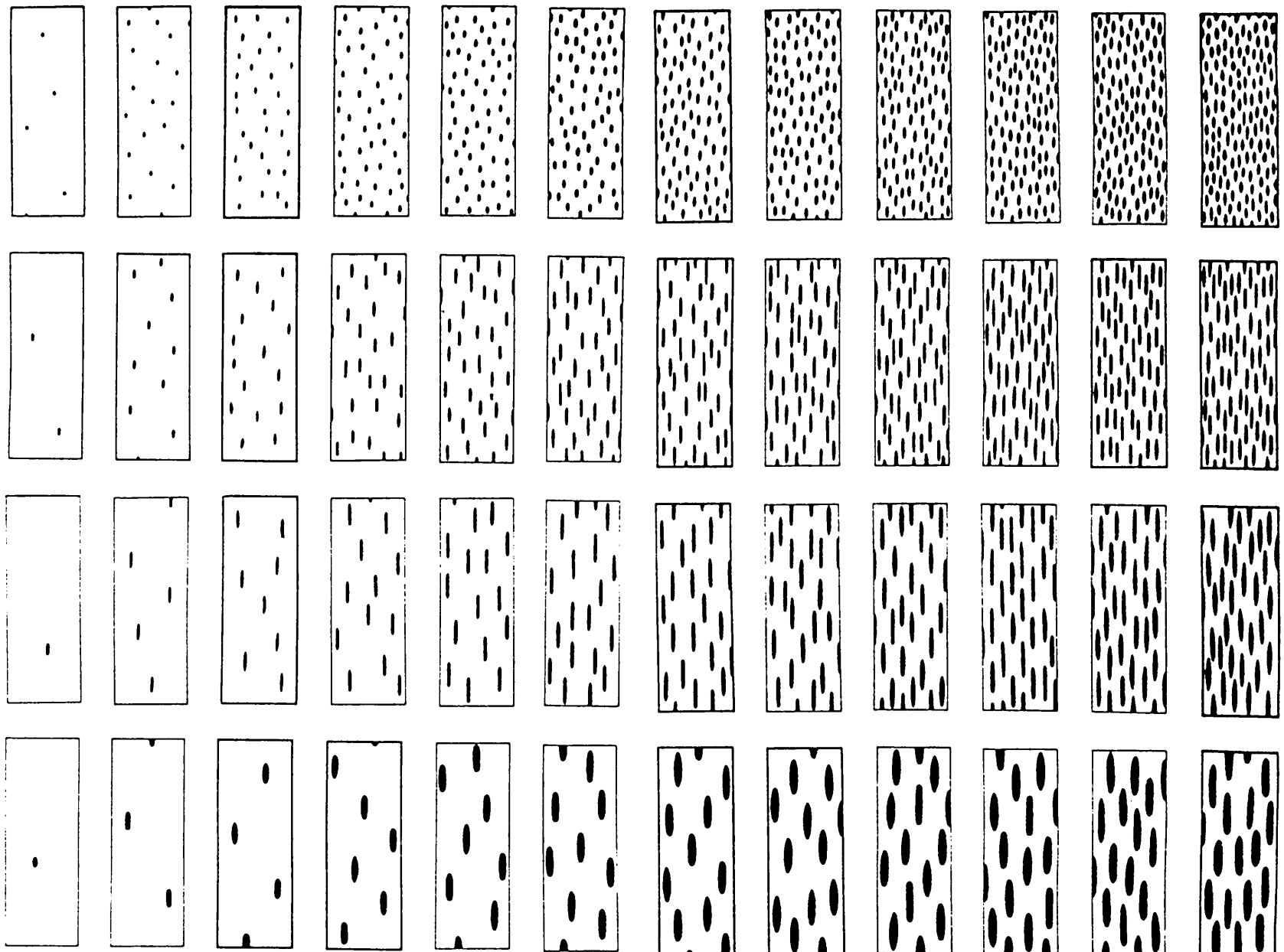
Mean No. ascospores/cm^2 trap surface[a]					
1982		1983		1984	
-		4 May	18	2 May	1.1
-		11 May	15	9 May	0.1
17 May	219	18 May	21	16 May	0.5
24 May	864	25 May	42	23 May	4.6
1 June	695	1 June	26	30 May	15.6
7 June	69	8 June	14	6 June	6.2
14 June	566	15 June	11	13 June	2.8
-		22 June	5	20 June	0.8
-		29 June	5	27 June	0.1
-		7 July	3		

[a] Counts are means of four traps in 1982 and eight traps in 1983 and 1984.

Table 31 : Numbers of ascospores caught per week on rod spore traps in field trials at Sutton Scotney.

Total number of ascospores trapped in					
1982		1983		1984	
Trap	Total count	Trap	Total count	Trap	Total count
12	13389	1	64	1	257
18	16301	2	72	2	117
46	9721	3	127	3	258
52	11857	4	177	4	127
		5	70	5	189
		6	67	6	280
		7	112	7	263
		8	108	8	141

Figure 3 : Key for assessment of % cover of leaves with petals (Peterson *et al.*, 1948).



Standard reading	1	5	10	20	30	40	50	60	70	80	90	100
Actual % of area	0.37	1.85	3.7	7.4	11.1	14.8	18.5	22.2	25.9	29.6	33.3	37.0

Table 32 : Flowering of winter oilseed rape cultivars at Sutton Scotney, 1982.

Cultivar	Mean score on flowering scale[a] at									
	April		May						June	
	22	28	2	7	11	21	24	28	2	9
Lingot	5.0	8.7	9.0	9.0	9.0	16.3	17.2	18.0	18.0	18.0
Bienvenu	5.0	8.5	9.0	9.0	9.0	14.8	16.3	18.0	18.0	18.0
Rafal	4.3	8.2	9.0	9.0	9.0	16.0	17.0	18.0	18.0	18.0
Jupiter	3.3	6.5	8.7	9.0	9.0	13.0	15.5	17.2	18.0	18.0
Semu 13/79	3.3	6.3	8.5	9.0	9.0	14.3	16.0	17.5	18.0	18.0
Fiona	2.0	4.8	8.5	9.0	9.0	13.8	16.0	17.2	18.0	18.0
St 1/80a	2.0	4.8	7.3	9.0	9.0	12.5	14.8	17.0	18.0	18.0
Jet Neuf	1.8	6.3	9.0	9.0	9.0	14.3	15.8	18.0	18.0	18.0
Elvira	1.8	4.0	7.3	9.0	9.0	12.8	14.8	17.0	18.0	18.0
Ledark	1.2	4.0	7.8	9.0	9.0	14.8	16.0	17.0	18.0	18.0
Korina	1.2	4.0	7.5	9.0	9.0	14.0	16.0	17.7	18.0	18.0
Valdor	1.0	3.0	6.8	9.0	9.0	12.3	15.0	17.0	17.0	18.0
Norli	1.0	2.8	5.8	9.0	9.0	13.3	15.0	17.0	18.0	18.0
Vigor	0.5	2.3	4.5	8.2	9.0	11.0	14.8	16.8	17.0	18.0
Lirama	0.5	1.8	4.0	8.2	9.0	11.3	14.0	16.0	17.2	18.0
Perle	0.5	1.2	3.3	7.3	9.0	10.2	13.8	15.8	17.0	18.0

[a] Values are means over four blocks on scale 0-18 where 0 = no flowers; 9 = full flowering; 18 = virtually no flowers left.

—— main flowering period

---- end of flowering

flowered later than the other cultivars. Jet Neuf occupied a position mid-way between these extremes.

Variation in the time of flowering was also indicated by data for percentage cover of plants with petals in 1983 (Table 33) and 1984 (Table 34) and assessments of growth stages in 1984 (Table 35), using the key of Harper & Berkenkampf (1975; Figure 4).

Additional data on disease incidence. In 1984, there was only one (final) assessment of stem rot but in 1982 and 1983 the incidence of stem rot was recorded, using the cane method (Section 2.2, p. 75) on two to three occasions. These assessments are shown in Tables 36 and 37. The data illustrate the wide range in apparent susceptibility of the cultivars under test, with Jet Neuf and Bienvenu amongst those with the highest disease incidence.

An assessment was also made of the unusual occurrence of winter kill by *S. sclerotiorum* in January/February 1984 until the end of March. (This was reported in the UK for the first time in a total of seven crops in the South East and is described further in Discussion). This winter kill was recorded - usually once a week - as the percentage area of bare ground in each plot due to the collapse of plants following fungal attack by the fungus.

In 1984, the amount of winter kill was considerable within some cultivars like Mikado, Liradonna and Barbara (Table 38). However, by 5 March the plants had started stem extension and appeared to have compensated at this stage for plants lost through winter kill . On some, less-affected plants, the spread of mycelium may also have been limited by a period of colder weather from 7 to 30 March.

Table 33 : Percentage cover of petals 1982-83 at Sutton Scotney.

Cultivar	Date of assessment 1983			
	25 May	1 June	8 June	15 June
Pamela	2	2	2	0
Norli	2	2	2	2
Elvira	2	2	2	0
Darmor	2	2	0	2
Diander	2	2	2	0
Brittander	5	5	2	0
Fiona	5	2	0	2
Korina	10	5	2	2
Lirabella	10	2	2	0
Belinda	10	5	2	0
Rafal	10	5	2	2
Tandem	10	5	2	2
Lingot	10	2	2	2
Bienvenu	10	2	2	2
Chrysander	10	5	2	2
Jet Neuf	15	2	2	2

Table 34 : Percentage cover of leaves with petals in plots of winter oil-seed rape cultivars at Sutton Scotney, 1984.

Cultivar	May				June		
	9	16	23	30	6	13	20
• Bienvenu	2	15	40	5	2	0	0
Mikado	2	30	30	5	2	0	0
• Fiona	5	15	30	20	2	2	0
Liradonna	2	15	30	15	2	0	0
Barbara	2	15	40	30	5	0	0
Belinda	2	20	40	20	2	0	0
• Rafal	2	15	50	5	2	0	0
Carola	2	15	40	5	2	2	0
Pamela	2	15	40	5	0	0	0
Lirabella	2	25	25	5	2	0	0
Falk	2	15	30	10	2	0	0
Diander	2	30	40	10	2	0	0
• Korina	2	15	40	10	2	0	0
• Jet Neuf	2	10	25	10	2	0	0
Jem	2	15	30	40	2	2	0
Darmor	0	2	10	30	5	5	0

• 1982 cultivars

Table 35 : Growth stages of winter oilseed rape cultivars at Sutton Scotney, 1984.

Cultivar	April		May					June			
	16	25	2	9	16	23	30	6	13	20	27
• Bienvenu	3.2	4.1	4.2	4.2	4.2	4.3	4.4	5.1	5.2	5.2	5.2
Mikado	3.2	3.3	4.2	4.2	4.2	4.3	4.4	5.1	5.2	5.2	5.2
• Fiona	3.2	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.2	5.2	5.2
Liradonna	3.2	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.2	5.2	5.2
Barbara	3.1	3.3	4.1	4.2	4.2	4.3	4.4	4.4	5.1	5.2	5.2
Belinda	3.1	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.1	5.2	5.2
• Rafal	3.2	3.3	4.1	4.1	4.2	4.3	4.4	5.1	5.2	5.2	5.4
Carola	3.2	3.2	4.1	4.1	4.2	4.3	4.4	5.1	5.2	5.2	5.2
Pamela	3.2	3.3	4.1	4.1	4.2	4.3	4.4	5.1	5.1	5.2	5.2
Lirabella	3.2	3.3	4.1	4.1	4.2	4.3	4.4	5.1	5.2	5.2	5.2
Falk	3.2	3.2	4.1	4.1	4.2	4.3	4.4	5.1	5.2	5.2	5.2
Diander	3.1	3.3	4.1	4.1	4.2	4.3	4.4	5.1	5.1	5.2	5.2
• Korina	3.1	3.2	4.1	4.1	4.2	4.3	4.4	5.1	5.2	5.2	5.2
• Jet Neuf	3.1	3.2	4.1	4.1	4.2	4.3	4.4	5.1	5.2	5.2	5.2
Jem	3.1	3.3	4.1	4.1	4.2	4.3	4.4	5.1	5.2	5.2	5.2
Darmor	3.1	3.2	3.3	4.1	4.1	4.2	4.4	4.4	5.2	5.2	5.2

• 1982 cultivars

Figure 4 : Growth stages in oilseed rape (Harper & Berkenkampf, 1975).

Descriptions are based on the main stem

Stage		
0	Pre-emergence	vegetative
1	Seedling	
2	Rosette	
	2.1 First true leaf expanded	
	2.2 Second true leaf expanded (add 0.1 for each additional leaf)	
3	Bud	
	3.1 Inflorescence visible at centre of rosette	
	3.2 Inflorescence raised above level of rosette	
	3.3 Lower buds yellowing	
4	Flower	reproductive
	4.1 First flower open	
	4.2 Many flowers opened, lower pods elongating	
	4.3 Lower pods starting to fill	
	4.4 Flowering complete, seeds enlarging in lower pods	
5	Ripening	
	5.1 Seeds in lower pods full size, translucent	
	5.2 Seeds in lower pods green	
	5.3 Seeds in lower pods green-brown mottled	
	5.4 Seeds in lower pods brown	
	5.5 Seeds in all pods brown, plant senescent	

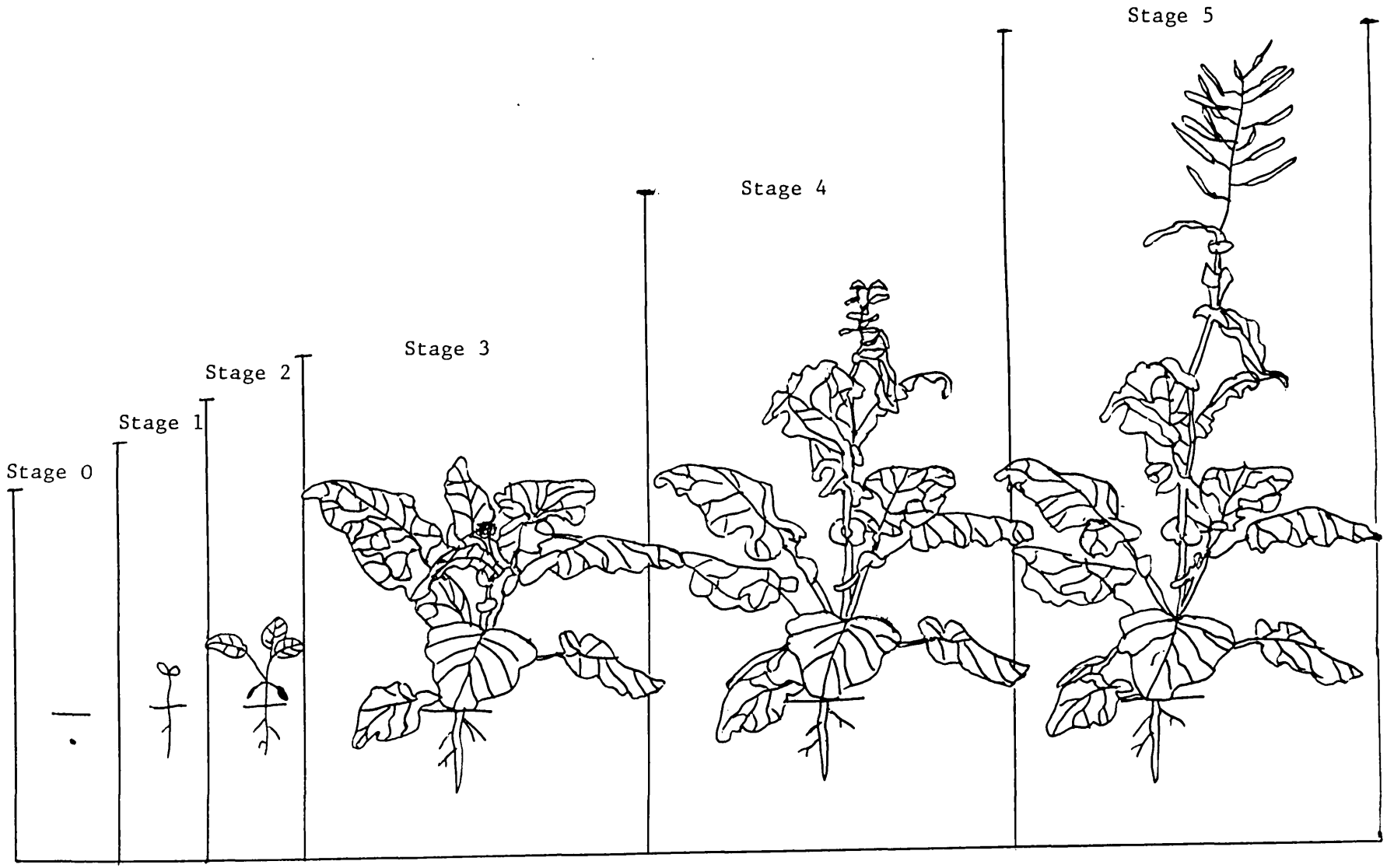

Stage 0
Stage 1
Stage 2
Stage 3
Stage 4
Stage 5

Table 36 : Incidence of stem rot in winter oilseed rape cultivars at Sutton Scotney, 1982.

Cultivar	Mean % plants with stem rot on	
	7 June	5 July
Lingot	5.7 a	21.5 a
Perle	5.4 a	25.3 a
Lirama	6.5 ab	27.1 a
Ledark	21.1 bcd	31.4 ab
Norli	18.0 abcd	32.0 ab
Valdor	22.0 cd	33.3 ab
Jupiter	13.6 abcd	39.6 bc
Vigor	19.3 bcd	39.7 bc
Rafal	25.5 cd	40.3 bc
St 1/80a	14.6 abcd	43.9 bc
Semu 13/79	11.0 abc	45.7 bc
Elvira	27.9 d	47.6 bc
Bienvenu	47.7 e	53.2 cd
Korina	27.2 cd	53.3 cd
Fiona	29.8 d	54.8 cd
Jet Neuf	58.4 e	67.9 d

Values for 7 June are means of two blocks (II + IV); those for 5 July are means of four blocks.

Values with no letter in each column the same are significantly different ($\underline{P} = 0.05$), Duncans Multiple Range Test using arcsin $\sqrt{\%}$ transformed data.

Table 37 : Incidence of stem rot in winter oilseed rape cultivars at Sutton Scotney, 1983.

Cultivar	Mean % plants with stem rot on		
	1 June	15 June	21 July
Darmor	0	0	0
Tandem	0	0	0
Pamela	0	4	2
Belinda	0	4	4
Elvira	0	4	4
Fiona	4	4	4
Korina	0	4	4
Lingot	0	0	4
Brittander	0	4	6
Chrysander	0	4	6
Diander	4	4	8
Lirabella	4	8	8
Norli	0	0	8
Rafal	4	8	8
Bienvenu	4	8	12
Jet Neuf	4	16	30

Table 38 : Incidence of winter kill by *Sclerotinia sclerotiorum* in winter oilseed rape cultivars at Sutton Scotney, 1984.

Cultivar	No. leaves[a] on 10 Feb.	% Winter kill[b] on			No. leaves on 5 Mar.
		10 Feb.	16 Feb.	5 Mar.	
Mikado	9-10	10	15	25	10-11
Liradonna	11-12	10	15	20	10-11
Barbara	11-12	10	15	20	10-11
Rafal	8-9	5	10	10	9-10
Jet Neuf	9-10	5	10	10	11-12
Pamela	10-11	5	5	10	11-12
Diander	11-12	5	10	10	10-11
Belinda	11-12	5	10	10	11-12
Carola	6-7	2	5	10	9-10
Darmor	9-10	2	5	10	9-10
Korina	9-10	2	5	10	11-12
Falk	9-10	2	10	10	12-13
Bienvenu	10-11	2	5	10	11-12
Lirabella	10-11	2	5	10	9-10
Jem	10-11	2	10	10	11-12
Fiona	11-12	2	10	10	10-11

[a] Measured as an indication of growth stage - range of 15 plants.

[b] Measured as % bare ground as compared to green leaves.

Relationship between incidence of stem rot and counts of airborne ascospores and flowering of the oilseed rape. There were considerable differences in the incidence of stem rot in the trials at Sutton Scotney over the three seasons, as indicated by data for five cultivars common to the three trials (Table 39). There were also marked differences in the amounts of ascospores trapped in the three seasons which are reflected by the maximum catches per cm^2 of trap surface: 864 ascospores in 1982, 42 in 1983 and 16 in 1984 (Table 30). Limitation in ascospore inoculum during 1983 and 1984, compared with its abundance in 1982, could account for the overall seasonal differences in disease incidence.

Differences between cultivars at this site during one season are less easily explained. However, in 1982 there appeared to be an association between the time of flowering and final incidence of stem rot. This is shown in Table 40, where the mean percentage stem rot has been calculated for the four groups of cultivars indicated by ranking them in order of flowering (Table 32). Similar associations using data for cover of leaves with petals in 1983 and 1984 were much less apparent (Tables 41 and 42). Although there were some indications that disease was linked with high levels of petal cover there was considerable variation and the amounts of stem rot were generally low.

(b) Trials at Silwood Park

Production of apothecia. Numbers of apothecia which developed from sclerotia placed in nylon-mesh bags beneath cultivars were counted about every 7 days only during the 1983-84 trial. These data are shown in Table 43. Apothecia were first seen on 23 April 1984, one month earlier than at Sutton Scotney, and peak production occurred on 19 May. The numbers

Table 39 : Disease incidence on five oilseed rape cultivars grown in trials at Sutton Scotney, 1981-84[a].

Cultivar	% Plants with stem rot in		
	1984	1983	1984
Jet Neuf	67.9	30	3.9
Bienvenu	53.2	12	10.3
Korina	53.5	4	8.3
Rafal	40.3	8	9.4
Fiona	54.8	4	1.9
Means	53.9	11.6	6.8

[a] Data from Table 20, Section 2.3.1.

Table 40 : Relationship between time of flowering and incidence of stem rot with oilseed rape cultivars at Sutton Scotney, 1982.

Flowering group	Cultivar	Final % stem rot[a]	Mean % stem rot for flowering group
1. Flowering at 22 April	Lingot	21.5	37.4
	Bienvenu	53.2	
2. Flowering at 28 April	Rafal	40.3	48.7
	Jupiter	39.6	
	Semu 13/79	45.7	
	Fiona	54.8	
	St 1/80a	44.0	
	Jet Neuf	67.9	
3. Flowering at 2 May	Elvira	47.6	39.1
	Ledark	31.4	
	Korina	53.3	
	Valdor	33.3	
	Norli	32.0	
	Vigor	36.7	
4. Flowering at 7 May	Lirama	27.1	26.3
	Perle	25.3	

[a] Data of Table 20, Section 2.3.1.

Table 41 : Relationship between maximum cover of leaves with petals and incidence of stem rot in oilseed rape cultivars at Sutton Scotney, 1983.

Cultivar	% Petal cover 25 May[a]	Final % stem rot[b]	Mean % stem rot for group
Jet Neuf	15	30	30
Korina	10	4	
Lirabella	10	8	
Belinda	10	4	
Rafal	10	8	
Tandem	10	0	5.75
Lingot	10	4	
Bienvenu	10	12	
Chrysander	10	6	
Brittander	5	6	5
Fiona	5	4	
Pamela	2	2	
Norli	2	8	
Elvira	2	4	4.5
Darmor	2	0	
Diander	2	8	

[a] Data of Table 33.

[b] Data of Table 20, Section 2.3.1.

Table 42 : Relationship between maximum cover of leaves with petals and incidence of stem rot in oilseed rape cultivars at Sutton Scotney, 1984.

Cultivar	% Petal cover 23 May[a]	Final % stem rot[b]	Mean % stem rot for group
Rafal	50	9.4	9.4
Bienvenu	40	10.3	
Barbara	40	0	
Belinda	40	1.9	
Carola	40	5.6	4.8
Pamela	40	1.8	
Diander	40	5.7	
Korina	40	8.3	
Mikado	30	3.6	
Fiona	30	1.9	
Liradonna	30	5.9	3.8
Falk	30	5.5	
Jem	30	2.0	
Lirabella	25	0	2.0
Jet Neuf	25	3.9	
Darmor	10	3.8	3.8

[a] Data of Table 34.

[b] Data of Table 20.

Table 43 : Production of apothecia at Silwood Park, 1984.

Cultivar	No. of apothecia from five bags (100 sclerotia) on							Total 'apothecia weeks'
	April	May				June		
	23	5	12	19	28	6	11	
Bienvenu	5	0	5	18	41	24	18	111
Rafal	12	27	29	19	51	37	18	193
Carola	20	29	38	83	73	30	9	282
Darmor	1	9	23	42	60	7	0	142
Pamela	30	39	47	73	56	12	4	265
Mikado	11	30	61	66	82	25	10	285
Lirabella	26	36	61	93	83	38	15	352
Diander	5	30	88	76	111	60	20	390
Korina	0	7	25	46	49	6	3	136
Jet Neuf	6	17	18	38	36	13	2	130
Falk	11	39	78	90	66	21	6	311
Liradonna	12	19	28	70	30	9	0	168
Barbara	3	4	32	38	14	5	0	96
Fiona	15	43	43	59	47	23	10	240
Belinda	15	26	40	36	71	17	2	207
Jem	63	44	88	102	44	13	10	364
Doral	84	83	68	53	12	0	0	300
Mean no. apothecia	18.8	28.4	45.4	58.9	54.5	20.0	7.5	

produced within each plot varied considerably on each date but reflected the overall peak of production. There were no apparent differences between plots.

Counts of airborne ascospores. In the 1983-84 trial only, rod spore traps were placed centrally within each cultivar plot directly above a bag of sclerotia and were exposed for weekly periods. Ascospores were first trapped on 30 April and the maximum number was recorded on 4 June (Table 44). Generally the numbers were low relative to the numbers of apothecia produced. There were also considerable differences in the numbers of ascospores caught in each trap in any one week and over the whole period of ascospore release. The regression of total numbers of ascospores trapped above each plot on 'apothecial weeks' was not significant ($P > 0.1$), possibly because within the small area of the trial the wind-blown ascospores readily became distributed throughout the plots.

Growth and flowering of the oilseed rape. Growth stage and petal cover were assessed once a week in both the 1982-83 and 1983-84 trials,using methods as described for Sutton Scotney.

The cultivars in each trial reached full flower at different times, with a corresponding time difference in petal cover of leaves. This can be seen in 1983 (Tables 45 and 46) and 1984 (Tables 47 and 48). Several groups could be identified. In 1983, Lingot, Bienvenu and Elvira flowered earlier while in 1984 Bienvenu, Rafal, Mikado and Falk flowered earlier. In both years Darmor flowered later and Jet Neuf occupied a position midway between the extremes.

Petal cover was both lower in percentage and shorter in duration in 1983 than 1984.

Table 44 : Ascospores at Silwood Park, 1984.

Cultivar	No. of ascospores caught per cm^2 trap surface in week ending								Totals
	April	May				June			
	30	7	14	21	28	4	11	18	
Diander	2.2	2.8	1.8	1.8	1.6	4.4	1.0	0.4	16
Doral	0	1.2	6.0	1.6	2.2	4.8	1.0	0	16.8
Brittander	2.8	1.2	1.8	1.0	0.8	2.8	1.6	0.4	10.4
Jem	0.4	2.0	1.6	0.4	0.2	2.2	2.2	0.2	9.2
Belinda	0.6	1.8	1.4	0.8	0.8	0.6	0	0	9.4
Korina	1.0	0.8	0.8	3.0	2.8	1.6	0	0	11.4
Bienvenu	0	1.6	3.2	1.0	1.2	1.2	0	0	13.4
Rafal	1.6	1.8	2.4	0.8	2.0	1.8	0	0	11.4
Fiona	0.2	1.4	8.2	2.0	4.0	1.0	0	0	20.4
Falk	0	0.8	4.4	3.0	3.2	2.0	1.8	0	18.4
Lirabella	0	1.0	1.4	3.2	3.0	1.2	0.2	0	13.8
Mikado	0.8	1.0	1.6	2.4	17.8	0.8	0	0	30.4
Carola	1.2	1.0	2.0	5.0	3.8	0.4	0	0	21.0
Pamela	0.4	4.0	2.6	2.4	1.2	1.2	0	0	16.6
Barbara	0	7.8	0.8	3.6	4.0	0.6	0	0	21.2
Darmor	0.8	0.4	2.4	2.2	7.2	0.8	0	0	14.6
Jet Neuf	0	0.8	2.2	2.0	4.4	1.6	0	0	13.6

Table 45 : Growth stages of winter oilseed rape cultivars at Silwood Park, 1983.

Cultivar	Date of assessment											Harvest date July
	April	May			June				July			
	28	4	16	25	3	9	20	30	6	11	17	
Lingot	4.3	4.3	4.3	4.4	4.4	4.4	5.2	5.3	5.3	5.4		15
Bienvenu	4.2	4.2	4.3	4.4	4.4	4.4	5.2	5.3	5.4			8
Elvira	4.2	4.2	4.3	4.3	4.4	4.4	5.2	5.2	5.3	5.3	5.4	16
Brittander	4.1	4.2	4.3	4.4	4.4	4.4	5.2	5.2	5.2	5.2	5.4	18
Lirabella	4.1	4.2	4.3	4.4	4.4	4.4	5.2	5.2	5.3	5.3	5.4	17
Pamela	4.1	4.2	4.3	4.3	4.4	4.4	5.2	5.2	5.3	5.3	5.4	18
Belinda	4.1	4.1	4.3	4.3	4.4	4.4	5.2	5.2	5.4	5.4		11
Jet Neuf	4.1	4.1	4.3	4.4	4.4	4.4	5.2	5.2	5.3	5.4		16
Diander	4.1	4.1	4.3	4.4	4.4	4.4	5.2	5.2	5.3	5.4		16
Doral	4.1	4.1	4.3	4.4	4.4	4.4	5.2	5.2	5.3	5.3	5.4	17
Fiona	4.1	4.1	4.3	4.4	4.4	4.4	5.2	5.2	5.3	5.4	5.4	18
Norli	3.3	4.1	4.3	4.4	4.4	4.4	5.2	5.2	5.3	5.3	5.4	18
Korina	4.1	4.1	4.2	4.3	4.4	4.4	5.1	5.2	5.2	5.3	5.4	18
Rafal	4.1	4.1	4.2	4.3	4.4	4.4	5.2	5.2	5.3	5.4	5.4	18
Chrysander	4.1	4.1	4.2	4.3	4.3	4.4	5.1	5.2	5.3	5.3	5.4	18
Tandem	3.2	4.1	4.2	4.3	4.4	4.4	4.4	5.2	5.2	5.3	5.4	18
Darmor	3.2	3.3	4.2	4.3	4.4	4.4	5.2	5.2	5.2	5.3	5.4	18

Table 46 : Percentage petal cover at Silwood Park, 1983.

Cultivar	Date of assessment				
	May			June	
	13	18	25	3	6
Lingot	25	20	35	5	-
Bienvenu	5	5	10	5	-
Elvira	10	5	10	5	-
Brittander	5	5	10	5	-
Lirabella	10	10	20	15	5
Pamela	2	2	10	5	-
Belinda	2	5	25	15	-
Jet Neuf	30	40	40	15	5
Diander	5	10	20	15	5
Doral	2	5	10	5	-
Fiona	10	10	15	15	-
Korina	10	10	20	5	-
Rafal	10	15	20	5	-
Chrysander	15	15	10	10	-
Norli	2	2	5	5	-
Tandem	2	5	10	5	-
Darmor	2	2	5	10	-

Table 47 : Growth stages of winter oilseed rape cultivars at Silwood Park, 1984.

Cultivar	Date of assessment									
	April			May					June	
	10	17	24	1	8	15	23	28	1	11
Bienvenu	3.2	3.3	4.1	4.2	4.3	4.3	4.4	4.4	5.1	5.2
Rafal	3.2	3.3	4.1	4.2	4.3	4.3	4.4	4.4	5.1	5.2
Mikado	3.2	3.3	4.1	4.2	4.2	4.3	4.3	4.4	5.1	5.2
Falk	3.2	3.2	3.3	4.2	4.2	4.2	4.4	4.4	5.1	5.1
Barbara	3.2	3.2	3.3	4.1	4.2	4.2	4.4	4.4	5.1	5.1
Belinda	3.2	3.2	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.1
Brittander	3.2	3.2	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.2
Korina	3.2	3.2	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.1
Lirabella	3.1	3.2	3.3	4.1	4.2	4.2	4.4	4.4	5.1	5.1
Jet Neuf	3.1	3.2	3.2	4.1	4.2	4.2	4.3	4.4	5.1	5.2
Carola	3.1	3.2	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.1
Diander	3.1	3.2	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.1
Doral	3.1	3.2	3.3	4.1	4.2	4.3	4.3	4.4	5.1	5.1
Fiona	3.1	3.2	3.3	4.1	4.2	4.3	4.3	4.4	5.1	5.1
Jem	3.1	3.2	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.1
Pamela	3.1	3.2	3.3	4.1	4.2	4.2	4.3	4.4	5.1	5.1
Darmor	3.1	3.2	3.3	3.3	4.1	4.1	4.2	4.4	4.4	5.1

Table 48 : Percentage petal cover at Silwood Park, 1984.

Cultivar	Date of assessment								
	May							June	
	5	8	12	15	19	23	28	6	11
Bienvenu	10	10	15	25	60	50	20	5	2
Rafal	5	10	25	10	60	50	20	5	2
Mikado	10	10	25	20	30	30	50	2	2
Falk	5	5	10	10	60	40	40	5	2
Barbara	2	2	10	15	60	40	20	10	2
Belinda	5	5	5	10	60	40	30	5	2
Brittander	5	5	5	15	50	30	20	5	2
Korina	2	2	10	15	40	40	20	5	2
Lirabella	5	5	10	10	50	40	60	5	2
Jet Neuf	2	2	10	15	60	40	40	10	5
Carola	2	2	10	5	35	40	30	2	2
Diander	2	2	10	10	25	40	30	10	2
Doral	2	2	2	5	30	30	15	10	2
Fiona	2	5	5	10	50	30	40	5	2
Jem	2	5	10	15	60	30	30	5	2
Pamela	2	2	10	10	50	50	40	5	2
Darmor	0	0	2	5	10	15	20	40	5

Additional data on disease incidence. In 1983, lesions were first noted on 26 May. By then nearly one-quarter of the Jet Neuf plants were infected and only slightly less of Fiona and Bienvenu. Four weeks later the incidence in plots of Jet Neuf and Bienvenu had risen to 70% and 90% respectively, but disease increase was less on Fiona reaching only 46% by 23 June. Chrysander, Korina and Tandem were least affected (Table 49). In 1984, disease levels were low and so only a final assessment was made.

Relationships between incidence of stem rot, counts of airborne spores and flowering of the oilseed rape. Disease incidence at Silwood was generally high in 1983 and very low in 1984. As at Sutton Scotney this difference was probably related to numbers of airborne ascospores, but these were monitored only in cultivar plots in 1984 so comparisons cannot be made directly. However, data from other trials at Silwood Park (Section 3.2) indicate that in 1983 the peak daily catch was 18,018 ascospores whereas in 1984 (from a similar inoculum of sclerotia) it was 4,162.

The factors resulting in the variation in disease incidence amongst cultivars in 1983 are thus of most interest. When the relationship between number of days at petal fall and final disease incidence was examined, using the Spearman rank coefficient, no significant association was found (Table 50). This suggested that factors other than the duration of petal fall per se were important in determining the incidence of disease. A further test using total (accumulated) % petal cover, indicated in Table 46, as a measure of both extent and duration of petal, gave only a slight improvement in the correlation coefficient (Table 51). However, when petal cover on each date was weighted by multiplying the value by the numbers of ascospores trapped in the corresponding week (data of Section 3.2) a significant

Table 49 : Disease development at Silwood 1983.

Cultivar	% Disease on				
	May	June			
	26	3	9	16	23
Fiona	22	36	42	42	46
Belinda	22	56	76	90	90
Norli	16	42	40	54	60
Brittander	16	38	54	54	60
Lirabella	10	44	60	60	64
Pamela	6	20	30	32	34
Elvira	4	20	30	30	40
Bienvenu	6	28	28	30	38
Lingot	8	34	42	42	44
Diander	0	6	22	24	26
Doral	0	6	18	32	36
Darmor	0	8	12	16	26
Korina	4	4	8	12	12
Chrysander	0	0	6	8	10
Rafal	0	24	24	38	38
Tandem	0	4	14	20	18
Jet Neuf	24	44	52	70	70

Table 50 : Association between the number of days at petal fall of each cultivar and the resulting disease incidence 1982-83.

Cultivar	Rankings		
	Number of days at GS 4.2 and 4.3	Disease incidence	di
Fiona	5	12	- 7
Belinda	14	17	- 3
Norli	2	13.5	-11.5
Brittander	13	13.5	- 0.5
Lirabella	12	15	- 3
Pamela	16	6	10
Elvira	17	10	7
Bienvenu	15	8.5	6.5
Lingot	9	11	- 2
Diander	4	4.5	- 0.5
Doral	1	7	- 6
Darmor	5	4.5	0.5
Korina	8	2	6
Chrysander	9	1	8
Rafal	11	8.5	2.5
Tandem	3	3	0
Jet Neuf	7	16	- 9

$\Sigma x^2 = 408$

$\Sigma y^2 = 406.5$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma(di^2)}{2\sqrt{\Sigma x^2 \,.\, \Sigma y^2}} = \frac{408 + 406.5 - 620.5}{2\sqrt{408 \times 406.5}} = \frac{194}{814.5}$$

$$= 0.24 \text{ n.s.}$$

Table 51 : Association between % disease and value for petal cover (duration and extent).

Cultivar	Disease incidence	Petal cover	di
Fiona	12	12.5	- 0.5
Belinda	17	10	7
Norli	13.5	1	12.5
Brittander	13.5	6.5	7
Lirabella	15	15	0
Pamela	6	2.5	3.5
Elvira	10	8	2
Bienvenu	8.5	6.5	2
Lingot	11	16	- 5
Diander	4.5	12.5	- 8
Doral	7	4.5	2.5
Darmor	4.5	2.5	2
Korina	2	9	- 7
Chrysander	1	12.5	-11.5
Rafal	8.5	12.5	- 4
Tandem	3	4.5	- 1.5
Jet Neuf	16	17	- 1

$\Sigma x^2 = 408 - 1.5 = 406.5$ $\Sigma di^2 = 574.5$

$\Sigma y^2 = 408 - 6.5 = 401.5$

$$r_s = \frac{406.5 + 401.5 - 574.5}{2\sqrt{406.5 \times 401.5}}$$

$= 0.289$

$$t = 0.289 \sqrt{\frac{15}{1 - (0.289)^2}}$$

$= 1.169$ $P < 0.1$ n.s.

association was obtained between the rankings of these adjusted values and disease incidence (Table 52). This indicates that disease incidence is related to the duration and extent of petal cover and the number of airborne ascospores in that period.

2.3.3. Effects of stem rot on yield

(a) Sutton Scotney

In 1982 plots were harvested by NIAB and yields of seed and oil were measured for every cultivar.

Comparisons of the yields obtained with those of the same cultivars in other NIAB trials provide the estimates of yield reduction shown in Table 53. Regressions of these estimated yield reductions on incidence of stem rot were highly significant ($P < 0.001$) and are shown in Fig. 5 (seed yield) and Fig. 6 (oil yield). The relationships indicate that a 1% increase in the incidence of stem rot results in 0.42% reduction in yield of seed and 0.49% reduction in yield of oil, averaged over all cultivars.

Due to the low incidence of stem rot in 1983 no assessments of yield were made.

In 1983-84 plots were harvested by taking three 0.25 m^2 quadrats from each cultivar, (two from the areas used for counting apothecia and one centrally in each plot). The plants were placed into brown paper bags (457 x 711 x 838 cm, Cleenol Ltd., Beaumont Road, Banbury, Oxon.) and left to dry. The plants were threshed (with the kind permission of Mr. W. Davenport, I.C.I. at Jealotts Hill) using their Wintersteiger Ear Thresher (F. Walter and H. Wintersteiger, KG Maschinenbau Ried, Innkreis, Austria), and total weights of seed for each quadrat were then obtained.

The results (Table 54) had no correlation either with the incidence of winter kill (Table 38) or with the incidence on 27 June (Table

Table 52 : Association between % disease and value for petal cover x ascospores on 4 dates.

Cultivar	Disease incidence	Petal cover x ascospores	di
Fiona	12	12	0
Belinda	17	15	2
Norli	13.5	1	12.5
Brittander	13.5	6.5	7
Lirabella	15	14	1
Pamela	6	3	3
Elvira	10	8	2
Bienvenu	8.5	6.5	2
Lingot	11	16	- 5
Diander	4.5	13	- 8.5
Doral	7	4.5	2.5
Darmor	4.5	2	2.5
Korina	2	10	- 8
Chrysander	1	9	- 8
Rafal	8.5	11	- 2.5
Tandem	3	4.5	- 1.5
Jet Neuf	16	17	- 1

$\Sigma x^2 = 408 - 1.5 = 406.5$ $\Sigma di^2 = 474.5$

$\Sigma y^2 = 408 - 1.0 = 407$

$$r_s = \frac{406.5 + 407 - 474.5}{2\sqrt{406.5 \cdot 407}}$$

$= 0.417$

$$t = 0.417 \sqrt{\frac{17-2}{1 - (0.417)^2}}$$

$= 1.777$ $P < 0.05$

Table 53 : Comparison of the Sutton Scotney trial 1981-82 with other NIAB trials yield results.

Cultivar	Percentage reduction in yield of		Incidence of *Sclerotinia* (mean of 7 June and 5 July)
	Seed	Oil	
Perle	11.4	6.7	13.4
Lingot	21.8	19.5	13.6
Lirama	25.7	26.4	18.4
Norli	17.1	16.2	25.0
Semu 13/79	21.9	20.7	25.8
Jupiter	26.3	25.0	26.6
Valdor	19.1	20.0	27.6
Ledark	27.1	26.0	29.0
St 1/80a	23.9	22.5	29.2
Vigor	14.7	12.6	29.5
Rafal	22.8	23.5	30.0
Elvira	24.5	22.9	37.8
Korina	30.4	29.2	40.1
Fiona	27.6	27.7	42.3
Bienvenu	35.6	36.6	53.0
Jet Neuf	37.8	39.4	63.3
Mean	24.2	23.4	31.6

Figure 5 : Effect of *S. sclerotiorum* on seed yield at Sutton Scotney 1982.

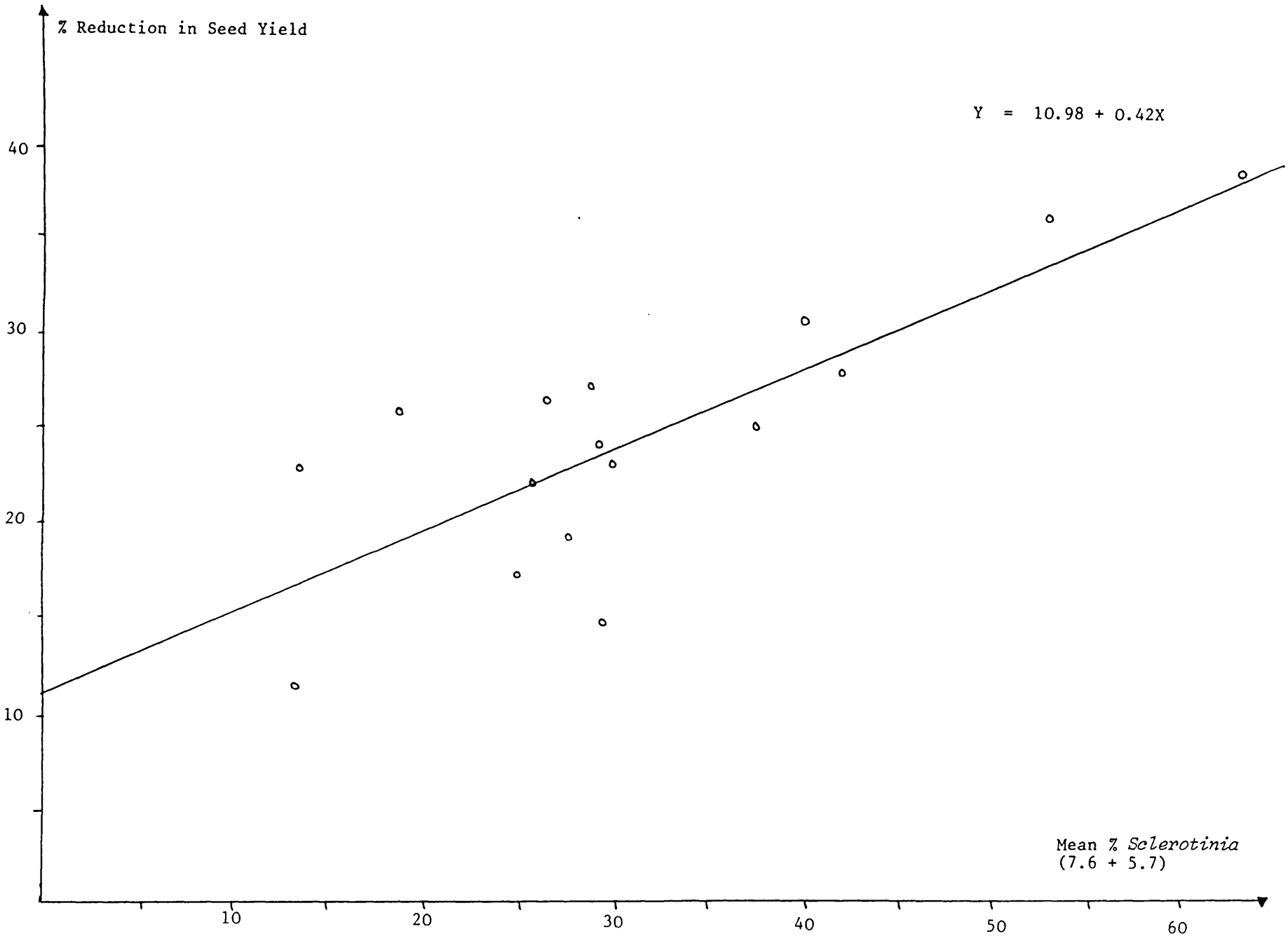

% Reduction in Seed Yield
Y = 10.98 + 0.42X
40
30
20
10
10
20
30
40
50
60
Mean % Sclerotinia
(7.6 + 5.7)

Figure 6 : Effect of *S. sclerotiorum* on oil yield at Sutton Scotney 1982.

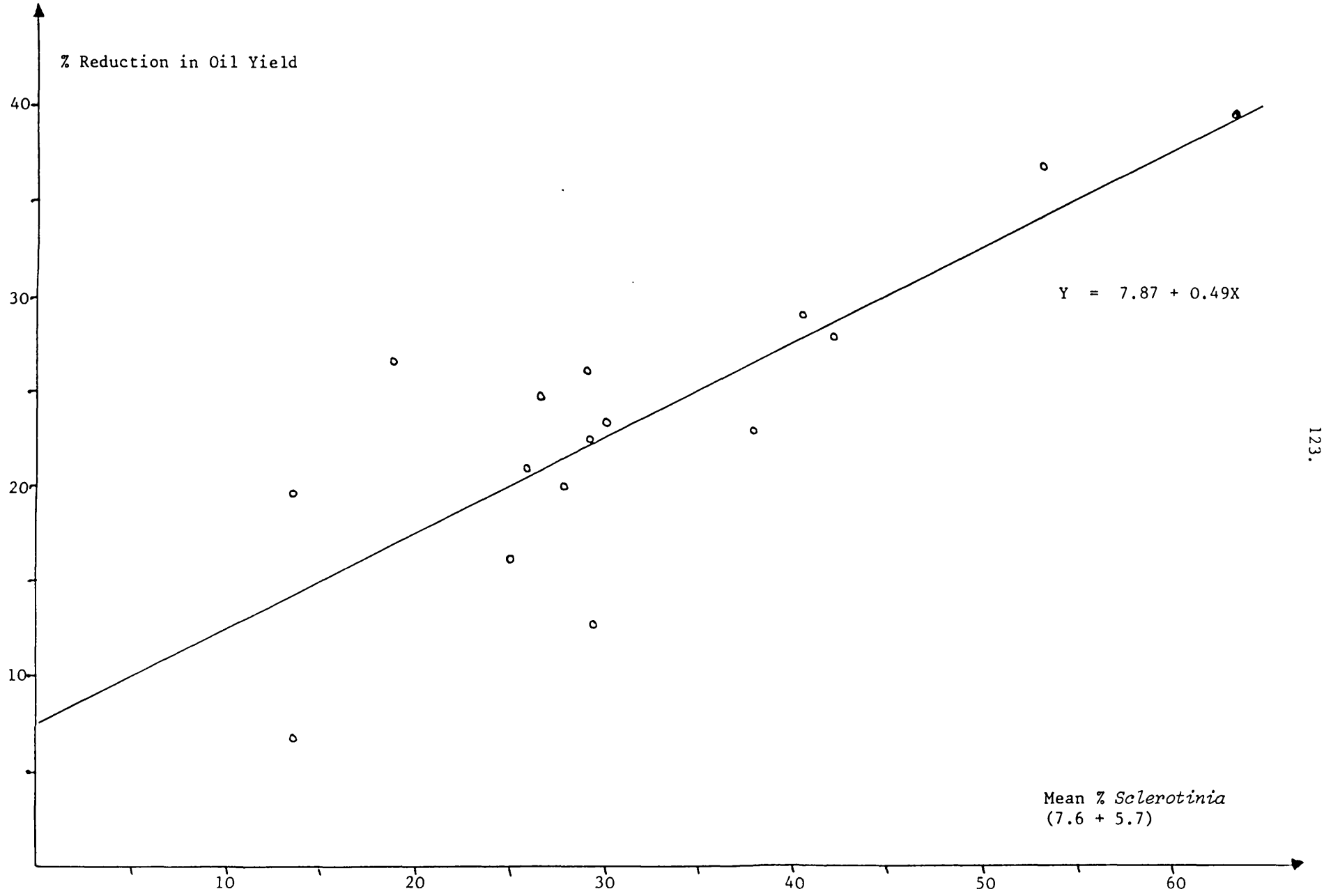

% Reduction in Oil Yield
40
30
20
10
Y = 7.87 + 0.49X
Mean % Sclerotinia
(7.6 + 5.7)
10
20
30
40
50
60

Table 54 : Seed yields at Sutton Scotney 1984.

Cultivar	Replicates g/0.25 m^2			Mean
	Hedge End	Centre	Village End	
Bienvenu	7.09	20.29	28.31	18.56
Rafal	13.61	19.02	23.41	18.68
Carola	12.58	53.61	47.98	38.06
Darmor	24.62	39.2	32.31	32.04
Pamela	14.92	44.5	34.25	31.22
Mikado	17.25	18.17	6.80	14.08
Lirabella	20.09	27.40	14.09	20.53
Diander	37.60	38.28	23.57	33.15
Korina	20.03	36.0	32.48	29.50
Jet Neuf	21.19	25.91	10.60	19.23
Falk	14.0	35.41	37.72	29.04
Liradonna	17.39	36.70	29.63	27.91
Barbara	9.51	46.11	24.45	26.69
Fiona	20.90	42.30	24.53	29.24
Belinda	18.28	23.38	47.81	29.82
Jem	15.67	22.98	14.61	17.75

20). This was using Spearmans Rank Correlation Coefficient.

(b) Silwood Park

The effects of stem rot on pod set and yield were studied in the 1982-83 trial. Fifty plants of each cultivar, distributed throughout the plot, were labelled before apothecia were detected. This number was chosen in view of the suggestion by Scarisbrick *et al.*(1982), that a minimum of 25 plants is required to determine yields of oilseed rape with a reasonable degree of accuracy. Each plant (plus root) was removed when at the same growth stage (5.4) and, if infected, the lengths of all lesions were measured and the numbers of sclerotia on the stem surface were recorded.

The plants were then dried and the number of branches on every plant was counted, plus the number of pods on five healthy and five infected plants per cultivar. After threshing each plant, the seed was collected and weighed. A mixed sample of seed from five healthy plants and a similar sample from five infected plants of each cultivar were counted on a Decca Radar Mastercount to give 1000 Seed Weights.

For most cultivars, the presence of stem rot lesions had no effect on the numbers of pods set but for a few - Lingot, Korina, Rafal - pod set was reduced significantly (Table 55).

Comparisons of seed yields of healthy and infected plants, from the sample of 50 labelled plants,showed considerable effects of stem rot on the yields of all cultivars. Losses ranged from 30% with Norli to 77% for Jet Neuf (Table 56). Seed weight was also reduced, values for percentage loss ranging from 6% for Chrysander to 52% for Belinda (Table 57).

Table 55 : Effect of stem rot lesions on pod numbers, Silwood 1983.

Cultivar	Mean pods/branch		Probability that means differ significantly
	Healthy plants	Infected plants	
Fiona	20.60	19.04	n.s.
Belinda	11.38	8.40	n.s.
Norli	16.92	14.00	n.s.
Brittander	20.10	16.12	n.s.
Lirabella	17.42	14.8	n.s.
Pamela	17.00	14.86	n.s.
Elvira	10.20	8.56	n.s.
Bienvenu	12.10	11.02	n.s.
Lingot	24.54	11.56	$\underline{P}$ = 0.01
Diander	13.54	12.26	n.s.
Doral	21.34	14.9	n.s.
Darmor	11.16	11.06	n.s.
Korina	31.58	19.48	$\underline{P}$ = 0.05
Chrysander	20.66	18.82	n.s.
Rafal	15.20	9.80	$\underline{P}$ = 0.01
Tandem	21.32	13.96	n.s.
Jet Neuf	16.82	8.68	n.s.

Table 56 : Seed yield total from the 50 labelled plants at Silwood 1983.

Cultivar	Healthy plants			Infected plants			% Loss in yield/plant
	Number	Weight	Mean/plant	Number	Weight	Mean/plant	
Fiona	25	244.7	11.65	25	121.9	4.9	58.1
Belinda	8	13.9	1.7	42	46.6	1.1	35.3
Norli	16	63.1	3.9	34	90.7	2.7	30.7
Brittander	14	71.3	5.1	36	84.7	2.4	52.9
Lirabella	15	83.5	5.6	35	127.1	3.6	35.7
Pamela	27	146.8	5.4	23	62.8	2.7	50.0
Elvira	35	119.2	3.4	15	30.1	2.0	37.8
Bienvenu	28	123.4	4.6	22	60.8	2.8	39.1
Lingot	34	95.0	2.8	16	27.4	1.7	39.3
Diander	44	217.5	4.9	6	17.9	3.0	38.8
Doral	34	218.4	6.4	16	67.8	4.2	34.4
Darmor	38	209.0	5.5	12	36.5	3.0	45.5
Korina	45	280.1	6.2	5	6.2	1.2	80.2
Chrysander	41	195.7	4.8	9	18.7	2.1	56.3
Rafal	18	84.5	4.7	32	38.0	1.2	74.5
Tandem	35	164.7	4.7	15	33.7	2.3	51.1
Jet Neuf	21	155.1	7.4	29	50.3	1.7	77.0

Table 57 : Thousand seed weight from Silwood 1983.

Cultivar	Mean of 5 replicates ± SD		Percentage loss in weight
	Healthy	Infection	
Fiona	4.61 ± 0.03	3.82 ± 0.06	17.14
Belinda	6.06 ± 0.13	2.92 ± 0.17	51.82
Norli	4.23 ± 0.36	3.12 ± 0.11	26.24
Brittander	4.74 ± 0.10	4.04 ± 0.09	14.77
Lirabella	4.57 ± 0.14	3.69 ± 0.08	19.26
Pamela	5.00 ± 0.5	3.62 ± 0.03	27.6
Elvira	4.80 ± 0.1	3.23 ± 0.07	32.71
Bienvenu	4.18 ± 0.04	3.50 ± 0.05	16.27
Lingot	4.19 ± 0.06	3.24 ± 0.10	22.67
Diander	5.13 ± 0.11	3.94 ± 0.16	23.20
Doral	4.79 ± 0.08	4.17 ± 0.27	12.94
Darmor	5.67 ± 0.25	4.27 ± 0.43	24.69
Korina	4.88 ± 0.19	4.17 ± 0.13	14.55
Chrysander	4.87 ± 0.08	4.57 ± 0.08	6.16
Rafal	5.07 ± 0.12	3.64 ± 0.96	28.21
Tandem	5.24 ± 0.08	3.79 ± 0.21	27.67
Jet Neuf	6.07 ± 0.15	5.00 ± 0.13	17.63

2.3.4. Lesion development

(a) Sutton Scotney

At the final disease assessment in 1983, five diseased plants were taken from each plot (except Tandem, where only one diseased plant was detected) and the lengths of lesions were measured.

There was considerable variation in lesion size, ranging from 110 mm on one plant of Fiona to 492 mm on a plant of Korina (Appendix XXVII). Mean lengths ranged from 135 mm on Lingot to about 322 mm on Korina. Between these extremes there was a gradation in mean lesion length on the various cultivars (Appendix XXVII).

(b) Silwood Park

In the 1982-83 trial, 10 plants of each cultivar were labelled as soon as stem rot lesions were seen on them and these lesions were measured at weekly intervals until harvest.

There was considerable variation in lesion size on all dates of assessment. At the final assessment on June 30, Korina had the longest lesions and Lingot was amongst those with the shortest lesions (Table 58).

Between the 8 and 23 June a large increase in lesion size occurred on all cultivars (Table 59) with Rafal having the least increase and Doral the greatest increase per day.

As the epidemic progressed, the stems dehydrated and shredded at the initial site of infection - eventually snapping and lodging. A scale was developed to measure this lodging within each cultivar plot:

1, no lodging

2, up to 10% of plants lodged

3, > 10% but < 50% plants lodged

Table 58 : Lesion development at Silwood, 1983.

Cultivar	Mean length (mm) of lesion on						
	May	June					
	27	3	8	16	23	30	i)
Darmor	0.0	57.0	69.2	109.8	152.2	208.1	a
Rafal	25.0	62.3	98.6	125.7	161.7	222.2	a
Tandem	0.0	27.7	62.5	122.1	164.5	237.5	a
Lingot	23.7	67.4	153.2	216.8	241.1	260.3	ab
Diander	4.3	80.0	77.4	154.5	197.1	287.8	ab
Bienvenu	29.7	97.0	161.9	252.0	323.0	354.0	bc
Doral	0.0	58.3	113.7	233.6	321.3	357.5	bc
Jet Neuf	56.2	93.2	144.1	200.3	263.6	390.3	bc
Elvira	67.8	109.8	171.0	249.6	313.0	392.3	c
Norli	33.7	96.9	178.6	264.4	368.2	401.6	cd
Belinda	58.1	115.6	187.0	309.4	335.8	410.7	cd
Pamela	50.1	120.8	209.2	307.8	361.9	412.7	cd
Brittander	46.4	79.8	154.0	247.8	322.7	419.8	cd
Chrysander	0.0	0.0	69.0	129.3	189.5	447.3	cd
Lirabella	67.5	106.1	156.3	257.0	348.5	459.1	cd
Korina	30.0	94.7	135.8	177.5	318.6	508.5	d
Fiona	65.1	115.0	183.2	265.1	339.7	L.	

L = all lodged and stems parted at initial site of infection.

i) All values with no letter in common are significantly different at $\underline{P}$ = 0.05 (Duncans Multiple Range Test).

Table 59 : Lesion development at Silwood 1983.

Cultivar	Lesion extension mm/day between 8 and 23 June
Rafal	4.21
Darmor	5.53
Lingot	5.86
Tandem	6.80
Jet Neuf	7.97
Diander	7.98
Chrysander	8.03
Elvira	9.47
Belinda	9.92
Pamela	10.18
Fiona	10.43
Bienvenu	10.74
Brittander	11.25
Korina	12.18
Norli	12.64
Lirabella	12.83
Doral	13.84

4, 50-80% plants lodged

5, most of the plants lodged.

Lodging was assessed throughout May, June and July.

Table 60 shows these grades of lodging and associations were then investigated between lesion length and disease incidence, and lesion length and lodging (Table 61) using Spearman's coefficient of rank correlation. The results indicated that lodging was closely associated with long lesions but there was no association between the frequency with which plants become infected and the subsequent length of lesions which develop on them.

Lesions were also measured and sclerotia counted on the 50 labelled plants used for examining effects of stem rot on yield (Section 2.3.3.).

Here Lirabella had the longest lesion size with Korina amongst the longest lesions and Lingot had the shortest lesion (Table 62).

As the first lesions appeared in each cultivar, an assessment was made of the leaf axil from which the lesion initiated and the level of the senescing leaf above that lesion, as a count up from the basal rossette scar. On 26 May 50 plants were assessed but as some cultivars did not have apparent lesions, 10 plants were assessed in these six on 22 June.

The senescing leaf level had increased up the plant between the two assessment dates and was always higher than the site of initial infection (Table 63). On 26 May, the initial infection site was not below leaf axil 3.0 (mean 3.9-5.4) and on 22 June the infections were not higher than leaf axil 7.0 (mean 5.2-6.9). On a particular cultivar, there was little variation between the infection sites, that is, a common level of infection was noticed. No consistent value could be found between the two

Table 60 : Plant lodging at Silwood 1983.

Cultivar	Grade of lodging on			
	June			July
	14	20	30	6
Bienvenu	1	1	1	1
Darmor	1	1	1	1
Doral	1	1	1	1
Lingot	1	1	1	1
Norli	1	1	1	1
Rafal	1	1	1	1
Diander	1	2	2	2
Fiona	1	2	2	2
Lirabella	1	2	2	2
Elvira	2	2	2	2
Pamela	2	2	2	2
Korina	2	2	2	2
Tandem	2	2	2	2
Chrysander	2	2	2	3
Brittander	3	3	4	4
Jet Neuf	4	4	4	4
Belinda	4	4	4	5

Based on 1, no lodging

2, up to 10% of plants lodged

3, > 10% but < 50% plants lodged

4, 50-80% plants lodged

5, most of the plants lodged

Table 61 : Association of lesion length with other parameters.

1. Disease incidence

Cultivar	Mean length 30.6	Disease incidence	di
Fiona	17	12	5
Belinda	11	17	-6
Norli	10	13.5	-3.5
Brittander	13	13.5	-0.5
Lirabella	15	15	0
Pamela	12	6	6
Elvira	9	10	-1
Bienvenu	6	8.5	-2.5
Lingot	4	11	-7
Diander	5	4.5	0.5
Doral	7	7	0
Darmor	1	4.5	-3.5
Korina	16	2	14
Chrysander	14	1	13
Rafal	2	8.5	-6.5
Tandem	3	3	0
Jet Neuf	8	16	-8

$\Sigma x^2 = 408$

$\Sigma y^2 = 406.5$

$$r_s = \frac{408 + 406.5 - 649.5}{2\sqrt{408 \times 406.5}}$$

$$= \frac{165}{814.5} = 0.20 \text{ n.s.}$$

2. Plant lodging

Cultivar	Length 30.6	Plant lodging 6.7	di
Fiona	17	10	7
Belinda	11	17	-6
Norli	10	3.5	6.5
Brittander	13	15.5	-2.5
Lirabella	15	10	5
Pamela	12	10	2
Elvira	9	10	-1
Bienvenu	6	3.5	2.5
Lingot	4	3.5	0.5
Diander	5	10	-5
Doral	7	3.5	3.5
Darmor	1	3.5	-2.5
Korina	16	10	6
Chrysander	14	14	0
Rafal	2	3.5	-1.5
Tandem	3	10	-7
Jet Neuf	8	15.5	-7.5

$\Sigma x^2 = 408$

$\Sigma y^2 = 361.92$

$$r_s = \frac{408 + 361.92 - 321.25}{2\sqrt{408 \times 361.92}}$$

$$= \frac{448.67}{768.54}$$

$$= 0.58 \text{ **}$$

Table 62 : Infection and lesion development at Silwood 1983.

Cultivar	% Infection	Lesion length (mm)
		Mean ± S.E.
Lingot	34	231 ± 31
Darmor	24	268 ± 25
Tandem	30	270 ± 18
Doral	32	302 ± 39
Bienvenu	44	309 ± 24
Fiona	50	336 ± 25
Pamela	46	336 ± 35
Rafal	66	338 ± 19
Chrysander	16	344 ± 59
Brittander	78	354 ± 24
Elvira	30	361 ± 33
Korina	8	389 ± 27
Jet Neuf	78	391 ± 28
Norli	72	405 ± 21
Diander	12	412 ± 26
Lirabella	76	448 ± 24
Belinda	88	L.

Data based on 50 labelled plants of each cultivar.

L = lodged plants and split apart at initial site of infection

Table 63 : The association between the leaf axil of infection and the senescent leaf level at Silwood 1983.

Cultivar	26 May 1983[a]		22 June 1983[b]	
	Leaf axil Mean ± S.E.	Senescent leaf	Leaf axil Mean ± S.E.	Senescent leaf
Fiona	4.78 ± 0.18	7.76		9.2
Belinda	5.42 ± 0.24	10.3		9.8
Norli	4.06 ± 0.07	8.3		10.8
Brittander	6.34 ± 0.09	8.24		10.3
Lirabella	4.54 ± 0.10	7.18		11.1
Pamela	4.64 ± 0.11	6.02		11.7
Elvira	4.68 ± 0.14	7.06		9.5
Bienvenu	3.96 ± 0.10	6.34		8.5
Lingot	3.86 ± 0.11	5.82		9.3
Diander	-	3.94	5.2 ± 0.2	10.7
Doral	-	3.24	5.4 ± 0.22	10.4
Darmor	-	4.0	6.9 ± 0.24	11.4
Korina	3.98 ± 0.07	5.74		10.6
Chrysander	-	4.2	6.3 ± 0.30	10.9
Rafal	-	4.1	6.0 ± 0.30	8.5
Tandem	-	3.26	5.8 ± 0.25	8.1
Jet Neuf	5.18 ± 0.21	6.92		9.4

(a) Mean of 50 plants

(b) Mean of 10 plants

assessment leaf axil levels (varying 1.5 to 5.5).

2.3.5. Production of sclerotia

(a) Sutton Scotney

In 1983, the numbers of sclerotia, both those on lesions and those within the stem were counted on the five plants of each cultivar used for measurements of lesion length (Section 2.3.4.).

The numbers of sclerotia formed, mostly in stem cavities below lesions varied between the cultivars (Table 64) but their numbers were not directly associated with lesion length.

(b) Silwood Park

When the cultivar trial at Silwood Park was harvested in 1983 the production of sclerotia was estimated from samples of infected plants.

Infected stems were threshed and the sclerotia collected, counted and weighed. On plants with lesions extending to soil level the roots were smashed open with a hammer and the sclerotia were collected to obtain the total number and weight of sclerotia per plant. Finally, the weight of 1000 sclerotia was determined. This was usually based on 20 replicate samples of 20 sclerotia but fewer samples were available for Tandem, Darmor, Bienvenu, Korina, Chrysander and Norli.

The total weight of sclerotia produced in the 9 x 9 m^2 cultivar plots varied from 1.5 g in Korina to 65.2 g in Lirabella (Table 65) with great variation between cultivars. The mean weight of lots of 20 sclerotia also varied with cultivar (Table 65) and an analysis of variance carried out on the results was highly significant ($P = 0.001$) with significantly heavier sclerotia produced on Pamela than on any other cultivar.

The study of the roots showed that sclerotia were found

Table 64 : Sclerotia numbers at Sutton Scotney, 1983.

Cultivar	Total number of sclerotia per stem				
	1 (a)	2	3	4	5
Pamela	21 (16)	14 (3)	1 (1)	14 (1)	5
Korina	7	1	15 (5)	7	12 (3)
Lirabella	22 (12)	7 (1)	7 (3)	4	8 (2)
Jet Neuf	3	3	4	5	1
Norli	6	0	6	7	9
Belinda	1	5	11	10 (1)	7
Brittander	5	7	12	10	3
Elvira	5	4	7	5 (1)	9
Rafal	8 (1)	6	12 (4)	20 (1)	5
Darmor	5 (1)	1	7	5 (2)	8
Fiona	11 (2)	5	3	4	5
Diander	7	7	6	7	6
Lingot	3	12 (1)	1	3	3
Bienvenu	3 (1)	11 (4)	9	6	2 (2)
Chrysander	9 (1)	1	5	8 (3)	9 (3)

(a) Figures in parenthesis are the number found externally on the stem.

Table 65 : Sclerotia weights from Silwood 1983.

Cultivar	Total weight in 9 m^2 (g)	1000 weight (g)		
Fiona	22.69	17.24	cdef[a]	
Belinda	27.36	20.18	fg	
Norli	50.78	19.23	efg	(19)[b]
Brittander	58.87	20.90	g	
Lirabella	65.16	20.30	fg	
Pamela	16.01	23.50	h	
Elvira	15.58	21.42	g	
Bienvenu	3.80	16.24	bcde	(10)
Lingot	11.60	18.94	defg	
Diander	11.48	17.36	cdef	(19)
Doral	17.0	22.03	g	
Darmor	5.8	15.71	bc	(17)
Korina	1.48	20.26	fg	(3)
Chrysander	2.26	13.71	ab	(7)
Rafal	17.18	15.92	bcd	
Tandem	1.70	12.45	a	(6)
Jet Neuf	27.91	15.07	abc	

Anovar on 1000 seed weights (individual lots of 20)

	d.f.	SS	MS	F	
Treatments	16	0.8595	0.054	8.68	***
Error	264	1.6330	0.0062		
Total	280	2.4925			

(a) Values with no letter in common are significantly different at P = 0.05 Duncans Multiple Range Test.

(b) Numbers in brackets are the number of 20 sclerotia lots weighed - if less than 20.

mainly on the root exterior where the outer cortex had sloughed off leaving a bleached look to the roots (Table 66). They had formed around the peripheral lateral roots (Plate 4). On four cultivars no sclerotia formed on the roots either internally or externally.

The number of sclerotia produced externally on the 50 harvested plants varied from nil on Tandem to 68% on Belinda and Lirabella (Table 67). Analysis using Spearmans rank correlation coefficient showed that there was a significant association between lesion length and the presence of external sclerotia (Table 68).

Further non-parametric tests on the ranked means showed a highly significant association ($\underline{P}$ = 0.001) between total sclerotia weight per cultivar and disease incidence for the plot (Table 69); a significant association ($\underline{P}$ = 0.05) between 1000 sclerotia weight and stem girth (mean of 5 stem measurements) (Table 70) and also between the average sclerotia weight per plant (based on the assumption that there were 990 plants per plot as seed was drilled at a rate to give 110 plants/m^2) and mean lesion length (Table 71).

Disease incidence and stem girth exerted a limit on sclerotia number and size respectively while lesion length also affected the number of external sclerotia and their size.

2.3.6. Sclerotial populations in soil

(a) Sutton Scotney

Soil samples were taken from an area of 20 x 20 cm and down to a maximum of 6 cm depth following the harvesting of the NIAB trial in July 1982 and over the 2 subsequent seasons. These were throughout the area covered with the NIAB trial 1981-82. Samples were air dried for 14 days at 20^{o}C, weighed and then washed under a running tap through graduated

Table 66 : Roots at harvest, Silwood 1983 (A summary).

Cultivar	50 Labelled plants				Root condition	
	Sclerotia presence infected stems					
	Internal %	External %	A	B	Description	Sloughed
Norli	95	80	✓	x	VC	✓
Jet Neuf	90	45	✓	x	VC	✓
Lirabella	60	x	✓	x	D	x
Chrysander	x	x	x	x	D	x
Tandem	x	x	x	x	D	x
Elvira	85	5	✓	x	D	x
Lingot	65	x	x	✓	D	x
Doral	75	x	✓	x	D	x
Brittander	70	10	✓	x	C	✓
Belinda	55	2	✓	x	C	✓
Diander	40	x	✓	x	C	✓
Fiona	60	25	x	✓	D	x
Rafal	5	x	✓	x	D	x
Pamela	85	2	✓	x	C	✓
Bienvenu	2	14	✓	x	C	✓
Darmor	x	x	x	x	D	x
Korina	x	x	x	x	D	x

A = Sclerotia in root only if lesion down to stem base.

B = Sclerotia in root from infected stem even if lesion does not reach base.

VC = very clean

C = clean

D = dirty

Plate 4 : Silwood Park, 1983: Sclerotia formed internally in roots of oil-seed rape, cultivar Bienvenu.

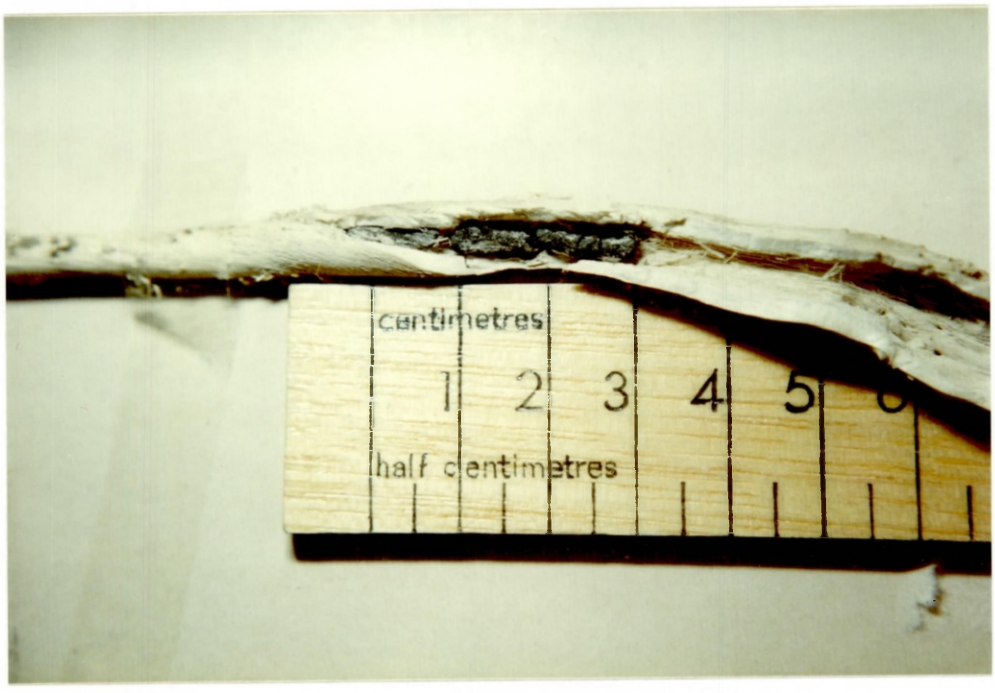


Table 67 : Presence of external sclerotia on lesions at Silwood, 1983.

Cultivar	Percentage of lesions with external sclerotia
Fiona	26.9
Belinda	68.2
Norli	14.3
Brittander	27.8
Lirabella	68.4
Pamela	30.4
Elvira	7.3
Bienvenu	14.0
Lingot	23.5
Diander	50.0
Doral	37.5
Darmor	8.3
Korina	25.0
Chrysander	25.0
Rafal	6.0
Tandem	0.0
Jet Neuf	26.0

Table 68 : Test for an association between the lesion length and the formation of external sclerotia at Sutton Scotney, 1983.

Cultivar	Lesion length	Lesions plus external sclerotia	di
Fiona	6	11	- 5
Belinda	17	16	- 1
Norli	14	6	8
Brittander	10	12	- 2
Lirabella	16	17	- 1
Pamela	7	13	- 6
Elvira	11	3	8
Bienvenu	5	5	0
Lingot	1	7	- 6
Diander	15	15	0
Doral	4	14	-10
Darmor	2	4	- 2
Korina	12	8.5	3.5
Chrysander	9	8.5	0.5
Rafal	8	2	6
Tandem	3	1	2
Jet Neuf	13	10	3

$\Sigma x^2 = 408$

$\Sigma y^2 = 408 - 0.5 = 407.5$

$$r_s = \frac{408 + 407.5 - 396.5}{2\sqrt{408 \times 407.5}} = \frac{419}{815.5} = 0.51$$

$p = 0.05$ *

Table 69 : Test for sclerotia total weight and disease incidence, Silwood 1983.

Cultivar	Sclerotia total weight	Disease incidence	di
Fiona	12	12	0
Belinda	13	17	4
Norli	15	13	-2
Brittander	16	13	-3
Lirabella	17	15	-2
Pamela	9	6	-3
Elvira	8	10	2
Bienvenu	4	8	4
Lingot	7	11	4
Diander	6	4	-2
Doral	10	7	-3
Darmor	5	4	-1
Korina	1	2	1
Chrysander	3	1	-2
Rafal	11	8	-3
Tandem	2	3	-1
Jet Neuf	14	16	2

$$r_s = \left| - \frac{6 \times 111}{(17)^3 - 17} \right| = 0.864 \quad ***$$

Table 70 : Test for sclerotial 1000 weight and stem girth, Silwood 1983.

Cultivar	1000 sclerotia weight	Stem girth	di
Fiona	7	12	5
Belinda	11	7	4
Norli	10	14	- 4
Brittander	14	10	4
Lirabella	13	17	- 4
Pamela	17	16	1
Elvira	15	4	11
Bienvenu	6	3	3
Lingot	9	2	7
Diander	8	6	2
Doral	16	14	2
Darmor	4	5	- 1
Korina	12	8	4
Chrysander	2	1	1
Rafal	5	9	- 4
Tandem	1	12	-11
Jet Neuf	3	11	- 8

$$r_s = \left| - \frac{6 \times 496}{(17)^3 - 17} \right| = 0.392 \quad *$$

Table 71 : Test for mean sclerotia weight per infected plant and lesion length.

Cultivar	Ranked means		di
	Average sclerotial weight/plant	Lesion length 30.6.83	
Fiona	14	17	- 3
Belinda	7	11	- 4
Norli	15	10	5
Brittander	16	13	3
Lirabella	17	15	2
Pamela	13	12	1
Elvira	8	9	- 1
Bienvenu	2	6	- 4
Lingot	6	4	2
Diander	10	5	5
Doral	12	7	5
Darmor	4	1	3
Korina	3	16	-13
Chrysander	5	14	- 9
Rafal	11	2	9
Tandem	1	3	- 2
Jet Neuf	9	8	1

$$r_s = \left| - \frac{6 \times 480}{(17)^3 - 17} \right| = 0.412 \quad *$$

sieves (Gallenkampf Test Sieves BS410, Endecotts Ltd., London EC2. Mesh no. 30 Mics 500 and Mesh no. 10 Mics 1680). The numbers of sclerotia retrieved were then counted and the number per kilogram air dried soil calculated.

On 8 September 1982, 10 soil samples were taken from near the 1982-83 trial as shown in Figure 7, approximately in the area of Blocks 1-2 in the previous trial. Rape stubble remained in this area. On 13 November 1982, four samples were taken from the now cultivated land drilled with barley in a transect parallel to the hedge, at 20 m intervals, approximately level with the top of the 1982-83 trial. Ten samples were also taken at 4 m intervals in the border rows of the 1982-83 trial.

One sample was then taken every 7 days from different locations in the border rows of the 1982-83 trial from 1 December until 1 June 1983.

Four samples were taken on 25 August 1983, 2 October 1983, 5 March 1984 and 17 July 1984. The locations were under the guard rows of the 1983-84 trial, in the centre of the trial, and in two places under the autumn sown fodder turnips and spring sown barley - one between the trial and the hedge (Block 4 1981-82) and the other from the middle of the 1982-83 trial. Three samples were taken at each site on each date.

The number of sclerotia retrieved are shown in Tables 72 (8.9.82), 73 (13.11.82), 74 (1.12.82-1.6.83) and 75 (1983-84). These show that following the 1981-82 trial there were 5.8 sclerotia per kg dry soil. After ploughing and drilling the number had decreased to 4.31/kg dry soil under the winter oilseed rape and 4.8 under winter barley. Throughout the following winter the mean value of sclerotia retrieved, up to the end of February,was 3.5/kg dry soil. By June, the number was 2.6/kg dry soil indicating a gradual decline.

Figure 7 : Plan of soil samples taken at Sutton Scotney 8 September 1982.

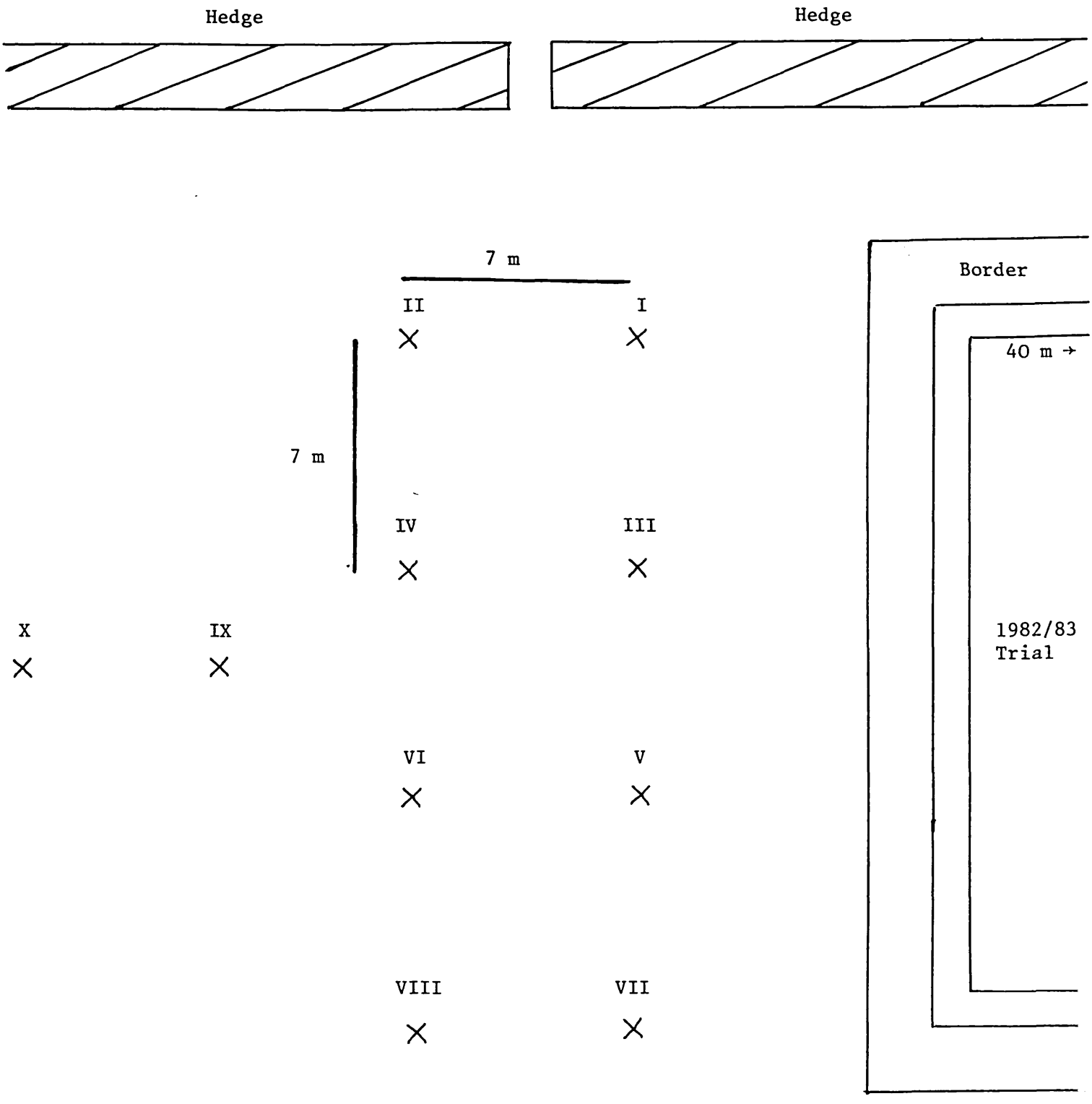


Table 72 : Number of sclerotia collected from soil 8 September 1982.

Plot number	No./kg dry soil before ploughing spring barley
I	3.9
II	10.9
III	3.9
IV	2.3
V	7.6
VI	3.4
VII	5.3
VIII	7.5
IX	1.8
X	11.0

Mean = 5.8 ± 1.49 (S.E.)

Table 73 : Number of sclerotia 13 November 1982.

	No./kg dry soil after ploughing and drilling crops	
Barley plot		
1	5.2	
2	4.9	Mean = 4.8 ± 0.64
3	6.0	
4	3.0	
Oilseed rape		
1	2.6	
2	6.0	
3	5.5	
4	4.5	
5	5.1	Mean = 4.31 ± 0.82
6	6.2	
7	4.7	
8	3.9	
9	2.3	
10	2.3	

Table 74 : Number of sclerotia collected during 1982-83.

Date of collection			Number per kg dry soil
1982	December	1	1.9
		8	1.6
		15	3.1
		22	3.0
		29	3.1
1983	January	1	6.9
		12	3.9
		19	5.3
		26	2.5
	February	2	2.9
		9	- (a)
		16	3.2
		23	4.3
	March	2	2.6
		9	3.2
		16	1.9
		23	2.0
		30	1.9
	April	6	2.4
		13	3.0
		20	2.1
		27	2.9
	May	4	2.2
		11	4.8
		18	2.1
		25	2.3
	June	1	2.8

(a) No sample taken.

Table 75 : Total sclerotia collected at Sutton Scotney 1983-84 from 3 replicate samples.

Date of assessment	Site			
	Guard row rape in trial	Centre of the trial	Spring barley/fodder turnips	
			Hedge/trial	1982-83 trial
25 August 1983	6 (1.8)	8 (2.6)	12 (3.5)	9 (2.8)
2 October 1983	6 (2.2)	9 (3.2)	13 (3.9)	11 (2.8)
5 March 1984	7 (2.8)	17 (4.1)	12 (4.1)	10 (3.9)
17 July 1984	10 (3.4)	18 (4.5)	13 (3.7)	16 (4.2)

(a) The figures in parenthesis are the number per kg/air dried soil.

Following harvest, samples show that on 25 August the number was the same 2.8/kg dry soil - but following fodder turnips and drilling of spring barley, the number had increased to 3.9/kg.

The area of the 1983-84 trial unmonitored during 1982-83 showed lower numbers of 1.8-2.6/kg dry soil. After drilling of the trial the number increased and following the winter kill detected from *Sclerotinia* the numbers increased again. After harvest in July, the numbers of sclerotia were nearly comparable to that detected after the 1981-82 trial.

The area that had no oilseed rape in the two seasons following the 1981-82 trial,remained fairly constant during 1983-84 at 3.5-4.1/kg dry soil, and finished just lower than the two areas that had had oilseed rape following the 1981-82 trial.

(b) Silwood Park

After harvesting the oilseed rape in the 1982-83 trial, five soil samples were taken at random from each cultivar plot. These were within a 20 x 20 cm quadrat and to a maximum depth of 8 cm. The samples were then air dried, coarsely sieved, weighed and washed through the graduated sieves under a running tap. The number of sclerotia recovered were counted. As the disease incidence was low in 1983-84 this was not repeated.

The bags of sclerotia used as inoculum were also recovered from each plot in 1982-83 and the number of remaining sclerotia counted. This was also repeated for the 1983-84 trial where 3 bags in each plot were recovered.

The number of sclerotia recovered from the soil in the five samples at harvest are shown in Table 76, Lirabella returning the most in the volume collected, with Jet Neuf a close second. Tests (Spearmans Rank Correlation) comparing this result with disease incidence was highly signi-

Table 76 : The number of sclerotia recovered from soil samples, Silwood 1983.

Cultivar	Air dry weight (g) of soil	No. sclerotia/ soil sample	No. sclerotia per kg soil
Fiona	2133.9	4	1.9
Belinda	1750.8	10	5.7
Norli	1768.0	21	11.9
Brittander	1636.8	9	5.5
Lirabella	1740.6	29	16.7
Pamela	1549.8	4	2.6
Elvira	1455.8	21	14.4
Bienvenu	2266.6	15	6.6
Lingot	2284.8	0	0
Diander	1308.6	2	1.5
Doral	1581.1	0	0
Darmor	1583.1	0	0
Korina	1818.9	1	0.6
Chrysander	1896.8	1	0.5
Rafal	1359.9	4	2.9
Tandem	1586.6	12	7.6
Jet Neuf	1825.5	28	15.3

ficant (P = 0.001), but with the percentage of lesions with external sclerotia, was not significant (Table 77). Comparison with the number of external sclerotia on the root was highly significant (P = 0.001) (Table 78).

The survival of sclerotia from the inoculum bags in 1982-83 is shown in Table 79. Analysis of variance on $\sqrt{x + 0.5}$ transformed data was highly significant for cultivars (P = 0.01) but not for the positioning in the plot. The means overlapped, with no one cultivar having a significantly differently survival rate than the others. However, Lingot had the greatest number surviving and Belinda the least number.

The survial of sclerotia from three inoculum bags in 1983-84 is shown in Table 80. Analysis of variance on $\sqrt{x + 0.5}$ transformed data was highly significant (P = 0.01) and there were clear differences in mean values. Jet Neuf had the lowest survival and was significantly different from the others; while Belinda and Korina with the highest survival were not significantly different from each other but were from the rest of the cultivars. Non-Parametric Statistics comparing the survival with the mean number of apothecia produced per cultivar was not significant (Table 81).

2.3.7. Production of apothecia at Sutton Scotney

(a) Initiation of apothecia production

The sclerotia retrieved from the soil samples during 1982-83 were placed into a No.11 dish containing moistened John Innes No.1 and incubated at 10°C. Dishes were then observed at weekly intervals to detect the time that carpogenic germination initiation was present.

The sclerotia retrieved on 16 February, produced stipes on 24 March and on placing under UV light developed apothecia. This was the earliest date of carpogenic germination from the field sclerotia.

Table 77 :

a) Test for sclerotia recovered in soil and disease incidence.

Cultivar	Ranked means		di
	Sclerotia in soil	Disease incidence	
Fiona	8	12	- 4
Belinda	11	17	- 5
Norli	14.5	13.5	1
Brittander	10	13.5	-3.5
Lirabella	17	15	2
Pamela	8	6	2
Elvira	14.5	10	4.5
Bienvenu	13	8.5	4.5
Lingot	2	11	- 9
Diander	6	4.5	2.5
Doral	2	7	- 5
Darmor	2	4.5	-2.5
Korina	4.5	2	2.5
Chrysander	4.5	1	3.5
Rafal	8	8.5	-0.5
Tandem	12	3	9
Jet Neuf	16	16	0

$\Sigma x^2 = 403$

$\Sigma y^2 = 406.5$

$$r_s = \frac{403 + 406.5 - 321.3}{2\sqrt{403 \times 406.5}}$$

$$= \frac{488.3}{809.5}$$

$= 0.603$ ***

Table 77 : Continued.

b) Test for sclerotia recovered in soil and lesions with external sclerotia.

Cultivar	Ranked means		di
	Sclerotia in soil	Lesion with sclerotia external	
Fiona	8	9	- 1
Belinda	11	14	- 3
Norli	14.5	17	- 2.5
Brittander	10	10	0
Lirabella	17	15	2
Pamela	8	11	- 3
Elvira	14.5	3	11.5
Bienvenu	13	5	8
Lingot	2	6	- 4
Diander	6	13	- 7
Doral	2	12	- 10
Darmor	2	4	- 2
Korina	4.5	7.5	- 3
Chrysander	4.5	7.5	- 3
Rafal	8	2	6
Tandem	12	1	11
Jet Neuf	16	16	0

$\Sigma x^2 = 403$

$\Sigma y^2 = 407.5$

$$r_s = \frac{403 + 407.5 - 569.5}{2\sqrt{403 \times 407.5}}$$

$$= \frac{241}{810.49}$$

$= 0.30$ n.s.

Table 78 : Test for sclerotia recovered and roots with external sclerotia.

Cultivar	Sclerotia in soil	External sclerotia on roots	di
Fiona	8	15	- 7
Belinda	11	9	2
Norli	14.5	17	- 2.5
Brittander	10	12	- 2
Lirabella	17	10	7
Pamela	8	13.5	- 5.5
Elvira	14.5	11	3.5
Bienvenu	13	13.5	- 0.5
Lingot	2	4.5	- 2.5
Diander	6	4.5	1.5
Doral	2	4.5	- 2.5
Darmor	2	4.5	- 2.5
Korina	4.5	4.5	0
Chrysander	4.5	4.5	0
Rafal	8	4.5	3.5
Tandem	12	4.5	7.5
Jet Neuf	16	16	0

$\Sigma x^2 = 403$

$\Sigma y^2 = 358$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma di^2}{2\sqrt{\Sigma x^2 \cdot \Sigma y^2}}$$

$$= \frac{403 + 358 - 244.5}{2\sqrt{403 \times 358}}$$

$$= \frac{516.5}{759.7}$$

$= 0.68$ ***

Table 79 : Survival of sclerotia in net bags, 1982-83 Silwood.

Cultivar	Number of sclerotia surviving in bags					Mean ± S.E.	5% Duncans Multiple Test	Survival %
	1	2	3	4	5			
Fiona	5	5	6	4	5	5 ± 0.32	bc	25
Belinda	6	7	6	0	0	3.8 ± 1.56	a	19
Norli	12	13	12	10	14	12.2 ± 0.66	fg	61
Brittander	2	10	12	16	12	10.4 ± 2.32	ef	52
Lirabella	7	8	9	7	6	7.4 ± 0.51	cde	37
Pamela	8	12	16	8	5	9.8 ± 1.91	def	49
Elvira	10	11	9	10	12	10.4 ± 0.51	fg	52
Bienvenu	13	3	0	10	20	9.2 ± 3.57	cde	46
Lingot	14	13	14	15	10	13.2 ± 0.86	gh	66
Diander	4	5	1	6	4	4.0 ± 0.84	ab	20
Doral	10	10	14	9	9	10.4 ± 0.9	fg	52
Darmor	7	7	6	5	8	6.6 ± 0.5	c	33
Korina	6	6	8	6	9	7.0 ± 0.6	cd	35
Chrysander	10	11	10	12	9	10.4 ± 0.5	fg	52
Rafal	16	17	17	15	16	16.2 ± 0.4	h	81
Tandem	12	13	12	14	11	12.4 ± 0.5	fg	62
Jef Neuf	7	6	4	4	5	5.2 ± 0.6	bc	26

Anovar on $\sqrt{x + 0.5}$ transformed data

	d.f.	SS	MS	F	
Cultivar	16	29.5	1.84	5.34	***
Position	4	0.13	0.03	0.09	n.s.
Error	64	21.98	0.34		
Total	84	51.60			

Table 80 : Survival of sclerotia in field trial, Silwood 1983-84.

Cultivar	Replicates			Mean ± S.E.	% survival
	1	2	3		
Diander	2	14	3	6.3 ± 3.85 cd	32
Doral	5	4	9	6.0 ± 1.52 d	30
Liradonna	11	8	7	8.7 ± 1.20 e	43
Jem	18	8	5	10.3 ± 3.93 ef	52
Belinda	13	13	15	13.7 ± 0.67 g	68
Korina	18	17	10	15.0 ± 2.51 g	75
Bienvenu	11	4	2	5.7 ± 2.73 cd	28
Rafal	9	0	3	4.0 ± 2.64 b	20
Fiona	3	10	4	5.7 ± 2.19 cd	28
Falk	9	8	11	9.3 ± 0.88 ef	47
Lirabella	14	13	8	11.7 ± 1.86 f	58
Mikado	4	0	10	4.7 ± 2.90 bc	23
Carola	7	14	6	9.0 ± 2.52 e	45
Pamela	9	0	10	6.3 ± 3.18 cd	32
Barbara	4	2	8	4.7 ± 1.77 bcd	23
Darmor	3	19	2	8.0 ± 5.51 d	40
Jet Neuf	0	0	2	0.7 ± 0.67 a	3

Anovar on $\sqrt{x + 0.5}$ transformed data

	d.f.	SS	MS	F	
Cultivar	16	25.43	1.59	3.25	***
Error	34	16.53	0.49		
Total	50	41.99			

Table 81 : Test for an association between sclerotial survival and mean apothecial production in 1983-84 Silwood.

Cultivar	Sclerotia survival	Numbers of apothecia	di
Diander	8	17	- 9
Doral	9	13	- 4
Liradonna	11	6	5
Jem	14	16	- 2
Belinda	16	8	8
Korina	17	4	13
Bienvenu	6	2	4
Rafal	2	7	- 5
Fiona	7	9	- 2
Falk	13	14	- 1
Lirabella	15	15	0
Mikado	3	12	- 9
Carola	12	11	1
Pamela	5	10	- 5
Barbara	4	1	3
Darmor	10	5	5
Jet Neuf	1	3	- 2

$$r_s = \left| - \frac{6 \times 548}{17^3 - 17} \right| = \left| - \frac{3288}{4896} \right| = 0.33 \qquad \text{n.s.}$$

(b) Apothecia production under non-host crops

Quadrats (0.5 x 0.5 m^2) placed randomly throughout the area of the 1981-82 trial in the winter barley (1982-83) and the spring barley (1983-84) on various dates from the end of April, were monitored for numbers of apothecia. Three quadrats on each assessment date were monitored.

The numbers of apothecia counted are shown in Table 82. The number produced were comparable to the number under the oilseed rape but were more difficult to find owing to the tillering of the barley. There did not appear to be any difference in the number produced under the two crops but the effect on spore dispersal by the crop was not examined, although on searching for the apothecia, puffing was seen on tiller seperation.

Table 82 : Numbers of apothecia under non host crops, Sutton Scotney.

Year	Crop	Quadrat	Date of Assessment							
			27.4	4.5	11.5	18.5	25.5	1.6	8.6	15.6
1982-83	W. Barley	1	0	3	1	3	4	3	2	0
		2	0	2	4	6	6	1	0	1
		3	0	1	3	6	5	1	1	0
			2.5	9.5	16.5	23.5	6.6	13.6	20.6	
1983-84	S. Barley	1	0	1	1	7	4	2	1	
		2	0	2	1	1	9	4	0	
		2	0	1	4	3	9	2	1	

SECTION 3

OTHER FIELD TRIALS AT SILWOOD PARK

The results of the field trials with a range of winter oilseed rape cultivars (Section 2) provided some information on the epidemiology of stem rot as well as cultivar susceptibility. The experiments described in this section investigated further the production of apothecia from sclerotia, disease development within a planting of Jet Neuf in relation to quantity of inoculum, crop phenology and the environment and attempted control of the disease by applying fungicide at times related to crop development and the production of fungal inoculum.

3.1 Survival of Sclerotia and Production of Apothecia

3.1.1. Effects of soil type, source of sclerotia, depth of burial and nitrogenous fertilizer

(a) Methods

An experiment, begun in August 1982 examined three factors:

Soil of two types. Soil was collected from Sutton Scotney within the area used for the 1981-82 winter oilseed rape trial (clay-loam soil) and from Silwood Park also from the area used subsequently for the oilseed rape cultivar trials (Bagshot sand). Both soil samples were coarsely sieved and used to fill rectangular pots (8 x 6.7 cm) to the rim.

Sclerotia from two sources. Sclerotia were obtained from plants with stem rot at Sutton Scotney when the 1981-82 cultivar trial was harvested (natural sclerotia). Isolate JN1 (obtained from Sutton Scotney, Table 1) was grown on wheat grain at 20°C for 4 weeks and the sclerotia were removed (culture sclerotia).

Placement of sclerotia at six positions. Twenty-five sclerotia of one type, in a net bag, were placed in a pot at one of the following positions: on the soil surface or 1, 2, 3, 4 or 6 cm beneath the surface.

There were three replicates for each of the 24 (2 x 2 x 6) treatments. The pots were placed in a trench in the field at Silwood Park on 10 September 1982 so that the soil surface in the pot was at the same level as the surrounding field soil. The treatments were completely randomized.

A second experiment, identical to the first, was placed in an adjacent trench, but on 29 September 1982 and 26 March 1983 it received applications of nitrogen (Growmore) at rates 40 kg/ha and 200 kg/ha respectively, used in the cultivar trial at Silwood. The numbers of apothecia produced in each pot, in both experiments, were counted, at least each week, throughout April and May 1983. It was intended that both experiments would continue to 1984 but that involving applications of nitrogen was inadvertently ploughed up, so counts of apothecia in 1984 were possible only in pots within the remaining experiment. On 26 July 1984 these pots were removed and the numbers of sclerotia left were counted.

(b) Results

The numbers of apothecia produced, in relation to the three main treatments, are summarized in Table 83 and detailed in Appendix XXIX. As apothecia were not removed after counting, totals over the entire 2 months are given as 'apothecial days'.

Apothecia were first observed in some treatments on 9 April and generally most were produced in mid May although there was some, relatively minor variation between treatments in this respect. In Experiment 1, except on 26 and 31 May, consistently more apothecia were present,

Table 83 : Production of apothecia from sclerotia produced on oilseed rape and in culture, buried at different depths in two types of soil, 1983.

(a) Experiment 1 (no nitrogen added)

Treatment comparisons	Total apothecia produced on										Total no. 'apothecial days'
	April				May						
	9	14	22	27	4	10	14	18	26	31	
A. Soil type											
Sutton Scotney	106	132	253	400	864	1056	969	780	330	61	4951
Silwood Park	42	93	152	336	718	846	849	681	310	18	4045
B. Sclerotia											
Natural	47	69	109	183	478	667	707	689	378	65	3392
Culture	101	156	296	553	1104	1242	1108	772	262	14	5608
C. Depth (cm)											
0	29	50	98	154	332	436	445	351	156	30	2081
1	13	40	95	176	465	573	458	358	118	16	2312
2	70	96	124	215	377	416	421	246	144	16	2125
3	18	20	55	125	260	320	309	288	79	4	1478
4	9	14	25	32	90	95	110	131	70	10	586
6	9	5	8	34	58	69	72	87	73	3	418

Table 83 : Continued.

(b) Experiment 2 (nitrogen added)

Treatment comparisons	Total apothecia produced on										Total no. 'apothecial days'
	April				May						
	9	14	22	27	4	10	14	18	26	31	
A. Soil type											
Sutton Scotney	17	19	55	156	471	615	787	731	462	78	3391
Silwood Park	8	17	89	208	606	747	831	737	325	84	3652
B. Sclerotia											
Natural	9	11	40	93	278	352	507	610	369	125	2394
Culture	16	27	104	271	799	1010	1111	858	418	37	4651
C. Depth (cm)											
0	1	3	17	64	292	344	415	350	222	33	1741
1	5	11	41	94	212	323	376	225	129	49	1465
2	15	19	52	103	277	307	368	311	208	43	1703
3	2	2	13	53	134	180	190	210	82	23	889
4	0	1	19	32	39	127	156	184	53	9	634
6	2	2	2	11	35	52	37	188	93	5	427

overall, in pots with soil from Sutton Scotney than in pots with Silwood Park soil. Similarly, except for these dates, more apothecia were present in pots with sclerotia produced in culture than in those with sclerotia obtained from infected plants. Consistently more apothecia were produced from sclerotia at or near the soil surface (0-2 cm) than at greater depths (3-6 cm). Basically, the results from Experiment 2 were similar, except that slightly more apothecia were produced in pots with soil from Silwood Park.

These results were examined in more detail by factorial analysis of the data between 27 April to 26 May for each experiment (Table 84). Generally, in Experiment 1 the type of sclerotia and the depth at which they were buried significantly influenced the numbers of apothecia present on most dates. On three dates (27 April, 4 and 10 May) there was also a highly significant soil type x sclerotia type x burial depth interaction. Despite the apparent differences indicated in Table 83, soil type had no significant ($\underline{P} > 0.05$) overall effect on the numbers of apothecia produced.

In Experiment 2, the type of sclerotia and depth of burial had highly significant effects on the numbers of apothecia present at five assessment dates. Additionally, on 4 and 10 May numbers of apothecia were significantly affected by the type of soil in which the sclerotia were buried. There were four significant interactions, between type of sclerotia and burial depth on 27 April, 4 May and 10 May and between type of sclerotia and burial depth on 27 April. Further examination of these interactions (Table 85) indicated that on the dates indicated there were similar numbers of apothecia from both types of sclerotia buried at 3, 4 and 6 cm but at each of the other depths (0, 1 and 2 cm) significantly ($\underline{P} = 0.001$) more apothecia were present in pots with sclerotia from cultures. Also on 27

Table 84 : Analysis of numbers of apothecia produced between 27 April and 26 May 1983.

(a) Experiment 1 (no nitrogen added)

Factor	Variance ratios (F-values) for numbers of apothecia present on					
	April	May				
	27	4	10	14	18	26
A. Soil type	0.19	0.54	1.17	0.30	0.43	0.11
B. Sclerotia type	20.65***	34.15***	22.10***	11.79***	0.28	3.92*
C. Depth of burial	7.99***	16.80***	22.84***	16.61***	4.87***	1.53
Interactions AB	1.98	1.08	1.11	0.75	0.63	0.22
BC	1.29	0.91	1.23	1.81	0.82	0.86
AC	1.09	1.16	1.47	0.99	1.36	0.57
ABC	2.81**	3.44**	3.06**	2.0*	1.87	0.30

(b) Experiment 2 (nitrogen added)

Factor	Variance ratios (F-values) for numbers of apothecia present on					
	April	May				
	27	4	10	14	18	26
A. Soil type	2.14	3.09*	3.12*	0.72	0.04	2.36
B. Scerotia type	13.54***	28.64***	11.79***	28.81***	3.20*	1.45
C. Depth of burial	3.37**	6.92***	16.61***	13.08***	1.50	5.94***
Interactions AB	5.60***	0.47	1.85	0.43	0.18	2.25
BC	4.87***	2.84**	2.51**	1.00	0.57	1.89
AC	1.57	0.78	0.56	1.69	0.83	1.01
ABC	0.46	0.53	2.0 *	1.15	1.06	0.95

*, **, ***, denote variance ratios significant at $P = 0.05$, $P = 0.01$ and $P = 0.001$ respectively based on analyses of transformed ($\sqrt{x + 0.5}$) data.

Table 85 : Further analysis of the interaction effects (type of sclerotia x depth of burial; type of sclerotia x soil type) on numbers of apothecia (Experiment 2).

(a) Type of sclerotia x depth of burial

	Depth (cm) of burial	Mean No. apothecia per 3 pots with sclerotia from		Variance ratio (F)
		Culture	Infected plants	
27 April				
	0	16.5	9.3	8.88 ***
	1	19.5	9.3	18.20 ***
	2	22.9	7.0	44.28 ***
	3	10.3	14.0	2.39 n.s.
	4	11.3	8.5	1.40 n.s.
	6	5.7	7.6	0.63 n.s.
4 May				
	0	33.9	18.8	3.95 ***
	1	27.4	19.2	11.34 ***
	2	37.8	13.4	51.58 ***
	3	23.1	13.9	7.26 ***
	4	23.3	13.8	7.76 ***
	6	9.9	10.5	0.02 n.s.
10 May				
	0	38.8	23.5	30.32 ***
	1	35.8	24.5	16.72 ***
	2	38.2	18.4	51.20 ***
	3	26.1	15.8	13.81 ***
	4	29.0	10.7	43.46 ***
	6	12.9	10.8	0.60 n.s.

Table 85 : Continued.

(b) Type of sclerotia

	Soil type	Mean No. apothecia per 3 pots with sclerotia from		Variance ratio (F)
		Culture	Infected plants	
27 April				
	Silwood	51.1	25.9	54.83 ***
	Sutton Scotney	35.2	29.7	2.89 n.s.
4 May				
	Silwood	70.7	30.3	45.34 ***
	Sutton Scotney	62.5	20.0	23.49 ***
10 May				
	Silwood	22.3	36.3	5.44 *
	Sutton Scotney	80.2	88.2	4.25 *

Analyses were on $\sqrt{x + 0.5}$ transformed data.

April, significantly (P = 0.001) more apothecia were present in pots with sclerotia from cultures where these contained Silwood soil. In Sutton Scotney soil, numbers of apothecia were similar for both types of sclerotia.

Finally, for each assessment date the total numbers of apothecia present in Experiment 1 (no nitrogen added) were compared with those in Experiment 2 (nitrogen added). Except for the assessments on 18, 26 and 31 May, more apothecia were present in pots with no added nitrogen (Table 86). A t-test on the paired comparisons indicated a highly significant (t = 26.56, P = 0.001) difference between the two sets of values (Appendix XXX).

In summary the most important features of these experiments were:

(i) The depth at which sclerotia were buried markedly influenced the numbers of apothecia produced. Most apothecia were produced from sclerotia buried 1 or 2 cm deep; relatively few apothecia were produced from sclerotia at 4 or 6 cm (Table 83).

(ii) Apothecia were produced earlier and in greater numbers from sclerotia produced in culture than from 'natural' sclerotia even though the fungus was obtained from the same site (Table 83, Fig. 8A).

(iii) Added nitrogen delayed and reduced the numbers of apothecia produced (Table 86, Fig. 8B).

Very few apothecia were produced during 1984 in the continuation of Experiment 1 (Table 87) and no detailed analysis was possible. However, overall, more apothecia were produced from sclerotia obtained from cultures than from those collected from infected plants, as in 1983, but in contrast to the 1983 results slightly more apothecia were produced from sclerotia in Silwood Park soil and those buried at 6 cm. No apothecia were produced from sclerotia on the soil surface.

Table 86 : Effect of nitrogen on production of apothecia.

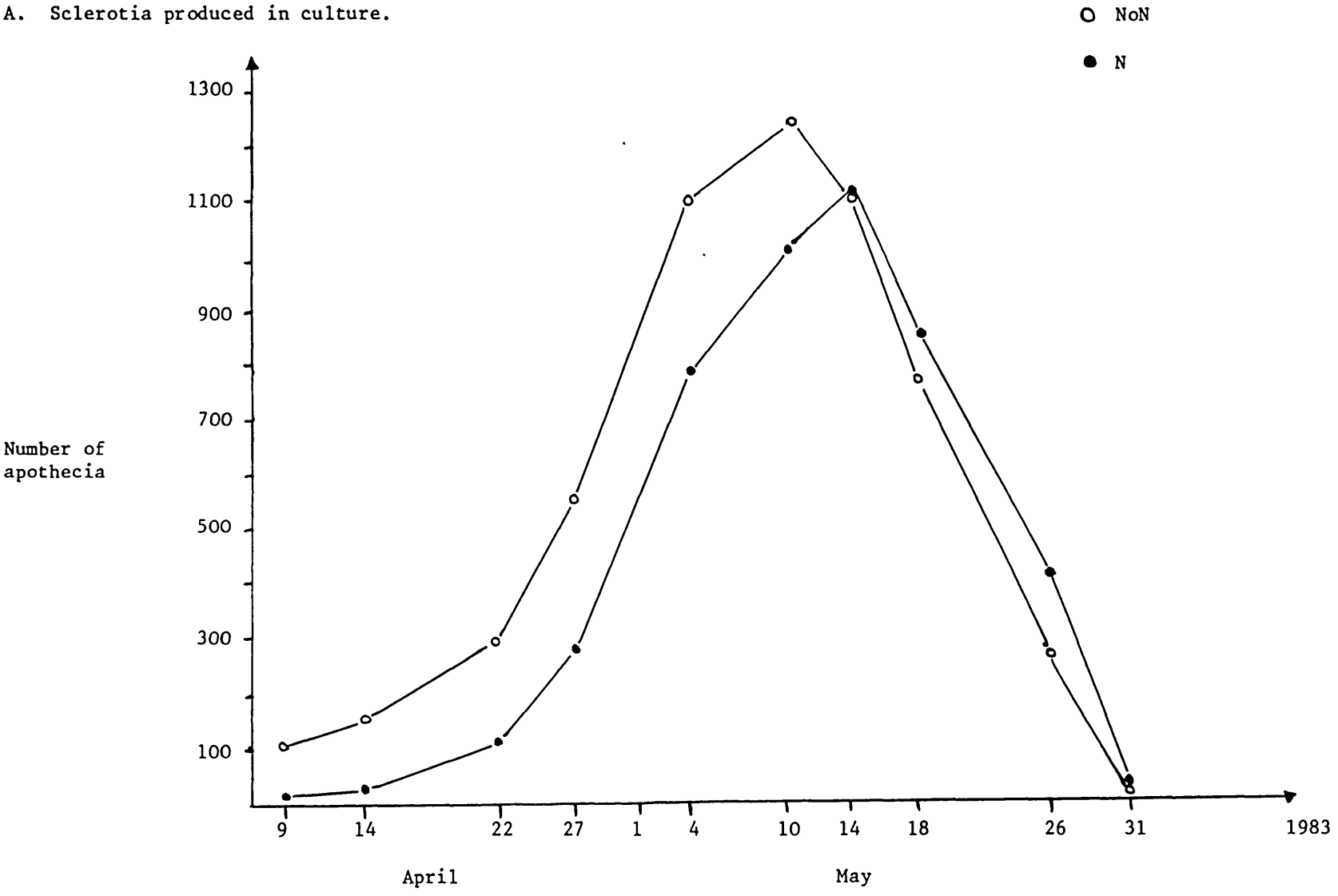
Date	Total No. of apothecia in treatments with	
	No. nitrogen	Nitrogen
April 9	148	25
14	225	38
22	395	144
27	726	365
May 4	1622	1077
10	1909	1352
14	1818	1608
18	1463	1466
26	660	797
31	79	162

Figure 8 : Production of apothecia in relation to source of sclerotia and addition of nitrogen.

A. Sclerotia produced in culture.

B. Sclerotia obtained from infected plants.

A. Sclerotia produced in culture.



B. Sclerotia obtained from infected plants.

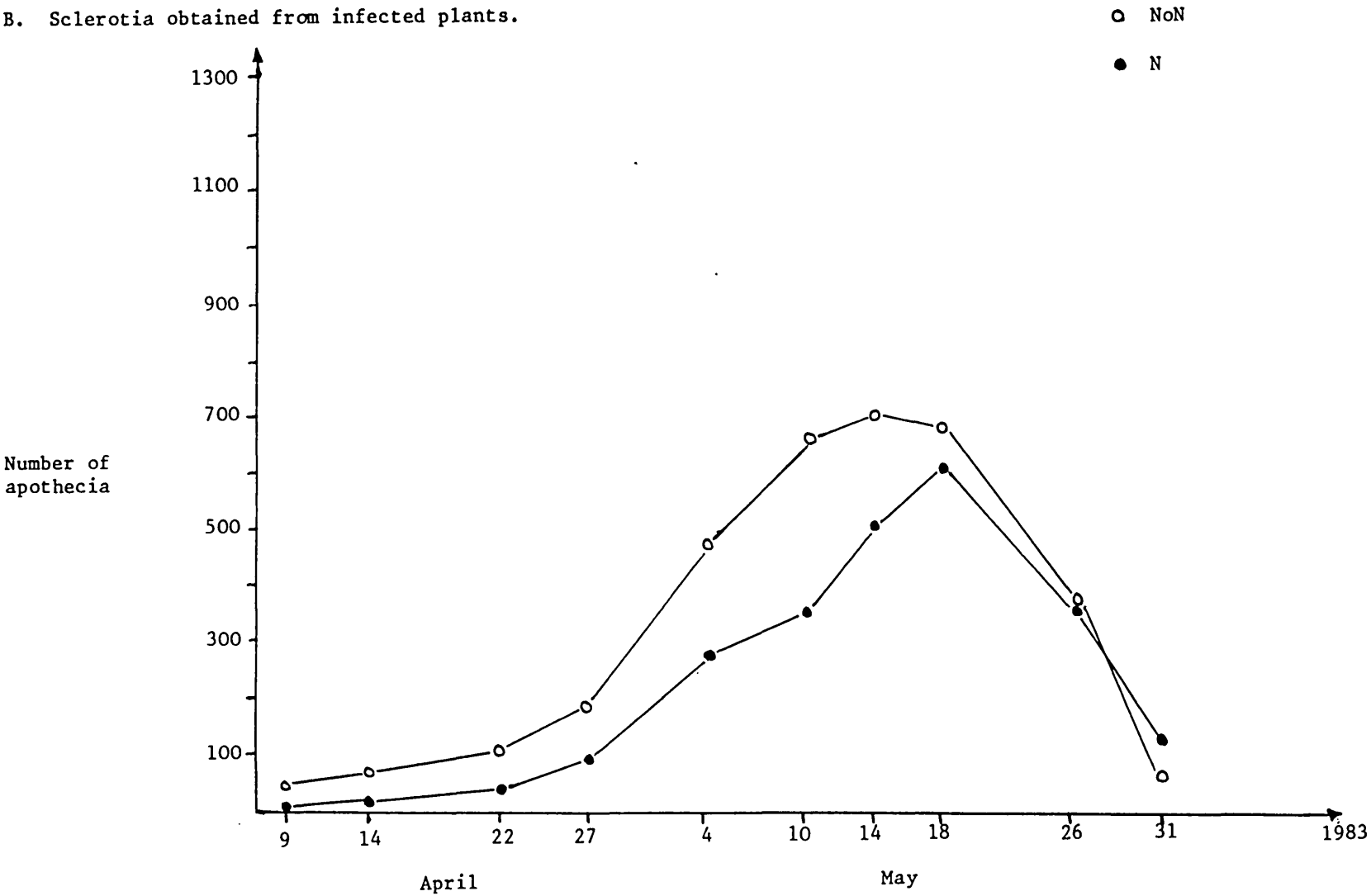


Table 87 : Production of apothecia in 1984 from sclerotia buried in soil, 1983 (Experiment 1).

Treatment comparisons	Total apothecia produced on				Total no. 'apothecial days'
	May		June		
	18	25	1	7	
A. Soil type					
Sutton Scotney	19	17	20	13	69
Silwood Park	25	22	30	7	84
B. Sclerotia					
Natural	2	7	8	6	23
Culture	42	32	42	14	130
C. Depth (cm)					
0	0	0	0	0	0
1	0	1	1	9	11
2	12	10	9	4	35
3	6	1	7	7	21
4	4	9	21	0	34
6	19	18	12	0	49

The numbers of sclerotia recovered in 1984 (after 23 months) from Experiment 1 are summarized in Table 88 and detailed for the three replicates of each treatment in Appendix XXXI. Recovery was affected significantly ($P = 0.001$) by the type of soil in which the sclerotia were buried, the depth at which they were buried and whether they were derived from cultures or infected plants. There were also significant ($P = 0.05$) soil type x depth of burial and sclerotia type x depth of burial interactions. Further analysis of these interactions (Table 89) showed that more natural sclerotia were recovered than culture sclerotia at depths of 1, 2 and 3 cm whereas at other depths similar numbers of each type were recovered. Also, more sclerotia were obtained at 2 and 3 cm from Silwood soil than from Sutton Scotney soil. Fewest sclerotia were recovered from the soil surface and 1 cm depth. In some replicates the numbers of sclerotia had increased beyond the 25 sclerotia originally placed in the pot and these gave higher overall values for percentage recovery than expected (Appendix XXXI).

3.1.2. Effect of burial date on production of apothecia

(a) Methods

Sclerotia were obtained by growing isolate JN1 on wheat grain at 20°C for 4 weeks. The harvested sclerotia were put in net bags, 25 sclerotia per bag, which were placed singly 2 cm deep in pots of John Innes No.1 compost. Three replicate pots were put in the field, buried in the field soil to the top of the pot, on each of the following dates: 18 August, 25 August, 1 September, 8 September, 13 October and 11 November 1983. The numbers of apothecia formed in each pot were assessed from mid-April to mid-June 1984.

Table 88 : Recovery of sclerotia in 1984 from Experiment 1, set up in 1983.

Treatment comparisons	Total no. sclerotia recovered	% Recovery
A. Soil type		
Sutton Scotney	388	43.1
Silwood Park	535	59.4
B. Sclerotia		
Natural	509	56.5
Culture	414	46.0
C. Depth (cm)		
0	15	5.0
1	43	14.3
2	115	38.3
3	186	62.0
4	264	88.0
6	300	100.0

Anovar

Factor		Variance ratio (F)
A. Soil type		12.75***
B. Sclerotia type		8.13***
C. Depth of Burial		40.43***
Ihteractions	AB	0.004
	AC	2.29*
	BC	3.81*
	ABC	1.15

*, ***, denote F-values significant at $P = 0.05$ and $P = 0.001$ respectively.

Table 89 : Recovery of sclerotia in 1984 from Experiment 1 in 1983 - interaction effects.

(a) Burial depth x sclerotia source

Depth (cm)	Type of sclerotia		F
	Culture	Natural	
0	7.0	8.0	0.2
1	8.5	13.5	5.99**
2	15.0	20.8	8.13***
3	13.9	28.3	50.62***
4	28.5	28.0	0.06
6	31.1	28.1	2.96

(b) Burial depth x soil type

Depth (cm)	Soil type		F
	Sutton Scotney	Silwood	
0	6.2	8.8	1.75
1	11.1	10.9	0.02
2	14.0	21.8	14.75***
3	16.5	27.5	29.41***
4	27.8	28.7	0.21
6	28.5	31.3	1.91

Analyses on $\sqrt{x + 0.5}$ transformed data.

(b) Results

The total apothecia present in the three replicate pots of each treatment are given in Table 90. Most apothecia were produced from sclerotia set out in the field on 18 August, productivity extending from 14 April to 14 June. Only sclerotia set out on 13 October produced comparable numbers. Although the peak production occurred on 17 May in all treatments, the numbers of apothecia produced from sclerotia set out on 25 August, 1 September and 8 September were particularly low. The reasons for this are not clear; possibly these sclerotia were affected more than the others by the dry weather in the latter half of 1984.

3.1.3. Production of apothecia from sclerotia of different isolates

(a) Methods

Sclerotia of 29 isolates of *S. sclerotiorum* and two of *S. trifoliorum* were obtained from 4 week-old cultures on wheat grain. These sclerotia were placed in net bags, 15 sclerotia of one isolate per bag, which were buried singly 2 cm deep in pots of John Innes No.1 compost. Three replicate pots of each isolate were set out in the field on 15 September 1983. The numbers of apothecia were counted during 1984 and then, on 3 December the pots were removed and the sclerotia surviving were counted.

(b) Results

One isolate (PW1) did not produce any apothecia and is omitted from the summary of results presented in Table 91. Two isolates identified as *S. trifoliorum* produced apothecia predominantly in the autumn of 1984 but relatively few of them. The isolate of *S. sclerotiorum* from radish was unique in producing apothecia both in spring and autumn. It was also the most productive isolate.

Table 90 : Production of apothecia from sclerotia buried 2 cm deep in pots and set out in the field on different dates.

Date (1983) set out in field	Total[a] apothecia produced on (1984)									Total no. 'apothecial days'
	April[b]		May					June		
	14	19	3	12	17	24	31	7	14	
Aug. 18	22	87	202	259	302	255	168	13	4	1312
25	10	34	31	39	45	10	3	0	0	172
Sept. 1	15	31	21	34	40	7	3	0	0	151
8	0	2	44	49	59	30	15	0	0	199
Oct. 13	95	87	163	200	212	189	91	1	0	1038
Nov. 10	9	10	7	18	32	169	84	30	0	359

(a) Total of three replicates.

(b) On 26 April all pots were dry because of lack of rain.

Table 91 : Production of apothecia from sclerotia of different isolates of *Sclerotinia sclerotiorum* and *S. trifoliorum* under field conditions.

	Isolate	Total apothecia produced on											Total no. 'apothecial days'
		April		May					June				
		14	19	3	10	17	24	31	7	14	21	28	
(a)	Radish[a]	3	5	18	40	48	52	65	31	15	5		282
	RC802	6	7	6	34	36	64	71	38				262
	JN5	2	2	4	34	33	46	49	43	12			225
	JN1	13	18	27	44	36	45	27	8	1			219
	V1	15	28	36	33	34	32	17	4	0	2		201
	FB1	5	10	21	21	30	30	23	6	1			147
	JN6	3	9	20	23	35	27	16	10	2			145
	Peanut[b]	11	15	8	12	16	12	3	7				84
	R1	10	11	6	1	11	11	9	3	0	2		64
	SS3	1	1	0	0	0	0	2	1				5
	SP	-	2	10	18	18	40	20	11	5			124

		May					June				July		
		3	10	17	24	31	7	14	21	28	19	25	
(b)	JN9	3	23	35	48	60	46	19	5	12			251
	SS2	10	10	30	34	66	61	13	12	5			241
	JN7	1	1	42	46	43	32	6					171
	CLOV	4	7	19	24	41	17	3	2	1			118
	JN2	7	13	18	37	19	16	7					117
	R1561	4	9	15	29	26	10	3	1				97
	PRI	4	6	7	8	8	3	1					37
	JN4	-	22	30	51	77	53	15					248
	PA1	-	18	35	17	17	16	2	1	1	1		108
	N1	-	4	9	29	36	17	3					98
	JN8	-	19	20	9	13	9	9	3	7	0	3	92
	L4776	-	10	15	21	20	18	1					85
	C3887	-	-	18	35	43	32	13	19				160
	RG1	-	-	3	26	41	30	17	9				126
	P5005	-	-	-	-	2	5	6					13

Table 91 : Continued.

Isolate	Total apothecia produced on												Total no. 'apothecial days'
	May		June				July		Aug.				
	24	31	7	14	21	28	19	26	2	9	16	23	
(c) L2E	14	22	23	19	8	6	7	6	2	5	10	3	125

Isolate	Aug.	Sept.			Oct.				Nov.		Total no. 'apothecial days'
	23	6	13	28	11	16	23	30	6	16	
(d) Strif II	-	5	5	8	4	7	10	15	14	3	71
Strif I	-	-	-	1	3	12	4	2	-	-	22
Radish[a]	3	2	1								6

[a] Included in both (a) and (d).

[b] Sclerotia recovered from artificially inoculation of peanut plants using JN1.

The remaining isolates varied considerably in the time at which apothecia were first formed, the period over which they were produced and in the numbers produced. This variability extended even to isolates from Jet Neuf. Of the isolates of *S. sclerotiorum*, L2E was one of the latest to produce apothecia (24 May) but then continued to 23 August, in contrast to P5005 which produced apothecia only over the 3 week period from 31 May to 14 June.

Recovery of sclerotia of the various isolates varied between 11% (RC802) and 53% (H01) but recovery from pots with sclerotia of the same isolate was very variable and differences between isolates were not significant (Table 92). Nor was there any relationship between numbers of sclerotia recovered and the numbers of apothecia produced.

3.1.4. Infection of weed species

The area immediately surrounding the pots with buried sclerotia (3.1.1.) became colonized with weeds during 1983. These were identified and observed throughout the season because it seemed likely that they would be in contact with many ascospores of *S. sclerotiorum*. Of the 13 weed species recorded, three developed lesions - *Trifolium medium* L. (clover), *Capsella bursa-pastoris* (L.) Medic. (shepherd's purse) and *Raphanus raphanistrum* L. ssp. *raphanistrum* (wild radish) (Table 93). Lesions were first observed on 9 June. When these lesions were surface-sterilized in sodium hypochlorite and plated on GAY agar at 20°C, characteristic colonies and sclerotia of *S. sclerotiorum* developed. By 20 June, sclerotia had begun to form on plants of wild radish and shepherd's purse where lesions had reached the full length of the stem. By 7 July these sclerotia were mature and the number per stem were counted. Plates 5 and 6 show the symptoms on these plants. On shepherd's purse, some sclerotia (mean of two sclerotia/root) had formed at the junction of lateral

Table 92 : Recovery of sclerotia from isolates set up in 1983.

Isolate code	Replicate pots			Total	% Recovery
	1	2	3		
HO1	8	12	4	24	53.3
JN9	11	7	3	21	46.6
JN8	8	5	7	20	44.4
JN1	6	6	7	19	42.2
RAD	3	15	1	19	42.2
JN9	9	4	4	17	37.8
PW1	4	2	9	17	37.8
C3887	3	4	9	16	35.5
JN2	8	7	1	16	35.5
L2E	7	3	6	16	35.5
St II	3	5	8	16	35.5
PRI	4	9	2	15	33.3
SS3	4	4	7	15	33.3
VI	5	5	5	15	33.3
SS2	5	2	7	14	31.1
PAI	5	6	2	13	28.9
P5005	2	8	3	13	28.9
CLOV	3	3	6	12	26.7
L4776	4	5	3	12	26.7
RG1	3	4	5	12	26.7
St 1	5	5	2	12	26.7
JN5	2	3	6	11	24.4
JN7	3	3	5	11	24.4
SP	2	4	5	11	24.4
FB1	4	5	1	10	22.2
JN4	1	5	3	9	20.0
R1561	2	3	4	9	20.0
R1	4	4	0	8	17.8
N1	2	2	3	7	15.6
PEANUT	1	1	5	7	15.6
RC802	2	0	3	5	11.1

Anovar

	d.f.	SS	MS	F	
Treatment	30	10.03	0.334	0.95	n.s.
Block	2	0.27	0.137	0.39	n.s.
Error	60	21.05	0.357		
Total	92	31.36			

Table 93 : Infection of weed species at Silwood Park 1983.

Weed species	Field lesion	Plating on GAY at 20°C				Field		No. infected plants
		Lesion		Sclerotia		Sclerotia		
		Mycelium	Sclerotia	Mycelium	Sclerotia	No./plant	Size (mm)	
Trifolium medium	✓	✓	✓	-	-	-	-	1
Capsella bursa-pastoris (L.) Medic.	✓	✓	✓	✓	✓	2	6 x 1	34
Raphanus raphanistrum L. Ssp. *raphanistrum*	✓	✓	✓	✓	✓	6	4 x 2	91

The following species remained uninfected:- *Raphanus raphanistrum* Ssp. *maritimus* (Sm.) Thell, *Veronica persica* Poir, *Chamamilla recutita* (L.) Rauschert, *Trifolium campestre* Schreb., *Vicia tetrasperma* (L.) Schreb., *Papava dubium* L., *Rumex obtusifolius* L., *Polygonum aviculare* L., *Stellaria media* (L.) Vill., *Viola arvensis* Murr.

Plate 5 : Silwood Park, 1983: Symptoms of *Sclerotinia sclerotiorum* on Wild Radish.



Plate 6 : Silwood Park, 1983: Symptoms of *Sclerotinia sclerotiorum* on Shepherds Purse.



roots.

Infections occurred on *Papaver dubium* L. and *Vicia tetrasperma* (L.) Schreb. where infected wild radish plants lodged against them but no sclerotia formed on these two species.

3.2 Epidemiological Studies with Jet Neuf

3.2.1. Description of the trials

(a) 1982-83

Jet Neuf was sown on 2 September 1982 in a 9 x 9 m square at a rate of 6-8 kg/ha. The seedbed received N:P:K (40:60:60 kg/ha) and a post emergence herbicide (Kerb 50W) was applied. Each 3 x 3 m^2 of Jet Neuf was inoculated with 5 terylene net bags containing 20 sclerotia c 1 cm deep on 16 September 1982, one centrally and four equidistant on the plot diagonals to give overall 100 sclerotia per 9 m^2.

A spring dressing of nitrogen (200 kg/ha) was applied on 26 March 1983 and once the crop was at G.S. 3.2, the plot was made into a circle of diameter 9 m by removing excess plants (Fig. 1). In the centre, a 2 m diameter circle was also made in which a Burkard Volumetric Spore Trap was placed on a packing case.

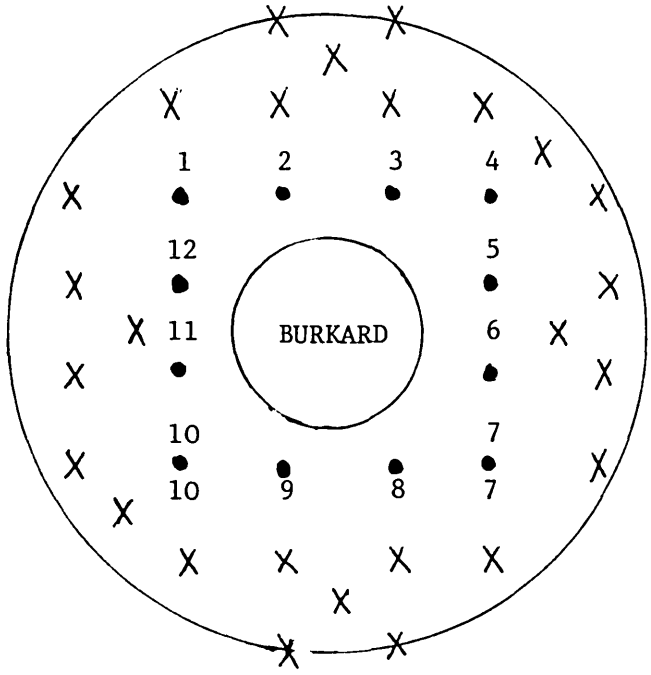
Twelve positions surrounding this central circle were chosen and a rod spore trap was placed at each, directly above a bag of sclerotia inoculum. These were the nearest inoculum bags to the Burkard spore trap and were for monitoring numbers of both apothecia and ascospores (Figure 9).

(b) 1983-84

The layout of the trial was identical to that in 1982-83. Drilling took place on 26 August 1983, and the inoculum bags were placed in the trial on 9 September 1983. Spring nitrogen application was split - half on 24 February 1984 and half on 20 March 1984 giving an overall rate of 200 kg/ha.

Assessments were only made in one 3 x 3 m^2 plot including five inoculum bags and a rod spore trap was placed centrally in this area.

Figure 9 : Plan of the Jet Neuf planting 1982-83.

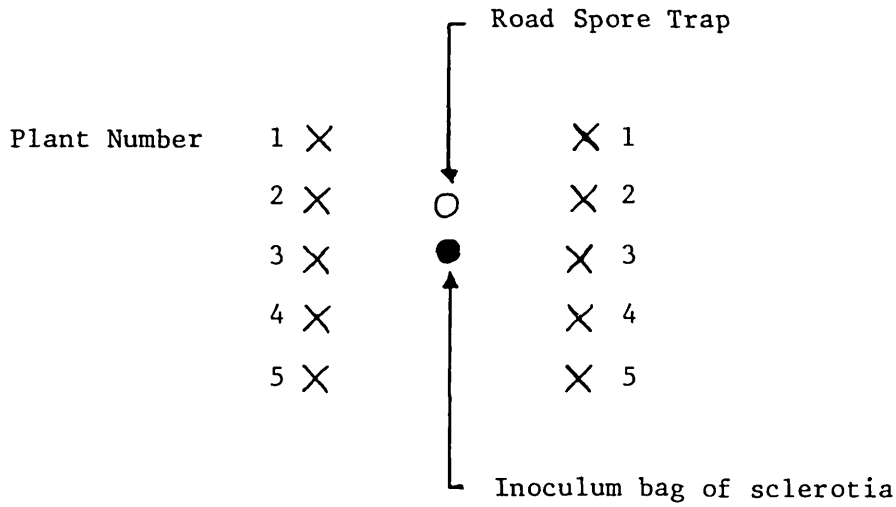


Diameter = 9 m

● Inoculum bags assessed

X Other inoculum bags under trial

Petal sweeping experiment



A Burkard spore trap was also placed centrally in the circular planting.

3.2.2. Production of apothecia and ascospores

(a) 1983

Apothecia were first observed on 28 April, their numbers increased to a peak on 20 May and then declined (Table 94). Overall, apothecia were present under the crop for 10 weeks. At two positions (3 and 9) few apothecia were produced.

Ascospores were first seen on rod spore traps exposed for the 7 days preceding 19 April, 9 days before apothecia were found at the marked positions within Jet Neuf. This suggests that even at this stage ascospores were widely distributed from apothecia at other positions within the planting of Jet Neuf or from outside this trial (in the burial experiment).

The maximum number of ascospores were trapped during the 7 day period ending 26 May, the week which included the highest number of apothecia (Table 95). The relationship between production of apothecia and counts of airborne ascospores is shown in Fig. 10.

Counts of ascospores from the Burkard spore trap confirmed that maximum spores were trapped in the period immediately preceding 26 May, particularly on 22 and 23 May. When counts for this period were combined (Fig. 11) peak ascospore release (between 13.00 and 15.00 h) was found to coincide with periods of minimum relative humidity and maximum temperature.

Attempts to relate the total number of spores/m^3 air/day with total rainfall in 24 hours; the number of hours in each day during which the ascospores were trapped and a) the rh below 80%, b) an interaction between temperature and rh, c) an interaction between temperature and rainfall did not give any convincing associations as to the weather features

Table 94 : Production of apothecia in 1983 from sclerotia set out in bags within the planting of Jet Neuf.

Position of sclerotia(a)	Number of apothecia on												Total no. of apothecial weeks
	April	May						June				July	
	28	4	9	16	20	25	30	6	13	20	30	6	
1	3	10	29	30	35	27	10	2	0	0	0	0	146
2	11	25	37	50	53	18	12	1	1	0	0	2	210
3	3	3	3	6	6	10	3	3	2	0	0	0	39
4	3	8	17	19	20	27	13	2	1	0	1	1	112
5	1	9	19	29	25	18	15	2	0	0	0	0	118
6	4	7	21	40	38	34	15	2	4	0	3	0	168
7	7	17	17	26	24	7	7	7	2	0	0	0	114
8	10	15	30	39	45	17	13	2	1	0	0	0	172
9	1	4	10	6	6	7	9	2	2	0	1	0	48
10	10	20	24	32	35	29	27	2	0	0	3	1	183
11	13	22	28	39	39	15	8	2	1	4	1	1	173
12	0	15	17	30	36	10	5	3	1	2	1	0	120
Total	66	155	252	346	362	219	137	30	13	6	10	3	

(a) See Figure 4.

Table 95 : Ascospores collected on rod spore traps within a planting of Jet Neuf, 1983.

Position of rod spore trap[a]	No. ascospores trapped in 7 day period ending													Total no. ascospores (thousands)
	April		May				June					July		
	19	26	4	12	19	26	2	9	16	23	30	7	14	
1	100	111	654	104	427	1003	3092	2201	340	137	92	41	34	8.34
2	122	186	641	127	194	1359	1562	1260	217	129	91	45	31	5.96
3	139	209	244	134	2134	9743	6345	2104	411	145	84	41	6	21.74
4	100	126	143	121	960	8260	7892	1239	341	167	98	32	8	19.49
5	34	53	271	144	850	9134	8113	1774	362	172	96	34	3	21.04
6	63	91	192	208	2631	7432	1560	1924	222	191	84	36	12	14.65
7	71	127	294	113	2092	2791	1492	1333	339	341	81	31	2	9.11
8	54	63	113	145	294	1234	1433	1400	414	117	72	30	1	5.37
9	28	333	360	163	3150	3459	1167	100	128	118	39	20	3	9.07
10	39	74	538	171	3241	4571	4136	2138	713	623	111	41	4	16.40
11	84	63	709	213	411	3966	3733	1357	322	345	34	21	19	11.28
12	47	114	278	192	2132	4443	1792	1672	189	211	99	39	13	11.22
Total	881	1550	4437	1835	18516	57395	42317	18502	3998	2695	981	411	136	
No./mm^2	1.76	3.1	8.87	3.67	37.03	114.79	84.63	37.0	7.99	5.39	1.96	0.82	0.27	

[a] See Fig. 9

Figure 10 : Relationship between production of apothecia within a planting of Jet Neuf and numbers of ascospores caught on rod spore traps[(a)].

(a) Data are totals for 12 positions (see text)

x Ascospore data

● Apothecia numbers

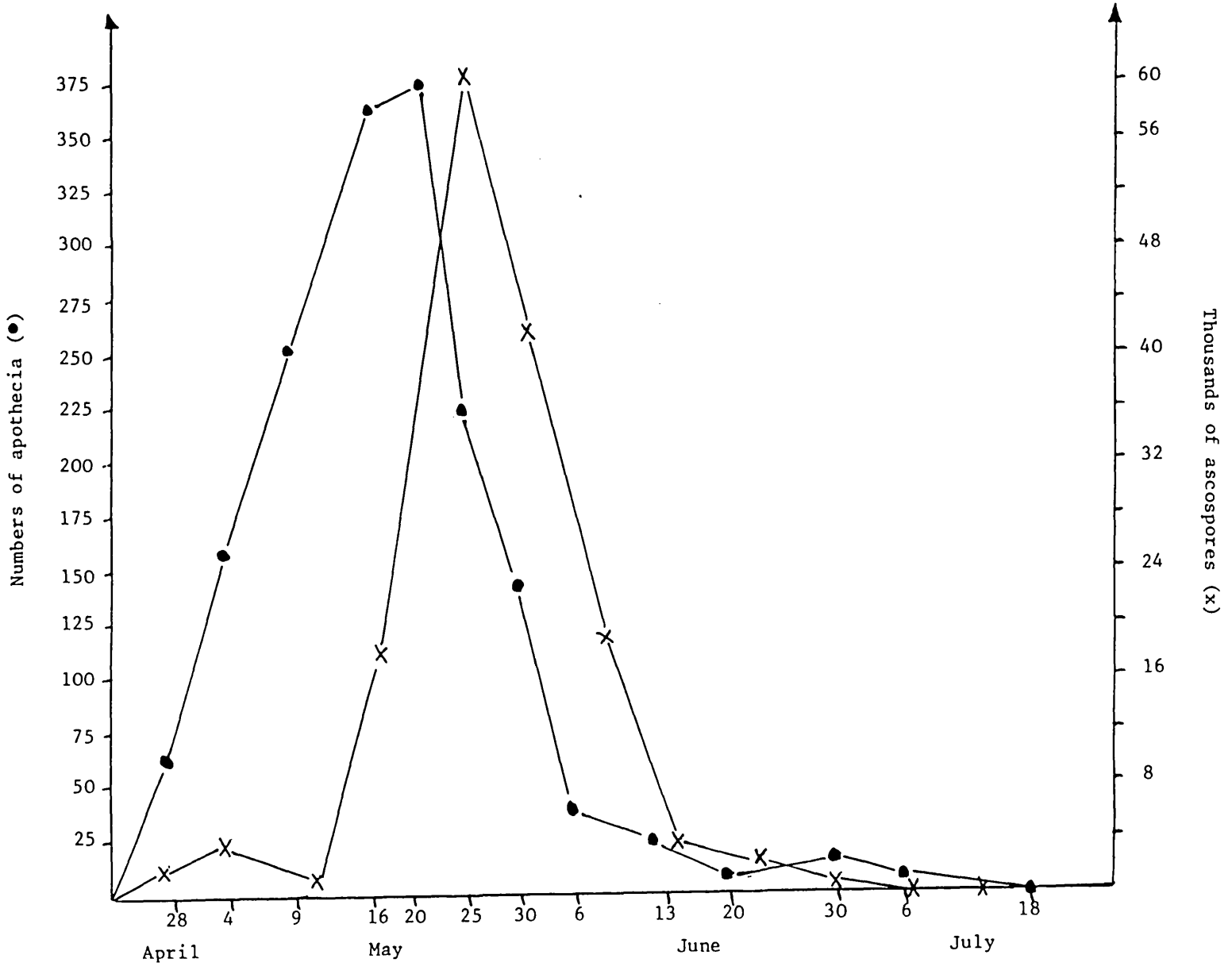
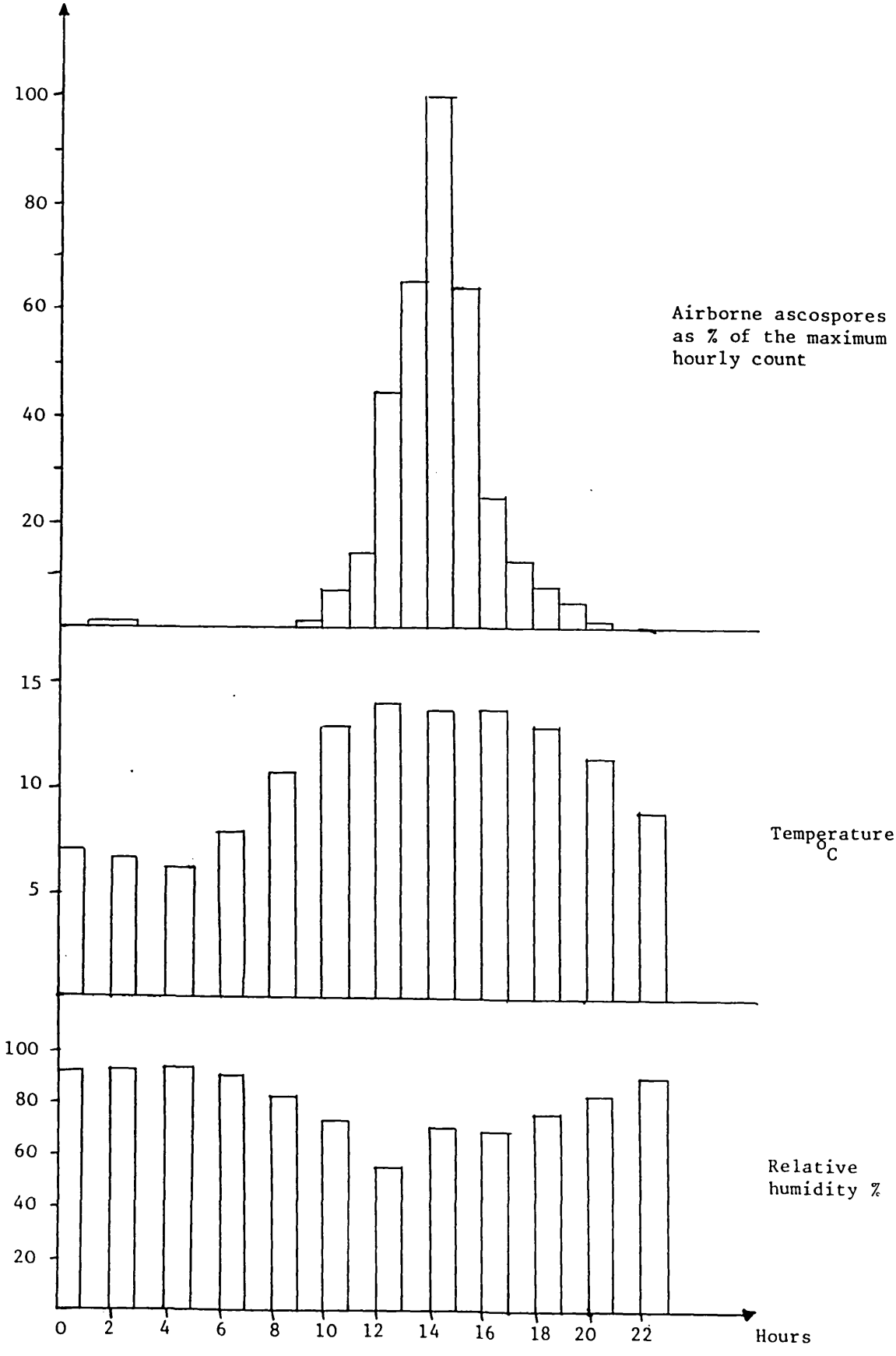

Numbers of apothecia (●)
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
Thousands of ascospores (x)
60
56
48
40
32
24
16
8
28
4
9
16
20
25
30
6
13
20
30
6
18
April
May
June
July

Figure 11 : Mean number of ascospores caught per hour between 20-26 May 1983 at Silwood Park.


100
80
60
40
20
Airborne ascospores as % of the maximum hourly count
15
10
5
Temperature °C
100
80
60
40
20
Relative humidity %
0
2
4
6
8
10
12
14
16
18
20
22
Hours

that initiate ascospore release.

(b) 1984

Apothecia were first observed on 23 April, their numbers increased to a peak on 28 May and then declined (Table 96). They were present for a shorter period than in 1983 - lasting 7 weeks. At one position only 7 apothecia were produced in one week.

Ascospores were first seen on the rod spore trap exposed for the 7 days preceeding the 7 May. The maximum numbers were trapped during the 7 day period ending 4 June, the week which included the highest number of apothecia (Table 97).

Counts of ascospores from the Burkard spore trap indicated that maximum spore production occurred during the 7 day period ending 13 May, and although this did not coincide with the rod spore trap, other apothecia in the circular planting would affect the spores trapped on the Burkard (Appendix XXXIII). The diurnal peak of ascospore release was between 13.00 and 16.00 h.

3.2.3. Comparison between numbers of apothecia produced in two situations

The number of apothecia produced in the Burial Experiment Treatment 3 plus nitrogen (Appendix XXIX) were compared to those at the twelve rod spore trap positions in 1982-83, as they were identical.

The sclerotia overwintering in the exposed site (Treatment 3) produced apothecia much earlier than those overwintering under the crop (Table 98). Also at the peak of production at each site, those sclerotia in the exposed position produced slightly higher numbers of apothecia.

However, those sclerotia under the crop produced apothecia for a longer period of time.

Table 96 : Production of apothecia from sclerotia set out in the Jet Neuf planting, 1984.

Bag position[(a)]	No. of apothecia on							Total no. of apothecial weeks
	April	May				June		
	23	5	12	19	28	6	11	
1	-	-	-	11	10	4	2	27
2	-	-	-	-	7	-	-	7
3	1	3	4	7	8	6	-	31
4	-	4	4	6	4	2	-	20
5	5	10	10	14	7	1	-	47
Total	6	17	18	38	36	13	2	

(a) Bags in a 3 x 3 m^2.

Table 97 : Ascospores trapped on a rod spore trap in Jet Neuf planting 1984.

	No. of ascospores trapped in 7 day period ending									Total no.
	April	May				June				
	30	7	14	21	28	4	11	18	25	
Jet Neuf	0	4	13	11	10	22	8	0	0	68

Table 98 : Comparison of apothecial numbers in 2 situations.

Number of apothecia produced per sclerotia			
Treatment 3 N	Date 1983		Under Jet Neuf
0.01	9.4		
0.05	14.4		
0.35	22.4		
0.76	27.4	28.4	0.28
1.04	4.5	4.5	0.65
1.72	10.5	9.5	1.05
1.84	14.5	16.5	1.48
1.19	18.5	20.5	1.56
0.51	26.5	25.5	0.91
0	31.5	30.5	0.57
		6.6	0.13
		13.6	0.07
		20.6	0.03
		30.6	0.04
		6.7	0.02

3.2.4. Effect of petals on initiation of stem rot

Five plants on either side of each rod spore trap were labelled during the 1983 trial. Plants on one side were swept daily at 11.00 h with a camel-hair brush to remove all petals adhering to the leaves and stems; plants on the other side were left untreated. The incidence of stem rot was assessed twice, on 30 May (during pod maturation) and on 16 July (pods mature). The 10 plants at each site were harvested on 16 July and threshed individually.

The association between plants with stem rot and those with adhering petals is shown in Table 99. On 30 May 15 out of 60 plants with adhering petals were infected with stem rot; by 16 July 37 plants in this group were infected. Only two plants of those kept free of petals became infected.

Yields from the two sets of five plants at each site (Table 100) were compared using a t-test. This indicated a highly significant ($P = 0.001$) difference in yields. Overall, there was a loss in yield of 51.6% when petals were allowed to lodge on the plants and infections by *S. sclerotiorum* developed.

3.2.5. Lesion development

Lesions were first seen on 23 May 1983. Three days later 40 plants with lesions were selected; 20 plants with leaves attached at the infected axil, 20 plants where the leaf had abscissed from the infected axil. The lengths of the lesion above and below the axil were measured on each of the 40 plants.

Where leaves were attached, lesion extension below the axil was significantly greater ($P < 0.01$) than that above the axil, but where leaves had abscissed there was no significant difference ($P > 0.05$) in lesion extension above and below the infected leaf axil (Table 101).

Table 99 : Association of stem rot with presence of petals.

(a) Assessment 30 May

		Plants with adhering petals (+) or not (-)		
		+	-	
Plants infected (+) or not (-)	+	15	1	16
	-	45	59	104
		60	60	

(b) Assessment 16 July

		Plants with adhering petals (+) or not (-)		
		+	-	
Plants infected (+)	+	37	2	39
	-	23	58	81
		60	60	

Table 100 : Yields from plants in the experiment on removing petals, Silwood Park 1983.

Position no.	Total weight of seed (g) from five plants	
	Petals removed	Petals not removed
1	8.35	4.15
2	5.04	1.64
3	10.22	8.36
4	7.69	5.31
5	4.47	1.39
6	9.02	8.11
7	12.04	6.24
8	4.85	4.43
9	16.72	10.08
10	12.34	3.09
11	11.68	0.78
12	14.84	3.20
Total	117.25	56.78

Value of t for difference between the two treatments is 4.56 ($P \leq 0.001$, 11 d.f.).

Table 101 : Lesion development on Jet Neuf, 1983.

Plant no.	Lesion length (mm) above (A) and below (B) the infected axil on plants with			
	Leaves attached		Leaves abscissed	
	A	B	A	B
1	22	30	28	24
2	18	28	19	17
3	12	18	50	69
4	4	23	51	40
5	2	21	50	65
6	5	19	30	15
7	38	64	15	10
8	28	36	20	23
9	40	59	17	12
10	10	40	28	19
11	5	20	27	21
12	45	65	10	15
13	30	47	36	30
14	34	85	31	29
15	19	20	20	25
16	10	37	40	15
17	30	41	25	21
18	25	37	22	14
19	15	24	39	17
20	34	43	36	25
Mean	21.3	37.9	29.7	25.3
Comparison of means[a]	$t = 6.7$; $P < 0.01$		$t = 1.85$; $P > 0.05$	

[a] t-test on paired samples.

3.3 Spraying Trial 1983-84

The effect on stem rot of applying Ronilan (B.A.S.F., 50% w:w vinclozolin) to a planting of Jet Neuf was examined during the 1983-84 season.

An area, 14 x 11 m^2 was drilled on 25 August 1983 and five net bags each with 20 sclerotia of *S. sclerotiorum* (JN1 - obtained from wheat grain) were placed 2 m apart between the drills indicated in Fig. 12, i.e. 7 rows of rape between each set of inoculum. The spring nitrogen dressing was split - half applied on 24 February and half on 20 March 1984. The trial was netted to prevent bird damage.

When the crop was established, plots with six 5 m rows were identified to give four blocks of four plots, three sprayed plots and an unsprayed plot per block. Sprays were applied in relation to growth of the crop and activity of the fungus. One plot per block was sprayed on 28 April (G.S. 3.3-4.1) when apothecia were first observed (Treatment A), another plot was sprayed on 24 May at petal fall (G.S. 4.3-4.4) (Treatment B) and the third plot was sprayed on 12 June (G.S. 5.1) when the first stem rot lesion was seen (Treatment C). The guard rows and intervening areas between plots were sprayed on each of these three dates.

Ronilan was applied at a rate of 1.5 kg in 450 l water/ha using a knapsack sprayer (CP3 - Cooper Pegler & Co. Ltd., Burgess Hill, Sussex) and a "Polijet" Yellow Nozzle (I.C.I. Plant Protection Division) inverted so that the 50 cm wide spray fan was projected horizontally (rather than the normal 45^{o} downwards). The sprayer was calibrated to spray 560 cc/min at 0.7 kg/cm^2.

Adjacent rows were sprayed just below the top of the racemes to ensure minimum spray drift. There were thus three traverses per plot. Sprays were applied between 11.00 and 14.30 h, on sunny days with little wind. These conditions allowed dew to dry before spraying and the plants to dry

Figure 12 : Plan of spray trial 1983-84.

1 Row of Jet Neuf

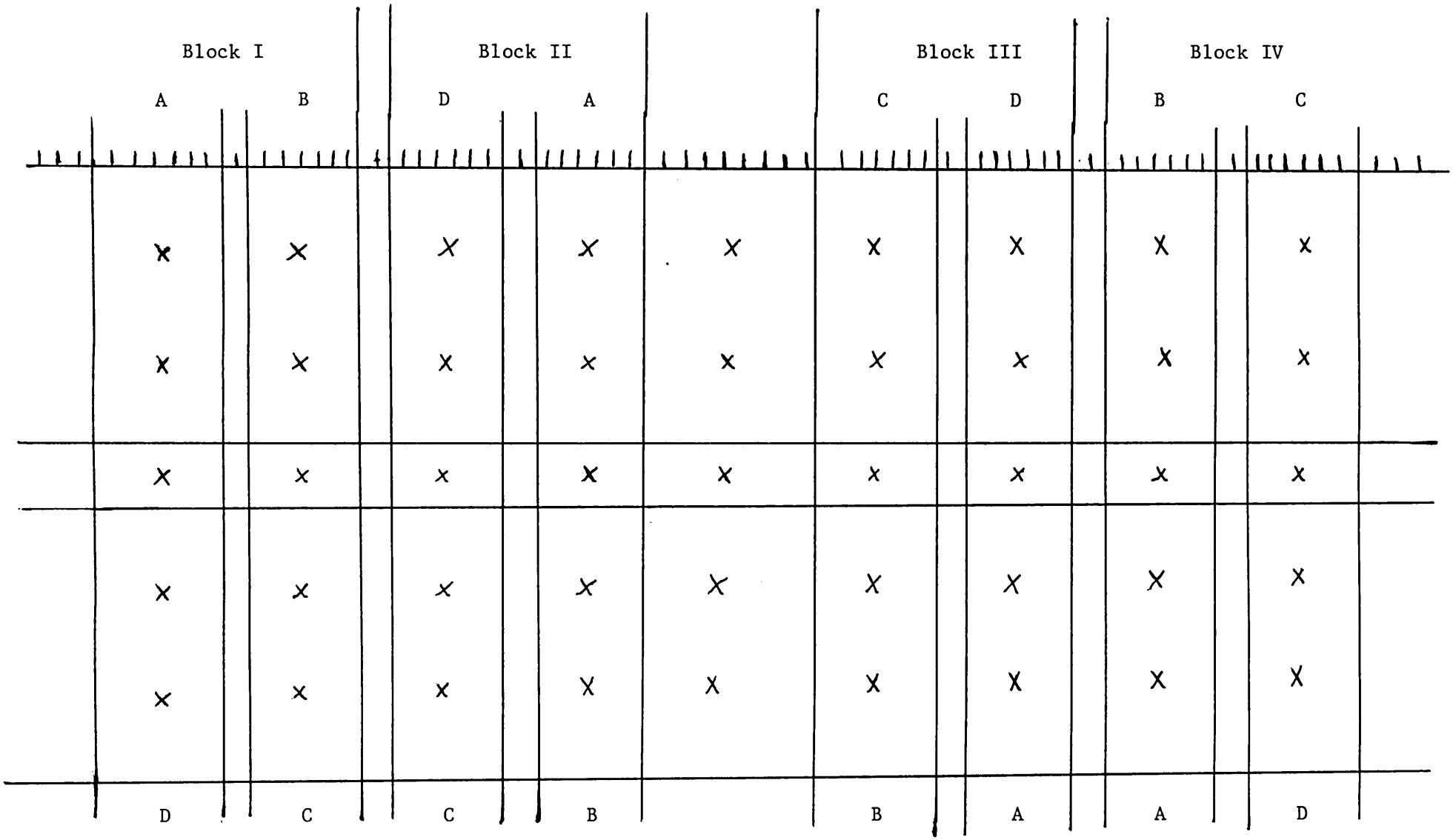
x Position of inoculum bag

A = Spray on 28 April 1984

B = Spray on 24 May 1984

C = Spray on 12 June 1984

D = Unsprayed


Block I
Block II
Block III
Block IV
A
B
D
A
C
D
B
C
D
C
C
B
B
A
A
D

after spraying.

Numbers of apothecia at each inoculum site were counted weekly. As stem rot incidence proved to be low, there was only one assessment (using the cane method, p. 75) on 28 June. Plants within a 0.5 x 0.5 m quadrat in each plot were harvested, bagged, air-dried and threshed to determine weight of seed. Two bags of sclerotia were recovered from each plot and the number of sclerotia remaining was counted.

There were differences in the numbers of apothecia produced at different sites (Table 102) but these were not related apparently to the spray treatments applied. The lack of stem rot made any conclusions of doubtful validity though sprays applied at petal fall (Treatment B) appeared most effective in reducing stem rot and there were significant differences ($P < 0.05$) between the mean for this treatment and those for treatments C (sprayed 12 June) and D (unsprayed) (Table 103).

Despite these differences in stem rot, yields (Table 104) for the treatments did not differ significantly ($P > 0.05$). Generally spraying reduced the number of sclerotia which survived (Table 105), the spray applied on 12 June being most effective.

Table 102 : Production of apothecia: spray trial 1984.

Treatment	Total no. of apothecia on								Total 'apothecial' days
	April	May					June		
	23	1	5	12	19	28	1	6	
A. Sprayed 28 April	0	0	6	12	37	24	7	2	86
B. Sprayed 24 May	4	4	39	76	87	51	19	0	270
C. Sprayed 12 June	8	8	60	74	92	65	45	23	365
D. Unsprayed	0	0	10	33	43	26	19	12	143

Table 103 : Incidence of stem rot on 28 June: spray trial 1984.

Treatment	% Stem rot in block no.				Total	Mean
	I	II	III	IV		
A. Sprayed 28 April	6	0	6	0	12	3.0
B. Sprayed 24 May	0	2	2	0	4	1.0
C. Sprayed 12 June	6	6	4	2	18	4.5
D Unsprayed	4	6	8	6	24	6.0

Table 104 : Yields: spray trial 1984.

Treatment	Wt. (g) of seed[a] in block				Total	Mean
	I	II	III	IV		
A. Sprayed 28 April	100	114	50	108	372	94.0
B. Sprayed 24 May	63	68	88	79	298	74.5
C. Sprayed 12 June	82	88	96	86	352	85.5
D. Unsprayed	34	69	76	78	257	64.3

[a] From a quadrat, 0.5 x 0.5 m, in each plot

Table 105 : Survival of sclerotia: spray trial 1984.

Treatment	No. of sclerotia[a] in block no.				Total	Mean
	I	II	III	IV		
A. Sprayed 28 April	37	37	42	20	136	34
B. Sprayed 24 May	35	40	24	27	126	32
C. Sprayed 12 June	24	22	20	18	84	21
D. Unsprayed	49	35	37	36	157	39

[a] Total for two bags of sclerotia

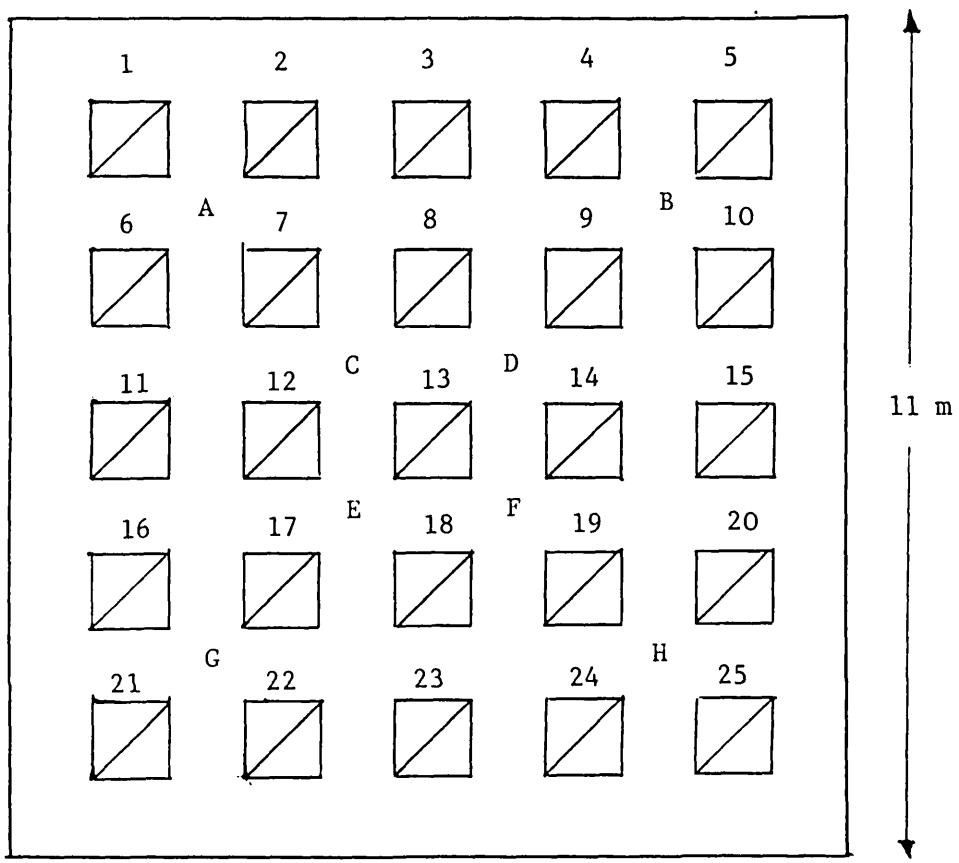
3.4 Inoculum Density Trial 1983-84

During the 1983-84 trial an attempt was made to determine the effect of inoculum density on the incidence of stem rot. Twenty-five plots (5 x 5) of Jet Neuf, each 1 m^2 and 1 m from each other were drilled on 27 August 1983. Winter wheat cv. Aquila was broadcast over the surrounding areas on 22 September and again on 22 October following pheasant predation. Bags containing 2, 5, 10 or 20 sclerotia were placed centrally in each of 16 plots as indicated in Fig. 13. Cultural practices were otherwise similar to those of the spray trial (3.3).

Rod spore traps were placed centrally in each plot in April and eight other traps were placed between plots (Fig. 13). Numbers of apothecia were recorded weekly and the spore traps were examined for ascospores also on these occasions. Disease was assessed on 28 June by examining each plant within the plots and recording presence or absence of stem rot. Finally, the survival of sclerotia was determined.

Apothecia were first observed on 12 May. The numbers subsequently produced reflected the numbers of sclerotia present at each site (Table 106). However, ascospores became distributed throughout the site and the numbers caught in the traps were not related to the numbers of apothecia beneath each trap. As many ascospores were caught above plots with no sclerotia as above those with sclerotia. Also, many ascospores were trapped above the intervening planting of wheat (Table 107). The mean incidence of stem rot in plots with no sclerotia (1.9%) was lower than that of plots with sclerotia (4.1-5.8%) but the generally low incidence of stem rot and the distribution of ascospores meant that the original aim of the trial could not be realized. The total number of sclerotia recovered from the five plots originally with 2, 5, 10 or 20 sclerotia were, respectively 9, 26, 62 and 90 sclerotia indicating that it some plots more sclerotia had formed.

Figure 13 : Plan of inoculum density trial 1983-84.



1 m^2 Jet Neuf
surrounded by winter wheat

Plan for sclerotia bags

0	2	5	10	20
10	5	0	20	2
5	20	10	2	0
20	10	2	0	5
2	0	20	5	10

Letters are interplot spore traps

Table 106 : Production of apothecia: inoculum density trial 1984.

Inoculum density (sclerotia/bag)	No. apothecia on						Total 'apothecial' days
	May			June			
	12	19	28	2	6	11	
Nil	0	0	0	0	0	0	0
2	4	5	13	8	20	1	21
5	0	9	14	22	10	1	56
10	0	6	67	75	59	14	221
20	0	0	128	137	94	5	364

Table 107 : Numbers of airborne ascospores: inoculum density trial 1984.

Inoculum density (sclerotia/bag)	No. ascospores trapped[a] week ending								Total
	April	May				June			
	30	7	14	21	28	4	11	18	
Nil	18	8	29	35	52	61	7	0	212
2	8	9	39	58	95	61	13	0	246
5	7	12	21	50	57	55	18	0	214
10	8	8	26	20	70	58	22	1	213
20	2	2	6	20	48	63	26	0	169
Inter-plot traps	12	53	37	36	60	103	47	0	348

[a] Total for five traps at each inoculum density and of eight inter-plot traps.

SECTION 4

EXPERIMENTS IN THE GLASSHOUSE AND LABORATORY

4.1 Introduction and Relevant Literature

Natural infection is sporadic being dependent upon a complex interaction of presence and germination of sclerotia, crop growth stage and weather conditions (Section 3). Infection requires the presence of dead petals and some cultivars that are covered with petals outside the ascospore peak may escape disease. Direct inoculation although time consuming, helps to eliminate this factor and allows the screening of cultivars under glasshouse and laboratory conditions, for resistance to *S. sclerotiorum*.

Infection processes of *S. sclerotiorum* in oilseed rape are vitally linked to the petal but the precise reason for this association has not been investigated. Most reports assume the role to be tied in with nutrition for the germinating spore (Purdy & Bardin, 1953; Mclean, 1958; Natti, 1971; Abawi & Grogan, 1975; Abawi *et al.*, 1975; Krüger, 1975). The presence of pollen grains in droplets along with ascospores has been shown to stimulate germination, germ tube growth and lesion development for conidia of *Botrytis cinerea* Fr. in Strawberry and Bean (Chu Chou & Preece, 1968) and reduce the number of conidia required for infection. Hartill (1975) observed clumps of tobacco pollen at loci of infection by *S. sclerotiorum* and showed that pollen stimulated germination and growth of ascospores on tobacco leaf disks. Sutton & Deverall (1983) found that pollen stimulated growth from germinating ascospores in vitro and in vivo of *S. sclerotiorum* but did not stimulate infection of bean.

Fungal pathogenesis may therefore be affected by these factors, but the general view is that pathogenicity of *S. sclerotiorum* is varied and

difficult to define for different isolates on different hosts (Price & Colhoun, 1975).

This section describes experiments which examine various aspects of infection and also records observations on sclerotia recovered from field experiments.

4.2 Inoculation Experiments with Plant Material Grown in the Glasshouse and Outdoors

4.2.1. Materials and methods

(a) Plant material

Seeds of the oilseed rape cultivars were placed in germination trays (40 x 25 x 10 cm, Leithen Valley Plastis Ltd) and allowed to imbibe water for 48 h at room temperature before sowing in pots (13.5 cm) of John Innes No. 3, usually five seeds per pot. These pots were placed in three situations:

(i) a heated glasshouse ($17^{o} \pm 2^{o}C$) with supplementary lighting (Poot Lichtenergi B.V. Shipluidan, 400W) to give a 14 h photoperiod;

(ii) an unheated glasshouse;

(iii) outside in a net cage to avoid damage by pests.

Pots were watered when necessary, usually every 2-3 days. Plants grown longer than 10 weeks were fertilized with Growmore (7:7:7 NPK granules) at the rate of 5 g per pot.

Additionally, plant material was taken from cultivars grown in the field trials at Silwood (Section 2, Table 17).

(b) Inoculations with mycelium

Isolate JN1 was grown on PDA, GAY, sterile carrot and wheat grain for 3 days at $20^{o}C$. The inocula derived from these were: 7 mm disks from the edge of colonies on PDA and GAY; a piece of colonized carrot, c 0.5 mm^3 and a single colonized wheat grain. These inocula were fixed to plant stems with parafilm. Colonization of the plant tissue was recorded using the following scale: 1, brown watery lesion; 2, white lesion; 3, collapse of plant tissue; 4, formation of sclerotia.

(c) Inoculations with ascospores

A series of preliminary experiments in which excised stem pieces were inoculated with ascospores suspended in water or nutrients failed to produce typical stem rot lesions. Therefore, further inoculations were tried in which inocula were placed on petals taken from field grown oilseed rape and these were attached to the plant material. Details of these preliminary experiments are given in Appendix XXXXI. The technique finally adopted was as follows.

Ascospores of isolate JN1, collected on dry millipore filters (Section 1, p. 52) were resuspended in sterile distilled water and the suspension was adjusted to 1 x 10^4 ascospores/ml. Air dried petals collected from field grown Jet Neuf were placed individually on excised stems and each was held in position by a double thickness of 'Cling Film' (Waitrose plc). A drop, usually 10 µ ml, of ascospore suspension was dispensed using a Drummond Microcap, at the top of the 'Cling Film' so that it was drawn by capillarity under the film and covered the petal. The stem pieces were placed in closed humid chambers kept moist by spraying periodically with distilled water from a hand sprayer. These chambers were incubated in a constant temperature room at 15°C with a 16 h photoperiod. Assessments of colonization by *S. sclerotiorum* at 5, 10 and 15 days after inoculation were made using the following scale:

0 No symptoms.

1 Brown watery lesions.

2 Mycelium seen under the cling film (low power binocular microscope).

3 Fluffy white mycelium extended beyond the cling film.

4 Mycelium spread up onto leaves/cotyledons.

5 Sclerotia forming or formed.

4.2.2. Experiments

(a) Inoculations with mycelium

Plants of Jet Neuf, Norli, Rafal and Elvira were grown in a heated glasshouse, outside in pots under a net and in the field. All types of plant were inoculated just prior to flowering; additionally some glasshouse grown plants were inoculated when 4-weeks-old. Inocula were applied to the second leaf axil of 4-week-old seedlings and midway along the stem of older plants. There were three replicates per treatment and symptoms were recorded at 5, 10 and 15 days after inoculation. Incubation was in the heated greenhouse for the potted plants (17°C and 14 hours light) while field grown plants (1981-82 at Silwood Park) were left intact in the field.

The results are shown in Table 108. Brown, water-soaked lesions developed on all inoculated stems within 5 days. The 4-week-old seedlings then collapsed rapidly and on some, sclerotia developed. White lesions, typical of stem rot in the field, formed only on older plants. With plants grown outside there were some small differences in the rate at which these lesions developed on the four cultivars but not with glasshouse grown plants. No sclerotia developed on the white lesions in 15 days.

(b) Inoculations with ascospores

10-day-old seedlings. Seed of all cultivars grown in the 1982-83 and 1983-84 field trials at Silwood were sown in germination trays and seedlings were grown on in these trays in a glasshouse (17° ± 2°C) until they were 10 days old. Stems were excised, inoculated with ascospores on dried petals and one stem of each cultivar was placed in each of five germination trays.

Table 108 : Development of symptoms on four oilseed rape cultivars inoculated with mycelium of *S. sclerotiorum*.

Type of plant	Stage	Days after inoculation	Mean score for symptoms on			
			Jet Neuf	Norli	Elvira	Rafal
Glasshouse	4-week	5	1.0	1.0	1.0	1.0
		10	1.7	1.7	1.7	1.7
		15	3.3	3.3	3.3	3.3
	Pre-flowering	5	1.0	1.0	1.0	1.0
		10	2.0	2.0	2.0	2.0
		15	2.0	2.0	2.0	2.0
Outside	Pre-flowering	5	1.0	1.0	1.0	1.0
		10	1.7	1.3	1.3	1.3
		15	2.0	2.0	2.0	2.0
Field	Pre-flowering	5	1.0	1.0	1.0	1.0
		10	1.7	1.7	2.0	1.7
		15	2.0	2.0	2.0	2.0

Results are the mean scores of three plants inoculated with mycelium on wheat grain using the scale: 1, brown watery soaked lesions; 2, white lesions; 3, collapse of plant tissues; 4, formation of sclerotia.

Table 109 shows the mean results of these inoculations. Analyses of variance indicated that, at each assessment (5, 10 and 15 days after inoculations) there were, overall significant differences ($P \leq 0.001$) in the development of the fungus on the various cultivars. At 5 and 10 days after inoculation there was considerable overlapping between the means for individual cultivars but at 15 days the means for cv. Mikado and Perle were both significantly different ($P = 0.05$) from each other and from the means of all other cultivars. All cultivars became infected and on none was there any evidence of lesion restriction by a marked host reaction though clearly lesions developed faster on some cultivars than on others. When portions of the infected stem tissues were planted on GAY agar colonies of *S. sclerotiorum* developed readily.

There appeared to be some measure of agreement between the results obtained in the three assessments. This was examined by ranking the means for each assessment from the lowest (1) to the highest (24) score for lesion development. An analysis using Kendall's coefficient of concordance indicated a significant degree of association between the three assessments ($W = 0.54$, $X^2 = 37.45$, $P = 0.05$; Appendix XXXXIV).

4-week-old seedlings. Plants were grown in the glasshouse ($17^{o} \pm 2^{o}C$) for 4 weeks, then the stems were excised, taken to the laboratory in plastic bags for experiments. There were three experiments.

Expt. 1. Fifteen stems taken from each of the 17 cultivars grown in the 1982-83 field trial at Silwood were inoculated. Each inoculated stem was supported on a slide resting on a glass angle so that it was not in contact with the damp filter paper in the seed germination tray. One stem of each cultivar was placed in each of 15 trays. Lesion develop-

Table 109 : Lesion development on 10-day-old seedlings inoculated with ascospores.

Cultivar	Mean score for lesion development at		
	5 days	10 days	15 days
Diander	1.0[a] d[b]	2.0 abcd	3.6 cdef
Brittander	1.0 d	2.6 def	3.4 cde
Lingot	0.6 bcd	1.8 abc	3.4 cde
Fiona	0.4 abc	2.2 bcde	3.8 defg
Jem	0.0 a	1.8 abc	3.4 cde
Korina	0.2 ab	1.4 a	3.0 c
Barbara	0.2 ab	2.0 abcd	3.4 cde
Falk	0.4 abc	1.6 ab	4.0 efgh
Jet Neuf	0.4 abc	1.6 ab	4.2 fgh
Belinda	0.6 bcd	1.6 ab	3.6 cdef
Perle	0.6 bcd	1.6 ab	2.4 b
Pamela	0.2 ab	1.6 ab	3.2 cd
Liradonna	0.4 abc	1.4 a	3.8 defg
Carola	0.4 abc	1.6 ab	3.4 cde
Rafal	0.2 ab	1.8 abc	3.8 defg
Darmor	0.6 bcd	1.4 a	3.4 cde
Bienvenu	0.6 bcd	2.6 def	4.0 efgh
Mikado	0.0 a	1.6 ab	1.6 a
Chrysander	0.8 cd	1.8 abc	4.0 efgh
Elvira	0.2 ab	2.2 bcde	4.0 efgh
Doral	0.4 abc	2.2 bcde	4.2 fgh
Norli	0.2 ab	1.8 abc	3.0 c
Lirabella	0.8 cd	2.6 def	3.6 cdef
Tandem	0.6 bcd	2.4 cdef	4.0 efgh
F-value (d.f. 92)	2.71***	3.08***	8.4***

Each value is the mean of five replicates assessed on the scale: 0, no symptoms; 1, brown watery lesions; 2, mycelium seen under cling film; 3, fluffy white mycelium beyond film; 4, mycelium spread to cotyledons/leaves; 5, sclerotia present.

Values in the same column with no letter in common are significantly different at $\underline{P}$ = 0.05 (Duncan's multiple range test).

ment was assessed 5 and 15 days after inoculation.

At 5 days there were some differences in lesion development on the different cultivars as indicated in Table 110. However, by 15 days sclerotia had formed on every stem in every tray so there were no differences in scores for lesion development.

Expt. 2. Cotyledons were detached from 12 plants of the 17 cultivars grown in the 1982-83 field trials at Silwood. The cotyledons from each plant were placed on damp filter paper in sterile petri dishes, opposite one another, four pairs per dish. One cotyledon of each pair was inoculated with petal plus ascospores; the other cotyledon was inoculated with ascospores only. Dishes were incubated at 15^{o}C and lesions were assessed 5 and 10 days after inoculation using both the scale previously described and estimates of % leaf area covered.

Differences in the development of *S. sclerotiorum* on the cotyledons were visible at 5 days and this was reflected in both types of assessment. Estimates of percentage cover of the cotyledons with lesions at 5 and 10 days are presented in Table 111. While at each assessment there were significant differences in lesion development on the cultivars the results of the two assessments did not appear very consistent. This was confirmed by an analysis of the ranked means for each assessment using Spearman's coefficient of rank correlation. This showed that there was no significant correlation between the ranks of the cultivars as determined on the two assessment days (Appendix XXXXVI).

Assessments of lesion development at 5 days using the graded scale are also shown in Table 111. There were significant differences between cultivars, lesion development being most extensive on Korina and least on Belinda and Fiona. However, a test comparing the ranked means for this assessment with those for percentage cover at 5 days

Table 110 : Lesion development on 4 week old seedlings (1982-83 cultivars) 5 days after inoculation with ascospores.

Cultivar	Mean score for lesion development
Fiona	2.47 a
Elvira, Jet Neuf, Tandem, Doral	2.67 ab
Belinda	2.73 bc
Darmor	2.8 bc
Brittander	2.87 bc
Crysander	2.93 cdef
Korina, Bienvenu, Rafal, Lingot, Norli, Diander, Pamela, Lirabella }	3.0 def
	(F = 5.33***, 224 d.f.)

Each is the mean of 15 replicates assessed on the scale given on p. 216 and footnote to Table 108.

Values with no letter in common are significantly different at $\underline{P} = 0.05$ (Duncan's multiple range test).

Table 111 : Lesion development on cotyledons from 4 week old seedlings (1982-83 cultivars) inoculated with ascospores.

Cultivar	Lesions development		
	% cotyledon area with lesion at		Mean score for lesion development at 5 days
	5 days	10 days	
Pamela	0.8 a	7.63 cdef	0.67 bcd
Lirabella	0.8 a	1.54 a	0.58 abc
Lingot	0.8 a	6.47 cde	0.92 de
Elvira	0.95 a	6.73 cdef	0.75 cde
Rafal	0.95 a	7.79 def	2.0 g
Belinda	1.1 a	5.58 cd	0.33 a
Darmor	1.1 a	4.99 cd	2.75 h
Korina	1.1 a	4.42 abc	3.50 i
Bienvenu	1.25 a	4.35 ab	0.42 ab
Tandem	2.01 a	6.09 cde	0.58 abc
Chrysander	2.31 a	4.02 ab	1.5 f
Diander	3.14 ab	6.62 cde	0.75 cde
Doral	3.57 ab	9.21 g	2.5 h
Norli	5.94 b	13.22 ef	0.42 ab
Jet Neuf	10.33 c	9.22 ef	0.67 bcd
Fiona	10.97 c	9.93 f	0.33 a
Liander	13.96 d	3.90 ab	0.58 abc
F value (187 d.f.)	16.01***	7.44***	7.7***

Each value is the mean of 12 replicates. Data for % cotyledons with lesions are transformed values (arcsin $\sqrt{\%}$). Values in the same column with no letter in common are significantly different at P = 0.001 (Duncan's multiple range test).

showed that there was no significant correlation between them (Appendix XXXXVII).

Expt. 3. Fifteen stems taken from each of 10 cultivars selected from those grown in the 1983-84 field trials were inoculated as in Experiment (1). Lesions were assessed at 5, 10 and 15 days after inoculation.

The results are shown in Table 112. Although there were significant differences in lesion development on the cultivars, the order in which cultivars could be ranked in this respect varied with each assessment. An analysis using Kendall's coefficient of concordance showed that there was no significant association between the ranks assigned to cultivars at the three assessments (Appendix XXXXIX).

Plants grown in an unheated glasshouse. The 17 cultivars used in the 1982-83 field trial at Silwood were grown in an unheated glasshouse in October 1983. At three growth stages: 6 leaf, G.S. 3.2, G.S. 4.1 (Harper & Berkenkamp, 1975; Fig. 4). Fifteen stems of each cultivar were excised and inoculated.

The results of the inoculations are summarized in Table 113. Tests at the 6 leaf stage were the least satisfactory because sclerotia formed on sixteen of the 17 cultivars after 15 days and no distinction could then be made between them. On all other occasions, particularly with material from growth stages 3.2 and 4.1, there were significant differences in lesion development on the 17 cultivars. However, the order in which cultivars could be ranked on this basis varied considerably from growth stage to growth stage and, within a test, from one assessment to the next.

These aspects were

Table 112 : Lesion development on 4 week old seedlings (1983-84 cultivars) inoculated with ascospores.

Cultivar	Mean score for lesion development at		
	5 days	10 days	15 days
Carola	1.80[(a)] abc[(b)]	3.0 ab	5.0 c
Falk	1.53 a	3.0 ab	4.53 a
Jet Neuf	1.67 ab	3.27 abcd	4.73 abc
Bienvenu	2.0 cd	2.93 a	4.87 bc
Darmor	1.80 abc	3.33 abcde	4.80 abc
Diander	1.87 bcd	3.60 cde	4.67 abc
Mikado	1.80 abc	3.67 e	4.93 bc
Liradonna	2.07 cd	3.67 e	4.6 ab
Jem	2.13 d	3.20 abc	4.87 bc
Barbara	2.0 cd	3.60 cde	4.87 bc
F-value (126 d.f.)	3.87***	4.7***	2.0***

(a) Each value is the mean of 15 replicates

(b) Values in the same column with no letter in common are significantly different at P = 0.05 (Duncan's multiple range test).

Table 113 : Lesion development on oilseed rape (1982-83) cultivars) inoculated with ascospores at three growth stages.

Cultivar	Mean score for lesion development on plants at						
	6 leaf stage after 5 days	G.S. 3.2 at			G.S. 4.1 at		
		5 days	10 days	15 days	5 days	10 days	15 days
Belinda	2.0 ab	1.93 fg	2.67 b	4.0 a	0.47 a	2.88 bc	5.0 c
Bienvenu	3.0 efg	1.40 abcde	3.60 efgh	4.33 c	1.88 ef	2.24 ab	5.0 c
Chrysander	3.7 ijk	1.67 defg	3.87 h	4.0 a	1.82 ef	3.3 cde	5.0 c
Darmor	3.13 fghi	1.67 defg	2.2 a	4.27 bc	1.59 cdef	3.0 cd	4.0 a
Diander	2.93 def	1.73 efg	3.2 def	4.27 bc	0.82 ab	3.47 de	5.0 c
Doral	1.70 a	1.60 cdef	3.73 gh	4.73 d	2.29 f	3.06 cde	5.0 c
Elvira	2.67 cde	1.20 abc	3.67 fgh	4.13 abc	1.06 abcd	3.77 ef	5.0 c
Fiona	2.33 fghij	1.13 ab	3.4 defg	4.2 abc	0.65 ab	3.65 ef	4.71 b
Jet Neuf	3.93 k	1.93 fg	4.07 h	4.27 bc	2.06 f	3.41 de	5.0 c
Korina	2.40 bcd	1.67 defg	4.13 h	4.0 a	0.53 ab	2.06 a	5.0 c
Liander	3.80 jk	1.53 cdef	2.93 bcd	4.27 bc	0.77 ab	2.88 bc	5.0 c
Lingot	2.30 bc	1.60 cdef	3.80 gh	4.07 abc	1.29 bcde	4.30 f	4.71 b
Lirabella	3.67 ijk	1.13 ab	3.53 efg	4.27 bc	0.29 a	2.65 abc	5.0 c
Norli	3.07 efgh	1.07 a	2.93 bcd	4.27 bc	1.0 abcd	3.06 cde	4.0 a
Pamela	2.93 def	1.27 abcd	3.60 efgh	4.07 ab	1.71 def	3.53 def	4.65 b
Rafal	3.80 jk	2.07 gh	3.13 bcde	4.07 ab	1.71 def	3.41 de	5.0 c
Tandem	3.47 fghijk	2.4 h	2.73 bc	4.07 ab	0.88 abc	3.06 cde	5.0 c
SE							
F value	11.83***	7.13***	11.23***	4.88***	6.44***	5.94***	33.46***
d.f.	16	16	16	16	16	16	16

Values are the means of 15 replicates at 6 leaf stage and G.S. 3.2 and of 17 replicates at G.S. 4.1.

Values in each column with no letter in common are significantly different at $\underline{P}$ = 0.001 (Duncan's multiple range test).

examined by analyses (Table 114) using non-parametric tests to compare the ranking of means from comparable assessments at different growth stages and, within one test, the ranking from assessments on different days. These analyses showed that there was no significant agreement between the ranking of cultivars from consecutive assessments or from comparable tests at different growth stages.

Field grown plants. Five plants selected at random from each plot of the 16 cultivars in the 1983-84 field trial at Silwood were cut off at soil level at G.S. 3.2. The leaves were removed, the stems were washed and air-dried, and then they were inoculated with ascospores on a petal. Lesions were assessed at 5, 10 and 15 days after inoculation.

Infection did not occur as readily as in the other tests. Lesions did not develop beyond the size attained 10 days after inoculation when some differences between cultivars were apparent (Table 115).

A non-parametric test was used to compare the rankings of the 10 day assessment for the cool greenhouse inoculation at G.S. 3.2 with the field grown plants. Table 116 shows that the association between the ranking of cultivars was negative i.e. that cultivars most susceptible in one test are least susceptible in the other - the two assessments were not comparable therefore.

Table 114 : Anayses of ranked means from data of Table 33.

Data for	Comparison of ranked means from assessments at	Test	Parameters
G.S. 3.2	5, 10 and 15 days after inoculation	Kendall coefficient of concordance	$W = 0.24$, $X^2 = 11.67$ n.s.
G.S. 4.1	5, 10 and 15 days after inoculation	Kendall coefficient of concordance	$W = 0.33$, $X^2 = 15.88$ n.s.
5 days after inoculation	6 leaf stage, G.S. 3.2, G.S. 4.1	Kendall coefficient of concordance	$W = 0.3$, $X^2 = 14.4$ n.s.
10 days after inoculation	G.S. 3.2, G.S. 4.1	Spearman coefficient of correlation	$t = 0.193$ n.s.
15 days after inoculation	6 leaf stage, G.S. 3.2, G.S. 4.1	Kendall coefficient of concordance	$W = 0.15$, $X^2 = 7.39$ n.s.

Table 115 : Lesion development on plants at G.S. 3.2 taken from field trials, 1983-84.

Cultivar	Mean score for lesion development at 10 days
Diander	0.6 a
Liradonna	0.6 a
Korina	0.4 a
Rafal	1.6 cd
Darmor	1.8 d
Barbara	0.4 a
Carola	1.4 cd
Mikado	0.8 ab
Bienvenu	0.4 a
Jem	0.6 a
Fiona	1.2 bc
Falk	0.6 a
Pamela	0.4 a
Jet Neuf	0.8 ab
Lirabella	0.6 a
Belinda	1.4 cd

Each value is the mean of five replicates.

Values with no letter in common are significantly different at $\underline{P}$ = 0.001 (Duncan's multiple range test).

Anovar

	d.f.	SS	MS	F	
Cultivar	15	16.60	1.11	2.25	***
Error	64	31.60	0.49		
Total	79	48.2			

Table 116 : Test for the comparison of ranked means for ascospore inoculations of field and glasshouse plants at 10 days.

Cultivar	Mean score for lesion development at 10 days		
	Glasshouse	Field	di
Jet Neuf	8	5	3
Bienvenu	6.5	2	4.5
Korina	9	2	7
Rafal	3	8	5
Fiona	4	6	2
Belinda	2	7	-5
Lirabella	5	4	1
Pamela	6.5	2	4.5
Darmor	1	9	-8

$\Sigma x^2 = 60 - 0.5 = 59.5$

$\Sigma y^2 = 60 - 2.0 = 58.0$

$$R_s = \frac{(59.5 + 58) - 217.5}{2\sqrt{59.5 \times 58}}$$

$$= \frac{-100}{117.49}$$

$$= -0.85$$

$P = 0.05$

4.3 Factors Influencing Infection

4.3.1. Effect of removing epicuticular waxes

Plants grown to G.S. 4.1 in a glasshouse at 17 ± 2°C did not become infected when inoculated with ascospores under cling film (Section 4.2.1.). Various treatments were therefore tried to remove epicuticular waxes so that their possible role in limiting infection could be determined. The methods used for areas to be inoculated on excised stem pieces were applying Sellotape and then removing it rapidly, or wiping the region with cotton wool soaked in acetone, chloroform or Tween 40 solution. The treated areas were washed in distilled water following treatment. They were inoculated by applying a dead petal to the treated area covering it with cling film and infiltrating with a 10 µl drop of suspension (5.2×10^5 ascospores/ml). The stem pieces were incubated in humid chambers at 20°C with 12 h light/12 h dark. There were five replicates for each of the four treatments. As a check stem pieces from oilseed rape grown in the field were inoculated in the same way. All stem pieces were examined daily for infection.

Despite the various treatments, lesions developed only on stem pieces taken from the field.

4.3.2. Effect of inoculum concentration

A suspension of ascospores was diluted serially to give the range of concentrations shown in Table 117. These were used to inoculate stem pieces from field grown Jet Neuf. There were 10 stem pieces for each concentration of inoculum. Each inoculation (with a 10 µl drop) was above a petal and enclosed in cling film as described previously. Lesion development was assessed after 5 and 15 days in a humid chamber at 20°C.

Lesions formed at all concentrations of inoculum but developed

Table 117 : Effect of inoculum concentration on the development of lesions on stem pieces from field grown Jet Neuf.

Concentration of ascospores	Mean[a] development of lesions after	
	5 days	15 days
6.8×10^{10}	3.4	5.0
$\times 10^{9}$	3.4	5.0
$\times 10^{8}$	2.8	5.0
$\times 10^{7}$	2.4	5.0
$\times 10^{6}$	2.8	5.0
$\times 10^{5}$	2.4	5.0
$\times 10^{4}$	2.8	5.0
$\times 10^{3}$	1.4	4.4
$\times 10^{2}$	1.0	3.2
$\times 10$	0	2.8

[a] Mean of 10 stem pieces assessed on scale: 0 = no symptoms; 1 = brown watery lesions; 2 = mycelium seen under cling film; 3 = fluffy white mycelium seen beyond film; 4 = mycelium spread to cotytedons/leaves; 5 = sclerotia present.

most rapidly at the higher concentrations.

4.3.3. Time required for infection

Stem pieces were obtained from field grown Jet Neuf at G.S. 4.1 and 4-week-old seedlings of this cultivar grown in a glasshouse at 17 ± 2°C. Disks (5 mm diameter) of mycelium were placed on each stem between the second and third internode and held in place with parafilm. These pieces were incubated in humid chambers at 20°C with a 12 h photoperiod. Inoculum was then removed from five stems after 12, 18, 24, 48 or 96 h. Lesion development was assessed after 10 and 15 days.

The experiment was then repeated using ascospores (10 µl of a suspension containing c 6 x 10^5 ascospores/ml), petals and cling film.

With both types of inoculum, infection occurred only when the inoculum was left for 24 h (Table 118).

4.3.4. Effect of pollen grains on infection

Pollen grains were collected from Jet Neuf at the initiation of flowering in the field by shaking heads over empty sterile petri dishes. Petals were also collected for use in the experiment. Pollen was suspended in distilled water and a dilution series was made from an initial concentration of 3.4 x 10^6 pollen grains/ml. Some pollen was kept in a deep freeze for a month and then a dilution series was made from an initial concentration of 4.0 x 10^6 pollen grains/ml.

Ten-day-old seedlings of Jet Neuf were inoculated with a 10 µl drop of a suspension containing 1.1 x 10^5 ascospores/ml to which was added 10 µl of one of the pollen grain suspensions. A dried petal was included in some of these treatments (Table 119) and inoculation with ascospores plus petal only served as a control. Germination of ascospores when combined with pollen was checked in drops on slides after 24 h at 20°C.

Table 118 : Time required for infection of oilseed rape from mycelium and ascospore inocula.

Hours inoculum in place	Lesion development[a] after			
	10 days		15 days	
	4 week old seedlings	Field plants	4 week old seedlings	Field plants
Mycelium				
12	-	-	-	-
18	-	-	-	-
24	2.4(a)	2.8	4.8	5.0
48	2.8	2.8	4.6	5.0
72	2.8	2.8	5.0	4.8
96	2.6	3.6	4.8	5.0
Ascospores				
12	-	-	-	-
18	-	-	-	-
24	1.0(a)	1.4	4.8	5.0
48	2.4	2.6	5.0	4.8
72	2.4	2.0	5.0	4.8
96	2.0	2.0	5.0	5.0

[a] Mean development on five stem pieces assessed on scale indicated in Table 117.

Table 119 : Effect of pollen on infection of oilseed rape by ascospores of *Sclerotinia sclerotiorum*

Additions to ascospore inoculum		% germination of ascospore[b]	Lesion development[c] after	
Pollen grains[a] (no./ml)	Dried petal		5 days	10 days
None	+		3.8	5.0
3.4 x 10	-	99.1	0	0
	+		3.6	4.8
3.6×10^2	-	98.3	0	0
	+		3.4	5.0
3.1×10^3	-	81.4	0	0
	+		3.6	5.0
3.8×10^4	-	92.2	0	0
	+		3.0	4.8
3.5×10^5	-	94.7	0	0
	+		3.8	5.0
3.4×10^6	-	97.8	0	0
	+		3.4	5.0

[a] Used immediately after collection

[b] Tested on glass slides; germination in water only was 100%.

[c] Mean of 10 replicates assessed on scale indicated in Table 117.

Inoculated stem pieces were incubated in humid chambers at 20°C and lesion development was assessed after 5 and 10 days.

Infection occurred only when a dried petal was present (Table 119). There was no indication that the presence of fresh pollen enhanced infection in any way. In tests with frozen pollen no petals were included and no lesions developed. Over 90% of the ascospores germinated in the presence of frozen pollen at concentrations ranging from 4.2 x 10 to 4.0 x 10^6 pollen grains/ml.

4.3.5. Effect of petals from different sources

Petals of 17 oilseed rape cultivars grown at Silwood in 1982-83 were collected on several mornings and were stored at -15°C in polyethylene bags in 4 g lots of each cultivar.

Samples of the petals were allowed to dry out for 72 h at room temperature and were then applied to defoliated stem pieces of field grown Jet Neuf which had been surface-sterilized in sodium hypochlorite for 3 min and washed in sterile distilled water. Six stem pieces were used for each collection of petals and these were inoculated under cling film with freshly-collected ascospores. The stem pieces were incubated in humid chambers at 20°C and lesions were assessed after 5 and 10 days.

All stem pieces became infected irrespective of the source of the petals but there were differences in the extent to which petals promoted infection (Table 120). Lesions developed most extensively with petals from Jet Neuf and Lirabella and least from petals of Fiona.

In a similar type of experiment, petals from *Amaryllis hippeastrum*, groundnut (*Arachis hypogea*) and daffodil (*Narcissus* sp.) were compared with those of oilseed rape. Five stem pieces of Jet Neuf were used for each type of petal, the techniques being otherwise those used previously.

Table 120 : Inoculations of rape stems (cv. Jet Neuf) using ascospores plus petals from different cultivars of oilseed rape.

Cultivar petals	Mean lesion development[a] after	
	5 days	10 days
Fiona	1.0	2.33
Belinda	0.67	2.83
Norli	0.67	3.33
Brittander	1.0	2.83
Lirabella	1.0	4.83
Pamela	1.0	3.33
Elvira	1.0	3.33
Bienvenu	1.0	2.83
Lingot	0.33	2.83
Diander	0.83	3.50
Doral	0.83	4.33
Darmor	1.0	4.67
Korina	0.83	4.67
Chrysander	0.83	4.0
Rafal	1.0	4.33
Tandem	1.0	4.33
Jet Neuf	1.0	4.83

[a] Each value is the mean of six replicates.

Lesions developed from inoculations with ascospores above petals of oilseed rape and groundnut but not with the other two types of petal.

4.4 The Role of the Petal in Infection

The previous experiments indicated that the presence of a dead petal was essential for infection of oilseed rape from ascospore inocula. The following experiments attempted to determine the factors associated with petals which favoured infection.

4.4.1. Germination of ascospores in petal extract and various nutrients

Petals of Jet Neuf from the deep freeze were defrosted overnight and ground in 30 ml distilled water plus a small amount of sand. The sample was then filtered under suction through a Whatman No.42 filter paper into a Buchner flask covered with black plastic. The filtrate was centrifuged at 3000 revs/min for 15 mins and the supernatant (petal extract) collected.

A drop (50 µl) of petal extract was pipetted onto each of six clean microscope slides. Drops were similarly dispensed onto the same slides using 1% glucose solution and distilled water. A 50 µl drop of a suspension of ascospores (1.3×10^6 spores/ml) was then added to each of these drops and the slides were placed in pairs on glass angle pieces in three plastic boxes lined with wet blotting paper. These boxes were incubated for 48 h at $20^{\circ}C$ with 12 h light/12 h dark cycle. The germination of 15 ascospores per drop was assessed and the lengths of 10 germ tubes per treatment were measured.

About 89% of the ascospores germinated in water, 100% in 1% glucose but only about 9% in petal extract. However, in petal extract germ tubes were about 11 µm long compared to 6 µm and 3 µm in 1% glucose and water respectively (Table 121).

In a second experiment, the germination of ascospores was examined in serial dilutions of the petal extract, based on counts of 60 ascospores per treatment after 48 h. Percentage germination increased with

Table 121 : Effect of an extract of oilseed rape petals on ascospore germination.

Medium	% germination[a]	Germ tube length[b] (µm) ± S.D.
Water	88.9	3.3 ± 0.78
1% glucose	100.0	6.1 ± 1.12
Petal extract	9.3	10.9 ± 1.11

[a] Mean germination after 48 h of 15 ascospores in each of six droplets.

[b] Mean length of 10 ascospores after 48 h.

Table 122 : Germination of ascospores in a dilution series of a petal extract.

Dilution of extract	0	10^{-1}	10^{-2}	10^{-3}
% germination[a]	10.0	15.0	33.3	71.7

[a] Mean germination of 60 ascospores after 48 h.

increasing dilution of the extract (Table 122).

Germination of ascospores in petal extract was next compared with that in water and in the constituents of GAY medium (Section 1, p. 25); glucose, aspargine, yeast extract individually and all three combined. The concentrations were equivalent to those used in this medium. Drops (25 µl) of each material were pipetted onto slides and a drop (also 25 µl) of ascospore suspension (2.4 x 10^6 ascospores/ml) was added to each. Germination was assessed on 45 ascospores per treatment after 48 h at 20°C.

The mean percentages for germination were: petal extract, 27.8; water, 93.5; glucose, 97.3; asparagine, 90.2; yeast extract, 85.3 and the last three materials combined, 95.2.

4.4.2. Attempts to infect oilseed rape using petal extract

The first experiment examined the possibility of obtaining infection from ascospores using extracts of petals rather than the petals themselves. Extracts were prepared both from freshly collected petals and from frozen petals of Jet Neuf.

All 23 cultivars used in the field trials from 1982 to 1984 were grown for 10 days at room temperature (17-20°C). These were: Jet Neuf, Diander, Barbara, Jem, Norli, Pamela, Falk, Korina, Doral, Liradonna, Bienvenu, Rafal, Tandem, Chrysander, Fiona, Brittander, Elvira, Lirabella, Mikado, Carola, Darmor, Belinda and Lingot. Plants were then inoculated under cling film using 10 µl of ascospore suspension (7 x 10^5 ascospores/ml) plus 10 µl petal extract (either from fresh or frozen petals) or a dead petal of Jet Neuf plus an extra 10 µl of water to maintain an equivalent ascospore concentration. There were 20 replicates of each treatment and infection was assessed after 15 days at 20°C.

All plants inoculated with ascospores plus a dead petal became infected but only one plant each of Jem and Pamela were infected when an

extract from frozen petals was used and none with an extract from fresh petals.

The second experiment examined the effect on infection of using small (0.5 x 0.5 cm) squares of sterile filter paper (Whatman No.1) soaked in petal extract, 1% glucose or water. These were applied to 10-day-old seedlings of Jet Neuf and inoculated under cling film with ascospores. Plants were similarly inoculated using a dead petal as a check. Infection was assessed after 5 days at 20°C.

All plants became infected but the symptoms were less advanced where filter paper was used than with dead petals.

4.4.3. Nutrient status of petal extract

Petal extracts from fresh and dead petals were analyzed for amino-acids. Samples (2 g) of petals were ground in Citrate buffer at pH 2.2. Small sub-samples (0.02 ml) were then run through an amino-acid analyzer (Locarte, London W12). Other samples were ground in hydrochloric acid for determination of amides. The results of these analyses are shown in Fig. 14 to 16 and summarized in Table 123. The composition of the two petal extracts varied slightly but amides (mainly asparagine) and γ-amino-N-butyric acid were the most abundant constituents.

Sugars were analyzed by thin layer chromatography (TLC) of the extract from dead petals only. Glucose, arabinose, sucrose, lactose, galactose, xylose and maltose were applied to TLC plates as standards along with the extract and these were run in butan-1-ol : acetic acid : water (4:1:1 by volume). After 8 h, when the solvent front was c 1 cm from the top of the plates, these were removed, marked and left to dry in a fume cupboard until free of acetic acid. Plates were sprayed first with 0.2 ml of saturated silver nitrate, allowed to dry and then sprayed with 0.5% (w/v) sodium hydroxide in ethanol. After about 10 min to allow development

Figure 14 : Fresh sample of petals in buffer.

Arginine
Ammonia
Lysine
Histidine
Gamma-amino-N-butyric acid
Tyrosine
Tryptophane
Phenylalanine
Leucine
Isoleucine
Methionine
Valine
Alanine
Glycine
Proline
Threonine
Amide
Aspartic acid
Glutamic acid
570
440

Figure 15 : Dried sample of petals in buffer.

Arginine
Ammonia
Lysine
Histidine
Phenylalanine
Tyrosine
Leucine
Isoleucine
Valine
Alanine
Glycine
Proline
Glutamic acid
Aspartic acid
Gamma-amino
N-butyric acid
Amide
0
10
20
30
40
50
60
70
80
90
100
440
570

Figure 16 : Dried sample of petals treated with HCL.

Arginine
Ammonia
Lysine
Histidine
Gamma-amino-N-butyric acid
Phenylalanine
Tyrosine
Leucine
Isoleucine
Valine
Alanine
Glycine
Glutamic acid
Arginine
Aspartic acid
Threonine
440
570

Table 123 : Amino acid analysis of extracts from fresh and dead petals.

Amino acid	% of total in extracts of	
	Fresh petals	Dead petals
Proline	14.3	7.7
Aspartic Acid	4.2	4.8
Glutamic Acid	3.2	1.8
Alanine	3.6	1.5
Valine	10.0	3.7
Methionine	5.8	3.1
Isoleucine	3.2	4.1
Leucine	4.7	5.2
Tyrosine	1.5	1.7
γ-Amino-N-Butyric Acid	8.0	12.1
Histidine	2.5	4.1
Lysine	5.9	4.1
Ammonia	7.8	6.9
Arginine	5.1	4.7
Phenylalanine	1.6	5.6
Amides	18.8	28.9

of the sugar spots, the plates were sprayed with 10% sodium thiosulphate to prevent rapid discolouration.

The Rf values obtained (Table 124) suggested that the extract contained arabinose (spot No.1), xylose (spot No.2) and galactose (spot No.4). A third spot could not be matched with any standard but no sucrose standard developed on any plate.

However, tests on 10-day-old seedlings of Jet Neuf using ascospores in 1% solutions of xylose, arabinose, galactose and sucrose failed to induce infection in the absence of petals.

Table 124 : Analysis of sugar in an extract from dried petals of oilseed rape.

Standards[a]	Rf Value
Glucose	0.158
Lactose	0.056
Galactose	0.120
Xylose	0.279
Maltose	0.078
Sucrose	0.0
Arabinose	0.197
Petal Extract[b]	
Spot No.1 (Yellow/Brown)	0.176
No.2 (Yellow/Brown)	0.317
No.3 (Yellow/Brown)	0.893
No.4 (Brown)	0.117

(a) mean of three replicates.

(b) mean of six replicates.

4.5 Effect of Hyphal Density on Infection

The following experiment attempted to produce hyphal growth of different density and to determine its effect on infection.

A series of 2% water agar plates were prepared with glucose at concentrations ranging from 0.2 to 2.0%. Three replicate plates of each glucose concentration were inoculated centrally with a disk (3 mm) from the edge of a 3-day-old culture of isolate JN1 on GAY medium. After 5 days at 20°C in the dark, colonies were measured along two diameters at right angles to each other.

While colonies on 2% water agar only grew poorly, differences in growth at the glucose concentrations were not particularly well marked (Table 125). Similarly, camera lucida drawings of standard areas of the colonies failed to reveal marked differences in hyphal density at the various glucose concentrations.

Disks taken from the colonies were used to inoculate stem pieces from field grown Jet Neuf. There were five stem pieces for each type of inoculum and lesions were assessed after 5 and 12 days at 20°C. Again there was no clear distinction in the ability of the inocula to induce lesions or to produce sclerotia on the lesions (Table 125).

Table 125 : Ability of mycelium produced on agar with different amounts of glucose to infect oilseed rape.

Glucose concentration (%)	Mean[a] colony diam. (mm)	Lesion development[b] after		No. of sclerotia[c]
		5 days	12 days	
0	19.7 x 18.7	0	0.4	-
0.2	56.7 x 51.3	2.2	4.4	28
0.4	58.3 x 55.7	2.8	4.8	11
0.6	63.7 x 61.0	2.8	4.8	14
0.8	58.3 x 58.0	2.8	4.4	6
1.0	66.0 x 62.7	2.8	4.8	12
1.2	69.3 x 66.0	2.6	4.4	6
1.4	68.0 x 70.0	2.6	4.4	9
1.6	65.7 x 62.7	2.8	4.8	7
1.8	70.7 x 67.3	2.8	4.6	26
2.0	72.3 x 70.3	2.8	4.8	9

[a] Mean of three replicate plates.

[b] Mean of five plants.

[c] Total from five inoculated plants.

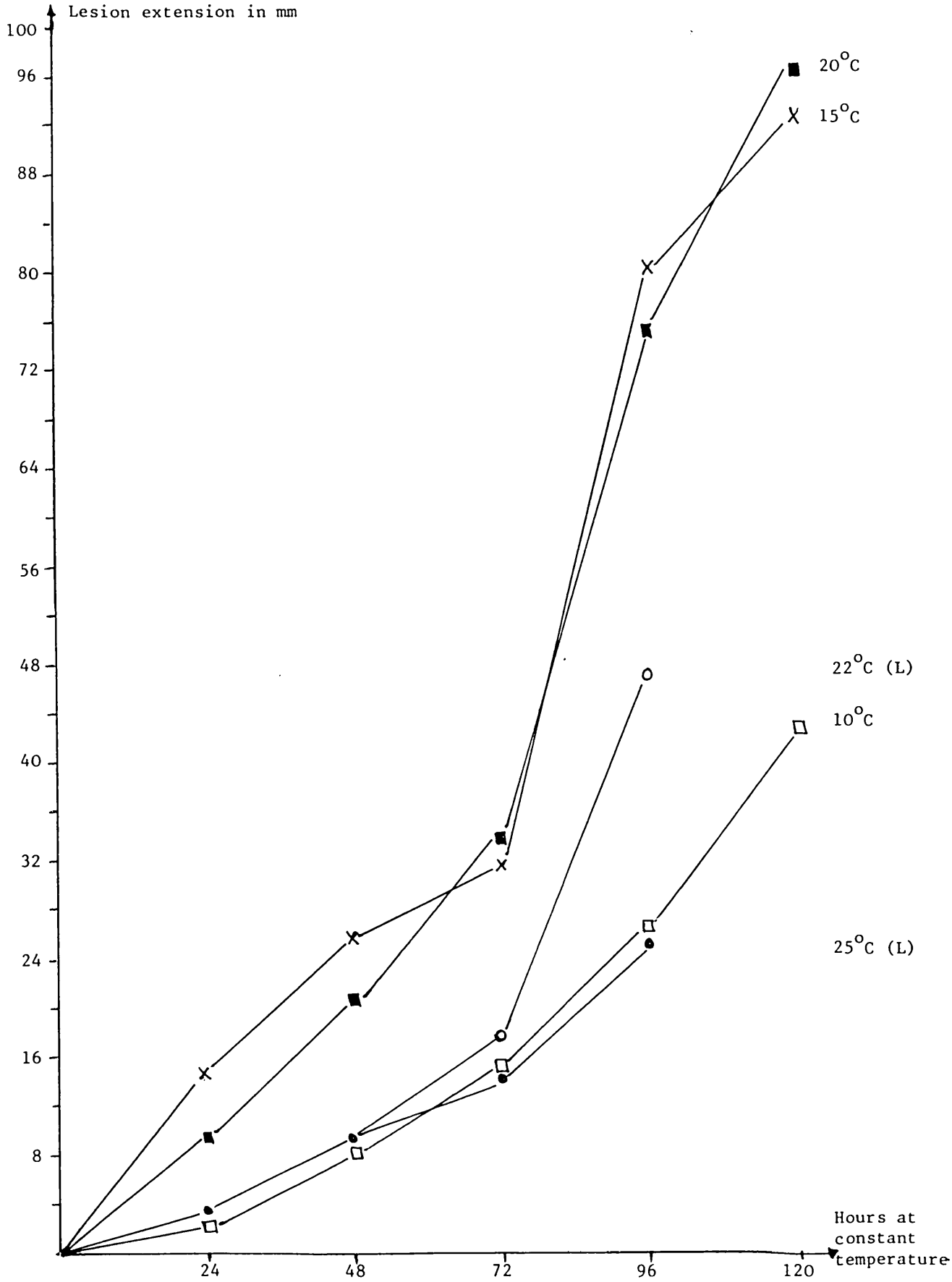
4.6 Lesion Extension at Controlled Temperatures

Plants with lesions of similar length were removed from the circular planting of Jet Neuf (Section 3) on 6 June 1983. The roots were washed free of excess soil and each plant was placed in a large beaker containing distilled water. Lesions were measured and five plants were placed at each of the following temperatures - 10, 15, 20, 22 and 25°C, all in a daily regime of 14 h light/10 h dark. Lesion extension was measured daily and plants were sprayed with a mist of water after these measurements were taken.

The daily extension was greatest at temperatures of 15° and 20°C (Fig. 17). Growth occurred at all temperatures but those lesions placed at 22° and 25°C dessicated rapidly and lodged.

Figure 17 : Lesion extension from field infections, incubated at constant temperatures.

(L) Stems snapped after 96 hours.


Lesion extension in mm
100
96
88
80
72
64
56
48
40
32
24
16
8
20°C
15°C
22°C (L)
10°C
25°C (L)
24
48
72
96
120
Hours at constant temperature

4.7 Pathogenicity to Oilseed Rape of *Sclerotinia* Isolates from Other Hosts

The pathogenicity of isolates from hosts other than oilseed rape was tested on stem pieces taken from field grown Jet Neuf at G.S. 4.1. Stems were surface sterilized prior to inoculation on the internodes with a mycelial disk (7 mm) which was held in place with parafilm. Five replicate stem pieces were used per isolate and symptoms were recorded after 5 and 9 days at 20°C.

All isolates infected the stem pieces but they did so to different extents, those from peas and beans being the slowest to produce symptoms (Table 126).

Table 126 : Pathogenicity of isolates of *S. sclerotiorum* to winter oilseed rape cv. Jet Neuf.

Isolate from		Lesion development[a] after	
		5 days	9 days
JN1	(Oilseed rape)	4.2(a)	5.0
SS2	(Sunflower)	4.2	5.0
RC802	(Cabbage)	4.6	5.0
L4776	(Lettuce)	3.8	5.0
C3887	(Celery)	0.8	3.4
P5005	(Parsley)	1.0	4.2
PW1	(Potato)	0.6	4.8
PR1	(Peas)	1.0	3.0
HO1	(Hogweed)	0.6	4.8
CUC	(Cucumber)	0.8	2.4
CHRYS	(Chrysanthemum)	1.0	3.4
CLOV	(Clover)	4.0	5.0
SP	(Shepherds purse)	3.4	5.0
RAD	(Wild radish)	2.8	5.0
FB1	(Field beans)	4.0	5.0
St.1	(Clover)	1.0	3.4
B1	(Beans)	1.0	3.0
SOY	(Soybean)	1.0	4.2

[a] Each value is the mean of five replicate plants.

4.8 Pathogenicity of Isolate JN1 to Hosts Other than Oilseed Rape

Plants of Sunflower cv. Giant Yellow, Cabbage cv. Primo, Lettuce cv. Cheshunt 5b, French Bean cv. The Prince and Pea cv. Onward, Clover - Red Late cv. Grasslands Turva - White cv. Kent Wild, were grown for 12 weeks in a glasshouse at 17°C. Each plant was then inoculated at the stem base with a disk (7 mm) cut from a 4-day-old culture of isolate JN1 on GAY medium. Each disk was held in place with parafilm. Plants were kept in the glasshouse and assessed for lesions at 5, 10 and 15 days after inoculation.

Colonization of all plants was rapid and most were covered with mycelium at the site of inoculation after 10 days (Table 127). Sclerotia subsequently formed in this mycelium. Leaves of lettuce and clover rotted extensively and stems of other inoculated hosts lodged.

Table 127 : Pathogenicity of JN1 isolate to a number of hosts.

Host species	Lesion development after			Number of sclerotia
	5 days	10 days	15 days	
Sunflower cv. Giant Yellow	2.4	4.6	5.0	9
Cabbage cv. Primo	4.0	5.0	5.0	12
Lettuce cv. Cheshunt 5b	3.8	5.0	5.0	38
Peanut	2.4	4.0	5.0	9
French Bean cv. The Prince	2.8	5.0	5.0	13
Pea cv. Onward	2.8	4.8	5.0	14
Clover - Red cv. Grasslands Turva	4.0	5.0	5.0	21
- White cv. Kent Wild	4.0	5.0	5.0	18

4.9 An Examination of Sclerotia Rinds Using the S.E.M.

Sclerotia recovered after 23 months from the Burial Experiment (Section 3) were surveyed to view any rind damage present. Sclerotia from the 24 treatments plus some from JN1 freshly cultured on the wheat grain medium and natural sclerotia from Jet Neuf collected on July 17 1983, were air dried and then fixed onto stubs with Durofix. They were left exposed for 48 h to allow any glue vapours to disperse and then stored in a desiccator. There were four sclerotia (where possible) per stub to obtain a representative view of the rind. Sclerotia were coated with a thin layer of gold while under vacuum before viewing in the S.E.M. Two stubs were accidentlly dropped after coating - treatments 3 and 22.

Representative micrographs are shown in Plate 7. Most sclerotia survived in the Silwood soil, from natural sclerotia and at depths of 4 and 6 cm (Section 3). Micrographs depict damage on every treatment sclerotium viewed although this varied from cracks across rind cells (7, 19); perforated cells (7, 5) to collapsed and missing cells (7, 6 and 11) leaving a 'skeleton' of the cell shape.

Micrographs of the control sclerotia (7, 1-4) reveal differences between the rinds of culture and natural sclerotia. The latter appear to have more compaction of the superficial cells probably due to their formation in the confines of the rape stem.

No clear cut association could be made between the numbers of sclerotia surviving in the treatments and their rind cell damage, which may thus result in a reduction of longevity through an increase in susceptibility to colonization by other micro-organisms. However, some regeneration of the rind can take place in *S. sclerotiorum* and so damage may not always result in sclerotia death. Many factors of the external environment may affect longevity and the superficially buried sclerotia (0, 1 and 2 cm)

Plate 7 : SEM micrographs of sclerotia surfaces.

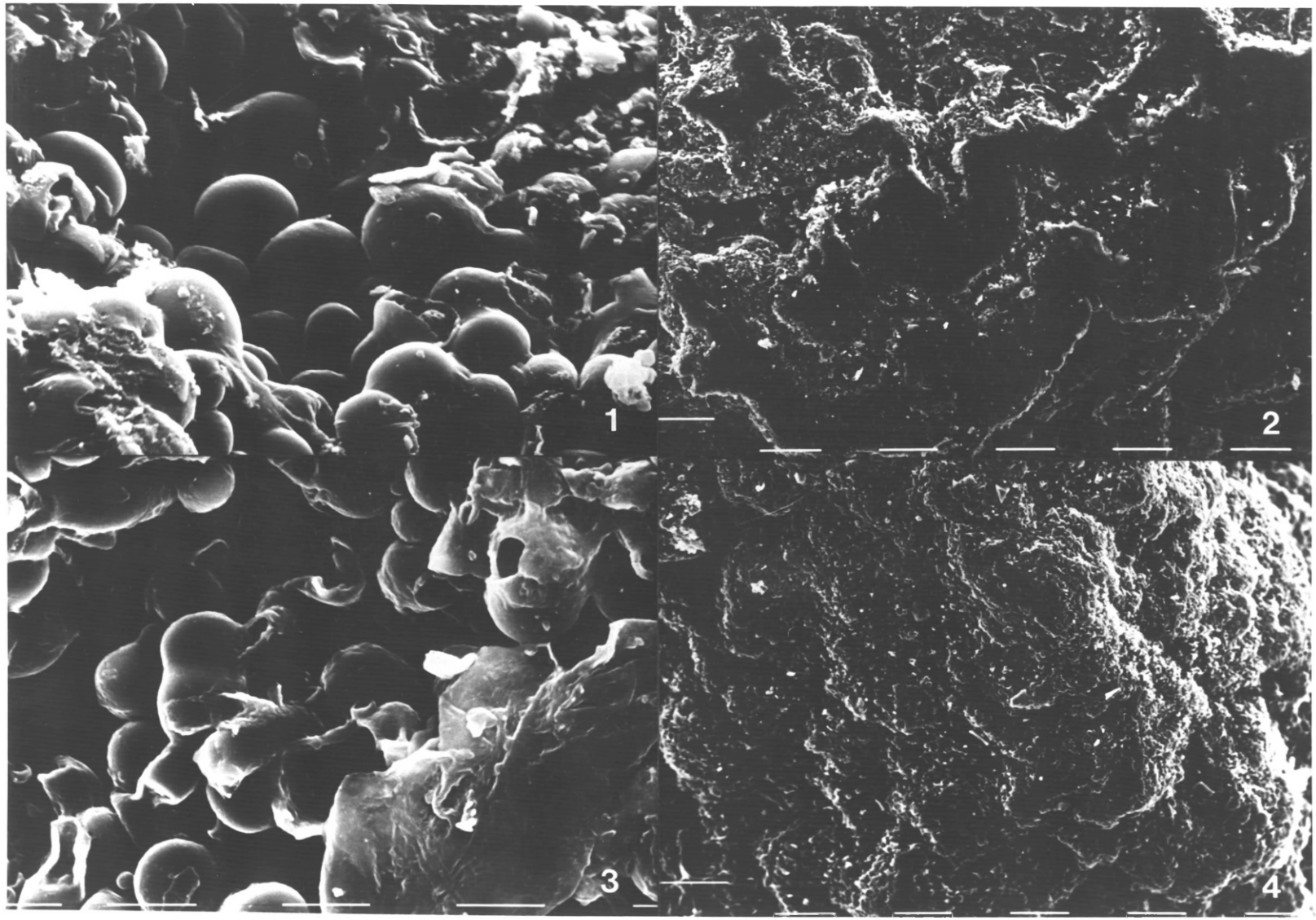
Number

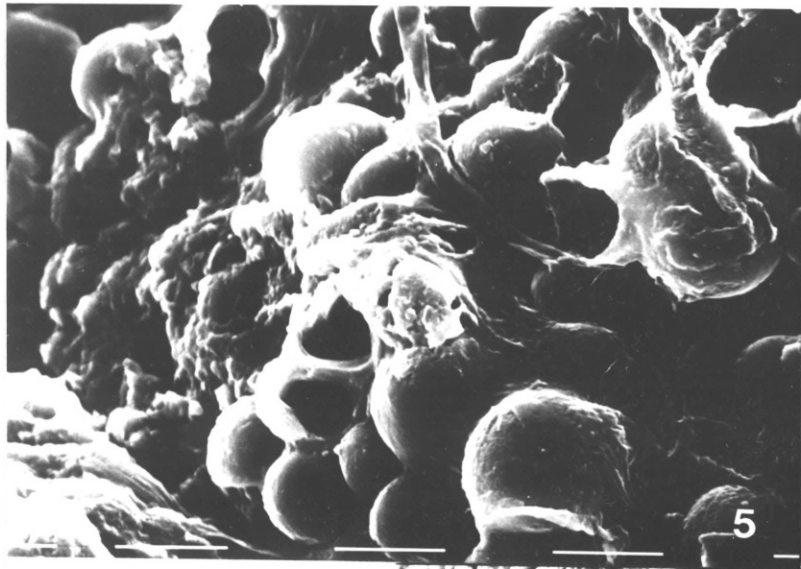
1	Natural sclerotia from infected stems Sutton Scotney x1600						
2	"	"	"	"	"	"	" x100
3	Sclerotia grown in wheat grain medium x1600						
4	"	"	"	"	"	"	x100
5	Treatment	1	x1600	Code:-	1	SS	C
6	"	2	x1600		1	SS	N
7	"	4	x400		1	S	N
8	"	5	x1600		2	SS	C
9	"	6	x800		2	SS	N
10	"	7	x1600		2	S	C
11	"	8	x1600		2	S	N
12	"	9	x1600		3	SS	C
13	"	10	x400		3	SS	N
14	"	11	x800		3	S	C
15	"	12	x400		3	S	N
16	"	13	x200		4	SS	C
17	"	14	x800		4	SS	N
18	"	15	x3200		4	S	C
19	"	16	x3200		4	S	N
20	"	17	x400		6	SS	C
21	"	18	x800		6	SS	N
22	"	19	x200		6	S	C
23	"	20	x400		6	S	N
24	"	23	x800		0	S	C
25	"	21	x400		0	SS	C
26	"	24	x800		0	S	N

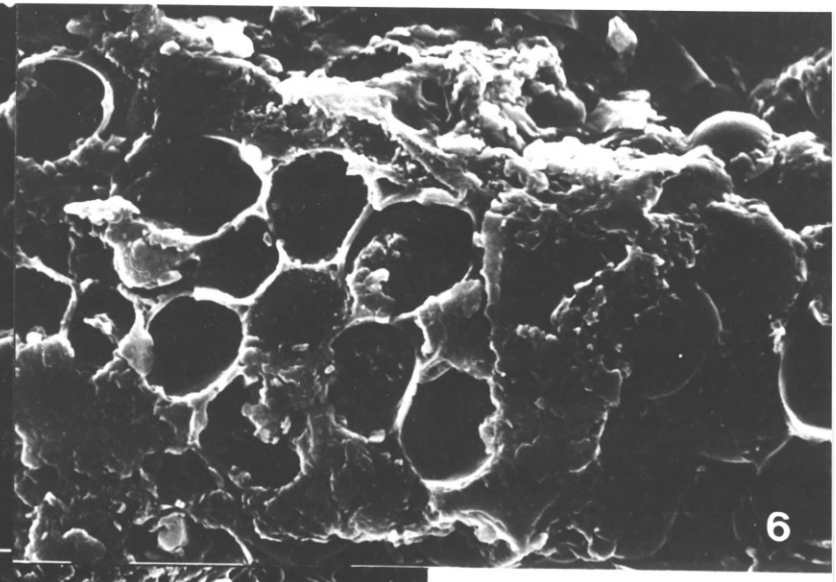
Burial depth 0-6 cm

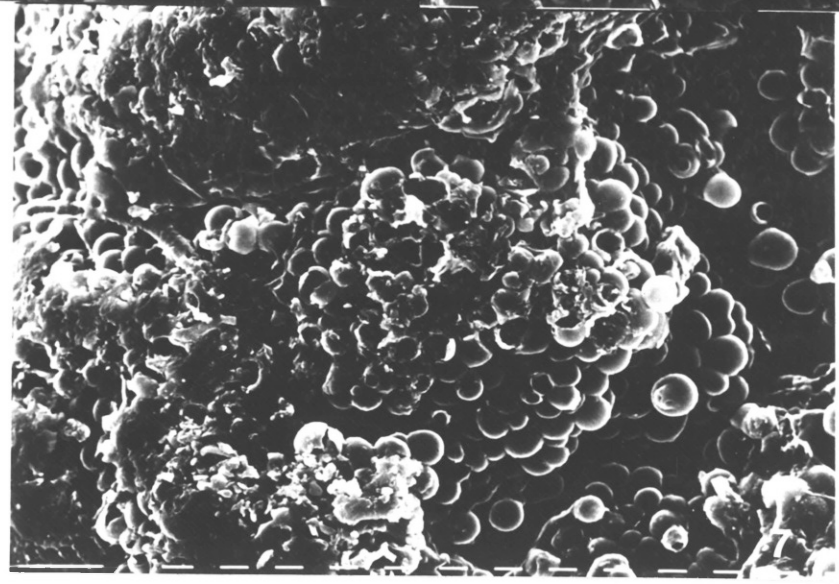
Soil type: SS = Sutton Scotney; S = Silwood

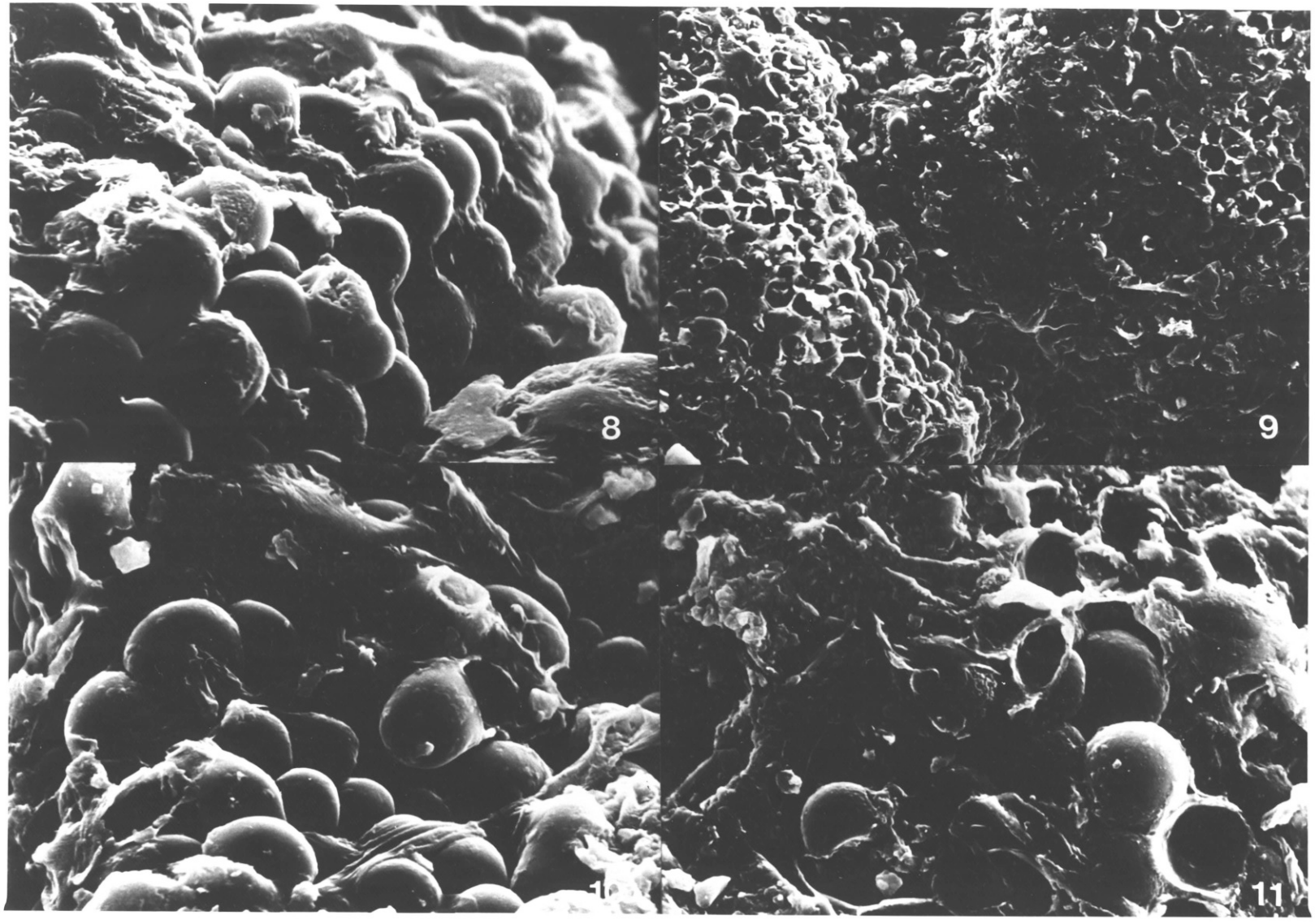
Sclerotia source: C = Culture; N = Natural

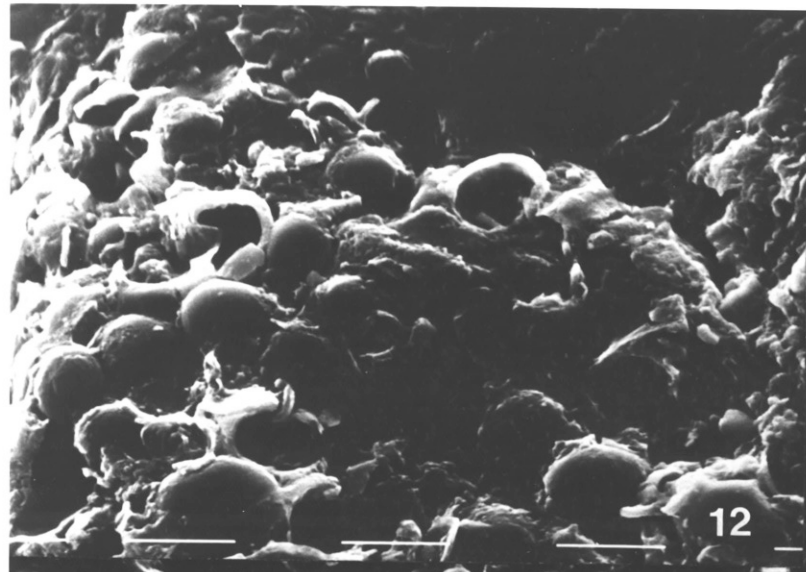

1
2
3
4

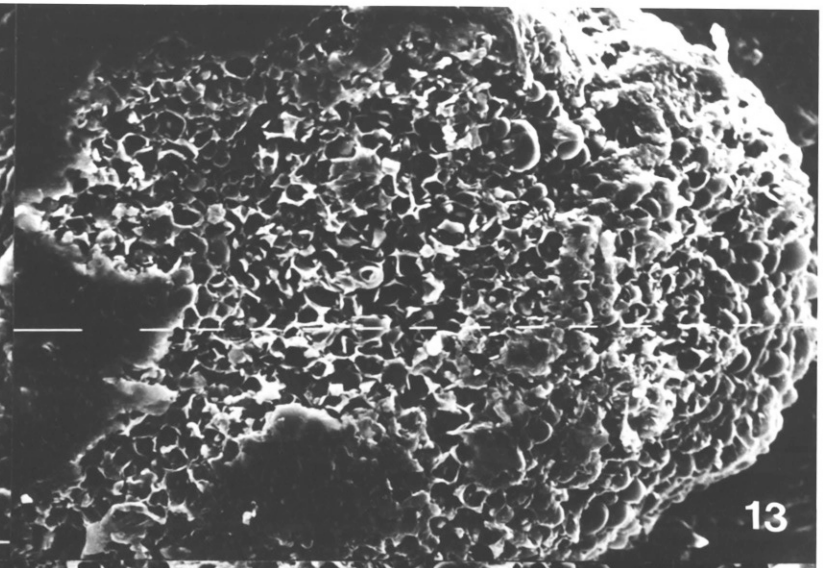

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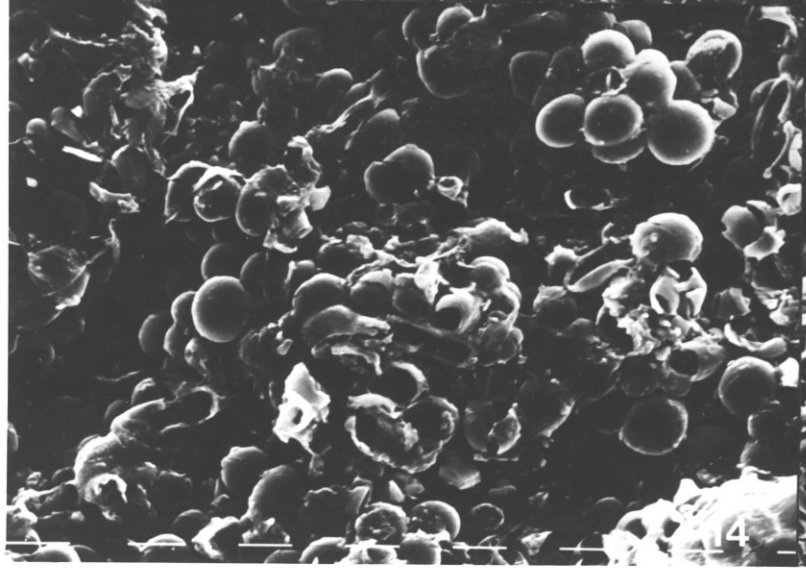

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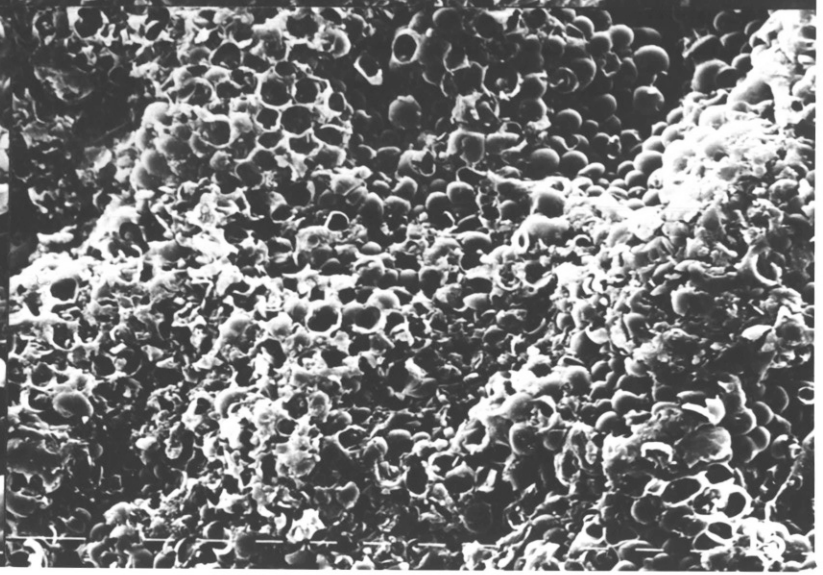

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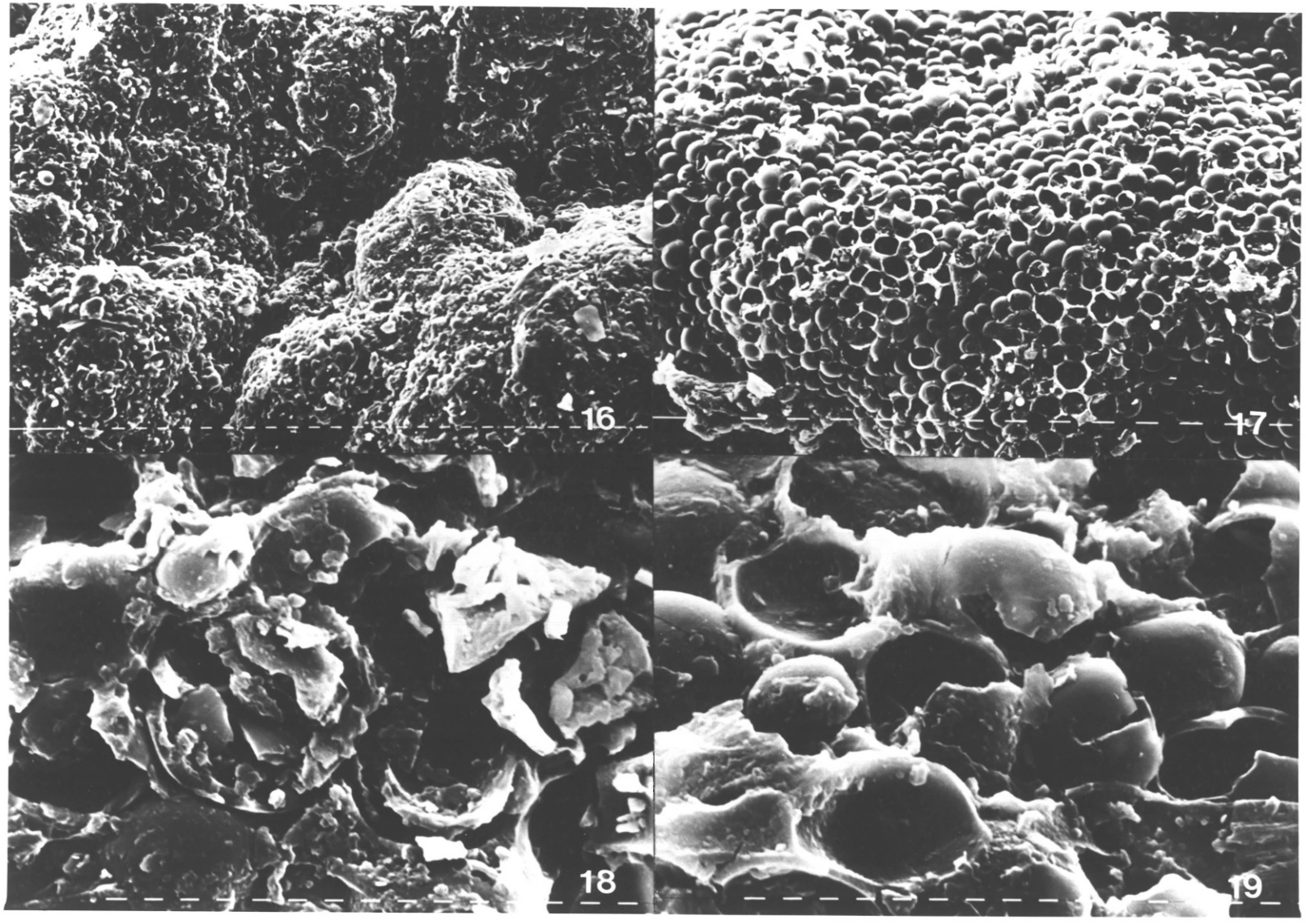

8
9
11

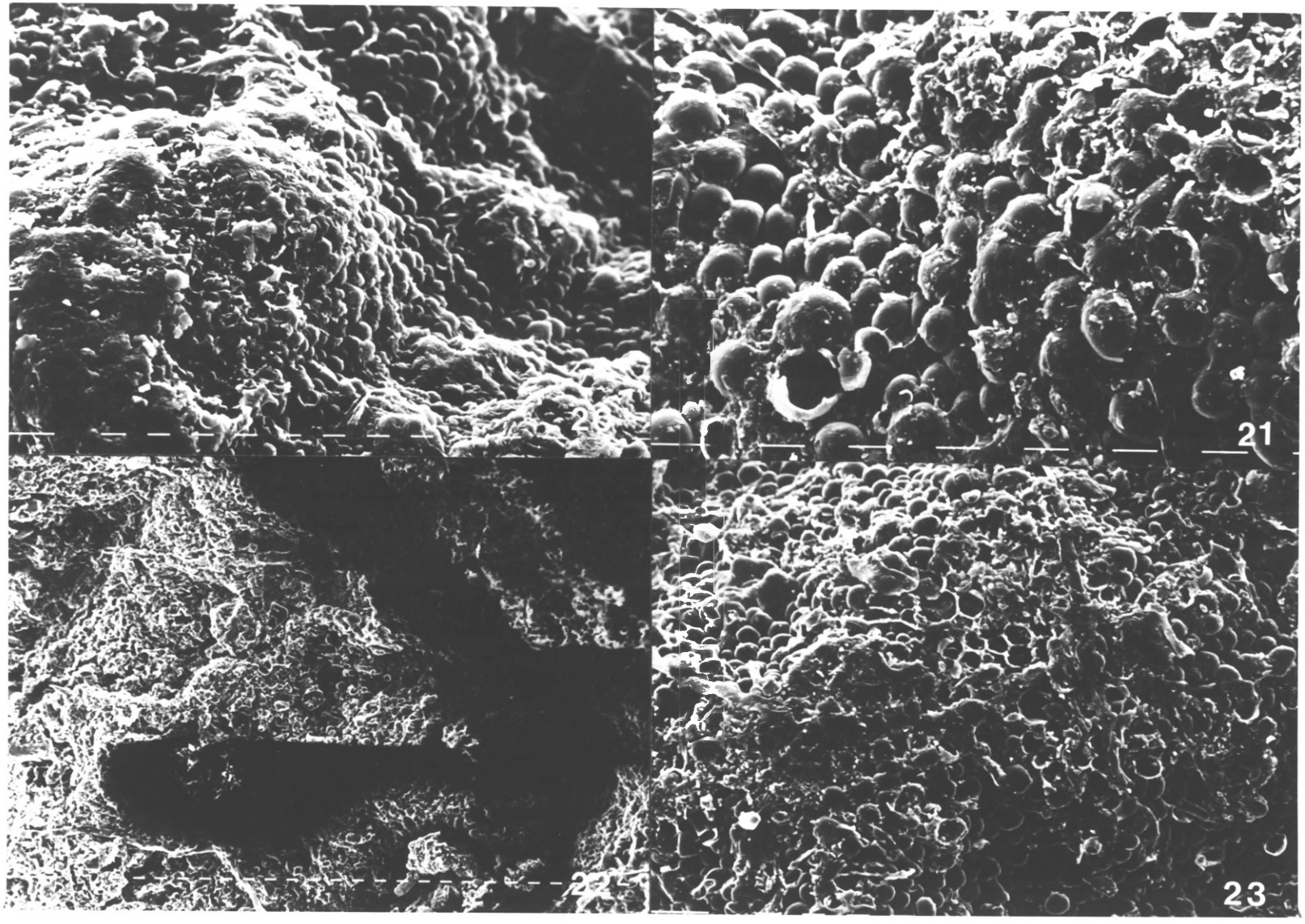

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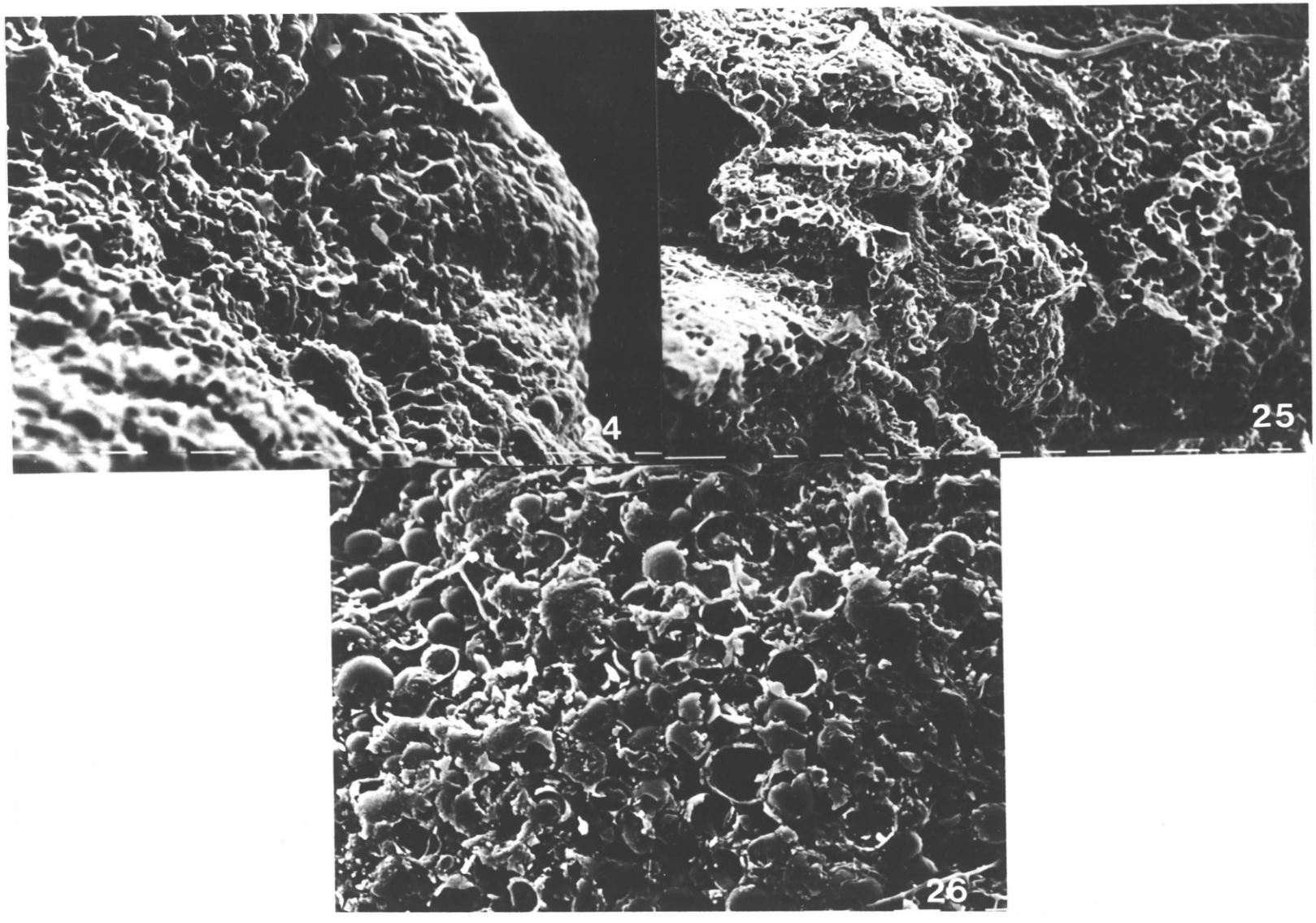

13


4




16
17
18
19


20
21
22
23


4
25
26

may have been more affected by the weather conditions than the lower depths, resulting in lower numbers.

DISCUSSION

The relative susceptibility of winter oilseed rape cultivars to stem rot caused by *S. sclerotiorum* has not previously been examined extensively under field conditions in the U.K. The trials described in this project indicated that all of the 31 cultivars tested were susceptible. However, not only were there considerable differences in the incidence of stem rot on any one cultivar in different seasons but also at different sites in one season. These features suggest that agronomic and environmental factors largely determine the amount of stem rot through their effects on either the production of fungal inoculum or infection of oilseed rape.

Production of Inoculum

S. sclerotiorum survives as sclerotia in soil and, indeed, in terms of time about 90% of its life cycle is spent in this form. Many of these sclerotia eventually give rise to apothecia from which ascospores are discharged and these ascospores provide inoculum for infection of the oilseed rape. There are thus three different but inter-related stages in the production of inoculum which can be influenced by agronomic and environmental factors: the survival of sclerotia, formation of apothecia and discharge of ascospores.

There have been few studies of natural populations of sclerotia of *S. sclerotiorum* in soil (Henderson, 1962; Abawi & Grogan, 1975; Hoes & Huang, 1975) though this information would be valuable for sites with a history of stem rot. Samples taken at Sutton Scotney from 1982 to 1984 (Tables 72-75) indicated clearly the ability of 'natural' sclerotia to survive. There was neither a marked increase nor decrease in numbers of sclerotia surviving under host or non-host crops. Three years after the original severe outbreak of stem rot on oilseed rape at this site there were still

considerable numbers of sclerotia present in the soil indicating the potential danger to future plantings of this crop. The observations of sclerotia formed in the roots of oilseed rape (Plate 4) was another method of sclerotia survival.

Experiments at Silwood Park suggested that the type of soil and depth to which sclerotia were buried influenced their survival, but these effects may partly reflect the extent to which the production of apothecia was affected by the same factors. Thus few apothecia were produced from sclerotia buried 4 and 6 cm deep but many sclerotia were recovered from these depths (Table 88). Presumably the depletion of food reserves by the apothecia and the rupture of the outer layers of the sclerotium, which may allow entry of other micro-organisms, reduced the ability of the sclerotia to survive.

There are several possible reasons why deeply buried sclerotia failed to produce apothecia. The hyphae of the stipes may be more vulnerable to antagonistic micro-organisms than are the outer tissues of the sclerotium. Also the formation of long stipes not only poses problems of nutrient transport, but may result in nutrient depletion to a level which cannot sustain the stipe reaching the soil surface for the development of the apothecium. The observed effects of soil type and added nitrogen on production of apothecia could similarly result from the inherent differences in the microflora of the soils or changes induced in the microbial populations by adding a nitrogenous fertilizer.

In addition to these external factors, there were features of the sclerotium itself which influenced its ability to produce apothecia. The experiments in Section I (particularly Experiment 15) showed that sclerotia need to be 'conditioned' by exposure to low temperatures before they will produce apothecia. The reasons for this are not clear but it does seem

likely that the ability of sclerotia to produce apothecia in the field could be influenced in part by winter temperatures.

In terms of field experiments, the differences in production of apothecia from sclerotia produced on plants and in culture are of particular interest. Again, the reasons for these differences remain to be investigated but the nutrient status of the sclerotium and structure of its outer tissue could be key features.

Variability in the numbers of apothecia produced within plantings of oilseed rape was a feature of the field trials. This may have reflected the unequal distribution of sclerotia as at Sutton Scotney but results from Silwood (Table 43), where standard inocula were used, indicated that other factors were responsible. These may be associated with the type of cover provided by the crop and the influence this has on soil moisture and humidity at ground level (Table 98). Generally, only one flush of apothecia occurred during April and June at Sutton Scotney (Tables 28 and 29) and at Silwood Park (Table 43) but isolates identified as *S. trifoliorum* produced apothecia in the autumn (Table 91).

So far, germination of sclerotia has been considered only in relation to their ability to produce apothecia, but at Sutton Scotney lesions on oilseed rape in January-March 1984 were associated with mycelial infections. Experiments in Section 1 showed that sclerotia produced mycelium only in sand or sterile compost and soil, suggesting that normally the growth of vegetative hyphae is inhibited by soil fungistasis. Possibly at Sutton Scotney, mycelial growth occurred primarily in leaf debris on the soil surface and nutrients available in these substrates were sufficient to overcome soil fungistasis. But whether this mycelium originated directly from sclerotia or from ascospores cannot be resolved for certain, though no apothecia were seen.

Finally, experiments under controlled conditions (Section 1) indicated that ascospore discharge was optimal at 15-20°C and about 93% r.h. (Table 13). The majority of ascospores were discharged in the light. In the field, maximum numbers of ascospores were trapped between 14.00 and 16.00 h during periods when rain favoured the production of apothecia. This period of the day coincided with minimum relative humidity and maximum temperatures (Fig. 11). In some instances, e.g. at Sutton Scotney, 1984 (Appendix LI) numbers of ascospores caught in traps were related to the numbers of apothecia present within the oilseed rape, but in other instances (Appendix LI (1983) + Table 107) there was no such association, presumably because the ascospores had been widely distributed by wind. This was particularly apparent in the inoculum density trial (Table 107). Similarly, although in some years low incidence of stem rot was associated with relatively low numbers of apothecia and ascospores, in other years it was not. The factors which lead to this latter situation are considered next.

Infection of Oilseed Rape

The ways in which *S. sclerotiorum* infects plants have been much studied since the pioneer work of de Bary (1886). These investigations have indicated three main modes of infection:-

i) mycelium from germinating sclerotia infects the stem base (Purdy, 1956; Dueck, 1979)

ii) ascospores released from apothecia germinate at wound sites and tissue penetration then follows (McLean, 1958; Abawi & Grogan, 1975)

and iii) ascospores germinated on dead flowers, senescent leaves or organic matter in contact with the host and the mycelium which develops in these nutrient bases then infects and colonizes intact tissues (Purdy & Bardin, 1953; McLean, 1958; Newton & Sequeira, 1972;

Abawi & Grogan, 1975; Abawi *et al.*, 1975).

Penetration via dead flowers and other tissue is believed to be the most important mode of entry and many reports indicate that in bean and other vegetables, epidemics occurred after and not before flowering.

Few detailed studies of the infection processes in oilseed rape have been conducted prior to this investigation, but Krüger (1974) suggested that flowers play an important role.

Results from this project demonstrate the important role of the petal in infection (Table 99). The nature of this role is still not clear, but laboratory experiments suggested that it is not entirely the provision of nutrients per se e.g. to support germination of ascospores, but rather that the petal provides a base for mycelium inoculum (Section 4.4).

Ascospore germination and germ tube growth was better in the dark than in the light (Table 14) and temperatures between 10° and 25°C had little effect overall on germination. Germ tube growth occurred optimally at 20°C in the presence of water. However, no infection of oilseed rape took place with ascospores and water alone under controlled conditions (Appendix XXXXI); only in the presence of the petal did lesions develop.

This key role was seen in field trials where incidence of stem rot in the different cultivars appeared to be associated with their time of flowering. However, better associations were obtained when infection was related jointly to flowering and ascospore production (Table 52). The pattern which emerges is that stem rot incidence is likely to be high when environmental factors favour the adhesion of petals to stems of oilseed rape, during periods of maximum production of apothecia and release of ascospores. These are the conditions which need to be predicted if spraying is to be carried out economically for the control of stem rot. However, the somewhat special conditions required for infection impose

practical limitations on spraying trials. For example, the trial at Silwood Park in 1984 (Section 3.3) was undertaken in a year when petal cover, ascospore inoculum and suitable weather did not combine suitably and infection was low.

Most of the data on incidence of stem rot amongst the different cultivars tested must be considered in relation to this availability of inoculum and suitable infection courts (i.e. dead petals adhering to the stem). All the evidence suggests there is little or no resistance per se in the current cultivars and lines, in the sense that lesions formed on all cultivars when conditions for infection were favourable in the field or were so maintained in laboratory experiments. This included cultivar Doral, which proved to be as susceptible as the other cultivars under trial at Silwood. Nevertheless, in the field there were substantial differences in lesion length on the various cultivars (Table 58) which led to different amounts of lodging (Table 61) and yield loss in terms of seed weight (Tables 52 and 56), size (Table 57) and oil content (Table 52). There would thus appear to be some host factors which affect lesion extension besides environmental factors such as temperature (Table 59). The nature of these host factors are of interest and importance because in addition to the relationships between long lesions, lodging and yield loss, plants with long lesions tended to have more sclerotia (Tables 65 and 68) and thus contributed more inoculum for future crops.

Future Work

While there was no evidence of substantial resistance amongst the cultivars and lines tested, it was evident that the two most commonly grown cultivars, Jet Neuf and Bienvenu, were amongst those most affected by stem rot over the three seasons. This is a cause for concern because the continued planting of those cultivars may increase the risk of *S.*

sclerotiorum becoming more widespread in the U.K. not only on crops of winter oilseed rape but also on legumes which might be part of a rotation with oilseed rape. Inter-relationships between these crops in respect of inoculum of *S. sclerotiorum* need to be examined as do the contribution of weed hosts (Hims, 1979; Table 93). There is a large potential for infection from a wide range of British isolates of *S. sclerotiorum* on oilseed rape (Table 126). However, the dispersal of ascospores over relatively long distances (Meier *et al.*, 1933; Williams & Stelfox, 1979) or from apothecia formed on sclerotia from weeds, could militate against the benefits expected of a crop rotation.

The lack of obvious resistance in present breeding lines suggest that a truly resistant cultivar of oilseed rape is unlikely to be obtained in the foreseeable future. Also the glasshouse and laboratory tests indicated that there is as yet no simple substitute for field screening; even with a reliable method of artificially producing ascospores. Possibly the screening of lines on a site with overhead irrigation within which sclerotia can be placed (as at NIAB), is the best system that can be devised at present. One other possibility is to breed a suitable petalless cultivar (Buzza & Mendham, 1983) which, presumably, would not then have suitable infection courts.

Meanwhile, more effort might be directed at field control of stem rot. Initially, risks of stem rot might be determined from counts of sclerotia in soil samples (Section 2.3.6). Some attempt might even be made to reduce the number of sclerotia using antagonistic micro-organisms but this would require initial basic research.

Recent work in Germany and Canada (Krüger & Stoltenberg, 1983; Dueck *et al.*, 1983) indicates that stem rot can be effectively controlled by a single application of one of several fungicides when plants are at early

flowering. The results suggest that such an application is economically profitable when there is a risk that 25% of the plants will become infected. Similar investigations by the Agricultural Development & Advisory Service in the U.K. (J.M.L. Davies, pers. comm., 1984) also indicate that a spray applied as a protectant prior to ascospore release at early flowering is optimum for stem rot control.

These promising results emphasize the need for a crop risk assessment based on observations of sclerotia, apothecia formation, ascospore release and weather at petal fall.

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Appendix I (Text Table 2) : Growth of *Sclerotinia sclerotiorum* isolate R1 on various media at 20°C.

i) Mean Linear Growth (mm) of R1 on Various Media at 20°C

	Days after inoculation		
Medium	2	4	6
PDA	31.33 ± 1.37(a)*	60.67 ± 1.97(a)	90 ± 0.0(a)
PSA	32.0 ± 2.45(ab)	64.67 ± 3.93(b)	90 ± 0.0(a)
GAY	34.83 ± 3.25(ab)	79.67 ± 3.61(c)	90 ± 0.0(a)
V8	65.83 ± 2.79(c)	89.67 ± 0.52(d)	90 ± 0.0(a)
MALT	69.17 ± 2.14(d)	90.0 ± 0.0(d)	90 ± 0.0(a)

i) Figures are the S.D. for 6 replicates.

* Letters in paranthesis are from Duncan's Multiple Range Test. Values with no letter in common are significantly different at P = 0.05.

ii) Days after Inoculation for Sclerotial Initials to Form (20°C)

	Replicates						
Medium	1	2	3	4	5	6	Mean ± S.D.
PDA	7	7	8	8	7	8	7.5 ± 0.55 ab
PSA	7	6	8	7	7	7	7.0 ± 0.63 ab
GAY	7	7	7	7	7	7	7.0 ± 0.0 ab
V8	8	8	9	8	8	8	8.17 ± 0.41 b
MALT	5	6	6	5	5	5	5.33 ± 0.52 a

Mean values with no letter in common are significantly different at P = 0.05. (Duncan's Multiple Range Test)

Appendix I : Continued.

iii) Days after Inoculation when Sclerotia are Mature (20°C)

	Replicates						
Medium	1	2	3	4	5	6	Mean ± S.D.
MALT	7	8	8	7	7	8	7.5 ± 0.55 a
GAY	9	10	9	9	9	10	9.33 ± 0.52 b
PSA	9	9	10	10	10	10	9.67 ± 0.52 bc
PDA	10	10	11	10	10	10	10.17 ± 0.41 c
V8	11	12	12	12	11	11	11.5 ± 0.55 d

Mean values with no letter in common are significantly different at P = 0.05.

(Duncan's Multiple Range Test)

iv) Total Number of Sclerotia per Plate (20°C)

	Replicates						
Medium	1	2	3	4	5	6	Mean ± S.D.
PDA	4	4	5	4	4	8	4.83 ± 1.6 a
V8	10	12	12	11	12	14	11.83 ± 1.33 ab
MALT	18	15	17	14	22	16	17.0 ± 2.83 ab
PSA	20	15	17	20	19	22	18.83 ± 2.48 bc
GAY	32	34	27	20	30	36	29.83 ± 5.24 c

Mean values with no letter in common are significantly different at P = 0.05.

(Duncan's Multiple Range Test)

Appendix II : Linear growth of R1 on various media at 20°C.
(Text Table 2)

		Growth after 2 days (mm)					
Media	Reps.	1	2	3	4	5	6
PDA		31	29	33	31	32	32
PSA		30	32	32	29	33	36
GAY		35	30	32	36	38	38
V8		64	71	63	65	66	66
MALT		69	71	69	68	66	72

		Growth after 4 days (mm)					
	Reps.	1	2	3	4	5	6
PDA		59	58	63	60	62	62
PSA		65	66	57	67	66	68
GAY		76	81	86	78	80	77
V8		90	90	90	90	90	90
MALT		90	90	90	90	90	90

		Growth after 6 days (mm)					
	Reps.	1	2	3	4	5	6
PDA		90	90	90	90	90	90
PSA		90	90	90	90	90	90
GAY		90	90	90	90	90	90
V8		90	90	90	90	90	90
MALT		90	90	90	90	90	90

Appendix III : Growth of R1 on GAY at different temperatures.
(Text Table 3)

Temperature °C	Days taken for mycelium to cover the plate	Days after inoculation for formation sclerotial initials	Days after inoculation when sclerotia are mature
5	14, 15, 15, 15, 14, 15.	26, 22, 24, 23, 24, 22.	30, 29, 29, 29, 29, 29.
10	9, 10, 8, 9, 9, 9.	12, 13, 12, 12, 12, 14.	21, 22, 20, 21, 21, 20.
15	7, 6, 6, 7, 7, 7.	8, 9, 9, 9, 9, 8.	10, 11, 11, 11, 12, 11.
20	6, 6, 6, 6, 6, 6.	7, 7, 7, 7, 7, 7.	9, 10, 9, 9, 9, 10.
25	5, 5, 6, 6, 6, 6.	11, 12, 12, 10, 11, 11.	13, 14, 14, 14, 14, 14.
30	8, 7, 8, 8, 7, 8.	14, 15, 16, 15, 15, 15.	20, 21, 22, 21, 21, 22.

Temperature °C	Total number sclerotia/plate	Sclerotial size Length x Width (mm)					
5	4, 3, 2, 4, 4, 4.	6.2 x 3.2,	7.4 x 3.6,	7.0 x 3.7,	6.8 x 3.7,	6.8 x 3.2,	7.2 x 3.8
10	21, 20, 20, 19, 19, 20.	5.3 x 3.5,	6.0 x 3.5,	6.2 x 3.2,	5.8 x 3.0,	5.7 x 3.0,	6.2 x 3.8
15	22, 24, 23, 17, 29, 31.	6.1 x 4.0,	4.2 x 3.2,	4.4 x 3.2,	5.8 x 3.9,	5.2 x 2.9,	4.9 x 3.2
20	32, 34, 27, 20, 30, 36.	5.3 x 3.8,	6.1 x 4.0,	5.8 x 3.2,	5.4 x 2.9,	5.6 x 3.0,	6.0 x 3.4
25	17, 18, 13, 18, 18, 15.	6.2 x 3.0,	6.4 x 3.2,	5.3 x 3.0,	5.8 x 3.1,	6.2 x 3.2,	6.4 x 3.2
30	8, 7, 3, 2, 7, 2.	4.2 x 2.0,	3.9 x 2.6,	3.2 x 2.8,	3.4 x 2.0,	4.2 x 2.9,	3.4 x 2.2

Appendix IV : Measurements of sclerotia produced on GAY agar at 20°C.
(Text Table 4)

Isolate	Mean values (mm)		Range of sclerotial size within each sample Length x Width (mm)
	Length	Length/Width	
SOY.	4.00	1.38	11.0-2.0 x 6.5-1.7
PR1	4.57	1.22	8.5-2.8 x 6.2-1.5
CHRY.	3.49	1.43	10.5-2.0 x 6.0-1.5
CUC.	4.86	1.47	12.2-1.5 x 8.4-1.2
BRUS.	5.00	1.40	8.4-2.8 x 7.2-2.1
CLOV.	3.97	1.51	7.8-2.2 x 4.5-1.7
RAD.	3.37	1.39	8.0-2.0 x 5.2-1.7
SP	2.96	1.29	5.2-1.8 x 3.5-1.4
HO1	3.69	1.26	6.8-2.3 x 4.9-2.0
PA1	5.15	1.32	12.5-2.7 x 6.5-1.8
R1	3.76	1.37	7.5-2.4 x 4.8-2.0
JN1	3.94	1.36	8.2-2.4 x 4.2-2.0
JN4	3.17	1.24	9.2-1.5 x 5.8-1.5
JN5	2.92	1.30	4.8-2.0 x 3.1-1.5
JN6	3.35	1.32	7.2-2.0 x 3.4-2.0
JN7	4.04	1.35	7.2-2.0 x 4.5-1.7
JN8	3.31	1.32	7.9-2.0 x 3.1-1.5
JN9	3.59	1.40	12.8-1.6 x 3.9-1.4
SS2	4.23	1.56	9.8-2.4 x 5.0-2.1
SS3	3.41	1.29	5.8-2.0 x 3.8-1.8
RC802	3.36	1.27	7.0-2.0 x 5.1-1.5
St. 1	3.63	1.44	7.8-2.2 x 4.3-1.6
L4776	3.32	1.37	6.8-2.0 x 4.0-1.8
L2E	3.33	1.38	5.8-2.0 x 3.4-1.8
FB1	2.08	1.22	3.4-1.3 x 2.7-1.0
B2	4.07	1.42	7.5-2.2 x 5.0-2.0
P5005	5.19	1.27	7.9-3.2 x 6.3-2.5
V1	3.57	1.31	10.4-1.2 x 5.1-1.2
C3887	3.03	1.31	5.0-2.0 x 3.2-1.8
PW1	5.60	1.26	11.8-3.1 x 8.3-2.5

Appendix V : Length of ascospores of *S. sclerotiorum* isolate JN1. (Text p. 54)

Replicate	Apothecium	Length of ascospore (µm) 1	2	3
1		11.25	10.5	11.25
2		12.0	10.5	12.0
3		8.0	11.25	12.5
4		10.5	12.5	12.5
5		10.0	10.5	12.5
6		10.0	10.0	12.5
7		10.0	11.25	11.25
8		9.75	13.0	11.25
9		9.5	11.25	11.25
10		10.0	12.5	12.5
11		8.75	13.0	13.0
12		10.5	12.5	13.0
13		10.5	11.25	13.0
14		9.5	12.5	12.0
15		10.0	12.5	12.0
16		10.0	12.5	12.0
17		10.0	11.25	12.0
18		10.5	12.5	12.5
19		8.0	11.25	11.25
20		11.25	12.0	12.5
21		10.25	12.0	12.5
22		11.25	12.5	12.5
23		9.75	13.0	13.0
24		10.0	13.0	10.5
25		12.5	13.0	13.0

Range 8.0-13.0

Mean 11.6

Appendix VI : Ascospores discharged (x 10^3) under different temperature, relative humidity and light regimes.
(Text Table 13)

Relative humidity	Light/ Dark	Temperature °C											
		4°			10°			15°			20°		
		1	2	3	1	2	3	1	2	3	1	2	3
100	L	26.3	25.6	21.4	145.6	113.2	40.3	234.6	211.1	141.1	214.6	137.6	127.6
	D	26.0	24.1	19.2	104.3	62.5	93.6	157.9	163.0	76.6	72.4	62.5	47.9
97	L	28.4	29.3	23.6	196.3	99.5	135.9	246.9	264.4	192.3	214.6	193.5	146.1
	D	26.3	28.0	19.9	87.8	89.9	83.1	162.4	139.5	116.1	104.6	85.9	93.0
92.8	L	29.7	28.3	27.4	183.3	132.7	36.1	314.3	392.2	172.9	274.5	253.4	264.7
	D	28.5	27.3	23.3	88.3	87.5	86.5	163.2	173.5	106.1	213.5	224.8	162.6
85.2	L	18.9	17.5	15.7	94.4	93.4	89.0	216.3	222.2	177.8	224.1	205.7	170.7
	D	18.1	18.3	13.7	64.3	64.5	60.6	121.7	173.6	8.2	214.5	184.3	180.6
73.4	L	10.5	7.1	10.0	5.0	87.4	100.0	84.9	82.1	82.7	84.9	79.3	82.2
	D	8.1	7.2	8.3	26.5	23.5	24.3	65.9	66.2	60.9	81.8	81.0	79.4
62.4	L	2.2	2.1	2.2	41.2	41.0	38.8	71.2	69.0	67.3	73.3	76.2	74.0
	D	2.1	3.4	1.7	12.2	11.5	11.3	49.9	53.0	53.4	74.1	62.3	50.4
44.3	L	1.1	1.5	1.7	7.3	8.2	6.5	59.3	61.3	60.7	9.1	9.3	9.3
	D	0.9	1.0	0.8	2.3	2.0	3.1	44.1	29.4	52.8	8.5	6.4	6.6
33.8	L	1.1	0.9	1.0	0.2	0.4	0.3	10.3	0.7	18.7	9.4	8.7	8.2
	D	0.1	0.2	0.02	0.2	0.3	0.3	9.9	10.3	2.6	2.7	1.2	2.5
16.9	L	0.3	0.2	0.2	0.09	0.1	0.1	0.7	0.9	0.8	0.9	0.8	0.7
	D	0.04	0.08	0.0	0.04	0.06	0.01	0.1	0.2	0.2	0.1	0.1	0.1
1.7	L	0.02	0.0	0.0	0.04	0.02	0.01	0	0.03	0.02	0	0.01	0
	D	0.01	0.1	0.0	0.01	0	0.01	0.01	0.02	0	0	0	0
0	L	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0	0	0

Appendix VII : Germination of ascospores under different temperature and light regimes.

Sample Number	Temperature °C							
	10°		15°		20°		25°	
	L	D	L	D	L	D	L	D
1	17.46	60.0	19.37	68.03	21.97	51.94	27.97	51.94
2	16.43	64.9	19.37	62.72	21.97	71.56	27.28	53.13
3	15.34	72.54	18.44	67.21	27.28	57.46	29.33	58.05
4	17.46	60.67	20.27	73.51	26.56	58.05	33.21	58.69
5	16.43	64.9	21.97	72.54	27.97	60.0	33.83	62.03
6	15.34	66.42	19.37	72.54	29.33	56.17	34.45	56.79
7	15.34	62.03	19.37	68.87	22.79	51.94	35.67	53.13
8	12.92	62.72	20.27	69.73	30.66	52.53	35.06	53.75
9	9.98	67.21	21.97	67.21	29.33	56.17	35.67	52.53
10	17.46	68.03	23.58	68.03	28.66	51.94	36.87	54.94
11	17.46	63.44	19.37	66.42	27.97	58.05	34.45	51.94
12	16.43	61.34	18.44	73.57	25.84	59.34	35.06	58.05
13	15.34	58.05	19.37	66.42	27.28	60.67	35.67	51.94
14	14.18	66.42	20.27	58.05	27.28	59.34	36.87	52.53
15	14.18	60.0	21.13	58.05	26.56	66.42	27.97	50.77

Ascospores were incubated in 6 hours in the light (L) or the dark (D)

Each figure is the arcsin $\sqrt{\%}$ transformation.

Anovar

1. Light	df	SS	MS	F	
Treatment	3	2609.7	896.57	143.52	***
Error	56	349.88	6.25		
Total	59	3039.88			

2. Dark	df	SS	MS	F	
Treatment	3	1490.61	498.7	25.3	***
Error	56	1105.69	19.74		
Total	59	2596.29			

Appendix VIII : Germ tube length (µm) after 6 hours on water agar.

Sample Number	Temperature °C							
	10°		15°		20°		25°	
	L	D	L	D	L	D	L	D
1	10	41	11	25	21	41	24	20
2	11	46	14	27	30	29	25	29
3	11	42	20	41	28	61	34	26
4	10	49	19	42	23	21	35	33
5	10	31	17	35	23	33	25	20
6	11	25	21	46	31	55	25	65
7	11	42	20	22	24	32	26	27
8	11	21	20	35	23	42	27	26
9	10	21	17	21	25	29	26	29
10	10	45	14	25	23	41	28	31
11	10	34	14	42	22	26	29	36
12	11	36	20	44	25	42	37	21
13	11	42	20	48	27	90	35	45
14	10	43	14	34	22	43	35	48
15	12	55	14	36	23	60	35	21
16	11	42	14	51	27	39	26	23
17	12	36	14	46	25	62	26	22
18	10	34	17	31	24	47	33	24
19	12	28	18	62	23	64	34	31
20	12	26	14	75	23	100	26	23
21	14	21	20	66	22	32	26	24
22	10	22	19	23	22	29	29	43
23	10	31	16	31	23	41	28	36
24	10	25	20	42	26	63	29	31
25	10	32	19	33	26	24	37	22

Anovar

1. Light

	df	SS	MS	F	
Treatment	3	5109.79	1703.3	279.6	***
Error	96	585.12	6.09		
Total	99	5694.91			

2. Dark

	df	SS	MS	F	
Treatment	3	3321.39	1107.13	5.63	***
Error	96	18863.4	196.46		
Total	99	22184.7			

Appendix IX : Randomised block design for Sutton Scotney 1981-82.

Cultivar	Plot number of cultivars in blocks			
	I	II	III	IV
Fiona	1	30	36	56
Lirama	2	28	41	63
Rafal	3	20	43	53
Jupiter	4	26	33	61
Perle	5	25	47	55
Ledark	6	24	45	49
Bienvenu	7	19	48	62
Korina	8	32	42	60
Valdor	9	21	38	50
Norli	10	23	44	54
St 1/80a	11	29	37	51
Jet Neuf	12	18	46	52
Semu 13/79	13	31	40	57
Vigor	14	17	39	59
Lingot	15	27	34	64
Elvira	16	22	35	58

Appendix X : Cambridge oilseed rape trial 1981-82.

Perle Fiona Bienvenu Elvira Lingot Jupiter Jet Neuf Rafal	Rep. (1)	St 1/80a Lirama Norli Ledark Semu 13/79 Valdor Vigor Korina
Vigor Jet Neuf Ledark St 1/80a Lirama Valdor Norli Semu 13/79	(2)	Fiona Perle Lingot Bienvenu Elvira Rafal Korina Jupiter
Lirama Fiona Vigor Bienvenu Ledark Pere Valdor St 1/80a	(3)	Jet Neuf Korina Lingot Jupiter Elvira Rafal Semu 13/79 Norli
Rafal Jet Neuf Fiona Perle Norli Korina Jupiter Bienvenu	(4)	Elvira Lingot St 1/80a Valdor Lirama Vigor Ledark Semu 13/79

Outline = Tunnel site with central path

Appendix XI : Cambridge oilseed rape trial 1982-83.

Jet Neuf Belinda Tandem Brittander Fiona Darmor Bienvenu Korina Elvira	Rep. (1)	Norli Chrysander Perle Lirabella Rafal Lingot Pamela Diander
Pamela Bienvenu Diander Elvira Lingot Lirabella Tandem Perle	(2)	Chrysander Rafal Fiona Brittander Korina Darmor Norli Jet Neuf Belinda
Lirabella Belinda Bienvenu Perle Darmor Diander Rafal Jet Neuf Brittander	(3)	Chrysander Pamela Tandem Elvira Korina Lingot Norli Fiona
Perle Darmor Diander Fiona Jet Neuf Korina Chrysander Bienvenu	(4)	Rafal Norli Lingot Elvira Tandem Lirabella Brittander Pamela Belinda

Appendix XII : Cambridge oilseed rape trial 1983-84.

Rafal Falk Jet Neuf Korina Darmor Pamela Liradonna Belinda	Rep. (1)	Carola Mikado Lirabella Bienvenu Diander Barbara Jem Fiona
Bienvenu Diander Korina Belinda Pamela Mikado Jet Neuf Lirabella	(2)	Jem Liradonna Fiona Darmor Rafal Falk Barbara Carola
Fiona Jem Belinda Falk Jet Neuf Mikado Carola Lirabella	(3)	Liradonna Bienvenu Diander Pamela Barbara Rafal Darmor Korina
Lirabella Rafal Diander Liradonna Barbara Falk Pamela Mikado	(4)	Jet Neuf Korina Belinda Jem Bienvenu Carola Darmor Fiona

Appendix XIII : Sutton Scotney 1981-82.
(Text Table 21)

Cultivar	Blocks I	II	III	IV	Mean
Elvira	41.2	62.8	44.0	42.6	47.6
Jet Neuf	74.6	76.0	62.8	58.2	67.9
Bienvenu	58.0	54.2	32.0	68.8	53.2
Jupiter	54.0	43.1	29.4	31.7	39.6
Korina	49.1	65.4	64.0	34.7	53.3
Lirama	46.2	26.0	13.7	22.5	27.1
Perle	30.1	27.5	30.0	13.7	25.3
Semu 13/79	64.7	36.0	52.0	30.0	45.7
St 1/80a	44.0	50.0	36.5	45.1	43.9
Vigor	52.0	43.1	36.2	27.5	36.7
Norli	31.5	52.0	12.0	32.7	32.0
Rafal	53.9	38.2	46.0	23.1	40.3
Fiona	66.0	56.0	41.2	56.0	54.8
Ledark	28.0	48.0	23.5	26.0	31.4
Lingot	23.5	14.0	19.5	28.9	21.5
Valdor	39.2	26.0	32.0	35.9	33.7

Anovar(a)

Factor	d.f.	SS	MS	F	
Total	63	5815.8			
Cultivar	15	3450.9	230.06	5.92	***
Block	3	616.5	205.5	5.29	**
Error	45	1748.4	38.9		

(a) Analysis was carried out on transformed data (arcsin $\sqrt{\%}$)

*** denotes an F value significant at $\underline{P}$ <

** denotes an F value significant at $\underline{P}$ <

Appendix XIV : Cambridge 1982-83.
(Text Table 21)

	Blocks			
Cultivar	I	II	III	IV
Elvira	56.8	43.2	71.1	36.0
Jet Neuf	58.5	12.9	50.0	32.9
Bienvenu	47.8	43.8	73.6	20.6
Korina	48.0	33.7	54.7	23.1
Norli	18.2	18.1	54.6	54.6
Rafal	39.1	45.8	43.8	49.0
Fiona	25.1	35.4	34.2	30.9
Lingot	24.6	59.8	53.5	50.0
Belinda	21.8	15.3	41.5	20.9
Brittander	16.1	26.9	52.2	27.7
Lirabella	24.8	41.1	56.7	20.7
Pamela	16.1	59.3	36.0	12.4
Diander	26.5	37.0	52.9	32.0
Darmor	28.1	19.0	39.1	44.7
Chrysander	17.3	20.0	20.7	15.7
Tandem	18.8	18.9	48.3	21.9

Anovar(a)

Factor	d.f.	SS	MS	F	
Cultivar	15	1790.9	119.4	2.0	*
Block	3	1397.6	465.9	7.79	***
Error	45	2688.8	57.8		
Total	63	5877.2			

(a) Anovar carried out on angular transformed data (arcsin $\sqrt{\%}$)

Appendix XV : Cambridge 1983-84.
(Text Table 21)

	Blocks			
Cultivar	I	II	III	IV
Jet Neuf	13.2	15.9	9.3	15.6
Bienvenu	13.2	22.7	22.8	22.2
Korina	18.5	19.4	29.3	20.7
Rafal	19.8	9.6	18.4	11.3
Fiona	21.4	13.0	17.2	10.0
Belinda	20.7	16.7	18.0	14.8
Lirabella	22.9	12.1	15.9	22.4
Pamela	20.6	15.4	21.7	1.6
Diander	32.1	26.0	22.4	32.7
Darmor	7.6	13.8	15.9	4.9
Carola	13.0	16.0	17.3	12.5
Mikado	11.3	16.3	11.1	1.3
Falk	19.7	20.0	20.0	14.1
Liradonna	20.8	6.1	16.7	19.1
Barbara	20.3	11.9	3.9	6.1
Jem	19.4	16.7	14.7	17.7

Anovar(a)

Factor	d.f.	SS	MS	F	
Cultivar	15	852.5	56.8	2.78	***
Blocks	3	144.8	48.3	2.37	n.s.
Error	45	916.1	20.4		
Total	63	1913.4			

(a) Anovar carried out an angular transformed data (arcsin $\sqrt{\%}$)

Appendix XVI : Anovar for the three sites from each season. (Text Table 22)

1982 (only Sutton Scotney and Cambridge)

Factor	d.f.	SS	MS	F	
Cultivar	15	5.6	0.37	0.49	n.s.
Site	1	216.9	216.99	285.38	***
Error	15	11.3	0.76		
Total	31	233.8			

1983

Factor	d.f.	SS	MS	F	
Cultivar	15	34.6	2.31	1.47	n.s.
Site	2	151.4	75.72	48.2	***
Error	30	47.3	1.57		
Total	47	233.3			

1984

Factor	d.f.	SS	MS	F	
Cultivar	15	5.0	0.33	0.77	n.s.
Site	2	48.83	24.13	56.64	***
Error	30	12.93	0.43		
Total	47	66.76			

All anovars carried out on mean transformed data ($\sqrt{x + 0.5}$)

Appendix XVII (Text Table 24) : Test for an association between the two sites from each season from ranking of cultivars[(a)].

a) 1982

Cultivar	Sutton Scotney	Cambridge	Difference in ranking
Elvira	12	7	5
Jet Neuf	16	14	2
Bienvenu	13	2	11
Jupiter	7	5	2
Korina	14	9	5
Lirama	3	15	-12
Perle	2	2	0
Semu 13/79	11	5	6
St 1/80a	10	10	0
Vigor	8	12	-4
Norli	5	13	-8
Rafal	9	7	2
Fiona	15	2	13
Ledark	4	5	-1
Lingot	1	16	-15
Valdor	6	11	-5

$$\Sigma x^2 = \frac{N^3 - N}{12} - \Sigma T = 340 \qquad \text{where } T = \frac{t^3 - t}{12}$$

$$\Sigma y^2 = 348$$

$$r_s = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma d^2}{2\sqrt{\Sigma x^2 \, \Sigma y^2}} = -0.29$$

$$t = r_s \sqrt{\frac{n - 2}{1 - r_s^2}} = 1.13$$

with 14 d.f., it is not significant

(a) Cultivars are ranked from least (1) to most (16) infected.

Appendix XVII : Continued.
(Text Table 24)

b) 1983

Cultivar	Sutton Scotney	Silwood Park	Cambridge	Rj
Elvira	6	9	16	31
Jet Neuf	16	15	11	42
Bienvenu	15	7.5	14	36.5
Korina	6	2	12	20
Norli	12.5	12.5	9	34
Rafal	12.5	7.5	13	33
Fiona	6	11.0	6	23
Lingot	6	10	15	31
Belinda	6	16	2	24
Lirabella	12.5	14	8	34.5
Pamela	3	6	5	14
Diander	12.5	4.5	10	27
Darmor	1.5	4.5	7	13
Chrysander	9.5	1	1	11.5
Tandem	1.5	3	3	7.5
Brittander	9.5	12.5	4	26
			ΣRj	408
			N	16
			$\frac{\Sigma Rj}{N}$	25.5

$$S = \Sigma \left(Rj - \frac{\Sigma Rj}{N} \right)^2 = 1580$$

$$\Sigma T = T_x + T_y + T_z$$

$$T_x = \frac{\Sigma(t^3 - t)}{12} = 16$$

$$T_y = 1.5$$

$$\Sigma T = 17.5$$

$$W = \frac{S}{\frac{1}{12} k^2 (N^3 - N) - k\Sigma T}$$

$$= \frac{1580}{\frac{1}{12} (3)^2 (16^3 - 16) - 3(17.5)}$$

$$= 0.52$$

d.f. = N - 1 = 15

$$\chi^2 = k(N - 1)W$$

$$\doteq 23.35$$

$\underline{P} < 0.1$

Appendix XVII : Continued.
(Text Table 24)

c) 1984

Cultivar	Sutton Scotney	Silwood Park	Cambridge	Rj
Jet Neuf	9	11	4	24
Bienvenu	16	5.5	14	35.5
Korina	14	15	15	44
Rafal	15	5.5	7	27.5
Fiona	4.5	11	8	23.5
Belinda	4.5	15	11	30.5
Lirabella	1.5	11	12	24.5
Pamela	3	5.5	6	14.5
Diander	12	5.5	16	33.5
Darmor	8	1.5	3	12.5
Carola	11	5.5	5	21.5
Mikado	7	5.5	1	13.5
Falk	10	1.5	13	24.5
Liradonna	13	15	9	37
Barbara	1.5	11	2	14.5
Jem	6	11	10	27
			ΣRj	408
$S = 1249$			$\frac{\Sigma Rj}{N}$	25.5

$t_x = 1$

$t_y = 120$

$\Sigma T = 121$

$$W = \frac{1249}{\frac{1}{12}(3)^2(16^3 - 16) - 3(120)} = 0.463$$

$\chi^2 = 20.84$ d.f. = 15

$\underline{P} < 0.20$

Appendix XVIII : Anovar from individual sites for the three years. (Text Table 25)

Cambridge

Factor	d.f.	SS	MS	F	
Cultivar	4	2.12	0.53	0.88	n.s.
Years	2	86.84	43.42	72.25	***
Error	8	4.81	0.61		
Total	14	93.77			

Sutton Scotney

Factor	d.f.	SS	MS	F	
Cultivar	4	4.44	1.11	1.22	n.s.
Years	2	66.96	33.48	36.87	***
Error	8	7.26	0.908		
Total	14	78.66			

Silwood Park

Factor	d.f.	SS	MS	F	
Cultivar	9	18.75	2.08	1.54	n.s.
Years	1	107.69	107.69	79.77	***
Error	9	12.18	1.35		
Total	19	138.63			

Appendix XIX (Text Table 26) : Test for an association between the years at each individual sites from ranking of cultivars.

A. Cambridge

Cultivar	1982	1983	1984	Rj
Jet Neuf	5	2	1	8
Fiona	1.5	1	3	5.5
Korina	4	3	5	12
Bienvenu	1.5	5	4	10.5
Rafal	3	4	2	9
				45

$S = 24.5$

$$W = \frac{24.5}{\frac{1}{12}(3)^2(5^3 - 5) - 3(0.5)} = 0.277$$

$\chi^2 = 3.32$ $\quad P < 0.7$

B. Sutton Scotney

Cultivar	1982	1983	1984	Rj
Jet Neuf	5	5	2	12
Fiona	4	1.5	1	6.5
Korina	3	1.5	3	7.5
Bienvenu	2	4	5	11
Rafal	1	3	4	8
				45

$S = 22.5$

$$W = \frac{22.5}{\frac{1}{12}(3)^2(5^3 - 5) - (3 \times 0.5)} = 0.254$$

$\chi^2 = 3.05$ $\quad P < 0.7$

Appendix XIX : Continued.
(Text Table 26)

C. Silwood

Cultivar	1983	1984	Difference in ranking
Jet Neuf	10	7	3
Fiona	8	7	1
Korina	1	10.5	-9.5
Bienvenu	6.5	3.5	3
Rafal	6.5	3.5	3
Belinda	11	10.5	0.5
Lirabella	9	7	2
Pamela	5	3.5	1.5
Diander	2.5	3.5	- 1
Darmor	2.5	1	1.5
Doral	4	9	-5

$\Sigma x^2 = 109$

$\Sigma y^2 = 80.5$

$$r_s = \frac{109 + 80.5 - 155}{2\sqrt{109 \times 80.5}} = 0.184$$

$$t = 0.184 \sqrt{\frac{9}{1 - (0.184)^2}} = 0.562$$

With 9 d.f., these are not significant

Appendix XX : Ascospore counts at Sutton Scotney 1982.
(Text Table 31)

Date (week ending)	Plot number Jet Neuf	Area of sellotape	Total number of ascospores	No. of ascospores/mm^2
17 May	12	230	693	3.01
	18	340	624	1.84
	46	210	531	2.53
	52	483	657	1.36
24 May	12	576	5721	9.93
	18	713	8564	12.01
	46	575	3501	6.09
	52	529	3460	6.54
1 June	12	528	4251	8.05
	18	624	3584	5.74
	46	552	3259	5.90
	52	480	3889	8.09
7 June	12	528	421	0.8
	18	520	326	0.63
	46	437	197	0.45
	52	468	405	0.87
14 June	12	560	2303	4.11
	18	500	3203	6.41
	46	400	2233	5.58
	52	525	3440	6.55

Appendix XXI (Text Table 36) : Anovar of the incidence of stem rot in winter oilseed rape cultivars at Sutton Scotney, 1982.

7 June (Blocks II and IV)

	d.f.	SS	MS	F	
Cultivar	15	3082.97	205.53	8.38	***
Block	1	281.02	281.02	11.46	**
Error	15	367.73	24.52		
Total	31	3731.72	120.38		

5 July (Blocks I, II, III and IV)

	d.f.	SS	MS	F	
Cultivar	15	3450.88	230.06	5.92	***
Block	3	616.45	205.48	5.29	**
Error	45	1748.44	38.85		
Total	63	5815.77			

Appendix XXII : Silwood 1983.
(Text Tables 50-52)

Cultivar	Petal		Petal cover x ascospores[b]		
	% Disease	Cover[a]	4 dates	3 dates	last 2 dates
Fiona	46	50	16.85	10.55	14.85
Belinda	90	47	21.49	15.19	20.55
Norli	60	14	5.35	3.25	4.95
Brittander	60	25	8.80	6.70	7.80
Lirabella	64	55	19.70	13.40	17.70
Pamela	34	19	8.20	6.10	7.80
Elvira	40	30	8.90	6.80	7.80
Bienvenu	38	25	8.80	6.70	7.80
Lingot	44	85	26.15	24.05	22.05
Diander	26	50	19.60	13.30	17.70
Doral	36	22	8.74	6.64	7.80
Darmor	26	19	7.45	3.25	7.05
Korina	12	45	15.50	13.40	13.50
Chrysander	10	50	12.90	8.70	9.90
Rafal	38	50	16.40	14.30	13.50
Tandem	18	22	8.74	6.64	7.80
Jet Neuf	70	125	36.90	30.60	29.10

[a] as total of %'s for 13, 18, 25 May and 3 June

[b] Proportion of petal cover x thousands of ascospores trapped on that date, accumulated over 4 dates or first 3 dates.

Appendix XXIII : Anovar for the comparison of the Sutton Scotney 1981-82 (Text Table 53) yield with other NIAB trials.

Seed Yield Regression Calculation

	d.f.	SS	MS	F	
Regression	1	464.58	464.58	25.10	***
Residuals	14	259.10	18.51		
Total	15	723.67			

Oil Yield Regression Calculation

	d.f.	SS	MS	F	
Regression	1	643.28	643.28	26.50	***
Residuals	14	339.90	24.28		
Total	15	983.17			

Appendix XXIV : Test for an association of disease incidence and yield at Sutton Scotney 1984.

Cultivar	Ranked means		
	Disease incidence		Yield
	Winter kill	June 27	
Bienvenu	6.5	16	3
Rafal	6.5	15	4
Carola	6.5	11	16
Darmor	6.5	8	15
Pamela	6.5	3	13
Mikado	16	7	1
Lirabella	14.5	1.5	6
Diander	6.5	12	14
Korina	6.5	14	12
Jet Neuf	6.5	9	5
Falk	6.5	10	9
Liradonna	6.5	13	8
Barbara	14.5	1.5	7
Fiona	6.5	4.5	10
Belinda	6.5	4.5	11
Jem	6.5	6	2

Winter kill

$$r_s = \left| - \frac{6 \times 736.8}{15 \times 16 \times 17} \right|$$

$= -0.08$ n.s.

June 27

$$r_s = \left| - \frac{6 \times 689}{15 \times 16 \times 17} \right|$$

$= -0.01$ n.s.

Appendix XXV : Effect of stem rot lesions on pod numbers in 1983 at Silwood.
(Text Table 55)

Cultivar	Healthy pod/branch					Infected pod/branch					Analysis of variance
Fiona	23.8	21.3	17.8	21.6	18.5	22.4	14.0	26.0	20.0	11.8	n.s.
Belinda	15.0	14.0	7.0	9.7	11.2	6.4	8.2	8.8	9.3	9.3	n.s.
Norli	14.7	18.5	14.8	21.3	15.3	9.0	23.0	15.5	11.3	11.2	n.s.
Brittander	36.0	16.0	26.0	19.2	3.3	12.7	18.6	17.4	14.6	17.3	n.s.
Lirabella	21.1	20.7	11.0	16.0	18.3	16.2	20.0	14.5	7.8	15.5	n.s.
Pamela	22.4	7.9	19.4	19.0	16.3	11.3	15.3	12.4	14.0	21.3	n.s.
Elvira	8.3	9.7	8.0	8.0	17.0	3.0	9.8	10.3	12.7	7.0	n.s.
Bienvenu	15.5	12.1	10.5	12.4	10.0	12.3	12.0	14.0	4.5	12.3	n.s.
Lingot	31.0	19.0	29.0	12.7	31.0	13.0	12.5	11.5	9.0	11.8	$\underline{P}$ = 0.01
Diander	15.5	14.8	12.0	12.3	13.1	11.6	23.7	11.5	9.7	4.8	n.s.
Doral	22.3	25.8	28.6	13.5	16.5	18.4	12.3	2.0	16.5	25.3	n.s.
Darmor	12.0	11.0	4.0	17.0	11.8	9.0	9.0	13.3	10.3	13.7	n.s.
Korina	37.2	32.2	31.3	30.0	27.2	9.8	31.7	28.7	15.8	11.4	$\underline{P}$ = 0.05
Chrysander	28.0	22.0	26.5	16.8	10.0	18.3	14.0	12.3	25.5	24.0	n.s.
Rafal	10.5	14.7	14.8	18.0	18.0	10.0	8.0	8.4	9.8	12.8	$\underline{P}$ = 0.01
Tandem	16.3	27.5	15.2	19.1	28.5	18.5	12.2	15.8	19.3	4.0	n.s.
Jet Neuf	39.0	11.6	7.8	9.7	16.0	14.0	7.0	3.7	11.7	7.0	n.s.

Appendix XXVI : Thousand seed weights, Silwood 1983.
(Text Table 57)

Cultivar	Healthy/infected	1	2	3	4	5
Belinda	H	6.231	6.100	5.922	5.949	6.077
	I	2.883	2.655	3.072	3.044	2.939
Diander	H	5.311	5.053	5.083	5.074	5.175
	I	4.115	4.03	4.008	3.742	3.81
Lingot	H	4.283	4.145	4.151	4.155	4.236
	I	3.257	3.102	3.24	3.22	3.374
Norli	H	4.855	4.053	4.005	4.054	4.182
	I	3.054	3.025	3.04	3.265	3.204
Chrysander	H	4.768	4.84	4.817	4.96	4.943
	I	4.531	4.511	4.578	4.70	4.529
Doral	H	4.837	4.65	4.739	4.827	4.878
	I	4.614	4.192	3.938	4.029	4.051
Pamela	H	5.219	5.397	5.08	5.163	4.12
	I	3.598	3.654	3.583	3.636	3.603
Lirabella	H	4.427	4.487	4.496	4.68	4.754
	I	3.723	3.685	3.792	3.66	3.581
Darmor	H	5.470	5.395	5.765	5.887	5.888
	I	3.996	4.015	3.963	4.421	4.967
Elvira	H	4.685	4.744	4.772	4.837	4.949
	I	3.31	3.185	3.174	3.168	3.311
Tandem	H	5.246	5.129	5.241	5.260	5.343
	I	3.658	3.577	3.737	3.873	4.12
Jet Neuf	H	5.845	6.042	6.064	6.132	6.268
	I	5.174	4.808	4.959	5.045	5.018
Fiona	H	4.602	4.656	4.630	4.571	4.606
	I	3.912	3.761	3.805	3.773	3.829
Bienvenu	H	4.228	4.109	4.149	4.178	4.216
	I	3.513	3.48	3.512	3.427	3.571
Korina	H	5.144	4.978	4.893	4.714	4.672
	I	4.318	4.261	4.179	4.075	4.001
Brittander	H	4.574	4.728	4.828	4.799	4.783
	I	3.919	3.968	4.093	4.074	4.127
Rafal	H	5.233	4.913	5.039	5.143	5.026
	I	2.992	2.777	3.074	4.506	4.828

Appendix XXVII : Lesion length on infected winter oilseed rape at Sutton Scotney, 1983.

Cultivar	Lesion length in mm					
	1	2	3	4	5	Mean
Pamela	295	233	151	301	255	247.0
Korina	492	291	262	244	320	321.8
Lirabella	408	287	182	184	360	284.2
Jet Neuf	175	300	386	205	205	254.2
Norli	240	165	250	301	265	244.2
Belinda	140	284	385	305	320	286.8
Brittander	374	420	310	274	210	317.6
Elvira	200	282	320	271	341	282.8
Rafal	230	410	270	181	356	289.4
Darmor	240	141	140	470	186	235.4
Fiona	260	339	110	280	220	241.8
Diander	310	220	182	354	194	252.0
Lingot	145	126	124	134	146	135.0
Bienvenu	240	352	265	232	226	263.0
Chrysander	395	216	172	325	298	281.2

Appendix XXVIII : Sutton Scotney 1981-84.

1. Investigation for an infection edge effect (1981-82)

In the trial 1981-82, an investigation was carried out to see if there was an edge effect in the infection of the cultivars in their 2 m wide plots. A one metre long portion selected at random within each Jet Neuf plot was assessed on 16 June 1982. The numbers of diseased and healthy plants down each row were counted. There were 10 rows in total and the percentage infection for each row was calculated.

Table A shows the results across the four blocks. An analysis of variance on arcsin $\sqrt{\%}$ transformed data was not significant for the rows of rape but it was for the blocks ($P = 0.01$). This reflected the actual disease incidence results over all cultivars in that Block 1 and 2 had a higher incidence of disease than 3 and 4. There was therefore no effect of plot width on the disease incidence recorded.

2. Disease incidence in an adjacent rape field to the trial (1981-82)

An assessment took place on 16 June 1982 in one of the fields of oilseed rape (cv. Jet Neuf) on the Four Counties Farm. The field was adjacent to the NIAB trial, seperated by an elder and hawthorn hedge and a tractor track (c. 3.5 m wide) that ran parallel to the hedge. The disease incidence was assessed going into the field away from the hedge two rows in from the tractor tram lines in the crop, assessing every plant for the presence/absence of a lesion. This was for the first 20 m. Thereafter the disease incidence was assessed in a one metre line every 10 m from the previous assessment.

Table B shows that the disease incidence generally decreased with distance from the hedgerow, the highest recording being in 1-2 m. There was not however a gradual decline with increasing distance, there were fluctuations from a lower to a higher incidence in adjacent positions of

Appendix XXVIII : Continued.

Table A : Results of the investigation into the presence/absence of an edge effect on plot disease incidence % (16 June 1982 Sutton Scotney).

Row	Blocks of Jet Neuf			
	1	2	3	4
1	81.3	60.0	60.0	46.2
2	42.1	64.3	23.1	33.3
3	81.8	58.3	10.0	28.6
4	53.9	50.0	66.7	18.8
5	66.7	80.0	20.0	60.0
6	66.7	56.3	62.5	25.0
7	61.5	58.3	57.1	33.3
8	50.0	75.0	40.0	41.7
9	71.4	46.7	54.6	7.1
10	84.6	75.0	50.0	42.9

Anovar on arcsin $\sqrt{\%}$

	d.f.	SS	MS	F	
Row	9	719.89	79.99	0.83	n.s.
Block	3	2694.0	898.0	9.31	***
Error	27	2603.0	96.41		
Total	39	6016.89			

	Mean		
Block 4	33.7	a	(a)
3	43.4	b	
2	62.4	c	
1	66.0	c	

(a) Means with no letter in common are significantly different at P = 0.05 Duncans Multiple Range Test.

Appendix XXVIII : Continued.

Table B : Disease incidence with increasing distance from the hedgerow of Sutton Scotney oilseed rape crop 1981-82 cv. Jet Neuf.

Distance from edge of field (m)	Number of healthy plants	Number of infected plants	% Disease incidence
0-1	12	3	20.0
1-2	8	11	57.9
2-3	5	3	37.5
3-4	7	3	30.0
4-5	12	3	20.0
5-6	11	1	8.3
6-7	5	3	37.5
7-8	13	2	13.3
8-9	16	5	23.8
9-10	16	3	15.8
10-11	17	3	15.0
11-12	18	7	28.0
12-13	15	1	6.3
13-14	19	5	20.8
14-15	27	0	0
15-16	17	1	5.6
16-17	11	4	26.7
17-18	14	1	6.7
18-19	6	7	53.9
19-20[(a)]	13	3	18.8
21-22	7	1	12.5
32-33	11	1	8.3
43-44	12	2	14.3
54-55	7	2	22.2
65-66	14	1	6.7
76-77	13	1	7.1
87-88	9	2	18.8
98-99[(b)]	12	0	0

(a) % incidence over first 20 m = 20.1%.

(b) % incidence generally up to 100 m = 11.8%

assessment. The overall pattern was one of groups of diseased plants and these could be seen by patches of brown racemes within the field.

Appendix XXIX : Burial experiment showing total number apothecia counted from 3 replicates - 1983.
(Text Table 83)

Code	9 April		14 April		22 April		27 April		4 May		10 May		14 May		18 May		26 May		31 May	
	NoN	N	NoN	N	NoN	N	NoN	N	NoN	N	NoN	N	NoN	N	NoN	N	NoN	N	NoN	N
1	1	-	7	1	38	2	47	18	132	68	150	92	106	100	61	56	40	56	-	18
2.	6	1	11	1	22	1	31	5	116	26	142	35	117	49	89	44	36	28	7	2
3	-	1	9	4	22	26	72	57	168	78	206	129	157	138	144	89	22	38	3	-
4	6	3	13	5	13	12	26	14	49	40	75	67	78	89	64	36	20	7	6	29
5	59	15	68	16	79	37	128	53	188	127	211	102	191	125	101	121	24	63	2	4
6	6	-	6	1	9	2	18	4	45	19	53	37	68	40	63	41	43	35	8	4
7	5	-	16	2	26	8	46	44	99	119	91	138	89	138	58	71	29	44	-	-
8	-	-	6	-	10	5	23	2	45	12	61	30	73	65	24	78	48	66	6	35
9	13	-	14	-	34	3	57	5	106	44	135	80	126	71	112	51	8	25	-	-
10	-	-	-	-	8	1	10	20	43	5	52	11	45	9	59	67	21	13	4	11
11	2	-	2	-	8	-	41	13	76	53	75	51	90	71	41	54	15	14	-	-
12	3	2	4	2	5	9	17	15	35	32	58	38	48	39	76	38	35	30	-	12
13	-	-	7	-	5	-	8	6	35	33	36	65	45	84	42	44	26	30	3	4
14	1	-	2	-	2	6	4	12	6	9	7	11	9	69	47	11	8	6	7	3
15	2	-	3	1	14	13	15	21	36	59	37	74	36	73	18	87	18	12	-	-
16	6	-	2	-	4	-	5	-	13	26	15	6	20	6	24	42	18	5	-	2
17	-	-	-	-	-	-	-	-	6	5	8	15	10	10	13	54	13	20	-	-
18	8	-	-	-	-	1	5	6	8	15	9	2	12	2	11	71	24	38	1	1
19	1	-	5	-	5	-	23	4	36	11	43	13	40	10	36	24	12	24	1	2
20	-	2	-	2	3	1	6	1	8	4	9	22	10	15	27	39	24	11	1	2
21	12	-	16	-	51	-	86	20	151	98	170	127	139	166	97	109	30	73	5	9
22	-	1	1	-	5	2	6	7	28	22	83	38	101	62	85	62	57	75	24	22
23	6	-	9	3	14	15	30	30	71	104	80	124	79	125	49	98	25	19	-	-
24	11	-	24	-	28	-	32	7	82	68	103	55	126	62	120	81	44	55	1	2
Total	148	25	225	38	395	144	726	365	1622	1077	1909	1352	1818	1608	1463	1466	660	797	79	162
Total	173		263		539		1091		2699		3261		3426		2929		1457		241	

Appendix XXX : Test for the effect of nitrogen on production of apothecia. (Text Table 86)

Date	Total no. of apothecia in treatments with		Relative advantage of no. nitrogen (x)
	No. nitrogen	Nitrogen	
April 9	148	25	123
14	225	38	187
22	395	144	251
27	726	365	361
May 4	1622	1077	545
10	1909	1352	557
14	1818	1608	210
18	1463	1466	- 3
26	660	797	-137
31	79	162	- 83
			2011

$\bar{x} = 2011$

$$S^2 = \frac{1}{n-1}\left[\Sigma x^2 - \frac{1}{n}(\Sigma x)^2\right]$$

$$= \frac{1}{9}(920461 - 404412.1)$$

$$= 57338.77$$

$$\frac{S}{\sqrt{n}} = \frac{239.46}{\sqrt{10}} = 75.72$$

$$t = \frac{\bar{x} - u}{S/\sqrt{n}} = 26.56 \quad ***$$

Appendix XXXI : Recovery of sclerotia in 1984 from Experiment 1, set up in 1983.

Treatment No.	Replicate			Total
	1	2	3	
1	-	9	1	10
2	2	8	2	12
3	2	-	1	3
4	9	7	2	18
5	2	2	3	7
6	4	18	6	28
7	10	8	14	32
8	14	7	27	48
9	-	-	6	6
10	23	12	17	52
11	12	10	26	48
12	31	30	19	80
13	28	26	14	68
14	16	21	23	60
15	28	23	16	67
16	28	18	23	69
17	36	14	30	80
18	32	23	6	61
19	32	33	22	87
20	23	28	23	72
21	1	-	2	3
22	-	-	1	1
23	-	1	2	3
24	3	3	2	8

Appendix XXXII : Burkard spore trap Silwood 1982-83.

Rate	Mid night	1	2	3	4	5	6	7	8	9	10	11	Mid day	13	14	15	16	17	18	19	20	21	22	23
Sat. 23.4												–	–	–	–	–	–	–	–	–	–	–	–	–
Sun. 24.4	–	–	–	–	–	–	–	–	–	–	33	–	–	–	–	–	–	–	–	–	–	–	–	–
Mon. 25.4	–	–	–	–	–	–	–	–	–	–	297	297	462	396	264	165	66	–	–	–	–	–	–	–
Tues. 26.4	–	–	99	–	–	–	–	–	–	66	132	132	297	330	363	66	–	–	–	–	–	–	–	–
Wed. 27.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Thurs. 28.4	–	–	–	–	–	–	–	–	–	–	–	–	–	66	528	363	231	198	–	–	–	–	–	–
Fri. 29.4	–	–	–	–	–	–	–	–	–	–	264	330	528	363	462	330	297	264	99	–	–	–	–	–
Sat. 30.4	–	–	–	–	–	–	–	–	–	–	–	–	–	132	726	693	396	–	99	99	–	–	–	–
Sun. 1.5	–	–	–	–	–	–	–	–	–	–	99	132	561	627	792	594	231	66	–	–	–	–	–	–
Mon. 2.5	–	–	–	–	264	–	–	–	–	66	231	297	528	429	627	627	462	132	132	–	–	–	–	–
Tues. 3.5	–	–	–	–	–	–	–	–	–	–	231	264	396	363	825	1056	627	264	165	99	–	–	–	–
Wed. 4.5	–	–	–	–	–	–	–	–	–	–	–	99	264	660	693	627	66	165	330	132	–	–	–	–
Thurs. 5.5	–	–	–	–	–	–	–	–	–	–	–	–	33	132	132	33	33	33	–	–	–	–	–	–
Fri. 6.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sat. 7.5	–	–	–	–	–	–	–	–	–	–	–	–	165	231	264	66	33	–	–	–	–	–	–	–
Sun. 8.5	–	–	–	–	–	–	–	–	–	–	330	231	231	825	1980	1023	495	330	66	–	–	–	–	–
Mon. 9.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	33	–	–	–	–	–	–	–	–	–
Tues. 10.5	–	–	–	–	–	–	–	–	–	–	99	198	–	330	1089	1155	396	924	99	132	–	–	–	–
Wed. 11.5	231	132	66	–	–	–	–	–	–	–	132	627	660	693	693	594	396	99	66	–	–	–	–	–
Thurs. 12.5	–	–	–	–	–	–	–	–	–	–	33	33	99	330	330	231	66	–	–	–	–	–	–	–
Fri. 13.5	–	–	–	–	–	–	–	–	–	–	165	561	363	396	66	–	–	–	–	–	–	–	–	–
Sat. 14.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sun. 15.5	–	–	–	–	–	–	–	–	–	–	–	–	–	66	99	33	–	–	–	–	–	–	–	–
Mon. 16.5	–	–	–	–	–	–	–	–	–	66	66	132	231	132	165	33	–	–	–	–	–	66	–	–
Tues. 17.5	–	–	–	–	–	–	–	–	–	–	99	132	132	165	231	–	–	–	–	–	–	–	–	–
Wed. 18.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	231	–	–	–
Thurs. 19.5	–	–	–	–	–	–	–	–	–	–	264	330	396	462	528	264	132	66	66	–	33	–	–	–

Appendix XXXII : Continued.

Rate	Mid night	1	2	3	4	5	6	7	8	9	10	11	Mid day	13	14	15	16	17	18	19	20	21	22	23
Fri. 20.5	-	132	33	-	-	-	-	-	-	-	66	363	1386	396	561	693	528	363	594	396	165	-	-	-
Sat. 21.5	-	-	-	-	-	-	-	-	-	-	66	297	462	132	429	99	66	-	-	-	-	-	-	-
Sun. 22.5	-	-	-	-	-	-	-	-	-	132	231	363	1947	2904	5874	3036	1155	1089	594	330	-	-	-	-
Mon. 23.5	-	-	-	-	-	-	-	-	-	-	396	462	495	3927	6468	4422	1221	462	99	66	-	-	-	-
Tues. 24.5	-	-	-	-	-	-	-	-	-	-	-	198	2475	2871	2706	2046	957	132	-	-	-	-	-	-
Wed. 25.5	-	-	-	-	-	-	-	-	-	-	132	297	264	297	330	132	66	-	-	-	-	-	-	-
Thurs. 26.5	-	-	-	-	-	-	-	-	-	-	165	297	297	330	330	231	33	-	-	-	-	-	-	-
Fri. 27.5	-	-	-	-	-	-	-	-	-	-	-	66	66	66	66	66	33	-	-	-	-	-	-	-
Sat. 28.5	-	-	-	-	-	-	198	66	-	-	-	99	-	-	-	-	-	-	-	-	-	-	-	-
Sun. 29.5	-	-	-	-	-	-	-	-	-	-	99	165	1980	3267	3366	231	-	-	-	-	-	-	-	-
Mon. 30.5	-	-	-	-	-	-	-	-	-	-	33	66	2277	2046	1650	396	-	-	-	-	-	-	-	-
Tues. 31.5	-	-	-	-	-	-	66	-	-	264	330	924	726	462	495	66	66	-	-	-	-	-	-	-
Wed. 1.6	-	-	99	-	-	-	-	-	-	-	66	99	330	396	627	66	33	-	-	-	-	-	-	-
Thurs. 2.6	-	-	-	-	-	-	-	-	-	-	-	-	66	66	66	33	-	-	-	-	-	-	-	-
Fri. 3.6	-	-	-	-	-	-	-	-	-	-	-	396	1485	1452	132	-	-	-	-	-	-	-	-	-
Sat. 4.6	-	-	-	-	-	-	462	660	660	660	696	957	1254	1386	759	-	-	-	-	-	-	-	-	-
Sun. 5.6	-	-	-	-	-	-	-	-	-	-	-	99	925	1221	1254	627	132	-	-	-	-	-	-	-
Mon. 6.6	-	-	-	-	-	-	-	264	693	330	792	627	792	858	957	330	264	132	-	-	-	-	-	-
Tues. 7.6	-	-	-	-	-	-	-	-	-	-	66	33	462	957	1584	2475	2046	627	330	66	-	-	-	-
Wed. 8.6	-	-	-	-	-	-	-	-	-	-	132	297	330	726	792	297	66	-	-	-	-	-	-	-
Thurs. 9.6	-	-	-	-	-	-	-	462	957	1122	1188	1386	1815	2046	2277	1980	1716	1023	627	66	33	-	-	-
Fri. 10.6	-	-	-	-	-	-	-	-	132	297	193	495	660	693	726	330	165	-	-	-	-	-	-	-
Sat. 11.6	-	-	-	-	-	-	-	-	-	-	-	66	66	99	132	33	-	-	-	-	-	-	-	-
Sun. 12.6	-	-	-	-	-	-	-	-	-	-	-	-	132	198	330	66	-	-	-	-	-	-	-	-
Mon. 13.6	-	-	-	-	-	-	-	-	-	-	-	-	132	132	297	429	396	330	-	-	-	-	-	-
Tues. 14.6	-	-	-	-	-	-	-	-	-	-	-	132	165	198	198	132	-	-	-	-	-	-	-	-
Wed. 15.6	-	-	-	-	-	-	-	-	-	-	-	-	132	330	462	693	330	132	-	-	-	-	-	-

Appendix XXXII : Continued.

Rate	Mid night	1	2	3	4	5	6	7	8	9	10	11	Mid day	13	14	15	16	17	18	19	20	21	22	23
Thurs. 16.6	-	-	-	-	-	-	-	-	-	-	264	330	2211	3861	2244	1782	627	-	-	-	-	-	-	-
Fri. 17.6	-	-	-	-	-	-	-	-	-	-	-	990	3828	4356	4785	2046	330	66	-	-	-	-	-	-
Sat. 18.6	-	-	-	-	-	-	-	-	-	-	693	792	627	330	528	792	990	363	132	99	-	-	-	-
Sun. 19.6	-	-	-	-	-	-	-	-	-	330	-	462	891	990	1023	627	330	66	-	-	-	-	-	-
Mon. 20.6	-	-	-	-	-	-	-	-	-	363	561	759	1056	1089	330	264	132	33	-	-	-	-	-	-
Tues. 21.6	-	-	-	-	-	-	-	-	-	-	-	1320	2475	363	1518	1254	-	-	-	-	-	-	-	-
Wed. 22.6	-	-	-	-	-	-	-	-	-	-	-	-	330	957	1221	990	330	264	66	-	-	-	-	-
Thurs. 23.6	-	-	-	-	-	-	-	-	-	627	924	1221	6930	1221	2244	990	264	132	33	-	-	-	-	-
Fri. 24.6	-	-	-	-	-	-	-	-	-	-	66	132	1089	1056	1221	1056	990	66	-	-	-	-	-	-
Sat. 25.6	-	-	-	-	-	-	-	-	-	165	3036	3102	4356	5445	5610	3300	2508	1056	330	-	-	-	-	-
Sun. 26.6	-	-	-	-	-	-	-	-	-	-	363	462	693	1122	1518	330	264	198	66	-	-	-	-	-
Mon. 27.6	-	-	-	-	-	-	-	-	-	-	-	33	132	198	165	99	33	-	-	-	-	-	-	-
Tues. 28.6	-	-	-	-	-	-	-	-	-	-	66	132	132	99	33	-	-	-	-	-	-	-	-	-
Wed. 29.6	-	-	-	-	-	-	-	-	-	-	33	165	198	132	66	-	-	-	-	-	-	-	-	-
Thurs. 30.6	-	-	-	-	-	-	-	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	-	-
Fri. 1.7	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-	-	-	-
Sat. 2.7	-	-	-	-	-	-	-	-	-	-	33	33	-	66	-	-	-	-	-	-	-	-	-	-
Sun. 3.7	-	-	-	-	-	-	-	-	-	-	66	99	132	165	198	33	-	-	-	-	-	-	-	-
Mon. 4.7	-	-	-	-	-	-	-	-	-	-	33	132	132	297	396	132	33	-	-	-	-	-	-	-
Tues. 5.7	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-	-	-	-
Wed. 6.7	-	-	-	-	-	-	-	-	-	-	33	132	198	462	957	264	33	-	-	-	-	-	-	-
Thurs. 7.7	-	-	-	-	-	-	-	-	-	165	627	924	1320	1815	2046	1980	627	33	-	-	-	-	-	-
Fri. 8.7	-	-	-	-	-	-	-	-	-	924	1221	1221	1089	2244	1221	1056	330	-	-	-	-	-	-	-
Sat. 9.7	-	-	-	-	-	-	-	-	-	-	330	693	2475	2244	1023	990	132	-	-	-	-	-	-	-
Sun. 10.7	-	-	-	-	-	-	-	-	-	-	-	99	165	297	330	66	-	-	-	-	-	-	-	-
Mon. 11.7	-	-	-	-	-	-	-	-	-	-	-	-	-	66	33	-	-	-	-	-	-	-	-	-
Tues. 12.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-	-
Wed. 13.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66	-	-	-	-	-	-	-	-	-

Appendix XXXIII : Burkard 1983-84 Silwood Park.

Date	1	2	3	4	5	6	7	8	9	10	11	Mid day	13	14	15	16	17	18	19	20	21	22	23	24
23.4																33	-	-	33	-	-	-	33	198
24.4	132	-	-	-	-	-	297	-	-	-	-	-	-	-	-	66	-	-	-	-	-	-	-	-
25.4	33	33	-	-	-	-	-	-	-	33	-	-	66	66	-	-	66	-	-	-	-	66	-	-
26.4	-	33	-	-	-	-	-	33	-	33	99	33	-	-	66	198	33	231	-	-	-	-	-	66
27.4	-	-	-	-	99	132	-	-	-	-	-	33	132	132	99	-	-	99	-	-	-	-	-	-
28.4	-	-	-	-	-	-	-	-	-	-	-	-	132	99	33	-	33	-	-	-	-	-	-	-
29.4	-	-	-	-	-	-	-	-	-	-	33	99	66	66	132	-	-	-	-	-	-	-	-	-
30.4	-	132	-	-	-	66	-	-	-	-	-	-	66	-	-	B	B	B	B	B	B	B	B	B
1.5	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B*	66	-	-	165	66	-	-	-
2.5	-	165	-	-	-	66	-	-	-	-	-	-	33	66	66	-	66	132	-	-	-	-	-	-
3.5	-	-	-	-	-	-	-	-	-	-	66	-	231	66	-	-*	-	-	-	-	-	-	-	231
4.5	-	-	-	-	-	-	-	-	-	-	-	231	1320	594	429	99	33	-	132	33	-	-	-	-
5.5	132	33	66	-	-	-	-	132	132	561	858	699	528	429	297	330	231	66	33	-	-	-	-	99
6.5	-	-	198	-	-	-	-	99	-	-	-	-	132	198	33	-	-	132	231	-	-	-	-	66
7.5	-	-	-	-	-	-	132	231	561	594	660	726	1122	957	132	99	198	132	33	-	-	-	33	-
8.5	-	-	-	-	-	-	-	-	-	-	-	-	132	165	33	33	-	-	-	-	-	-	-	-
9.5	-	-	-	-	-	-	-	-	-	-	-	-	-	66	99	66	33	-	-	-	-	-	-	-
10.5	-	-	99	-	-	-	-	-	-	-	-	-	33	132	99	132	66	-	-	-	-	-	-	-
11.5	-	-	-	-	-	-	-	-	33	-	-	66	165	264	363	330	99	132	33	-	-	-	-	-
12.5	-	-	-	-	-	132	-	-	-	66	66	132	132	99	699	1320	396	231	-	-	-	-	-	-
13.5	-	-	-	-	-	-	-	165	297	132	132	297	495	726	891	627	297	66	33	-	-	-	-	-
14.5	-	-	-	-	-	-	-	-	-	-	-	66	66	132	33	33	33	-	-	-	-	-	-	-
15.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-	-	-
16.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17.5	-	-	-	-	-	-	-	-	-	-	-	-	330	396	231	165	132	495	330	66	-	-	-	-
18.5	-	-	-	-	-	-	-	-	-	-	-	99	231	231	231	231	264	132	132	-	-	-	-	-
19.5	-	-	-	-	-	-	-	-	-	-	-	-	66	99	33	-	-	-	-	-	-	-	-	-
20.5	-	-	-	-	-	-	-	-	-	-	-	-	132	198	-	-	-	-	-	-	-	-	-	-

Appendix XXXIII : Continued.

Date	1	2	3	4	5	6	7	8	9	10	11	Mid day	13	14	15	16	17	18	19	20	21	22	23	24
21.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22.5	-	-	-	-	-	-	-	-	-	-	-	66	231	363	198	66	-	-	-	-	-	-	-	-
23.5	-	-	-	-	-	-	-	-	-	-	33	132	264	462	297	132	99	66	-	-	-	-	-	-
24.5	-	-	-	-	-	-	-	-	-	-	33	33	231	264	132	132	165	132	66	-	-	-	-	-
25.5	-	-	-	-	-	-	-	-	-	-	-	66	132	297	66	66	132	-	-	-	-	-	-	-
26.5	-	-	-	-	-	-	-	-	-	-	-	-	66	66	33	-	-	-	-	-	-	-	-	-
27.5	-	-	-	-	-	-	-	-	-	-	-	-	33	33	33	-	-	-	-	-	-	-	-	-
28.5	-	-	-	-	-	-	-	-	-	-	-	198	264	330	132	-	-	-	-	-	-	-	-	-
29.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	99	99	-	-	-	-	-	-	-	-
30.5	-	-	-	-	-	-	-	-	-	-	99	165	231	264	132	132	99	-	-	-	-	-	-	-
31.5	-	-	-	-	-	-	-	-	-	-	-	33	33	33	-	-	-	-	-	-	-	-	-	-
1.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.6	-	-	-	-	-	-	-	-	-	-	-	330	462	528	396	297	66	33	-	-	-	-	-	-
3.6	-	-	-	-	-	231	-	198	-	231	297	363	528	726	363	165	33	-	-	-	-	-	-	-
4.6	-	-	-	-	-	-	-	-	-	-	-	33	66	33	-	-	-	-	-	-	-	-	-	-
5.6	-	-	-	-	-	-	-	-	-	-	-	-	33	33	-	-	-	-	-	-	-	-	-	-
6.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7.6	-	-	-	-	-	-	-	-	-	-	-	-	66	66	-	-	-	-	-	-	-	-	-	-
8.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14.6	-	-	-	-	-	-	-	-	-	-	-	-	33	33	132	66	-	-	-	-	-	-	-	-
15.6	-	-	-	-	-	-	-	-	-	-	-	-	33	66	-	-	-	-	-	-	-	-	-	-
16.6	-	-	-	-	-	-	-	-	-	-	-	198	132	132	66	-	-	-	-	-	-	-	-	-
17.6	-	-	-	-	-	-	-	-	-	-	-	66	99	66	33	-	-	-	-	-	-	-	-	-

Appendix XXXIII : Continued.

Date	1	2	3	4	5	6	7	8	9	10	11	Mid day	13	14	15	16	17	18	19	20	21	22	23	24
18.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

B = Burkard broken.

* = Battery operated Burkard.

Appendix XXXIV : Petal experiment on Jet Neuf.
(Text Table 99)

Inoculum bag	Petals removed						Petals left naturally					
												30 May
1	x	x	x	x	x		x	x	x	✓	✓	
2	x	✓	x	x	x		x	x	✓	✓	✓	
3	x	x	x	x	x		✓	✓	x	x	x	
4	x	x	x	x	x		x	x	x	x	x	
5	x	x	x	x	x		✓	✓	x	x	x	
6	x	x	x	x	x		x	x	✓	x	x	
7	x	x	x	x	x		x	x	x	x	x	
8	x	x	x	x	x		x	x	x	✓	x	
9	x	x	x	x	x		x	x	x	x	x	
10	x	x	x	x	x		x	x	x	x	x	
11	x	x	x	x	x		x	x	✓	✓	x	
12	x	x	x	x	x		x	x	✓	✓	x	
						2%						25%
												16 July
1	x	x	x	x	x		x	x	x	✓	✓	
2	x	✓	x	x	x		x	x	✓	✓	✓	
3	x	x	x	x	x		✓	✓	✓	✓	x	
4	x	x	x	x	x		x	x	x	x	✓	
5	x	x	x	x	x		✓	✓	✓	✓	x	
6	x	x	x	x	x		✓	✓	x	x	✓	
7	x	x	x	x	x		x	x	✓	✓	x	
8	x	x	x	x	x		✓	x	✓	x	✓	
9	x	x	x	x	x		x	✓	✓	✓	✓	
10	x	x	x	x	x		✓	✓	x	✓	x	
11	x	x	x	✓	x		✓	x	x	✓	✓	
12	x	x	x	x	x		✓	✓	✓	✓	✓	
						3%						67%

x No lesion.

✓ Lesion present

Appendix XXXV (Text Table 100) : Analysis on harvest yield from petal experiment Silwood 1982-83.

(Method of paired observations)

Plant position	A Infected	B Uninfected	Relative advantage of B
1	4.419	8.347	+ 4.198
2	1.641	5.035	+ 3.394
3	8.363	10.224	+ 1.861
4	5.309	7.686	+ 2.377
5	1.388	4.469	+ 3.081
6	8.110	9.017	+ 0.907
7	6.244	12.041	+ 5.797
8	4.430	4.853	+ 0.423
9	10.077	16.712	+ 6.635
10	3.09	12.341	+ 9.251
11	0.778	11.679	+ 10.901
12	3.203	14.842	+ 11.639
Σx	56.78	117.246	60.464
$\bar{x}$	4.73	9.47	5.039

$$S^2 = \frac{1}{n-1}\left[\Sigma x^2 - \frac{1}{n}(\Sigma x)^2\right] = \frac{1}{11}(466.26 - 304.66) = 14.69$$

$$\frac{S}{\sqrt{n}} = 1.106$$

$$t = \frac{x - \mu}{S/\sqrt{n}} = \frac{5.039 - 0.0}{1.106} = 4.56$$

With 11 d.f., P = 0.001

Appendix XXXVI : Detail of apothecial production in the density trial 1983-84.
(Text Table 106)

Inoculum density	Rep.	Date of assessment 1984											
		12.5		19.5		28.5		2.6		6.6		11.6	
			Total		Total		Total		Total		Total		Total
2	1	4		5		5		1		-		-	
	2	-		-		1		1		1		-	
	3	-	4	-	5	-	13	-	8	19	20	1	1
	4	-		-		7		6		-		-	
	5	-		-		-		-		-		-	
5	1	-		-		3		5		3		-	
	2	-		9		9		7		-		1	
	3	-		-	9	-	14	7	22	5	10	-	1
	4	-		-		2		3		2		-	
	5	-		-		-		-		-		-	
10	1	-		-		-		-		-		-	
	2	-		-		-		-		-		-	
	3	-		6	6	51	67	62	75	48	59	5	14
	4	-		-		10		8		3		-	
	5	-		-		6		5		8		9	
20	1	-		-		10		15		14		-	
	2	-		-		13		17		6		1	
	3	-		-		84	128	87	137	69	94	4	5
	4	-		-		7		6		3		-	
	5	-		-		14		12		2		-	

Appendix XXXVII : Ascospores trapped in the inoculum density trial 1984. (Text Table 107)

Position of spore trap	No. of ascospores trapped week ending								Total no.
	April	May				June			
	30	7	14	21	28	4	11	18	
1	-	-	14	7	1	25	5	-	52
2	-	-	7	20	12	5	1	-	45
3	1	12	3	6	4	22	8	-	56
4	3	6	7	4	30	7	2	-	59
5	-	-	2	7	6	1	1	-	17
6	-	-	14	7	8	8	7	-	44
7	6	-	7	5	5	3	4	-	24
8	5	3	3	2	10	-	-	-	23
9	3	2	2	2	4	16	7	-	36
10	2	-	-	2	46	5	2	-	57
11	-	-	6	24	20	13	4	-	67
12	-	1	-	2	14	10	7	-	34
13	2	2	3	2	4	19	10	1	43
14	6	7	22	23	5	2	1	-	66
15	10	-	1	3	7	19	2	-	42
16	2	-	-	7	8	-	2	-	19
17	1	-	-	-	-	-	-	-	1
18	-	2	7	2	11	4	5	-	31
19	-	1	1	19	25	11	2	-	59
20	-	-	2	4	13	16	2	-	37
21	-	-	3	11	21	8	4	-	47
22	3	4	10	4	9	6	-	-	36
23	-	1	2	2	13	36	9	-	63
24	-	-	3	11	15	1	-	-	30
25	2	-	2	7	28	24	3	-	66
A	1	-	6	10	20	18	26	-	81
B	-	8	-	2	13	26	4	-	53
C	5	5	5	1	-	2	2	-	20
D	2	3	8	6	1	9	2	-	31
E	1	5	1	4	8	5	3	-	27
F	-	7	6	3	10	18	3	-	47
G	1	18	7	5	2	17	5	-	55
H	2	7	4	5	6	8	2	-	34

Appendix XXXVIII : Analysis of variance on disease incidence (arcsin $\sqrt{\%}$)

Disease incidence in the density trial

1. 1.16	2. 2.78	3. 6.67	4. 7.22	5. 8.86
6. 1.22	7. 3.23	8. 0	9. 10.26	10. 10.0
11. 0	12. 6.94	13. 9.52	14. 7.23	15. 7.29
16. 1.41	17. 1.22	18. 4.05	19. 1.09	20. 13.58
21. 2.44	22. 0	23. 1.56	24. 2.41	25. 1.12

Sclerotia density	% disease
0	1.91
2	5.3
5	5.12
10	4.06
20	5.81

	d.f.	SS	MS	F		
Rows	4	16.66	4.17	1.57	n.s.	
Columns	4	35.06	8.76	3.31	0.05	**
Treatment	4	21.79	5.45	2.06	n.s.	
Error	12	31.77	2.65			
Total	24	105.28				

Appendix XXXIX : Survival of sclerotia from density trial 1984.

Survival of sclerotia from density trial 1984

1. 0	2. 2	3. 3	4. 9	5. 17
6. 10	7. 7	8. 0	9. 20	10. 2
11. 5	12. 15	13. 18	14. 2	15. 0
16. 15	17. 9	18. 1	19. 0	20. 6
21. 2	22. 0	23. 16	24. 5	25. 16

Anovar on $\sqrt{x + 0.5}$ transformed data

	d.f.	SS	MS	F		
Rows	4	0.44	0.11	0.8	n.s.	
Columns	4	0.19	0.05	0.4	n.s.	
Treatments	4	39.79	9.95	79.89	***	P = 0.01
Error	12	1.49	0.13			
Total	24	41.92				

Sclerotia density

	Total	Mean	Duncans Multiple Range (5%)
0	0	0	a
2	9	1.8	b
5	26	5.2	c
10	62	12.4	d
20	83	16.6	e

Appendix XXXX : Association of ascospores with pollen, Silwood 1984.

On viewing rod spore trap slides in 1982 and 1983 an association was seen between pollen grains and ascospores adhering to them (Plate A). In 1984 during flowering (G.S. 4.2) the heads of 5 plants in each cultivar plot were shaken over sterile microscope slides in petri dishes. The collection took place at 5 p.m. on 18 May 1984 from the centre of each plot. In the laboratory, lactophenol was placed on the slide and then viewed under the light microscope using the blue filter. The pollen was assessed for the presence or absence of adhering ascospores in 3 traverses across each slide (64 mm long).

Secondly, 10 plants in each cultivar randomly throughout the plot were shaken over 2 plates of GAY. This took place on 23 May at 4 p.m., and any petals adhering were left. The plates were then incubated at 15°C and checked for growth after a couple of days, of *Sclerotinia*.

Table A shows that the incidence of association was low varying from 0.7% (Diander) to 7.3% (Mikado) and although an analysis of variance was significant ($P \lesssim 0.001$), the results could be obtained by chance contamination.

After 4 days incubation, mycelium of *Sclerotinia* was detected on most plates along with some immature sclerotia (Table B). After 8 days mature sclerotia had formed and only plates shaken under Falk and Jem had no mycelium.

Plate A : Silwood Park, 1984: Ascospore adhering to a pollen grain from cultivar Bienvenu x600.

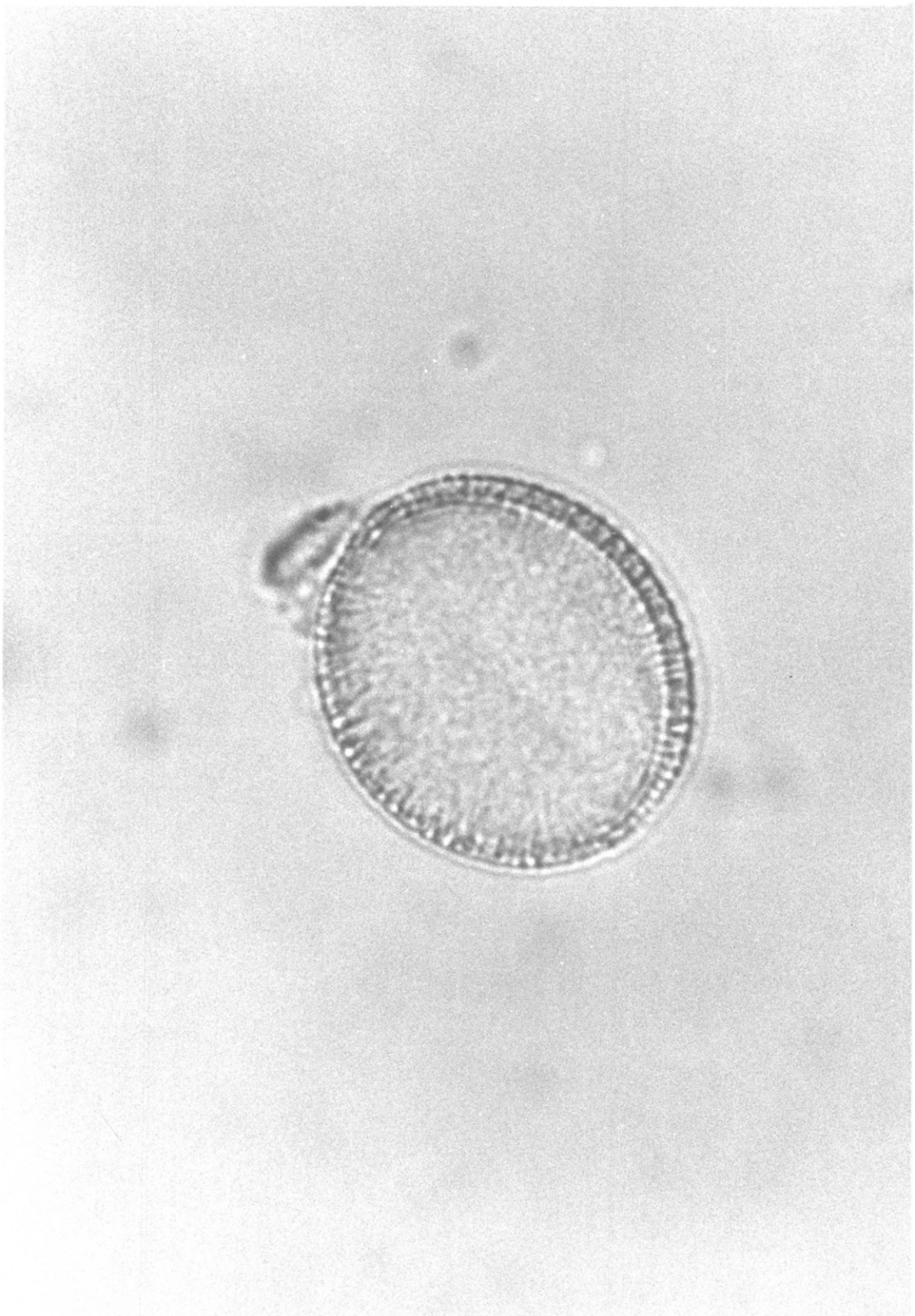


Table A : Association of ascospores with pollen, Silwood 1984.

Cultivar	Traverse across slide						Mean % with ascospores
	Top		Middle		Bottom		
	-	+	-	+	-	+	
Diander	406	1	365	4	268	3	0.7
Doral	253	3	378	6	309	4	1.4
Liradonna	262	4	145	3	249	2	1.4
Jem	202	3	160	1	242	4	1.3
Belinda	155	2	305	1	273	2	0.7
Korina	156	2	296	14	150	8	3.8
Bienvenu	238	8	105	5	100	4	3.7
Rafal	80	1	128	2	48	1	1.5
Fiona	199	4	228	3	82	2	1.7
Falk	406	5	308	4	235	3	1.3
Lirabella	90	3	230	4	216	6	2.4
Mikado	52	6	55	2	32	3	7.3
Carola	153	3	190	4	25	1	2.1
Pamela	86	2	38	2	21	1	3.3
Barbara	39	2	106	4	74	2	3.5
Darmor	303	6	199	2	137	3	1.4
Jet Neuf	81	5	92	3	143	6	4.2

Table B : Cultures obtained from the cultivar.

Flower heads shaken over GAY plates on 23.5

Cultivars	Assessment date			
	29.5		1.6	
	Plate 1	Plate 2	Plate 1	Plate 2
Diander	x	x	(3)G	(7)A
Doral	(2)A	x	(4)2	(3)G
Liradonna	(4)G	x	4	x
Jem	x	x	x	x
Belinda	x	x	(8)G	(2)G
Korina	(2)A	x	(2)2	(6)S
Bienvenu	(2)G	x	(2)1	(1)G
Rafal	(1)P	(1)P	(3)1	(1)2
Fiona	x	x	(9)A	(5)A
Falk	x	x	x	x
Lirabella	(3)A	x	(9)	(6)G
Mikado	(1)P	(2)A	(3)1	(2)1
Carola	(1)S	(1)P, (3)A	(1)5	(1)5
Pamela	(1)A	(1)P	(1)4	(4)
Barbara	x	x	(6)G	(4)P
Darmor	x	(2)A	x	(2)4
Jet Neuf	(3)P	x	(3)5	(5)A

(1) No sclerotia forming - still immature

1 No sclerotia formed - mature

P = Petal
A = Anther
G = Pollen grain
S = Sepal

} Source of mycelium

Appendix XXXXI : Development of an inoculation technique using ascospores from isolate JN1.

Ascospores were collected dry on millipore filters (Section 1, p. 52) and resuspended in sterile distilled water to give 2 x 10^3 spores/ml. Three experiments were carried out using this suspension.

Experiment 1

Droplets of varying size (0.01, 0.05 and 0.1 cm^3) were placed onto agar disks (252 per droplet) using an Agla Precision Micometer Syringe. The disks (5 mm in diameter) of water agar, water agar plus 2% glucose or GAY sat on microscope slides in humid plastic boxes. Half (42/droplet) were allowed to dry out on the disks while the rest were kept in a damp chamber. 21 disks per droplet size were then incubated for 4 hours at room temperature (22 ± 2°C) and 21 were placed directly onto excised rape stems of c 5 cm in length from 20 week old plants of cv. Jet Neuf (after surface sterilisation and two washings in sterile distilled water).

Three replicate stems from the above were then incubated in the following ways:

i) vertically in water agar in 250 ml flasks.

ii) vertically in sterile moistened vermiculite in plastic boxes.

iii) vertically in a moistened oasis.

iv) vertically in sand in plastic boxes.

v) vertically through stretched parafilm over a glass beaker containing distilled water.

vi) horizontally on sand in plastic boxes.

vii) horizontally on vermiculite in plastic boxes.

Infection occurred on all treatments, with brown watery rots developing on all stems held vertically. Horizontally inoculated stems only developed

Appendix XXXXI : Continued.

lesions from 10% of the agar disks containing GAY but appeared to be mainly from mycelial extension up to the pith.

Experiment 2

Droplets of the ascospore suspension were applied directly to the vertical and horizontal placed stems as in Experiment 1 and some were on 2% glucose solution plus ascospores. No infection resulted in any treatment.

Experiment 3

Petals were collected from field grown Jet Neuf plants and treated in four ways prior to inoculation with a drop of ascospore suspension (0.05 cm^3 c 100 spores);-

i) Freshly collected.

ii) Air dried for 7 days.

iii) Dipped into industrial meths and dried in the air.

iv) Simmered in boiling water for 5 mins before air drying.

Thirty petals were placed onto stems immediately while thirty inoculated petals were incubated on damp filter paper in petri dishes for 24 hours before placing onto field grown rape stems of cv. Jet Neuf. Stem portions were inoculated centrally with the petal which was held in place with

i) damp cotton wool,

ii) piece c 5 x 3 cm of cling film (Waitrose plc), or

iii) left unwrapped.

Inoculated stems were lain in seed germination trays on damp filter paper and incubated at room temperature.

This resulted in infection only from dead or boiled petals when wrapped

Appendix XXXXI : Continued.

around with damp cotton wool or cling film. The latter was best as the brown watery lesion could be easily detected without disturbing the petal and no colonisation of the film occurred.

The technique was subsequently modified using air dried petals collected from field grown plants of cv. Jet Neuf, held on stem pieces by cling film and a drop of ascospore suspension - 1×10^4 spores/ml - (10 µl using the Drummond Microcaps, USA) placed at the top of the film drawn in under the film by capillarity forming a complete film around the stem and the petal.

Appendix XXXXII : Mycelial inoculations of rape stems.
(Text Table 108)

Inoculum	Cultivar	Glasshouse						Outside			Field		
		4 week			Pre-flowering			Pre-flowering			Pre-flowering		
		5	10	15	5	10	15	5	10	15	5	10	15
GAY	Jet Neuf	1.0[(a)]	1.7	4	1.0	2.0	2.0	1.0	1.7	2.0	1.0	2.0	2.0
	Norli	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.7	2.0	1.0	2.0	2.0
	Elvira	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.3	2.0	1.0	2.0	2.0
	Rafal	1.0	1.7	3.0	1.0	2.0	2.0	1.0	1.3	2.0	1.0	2.0	2.0
PDA	Jet Neuf	1.0	2.3	4	1.0	2.0	2.0	1.0	1.7	2.0	1.0	2.0	2.0
	Norli	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.7	2.0	1.0	2.0	2.0
	Elvira	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.3	2.0	1.0	2.0	2.0
	Rafal	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.7	2.0	1.0	2.0	2.0
Wheat grain	Jet Neuf	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.7	2.0	1.0	1.7	2.0
	Norli	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.3	2.0	1.0	1.7	2.0
	Elvira	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.3	2.0	1.0	2.0	2.0
	Rafal	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.3	2.0	1.0	1.7	2.0
Carrot	Jet Neuf	1.0	2.3	4	1.0	2.0	2.0	1.0	1.3	2.0	1.0	2.0	2.0
	Norli	1.0	1.7	4	1.0	2.0	2.0	1.0	1.3	2.0	1.0	2.0	2.0
	Elvira	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.3	2.0	1.0	2.0	2.0
	Rafal	1.0	1.7	3.3	1.0	2.0	2.0	1.0	1.3	2.0	1.0	2.0	2.0

(a) Results are the mean scores of three plants inoculated to mycelial on wheat grain using the scale:
1, brown water soaked lesion
2, white lesion
3, collapse of plant tissue

Appendix XXXXIII : Anovar on 10 day old seedlings inoculated with ascospores. (Text Table 109)

5 days

	d.f.	SS	MS	F	
Cultivar	23	8.9	0.387	2.71	***
Block	4	13.62	3.404	23.81	***
Error	92	13.18	0.143		
Total	119	35.7			

10 days

	d.f.	SS	MS	F	
Cultivar	23	17.17	0.75	3.08	***
Block	4	32.95	8.24	34.04	***
Error	92	22.25	0.24		
Total	119	72.37			

15 days

	d.f.	SS	MS	F	
Cultivar	23	39.99	1.74	8.40	***
Block	4	8.95	2.24	10.81	***
Error	92	19.05	0.21		
Total	119	67.99			

Appendix XXXXIV : Analysis on the rankings of 10 day old seedlings inoculated with ascospores.

Cultivar	5 days	10 days	15 days	Rj
Jet Neuf	11.5	7	20	38.5
Bienvenu	17.5	23	20	60.5
Korina	5.5	2	3.5	11.0
Rafal	5.5	13	16	34.5
Fiona	11.5	19	16	46.5
Elvira	5.5	19	20	44.5
Belinda	17.5	7	13	37.5
Darmor	17.5	2	8.5	28.0
Tandem	17.5	21	20	58.5
Pamela	5.5	7	5	17.5
Lirabella	21.5	23	13	57.5
Lingot	17.5	13	8.5	39.0
Norli	5.5	13	3.5	22.0
Doral	11.5	19	23.5	54.0
Perle	17.5	7	2	26.5
Diander	23.5	16.5	13	53.0
Chrysander	21.5	13	23.5	56.0
Brittander	23.5	23	8.5	55.0
Jem	1	13	8.5	22.5
Barbara	5.5	16.5	8.5	30.5
Carola	11.5	7	8.5	27.0
Mikado	2	7	1	10.0
Falk	11.5	7	20	38.5
Liradonna	11.5	2	16	29.5

Rj Total = 898

Mean = 37.45

$T_x = 53.5$

$T_y = 45.5$

$T_z = 33.4$

$\Sigma T = 132.4$

$S = 5401.44$

$$W = \frac{5401.44}{\frac{1}{12}(3)^2\ (24^3-24) - 3(132.4)}$$

$= 0.543$

$X^2 = 3 \times 23 \times 0.543$

$= 37.45$

d.f. = 23

$\underline{P} = 0.05$

Appendix XXXXV : Analysis of variance tables for ascospore inoculations (Text Table 111)
on cotyledons from 4 week old seedlings.

Leaf Area Assessment

5 days

	d.f.	SS	MS	F	
Cultivar	16	3343.2	208.9	16.01	***
Error	187	2441.1	13.1		
Total	203	5784.3			

10 days

	d.f.	SS	MS	F	
Cultivar	16	1491.1	93.2	7.44	***
Error	187	2342.3	12.5		
Total	203	3833.4			

Score Assessment

	d.f.	SS	MS	F	
Cultivar	16	179.51	11.22	7.77	***
Error	187	269.92	1.44		
Total	203	449.43			

Appendix XXXXVI : Analysis on the rankings of 4 week old seedling cotyledons assessed from leaf area covered by the lesion (1982-83).

Cultivar	5 days	10 days	di
Jet Neuf	15	15	0
Bienvenu	9	4	5
Lirabella	2	1	1
Pamela	2	12	-10
Brittander	17	2	15
Chrysander	11	3	8
Diander	12	10	2
Doral	13	17	- 4
Lingot	2	9	- 7
Rafal	4.5	13	- 8.5
Elvira	4.5	11	- 6.5
Norli	14	14	0
Darmor	7	6	1
Tandem	10	8	2
Belinda	7	7	0
Fiona	16	16	0
Korina	7	5	2

$\Sigma x^2 = 403.5$

$\Sigma y^2 = 408$

$$r_s = \frac{403.5 + 408 - 607.5}{2\sqrt{403.5 \times 408}} = \frac{204}{811.49} = 0.251 \quad \text{n.s.}$$

Means are ranked from the least leaf area (1) to the most (17) analysis carried out on arcsin $\sqrt{\%}$ transformed data.

Appendix XXXXVII : Analysis between 5 day assessments between the stem and the cotyledons of 4 week old seedlings (1982-83).

Cultivar	Cotyledon	Stem	di
Jet Neuf	8.5	3.5	5
Bienvenu	3.5	13.5	-10
Lirabella	6	13.5	- 7.5
Pamela	8.5	13.5	- 5
Brittander	6	8	- 2
Chrysander	13	9	4
Diander	10.5	7	3.5
Doral	15	3.5	11.5
Lingot	12	13.5	1.5
Rafal	14	13.5	1.5
Elvira	10.5	3.5	7
Norli	3.5	13.5	-10
Darmor	16	13.5	2.5
Tandem	6	3.5	2.5
Belinda	1.5	6	- 4.5
Fiona	1.5	1	0.5
Korina	17	13.5	3.5

$\Sigma x^2 = 404$

$\Sigma y^2 = 359$

$$r_s = \frac{404 + 359 - 569.5}{2\sqrt{404 \times 359}} = \frac{193.5}{761.67} = 0.254 \qquad \text{n.s.}$$

Appendix XXXXVIII : Anovar tables for 4 week old seedlings (1983-84). (Text Table 112)

5 days

	d.f.	SS	MS	F	
Cultivar	9	4.67	0.52	3.87	***
Block	14	1.73	0.12	0.93	n.s.
Error	126	16.93	0.13		
Total	149	23.33			

10 days

	d.f.	SS	MS	F	
Cultivar	9	11.53	1.28	4.74	***
Block	14	5.49	0.39	1.45	n.s.
Error	126	33.97	0.27		
Total	149	50.99			

15 days

	d.f.	SS	MS	F	
Cultivar	9	3.04	0.34	2.00	***
Block	14	1.00	0.07	0.41	n.s.
Error	126	21.13	0.17		
Total	149	25.17			

Appendix XXXXIX : Analysis on the ranking of 4 week old seedlings (1983-84) inoculated with ascospores.

Cultivar	5 days	10 days	15 days	Rj
Jet Neuf	2	5	4	11.0
Bienvenu	7	1	7	15.0
Darmor	4	6	5	15.0
Carola	4	2.5	10	16.5
Barbara	8	7.5	7	22.5
Mikado	4	9.5	9	22.5
Liradonna	9	9.5	2	20.5
Jem	10	4	7	21.0
Falk	1	2.5	1	4.5
Diander	6	7.5	3	16.5
				Σ 165 $\bar{x}$ = 16.5

$T_x = 2.0$

$T_y = 1.5$ $\quad \Sigma T = 5.5$

$T_z = 2.0$

$S = 287$

$$W = \frac{287}{\frac{1}{12}(3)^2 (10^3-10) - 3(5.5)} = 0.395$$

$X^2 = 3 \times 10 \times 0.395 = 11.86$

$\underline{P} = 0.3$ with 9 d.f.

Means are ranked from the least (1) to the most (10) scoring of infection.

Appendix L : Carpogenic germination from field trial collected sclerotia.

Sclerotia formed in or on the cultivars grown in the 1982-83 cultivar trial at Silwood Park were run through the artificial apothecia production method (Section 1, p. 42). However, the sclerotia were cold treated at $4^{o}C$ for 4 weeks in lots of 20 sclerotia per cultivar in small plastic petri dishes (20 mm diameter) and then treated as before. The numbers of apothecia produced were counted every 7 days or so.

Table A shows the numbers produced and the time scale over which their production occurred from a total of 40 sclerotia per cultivar. The lining of production was very varied, sclerotia from cvs Lingot and Tandem were first after 79 days from the initial day of cold treatment. Sclerotia from Pamela produced apothecia for the shortest time span. The numbers also varied with cultivar, the largest numbers were produced from Fiona and the least from Diander sclerotia. This variability was not expected as the infection of all cultivars was from the same original source - JN1 culture sclerotia. Sclerotia recovered from under the spray trial in the inoculum bags placed in position in September 1983, were tested in two ways for their viability. Firstly, 3 sclerotia from each treatment plot and block were surface sterilised in sodium hypochlorite for 3 minutes, followed by washing in sterile distilled water before plating out on GAY agar (1 sclerotia per plate). These were then incubated at $20^{o}C$ and checked for mycelial growth for 7 days.

Secondly, 10 sclerotia from each treatment plot and block were placed in the small plastic petri dishes and incubated at $4^{o}C$ for 4 weeks and run through the apothecia production method as described above. Apothecia were counted as they formed.

Table A : Numbers of apothecia produced from sclerotia collected from the cultivar trial at Silwood Park 1982-83.

Cultivar	Date of assessment 1984[a]															
	28.1	3.2	10.2	17.2	24.2	3.3	15.3	22.3	29.3	6.4	12.4	18.4	26.4	3.5	10.5	15.5
Lingot	2[b]	6	10	16	18	-	-	-	-	-	-	-	-	-	-	-
Tandem	4	4	12	12	8	10	10	9	2	-	-	-	-	-	-	-
Diander	-	-	-	2	5	5	4	4	3	1	1	1	-	-	-	-
Elvira	-	-	-	-	-	-	9	13	4	6	8	4	1	4	-	-
Pamela	-	-	-	-	9	14	22	-	-	-	1	-	-	1	2	-
Brittander	-	-	-	-	7	11	22	14	4	5	3	-	-	-	-	-
Rafal	-	-	-	-	2	8	10	12	19	7	-	-	-	-	-	-
Belinda	-	-	-	-	-	-	9	12	5	4	3	1	1	-	2	-
Fiona	-	-	-	-	-	22	69	60	22	11	5	9	6	-	-	-
Korina	-	-	-	-	-	-	-	2	27	18	25	12	1	1	-	-
Doral	-	-	-	-	-	-	17	26	30	27	46	32	10	1	5	-
Chrysander	-	-	-	-	-	10	45	35	8	-	-	-	-	-	-	-
Jet Neuf	-	-	-	-	-	-	3	4	8	11	12	4	1	1	1	-
Bienvenu	-	-	-	-	-	-	11	15	10	7	7	5	-	-	-	-
Darmor	-	-	-	-	-	-	-	4	9	5	25	21	6	7	-	-
Lirabella	-	-	-	-	-	5	30	40	52	20	12	-	-	1	2	-
Norli	-	-	-	-	-	-	-	8	50	38	10	4	4	4	4	-

(a) Sclerotia were placed at $4^{o}C$ on 10 November 1983.

(b) Number of apothecia from 40 sclerotia.

Appendix L : Continued.

All the sclerotia plated out on GAY produced characteristic colonies of *S. sclerotiorum* within 7 days and sclerotia formation occurred on all plates.

Table B shows that carpogenic germination was not impaired in any treatment and apothecia production occurred within 64 days from the first day of cold treatment. The production was in a similar time span in all spray treatments and analysis of variance on the highest number produced across the 4 blocks was not significant for either treatments or blocks. However, treatment 3 produced the least and treatment 2 the most, averaging 1-7 apothecia per sclerotium.

Table B : Numbers of apothecia formed from sclerotia retrieved from the spray trial at Silwood 1982-84 in artificial production method.

Spray time	Block	Date of assessment					
		5.9.84	13.9.84	28.9.84	4.10.84	11.10.84	13.10.84
1	I	Stipes	3	16	3	3	-
2		"	30	29	2	-	-
3		"	15	23	3	-	-
4		"	18	17	-	2	-
1	II	"	11	4	-	-	-
2		"	14	5	3	-	-
3		"	14	8	-	-	-
4		"	20	21	-	-	-
1	III	"	8	3	-	-	-
2		"	5	3	-	-	-
3		"	21	2	-	-	-
4		"	1	6	8	2	-
1	IV	"	25	30	5	-	-
2		"	8	22	11	-	-
3		"	-	1	1	2	-
4		"	16	20	2	-	-

Anovar

	d.f.	SS	MS	F	
Blocks	3	279.19	93.06	1.15	n.s.
Treatments	3	15.69	5.23	0.07	n.s.
Error	9	727.07	80.79		
Total	15	1021.95			

Appendix LI : Regression analysis of apothecial weeks vs the total number of ascospores trapped/cm^2.

Sutton Scotney 1983

Cultivar	Apothecial weeks	Total no. ascospores/cm^2
Korina	0	12.8
Jet Neuf	10	14.4
Belinda	14	25.4
Elvira	12	35.4
Darmor	13	14.0
Diander	7	13.4
Lingot	8	22.4
Chrysander	2	21.6

Anovar

	d.f.	SS	MS	F	
Regression	1	63.7	63.7	1.02	n.s.
Error	6	373.6	62.3		
Total	7	437.4			

$$Y = 15.0 + 0.593X$$

Appendix LI : Continued.

Sutton Scotney 1984

Cultivar	Apothecial weeks	Total no. ascospores/cm^2
Bienvenu	21	51.4
Carola	13	23.4
Pamela	41	51.6
Lirabella	6	25.2
Korina	2	37.8
Falk	32	56.0
Barbara	17	52.6
Belinda	3	28.2

Anovar

	d.f.	SS	MS	F	
Regression	1	716.0	716.0	7.19	**
Error	6	597.2	99.5		
Total	7	1313.2			

$$Y = 28.6 + 0.722X$$

Appendix LI : Continued.

Silwood 1984

Cultivar	Apothecial weeks	Total no. ascospores/cm^2
Diander	390	1.6
Doral	300	16.8
Liradonna	168	10.4
Jem	364	9.2
Belinda	207	9.4
Korina	136	11.4
Bienvenu	111	13.4
Rafal	193	11.4
Fiona	240	20.4
Falk	311	18.4
Lirabella	352	13.8
Mikado	285	30.4
Carola	282	21.0
Pamela	265	16.6
Barbara	96	21.2
Darmor	142	14.6
Jet Neuf	130	13.6

Anovar

	d.f.	SS	MS	F	
Regression	1	11.6	11.6	0.38	n.s.
Error	15	455.8	30.4		
Total	16	467.4			

$$Y = 13.6 + 0.009X$$

INCIDENCE OF *SCLEROTINIA* STEM ROT IN OILSEED RAPE CULTIVAR TRIALS 1982-84

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ABSTRACT

The percentage of plants with stem rot (*Sclerotinia sclerotiorum*) on the main stem was assessed on eight trials between 1982 and 1984. These were conducted at three sites with a total of 31 winter oilseed rape cultivars selected from the National Institute of Agricultural Botany National Lists. At Silwood Park and Cambridge, inoculum came from sclerotia produced in culture by an isolate of *Sclerotinia sclerotiorum* from oilseed rape placed c. 1 cm deep in the soil after crop establishment. At Sutton Scotney, inoculum was derived naturally from an outbreak of stem rot in 1982, following a crop of peas. The incidence of stem rot varied considerably in the trials over the 3 years and between the 3 sites in any one year but, at each site, disease incidence was consistently higher on some cultivars than others. Jet Neuf and Bienvenu were among those most affected with maximum infections of 70% (in 1983) and 53% (in 1982) respectively.

INTRODUCTION

Stem rot induced by *Sclerotinia sclerotiorum* is a major disease of oilseed rape in Western Canada, Germany and France causing substantial yield losses in some years (Scheibert-Böhm *et al.* 1981). In the UK only a few outbreaks of stem rot have so far been reported, mainly in 1980, 1982 and 1984 (Jellis *et al.* 1984). However with even more oilseed rape being grown, the incidence of stem rot could increase, thus posing a serious threat to British growers. This study, which was part of a broader investigation of the disease (Mylchreest 1984), examined the susceptibility of different rape cultivars to stem rot in the field.

MATERIALS AND METHODS

Cultivars

In each trial there were 16 winter oilseed rape cultivars which were in at least their second year of National List Trial by the National Institute of Agricultural Botany (NIAB).

Sites and design of the trials

Three sites were used: Sutton Scotney, Hampshire (1981-2, 1982-3, 1983-4); NIAB, Cambridge (1981-2, 1982-3, 1983-4); Silwood Park, Berkshire (1982-3, 1983-4).

At Sutton Scotney, the first trial was drilled by NIAB on 28 August 1981 on land previously planted to peas which had been slightly infected with *Sclerotinia* in 1980. There were four replicate plots (each approximately 40 x 20 m) of each cultivar in a randomised block design. In the two subsequent trials, one block with a single plot (20 x 2 m) of each cultivar, was surrounded by a border of Jet Neuf and netted to prevent pest damage. Drilling took place on 8 September 1982 and 25 August 1983. Both of these trials were within the area previously occupied by the first trial, thus all three trials at this site relied on natural inoculum.

At NIAB Cambridge, there were four replicates (two rows of 2m) sown of each cultivar on 17 September 1981, 15 September 1982, 10 September 1983, in a randomised block design. Thirty sclerotia of *S. sclerotiorum* were buried c. 1 cm deep between the two rows of each cultivar; in January 1982 (first trial) and in September of 1982 and 1983 (second and third trials). Sclerotia were produced by growing the fungus on autoclaved wheat grain for 28 days at 25°C. The isolate used in the first trial was from an unknown oilseed rape cultivar; the isolate used in the other two trials was obtained from infected Jet Neuf at Sutton Scotney in 1982.

At Silwood Park, the 16 cultivars plus cv Doral (claimed by German workers (Krüger 1983) to have low susceptibility to stem rot) were drilled on 2 September 1982 and 26 August 1983. A single plot (3 x 3 m) of each cultivar formed a square enclosing a central, circular plot of Jet Neuf. Sclerotia (Jet Neuf isolate) were buried c. 1 cm deep in terylene net bags (100 sclerotia per 9 m^2 plot in 5 bags) after crop establishment in early September.

All trials were sown with dressed (iprodione) seed, at 18 cm row spacing, fertilised with NPK (40:60:60 kg/ha), to the seed bed and given 200 kg/ha nitrogen in the spring. Post-emergence herbicides were applied in all trials but only at stem extension at Sutton Scotney during the 1982-3 trial. Plots were harvested in mid-July in all years.

Assessment of stem rot

Stem rot was assessed as near to harvest as possible. At Sutton Scotney and Silwood Park a 2.5 m long cane was inserted across the drill rows at ground level in two or three places at random along the edge of each plot. Percentage plants infected was calculated from counts of presence or absence of stem rot lesions on a minimum of 50 plants touching the cane. At Cambridge every plant was assessed, by the presence/absence of lesions.

RESULTS

Table 1 shows the percentage of plants with stem rot in the eight trials and ranks the cultivars in each trial from least (1) to most infected (17). The mean rank is given where two or more cultivars had the same incidence of disease.

At sites where there were replicate plots of each cultivar (Sutton Scotney 1981-2; Cambridge 1981-2, 1982-3 and 1983-4), differences between cultivars were examined by analysis of variance of transformed ($\sqrt{x+0.5}$ data. The variance ratios indicated a significant difference between cultivars at Sutton Scotney in 1981-2 ($P = 0.01$) and at Cambridge in 1982-3 ($P = 0.05$) and 1983-4 ($P = 0.01$) but not at Cambridge 1981-2. These differences are shown in Table 2.

Mean transformed data from each season for the three sites were analysed to determine differences between sites (blocks) and cultivars. The difference between sites was highly significant ($P = 0.01$ for each year 1982, 1983, 1984) but that between cultivars was not, suggesting a low degree of agreement between the behaviour of cultivars at the three sites. This feature was examined further by two non-parametric tests (Siegel 1956) on the ranked values for 1981-2 (using Spearman's coefficient of rank correlation) and for 1982-3 and 1983-4 (using the Kendall coefficient of

TABLE 1

Percentage plants with stem rot (%) and ranking (R) of cultivars grown in winter oilseed rape trials, 1981-84

Cultivar	Site and Season															
	Sutton Scotney						Silwood				Cambridge					
	1981-2		1982-3		1983-4		1982-3		1983-4		1981-2		1982-3		1983-4	
	%	R[b]	%	R	%	R	%	R	%	R	%	R	%	R	%	R
Elvira	48	12	4	6			40	10			1	7	52	16		
Jet Neuf	68	16	30	16	4	9	70	16	4	11	1	14	39	11	14	4
Bienvenu	53	13	12	15	10	16	38	8.5	2	5.5	0	2	46	14	20	14
1[a]	40	7									0	5				
Korina	53	14	4	6	8	14	12	2	6	15.5	1	9	40	12	22	15
Lirama	27	3									2	15				
2	25	2									0	2				
3	46	11									0	5				
4	44	10									1	10				
5	37	8									1	12				
Norli	32	5	8	12.5			60	13.5			1	13	36	9		
Rafal	40	9	8	12.5	9	15	38	8.5	2	5.5	1	7	44	13	15	7
Fiona	55	15	4	6	2	4.5	46	12	4	11	0	2	31	6	15	8
6	31	4									0	5				
Lingot	22	1	4	6			44	11			5	16	47	15		
7	33	6									1	11				
Belinda			4	6	2	4.5	90	17					25	2	18	11
8			6	9.5			60	13.5					31	4		
9			8	12.5	0	1.5	64	15	4	11			36	8	18	12
10			2	3	2	3	34	6	2	5.5			31	5	15	6
11			8	12.5	6	12	26	4.5	2	5.5			37	10	28	16
Darmor			0	1.5	4	8	26	4.5	0	1.5			33	7	11	3
Doral							36	7	6	15.5						
12			6	9.5			10	1					18	1		
Tandem			0	1.5			18	3					27	3		
13					6	11			2	5.5					15	5
14					4	7			2	5.5					10	1
15					6	10			0	1.5					18	13
16					6	13			6	15.5					16	9
17					0	1.5			4	11					11	2
18					2	6			4	11					17	10

(a) Unlisted cultivars are coded by number
(b) Cultivars are ranked from least (1) to highest (17) incidence of stem rot.
(c) Figures are rounded up to nearest percentage, to fit into table. Ranks are derived from unrounded up figures.
(d) The mean rank is given for those cultivars with the same disease incidence.

TABLE 2

Differences in incidence of stem rot on varieties grown in replicated trials at individual sites

Ranking of cultivars in trials at					
Sutton Scotney 1981-82		Cambridge 1982-83		Cambridge 1983-84	
Lingot	a	12	a	Darmor	a
2	ab	Belinda	ab	11	ab
Lirama	ab	Tandem	abc	14	ab
Norli	abc	10	abc	15	abc
6	abc	8	abcd	Bienvenu	abc
7	abc	Fiona	abcd	Korina	abc
1	bcd	Darmor	abcd	10	abc
5	bcd	Norli	abcd	Rafal	abc
Rafal	bcd	9	abcd	16	abc
4	cd	11	abcd	9	abc
3	cd	Jet Neuf	abcd	Belinda	abc
Elvira	cd	Korina	bcd	18	bcd
Bienvenu	de	Rafal	bcd	Fiona	cd
Korina	de	Bienvenu	bcd	Jet Neuf	cd
Fiona	de	Lingot	cd	17	cd
Jet Neuf	e	Elvira	d	13	d

Cultivars are ranked in descending order - from least to highest incidence.
Values with no letter in common are significantly different at P = 0.05 (Duncan's multiple range test)

TABLE 3

Mean disease incidence of the cultivars grown in all eight trials

Cultivar	Mean % disease incidence	Rank
Jet Neuf	28.7	5
Bienvenu	22.8	4
Fiona	19.7	3
Rafal	19.6	2
Korina	18.3	1

concordance). These tests confirmed that there was no significant measure of agreement between the ranking of cultivars at the various sites.

Further analyses examined differences between disease (as mean transformed disease incidence and ranking of cultivars) recorded over 2 or 3 years for each site. These analyses showed a highly significant difference (i.e. P = 0.01 at each site, Sutton Scotney, Cambridge and Silwood) in disease incidence between the three years but again little agreement between the ranking of cultivars at any one site in those years.

However, despite this variation, again seen on analysis of variance of mean transformed disease incidence on the five cultivars common to all eight trials (P = 0.01 for sites and years, no significance was detected between cultivars), it was clear that the two currently recommended varieties (Anon. 1983) - Jet Neuf and Bienvenu - had the highest disease incidence (Table 3).

DISCUSSION

The results of these trials demonstrate that all the major oilseed rape cultivars tested by NIAB for the National List are susceptible to stem rot. The incidence of the disease varied on each cultivar with both year and site. The highly significant difference in disease incidence between the cultivars grown at the individual sites, disappeared when data were analysed for all sites in one year or for one site in all three years. This indicates that no consistent measure of cultivar susceptibility can be made from such records of disease incidence.

The differing expression of cultivar susceptibility in these trials may reflect important differences in environmental conditions at each location or in each year or in some cases may be due to simple escape from infection. At Cambridge 1981-2, the low infection detected was due to the late seeded sclerotia not receiving the overwintering required for apothecial production in May-June. Further investigation into the epidemiology of the disease has been carried out in the 8 trials (Mylchreest 1984) in order to understand the varying cultivar response to *Sclerotinia* more fully.

Nevertheless, the results show that no cultivar currently being evaluated for performance under UK conditions is resistant to stem rot. This includes cv Doral which proved to be as susceptible as the other cultivars under trial at Silwood. Moreover, the cultivars now commonly grown, Jet Neuf and Bienvenu, are among those most likely to be infected and thus may increase the risk of stem rot becoming more widespread in the UK.

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