# STUDIES ON FOOT ROT AND LEAF SPOT DISEASE CAUSED BY COCHLIOBOLUS SATIVUS.

BY

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## Summary.

The study investigated the occurrence and importance of the foot rot fungus *Cochliobolus sativus* in Great Britain. Although the fungus is widespread in seed samples, the disease caused by the fungus appears to be of sporadic occurrence and restricted to highly susceptible varieties growing under conducive environmental conditions. In the last few years there have only been a few reports of severe outbreaks in the field.

The British isolates of the fungus were shown to be pathogenic towards barley. Wheat and oat appeared to be resistant. The recommended British barley varieties showed a range of susceptibility towards *C.sativus* when tested in laboratory, greenhouse and field experiments. The variety Clermont was shown to be highly susceptible while the majority of the varieties were fairly resistant.

Cultural studies of isolates of *C.sativus* from Britain, Netherlands, Canada, India and Australia demonstrated the extreme variability of the fungus. Sporulation, aerial mycelium, colony margin and saltation characters were found to be highly variable and could be used in isolate separation.

The isolates were also tested to compare their pathogenicity towards barley, wheat and oat. The British and Netherlands isolates were found to be similar being most pathogenic towards barley while the Indian isolates were more pathogenic towards wheat. The barley varieties ranged in their susceptibility towards the British and Netherlands isolates, this was not apparent for the Canadian, Australian and Indian ones.

The control of the fungus by the use of seed treatment was investigated in both field and laboratory experiments. The treatments, incorporating a large number of different active ingredients, showed a range of control. Guazatine/Imazalil and 26,019 RP gave excellent control of the fungus while Benlate was found to increase the incidence and severity of the disease in the field.

Spore trapping experiments performed in 1974 and 1975 to investigate dissemination of spores of the fungus showed very few spores to be released throughout the growing period.

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# I. Introduction.

<u>Helminthosporium sativum</u> P.K.B. was first described by Pammel, King and Bakke (1910) but Luttrell (1955) classed it as synonymous with <u>H.acrothecoides</u> Lindfors, <u>H.californicum</u> Mackie & Paxton and <u>H.sorokinianum</u> Sacc.. <u>H.sorokinianum</u> is a Saccardian species based on a Russian description by Sorokin in the early 1890's. However Shoemaker (1959) pointed out that the name " Helminthosporium " was invalid and he segregated graminicolous species belonging to this genus into <u>Drechslera</u> and <u>Bipolaris</u>. In terms of this reclassification <u>H.sativum</u> is referred to the latter genus (characterised by species with fusoid conidia with polar germination) under the new combination <u>Bipolaris sorokiniana</u> (Sacc. in Sorok.) Shoemaker. The name <u>H.sativum</u> however is still retained in most literature.

The ascigerous stage of <u>H.sativum</u> has never been reported in nature. It has, however, been reported in laboratory cultures. Ito and Kuribayashi (1921) were the first to describe perithecia which showed characters of the genus <u>Ophiobolus</u>. The perithecia of <u>O.sativus</u> were described as "erumpent, black-walled, pseudoparenchymatous and globose or subglobose, 370-530 x 340-470μ in diameter with well developed, subconidial or cylindrical or long-fusoid straight or curved, slightly stipitate asci with round apices, measuring 110-220 x 32-43μ and containing 1-8 (mostly 4 or 8) flagelliform filiform pale olive green, 6-13 septate ascospores, coiled in a close helix and measuring 160-360 x 6-9μ".

Later Drechsler (1934) erected the new genus <u>Cochliobolus</u> to include the helicoid ascigerous species, with conidia belonging to <u>Helminthosporium</u>, that had previously been referred to the genus <u>Ophiobolus</u>. He based his new genus on <u>O.heterostrophs</u> Drechsler, but did not specifically transfer

O.sativus to the new genus. However, in 1942, Dastur attributed the transfer to him, using the binomial Cochliobolus sativus (Ito & Kurib) Drechsler. The full authority for C.sativus was given as (Ito & Kurib) Drechsler ex Dastur (Tinline 1951).

Tinline (1951) showed the fungus to be heterothallic and designated the two mating types as A and a. Dickson and Tinline (1958) investigated the effects of some environmental factors on the formation and maturation of perithecia. They found perithecia failed to develop on media from which plant parts were excluded. The incubation of cultures at 24°C for 7 days followed by 20°C for 14 days on media of pH 4-6 favoured the development of mature perithecia. Although perithecia formed under all light conditions, sunlight apparently inhibited to some extent the delimitation of ascospores.

The fungus grows freely on Potato Dextrose Agar at 25°C to form a compact, velvety layer of black, olivaceous mycelium which soon becomes covered with a dense mass of short conidiophores, but the appearance of the colony varies greatly according to the strain of the fungus, type of media and incubation conditions. Mycelial growth and conidial production occur in culture over a wide range of temperature from 4°C to 36°C (Andersen 1952) but vegetative development and sporulation are optimal at 24-28°C (Dosdall 1923, McKinney 1923). According to Dosdall the conidia germinate satisfactorily at all temperatures between 6°C and 39°C and over a range of pH (4.4 to 11.4) with optimal germination tending to occur under neutral to slightly alkaline conditions.

In studies on the nutrition of H.sativum Peterson and

Katznelson (1954, 1956) found that growth was stimulated in the presence of certain trace elements including zinc, iron and manganese but not of other elements, or of any of eight vitamins, tested. Hrushovetz (1957) found that the presence of certain amino acids in culture media led to progressive attenuation of virulence by H.sativum.

On the host the conidiophores of the fungus emerge through stomata or through epidermal cells, either singly or in groups of two or three. The conidiophores are brown, septate and bulge out in knee-fashion just above the septa. In shape and dimensions the conidia are highly variable. They are somewhat cylindrical or distinctly curved, and range in size from 24-134 x 14-30µ and furnished with as many as twelve septa but usually 3-10 septa. Sometimes oblique instead of transverse septa are found but these are exceptional. The germination of conidia normally proceeds from polar cells only.

Christensen (1922) provided early proof of the ability of H.sativum to overwinter on naturally or artificially infected straw under North American conditions where soil-borne inoculum played a very important role in disease outbreaks. Christensen also reported the recovery after 14 months of H.sativum from wheat straws "placed outdoors" in bottles. Hynes (1932, 1938) found that H.sativum retained its viability in infected stubble stored indoors for at least twenty one months and that a small percentage of spores continued to germinate after a storage period of thirty three months in sealed glass tubes buried in the soil. More recently Chinn and Ledingham (1958) have shown that spores of H.sativum may remain viable in soil under field conditions for almost two years.

The fungus attacks wheat, barley, rye and oats. It is also known to attack a large number of weed and pasture grasses including species of Agropyron, Bromus, Festuca, Hordeum and Lolium. All of these grasses are highly susceptible and may serve as carriers of infection in the field (Christensen 1922).

The symptoms of the various stages of the disease have been well documented by many workers (Christensen 1922, Dosdall 1923, Dastur 1932, Hynes 1932, 1935, and Fuentes, Exconde and Gicales 1966).

In favourable conditions for rapid development of the fungus, the percentage germination of seed may be reduced considerably.

Some infected seedlings emerge from the soil but are soon killed by invasion of the fungus. This occurs, however, only in extreme cases. Other seedlings may be severely stunted and in heavily infected areas these stunted plants may occur in characteristic patches which are usually circular but frequently irregular in outline, and may be from a few feet to several yards in diameter. Similar dwarfed plants may be found intermixed with healthy ones.

Some of the infected seedlings make considerable growth and then become yellowish and die from attack by the parasite which has penetrated the roots and base of the stem, producing brown discolourations, while others may recover and make quite good growth.

The infection of germinating seedlings, developed from either diseased seed or from soil inoculum is first evident from the presence of lesions on the coleoptile and coleorhiza. The lesions are at first tiny spots, dark brown in colour. On the coleoptile the lesions elongate and may coalesce completely covering it. These foot rot symptoms cannot be distinguished from those caused by Pyrenophora spp. or Fusarium culmorum. If the fungus has managed to penetrate through the coleoptile to the enclosed prophylls and the primary shoot, the first leaf will probably show lesions when it unfolds.

Infection of the coleorhiza leads to colonization of the primary and seminal roots, appearing as irregular dark brown lesions which may coalesce and completely discolour them. If the primary root is completely infested early on in the development of the seedling, the seedling may be killed.

Infected plants generally show a reduction in height and the leaves may become a darker green than those of healthy plants. Severely infected plants usually remain dwarfed and may tiller excessively. As many as forty tillers are not uncommon on diseased plants, but as a rule not more than half of them develop more than three to eight inches. In many cases only one or two develop normally to produce seed. Sometimes, however, the fungus prevents tillering by attacking the new shoots before they emerge from the sheaths, or soon after. In extreme conditions the fungus sporulates abundantly on the nodes, giving them a black velvety appearance. The internodes seldom become darkened except near the base of the stem, though occasionally all of them may be discoloured. When heading stages are reached the ears are often undersized and only partially filled with seed.

The earliest symptoms of the disease on young or mature leaves appear as watersoaked, more or less oval spots ranging in size from pinpricks to about one millimetre. With age these spots turn brown with a yellowish margin on wheat plants and light brown with a darker margin on barley. Later the spots enlarge parallel to the veins and become more or less elliptical, measuring about two to fifteen millimetres long. Mature spots may coalesce to form dead patches on the leaves. Severely infected leaves become shrunken, the tips become discoloured and gradually die back. Lesions may also be found on the stems.

Infection by air-borne spores of the fungus during the flowering processes may also occur. The awns and the glumes enclosing the ripening seed may bear dark lesions. The seed may be quite plump and normal looking but at the germ end the disease can be noticed by the presence of a tiny black spot. Seeds bearing these discoloured areas are said to be "black pointed". These symptoms have also been described as "kernel smudge". If the blackening extends to about half the length of the seed or more, it generally fails to germinate. Sometimes even when the whole of the embryo is blackened the seed may still germinate.

The disease is very widespread throughout the world being particularly important in Canada, United States, Argentina, Mexico, India and Australia predominantly on wheat and barley. It has been of relatively little importance in Europe and there are only a few records of its occurrence in Britain.

The first record of the disease appeared in 1911 by the Dominion botanist Guisson. He described a discolouration of wheat kernels from Ontario and Saskatchewan which was similar, if not identical to symptoms now known as those caused by C.sativus. A year later Guisson reported C.sativus occurring on barley in Ottawa (Simmonds 1939) and Henry (1920) isolated an Helminthosporium (tentatively determined as H.sativum, for there was still some uncertainty concerning species) from wheat, barley and rye from Western Canada.

Within the period 1920- 1930 there was a rapid development in plant pathological work in Western Canada, and with this, investigation on root diseases expanded integrally. A survey (Simmonds 1939) carried out between 1927- 1930 showed that C.sativus with F.culmorum, by now recognised as the two major fungi associated with common root rot, to be prevalent in the three Prairie States of Manitoba, Alberta and Saskatchewan.

For the period 1930-1939 Simmonds (1941) estimated the annual loss from common root rot in the Western Canadian Provinces to be 12 million bushels, and it was then considered to be the most widespread and destructive of all cereal diseases. Craigie (1939) working with experimental plots estimated the loss from the wheat crop to be not less than 1,909,000 bushels or an annual loss of \$ 1,336,000 for that period. Machacek (1943) in an independent survey also in Manitoba sampling 180 fields, including eight different field types, found that none of the fields were absolutely free from the fungus, that on average 38.3% of the plants were diseased and that the average reduction in yield for three years 1939- 1941 was 12.1%. This represented an average loss of \$3,827,000.

An unusually severe outbreak of common root rot in Saskatchewan was reported by Sallans and Ledingham (1943) when grain yields were reduced by 28%, and in 1956 the incidence of common root rot in Saskatchewan was considered to be increasing. Data from a ten year survey showed an average loss amounting to 5 bushels per acre equivalent to approximately one third of the yield actually harvested.

By now the importance of the disease in Canada was established and no further comprehensive surveys to estimate losses were carried out until 1969 when Ledingham, Atkinson, Horricks and Mills (1973) undertook a survey over the years 1969-1971. Despite the introduction of chemical control and better husbandry the average loss due to common root rot of wheat for the Prairie Provinces was 5.7% or 30 million bushels. Wheat and barley dominate the Prairie agriculture and so rotations that free the land for one or two years at a time are not practical. Thus cereals are seldom planted on land with an inoculum level low enough to significantly limit development of the disease.

Records of crop losses and levels of common root rot for the United States are less readily available. However, here too the disease has been of great importance. In 1924 Helminthosporium root rot was reported as causing appreciable damage in several states with losses as much as 10% in N.Dakota where the disease was reported to be in epidemic proportions. Similarly as many as 75% of wheat plants were killed in some fields. By 1935 although levels had fallen the disease had spread throughout the United States attacking both wheat and barley. Washington State reported in 1943 the wheat crop loss in average seasons amounted to about 4% or 2,500,000 bushels. The aggregate loss due to barley and wheat root and foot rot diseases in the United

States in 1939 was approximately 10 million bushels (Butler 1961).

The occurrence of Helminthosporium spp. in India was reported first in 1919 on a wide range of hosts including cereals (Hamblin 1922). However it was not until 1930 that investigations separating the Helminthosporium spp. were first carried by Mitra (1930) who then reported C.sativus occurring in various provinces of India, except Burma, but it did not appear to cause much disease. Infact its importance was not recognised until its occurrence in severe form in the Darjeeling and plains of West Bengal between 1952-1958. In 1968, C.sativus as a foliar pathogen (and as such considered to be most destructive) was present in many fields distributed in six states of India viz., Madhya Pradhesh, Uttar Pradhesh, West Bengal, Bihar, Punjab, and Haryana causing an epidemic of black point disease of wheat and a shortage of disease-free seed (Nema and Joshi 1971).

In Australia the disease has been known since 1913. It caused heavy losses in the 1920s but apart from isolated heavy losses it was considered to be relatively unimportant.

First isolations of C.sativus in Europe came in the 1930's. These were in Holland, Germany (1934) and Denmark (1930). But Europe at this time paid little attention to the disease. However by 1940's in Holland high infection levels were found, and it was thought that these were due to infected seed imported from warmer regions. In subsequent years levels declined, only occasionally reappearing, indicating that sufficient inoculum was present but the conditions were unsuitable for disease development.

In routine testing of wheat seed in Holland the infection was not observed until the harvest of 1953 when many samples had 1-2% infection levels. As barley was considered the more susceptible host of C.sativus in Europe, the disease was clearly important at this time. Muller (1956) reported that the fungus was widespread throughout Germany.

Between 1956-1966 the Danish Plant Protection Service examining large numbers of seed lots of commercial barley found C.sativus in a large number (Jorgensen 1969). Jorgensen (1974) stated the relative frequencies of C.sativus was similar to those found in similar studies carried out in Northern Europe. A further survey between 1965-1972 of 100 seed samples of barley revealed fluctuating levels.

| Year | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 |
|---|---|---|---|---|---|---|---|---|
| % infect. | 0.8 | 4.0 | 3.5 | 0.8 | 0.7 | 4.1 | 5.2 | 4.4 |

De Temp (1958) had observed that 3-5% seed-borne infection resulted in a 1% reduction of both emergence and yield.

With the rising disease levels in the early 1970's isolations of C.sativus for the first time were made in Finland (Makela 1971) and West Slovakia (Michalikova 1972). A further investigation in Finland (1970-1971) of 180 fields of barley showed C.sativus to be present in 15% of the fields as leaf spot symptoms. Makela (1972) also reported that in Sweden barley seed was highly infected with C.sativus and the fungus occurred in great abundance in barley fields even in the remotest parts of the country.

The literature sited indicates C.sativus to be less common and destructive in Europe than in North America. Skou (1966) and De Temp (1964) suggested that this was due to climatic conditions. The summers in North America are generally much warmer than those in Europe, so that fungal propagation in Europe may be slower and the attacks so late that inoculum levels are low. Also, in the North American Wheat Belts the fungus has gradually accumulated so that soil-borne infection is more important for continuation of the disease than seed-borne infection. Under European agricultural conditions, however, the seed infection strongly dominates.

Skou (1966) suggested another possible factor accounting for low occurrence of the fungus was the 'relatively unspecific symptoms' of the disease and that the foot rot symptoms are very similar to those of Fusarium spp., Gaeumannomyces graminis and Pseudocercosporella herpotrichoides and may easily be confused with these fungi. Makela (1972) also suggested that leaf spot sympoms of C.sativus infection in Finland are often masked by symptoms of P.graminea and H.teres.

The first recorded occurrence of C.sativus in England at Cambridge by Smith was reported by T.A.Russell (1932). It revealed the presence of two strains collected from wheat and barley from widely differing sources. Infection experiments carried out with these isolates showed that wheat seedlings ('Little Joss') were yellowed and distinctly checked in growth and a browning at the base of the stem showed the characteristic foot rot symptoms associated with the disease.

The fungus, only reported two or three times in Britain on wheat and barley by 1945, had been isolated from bases of wheat plants at Rothamsted and also on rye for the first time in this country in 1944 (Moore 1945).

No further reports of C.sativus were made until 1962 when the fungus was noted on winter rye at Trawscoed Experimental Husbandry Farm in Wales.

In the early 1970's the incidence of C.sativus throughout the whole of Great Britain became more frequent. Richardson (1975) reported that 4% of 375 barley crops examined in Scotland between 1970-1974, showed infections by C.sativus. In 1972 the fungus was recorded on Clermont and in 1973 on Clermont, Golden Promise, Ruby, Midas, and Zephyr and also on oats in Scotland. It was reported on Zephyr in Lincolnshire and Lofa Abed at Cardiff in 1973. The potential destruction of the disease was illustrated in this country for the first time when the yield of a Clermont crop in Scotland was reduced to 17½ cwt per acre and seed was found to be 98% infected with C.sativus (Whittle pers. comm.) Also another Clermont crop in Anglesey completely failed yielding 80% seed infection (Hewett 1975). In 1972 the leaf spot phase of the disease was seen for the first time in many crops. This phase of the disease had not previously been seen in Britain.

Hewett (1975) carried out a survey of fungi on barley seed in 1972-1973 and reported that C.sativus, once rare, was now the commonest of the five seed-borne pathogens, Drechslera teres, D.graminea, Septoria nodorum, F.nivale and C.sativus. It was widespread in seed samples throughout England and Wales. For seed tested at the Official Seed Testing Station at Cambridge percentage infections were as follows:-

Mean % Seed Infection by C.sativus in 60 samples of each barley variety.

| Variety. | 1972. | 1973. |
|---|---|---|
| Clermont | 22.8 | 21.8 |
| Zephyr | 3.2 | 7.0 |

| | | |
|---|---|---|
| Julia | 0.9 | 4.9 |
| Mazurka | 0.2 | 0.5 |
| Proctor | Trace | 0.3 |

For 1972 and 1973, % samples infected with C.sativus.

| Variety. | No.samples. | % samples infected. |
|---|---|---|
| Clermont | 27 | 81 |
| Zephyr | 28 | 68 |
| Julia | 29 | 38 |
| Mazurka | 23 | 26 |
| Proctor | 30 | 13 |

In September 1973, with the increasing number of reports of C.sativus as cited, above this project was initiated. Among its objectives was the investigation of further incidences of the occurrence of C.sativus in Great Britain and their importance.

The production of resistant varieties of cereals as a means of controlling C.sativus and preventing heavy crop losses was recognised by early workers. In Australia, consideration was first given to breeding wheat resistant to C.sativus following the observation by Hamblin (1922) that late-sown, quick maturing varieties tended to escape heavy infection. However, the programme was not persued when it was established that three such varieties (Turkey Red, Early May and Red Wave), which Hamblin regarded as offering some resistance, were infact distinctly susceptible to C.sativus (Hynes 1923). Subsequently Hynes (1932), in keeping with Hamblin's original observation reported that short season, early maturing varieties were less severely attacked than those of long season and late maturing habit. Once again this observation was not confirmed by later tests which showed all of 100 varieties to be of similar resistance. (Hynes 1938).

For the most part equally disappointing results beset efforts made in North America to locate worthwhile resistance to the fungus in bread and other types of wheat. None of a wide collection of 104 species and varieties of durum, club, emmer, spelt, poulard, Polish and common bread wheats tested by Christensen and Stakman (1925) proved resistant. Greaney, Machacek and Johnson (1938) likewise found a general marked susceptibility in their test varieties of wheat and oats to <u>C.sativus</u>, though some resistance was observed in Apex and Thatcher wheats, and in Ohio and Victoria oats. Simmonds and Sallans (1946) also commented on partial resistance of Apex and Thatcher, and of other varieties including Red Bobs and Marquis, to <u>C.sativus</u>. Similarly wheat varieties and breeding material in New Zealand (Blair 1937) and in Bavaria (Muller 1956) also appeared to lack worthwhile resistance.

Claims of resistance to <u>C.sativus</u> by the Canadian barley varieties, Vantmore, Anoidum, Rabat, and Vaughn (Goulden 1955) and the Bavarian varieties, Hado-Streng and Donaria (Muller 1956) have been made.

Hayes and Stakman (1921) were the first workers to study the genetics of resistance to <u>C.sativus</u> in barley. They showed the recessive resistant factor was associated with colour of spike and with rough awns. Griffee (1925) concluded there were at least three genetic factors responsible for mature plant reaction to <u>C.sativus</u> viz: (1) one linked with the factor for 2 row versus 6 rowed varieties (2) one with the factor for black or white spikes and (3) and one with the factor for rough or smooth awns. However Arny (1951) found no detectable association of spot blotch reaction with any linkage groups, the difference between susceptibility and resistance to spot blotch in barley seedlings appeared to be due to a single factor pair, with susceptibility dominant.

Loiselle (1965) postulated two dominant genes present for resistance but found no linkage between genes for awn characteristic and resistance. Cohen, Helgason and McDonald (1969) also postulated polygenic inheritance for seedling reaction to C.sativus.

Sallans and Tinline (1956) investigated the resistance of wheat to C.sativus and proposed that as no highly resistant varieties had been found that this indicated that several genetic factors must determine the inheritance of root rot reaction. McKenzie and Atkinson (1968) found one major gene and one or two minor genes differentiated the root rot susceptibility of wheat. In 1970 Larson and Atkinson identified chromosome 5B as the most important in differentiating root rot susceptibility with chromosomes 2B and 2D also related in resistance.

There have been no studies of the resistance of British grown cereal cultivars to C.sativus. Hewett (1975) from his seed health testing studies postulated that a range of susceptibility probably existed. A study of the reaction of British cereal cultivars to C.sativus was therefore undertaken as part of this project.

Sallans (1933) reviewed the methods used by early workers for assessing cultivar susceptibility to the foot rot phase of the disease. Either a solid medium overgrown with the fungus was added to soil in which the test cultivars were planted, or a spore suspension of the fungus was added to the soil or to the seed to be tested.

The solid inoculum used was generally derived from a cereal host. Autoclaved wheat was chosen by many workers (Christensen 1922, Dosdall 1923, Henry 1924, Greaney and Bailey 1927) with wheat being a susceptible host. However McKinney and Davis (1925) considered this medium to be toxic to wheat plants and used a mixture of equal parts of barley and oats. Other solid media were also used by some workers eg. wheat/barley (Griffee 1925), wheat/oats (Christensen 1925), oats (Dosdall 1923), oatmeal (Christensen 1922), oat hulls (Scott and Simmonds 1928,1929) and diseased plant parts (Christensen 1922).

Spore suspensions of the fungus were used in different ways to induce infection. Dosdall (1923), McKinney (1923) and Mitra (1930) applied spore suspensions to the soil while Stakman (1920) and McKinney (1923) immersed the test seed in a spore suspension before planting and Simmonds (1928) dried spores on to the seed coat surface.

Sallans compared both types of infection methods. He found the solid medium method a very effective one and obtained high degrees of infection. However, he maintained the weakness of the method was the difficulty in producing similar conditions in the controls for the addition of an equal volume of sterile medium or sterilised inoculum was found to be injurious to the plants. Using spore suspensions and applying them to the seed he found a fair degree of uniformity of infection could be achieved and recommended this method over the solid inoculum.

Simmonds and Sallans (1946) developed a quick seven day test method to analyse the reaction of a large number of varieties and lines to C.sativus. Test tubes or petri dishes were used to house seeds inoculated with a spore suspension and they were assessed for foot rot lesioning.

Ludwig, Clark, Julien and Robinson (1956) again reviewed methods of artificial inoculation. Using spore suspensions they experienced a large variation between plants within treatments and so reverted to a solid inoculum technique. A standard medium consisting of sand, cornmeal and nutrient salts was developed for the production of inoculum. This medium had several advantages over other media tested (wheat and oathulls). Its composition and method of preparation was easily standardised, its loose texture allowed a rapid and uniform growth of the fungus and it could easily and uniformly be incorporated with soil. Ludwig pointed out that the amount of foreign matter added to the soil with this inoculum was very small since the medium itself contained less than 5% by weight of cornmeal. Some toxic effects, however, were still found to exist.

Hamilton, Clark, Hannah and Loiselle (1960) with modifications to Ludwigs solid inoculum method tested 600 varieties of barley for their reaction to C.sativus. Loiselle (1962, 1964) also used this method to test a further 172 barley varieties and the inheritance of resistance to root rot and seedling blight in barley.

Later workers (Sallans and Tinline 1965), and Harding (1972), and Piening (1973) used naturally infested soil under field conditions. Tyner and Broadfoot (1943) comparing results obtained from naturally infested soil and artificially inoculated field trials suggested that varietal response tests should only be carried out in naturally infested soil for artificial inoculations giving severe disease may kill off seedlings early and the remaining ones having less competition become vigorous and healthy.

Other workers Hayes and Stakman (1921), Arny (1951), Clark (1965) and Nema and Joshi (1971) used the leaf spot response as a criterion for the susceptibility of cultivars to C.sativus. In all cases, except Hayes and Stakman whose work was performed in field conditions, test plants were sprayed with spore suspensions of the fungus, incubated in a moist chamber for 48-72 hours and assessed for leaf lesions. The workers all chose to spray the plants at different growth stages:- Arny at 2nd Leaf Stage, Clark at Leaf Stages 3-4 while Nema and Joshi chose to test the flag leaf susceptibility for the contribution from the flag and upper leaves to the yield in cereal plants has been stressed by a number of workers. In all cases a varying response by different cultivars to this type of infection was experienced.

The head blight phase of the disease was also used for testing the varietal response to C.sativus by Clark (1966). He sprayed plants at the heading stage with a spore suspension and plated out the resultant seed, after surface sterilisation, on Potato Dextrose Agar. The varieties showed a range of susceptibility as seen for the other phases of the disease. An assessment of Kernel Smudge to determine the relative susceptibilities of wheat varieties by observations of the numbers of discoloured kernels was found to be an unreliable method, for Alternaria sp. was found to be the main pathogen. Also the percentage of kernels infected internally with Alternaria sp. and C.sativus was appreciably higher than the percentage exhibiting external symptoms of smudge (Greaney and Wallace 1943).

Workers using the foot rot and leaf spot phases as criteria for disease assessment have shown good correlation between the two phases.

Kommedhahl and Patel (1966) tried to develop a quick and easy method for evaluating hundreds of lines of varieties of wheat for resistance to C.sativus. Ten plants of each variety to be tested were pulled by the heads when grain was in the hard-dough stage. If the root system was badly decayed, the plants were easily uprooted; if not, the heads would break off on being pulled. The number of plants that would be uprooted of ten pulled, would provide a relative measure of that variety's resistance. However, Purss (1970) found no relationship between ease of pulling from the ground and resistance to the disease as measured by discolouration of the subcrown internode.

Techniques used in the present study of varietal response to C.sativus include both solid inoculum and spore suspensions in greenhouse and field trials. A detached leaf method based on a method developed by Person, Samborski and Forsyth (1957) for a quick method of testing large numbers of cultivars has been adapted.

The use of chemical seed treatments as a form of control of C.sativus has been investigated by a number of workers. Early workers Simmonds and Scott (1928) and Machacek, Greaney (1935) found organomercurial seed treatments Ceresan and Semesan to be effective giving better control than copper, nickel or iodine dusts. The mercury compounds gave increased seedling emergence and decreased disease ratings on mature plants with treatments either as dusts or liquids. Greaney and Wallace (1943) testing dressings on naturally infected seed also found mercury compounds Ceresan and Leytosan to be the most effective.

However Moore (1945) and also Jorgensen (1974) reported seed treatment with organomercurial dusts would kill spores adhering to seed but not mycelia present in the tissues of black-pointed seed and mercurial compounds began to loose favour.

Burrage and Tinline (1960) still found organomercurials to have beneficial effects on root rots in the Canadian Prairie Provinces but their use was no longer recommended in Saskatchewan for common root rot. In 1965 in all three Prairie States all seed treatments had only limited use for the control of common root rot for although seed-borne, the soil inoculum of C.sativus built up through many years of monocropping far surpassed seed-borne inoculum in importance. Spring-seeded cereals, when planted into cold Prairie soil, generally escaped root rot infections for several weeks by which time the zones of protection in the immediate vicinity of treated seed would not extend to the developing root system as it spread through the soil making contact with infected debris (Simmonds 1953).

An epidemic of black point disease of wheat in certain parts of India led to a shortage of disease-free seed resulting in a need for a suitable seed treatment to prevent the spread of the disease throughout the whole country. Attempts by several workers were made to evaluate the efficiency of a number of fungicides. Kumar, Ram and Singh (1971) and Vir (1974) used laboratory tests finding that mercury compounds and also some dithiocarbamates gave control of C.sativus.

With the advent of systemic fungicides in the early 1960's North American workers turned to these for control of the soil-borne infection of C.sativus. Edington and Barron (1967) and Kingsland (1969) reported the oxathiin compound, carboxin (Vitavax) to be effective against C.sativus in agar plate tests giving good control at low concentrations. Richardson (1972) with further plate work and seedling tests evaluated further systemics. He also found carboxin effective and also a coded compound G 696 (2.4.dimethyl 5 carboxanilidothiazole) while Benomyl (Benlate 50WP) and Thiophanate (Cercobin) gave no control.

A programme of screening of both commercially available and new experimental seed dressings was undertaken as part of the present project.

C.sativus has been shown by many workers to be a highly variable fungus. Infact it was described by Christensen (1925) as 'a group species consisting of many elementary species or physiologic forms'. These physiologic forms manifest themselves when the fungus is grown on artificial media, and can be separated by morphological and physiological differences. Christensen (1925, 1926), Greaney and Bailey

(1927) and Hynes (1935) separated physiologic forms of the fungus by the observation of morphological characters such as type and amount of aerial mycelia, conidial production, density of conidial clusters and colour of mycelia. Also by combining different temperature and media effects further differentiation was possible (Hynes 1935) and many workers also chose to compare the rate of growth of isolates across agar plates.

Many workers have reported the presence of 'fans' or 'sectors' in growing colonies. These sectors often extend further than the growing colonies due to their faster growth rate and exhibited different morphological characters to the rest of the colony. The 'saltants' could also manifest themselves as 'islands' within the growing colonies usually appearing as sterile white clumps of a much slower growth rate. Christensen (1925) and other early workers proposed that saltations were derived from asexual mutations within the colonies. The mutations were found to occur as frequently in monosporous cultures as in those derived from many spores or from mycelia.

Various factors were found to influence the frequency of the mutations. Many workers found them more prevalent on certain media and Paxton (1932) produced a medium for consistent mutation. This was basically Czapek's salt medium but with the sodium nitrate ommitted and he concluded that a lack of nitrogen was an important factor in causing mutations. Also he found when sucrose was omitted from the Czapeks medium very few sectors were found. Mitra (1931) noted a frequency of sectors in 'rich media' but also noted a tendency for sector formation in shallow rather than deep plates. Christensen (1929) studied the influence of temperature on the frequency of mutation and observed most mutations at temperatures between 25-30°C with very few either below 20°C or above 30°C.

Christensen and Davies (1940) observed isolates of _Bacillus mesentericus_ when grown on artificial liquid or on solid media, produced a substance that induced mutation in certain races of _C.sativus_ while Greaney and Machacek (1932) produced saltations by exposing cultures to ultraviolet light for a four minute period for three successive days.

In a cytological study of conidiogenesis, Christensen and Davies (1937) found that only rarely did more than one nucleus enter the young conidiophore and conidium. They also concluded, therefore, that the occurrence of variants and new strains in _C.sativus_ was attributable mainly to mutations and that heterokaryosis assumed only a minor role, if any. Dickinson (1932) had earlier obtained similar findings with three other species of _Helminthosporium_. However the cultural studies by Shands and Dickson (1933) of hyphal tips from monoconidial isolates and the cytological studies by Graham (1935) suggested that in the related species _H.gramineum_ heterokaryosis might play an important role in variation.

Hrushovetz (1956) with cytological staining methods showed that mechanisms existed for the perpetuation of heterokaryons in _C.sativus_. He showed that hyphal fusions occurred in all parts of colonies and nuclei were observed in the bridging hyphae. In conidiogenesis two or more nuclei were shown to enter the young conidium before it is delimited from the conidiophore.

Tinline (1962) following Hrushovetz's work presented further evidence through genetic studies to substanciate variation through heterokaryosis. He showed herterokaryons were formed by hyphal anastomoses and nuclear migration. However, only a low frequency (6%) of conidia from heterokaryotic cultures perpetuated the heterokaryons. This he suggested was due to a non-random distribution of nuclei in the conidium. Tinline also showed a parasexual cycle to exist with the formation of diploids from the heterokaryotic cells. However the significance of the parasexual cycle in variation is still uncertain.

In the present study a number of isolates of C.sativus obtained from various parts of the world where the fungus is known to be of importance viz. Canada, Australia, India, and the Netherlands, with British isolates using various cultural methods,was compared.

A more important consequence of the variation presented by C.sativus is that of changes in pathogenicity and virulence. Christensen (1925) showed that some mutants differed from their parents colonies, often exhibiting greater virulence. Greaney and Bailey (1927) and Hynes (1935) also presented evidence for differences in virulence of isolates of C.sativus.

More recently evidence has come from Wood (1954) for C.sativus although prevalent for some years on the barley cultivar Kindred, did not become generally destructive on that variety until 1953. In that year losses amounting to 50% of the potential crop occurred in certain areas. Similarly other commercial varieties such as Mars and Bardless, originally fairly resistant to C.sativus have become susceptible. Wood attributed this to new strains of the fungus becoming prevalent.

Hamilton, Clark, Hannah and Loiselle (1960), after evaluating seven isolates of C.sativus in seedling blight tests on four barley varieties stated that there was no evidence of a differential response of the test varieties to those isolates. Hamilton interpreted this as indicating the absence of physiological races within C.sativus. Isolates did, however, differ in their degree of virulence.

Results from further work by Wood (1962) using 103 monosporous isolates of C.sativus obtained from seventeen different states in America from several plant species and parts showed striking differences in parasitism of wheat, barley and oats. Of the 103 isolates tested, 28% were virulent on barley, wheat and oats; 19% on barley and wheat; 1% on wheat and oats; 15% on wheat only; 5% on barley only and 1% on oats only. While 31% were nonpathogenic or caused no apparent damage on any of the three hosts. There was no association between the source of an isolate and its virulence.

The British isolates collected by the author and examined for cultural differences were also compared for differences in pathogenicity and virulence in an attempt to find whether physiologic races or strains of differing virulence exist within Great Britain. Also the pathogenicity and virulence of the British isolates was compared with those from Canada, Australia, India and the Netherlands.

Black-pointed seed are the result of barley kernels becoming infected with spores of C.sativus during maturation. The spores may come from neighbouring crops, grasses or crop refuse (Mead 1942). Little work appears to have been performed on air borne dissemination of C.sativus. However Stakman et al (1922) reported that, as a part of rust epidemiology studies made by the Office of Cereal Investigation of U.S. Department of Agriculture during the summer of 1921, numerous spores of Helminthosporium spp. were present at elevations of upto ten thousand feet.

Simmonds et al (1950) recognised that conidia of C.sativus may be moved by high winds, but that they are not well adapted for air dissemination, the spores being rather large compared to those of the mildew or rust fungi. They also showed that conidia of C.sativus were rarely present in spore trap slides used in rust epidemiology studies in W.Canada.

Investigations were carried out in the present project to ascertain the importance of air-borne dissemination in seed infection by C.sativus under British conditions and to correlate any release of spores with the prevailing environmental conditions or time of day.

## 2. Methods and Materials.

### 2.I. Source of Isolates.

The British isolates of C.sativus were obtained by isolation from infected seed or plant material. The other isolates were sent from various parts of the world on request by the author. Further information of the isolates is given below.

| Isolate No. | Country. | Location. | Date. | Cereal Variety. | Isolate form |
|---|---|---|---|---|---|
| CSS I. | Scotland | Not known. | 1973 | Barley,Clermont. | Seed |
| CSS 2. | Scotland | Not known. | 1973 | Oats. | Seed |
| CSE I. | England | Riseholm, Lincs. | 1972 | Barley,Clermont | Seed |
| CSE 2. | England | Wysall, Notts. | 1973 | Barley, Deba Abed. | Volunteer plants. |
| CSE 3. | England | Peterborough Lincs. | 1974 | Barley,Clermont | Seed |
| CSE 4. | England | Peterborough Lincs. | 1974 | Barley, Deba Abed | Seed |
| CSE 5. | England | Bourne, Lincs. | 1974 | Barley,Clermont | Seed |
| CSN I. | Nethlnds | Not known. | 1973 | Barley, Zephyr | Seed |
| CSN 2. | Nethlnds | Not known. | 1973 | Barley, Delisa | Seed |
| CSN 3. | Nethlnds | Not known. | 1973 | Barley, Cambrinus. | Seed |
| CSN 4. | Nethlnds | Not Known. | 1973 | Barley, Berac | Seed |
| CSC I. | Canada | Saskatoon | 1966 | Wheat, Neewapa | Seed |
| CSC 2. | Canada | Scott. | 1970 | Wheat, Neewapa | Seed |
| CSC 3. | Canada | Regina. | 1972 | Wheat, Cypress | Seed |
| CSC 4. | Canada | Scott. | 1972 | Wheat, Neewapa | Seed |
| CSC 5. | Canada | Swift Current. | 1974 | Wheat, Potam | Seed |

| | | | | | |
|---|---|---|---|---|---|
| CSI 1. | India | Not known. | 1974 | Not known. | |
| CSI 2. | India | Not known. | 1974 | Not known. | |
| CSA I. | Australia | Queensland | 1974 | Wheat | Wheat straw. |

The isolate of F.culmorum was obtained from infected barley cv. Clermont at Codnor, Derbyshire in 1975.

2.2. Maintenance of isolates.

Initially incoming isolates of C.sativus were maintained on slopes of Potato Dextrose Agar (P.D.A.) at 4° C and regularly subcultured.

However, later it was found that maintenance in this way led to some variation in the cultures. In order to prevent this, the fungus was reisolated from the original material. Single spore cultures were prepared and freeze dried. Spores were taken from the cultures of the original material and mixed with 15-20 ml of sterile distilled water in MacCartney bottles. A 0.5 ml aliquot of these spore suspensions was then mixed thoroughly with 20 ml of cooled molten P.D.A. and poured into sterile petri dishes. After incubation at 16° C for 2-3 days colonies from the single spores were removed, replaced on P.D.A. and incubated at 16° C until sporulation was noted. Spore suspensions were then prepared in skimmed milk and freeze dried using a Speedivac Centrifugal Freeze Drier Model 5PS. Freeze dried cultures were then maintained at 4° C until required.

2.3. Preparation of Inoculum.

Several methods of preparation of inoculum for the various procedures within the project were used.

2.3.I. Spore suspensions from Agar Plates.

Spore suspensions were prepared by placing a small volume of sterile distilled water containing a drop of dilute 'Tween 80' on the colony and scaping off the spores with a needle. The resulting spore suspension was then filtered through muslin to remove any mycelium. The concentration of the spore suspension was then adjusted as required using an haemocytometer.

2.3.2. Spore suspensions from Straw Cultures.

Inoculum was also obtained by inoculating cut straw segments with C.sativus and using the resuling spore suspension.

The inoculum was prepared in 250 ml flasks, I.2 gm of cut straw were placed in each flask and moistened with I5 ml of distilled water. The flasks were then autoclaved at I5 lbs/sq.in for I5 minutes. The straw was inoculated with plugs of spores and mycelia taken from I4 day old cultures of C.sativus. After I4 days incubation in a light cabinet at room temperature, 30 ml of sterile distilled water was added to the flasks, their contents placed in a Waring Blendor and mixed for 30 sec so dislodging the spores from the straw segments forming a spore suspension which was then filtered through muslin.

The spore suspension prepared in this way was used for the Wet and Dry Spore inoculation methods (2.4.3.).

2.3.3. Production of Sand/Oatmeal Inoculum.

A sand/oatmeal mixture (I90g sand and I0g oatmeal) was added to a 250 ml flask and moistened with 30 ml of distilled water. The flasks were then autoclaved at a pressure of I5 lbs/sq. in. for I5 minutes. These were then inoculated with I ml of a spore suspension prepared from a ten day old culture of C.sativus. Finally the flasks were incubated in a light cabinet at room temperature for I4 days.

## 2.4. Methods of Inoculation.

### 2.4.1. Naturally infected seed.

In all experiments to test the control of C.sativus by seed dressings naturally infected seed of barley cultivar Clermont was used. This seed was supplied by M.J. Richardson (M.A.F.F. East Craigs, Edinburgh).

### 2.4.2. The Detached Leaf Method.

In this method leaf segments of I4 day old seedlings were inoculated with spore suspensions of C.sativus.

Seeds of the variety to be tested were surface sterilised and planted in John Innes Compost No.2 in the greenhouse. After I4 days the first leaves of the resulting seedlings were removed and 3 cm segments cut. These were then floated (adaxial surface uppermost) in distilled water which filled the compartments (3 x 4 x 3 cm) of ice cube trays which were housed in clear plastic boxes (6 x IO x 25 cm).

Twenty microlitre aliquots of the spore suspension (as described in 2.3.I.) was placed on the centre of the leaf segments using an Eppendorf microlitre pipette. The lids were then placed on the plastic boxes and they were incubated in a light cabinet at room temperature and illuminated with four fourty watt fluorescent strip lights.

In later experiments the ice tray/plastic box system was replaced by the use of small plastic boxes (3.5 x5.5 x I.5 cm). These were found easier to handle and there was less likelihood of the inoculum droplets being dislodged when moved. Also the light cabinet was replaced by a light incubator with controlled temperature.

2.4.3. Inoculations in Greenhouse Experiments.

2.4.3.1. The Wet Spore Method.

The inoculum for this method was prepared from straw cultures as described earlier (2.3.2.). The seeds were immersed in aliquots of the spore suspension in plastic boxes and shaken for 30 sec then drained of the suspension. Thirty seeds, now covered with spores were planted in John Innes Compost No.2 in 7 inch plant pots and covered to a depth of about I inch.

2.4.3.2. The Dry Spore Method.

As with the Wet Spore Method the inoculum was prepared as desribed earlier (2.3.2.). The seeds were immersed in the spore suspension in small plastic boxes. The suspension was then drained off. The seeds were placed in a desiccator overnight. Examination under a stereomicroscope revealed that the spores had adhered to the seed surface. Preliminary experiments had shown spores to maintain viability after this treatment.

2.4.3.3. Sand/Oatmeal Method.

The sand/oatmeal inoculum (2.3.3.) was thoroughly mixed with John Innes Compost No.2 (I part sand/oatmeal to 9 parts compost by volume) and placed in 7 inch plant pots. The seeds were planted at a depth of about I inch.

2.4.4. Inoculations in Field Trials.

Ideally soil naturally infected with C.sativus would have been used for all field experiments. However no such site was available, so an artificial soil inoculum was used. This was prepared as described earlier (2.3.2.). In the I974 field experiments a weighed amount of seed was thoroughly mixed with the straw inoculum. The seed covered with spores were hand sown together with the infected straw to a depth of about I inch. However in 1975 the seeds were sown without the infected straw segments.

The field experiments of 1975 revealed the presence of the foot rot fungus Fusarium culmorum in the soil. F.culmorum was found to be well controlled by Benlate so that in the field trials of varietal resistance to C.sativus in 1976 all the seeds were first treated with Benlate (at the recommended rate of 2.00 gm/Kg seed) and then inoculated with C.sativus using the Dry Spore method as described above (2.4.3.).

## 2.5. Sources of Seed Material.

The seeds were obtained from the following sources:-

| Suppliers. | Cereal. | Variety. | |
|---|---|---|---|
| J.& V. Dalton Ltd. | Barley | Midas | Zephyr |
| Eye, Peterborough | | Berac | Hassan |
| Lincs. | | Proctor | Tern |
| | | Mazurka | Deba Abed |
| | | Wing | Lofa Abed |
| | | Clermont | Vada |
| | | Julia | |
| Wherry Bros. | Barley | Clermont | Wing |
| Bourne | | Zephyr | Abacus |
| Lincs. | Wheat | Mega | Maris Nimrod |
| | | Bouquet | |
| National Institute | Barley | Maris Mink | Mirra |
| Agricultural Botany | | Maris Dingo | Senta |
| Cambridge. | | Hornisse | Astrix |
| | | Maris Otter | Gerkra |
| | | Imber | |

| Supplier. | Cereal. | Variety. | |
|---|---|---|---|
| N.I.A.B. (cont) | Wheat | Tommy | Cardinal |
| | | Cappelle | Champlein |
| Station D'amelioration des plantes. Clermont-Ferrand France. | Barley | Frisia | Kenia |
| | | Bordia | BK 84 |
| Plant Breeding Institute Cambridge. | Barley | Sultan* | |
| Rothwell Plant Breeders Rothwell Lincs. | Barley | Armelle | |

* treated.

## 2.6. Disease Assessment.

### 2.6.I. Assessment of Detached Leaf Inoculations.

(A) Varietal Response.

The assessment of the varietal response of leaf segments to inoculation with spore suspensions was taken as a measure of the size of the lesions produced in response to the inoculum. Those segments showing no lesions were given a score of zero while those showing lesions were scored I - 3 depending on the lesion size.

(B) Pathogenicity Testing.

In the experiments to compare the pathogenicity of different isolates of C.sativus, the size of the lesion produced was again used as the assessment criterion. However in these experiments the length of the lesions (in mms) was measured.

### 2.6.2. Assessment of Foot Rot symptoms.

(A) Visual.

In both greenhouse and field experiments assessment of disease was based on the degree of foot rotting shown. Seedlings were removed from the soil, washed free of any soil particles and given a foot rot rating from the following table.

| Score. | Symptoms. |
|---|---|
| 0 | No visible foot rot symptoms. |
| I | 0-50% of the coleoptile showing foot rot symptoms. |
| 2 | 50-100% of the coleoptile showing symptoms. |
| 3 | All of the coleoptile plus some of the stem and first leaf showing symptoms. |
| 4 | Seedling dead. |

(B) Isolation.

All seedlings showing foot rot symptoms were examined to determine the causal agent. The diseased region was removed, surface sterilised in 10% sodium hypochlorite solution for six minutes, rinsed in sterile distilled water and placed on Potato Dextrose Agar. After 3 - 4 days at room temperature the colonies arising from the infected material were examined under a stereomicroscope and identified.

2.6.3. Assessment of Plant Vigour.

Assessment of plant vigour were performed throughout the growing period of the field trials. Plants assessed after 3 and 5 weeks were categorised according to their stem sheath thickness and degree of tillering:

| Plant Vigour. | Assessment Score. |
|---|---|
| I | Increasing thickness |
| 2 | of stem sheath. |
| 3 | |

4 Seedling tillering.

Representative seedlings for each plant vigour score were first chosen as references. The assessments made in the later weeks and those at harvest were of the number of tillers.

### 2.6.4. Seed Infection levels.

To determine seed infection levels either of incoming samples of seed to the Polytechnic or of seed samples from the field trials, the seed was surface sterilised as described earlier (2.6.2.) plated out on Potato Dextrose Agar and the numbers of seed infected with C.sativus noted.

## 2.7. Chemical Control.

### 2.7.I. Seed Dressing.

Seed dressings were applied at the recommended rates, where known, to naturally infected seed of barley cultivar Clermont. Those dressings of powder formulation were shaken with the seed in plastic bags, while for the liquid dressings the method was to apply the liquids to the inside of a plastic bottle and then agitate the seed in the bottle for 3 - 5 minutes.

### 2.7.2. Sources of Chemical Dressings.

Details of the formulation of the seed dressings are given below.

| Name. | Manufacturers. | Active Ingredient. | Rate. |
|---|---|---|---|
| FX 3248 | Shell | 40% WL 22,36I<br>40% Maneb | 2.0 gm/Kg |
| FX 3250 | Shell | 40% WL 22,36I | 2.0 gm/Kg |
| MC 30/30 | Murphy | Guazatine<br>Maneb | 2.0 gm/Kg |
| MC 30/50 | Murphy | Guazatine<br>Carboxin | 2.0 gm/Kg |
| 6588 | Bayer | Not known | 2.0 gm/Kg |

| Name. | Manufacturers. | Active ingredient. | Rate. |
|---|---|---|---|
| Safeguard | Uniroyal | 20% Carboxin<br>40% Thiram | 2.0gm/Kg |
| Vitaflo | Uniroyal | I5% Carboxin<br>I3% Thiram | 3.0gm/Kg |
| 26,0I9 RP | May, Baker | Hydantoin | I.0gm/Kg |
| SCO 75 | Ciba Geigy | Not known | 2.0ml/Kg |
| FO I50 | Ciba Geigy | Not known | 4.5ml/Kg<br>(after diln.) |
| Apron | Ciba Geigy | Quintacefate<br>Maneb<br>BHC | 2.0gm/Kg |
| Harvesan | Boots | Mercury | 2.0gm/Kg* |
| Mistomatic | Murphy | Mercury | 3.0ml/Kg* |
| Benlate | Du Pont | Benomyl | 2.0ml/Kg* |
| Nusan 30 EC | Buckman Lab. | T.C.M.T.B. | 2.0ml/Kg |
| Benlate T | Du Pont | Benomyl<br>Thiram | 2.0ml/Kg* |

* recommended rate unknown.

2.7.3. Field Trials.

The field trials were carried out at Codnor, Derbyshire. The land was ploughed and rotavated to give, as far as possible, an even tilth. A 20 : I0 : 10 fertiliser was then applied to the soil at a rate of 3.5 cwt/acre.

2.7.3.I. Field Trials I974.

Some preliminary trials were carried out in the summer of I974 to test the effect of a limited number of chemical dressings on *C.sativus*. Two types of field trial were performed. In one the seed dressings were tested under normal field conditions while in the other dressed seeds were sown in compost in pots buried in the soil.

The field sown experiment consisted of two fully randomised replicate blocks (8 x 4 ft) containing two replicate plots of each of three seed dressing treatments and one undressed control. The seed dressings used were Apron, Safeguard, and Harvesan. The seed was hand broadcast within the individual plots (2 x 2ft) and covered to a depth of about one inch. Assessments of the degree of foot rot lesioning were made after 3 and 5 weeks.

In the pot sown experiment the seeds were planted in John Innes Compost No.2 in 9 inch pots and buried in the field. In this way infection levels could be compared with those of the seed grown under normal field conditions (apart from soil) and an assessment of the foot rotting fungi in the field soil made. The design of the experiment was the same as in the field experiment but with fifty seeds sown per pot.

2.7.3.2. Field Trials 1975.

In the summer of 1975 further field trials were performed to test the efficiency of chemical seed dressings against *C.sativus*. Fourteen dressings (2.7.2.), some commercial while others still in experimental stages, were tested.

The experiment was laid down as a single block measuring 36 x 20 ft and contained 45 individual plots each being 4 ft square. Each treatment and the untreated control was replicated three times and fully randomised throughout the block. Within each individual plot six rows of approximately thirty seeds were sown at one inch intervals, the rows being six inches apart.

In the 1974 field trials a certain amount of bird damage had been experienced, in order to combat this plastic netting was erected for protection.

2.7.3.3. Field Trials 1976.

In 1976 a further field trial was performed to test a limited number of seed dressings for control of C.sativus. The dressings, with one exception, had either shown good control in the 1975 trials or contained active ingredients which promised good control.

The experiment was designed in the form of a single block (20 x 12 ft) and comprised of thirty individual plots (4 x 2 ft) containing three replicated rows. These rows were sown with approximately 36 seeds. The six treatments were randomly distributed throughout the block with separate plots for the five different sampling times.

Again the block was covered and surrounded with netting for protection against bird damage.

An experiment to estimate yield loss due to infection by C.sativus and F.culmorum was also designed in 1976. Two seed lots of Clermont barley both naturally infected with C.sativus to differing degrees (13% and 42%) were treated with seed dressings which in the previous year's experiment had been shown to differ widely in control capabilities for C.sativus and F.culmorum. The infection by F.culmorum was provided from the soil.

The lay out of the experiment was the same as that for the control plot above.

## 2.8. Yield Assessments.

At harvest samples were taken from the individual plots and left for several weeks to dry out in the greenhouse. All samples were left to dry for the same time period.

### 2.8.1. Head Weight Determination.

Before thrashing, the weights of intact plant heads were determined. The heads were cut at a distance one inch from the top of the plant stem and individual plant heads weighed.

2.8.2. Total Yields.

All heads within the samples were then thrashed using an Almaco S.P Thresher (Model S.P.T. 66) provided by Sandoz Products Ltd (Agrochemical Division) and the total yields, as weights, from the individual plots determined once the samples had been sieved through a sieve (mesh size 2mm) and any chaff removed.

## 2.9. Cultural Studies.

### 2.9.1. Measurement of Colony Growth Rate.

The rate of growth of isolates of *C.sativus* was measured by recording the growth of the colonies across agar plate surfaces. Each plate contained a measured 20 ml of medium so as to cancel any differences in growth rate that might occur due to availability of substrate or from staling.

The plates were inoculated with a plug, 4 mm in diameter, containing a mass of spores and mycelium. The plug was taken from a ten day old culture of the isolate under examination. The isolates had been maintained at 16°C and originated from a single spore culture .

Measurements of the diameter of growth in two directions at right angles to each other were made every 24 hr. A cross, with its centre directly under the inoculum plug, was drawn on the underside of the plates to ensure the same diameters were measured each day. Four replicates were made of each test.

### 2.9.2. Effect of Media on the Rate of Growth.

The effect of various media on the rate of growth of isolates of *C.sativus* was determined by inoculating plates containing different media as described above.

The test media used were:-

Potato Dextrose Agar. (Difco)

This medium was prepared by adding 39 gm of the powdered medium to I litre of water and boiling until it was completely dissolved.

Oatmeal Agar.

30 gm of powdered oatmeal was boiled in I litre of water for I hour with occasional stirring. The oatmeal solution was then filtered through muslin, made up to 1000 ml, 20 gm of plain agar added and boiled until dissolved.

Potato Carrot Agar.

40 gm of grated potatoes and carrots were first boiled for I hour in tap water, then strained through a fine sieve and 20 gm of agar added. The mixture was then boiled until the agar had dissolved.

V/8 Agar.

20 gms of agar was first dissolved in 800 ml of water and then 200 ml V/8 vegetable juice was then stirred in. The pH was then adjusted to 6.0 with 10% sodium hydroxide.

Czapek Dox Agar (Difco).

The powder was rehydrated by suspending 49 gm in I litre of distilled water. The medium was then completely dissolved by boiling.

Tap Water Agar.

15 gm of plain agar was dissolved in I litre of tap water.

All media were autoclaved at 15 p.s.i. for 15 minutes before use.

2.9.3. Effect of Temperature on Rate of Growth.

The effect of temperature on the rate of growth of different isolates of <u>C.sativus</u> was determined by incubating cultures inoculated as desribed earlier (2.9.I.) at temperatures 16°, 25° and 30°C.

2.9.4. <u>Parameters of Morphological Characters</u>.

A number of different morphological characters of growing colonies were chosen to distinguish isolates of <u>C.sativus</u>. These characters were noted after 6 or 7 days for isolates grown on a number of different media incubated at different temperatures.

2.9.4.I. <u>Aerial Mycelium</u>.

Colonies often differed in their abundance and character of aerial mycelium. In some cases it was so scant as to be unnoticeable, while in others so abundant and fluffy as to obscure from vision the colony beneath, while in other cases still it collected in clumps.

2.9.4.2. <u>Colony Margin</u>.

The colony margins were observed and categorised as either regular, irregular or highly regular.

2.9.4.3. <u>Degree of Sporulation</u>.

Colonies were examined for conidial production and categorised as absent, sparse, moderate or abundant.

2.9.4.4. <u>Production of Sectors</u>.

Saltations appearing as morphologically distinct sectors in the fungal colonies, were noted. The sectors usually appeared as fan-shaped growths if their growth was the same or faster than the parent colonies.

2.9.4.5. <u>Sterile White Clumps</u>.

When the growth rate of saltations was slower than the parent colony they appeared as "islands" on the parent colony and usually did not produce spores. These saltants are described as 'sterile white clumps'.

2.9.5. Cultural Studies testing Seed Dressings.

The seed dressing to be tested was incorporated in Potato Dextrose Agar and the rate of growth of *C.sativus* and *F.culmorum* across the plate determimed. For seed dressings in powder form agar was first dissolved in water before the desired amount of dressing was added. For dressings in liquid form, these were first diluted in distilled water to the desired concentrations, powdered agar added and then boiled until fully dissolved. The concentrations used were 10, 25, 50 and 100 ppm of seed dressing in the media and agar without any seed dressing incorporated acted as the control.

Twenty millilitre aliquots of the molten agar solutions were pipetted into MacCartney bottles which were then autoclaved for 15 minutes at 15 lb/sq.in. At least four replicates of each treatment were prepared. After autocaving the contents of the MacCartney bottles were then poured into individual petri dishes and left to set. The plates were then inoculated as previously described (2.9.1.) and after three days the
2.10. Spore Trapping Experiments rmined.

## 2.10. Spore Trapping Experiments.

2.10.1. Spore Trap and Plot.

A 'Burkard' Seven Day Recording Volumetric Spore Trap was used to examine the dispersal of spores by *C.sativus*. Air was drawn over a tape coated with an adhesive mixture (Vaseline plus 10% paraffin wax in toluene) at a rate of ten litres per minute so trapping released spores. The spore trap was set in the middle of a circular plot (diameter 5 yds) of barley cv. Clermont grown from naturally infected seed.

2.10.2. Examination of Tapes.

The tape rotated within the trap at such a rate as to make one complete revolution in a week. After this time the drum holding the tape was removed and returned to the laboratory. The tape was then cut into segments corresponding to days and mounted on slides in 10% Gelvatol solution before examination under the microscope. Low power examination was found to be sufficient as *C.sativus* produces large spores. On location of a spore the time of trapping to the nearest quarter of an hour could be determined.

Spore trapping in this way was carried out through the entire growing period in 1974 and 1975.

# Results.

## 3.I. Varietal Response.

Commercial varieties of barley, wheat and oats were tested for their resistance to an isolate of C.sativus obtained from infected seeds from Scotland. These tests were carried out in the laboratory, the greenhouse and field.

### 3.I.I. Laboratory Tests : Detached Leaf Method.

A series of experiments were carried out in the laboratory using the detached leaf method. The assessment values are those calculated from the formula -

$$\frac{(a \times 3) + (b \times 2) + (c \times I)}{3 \times (a + b + c)}$$

where 3, 2, and I are the assessment scores for the leaf lesions, and a, b, and c are the numbers of each assessment score.

In all of these experiments significant differences (P =0.005) were recorded between varieties. The results in Table I show the response of 24 varieties of winter and spring barleys to inoculations at spore concentrations of $IO^5$ and $4 \times IO^6$ spores/ml The statistical analysis for this data is given in Appendix Table I. The varieties showed a range of reactions from extremely susceptible (Clermont, Frisia, Astrix) to highly resistant (Sultan).

Tables I and 2. Mean Assessment (0 - I) of Spring and Winter varieties to inoculation with spore suspensions of C.sativus.

| Table I. | Conc. Spores/ml | | Table 2. | Conc. Spores/ml | |
|---|---|---|---|---|---|
| Variety. | $IO^5$ | $4 \times IO^6$ | | $IO^5$ | $5 \times IO^5$ |
| Clermont | 0.777 | I.000 | | I.000 | I.000 |
| Frisia | 0.666 | I.000 | | I.000 | I.000 |
| Astrix | 0.499 | 0.722 | | 0.888 | I.000 |
| Senta | 0.388 | 0.499 | | 0.888 | 0.722 |

Tables I and 2 (cont.)

| Variety. | $IO^5$ | $4 \times IO^6$ | $IO^5$ | $4 \times IO^6$ |
|---|---|---|---|---|
| D. Abed | 0.333 | 0.277 | 0.833 | 0.777 |
| Julia | 0.333 | 0.277 | 0.555 | 0.6II |
| L. Abed | 0.333 | 0.222 | 0.500 | 0.500 |
| Zephyr | 0.277 | 0.277 | 0.722 | I.000 |
| Midas | 0.222 | 0.388 | 0.500 | 0.500 |
| Gerkra | 0.166 | 0.277 | 0.388 | 0.666 |
| Proctor | 0.166 | 0.166 | 0.333 | 0.733 |
| Wing | 0.166 | 0.277 | 0.305 | 0.6II |
| Mirra | 0.III | 0.166 | 0.500 | 0.500 |
| M.otter | 0.III | 0.277 | 0.444 | 0.444 |
| Hassan | 0.III | 0.166 | 0.444 | 0.444 |
| Imber | 0.III | 0.277 | 0.666 | 0.444 |
| Tern | 0.III | 0.166 | 0.444 | 0.666 |
| Kenia | 0.III | 0.166 | 0.400 | 0.6II |
| Vada | 0.III | 0.333 | 0.500 | 0.6II |
| G. Promise | 0.III | 0.222 | 0.444 | 0.666 |
| Bordia | 0.III | 0.055 | 0.6II | 0.555 |
| Mazurka | 0.055 | 0.066 | 0.444 | 0.666 |
| Berac | 0.000 | 0.III | 0.6II | 0.6II |
| Sultan | 0.000 | 0.055 | 0.444 | 0.733 |
| B.K. 84 | | | 0.388 | 0.733 |

L.S.D. ( at 0.I%) for $IO^5$ conc - 0.342.

L.S.D. ( at 0.I%) for $4 \times IO^6$ conc - 0.363.

L.S.D. (at 0.I%) for $IO^5$ conc - 0.218

L.S.D. (at 0.I%) for $5 \times IO^5$ conc - 0.224.

Similar results were obtained in the second experiment presented in Table 2 (statistical analysis in Appendix Table 2) where the spore concentrations used were $IO^5$ and $5 \times IO^5$

spores/ml and an additional cultivar of barley used.

The results were further confirmed in a third experiment (see Table 3 and Appendix Table 3) where the spore concentrations were $5 \times 10^{4}$ and $3 \times 10^{5}$ spores/ml.

Table 3. Mean assessment (0 - I) of Spring and Winter barley varieties to inoculation with spore suspensions of *C.sativus*.

Table 4. Mean assessment (0 - I) three wheat and three barley varieties to inoculation with spore suspensions of *C.sativus*.

| Table 3. Variety. | Conc. Spores/ml. $5\times10^{4}$ | $3\times10^{5}$ |
|---|---|---|
| Clermont | I.000 | I.000 |
| Frisia | 0.555 | 0.666 |
| Astrix | I.000 | I.000 |
| Senta | 0.943 | I.000 |
| D. Abed | 0.888 | I.000 |
| Julia | 0.555 | 0.888 |
| L. Abed | 0.333 | 0.666 |
| Zephyr | 0.777 | I.000 |
| Midas | 0.333 | 0.666 |
| Gerkra | 0.333 | 0.666 |
| Proctor | 0.388 | 0.722 |
| Wing | 0.333 | 0.666 |
| Mirra | 0.333 | 0.666 |
| M.otter | 0.333 | 0.722 |
| Hassan | 0.333 | 0.666 |
| Imber | 0.499 | 0.722 |
| Tern | 0.333 | 0.666 |

| Table 4. Variety. | Conc. Spores/ml. $10^{5}$ |
|---|---|
| Clermont | I.000 |
| M. Mink | 0.444 |
| Sultan | 0.444 |
| Hornisse | 0.444 |
| M. Dingo | 0.222 |
| Champlein | 0.000 |
| Cardinal | 0.III |
| Tommy | 0.III |

L.S.D. (at 0.I%) - 0.4I4

Table 3 (cont.)

| Variety. | Conc. Spores/ml $5 \times 10^4$ | $3 \times 10^5$ |
|---|---|---|
| Kenia | 0.277 | 0.610 |
| Vada | 0.333 | 0.666 |
| G. Promise | 0.333 | 0.666 |
| Bordia | 0.333 | 0.666 |
| Mazurka | 0.333 | 0.666 |
| Berac | 0.555 | 0.733 |
| Sultan | 0.333 | 0.666 |
| B.K. 84 | 0.388 | 0.722 |
| Armelle | 0.333 | 0.666 |

L.S.D. (at 0.1%) for $5 \times 10^4$ conc.- 0.173

L.S.D. (at 0.1%) for $3 \times 10^5$ conc.- 0.115.

In the fourth experiment three varieties of wheat were tested together with three new barley varieties (Hornisse, Maris Dingo and Maris Mink) and two standard barley varieties (Clermont and Sultan). The results are presented in Table 4 and the statistical analysis in Appendix Table 4. The wheat varieties were found to be highly resistant.

3.1.2. Greenhouse Experiments.

Using the dry spore method greenhouse experiments to test varietal response to C.sativus, using the foot rot symptoms for susceptibility assessment, were performed on a number of barley, wheat and an oat variety. Two experiments were carried out, one in July 1974 and the other in September 1974. The mean foot rot rating (from visual assessment) was calculated for each variety and is presented in Table 5 and the statistical analysis of the data in Appendix tables 5a and 5b.

Table 5 a and b.

Mean foot rot ratings of varieties of Barley Wheat and Oats after inoculation with C.sativus using the Dry Spore Method.

| Expt a. Variety. | CON | INOC | Expt b. Variety. | CON | INOC |
|---|---|---|---|---|---|
| Clermont | 0.192 | 0.766 | Clermont | 0.034 | 0.671 |
| D. Abed | 0.321 | 0.523 | D. Abed | 0.055 | 0.306 |
| Julia | 0.018 | 0.281 | Julia | 0.000 | 0.288 |
| L. Abed | 0.125 | 0.347 | L. Abed | 0.000 | 0.233 |
| Zephyr | 0.101 | 0.547 | Zephyr | 0.009 | 0.433 |
| Midas | 0.038 | 0.289 | Midas | 0.009 | 0.279 |
| Proctor | 0.091 | 0.375 | Proctor | 0.014 | 0.277 |
| Wing | 0.013 | 0.097 | Wing | 0.004 | 0.126 |
| Hassan | 0.026 | 0.414 | Hassan | 0.013 | 0.191 |
| Tern | 0.005 | 0.162 | Tern | 0.023 | 0.188 |
| Vada | 0.039 | 0.299 | Vada | 0.013 | 0.283 |
| G. Promise | 0.123 | 0.391 | G. Promise | 0.013 | 0.184 |
| Mazurka | 0.217 | 0.435 | Mazurka | 0.032 | 0.327 |
| Berac | 0.037 | 0.381 | Berac | 0.009 | 0.255 |
| Sultan | 0.009 | 0.236 | Sultan | 0.008 | 0.230 |
| M. Mink | 0.064 | 0.309 | M. Mink | 0.015 | 0.222 |
| M. Dingo | 0.109 | 0.383 | M. Dingo | 0.017 | 0.218 |
| Hornisse | 0.088 | 0.293 | Hornisse | 0.045 | 0.279 |
| Armelle | 0.000 | 0.064 | Armelle | 0.009 | 0.022 |
| Cappelle | 0.053 | 0.152 | Cappelle | 0.034 | 0.179 |
| Cardinal | 0.000 | 0.100 | Cardinal | 0.006 | 0.169 |
| Champlein | 0.048 | 0.199 | Champlein | 0.035 | 0.094 |
| Tommy | 0.011 | 0.000 | Tommy | 0.000 | 0.020 |
| Oats | 0.028 | 0.073 | Oats | 0.005 | 0.019 |

Highly significant differences (P = 0.005) in susceptibility were found between the varieties. The response of the varieties was similar to that found with the detached leaf method. experiments.

### 3.I.3. Field Assessment of Varietal Response.

Field experiments were carried out in 1974, 1975 and 1976 to evaluate the response of varieties after seed inoculation by C.sativus under field conditions.

In the field experiment carried out in 1974 twenty four varieties were tested. Fifty seedlings were removed from the plots 28 days after sowing (growth stages 2 - 3) and visually assessed. The mean percentage infection and foot rot rating for each variety was calculated. These results are presented in Table 6 and the statistical analysis of the data in Appendix

Table 6. Mean percentage infection and foot rot rating of 24 varieties of barley, wheat and oats in a field test after seed inoculation with C.sativus.

| | % infection. | | Foot Rot Rating. | |
|---|---|---|---|---|
| Variety. | CON. | INOC. | CON. | INOC. |
| Clermont | 74.0 | 100.0 | 0.340 | 0.590 |
| D. Abed | 74.0 | 99.0 | 0.285 | 0.450 |
| Julia | 32.0 | 97.0 | 0.090 | 0.433 |
| L. Abed | 46.0 | 87.0 | 0.160 | 0.325 |
| Zephyr | 16.0 | 97.0 | 0.060 | 0.503 |
| Midas | 22.0 | 81.0 | 0.070 | 0.215 |
| Proctor | 18.0 | 99.0 | 0.060 | 0.390 |
| Wing | 56.0 | 86.0 | 0.190 | 0.325 |
| Hassan | 32.0 | 81.0 | 0.090 | 0.263 |
| Tern | 52.0 | 81.0 | 0.150 | 0.325 |

Table 6 (cont.)

| | % infection. | | Foot Rot Rating. | |
|---|---|---|---|---|
| Variety. | CON | INOC | CON | INOC |
| Vada | 48.0 | 86.0 | 0.135 | 0.278 |
| G. Promise | 24.0 | 91.0 | 0.065 | 0.275 |
| Mazurka | 14.0 | 84.0 | 0.050 | 0.308 |
| Berao | 28.0 | 90.0 | 0.085 | 0.305 |
| Sultan | 38.0 | 65.0 | 0.105 | 0.218 |
| M.Mink | 56.0 | 74.0 | 0.185 | 0.250 |
| M.Dingo | 60.0 | 98.0 | 0.240 | 0.380 |
| Hornisse | 30.0 | 100.0 | 0.095 | 0.473 |
| Armelle* | 20.0 | 34.0 | 0.051 | 0.098 |
| Cappelle | 54.0 | 50.0 | 0.160 | 0.155 |
| Cardinal | 36.0 | 28.0 | 0.095 | 0.095 |
| Champlein | 42.0 | 69.0 | 0.120 | 0.213 |
| Tommy | 4.0 | 87.0 | 0.160 | 0.325 |
| Astor | 8.0 | 26.0 | 0.020 | 0.067 |

*treated

It is seen that high levels of foot rot symptoms were present even in the uninoculated plants. Plants inoculated were however significantly (P = 0.005) more diseased than the inoculated. The data on percentage infection failed to show a significant difference between the varieties but on foot rot rating a significant (P = 0.05) difference existed. Lesions from infected seedlings were not plated out in this experiment and therefore the causal agents in the infected plants were not ascertained.

In 1975 a further trial was carried out but with fewer varieties and assessments were made after 21 and 63 days after sowing at growth stages 1 - 2 and 10 - 11 respectively.

In this experiment all seedlings showing foot rot symptoms were plated out so that the lesions could be attributed to either C.sativus or Fusarium spp.

The mean percentage infections attributed to C.sativus and Fusarium spp at the two assessment dates are given in Table 7 and the statistical analysis in Appendix Tables 7a – e.

Table 7. Assessment of Percentage infection of varieties attributed to C.sativus and Fusarium spp. after after 2I and 63 days.

| | C.sativus | | | | Fusarium spp | | | |
|---|---|---|---|---|---|---|---|---|
| | 2I days | | 63 days | | 2I days | | 63 days | |
| Variety. | CON | INOC | CON | INOC | CON | INOC | CON | INOC |
| Clermont | 6.2 | 65.4 | 8.7 | 53.9 | 4.2 | II.9 | 30.4 | I7.I |
| Zephyr | 0.0 | 52.8 | 0.0 | 50.8 | 2.2 | 2.2 | 50.0 | 36.7 |
| Midas | 0.0 | 45.5 | 0.0 | I2.6 | I3.9 | 7.9 | 8I.I | 3I.I |
| Proctor | 0.0 | 40.9 | 0.0 | 36.4 | 0.0 | 4.2 | 46.2 | 28.4 |
| Wing | 0.0 | 43.3 | – | 5.0 | 3.3 | 3.I | – | 30.0 |
| Tern | 0.0 | 55.3 | 0.0 | 30.3 | 3.I | 7.3 | 64.5 | 33.2 |
| G.Prmise | 0.0 | 55.4 | 0.0 | 38.2 | 0.0 | 5.6 | 83.3 | 3I.4 |
| Berac | 0.0 | 2I.I | 0.0 | I5.0 | 4.3 | 2.9 | 62.5 | 58.0 |
| Sultan | 0.0 | 2I.I | 0.0 | 9.5 | 0.0 | 0.0 | 76.0 | 33.3 |
| Cardinal | 0.0 | 22.5 | 0.0 | 25.0 | II.I | I0.0 | 60.0 | 58.3 |
| Oats | I4.0 | I0.0 | 0.0 | 0.0 | 3.4 | 0.0 | 92.3 | 5.6 |

Analysis of the results of percentage infection showed that after 2I days and 63 days the differences between varieties were not significant except for those infected by C.sativus after 63 days.

Fusarium spp. were recovered more often (P = 0.05) from the control plants than from those inoculated with C.sativus after 63 days.

The experiment shows that the foot rot symptoms in the control plots are predominantly due to infections from the soil by Fusarium spp. and this was probably the case in the experiment carried out in 1974.

The calculated mean foot rot ratings of the plants are given in Table 8 with the statistical analyses in Appendix Tables 8a - d.

Table 8. Assessment of mean Foot Rot Rating for varieties attributed to C.sativus and Fusarium spp. after 21 and 63 days.

| Variety. | C.sativus + Fusarium spp. 21 days. | | C.sativus 63 days | | Fusarium spp. 63 days. | |
|---|---|---|---|---|---|---|
| | CON | INOC | CON | INOC | CON | INOC |
| Clermont | 0.030 | 0.345 | 0.054 | 0.395 | 0.183 | 0.127 |
| Zephyr | 0.043 | 0.213 | 0.000 | 0.263 | 0.375 | 0.185 |
| Midas | 0.085 | 0.169 | 0.000 | 0.039 | 0.483 | 0.180 |
| Proctor | 0.017 | 0.143 | 0.000 | 0.170 | 0.250 | 0.136 |
| Wing | 0.108 | 0.131 | - | 0.031 | - | 0.168 |
| Tern | 0.050 | 0.176 | 0.000 | 0.168 | 0.463 | 0.221 |
| G. Promise | 0.100 | 0.188 | 0.000 | 0.245 | 0.358 | 0.123 |
| Berac | 0.097 | 0.105 | 0.000 | 0.080 | 0.260 | 0.269 |
| Sultan | 0.033 | 0.100 | 0.000 | 0.030 | 0.320 | 0.188 |
| Cardinal | 0.067 | 0.137 | 0.000 | 0.062 | 0.215 | 0.354 |
| Oats | 0.043 | 0.046 | 0.000 | 0.000 | 0.423 | 0.006 |

Significant differences (P = 0.05) were only found in foot rot ratings for infection by C.sativus after 63 days.

Also the foot rot ratings attributed to Fusarium spp. in the control plots were significantly (P = 0.05) higher than those inoculated with C.sativus.

An assessment of plant vigour at 2I days and of tillers at 63 days showed there to be no significant differences between inoculated and control plots (Table 9 and Appendix Tables 9a and b).

Table 9. Assessment of Plant Vigour after 2I days and of number of tillers after 63 days.

| | Plant Vigour at 2I days. | | No. Tillers at 63 days. | |
|---|---|---|---|---|
| | CON | INOC | CON | INOC |
| Varieties. | | | | |
| Clermont | 0.583 | 0.606 | I.26 | 0.78 |
| Zephyr | 0.750 | 0.732 | I.20 | 3.60 |
| Midas | 0.855 | 0.8I0 | 3.I8 | 5.73 |
| Proctor | 0.767 | 0.59I | 2.46 | I.42 |
| Wing | 0.865 | 0.8I0 | 6.20 | 6.30 |
| Tern | 0.895 | 0.70I | 4.48 | 3.6I |
| G. Promise | 0.880 | 0.608 | 4.00 | 4.73 |
| Berac | 0.880 | 0.788 | 4.I6 | 3.59 |
| Sultan | 0.875 | 0.544 | 5.44 | 6.95 |
| Cardinal | 0.597 | 0.275 | 0.73 | 0.99 |
| Oats | 0.575 | 0.638 | 0.30 | 0.50 |

A further field trial was initiated in the summer of I976. As in I975 the seeds were also treated by drying spores on to the seed coats but all the seeds were also treated with Benlate to suppress infection by Fusarium spp. from the soil (C.sativus was found to be insensitive to Benlate see 3.4). However, germination was extremely erratic because of the very dry soil conditions and assessments were therefore not possible.

A correlation analysis of the disease rating for 8 varieties was carried out with data from the detached leaf method (Table 4) and greenhouse tests (Table 5b). A correlation was found at the 0.005 level. The correlation coefficient was 0.8868. (See Appendix Table IO).

Because of the interfering presence of <u>Fusarium</u> spp. and the low infection levels of <u>C.sativus</u> no analysis was carried out for field response and greenhouse or detached leaf tests.

## 3.2. Cultural Studies.

The isolates of *C.sativus* collected from Britain and other parts of the world (Netherlands, India, Australia and Canada) were compared for morphological and cultural features as considerable variation in these have been reported.

A preliminary experiment to select media for use for possible separation of isolates was performed using six media on which the growth of the isolates at 25°C was determined.

### Types of Growth on six media.

Potato Dextrose Agar.

Thick, compact colonies with differing degrees of sporulation and aerial mycelia.

Tap Water Agar.

Very sparse growth, with no sporulation observed. The colonies were very difficult to measure on account of their thin growth.

Czapek Dox Agar.

Rapid growth with abundant sporulation.

Potato Carrot Agar.

Thick compact growth with differing amounts of sporulation.

Oatmeal Agar.

Very thick, rapid growth across the plate surface.

V-8 Agar.

Compact colonies with varying degrees of sporulation.

Potato Dextrose Agar, V-8 Agar and Czapek Dox Agar were chosen for further experiments as these had shown the best possibilities of separating isolates by morphological characteristics.

The isolates of *C.sativus* were grown on the media at 16°C 25°C and 30°C and their colony diameters measured. The results are presented in tables 10,11 and 12.

Table IO. Growth of C.sativus on Potato Dextrose Agar.

Mean Diameter (mms)

| Isolate No. | I6°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSS I | 34.33 | 47.I2 | 38.I2 |
| CSS 2 | 33.I6 | 48.I8 | 39.37 |
| CSE 3 | 30.58 | 47.50 | 52.87 |
| CSE 4 | 34.33 | 45.43 | 4I.62 |
| CSE 5 | 30.42 | 44.I8 | 36.43 |
| CSN I | 3I.66 | 48.I8 | 39.37 |
| CSN 2 | 29.I7 | 37.3I | 34.37 |
| CSN 3 | 34.33 | 45.37 | 39.75 |
| CSN 4 | 35.30 | 59.50 | 46.I8 |
| | LSD = 4.8I at I% | LSD = 4.69 at I% | LSD = 2.74 at I% |

| Isolate No. | I6°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSC I | I9.I6 | 27.87 | 37.50 |
| CSC 2 | 27.00 | 36.37 | 67.50 |
| CSC 3 | 33.75 | 50.8I | 6I.50 |
| CSC 4 | 27.66 | 3I.68 | 45.33 |
| CSC 5 | I7.63 | 26.68 | 30.50 |
| | LSD = I.5I at I% | LSD = 2.75 at I% | LSD = 4.86 at I% |

| Isolate No. | I6°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSI I | 23.25 | 37.25 | 42.86 |
| CSI 2 | I9.I6 | 20.50 | 24.08 |

Table II. Growth on Czapek Dox Agar.

Mean Diameter (mms)

| Isolate No. | I6°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSS I | I6.I6 | 74.25 | 73.37 |
| CSS 2 | I0.58 | 77.37 | 73.37 |
| CSE 3 | I2.58 | 55.37 | 65.37 |

Table II (cont) .

| Isolate No. | 16°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSE 4 | I4.75 | 7I.00 | 76.00 |
| CSE 5 | I5.00 | 7I.25 | 73.25 |
| CSN I | I3.75 | 74.00 | 73.50 |
| CSN 2 | I3.50 | 6I.90 | 64.25 |
| CSN 3 | I5.75 | 74.00 | 7I.25 |
| CSN 4 | 20.33 | 76.62 | 73.75 |
| | LSD = 2.9I at I% | LSD = 2.94 at I% | LSD = 2.93 at I% |

| Isolate No. | I6°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSC I | 9.50 | 26.33 | 60.00 |
| CSC 2 | I4.I6 | 74.50 | 79.00 |
| CSC 3 | I3.00 | 80.66 | 7I.83 |
| CSC 4 | I6.50 | 74.33 | 74.I6 |
| CSC 5 | I4.I6 | 37.83 | 59.33 |
| | LSD = 2.62 at I% | LSD = 4.99 at I% | LSD = 8.54 at I% |

| Isolate No. | I6°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSI I | I5.66 | 73.83 | 79.00 |
| CSI 2 | II.33 | 65.I6 | 77.60 |

Table I2. Growth on V-8 Agar.

Mean Diameter (mms)

| Isolate No. | I6°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSS I | 23.58 | 4I.60 | 49.I6 |
| CSS 2 | 20.75 | 34.60 | 42.50 |
| CSE 3 | 23.33 | 39.75 | 5I.50 |
| CSE 4 | 24.42 | 38.70 | 43.I2 |
| CSE 5 | 25.58 | 42.50 | 39.75 |
| CSN I | 22.25 | 47.40 | 50.87 |
| CSN 2 | 22.08 | 47.60 | 50.56 |

Table I2 (cont.)

| Isolate No. | I6°C | 25°C | 30°C |
|---|---|---|---|
| CSN 3 | 22.83 | 45.60 | 53.87 |
| CSN 4 | 24.83 | 50.50 | 53.I6 |
| | LSD = 2.I4 at I% | LSD = 2.34 at I% | LSD = 2.98 at I% |

| Isolate No. | I6°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSC I | I8.66 | 30.33 | 29.83 |
| CSC 2 | 20.83 | 37.50 | 49.66 |
| CSC 3 | 26.50 | 54.I6 | 66.66 |
| CSC 4 | 26.33 | 49.83 | 52.50 |
| CSC 5 | I8.66 | 29.00 | 32.66 |
| | LSD = 2.79 at I% | LSD = 9.53 at I% | LSD = 3.95 at I% |

| Isolate No. | I6°C | 25°C | 30°C After 6 days |
|---|---|---|---|
| CSI I | 27.88 | 43.50 | 62.50 |
| CSI 2 | 2I.50 | 32.70 | 34.66 |

Significant differences between isolates were found regarding the growth on the three media at the three temperatures, by combining the results all isolates could be separated.

The regularity of colony margins, the nature of aerial mycelia, the sporulation, sectoring and presence of sterile white clumps were determined in all the cultures. The results are presented in Tables I3, I4 and I5.

Table I3. Colony Characters on Potato Dextrose Agar.

I6°C. After 6 days.

| Isolate No. | Colony Margin. | Aerial Mycelia. | Sporulation. | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS I | Regular | None | Sparse | None | None |
| CSS 2 | Regular | None | Moderate | None | None |
| CSE 3 | Regular | None | Moderate | None | None |
| CSE 4 | Regular | None | Abundant | None | None |

| Isolate No. | Colony Margin. | Aerial Mycelia. | Sporulation. | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSE 5 | Regular | None | Moderate | None | None |
| CSN I | Regular | None | Abundant | None | None |
| CSN 2 | Regular | None | Sparse | None | None |
| CSN 3 | Regular | None | Moderate | None | None |
| CSN 4 | Regular | None | Moderate | None | None |
| CSC I | Regular | V.thin covering | Moderate | None | None |
| CSC 2 | Regular | Thin white covering | Sparse | None | None |
| CSC 3 | Regular | Thin white covering | Sparse | None | None |
| CSC 4 | Regular | Thin white covering | Sparse | None | None |
| CSC 5 | Regular | V.thin covering | Moderate | None | None |
| CSI I | Regular | Thin white covering | Moderate | None | None |
| CSC 2 | Fluffy | Thin white covering | Moderate | None | None |

25°C. After 6 days.

| Isolate No. | Colony Margin. | Aerial Mycelia. | Sporulation. | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS I | Regular | Thin white covering | Abundant | None | + |
| CSS 2 | Regular | Thin white covering | Abundant | None | + |
| CSE 3 | Irregular | Small tufts | Abundant | None | None |
| CSE 4 | Irregular | Compact thick covering | Abundant | None | None |
| CSE 5 | Regular | Thick white covering | Abundant | None | + |
| CSN I | Irregular | None | Abundant | None | + |
| CSN 2 | Irregular | None | Abundant | None | + |
| CSN 3 | Irregular | Thin white covering | Abundant | None | None |
| CSN 4 | Irregular | Compact thick covering | Abundant | One | ++ |
| CSC I | Irregular | None | Abundant | None | None |
| CSC 2 | Irregular | Thin white covering | Abundant | None | None |
| CSC 3 | Irregular | None | Abundant | None | None |
| CSC 4 | Irregular | Thin white covering | Abundant | None | None |
| CSC 5 | Irregular | None | Abundant | None | None |
| CSI 1 | Irregular | Some around edges | Abundant | None | None |

30°C. After 6 days

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS I | Regular | Covering colonies | Abundant | None | ++ |
| CSS 2 | Regular | Thin white covering | Abundant | None | ++ |
| CSE 3 | Irregular | Little white tufts | Abundant | None | + |
| CSE 4 | Regular | Thick white ring | Abundant | None | ++ |
| CSE 5 | Regular | Thick white ring | Abundant | None | + |
| CSN I | Regular | Thin white covering | Abundant | None | ++ |
| CSN 2 | Regular | Thin white covering | Abundant | None | + |
| CSN 3 | Regular | Thin white covering | Abundant | None | ++ |
| CSN 4 | Regular | Thin white covering | Abundant | None | ++ |
| CSC I | Irregular | Some around centre | Moderate | None | + |
| CSC 2 | Irregular | Thin white covering | Sparse | None | + |
| CSC 3 | Irregular | Thin white covering | Only around colony edge | Two | + |
| CSC 4 | Regular | Thin white covering | Only around colony edge | None | None |
| CSC 5 | Irregular | Some around centre | Abundant | None | + |
| CSI 1 | Irregular | None | Abundant | None | None |
| CSI 2 | Irregular | None | Abundant | One | ++ |

Table I4. Czapek Dox Agar.

After 6 days at I6°C.

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation. | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS I | Regular | None | Sparse | None | None |
| CSS 2 | Regular | None | Sparse | None | None |
| CSE 3 | Regular | None | Sparse | None | None |
| CSE 4 | Regular | None | Sparse | None | None |
| CSE 5 | Regular | None | Sparse | None | None |
| CSN I | Regular | None | Sparse | None | None |
| CSN 2 | Regular | None | Sparse | None | None |
| CSN 3 | Regular | None | Sparse | None | None |
| CSN 4 | Regular | None | Sparse | None | None |

Table I4 (cont)

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation. | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSC I | Regular | None | Sparse | None | None |
| CSC 2 | Regular | Thin white covering | None | None | None |
| CSC 3 | Regular | Thin white covering | None | None | None |
| CSC 4 | Irregular | Thin white covering | None | None | None |
| CSC 5 | Regular | None | Sparse | None | None |
| CSI 1 | Irregular | Thin white covering | Sparse | None | None |
| CSI 2 | Regular | Thin white covering | Sparse | None | None |

25°C. After 6 days.

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS 1 | Regular | None | Abundant | None | None |
| CSS 2 | Regular | None | Abundant | None | None |
| CSE 3 | Regular | None | Moderate | None | None |
| CSE 4 | Regular | None | Moderate | None | None |
| CSE 5 | Regular | None | Abundant | None | None |
| CSN I | Regular | None | Moderate | None | None |
| CSN 2 | Regular | None | Moderate | None | None |
| CSN 3 | Regular | None | Abundant | None | None |
| CSN 4 | Regular | None | Abundant | None | None |
| CSC I | Regular | None | Moderate | None | None |
| CSC 2 | Irregular | Thin white covering | Moderate | None | + |
| CSC 3 | Regular | Thick white covering | Moderate | None | None |
| CSC 4 | Irregular | Sparse white covering | Moderate | None | None |
| CSC 5 | Irregular | None | Moderate | Many | None |
| CSI I | Irregular | None | Moderate | None | None |
| CSI 2 | Regular | Thick white covering | Moderate | None | None |

30°C. After 6 days.

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS I | Regular | None | Abundant | None | + |

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS 2 | Regular | None | Abundant | None | ++ |
| CSE 3 | Regular | None | Abundant | None | + |
| CSE 4 | Regular | None | Moderate | None | +++ |
| CSE 5 | Regular | None | Abundant | None | + |
| CSN I | Regular | None | Abundant | None | + |
| CSN 2 | Regular | None | Moderate | None | + |
| CSN 3 | Regular | None | Abundant | None | + |
| CSN 4 | Regular | None | Abundant | None | ++ |
| CSC I | Irregular | None | Moderate | None | ++ |
| CSC 2 | Irregular | None | Moderate | None | None |
| CSC 3 | Irregular | None | Moderate | None | None |
| CSC 4 | Irregular | None | Moderate | None | None |
| CSC 5 | Irregular | None | Moderate | None | ++ |
| CSI I | Irregular | None | Moderate | None | None |
| CSI 2 | Irregular | None | Moderate | None | ++ |

Table I5. V-8 Agar.

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS I | Highly Regular | None | Moderate | None | None |
| CSS 2 | Highly Regular | None | Moderate | None | None |
| CSE 3 | Highly Regular | None | Moderate | None | None |
| CSE 4 | Highly Regular | None | Moderate | None | None |
| CSE 5 | Highly Regular | None | Moderate | None | None |
| CSN I | Highly Regular | None | Moderate | None | None |
| CSN 2 | Highly Regular | None | Moderate | None | None |
| CSN 3 | Highly Regular | None | Moderate | None | None |
| CSN 4 | Highly Regular | None | Moderate | None | None |
| CSC I | Highly Regular | None | Sparse | None | None |
| CSC 2 | Highly Regular | Thin white covering | Sparse | None | None |

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSC 3 | Regular | Thin white covering | Sparse | None | None |
| CSC 4 | Highly Regular | Thin white covering | Sparse | None | None |
| CSC 5 | Highly Regular | Thin white covering | Sparse | None | None |
| CSI I | Highly Regular | Thin white covering | Only around edge | None | None |
| CSI 2 | Highly Regular | Thin white covering | None | None | None |

25°C. After 6 days.

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS 1 | Regular | None | Only around edge | None | None |
| CSS 2 | Regular | None | Only around edge | None | None |
| CSE 3 | Regular | None | Only around edge | None | None |
| CSE 4 | Regular | None | Only around edge | None | None |
| CSE 5 | Regular | None | Only around edge | One | None |
| CSN 1 | Regular | None | Abundant | None | None |
| CSN 2 | Regular | None | Reduced at edge,centre | None | None |
| CSN 3 | Regular | None | Abundant | None | None |
| CSN 4 | Regular | None | Only around edge | One | None |
| CSC I | Regular | Thin white covering | Moderate | None | None |
| CSC 2 | Irregular | Thin ring around adge | Only around centre | None | + |
| CSC 3 | Regular | None | None | None | None |
| CSC 4 | Regular | None | Only around edge | None | None |
| CSC 5 | Regular | Thin white covering | Moderate | One | None |
| CSI I | Highly Regular | Thin white covering | Only around edge | None | None |
| CSI 2 | Highly Regular | Thick white covering | Only around edge | None | + |

30°C. After 6 days.

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSS I | Highly Regular | None | Sparse | None | ++ |
| CSS 2 | Highly Regular | None | Sparse at centre,edge | One | ++ |
| CSE 3 | Highly Regular | None | Sparse at centre,edge | None | ++ |

Table I5 (cont)

| Isolate No. | Colony Margin | Aerial Mycelia | Sporulation | Sectors | S.W.C. |
|---|---|---|---|---|---|
| CSE 4 | Highly Regular | None | Sparse | None | +++ |
| CSE 5 | Highly Regular | None | Sparce around edge | One | ++ |
| CSN I | Highly Regular | None | Abundant | None | + |
| CSN 2 | Highly Regular | None | Abundant | One | ++ |
| CSN 3 | Highly Regular | None | Moderate | None | + |
| CSN 4 | Highly Regular | None | Sparse | One | + |
| CSC I | Regular | Thick ring within colony | Only around centre | None | ++ |
| CSC 2 | Regular | Thick ring within colony | Only around centre | None | ++ |
| CSC 3 | Regular | None | None | None | None |
| CSC 4 | Regular | None | Only around edge | None | None |
| CSC 5 | Regular | Thick ring around centre | Only around edge | None | None |
| CSI I | Highly Regular | None | Only around edge | None | + |
| CSI 2 | Highly Regular | Thick white ring within | Only around edge | None | + |

Key.

+
++ Increasing numbers of S.W.C.
+++

Combining the colony characters of the isolates grown on the different media, all isolates could be separated by their morphological characteristics. Any colony within a number of replicates that possessed different characteristics to its counterparts was disregarded. At I6°C a very few differences between isolates were experienced on any of the media while at 25°C and 30°C, especially for Potato Dextrose and V-8 Agars morphological differences were most apparent.

No sectors or sterile white clumps were found on colonies grown at I6°C while the number of sterile white clumps was found to increase with incubation temperature. A few sectors were found at both 25°C and 30°C on Potato Dextrose and V - 8 agars, but none on Czapek Dox.

The rates of the growth of the isolates were found to vary with temperature with only slow growth at I6°C while that at 25°C and 30°C, though more rapid, showed little difference. With the slow growth rate at I6°C colony margins were generally regular while at the higher temperatures margins were less so, especially for those grown on Potato Dextrose Agar that secreted brown staling products into the media.

Sporulation was generally sparse or non-existent at I6°C, increasing at 25°C and 30°C, similarly for the amount of aerial mycelium produced which was found to be the most distinct morphological character for isolate sparation.

## 3.3. Pathogenicity of Isolates of C.sativus.

The pathogenicity of isolates of C.sativus was compared using the detached leaf method. Tests were carried out at I6°C and 25°C on varieties of barley, wheat and oat. The barley varieties chosen had shown differential responses in earlier tests using a Scottish isolate of C.sativus.

The isolates were first tested in groups depending on country of origin and then representatives of the groups were compared. The results for barley tested at I6°C are presented in Tables I6 - I9 and the statistical analyses in Appendix Tables IIa - d.

Table I6. Pathogenicity of British Isolates of C.sativus to barley varieties at I6°C.

Mean lesion size (mms)

| Isolate. | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSS I | I3.0 | I2.6 | 9.3 | 3.0 | 9.5 |
| CSS 2 | I0.3 | II.8 | I0.0 | 5.6 | 9.4 |
| CSE I | I0.8 | I2.0 | I0.8 | 3.8 | 9.4 |
| CSE 2 | I0.6 | I2.4 | II.2 | 5.0 | 9.8 |
| CSE 3 | I5.0 | I4.4 | II.4 | 4.0 | II.2 |
| CSE 4 | I4.4 | I3.7 | I0.6 | 3.2 | I0.5 |
| CSE 5 | I0.6 | I2.0 | 7.8 | 4.2 | 8.7 |

Table I7. Pathogenicity of Netherlands Isolates of C.sativus to barley varieties at I6°C.

Mean Lesion Size (mms)

| Isolate. | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSN I | I2.4 | 9.4 | 6.8 | 3.4 | 8.0 |
| CSN 2 | I2.2 | 9.8 | 9.0 | 2.2 | 8.3 |
| CSN 3 | I3.4 | II.4 | I4.0 | 7.8 | II.6 |
| CSN 4 | I2.8 | 8.8 | 7.4 | 4.0 | 8.3 |

Table I8. Pathogenicity of Canadian Isolates of C.sativus to barley varieties at I6°C.

Mean Lesion-size (mms)

| Isolate | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSC I | I2.2 | I0.8 | II.4 | I0.2 | II.2 |
| CSC 2 | 7.6 | 4.2 | 6.2 | 7.4 | 6.4 |
| CSC 3 | 8.2 | 7.6 | 7.4 | II.0 | 8.6 |
| CSC 4 | II.0 | 9.2 | I0.4 | II.0 | I0.4 |
| CSC 5 | 9.8 | 6.8 | 8.4 | 7.8 | 8.2 |

L.S.D. = 3.I
at I%

Table I9. Pathogenicity of Indian and Australian Isolates of C.sativus to barley varieties at I6°C.

Mean Lesion Size after 3 days.

| Isolate | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSI I | I.6 | 2.2 | 0.6 | 2.8 | I.8 |
| CSI 2 | I.6 | I.4 | 2.4 | 3.0 | 2.I |
| CSA I | 2.4 | I.4 | 2.0 | I.8 | I.9 |

No significant differences in pathogenicity were found within the British, Netherlands, and Indian groups, however differences (P = 0.005) were present within the Canadian isolates.

Table 20. Pathogenicity of Group Representatives to barley varieties after 2 days at I6°C.

Mean Lesion Size (mms).

| Isolate | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSE 2 | II.6 | 8.8 | 8.2 | 5.2 | 8.4 |
| CSE 3 | I2.3 | 9.8 | 4.4 | 3.8 | 7.6 |
| CSN 3 | 8.4 | 5.4 | 7.0 | 3.4 | 6.I |
| CSN 4 | 7.6 | 6.2 | 3.0 | I.6 | 4.6 |

Table 20 (cont)

| Isolate | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSC I | 3.8 | 4.4 | 3.8 | 4.2 | 4.I |
| CSC 2 | 3.8 | 3.6 | 2.8 | 4.0 | 3.6 |
| CSC 3 | 2.8 | 3.0 | I.8 | 3.0 | 2.7 |
| CSI 2 | 3.4 | 3.4 | I.6 | 2.4 | 2.7 |
| CSA I | 2.2 | 2.7 | 2.0 | 2.4 | 2.3 |

L.S.D. = 2.4 at I%

Statistical analysis of the group representatives was performed and the results taken after 2 days for some leaf segments were fully colonised by 3 days. The analysis showed significant differences (P = 0.005) between the group representatives (See Appendix Table IIe). The British isolates CSE 2, CSE 3, were found to be the most virulent, with the Netherlands isolates intermediate and the other isolates (Canadian, Indian and Australian) the least pathogenic.

The British and Netherlands isolates showed a similar reaction regarding variety susceptibility with the order of susceptibility being Clermont > Zephyr > Julia > Wing. However for the Canadian, Australian and Indian isolates the varieties showed similar susceptibility.

The reaction of wheat varieties to inoculation with a spore suspension of C.sativus was less clear than that for barley. With barley distinct brown lesions were apparent while with wheat small necrotic spots were found on less susceptible varieties compared to light yellow-brown lesions on those more susceptible. The results of the tests performed in groups as for the barley are presented in Tables 2I - 24 and the statistical analyses in Appendix Tables I2a - d.

Table 2I. Pathogenicity of British isolates of C.sativus to wheat varieties after 2 days at I6°C.

Mean Lesion Size (mms).

| Isolate | M.Nimrod | Bouquet | Mega | Atou | Mean |
|---|---|---|---|---|---|
| CSS I | 0.2 | 0.8 | 0.4 | I.2 | 0.7 |
| CSS 2 | 0.8 | I.0 | 0.8 | I.8 | I.I |
| CSE I | 0.0 | I.0 | I.6 | I.6 | 0.9 |
| CSE 2 | 2.0 | 2.0 | 2.4 | 2.4 | 2.2 |
| CSE 3 | I.6 | I.8 | 2.0 | 2.0 | I.9 |
| CSE 4 | 0.2 | I.2 | I.2 | I.2 | 0.9 |
| CSE 5 | I.4 | I.2 | I.8 | 2.0 | I.6 |

Table 22. Pathogenicity of Netherlands isolates of C,sativus TO WHEAT VARIETIES after 3 days at I6°C.

Mean Lesion Size (mms).

| Isolate | M.Nimrod | Bouquet | Mega | Atou | Mean |
|---|---|---|---|---|---|
| CSN I | 3.8 | 3.6 | I.6 | 2.4 | 2.9 |
| CSN 2 | 4.2 | 4.2 | 2.2 | 3.4 | 3.5 |
| CSN 3 | 0.0 | 0.2 | 0.6 | 0.8 | Low inoc |
| CSN 4 | 3.2 | 4.6 | 3.8 | 2.8 | 3.6 |

Table 23. Pathogenicity of Canadian Isolates of C.sativus to Wheat Varieties after 4 days at I6°C.

Mean Lesion Size (mms).

| Isolate | M.Nimrod | Bouquet | Mega | Atou | Mean |
|---|---|---|---|---|---|
| CSC I | 4.8 | 3.4 | I.6 | 2.4 | 3.I |
| CSC 2 | 7.6 | 4.4 | 2.0 | 5.8 | 4.9 |
| CSC 3 | 6.0 | I.0 | 5.8 | I.8 | 3.7 |
| CSC 4 | I.0 | 0.4 | I.4 | 0.4 | 0.8 |

Table 23 (cont)

| Isolate | M.Nimrod | Bouquet | Mega | Atou | Mean |
|---|---|---|---|---|---|
| CSC 5 | 3.4 | I.4 | 2.2 | 2.2 | 2.3 |

L.S.D. = I.6 at I%

Table 24. Pathogenicity of Indian and Australian isolates of C.sativus to Wheat varieties after 3 days at I6°C.

Mean Lesion Size (mms)

| Isolate | M.Nimrod | Bouquet | Mega | Atou | Mean |
|---|---|---|---|---|---|
| CSI I | 7.4 | 5.6 | 9.0 | 8.4 | 7.6 |
| CSI 2 | 9.0 | 4.6 | 8.8 | 9.3 | 7.9 |
| CSA I | 4.2 | 3.0 | 2.4 | 4.0 | 3.4 |

No significant differences were found within the groups of British, Netherlands and Indian isolates, but as with barley, significant differences (P = 0.005) were found within the Canadian group of isolates.

Significant differences (P =0.005) in pathogenicity were found in representatives of the groups ( Table 25 and Appendix Table I2e) with the Australian isolate CSA I appearing less virulent than the other isolates. The pathogenicity of all isolates was much less than for the barley varieties.

Table 25. Pathogenicity of Group Representatives to wheat after 3 days at I6°C.

Mean Lesion Size (mms)

| Isolate | M.Nimrod | Bouquet | Mega | Atou | Mean |
|---|---|---|---|---|---|
| CSE 2 | I.2 | 2.0 | I.2 | I.0 | I.4 |
| CSN 4 | I.8 | I.4 | I.8 | I.2 | I.5 |
| CSC I | 4.0 | 2.0 | I.4 | 2.4 | 2.5 |
| CSC 2 | 2.8 | I.2 | I.4 | 4.8 | 2.6 |

Table 25 (cont).

| Isolate | M.Nimrod | Bouquet | Mega | Atou | Mean |
|---|---|---|---|---|---|
| CSC 4 | I.4 | 0.8 | I.4 | 2.0 | I.4 |
| CSI 2 | 2.8 | 0.2 | 4.8 | I.8 | 2.4 |
| CSA I | 0.6 | 0.6 | 0.4 | I.4 | 0.8 |

L.S.D. = I.3 at I%

Infection of oats (cv Astor) leaf segments was found to be less than for either barley or wheat. Significant differences (P = 0.005) between isolates from the British and Canadian groups were found but not for the Netherlands and Indian isolates. See Table 26 and Appendix Tables I3a - c.

Table 26. Pathogenicity of all isolates of C.sativus to Astor (oats) after 3 days at I6°C.

Leaf Lesion Size (mms)

| Isolate | Lesion Size | Isolate | Lesion Size. |
|---|---|---|---|
| CSS I | - | CSN I | I.8 |
| CSS 2 | I.4 | CSN 2 | I.6 |
| CSE I | 0.8 | CSN 3 | - |
| CSE 2 | I.6 | CSN 4 | I.6 |
| CSE 3 | 0.6 | **Isolate** | **Lesion Size** |
| CSE 4 | I.4 | CSC I | 6.8 |
| CSE 5 | 0.6 | CSC 2 | 2.0 |
| **Isolate** | **Lesion Size** | CSC 3 | 2.0 |
| CSI I | I.4 | CSC 4 | 2.0 |
| CSI 2 | I.2 | CSC 5 | 5.0 |
| CSA I | 0.2 | | |

Comparison of representatives of the groups (See Table 27 and Appendix Table I3d) showed significant differences (P =0.005) between the isolates but the variety of oats used must be considered to be highly resistant to C.sativus.

Table 27. Pathogenicity of Group Representatives to Astor (oats) after 3 days at I6°C.

Mean Lesion Size (mms).

| Isolate | Lesion Size | Isolate | Lesion Size |
|---|---|---|---|
| CSE 3 | I.8 | CSC 5 | 2.0 |
| CSN 4 | 2.0 | CSI 2 | 3.0 |
| CSC 4 | 0.8 | CSA I | 2.0 |
| CSC 2 | 2.4 | L.S.D. = 0.8 at I% | |

Tests of pathogenicity of the isolates at 25 C on barley showed infection was accelerated with the temperature increase with readings being taken after I or 2 days instead of 3 or 4. The tests were performed in groups as for those at I6 C. The results are presented in Tables 28 - 3I and the statistical analyses in Appendix Tables I4a - d.

Table 28. Pathogenicity of British Isolates of C.sativus to barley varieties after 2 days at 25°C.

Mean Lesion (mms).

| Isolate | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSS I | I2.0 | 8.3 | 5.0 | 2.0 | 6.8 |
| CSS 2 | II.3 | 9.0 | 6.0 | 2.0 | 7.I |
| CSE I | 8.8 | 3.5 | 3.5 | I.7 | 4.8 |
| CSE 2 | 9.2 | 8.5 | 5.0 | 2.0 | 6.2 |
| CSE 3 | I0.8 | 6.0 | 4.0 | 2.0 | 5.7 |
| CSE 4 | II.2 | 7.8 | 5.0 | 2.0 | 6.5 |
| CSE 5 | I0.0 | 7.0 | 5.0 | 3.0 | 6.3 |

Table 29. Pathogenicity of Netherlands Isolates to barley varieties after I day at 25°C.

Mean Lesion Size (mms)

| Isolate | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSN I | 5.4 | 4.8 | 2.0 | 2.0 | 3.6 |
| CSN 2 | 6.2 | 2.8 | 2.0 | I.8 | 3.2 |
| CSN 3 | 5.2 | 0.4 | I.0 | 0.4 | I.8 |
| CSN 4 | 6.4 | I.2 | I.2 | 0.2 | 2.3 |

L.S.D. = I.7 at I%

Table 30. Pathogenicity of Canadian isolates of C.sativus to barley varieties after 2 days at 25°C.

Mean Lesion Size (mms)

| Isolate | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSC I | 2.4 | I.8 | 0.4 | 2.2 | I.7 |
| CSC 2 | 2.6 | 0.2 | 0.0 | I.8 | I.2 |
| CSC 3 | 2.2 | 2,2 | 2.0 | 3.2 | 2.4 |
| CSC 4 | 2.0 | 0.4 | I.0 | I.8 | I.3 |
| CSC 5 | I.6 | I.2 | I.2 | 2.4 | I.6 |

Table 3I. Pathogenicity of Indian and Australian Isolates of C.sativus to barley varieties after 2 days at 25°C

Mean Lesion Size (mms)

| Isolate | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSS I | 2.0 | I.6 | I.8 | 2.0 | I.9 |
| CSI 2 | 2.0 | I.0 | I.4 | I.2 | I.4 |
| CSA I | 3.8 | 2.0 | 2.0 | 2.0 | 2.5 |

No significant differences in isolate pathogenicity were found within the British, Canadian and Indian groups but significant differences ($P = 0.05$) were found within the

Netherlands group. The varietal susceptibility differences seen in the tests at 16 C were also present at 25°C.

Comparison of pathogenicity of representatives from the groups (See Table 32 and Appendix Table 14d) gave highly significant differences (P = 0.005) at 25°C with again the British and Netherlands isolates showing greater pathogenicity than the Indian, Canadian and Australian ones.

Table 32. Pathogenicity of Representatives of Groups to barley varieties after 2 days at 25°C.

Mean Lesion Size (mms).

| Isolate | Clermont | Zephyr | Julia | Wing | Mean |
|---|---|---|---|---|---|
| CSE 4 | 13.2 | 4.5 | 4.8 | 2.2 | 6.2 |
| CSN 3 | 9.2 | 4.8 | 4.4 | 2.0 | 5.1 |
| CSN 4 | 9.5 | 4.8 | 4.8 | 5.8 | 6.2 |
| CSC 4 | 2.2 | 2.0 | 1.8 | 1.6 | 1.9 |
| CSI 2 | 2.0 | 2.6 | 1.6 | 3.4 | 2.4 |
| CSA 1 | 2.0 | 1.0 | 1.8 | 1.4 | 1.6 |

The pathogenicity of the isolates to wheat at 25°C was not as accelerated as had been found for the barley, the results are presented in Tables 33 - 36 and Appendix Tables 15a - d.

Tables 33. Pathogenicity of British Isolates of C.sativus to Wheat varieties after 2 days at 25°C.

| Isolate | M.Nimrod | Bouquet | Mega | Atou | Mean |
|---|---|---|---|---|---|
| CSS 1 | 1.6 | 1.0 | 1.4 | 1.4 | 1.4 |
| CSS 2 | 1.6 | 2.0 | 2.8 | 2.4 | 1.9 |
| CSE 1 | 3.0 | 2.0 | 2.8 | 2.4 | 2.6 |
| CSE 2 | 1.1 | 2.0 | 2.4 | 2.8 | 2.1 |
| CSE 3 | 2.2 | 3.2 | 2.2 | 3.4 | 2.4 |
| CSE 4 | 1.8 | 2.2 | 2.0 | 2.0 | 2.0 |
| CSE 5 | 3.6 | 2.2 | 2.6 | 3.2 | 2.9 |

L.S.D. = 0.68 at 1%

Table 34. Pathogenicity of Netherlands Isolates of C.sativus

| Isolate | M.Nimrod | Bouquet | Atou | Mean |
|---|---|---|---|---|
| CSN I | 0.4 | I.0 | 0.4 | 0.6 |
| CSN 2 | I.4 | I.2 | I.4 | I.3 |
| CSN 3 | 2.0 | I.0 | I.6 | I.5 |
| CSN 4 | 0.6 | 0.6 | I.0 | 0.7 |

L.S.D. =0.9 at I%

Table 35. Pathogenicity of Canadian Isolates of C.sativus to Wheat varieties after 2 days at 25°C.

Mean Lesion Size (mms)

| Isolate | M.Nimrod | Bouquet | Atou | Mean |
|---|---|---|---|---|
| CSC I | 0.6 | 0.6 | I.6 | 0.9 |
| CSC 2 | 5.4 | 3.8 | 6.2 | 4.8 |
| CSC 3 | 0.4 | 0.0 | I.4 | 0.6 |
| CSC 4 | I.4 | 2.4 | 3.8 | 2.5 |
| CSC 5 | 3.0 | 2.4 | 2.4 | 2.8 |

L.S.D. = 0.7 at I%

Table 36. Pathogenicity of Indian and Australian Isolates of C.sativus to Wheat Varieties after 2 days at 25°C

Mean Lesion Size (mms)

| Isolate | M.Nimrod | Bouquet | Atou | Mean |
|---|---|---|---|---|
| CSI I | 4.2 | 4.8 | 0.0 | 3.0 |
| CSI 2 | 7.4 | 7.2 | 6.6 | 7.I |
| CSA I | 2.0 | 0.6 | 2.2 | I.6 |

Highly significant differences (P = 0.005) were found within the British, Canadian, and Indian groups with significant differences (P = 0.05) within the Netherlands isolates.

The results of the comparison of the representatives of the groups are presented in Table 37 and the statistical analysis in Appendix Table I5a.

Table 37. Pathogenicity of Group Representatives to wheat varieties after 2 days at 25°C.

| Isolate | Mean Lesion Size (mms) M.Nimrod | Bouquet | Atou | Mean |
|---|---|---|---|---|
| CSS I | 4.0 | 2.4 | 3.4 | 3.3 |
| CSE 3 | 3.2 | 3.2 | 3.0 | 3.I |
| CSN 3 | 2.2 | I.8 | 0.8 | I.6 |
| CSN 4 | 0.8 | 2.4 | 2.4 | I.9 |
| CSC 2 | 4.6 | 3.8 | 6.0 | 4.8 |
| CSC 3 | 6.6 | 5.8 | 7.4 | 6.6 |
| CSI I | 6.2 | 5.0 | 6.8 | 6.0 |
| CSI 2 | 7.0 | 6.4 | 7.0 | 6.8 |
| CSA I | 2.6 | 2.6 | 2.2 | 2.5 |

L.S.D. = I.5 at I%

Highly significant differences between the isolates (P =0.005) were found. The Indian and the Canadian isolate CSC 2 were found to be the most pathogenic to the wheat varieties at 25°C. There was little difference between the other isolates.

The reaction of the isolates to Astor (oats) was very similar at 25°C to that at I6°C.See Table 38 and Appendix Table I6a - c.

Table 38. The Pathogenicity of all isolates of C.sativus to Astor (oats) after 2 days at 25°C.

| Isolate | Lesion size | Isolate | Lesion size (mms) |
|---|---|---|---|
| CSS I | 0.5 | CSN I | I.0 |
| CSS 2 | 2.0 | CSN 2 | 0.4 |
| CSE I | 0.3 | CSN 3 | 0.0 |
| CSE 2 | 0.3 | CSN 4 | 0.2 |

| Isolate | Lesion Size | Isolate | Lesion Size |
|---|---|---|---|
| CSE 3 | 0.3 | CSC I | 0.0 |
| CSE 4 | 0.3 | CSC 2 | 0.0 |
| CSE 5 | 0.5 | CSC 3 | 0.2 |
| CSI I | 0.0 | CSC 4 | 0.0 |
| CSI 2 | I.2 | CSC 5 | 0.0 |
| CSA I | 0.0 | | |

Infection levels as in the tests at I6°C were extremely low showing Astor to be highly resistant. Significant differences (P = 0.05) were found between the Netherlands isolates. The comparison of the group representatives are shown in Table 39 and the statistical analysis in Appendix Table I6d.

Table 39. Pathogenicity of Group Representatives of C.sativus to Astor (oats) after 2 days at 25°C.

Mean Lesion Size (mms)

| Isolate | Lesion Size | Isolate | Lesion Size |
|---|---|---|---|
| CSE 4 | 0.2 | CSC 4 | 0.4 |
| CSN 3 | 0.4 | CSI 2 | 0.6 |
| CSN 4 | 0.8 | CSA I | 0.6 |

No significant differences were found between the isolates with extremely low infection levels.

## 3.4. Chemical Control.

Field experiments were carried out in I974, I975 and I976.

### 3.4.I. Field Experiment I974.

In I974 two preliminary experiments were carried out in the field to test the effectiveness of three commercially available cereal seed dressings. A naturally infected seed sample of barley cv. Clermont from Scotland was used in both experiments and the dressings were applied at the recommended rates.

In the first experiment the seeds were sown in pots (John Innes Compost No.2) which were buried in the soil and protected by netting. The germination and visual assessment were made at 2I days and 42 days after sowing and these are shown in Table 40 and the statistical analysis of the data is given in Appendix Tables I7 a - e. At both dates although it appeared that the seed treaments gave an increase in the percentage germination over the untreated control, the differences were not statistically significant.

Table 40. The mean percentage germination, infection and foot rot rating of seedlings of barley cv Clermont treated with Harvesan, Apron and Safeguard in pots in the field.

| | 2I days | | 42 days | | |
|---|---|---|---|---|---|
| Treatment | % germ | % inf | % germ | % inf | FRR |
| Untreated | 87.00 | 86.I2 | 85.00 | 97.64 | 0.578 |
| Harvesan | 90.00 | 7.45 | 93.00 | 73.32 | 0.267 |
| Apron | 99.00 | 7.I5 | 95.00 | 7I.49 | 0.244 |
| Safeguard | 97.00 | I.02 | 93.00 | 63.79 | 0.255 |

LSD (at I%) for % inf. at 2I days = 4.36

LSD (at I%) for % inf. at 42 days = 3.48

LSD (at 1%) for F.R.R. at 42 days = 0.008

When the germinated seedlings were examined after 2I days a visual assessment showed that 86% of the emerged seedlings from the untreated seeds were showing disease symptoms (foot rot). The chemical treatment of the seeds significantly reduced the observed disease symptoms, with Safeguard giving the most effective and very satisfactory control.

By the 42nd day the level of disease in the untreated had risen to 98%. This was also accompanied by a increase in disease levels in the treated seeds. The levels of disease in the treated seedlings were however significantly less (P =0.05) than in the untreated but not at a satisfactory level.

The foot rot rating of seedlings assessed on the 42nd day showed that the chemical treatment also significantly (P = 0.005) reduced the severity of the foot rot symptoms on the diseased seedlings.

In the second experiment the seeds were sown in the soil of the field plots were not protected. A sample of 100 seedlings from each plot were examined at 2I days and 35 days after sowing. The levels of disease, in this experiment are shown in Table 4I and the statistical analysis in Appendix Tables I8a - c. It can be seen that the percentage infection of emerged seedlings was of the same order as in the pot sown plots. As before three chemical treatments appreciably (P = 0.005) reduced disease incidence and severity.

Table 4I. The mean percentage infection and foot rot rating of seedlings of barley cv Clermont treated with Harvesan Apron, and Safeguard in field plots.

| Treatment | 21 days % inf. | 35 days % inf. | F.R.R. |
|---|---|---|---|
| Untreated | 84.50 | 96.00 | 0.596 |
| Harvesan | 14.50 | 52.00 | 0.211 |
| Apron | 27.50 | 62.50 | 0.293 |
| Safeguard | 15.75 | 45.00 | 0.169 |

LSD (at 1%) for mean % inf at 21 days = 2.33

LSD (at 1%) for mean % inf at 35 days = 3.78

LSD (at 1%) for mean F.R.R. at 35 days = 0.03

### 3.4.2. Field Experiment 1975.

A field experiment was carried out in 1975 where fourteen seed dressings were applied to the same sample of seed of barley cv Clermont as used in 1974.

As the two assessment dates in the 1974 experiments showed differences in levels of disease with time it was decided to remove and examine seedlings from 3ft rows at two weekly intervals from the 3rd week after sowing.

Initially all the seedlings which were removed and assessed for symptoms were plated out on to P.D.A. All seedlings not showing foot rot symptoms did not yield any fungus so at later assessments only those showing lesions were plated out.

The percentage of emerged seedlings with lesions at 3, 5, 7 and 9 weeks after sowing attributed to C.sativus alone is given in Table 42 and the statistical analyses in Tables 19a - d.

Table 42. Mean percentage infection of seedlings of barley cv Clermont attributed to C.sativus when treated by seed dressings.

| Treatment. | Assessment times (after sowing). 21 days | 35 days | 49 days | 63 days |
|---|---|---|---|---|
| Untreated | 41.83 | 53.00 | 45.20 | 40.86 |
| Benlate | 35.86 | 66.56 | 79.60 | 78.30 |
| FX 3250 | 25.06 | 20.90 | 34.23 | 30.13 |
| Harvesan | 12.00 | 24.06 | 24.53 | 15.63 |
| FO 150 | 9.53 | 22.46 | 20.36 | 13.96 |
| SCO 75 | 9.36 | 18.75 | 18.33 | 22.66 |
| Safeguard | 7.60 | 10.43 | 18.33 | 13.53 |
| Apron | 7.40 | 14.06 | 21.00 | 13.23 |
| 6588 | 7.13 | 23.53 | 24.46 | 21.03 |
| 26,019 RP | 3.26 | 8.30 | 11.43 | 3.63 |
| Mistomatic | 5.26 | 23.10 | 21.83 | 20.33 |
| FX 3248 | 0.10 | 14.26 | 20.76 | 12.96 |
| Vitaflo | 0.00 | 0.00 | 9.60 | 5.43 |
| MC 30/30 | 0.00 | 12.73 | 2.90 | 11.30 |
| MC 30/50 | 0.00 | 9.60 | 5.66 | 4.36 |

With the exception of Benlate, the seed dressings significantly ($P = 0.005$) reduced the level of infection. The dressings ranged in their effectiveness which, as in 1974, seemed to decrease with time after sowing. Benlate significantly increased the incidence at 3 out of the 4 assessment periods. When the isolations from the seedlings taken after 21 days were examined it was found that a number of the lesions could be attributed to infection by Fusarium spp. and in particular F.culmorum. Table 43 shows the percentage of infected seedlings which could be attributed to Fusarium spp. infection. The statistical analysis is given in Appendix Tables 20a - d.

Table 43. Mean percentage infection of seedlings of barley cv. Clermont attributed to Fusarium spp when treated with seed dressings.

| | Assessment time (after sowing). | | | |
|---|---|---|---|---|
| Treatment | 21 days | 35 days | 49 days | 63 days |
| Untreated | 5.23 | 11.80 | 12.53 | 7.23 |
| Benlate | 0.00 | 0.00 | 2.96 | 2.00 |
| FX 3250 | 7.16 | 24.40 | 21.50 | 14.70 |
| Harvesan | 0.00 | 2.53 | 6.56 | 5.70 |
| FO 150 | 3.30 | 3.96 | 18.56 | 6.56 |
| SCO 75 | 0.00 | 1.80 | 17.46 | 4.93 |
| Safeguard | 0.00 | 3.33 | 1.43 | 5.76 |
| Apron | 2.23 | 15.10 | 9.53 | 20.93 |
| 6588 | 0.00 | 17.60 | 10.63 | 13.20 |
| 26,019 RP | 10.30 | 28.96 | 22.66 | 27.56 |
| Mistomatic | 0.63 | 1.10 | 0.63 | 1.26 |
| FX 3248 | 3.16 | 23.43 | 23.23 | 24.53 |
| Vitaflo | 0.00 | 2.30 | 8.10 | 15.63 |
| MC 30/30 | 1.23 | 3.66 | 7.90 | 9.20 |
| MC 30/50 | 0.00 | 11.10 | 10.26 | 10.90 |

The level of infection attributed to Fusarium spp detected in the emerged seedlings of the untreated plots varied from 5 - 13%. The chemical treatments varied in their effectiveness with some, notably Benlate, giving excellent control whereas others eg. 26,019 RP, FX 3248 and FX 3250 giving higher levels than in the untreated control.

The degree of foot rot lesioning attributed to C.sativus and Fusarium spp are presented in Table 44 and the statistical analyses in Appendix Tables 2Ia - d.

Table 44. Mean foot rot rating of seedlings of barley cv Clermont attributed to C.sativus and Fusarium spp when treated by seed dressings.

| Treatment. | C.sat & Fusarium 2I days | C.sat 35 days | C.sat 49 days | Fusarium 49 days |
|---|---|---|---|---|
| Untreated | 0.233 | 0.288 | 0.327 | 0.079 |
| Benlate | 0.I76 | 0.368 | 0.542 | 0.0I8 |
| FX 3250 | 0.I29 | 0.I05 | 0.235 | 0.II9 |
| Harvesan | 0.054 | 0.099 | 0.I68 | 0.023 |
| FO I50 | 0.055 | 0.I25 | 0.I53 | 0.076 |
| SCO 75 | 0.099 | 0.I20 | 0.II9 | 0.075 |
| Safeguard | 0.022 | 0.053 | 0.II9 | 0.004 |
| Apron | 0.059 | 0.084 | 0.I2I | 0.048 |
| 6588 | 0.026 | 0.II3 | 0.234 | 0.040 |
| 26,0I9 RP | 0.052 | 0.048 | 0.064 | 0.I09 |
| Mistomatic | 0.025 | 0.I07 | 0.I42 | 0.00I |
| FX 3248 | 0.043 | 0.085 | 0.I46 | 0.I3I |
| Vitaflo | 0.002 | 0.000 | 0.064 | 0.026 |
| MC 30/30 | 0.009 | 0.069 | 0.020 | 0.037 |
| MC 30/50 | 0.009 | 0.049 | 0.040 | 0.045 |

At 2I days when the foot rot ratings were calculated from visual assessment only ( and therefore included lesions attributed to both C.sativus and Fusarium spp ) all chemically treated seedlings were significantly less (P = 0.005) diseased than the untreated control.

At 35 days when the ratings were calculated from the isolations it can be seen that apart from Benlate all the dressings again significantly (P = 0.005) reduced the disease rating.

At 49 days when the disease ratings were calculated from isolations for <u>C.sativus</u> and <u>Fusarium</u> spp it can be seen that the pattern for <u>C.sativus</u> is similar to that found after 35 days and that it differs from that shown for <u>Fusarium</u> spp. Treatment with FX 3248, FX3250 and 26,0I9 RP increased the disease rating for <u>Fusarium</u> spp. whereas the other compounds decreased it.

Assessment of plant vigour after 2I and 35 days and number of tillers after 63days are presented in Table 45 and the statistical analyses in Appendix Tables 22a - c. There were no significant differences between treatments for plant vigour and number of tillers at these sampling times.

Table 45. Mean plant vigour and mean number of tillers of barley seedlings cv Clermont after treatment with seed dressings

| | Plant Vigour | | No.tillers |
|---|---|---|---|
| Treatment. | 2I days | 35 days | 63 days |
| Untreated | 0.466 | 0.886 | I.08 |
| Benlate | 0.503 | 0.968 | I.I7 |
| FX 3250 | 0.6II | 0.945 | I.29 |
| Harvesan | 0.552 | 0.877 | I.22 |
| FO I50 | 0.583 | 0.944 | 2.I4 |
| SCO 75 | 0.58I | 0.886 | I.26 |
| Safeguard | 0.458 | 0.765 | I.32 |
| Apron | 0.639 | 0.93I | I.IO |
| 6588 | 0.489 | 0.887 | I.58 |
| 26,0I9 RP | 0.496 | 0.9I0 | I.08 |
| Mistomatic | 0.579 | 0.824 | I.47 |
| FX 3248 | 0.547 | 0.920 | I.40 |

Table 45 (cont)

| Treatment | 21 days | 35 days | 63 days. |
|---|---|---|---|
| Vitaflo | 0.494 | 0.902 | I.38 |
| MC 30/30 | 0.544 | 0.896 | I.36 |
| MC 30/50 | 0.532 | 0.922 | I.49 |

At harvest ( after 84 days ) assessments were made of the number of tillers, head weight and weight of seed per plant. These are given in Table 46 and the statistical analysis in Appendix Tables 23a - c.

Table 46. Mean number of tillers, mean head weight and mean weight seed per plant at harvest of plants of barley cv Clermont when treated with seed dressings.

| Treatment. | No.Tillers | Head Wt (gms) | Wt.Seed/Plant (gms) |
|---|---|---|---|
| Untreated | I.I9 | 0.999 | I.045 |
| Benlate | I.32 | I.048 | I.444 |
| FX 3250 | I.43 | I.II2 | I.496 |
| Harvesan | 0.88 | I.I58 | I.232 |
| FO I50 | I.69 | I.359 | 2.283 |
| SCO 75 | I.II | I.259 | I.542 |
| Safeguard | I.34 | I.I76 | I.60I |
| Apron | I.II | I.I34 | I.426 |
| 6588 | I.38 | I.I88 | I.59I |
| 26,0I9 RP | I.09 | I.080 | I.203 |
| Mistomatic | I.05 | I.229 | I.925 |
| FX 3248 | I.84 | I.I68 | 2.033 |
| Vitaflo | I.63 | I.376 | 2.I29 |
| MC 30/30 | I.35 | I.277 | I.657 |
| MC 30/50 | I.35 | I.270 | I.979 |

As after 63 days there were no differences in the number of tillers between the treatments. Data on mean head weight of plants showed that treatments with seed dressings gave a significantly (P = 0.005) higher weight. Similarly mean weight of seed per plant was significantly (P = 0.05) increased compared with that of the untreated control.

### 3.4.3. Field Experiment 1976.

Two further field experiments were carried out in 1976. In the first five seed dressings were further evaluated in the field for the control of foot rot disease. The same seed sample was used as in 1974 and 1975. Seedlings were examined at 25, 37, and 55 days after sowing and the result of infection attributed to *C.sativus* are given in Table 47 and the statistical analysis in Appendix Tables 24a - c. Infection levels in untreated plots were much lower than those in 1975, with the highest level of 16% recorded after 55 days.

Table 47. Mean percentage infection by C.sativus of barley cv Clermont when treated with seed dressings.

| Treatment | Percentage Infection. 25 days | 37 days | 55 days |
|---|---|---|---|
| Untreated | 7.14 | 4.23 | 16.37 |
| Benlate T | 0.00 | 5.81 | 2.08 |
| Carboxin | 2.47 | 0.00 | 2.22 |
| Guazatine/ Imazalil | 0.00 | 0.00 | 0.00 |
| T.C.M.T.B. | 0.98 | 1.71 | 1.65 |
| 26,019 RP | 0.00 | 0.00 | 0.00 |

The five dressings reduced significantly (P = 0.01) after 55 days the level of disease with 26,019 RP and Guazatine/Imazalil giving complete control.

Infection levels of Fusarium spp are given in given in Table 48 and the statistical analyses in Appendix Tables 25a - c.

Table 48. Mean percentage infection by Fusarium spp. of barley seedlings cv Clermont when treated with seed dressings.

| Treatment. | 25 days | 37 days | 55 days |
|---|---|---|---|
| Untreated | 6.33 | 12.10 | 33.83 |
| Benlate T | 0.00 | 0.00 | 1.04 |
| Carboxin | 14.83 | 16.47 | 28.13 |
| Guazatine/ Imazalil | 0.00 | 1.59 | 5.22 |
| T.C.M.T.B. | 0.00 | 0.85 | 11.21 |
| 26,019 RP | 4.89 | 8.22 | 12.62 |

The levels of Fusarium spp. increased through the growing season from 6% after 25 days to 34% after 55 days. Chemical treatment significantly (P =0.005) reduced the levels of Fusarium spp. with Benlate T and Guazatine/Imazalil being outstanding. Assessment of the degree of foot rotting was also calculated for both C.sativus and Fusarium spp. and are given in Tables 49 and 50 and the statistical analyses in Appendix Tables 26a - c and 27a - c respectively.

Table 49. Mean Foot Rot Rating of seedlings of barley cv Clermont attributed to C.sativus when treated with seed dressings

| Treatment. | 25 days | 37 days | 55 days |
|---|---|---|---|
| Untreated | 0.021 | 0.021 | 0.081 |
| Benlate T | 0.000 | 0.027 | 0.007 |
| Carboxin | 0.009 | 0.000 | 0.013 |
| Guazatine/ Imazalil | 0.000 | 0.000 | 0.000 |
| T.C.M.T.B. | 0.003 | 0.013 | 0.011 |
| 26,019 RP | 0.000 | 0.000 | 0.000 |

Table 50. Mean foot rot rating of barley seedlings cv Clermont attributed to Fusarium spp when treated with seed dressings.

| Treatment. | 25 days | 37 days | 55 days |
|---|---|---|---|
| Untreated | 0.021 | 0.039 | 0.179 |
| Benlate T | 0.000 | 0.000 | 0.001 |
| Carboxin | 0.037 | 0.058 | 0.149 |
| Guazatine/ Imazalil | 0.000 | 0.006 | 0.024 |
| T.C.M.T.B. | 0.000 | 0.006 | 0.062 |
| 26,019 RP | 0.012 | 0.046 | 0.077 |

At all sampling times significant differences were found in the degree of foot rotting for the different treatments for both *C.sativus* and *F.culmorum*.

Assessment of plant vigour was made after 37 days and also of the number of tillers at harvest. (See Table 51 and Appendix Tables 28a and b.)

Table 51. Plant Vigour after 37 days and mean number of tillers at harvest of barley plants cv Clermont when treated with seed dressings.

| Treatment. | Plant Vigour After 37 days. | No.Tillers. At Harvest. |
|---|---|---|
| Untreated | 2.42 | 1.40 |
| Carboxin | 2.36 | 1.69 |
| Benlate T | 2.36 | 1.15 |
| Guazatine/ Imazalil | 2.20 | 1.94 |
| T.C.M.T.B. | 2.53 | 1.31 |
| 26,019 RP | 2.14 | 1.12 |

No significant differences were found in plant vigour after 37 days, however significant differences ($P = 0.01$) were found in the number of tillers at harvest. Analysis of the mean weight of heads from plants of different treatments showed there to be no significant differences, but significant differences (P 0.05) were found for the mean weight per plant. The results are presented in Table 52 and the statistical analyses in Appendix Tables 29a and b.

Table 52. Mean weight per head (gms) and mean weight per plant (gms) at harvest of barley plants cv Clermont when treated by seed dressings.

| Treatment. | Wt./Head (gms) | Wt./Plant (gms) |
|---|---|---|
| Untreated | 2.090 | 5.113 |
| Carboxin | 1.995 | 4.915 |
| Benlate T | 2.016 | 4.133 |
| Guazatine/ Imazalil | 2.155 | 6.507 |
| T.C.M.T.B | 2.286 | 5.043 |
| 26,019 RP | 2.033 | 4.056 |

In the second field experiment two samples of seed (infected and uninfected) were used. These were treated with Benlate (shown in 1975 to be ineffective in the control of C.sativus and effective in the control of Fusarium spp.) and Vitaflo (shown in 1975 to be effective in the control of C.sativus and fairly effective against Fusarium spp) with the main aim of establishing the effect of foot rot disease on yield. The disease levels for C.sativus and Fusarium spp. were assessed after 23, 39 and 60 days and are given in Tables 53 and 54 respectively and the statistical analyses in Appendix Tables 30a - c and 31a - c respectively.

Table 53. Mean percentage infection of barley seedlings cv Clermont of two different seed lots attributed to C.sativus.

| Treatment. | 23 days | 39 days | 60 days |
|---|---|---|---|
| | Assessment time (after sowing). | | |
| Infected Clermont | 7.07 | II.2I | I0.I2 |
| Infected Clermont plus Benlate | 9.88 | 9.72 | I8.5I |
| Infected Clermont plus Vitaflo | 0.00 | 2.47 | 7.50 |
| Uninfected Clermont | 2.08 | 0.00 | 3.7I |
| Uninfected Clermont plus Benlate | 2.34 | 3.57 | 5.56 |
| Uninfected Clermont plus Vitaflo | 0.00 | 0.00 | 0.00 |

Table 54. Mean percentage infection of barley seedlings cv Clermont of two seed lots attributed to Fusarium spp.

| Treatment. | 23 days | 39 days | 60 days |
|---|---|---|---|
| | Assessment time (after sowing). | | |
| Infected Clermont | I4.39 | I7.57 | 24.55 |
| Infected Clermont plus Benlate | 0.00 | 0.00 | II.I9 |
| Infected Clermont plus Vitaflo | 0.00 | 7.32 | I9.I8 |
| Uninfected Clermont | 0.00 | 2.38 | I6.23 |
| Uninfected Clermont plus Benlate | 0.00 | 0.00 | 0.90 |
| Uninfected Clermont plus Vitaflo | 0.00 | 0.00 | I4.I9 |

The degree of foot rotting at the same times are given in Tables 55 and 56 and the statistical analyses are given in the Appendix Tables 32a - c and 33a - c.

Table 55. Mean foot rot rating of barley seedlings cv Clermont of two different seed lots attributed to C.sativus.

| Treatment. | Assessment time (after sowing) 23 days | 39 days | 60 days |
|---|---|---|---|
| Infected Clermont | 0.025 | 0.056 | 0.06I |
| Infected Clermont plus Benlate | 0.025 | 0.055 | 0.I34 |
| Infected Clermont plus Vitaflo | 0.000 | 0.0I2 | 0.06I |
| Uninfected Clermont | 0.005 | 0.000 | 0.032 |
| Uninfected Clermont plus Benlate | 0.006 | 0.021 | 0.03I |
| Uninfected Clermont plus Vitaflo | 0.000 | 0.000 | 0.000 |

Table 56. Mean foot rot rating of barley seedlings cv Clermont of two different seed lots attributed to Fusarium spp.

| Treatment. | Assessment time (after sowing) 23 days | 39 days | 60 days |
|---|---|---|---|
| Infected Clermont | 0.036 | 0.I04 | 0.II4 |
| Infected Clermont plus Benlate | 0.000 | 0.000 | 0.05I |
| Infected Clermont plus Vitaflo | 0.000 | 0.028 | 0.086 |
| Uninfected Clermont | 0.000 | 0.0I2 | 0.092 |
| Uninfected Clermont plus Benlate | 0.000 | 0.000 | 0.005 |
| Uninfected Clermont plus Vitaflo | 0.000 | 0.000 | 0.064 |

Significant differences ($P = 0.0I$) in the percentage infection by C.sativus were not found until 39 and 60 days, while for Fusarium spp. highly significant differences ($P = 0.005$) were found after 23and 39 days but not after 60 days.

In the degree of foot rotting significant differences ($P = 0.0I$) were only found after 60 days for C.sativus but the low level of C.sativus infection in the uninfected was completely controlled by Vitaflo. For Fusarium spp. disease ratings complete control was found at 23 days and 39 days (except for infected Clermont plus Vitaflo). The analysed data for 60 days showed that the differences were not at a significant level.

Assessments of Plant Vigour were made after 39 days and of the number of tillers after 60 days and at harvest. The results are given in Table 57 and the statistical analyses in Appendix Tables 34a - k.

Table 57. Plant vigour after 39 days and number of tillers after 60 days and at harvest of barley plants cv Clermont of two different seed lots.

| Treatment. | Plant vigour 39 days | No. Tillers 60 days | No. Tillers Harvest |
|---|---|---|---|
| Infected Clermont | 2.47 | I.90 | 0.99 |
| Infected Clermont plus Benlate | 2.72 | 2.16 | I.54 |
| Infected Clermont plus Vitaflo | 2.37 | I.97 | I.44 |
| Uninfected Clermont plus Benlate | 2.72 | 2.47 | I.58 |
| Uninfected Clermont | 2.83 | I.97 | I.44 |
| Uninfected Clermont plus Vitaflo | 2.62 | 2.58 | I.39 |

After 39 days significant differences (P 0.05) in plant vigour were found between the treatments. These were shown to be between the two different seed lots and no differences were found for treatments within the seed lots.

Similarly after 60 days differences (P 0.0I) in the number of tillers were found for the different seed lots. However no differences were found at harvest.

Assessment of the mean weight of heads and mean weight per plant at harvest showed there to be no significant differences between or within the two seed lots. See Table 58 and Appendix

Tables 35a and b.

Table 58. Mean weight of head and mean weight per plant at harvest of barley plants cv Clermont of two seed lots.

| Treatment. | Wt./Head. (gms) | Wt./Plant (gms) |
|---|---|---|
| Infected Clermont | I.846 | 3.607 |
| Infected Clermont plus Benlate | I.987 | 5.004 |
| Infected Clermont plus Vitaflo | I.864 | 3.8I0 |
| Uninfected Clermont | I.856 | 4.462 |
| Uninfected Clermont plus Benlate | I.739 | 4.762 |
| Uninfected Clermont plus Vitaflo | I.834 | 3.733 |

## 3.5. Laboratory evaluation of Seed Dressings.

All the chemical formulations evaluated in the field were tested in the laboratory to establish their effectiveness in the control of *C.sativus* and *F.culmorum* in pure culture.

The formulations were incorporated into Potato Dextrose Agar at concentrations of 0, IO, 25, 50 and I00 ppm and colony diameters of the fungi measured after 3 days growth at 25°C. In some cases the characters of the colonies grown on media plus dressings were altered, with reduction in sporulation and extra aerial mycelia.

The mean colony diameters for both *C.sativus* and *F.culmorum* grown on the media are presented in Tables 59 and 60.

Table 59. The effect of different concentrations of seed dressings after 3 days at 25°C on growth (colony diameter) of C.sativus in pure culture.

FX 3248.

| ppm | Mean Diam. mms | S.D. |
|---|---|---|
| 0 | I5.37 | 0.92 |
| IO | I5.00 | 0.89 |
| 25 | I5.25 | I.9I |
| 50 | I5.75 | I.83 |
| I00 | I9.75 | 0.46 |

FX 3250.

| ppm | Mean Diam. mms | S.D. |
|---|---|---|
| 0 | I4.00 | I.4I |
| IO | I2.16 | 0.75 |
| 25 | I3.87 | I.I3 |
| 50 | I5.50 | I.4I |
| I00 | II.62 | 0.52 |

MC 30/30

| ppm | Mean Diam. mms | S.D. |
|---|---|---|
| 0 | 29.I3 | I.73 |
| IO | I3.38 | 0.85 |
| 25 | IO.38 | I.35 |
| 50 | 8.I3 | 0.69 |
| I00 | 5.75 | I.69 |

MC 30/50

| ppm | Mean Diam. mms | S.D. |
|---|---|---|
| 0 | I2.35 | 0.88 |
| IO | 8.20 | I.87 |
| 25 | 5.30 | I.25 |
| 50 | 2.20 | I.48 |
| I00 | I.60 | I.I7 |

| 6588 | | | Safeguard | | |
|---|---|---|---|---|---|
| ppm | Mean Diam. (mms) | S.D. | ppm | Mean Diam. (mms) | S.D. |
| 0 | 16.33 | 1.52 | 0 | 12.63 | 1.97 |
| 10 | 19.55 | 2.24 | 10 | 10.38 | 1.11 |
| 25 | 19.00 | 2.34 | 25 | 9.50 | 0.91 |
| 50 | 16.75 | 0.64 | 50 | 8.83 | 1.35 |
| 100 | 14.87 | 0.24 | 100 | 9.00 | 0.00 |

| Vitaflo. | | | 26,019 RP. | | |
|---|---|---|---|---|---|
| ppm | Mean Diam. (mms) | S.D. | ppm | Mean Diam. (mms) | S.D. |
| 0 | 23.75 | 1.56 | 0 | 18.13 | 1.11 |
| 10 | 19.38 | 1.76 | 10 | 11.37 | 1.25 |
| 25 | 14.75 | 0.88 | 25 | 7.25 | 0.86 |
| 50 | 13.88 | 1.13 | 50 | 5.25 | 0.86 |
| 100 | 8.63 | 1.06 | 100 | 1.00 | 0.40 |

| SCO 75. | | | FO 150. | | |
|---|---|---|---|---|---|
| ppm | Mean Diam. (mms) | S.D. | ppm. | Mean Diam. (mms) | S.D. |
| 0 | 13.62 | 0.92 | 0 | 12.13 | 1.65 |
| 10 | 11.37 | 1.87 | 10 | 14.13 | 2.84 |
| 25 | 11.66 | 1.86 | 25 | 13.50 | 4.97 |
| 50 | 11.00 | 1.48 | 50 | 14.63 | 1.40 |
| 100 | 10.86 | 1.88 | 100 | 11.75 | 1.66 |

| Apron. | | | Harvesan. | | |
|---|---|---|---|---|---|
| ppm | Mean Diam. (mms) | S.D. | ppm. | Mean Diam. (mms) | S.D. |
| 0 | 12.00 | 1.96 | 0 | 13.40 | 0.84 |
| 10 | 6.50 | 1.00 | 10 | 11.90 | 1.19 |
| 25 | 6.00 | 0.55 | 25 | 11.40 | 1.52 |
| 50 | 6.18 | 1.32 | 50 | 12.10 | 1.64 |
| 100 | 5.75 | 1.26 | 100 | 4.80 | 1.98 |

**Mistomatic.**

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 11.10 | 2.53 |
| 10 | 12.40 | 2.44 |
| 25 | 12.75 | 1.66 |
| 50 | 9.00 | 0.93 |
| 100 | 3.50 | 0.96 |

**Benlate.**

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 12.87 | 0.68 |
| 10 | 12.75 | 2.05 |
| 25 | 13.00 | 2.33 |
| 50 | 12.63 | 2.29 |
| 100 | 11.75 | 1.75 |

**T.C.M.T.B.**

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 13.00 | 0.89 |
| 10 | 11.38 | 1.81 |
| 25 | 5.88 | 1.64 |
| 50 | 4.88 | 2.94 |
| 100 | 3.88 | 1.24 |

**Benlate T.**

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 14.37 | 1.26 |
| 10 | 15.13 | 1.26 |
| 25 | 14.63 | 1.84 |
| 50 | 13.25 | 1.44 |
| 100 | 12.62 | 1.11 |

Table 60. The effect of different concentrations of seed dressings after 3 days at 25°C on growth (colony diameter) of Fusarium culmorum in pure culture.

**FX 3248.**

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 28.13 | 2.34 |
| 10 | 41.57 | 2.93 |
| 25 | 37.50 | 1.45 |
| 50 | 37.38 | 1.99 |
| 100 | 30.25 | 3.84 |

**FX 3250.**

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 43.75 | 2.49 |
| 10 | 42.62 | 1.51 |
| 25 | 40.75 | 2.40 |
| 50 | 38.75 | 1.91 |
| 100 | 36.29 | 2.13 |

**MC 30/30.**

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 39.75 | 5.39 |
| 10 | 15.38 | 1.96 |
| 25 | 17.75 | 0.86 |
| 50 | 18.63 | 1.73 |
| 100 | 17.50 | 1.00 |

**MC 30/50.**

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 35.80 | 6.53 |
| 10 | 16.70 | 1.10 |
| 25 | 12.70 | 1.10 |
| 50 | 9.90 | 2.38 |
| 100 | 3.40 | 0.84 |

6588.

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 55.00 | I.4I |
| IO | 20.I6 | I.46 |
| 25 | I9.62 | I.92 |
| 50 | I5.87 | 0.47 |
| I00 | I0.37 | 0.85 |

Safeguard.

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 30.83 | 2.56 |
| IO | 36.63 | 2.49 |
| 25 | 38.50 | 3.24 |
| 50 | 40.I3 | 3.I4 |
| I00 | 39.33 | 0.9I |

Vitaflo.

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 24.38 | 3.05 |
| IO | 24.33 | 2.87 |
| 25 | 24.88 | 2.69 |
| 50 | 2I.I7 | I.94 |
| I00 | 23.86 | 2.47 |

26,0I9 RP.

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 54.62 | 5.I3 |
| IO | 52.37 | 7.I8 |
| 25 | 54.25 | 2.90 |
| 50 | 48.87 | I.65 |
| I00 | 34.I2 | 5.I3 |

SCO 75.

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 66.75 | I.75 |
| IO | 60.75 | I.38 |
| 25 | 65.25 | 2.6I |
| 50 | 6I.37 | I.99 |
| I00 | 60.37 | 2.77 |

FO I50.

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 22.20 | I.89 |
| IO | I8.75 | 0.64 |
| 25 | I6.86 | 2.58 |
| 50 | I8.60 | I.72 |
| I00 | I8.28 | 0.49 |

Apron.

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 36.00 | 4.4I |
| IO | 24.63 | I.97 |
| 25 | I7.00 | I.4I |
| 50 | I6.I3 | 2.46 |
| I00 | I4.I3 | 3.34 |

Harvesan.

| ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 44.37 | 4.03 |
| IO | 33.80 | 4.94 |
| 25 | 28.70 | 2.74 |
| 50 | I0.00 | I.94 |
| I00 | 3.25 | 0.46 |

| Mistomatic. ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 34.75 | I.48 |
| IO | 34.25 | 6.29 |
| 25 | I5.50 | 4.4I |
| 50 | 4.50 | I.60 |
| IOO | 2.00 | 0.00 |

| Benlate. ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 30.00 | 2.24 |
| IO | 0.00 | 0.00 |
| 25 | 0.00 | 0.00 |
| 50 | 0.00 | 0.00 |
| IOO | 0.00 | 0.00 |

| T.C.M.T.B. ppm | (mms) | S.D. |
|---|---|---|
| 0 | 42.50 | 3.54 |
| IO | 37.50 | 3.5I |
| 25 | 22.00 | 2.07 |
| 50 | I5.75 | 2.7I |
| IOO | 7.87 | I.I3 |

| Benlate T. ppm | Mean Diam. (mms) | S.D. |
|---|---|---|
| 0 | 58.50 | 9.80 |
| IO | 0.00 | 0.00 |
| 25 | 0.00 | 0.00 |
| 50 | 0.00 | 0.00 |
| IOO | 0.00 | 0.00 |

In order to compare the effects of the dressings the $E.D._{50}$ (the concentration required to inhibit the growth of the colony by 50%) for each dressing was calculated. Graphs of the mean colony diameter against seed dressing concentration were used to calculate the $E.D._{50}$s and in some cases extrapolation of the graphs was necessary. The $E.D._{50}$s are presented in Tables 6I and 62.

Table 62. $E.D._{50}$ of the seed dressings after 3 days for C.sativus

| Seed Dressing. | $E.D._{50}$ (ppm) | Seed Dressing. | $E.D._{50}$ |
|---|---|---|---|
| MC 30/30 | 8.2 | Harvesan | 77.0 |
| Apron | I4.0 | Mistomatic | 78.0 |
| 26,0I9 RP | I6.0 | FX 3248 | I20.0 |
| MC 30/50 | I9.0 | FX 3250 | 230.0 |
| T.C.M.T.B | 23.0 | FO I50 | 430.0 |
| Vitaflo | 64.0 | 6588, Safeguard, SCO 75, Benlate, Benlate T | > I000.0 |

Table 63. $E.D._{50}$ of the seed dressings after 3 days for *F.culmorum*.

| Seed Dressing. | $E.D._{50}$ ppm | Seed Dressing. | $E.D._{50}$ ppm |
|---|---|---|---|
| Benlate | 3.2 | Harvesan | 35.0 |
| Benlate T | 3.2 | 26,019 RP | 370.0 |
| 6588 | 6.8 | Safeguard | > 1000.0 |
| MC 30/30 | 7.2 | Vitaflo | > 1000.0 |
| MC 30/50 | 8.8 | FX 3248 | > 1000.0 |
| Apron | 21.0 | FX 3250 | > 1000.0 |
| Mistomatic | 22.5 | SCO 75 | > 1000.0 |
| T.C.M.T.B. | 27.0 | FO 150 | > 1000.0 |

Five of the isolates of *C.sativus* were tested against two of the seed dressings (one effective and one ineffective) to compare their reactions. All five isolates showed similar responses to both chemicals.

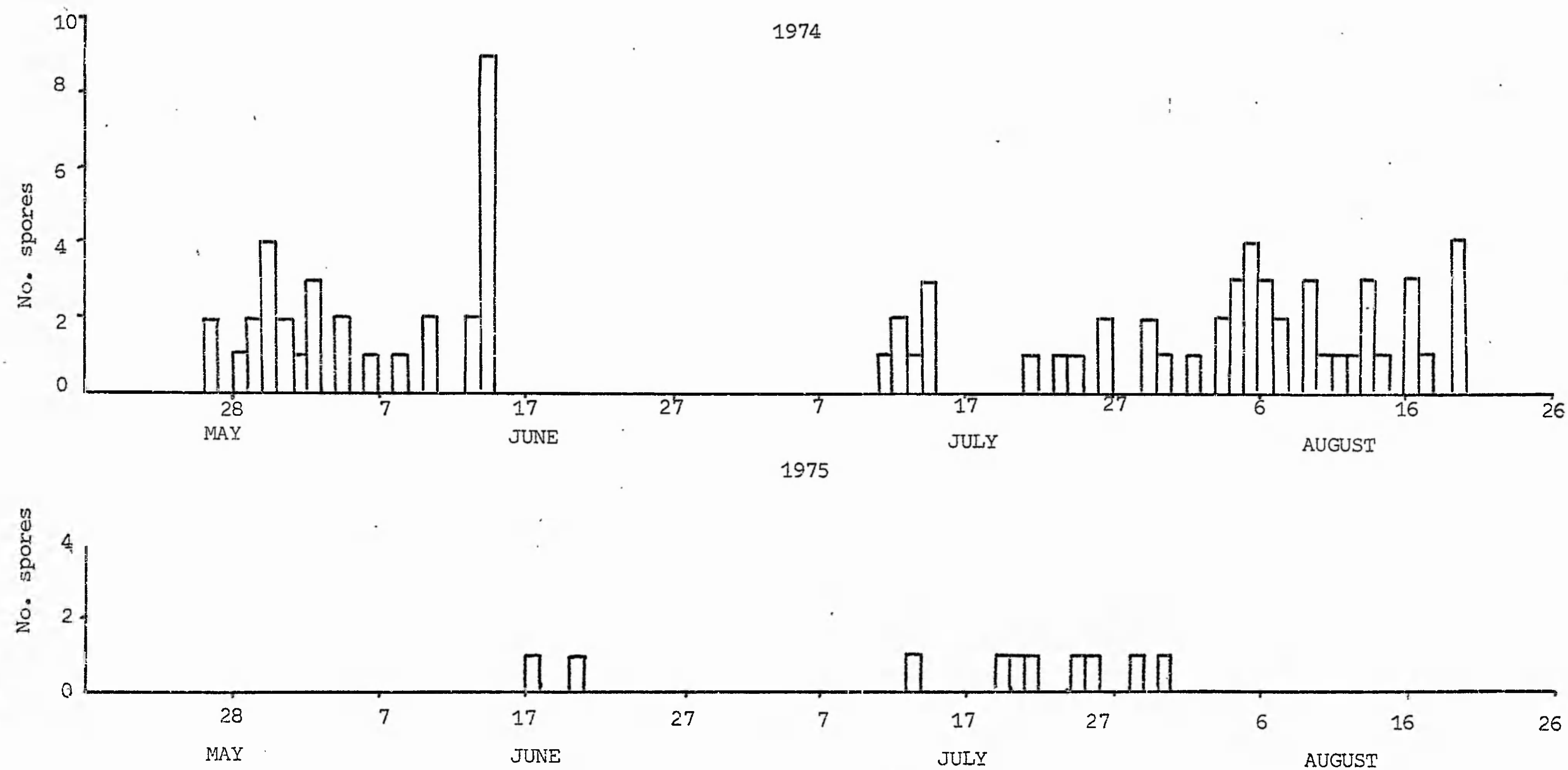
## 3.6. Spore Trapping Experiment.

Spore trapping was carried out in the summers of I974 and I975. The numbers of spores and their time of trapping are shown in graphs I and 2. In I974 76 spores of C.sativus were trapped throughout the growing period and in I975 only IO.

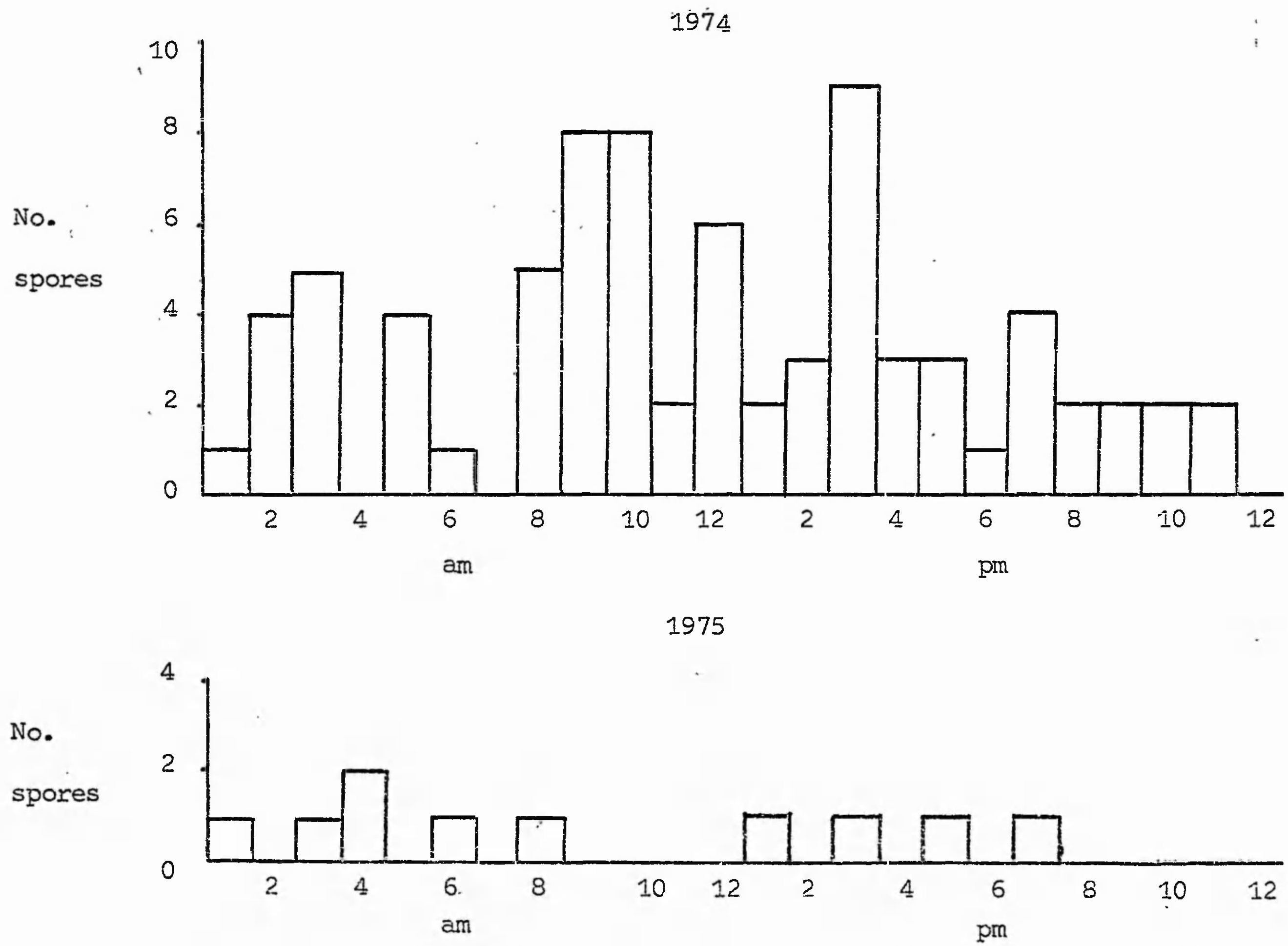
No optimium time of day for spore release was found.

When the seed progeny of the spore trap plot was plated out on to Potato Dextrose Agar only a 4% infection rate was found.

Graph 1. No. spores of C. sativus trapped throughout growing periods 1974, 1975



Graph 2. Times of trapping of spores of *C. sativus* in growing periods 1974, 1975



### 3.7. Reports of C.sativus in Great Britain 1973 - 1975.

Questionnaires were sent to each of the Agricultural Development and Advisory Service regional stations in England and Wales and the Ministry of Agriculture, Fisheries and Food of Scotland to determine the importance and occurrence of C.sativus. The questionnaire was designed also to determine which phase of the disease (foot rot, leaf spot or infected seed) had been reported, the cereal host and variety, and the previous crop.

The questionnaires returned in 1973 showed there had been no further reports anywhere in the country other than those already mentioned in the introduction.

In 1974, severe leaf infections causing leaf shredding were observed very occasionally on barley crops in the North Riding of Yorkshire. These symptoms were always associated with home-sown non-dressed seed. Incidental seed infections by C.sativus were reported from the East and West Midland regions. The East Midland report was of a 2% seed infection of Julia barley from Stanton by Langworth, Lincolnshire. While the West Midland report was of low seed infection in Clermont barley, leaf spot symptoms were present but often concealed by leaf stripe. The original seed had not been treated.

No reports of incidences of C.sativus in England were made in 1975. However one report of the foot rot phase on barley was reported from Bishopbriggs, W.Scotland. Also C.sativus was reported as causing leaf spotting on varietal trials of oats in Trawscoed.

## 4. Conclusions and Discussion.

Foot rot diseases of cereals in Britain are found to be increasing in importance. This is mainly due to the increased production of winter varieties of cereals and to the lack of adequate resistance to the diseases despite breeding progammes. One of the fungi associated with the foot rot complex in cereals, C.sativus gave cause for considerable concern in the early 1970's when some severe outbreaks of the disease, caused by the fungus, were reported in a number of barley crops. The present study on C.sativus was initiated in the light of these observations.

The formulation of effective control measures for the disease would depend on a knowledge of factors such as the host range and varietal susceptibility, cultural and pathological characteristics of the fungus, dissemination of the fungus and the geographical distribuion of the disease. These were the major areas of investigation in the present study.

The testing of the host range and varietal response to an isolate of C.sativus was performed under artificial experimental conditions in the laboratory, greenhouse and in the field. It was not possible to perform field experiments using naturally infected soil as no site was available locally or elsewhere in Britain. Also there was no source of cereal varieties naturally infected with the fungus.

The three methods used for testing susceptibility to C.sativus gave comparable results. The detached leaf method allowed susceptibility testing to be carried out on a large number of varieties relatively quickly in a small area and required only a small amount of plant material. Replicate experiments showed good agreement in response as determined by leaf lesion size.

In greenhouse experiments the 'Wet Spore' method used for infection overcame the possibility of toxic effects of solid medium inoculum. The foot rot phase of the disease was used for the disease assessment. This was preferred to either the leaf spot phase or head blight for at the time of experimentation the potential of the disease was uncertain. The foot rot phase was considered as the primary stage without which the others could not follow.

The field experiments of varietal response to C.sativus were inconclusive for significant differences in percentage infection and foot rotting for the different varieties were not readily found. In 1975 and 1976 germination levels within the plots had in some cases been very low. The use of the foot rot rating formula used firstly by McKinney (1923) and many other workers subsequently, overcame assessment difficulties to some extent.

The inoculation method in the 1974 field trials was one of infected straw material together with 'Wet Spore' inoculum. Levels of infection other than percentage infection were not determined and high percentage infection levels noted in the controls were shown in 1975 to be due to infection from the soil by Fusarium spp. Inoculation in 1975 using the 'Wet Spore' method alone gave levels of infection by C.sativus as measured by foot rot rating appreciably lower after 9 weeks than those using the same method in the greenhouse experiments and assessed after 3 weeks.

These results indicate the importance of environmental conditions in infection by C.sativus. In its role as a seedling pathogen McKinney considered the fungus to favour high soil moisture levels though it has been destructive in dry soils (Dosdall 1923). The later root and foot rot phase of the disease, on the other hand, was considered to be more prevalent and damaging at low soil moisture contents (Hynes 1938). Under conrolled conditions the development of foot rot by C.sativus has been shown to favour soil temperatures 20 - 32°C, the optimum temperature being 28°C (McKinney 1923). Also McKinney showed that infection tends to be most severe at high temperatures when moisture is not limiting.

Another possible effect accounting for the field infection is the antagonistic and competitive effects of microorganisms in the soil, partially sterilised compost being used in the greenhouse experiments. C.sativus has been shown to be extremely sensitive to the antagonistic and competitive effects of indigenous microflora of the soil. Anwar (1949) showed soil isolates of Bacillus subtilis, Penicillium spp., Aspergillus spp. and Trichoderma lignorum to be antagonistic towards C.sativus, protecting plants against soil infection. Though Sandford and Cormack (1940) suggested some Penicillium species may actually increase virulence. Bisby, James and Timonin (1933) also showed T.lignorum suppressed the virulence of C.sativus in pot tests and Christensen (1936) that other microorganisms could suppress and even prevent infection when the pathogen is applied directly to the seed. Ledingham (1942) in inoculation tests showed C.sativus and F.culmorum when mixed, reduced injury, indicating antagonism. Sandford and Cormack (1940) also suggested some actinomycetes may show antagonistic qualities.

Twenty four barley varieties taken from the 1973 N.I.A.B. recommended lists of cultivars showed a range of response towards a British isolate of C.sativus with some highly susceptible varieties, a few fairly resistant ones and the majority intermediate. The cultivar Clermont was found to be the most susceptible with one of its parents Frisia, winter varieties Astrix and Senta and Spring barley varieties Zephyr and Deba Abed. Sultan and Wing were considered fairly resistant.

These observations are in keeping with the reports of infections in the early 1970's in Britain and the cereal varieties from which isolates of C.sativus had been made for the present study. Frisia was reported by De Temp (1958) as being a susceptible variety to C.sativus in Europe. The order of susceptibility found in the present study agrees with that for seed infection levels by C.sativus in samples of different varieties of spring barley tested by Hewett (1975).

The limited number of wheat varieties tested were found to be highly resistant to this isolate and there have been no recent reports of wheat infection in Britain. The oats variety, Astor, which was tested was also found to be highly resistant. However, as one isolate of C.sativus used in the present study had been from a sample of oat seed varieties with less resistance may exist.

Earlier workers have reported that isolates of C.sativus vary extremely in cultural and morphological features(Christensen 1926). The present work confirmed these reports as isolates, even from within the same country, could be individually separated on cultural and morphological characters. Freeze dried cultures, prepared from single spore isolates from the original source, were used throughout to minimise the possibility of using variants or saltants. Such variants and saltants had been found to occur in cultures stored at 4°C.

The separation of isolates by growth on different synthetic media as used by earlier workers appeared to be a reliable method. Replicate plates of isolates showed almost identical colonies and the characters of the same isolates in replicate experiments were also identical. In the present study P.D.A. and V - 8 Agar proved the most useful media in the separation of isolates on morphological features and on the degree of sporulation.

The type and degree of aerial mycelium produced by the isolates was found to be a major characteristic particularly when grown at the higher temperatures (25 and 30°C). Aerial mycelium was almost absent at I6°C. The type of aerial mycelium ranged from sparse tufts to thick compact coverings which often gave the appearance of concentric zones as experienced by Christensen (I926) who attributed zonation to variation in conidial and to aerial mycelium production or to both. Difficulty in separating these two characters was experienced in this present study. Zonation has been attributed to such causes as short exposures of light, alternation of light and darkness, staling products and variation in amount of food but as shown by Christensen (I926) and substanciated in this study, it seems a character of a particular isolate for C.sativus. Zonation occurred when different isolates were kept under a controlled environment regarding light, temperature and availability of substrate. Staling products, manifested as brown secretions in the agar surrounding growing colonies, were noted in some isolates grown on P.D.A. at 25 and 30°C but not on V - 8 Agar where zonation was also apparent. Zonation due to either aerial mycelium or sporulation or both is therefore considered as a legitimate character for isolate separation.

Colony colour which has been used by some workers to separate isolates, was not used in the present study for it was considered to be related to the degree of sporulation. Sporulation was observed to be negatively correlated with the growth rate of the isolates. Slow growth rate corresponded to high conidial production and rapid growth rate with paleness of colony and low conidial production. This was in agreement with observations made by Stevens (1922). Sporulation was generally more abundant, irrespective of the media used, at 25 and 30°C than at 16°C as noted by Christensen (1926), Mitra (1930) and Andersen (1952).

The colony margins were found to be related to temperature of incubation and rate of growth. For the slower growing colonies at 16°C the margins were usually very regular while at the higher temperatures (25 and 30°C) they were more irregular. The production of staling products by some isolates on P.D.A. at 25°C gave rise to highly irregular colony margins.

In general all isolates showed a slower growth rate at 16°C than at 25 or 30°C. This had also been experienced by Dosdall (1923) and Fuentes et al (1966). These workers who only used one isolate in their studies also reported a faster growth rate at 30 than 25°C. In the present study however, the various isolates showed different temperature preferences regarding these two temperatures. All of the isolates could be separated by combining the results of their mean growth rates at the different temperatures on the three media employed.

In the present study the occurrence of saltants both as sectors and sterile white clumps appeared to be dependent on several factors. Temperature, as noted by Christensen (1929), Mitra (1931) and Hynes (1935), was observed to exert an important effect on their occurrence. As reported by Christensen (1929) and Mitra (1931) saltants were not recorded at 16°C. In accordance with this observation all cultures grown for subsequent experiments in the project were grown at 16°C ensuring or limiting the likelihood of saltation.

The number of sectors observed in the cultural studies was small but generally more were observed at 30 than 25°C. Similarly more sterile white clumps, which were found to occur more frequently than the sectors, were observed at 30°C than 25°C. Christensen (1929) had observed the optimum temperature for saltation to be between 25°C - 27°C.

The growth medium also appeared to influence the production of saltants. Czapek Dox agar yielded one sector while Potato Dextrose and V - 8 agars yielded four and seven respectively. Similarly fewer sterile white clumps were observed on Czapek-Dox than on the other two media. Mitra (1931) had also observed a 'medium effect' suggesting the richness of media as governed by concentration and depth of plate influenced the frequency of saltation. Paxton (1933) also found sectors occurring only occasionally on Czapek Dox media.

Although the isolates of <u>C.sativus</u> varied extensively on morphological characteristics they were less variable in respect of pathogenicity. In the tests carried out in the present investigation there were few differences in the pathogenicity of the isolates within any of the locational groups. However differences were noted between representative isolates from different countries. The British and Netherlands isolates were most pathogenic towards barley while the Indian isolates were more pathogenic towards wheat. Pathogenic groups within C.sativus had been recognised by Ashworth et al (1960) and also by Wood (1960) when testing reaction of isolates towards wheat, oats and sorghum.

The strong similarity between the British and Netherlands isolates could be expected as many of the barley varieties grown in Great Britain are also grown on the Continent. Many of these varieties have been associated through breeding programmes. Also when the interest in C.sativus in Great Britain was renewed in the early 1970's most of the outbreaks were associated with the variety Clermont which is a continentally bred variety.

While the Canadian, Indian and Australian isolates proved to be less pathogenic on barley than the British and Netherlands isolates, it should be noted that in the present study the varieties of barley used were European in origin. The similarity in pathogenicity of the Indian, Canadian and Australian isolates may not be a consequence of geographical location. Loiselle (1962) when testing a large number of different varieties of barley for resistance including many from different parts of the world found, using an Ottawa isolate of C.sativus, that most of the resistant varieties were from Northern Europe and Asia. This could be a consequence of the Ottawa isolate being less virulent towards European and Asian cultivars. On the other hand Mukewar (1973) reported the interception of a highly virulent isolate of *C.sativus* from Canada which was found to show greater virulence than the Indian isolates when used in infection studies with Indian wheat varieties. When comparing pathogenicity of isolates of *C.sativus* from different parts of the world these reports and the present work indicate the importance of the inclusion of varieties from the same geographical location as the isolates.

The pathogenicity of the various isolates on the wheat varieties at the low temperature (16°C) was generally low and apart from the Australian isolate, which appeared to be less virulent than the others, there were no distinct differences in their pathogenicity. At 25°C the level of infection was greater and the Indian isolates appeared to be preferentially favoured at this temperature.

Although significant differences were found between the isolates towards the oat variety tested at 16°C, the infection levels were very low even with the most virulent isolates. Infection at the higher temperature (25°C) did not noticeably accelerate infection.

The present work indicates that the infection rate of *C.sativus* on wheat and barley is accelerated with increase in temperature from 16 to 25°C as has also been shown by Dosdall (1923), McKinney (1923) and Greaney (1946). The reaction at 16°C and 25°C for oats were very similar, but the infection levels were low. Although the tests were carried out in unnatural conditions using the detached leaf method, work in the varietal response testing showed the results to be consistent with those obtained for seedlings grown under greenhouse conditions.

In Britain at present C.sativus is considered to be more prevalent as a seed-borne pathogen than as a soil-borne one. For this reason chemical control measures were aimed at the seed-borne phase by treatment of naturally infected seed of the highly susceptible variety Clermont. The fungicides tested in the field experiment varied considerably in their effectiveness in the control of foot rot lesions caused by C.sativus and Fusarium spp. As Fusarium spp. were found to be regularly associated with foot rot symptoms in the field an isolate of F.culmorum was used together with C.sativus in the laboratory fungitoxicity tests.

In the 1975 field tests good control of infection by C.sativus was achieved by the treatment with MC 30/30, MC 30/50, Vitaflo, and 26,019 RP. The MC 30/30 and MC 30/50 (Murphy) comprised active ingredient guazatine/maneb and guazatine/carboxin respectively. The latter compound was also present in Vitaflo. Edington and Barron (1967) and Richardson (1972) had earlier found carboxin to give effective control against C.sativus. The 1976 field experiments showed Guazatine/Imazalil, suggested as an improved compound over MC 30/30 and MC 30/50 (Ballard pers. comm.) to be extremely effective against C.sativus while carboxin alone was less so. Maneb, also present as an active ingredient in FX 3248 (Shell) was found to give improved performance over FX 3250 carrying the active ingredient WL 22,361 alone.

The mercury containing compounds Harvesan and Mistomatic were found to give only partial control of C.sativus. Moore and Moore (I950) and Jorgensen (I974) also reported similar finding.

Benlate treatment of the seed was found to increase above that of the untreated seed, both the incidence and severity of foot rotting caused by C.sativus. Richardson (I972) had also found it ineffective in controlling the fungus. However, Benlate was extremely effective in controlling Fusarium spp., with only very low infection levels appearing towards the end of the growing season. It therefore appears that the higher infection levels in the Benlate treated plots could be due to the removal of the competition between the two fungi once the fusaria had been eliminated. C.sativus and Fusarium spp. were rarely isolated together from infected material. Ledingham (I942) noted antagonism between these two fungi and the present results substanciate this. Similar effects were found for carboxin treated plants. The reverse effects were found for plants treated with 26,0I9 RP, this compound gave excellent control of C.sativus but not Fusarium spp. and the levels of infection by the latter fungus were found to be higher than in the untreated plots.

Besides Benlate, good control of Fusarium spp. was found with the mercury compounds and also with Guazatine/Imazalil. Assessment through the growing season had shown the continually rising levels of infection by Fusarium spp. indicating its origin was from the soil rather than from seed.

In the laboratory fungitoxicity tests where the fungicides were evaluated for their activity against C.sativus and F.culmorum, comparable results were obtained to those found in the field experiments. Those compounds effective against Fusarium spp. must therefore be persistent enough in the soil to combat the infection of the roots from soil inoculum for several weeks.

Assessments of plant vigour and number of tillers in the field experiments of 1975 did not show any significant differences between the treated and untreated seed. However at harvest significant differences ($P = 0.005$) were found for the mean weight of heads for plants grown from differently treated seed. Similarly significant differences were found for the weight of seed per plant but these results are considered unreliable for some seed had been lost during the threshing.

The yield experiment designed in 1976 to determine which of the two fungi, C.sativus or Fusarium spp., was the primary pathogen and to determine their respective effects on yield gave inconclusive results.Significant differences were found in plant vigour and number of tillers for the two different seed lots used, but not for the different treatments within them. However at harvest no significant differences were found for any of the parameters measured. In the field experiment of chemical control of 1976 significant differences were found at harvest in the number of tillers and the mean weight of heads per plant. It appeared that the guazatine/imazalil treatment which suppressed both C.sativus and Fusarium spp. produced plants with most tillers and the highest mean weight of heads per plant. However no real correlation between the infection levels of the fungi and harvest assessment criterion could be established. Clark and Wallen (1969) also found that yield losses from planting barley seed heavily infected with C.sativus, were not significant at normal planting rates.

They also found that treatment with mercury fungicides gave no significant improvement in seed yields but slightly improved kernel weight. Greaney and Wallace (I943) and Machacek et al (I954) also reported seed infection had little effect on yield. Sallans (I959) had found that wheat plants were able to recover from early infections by C.sativus and F.culmorum, as experienced in seed infection, so that no losses in yield were apparent. The I974 field experiments had shown there to be no significant reduction in germination with the infected seed.

Clark and Wallen (I969), therefore, suggested there was little practical value in treating barley seed infected with C.sativus with fungicides under normal Canadian environmental conditions for no increase in yield was obtained. However, occasionally, unusual weather conditions of high relative humidity, dew point and temperature occurred and treatment of seed in these situations might prevent an extensive build up of the disease inoculum which would be important at crop maturity.

The spore trapping experiments of I974 and I975 showed very few spores to be disseminated throughout the growing seasons despite a very high level of seedling infection. This was substanciated by the very low infection level of the seed progeny and lack of leaf spot lesions due to infection by C.sativus in the plots..

The time of infection of seed kernels is important. The opportunities for infection by air-borne conidia become limited by the changes in the tissues during development. The floral glumes become hard in texture and after the third week following flowering they adhere to the pericarp. This is an important barrier to the entry of the spores. In addition to this, the caryopsis steadily develops a resistant membrane, the testa, which becomes resistant as time goes on (Mead 1942).

Environmental conditions play an important role in dissemination of diseases. Infection levels of seeds for both years were considered low. A good build up of inoculum from the base of the plant, and for this to move upwards probably by way of leaf lesions is required for successful infection at the time of flowering. It is therefore envisaged that environmental conditions in the summer of 1974 and 1975 were not at their optimal for seed infection to occur.

Replies to questionnaires sent between 1973 - 1975 to the A.D.A.S. regional centres in Great Britain showed only a few records of C.sativus over this period and these cases were mainly of incidental seed infection. These results and the present study suggests that the heavy crop losses in Scotland and Anglesey in 1972 were an exception rather than the rule.

Skou (1966) had suggested that a factor accounting for the low incidence of the fungus in Europe was its rather 'unspecific symptoms' and that the foot rot phase of the disease could easily be confused with those of more common diseases such as those caused by Fusarium spp., G.graminis and P.herpotrichoides. The present study substanciates this with Fusarium spp. infections only being separated by plating out infected lesions. Makela (1972) also pointed out that the leaf spot symptoms are often masked by symptoms of P.graminea and H.teres. This was also found by one of the A.D.A.S. pathologists.

Records of leaf spot symptoms of C.sativus are very rare in Britain.

Hewett's (1975) results of seed infection levels and the present study indicate that C.sativus is more common throughout the country than generally realised by A.D.A.S. pathologists who do not look for it or recognise it until important crop losses are found.

The present study suggests that infections by C.sativus are generally of minor consequence even on highly susceptible varieties. Several factors probably prevent the fungus from becoming an important pathogen in this country. The most important ones are the climatic and environmental conditions. Both De Temp (1964) and Skou (1966) suggested the Northern American summers were much warmer than those found in Great Britain and Europe and so inoculum levels are slower to build up. The present work has shown temperature to be an important factor. Soil moisture has also been considered to play an important role (McKinney 1923).

Seed- borne rather than soil-borne infection by C.sativus in Great Britain and Europe is an important factor. In America, where soil-borne infection predominates, infection can occur throughout the growing season. While in the seed-borne infections of Great Britain and Europe for heavy infections to occur the environmental conditions must be at an optimum at the seedling stage.

References.

ANDERSON A.A. Development of Wheat Head Blight incited by *H.sativum*. Phytopathology 42, 453-456, (1952)

ANWAR A.A. Factors affecting the survival of *H.sativum* and *F.culmorum*. Phytopathology 39, 1005-1028, (1949).

ARNY D.C. Inheritance of resistance to spot blotch in barley seedlings. Phytopathology 41, 691-698, (1952).

ASHWORTH L.J.,LAHR K.A., COLLINS R.J. Pathogenic specialization of *H.sativum*. Phytopathology 50, 627, (1960)

BISBY G.R., JAMES M., TIMONIN,. Fungi isolated from soil profiles in Manitoba. Canadian Journal Research C, 13, 47-65, (1933).

BLAIR I.D. An investigation of foot rot of wheat in New Zealand. New Zealand Journal Scientific Technology 19, 1-21, (1937).

BROADFOOT W.C. Studies on foot rot and root rot of Wheat. I. Effect of age of the wheat plant upon the development of foot and root rot. Canadian Journal Research 8, 483-491 (1933).

BUTLER F.C. Root and Foot Rot diseases of wheat. Department of Agriculture for New South Wales Scientific Bulletin 77, (1961).

CHINN S.H.F., LEDINGHAM R.J. Application of a new laboratory method for determination of the survival of *H.sativum* spores in soil. Canadian Journal of Botany 36, 289-295, (1958).

CHRISTENSEN J.J. Studies on the parasitism of H.sativum. University of Minnesota Agricultural Experimental Station Technical Bulletin II, (I922).

CHRISTENSEN J.J. Physiologic specialization and mutation in H.sativum. Phytopathology I5, 785-796 (I925)

CHRISTENSEN J.J. Physiologic specialization and parasitism in H.sativum. Minnesota Agicultural Experimental Station Technical Bulletin 37, (I926).

CHRISTENSEN J.J. Influence of temperature on frequency of mutation in H.sativum. Phytopathology I9, I55-I62, (I929).

CHRISTENSEN J.J. Associations of microorganisms in relation to seedling injury arising from infected seed. Phytopathology 26, I09I-II05, (I936)

CHRISTENSEN J.J. DAVIES F.R., Nature of Variation in H.sativum Mycologia 29, 85-99, (I937).

CHRISTENSEN J.J. DAVIES F.R., Variation in H.sativum induced by toxic substances produced by Bacillus mesentericus. Phytopathology 30, I0I7-I032, (I940).

CHRISTENSEN J.J. STAKMAN E.C. Foot and root rots of wheat in Minnesota in I924. Phytopathology I5, 53, (I925).

CLARK R.V. The reaction of barley lines to root rot, leaf spot, and head blight. Canadian Journal Plant Science 46, 603-609, (I966).

CLARK R.V. WALLEN V.R. Seed infection of barley by C.sativus and its influence on yield. Canadian Plant Disease Reporter 49, 60-64 (I969).

CRAIGIE J.H. Economic diseases of field crops in Manitoba. Economic Survey Board, Province of Manitoba (I939).

COHEN E. HELGASON S.B. McDONALD W.C. A study of factors influencing the genetics of reaction of barley to root rot caused by H.sativum. Canadian Journal of Botany 47, 429-443 (I969).

DASTUR J.F. Foot rot and black point diseases of Wheat in Central Provinces. Agriculture and Livestock in India, 2, 275-282, (I932)

DASTUR J.F. Notes on some fungi isolated from black point affecting wheat kernels in the Central Provinces. Indian Journal Agricultural Sciences I2, 73I-742, (I942).

De TEMP J. 3 years of field trials of seed-borne disease and seed treatment of cereals. International Seed Testing Association Proceedings 23, 38-67, (I958).

De TEMP J. Helminthosporium spp. in seeds of wheat, barley, oats, rye. Internatioal Seed Testing Association 26, II7-I40, (I964).

DICKSON R.D. TINLINE R.D. C.sativus I. Perithecial development and the inheritance of spore colour and mating type. Mycologia, 50, 697-706, (I954).

DICKENSON S. The nature of saltation in Fusarium, Helminthosporium. Minnesota Agricultural Experimental Station Technical Bulletin 88, (I932).

DOSDALL L. Factors influencing the pathogenicity of H.sativum . University Agricultural Experimental Station Technical Bulletin I7, (I923).

EDINGTON L.V. BARRON G.L. Fungitoxic spectrum of Oxathiin compounds. Phytopathology 57, I256-I257, (I967).

EVANS N.S. Black point of wheat. Phytopathology II, 5I5, (I92I).

FUENTES F.D. EXCONDE O.R. GICALES E.S. Etiology of Helminthosporium leaf spot of wheat in the Phillipines. Phillipine Agriculture 49, 7II-729 (I966).

GRAHAM T.W. Nuclear phenomena in Helminthosporium gramineum. Phytopathology 25, 284-286, (I935).

GOULDEN C.H. Breeding for root rot resistance. Cereal Crops Division Central Experimental Farm, Ottawa, 27-28, (I955).

GREANEY F.J. Influence of temperature,rate, depth of seeding on incidence of root rot . Phytopathology 36, 252-263, (I946).

GREANEY F.J. BAILEY D.L. Root rots and foot rots of wheat in Manitoba. Dominion of Canada Department Agriculture Bulletin 85, (I927).

HAYES H.K. STAKMAN E.C. Resistance of barley to H.sativum. Phytopathology II, 405-4II, (I92I).

HENRY A.W. Root rots of wheat. Technical Bulletin of Minnesota Agriculture Experimental Station 22, (I924).

HEWETT P.D. A Health survey of seed barley. Plant Pathology 24, 229-233, (I975).

HRUSHOVETZ S.B. Cytological studies of H.sativum. Canadian Journal of Botany 34, 32I-327, (I956).

HRUSHOVETZ S.B. Effect of amino acids on the the virulence of H.sativum to wheat seedlings. Phytopathology 47, 26I-264, (I957).

HYNES H.J. Investigations by the late C.O. Hamblin into the Helminthosporium disease of wheat. Journal Royal Society New South Wales 57, I60-I72, (I923).

HYNES H.J. Foot rot of cereals. Observations on the disease in New South Wales. Agricultural Gazette New South Wales 43, I07-II5, (I932).

HYNES H.J. Studies on Helminthosporium root rot of wheat and other cereals. Department of Agriculture New South Wales Scientific Bulletin 47, (I935).

HYNES H.J. Studies of Helminthosporium root rot of wheat cereals. Department of Agriculture New South Wales Scientific Bulletin 6I, (I938).

JORGENSEN J. Species of Fusarium and Helminthosporium on seeds of barley grown in Denmark during I965-I967. Acta Agriculture Scandinavica I9, 92-98, (I969).

JORGENSEN J. Occurrence and importance of seed-borne inoculum of C.sativus on barley seed in Denmark. Acta Agriculture Scandinavica 24, 49-54, (1974).

KINGSLAND G.C. Barley leaf stripe control and invitro inhibition of H.sorokinianum obtained with Vitavax in S.Carolina. Phytopathology 59, 115, (1969).

KOMMEDAHL T. PATEL K.P. A method for rating varieties in the field for resistance to common root rot. Plant Disease Reporter 50, 26-27, (1966).

KUMAR K. RAM G. SINGH S. Bioassay of new fungicide agents. Labdev Journal Science and Technology 9B, 225-226, (1971).

KURIBAYASHI K. The ascigerous stage of H.sativum. Transactions of Sapporo Natural History Society X, 138-143, (1929).

LARSON R.I. ATKINSON T.G. A cytogenetic analysis of reaction to common root rot in some hard red spring wheat. Canadian Journal of Botany 48, 2059-2067, (1970).

LEDINGHAM R.J. Observations on antagonism in inoculation tests of wheat with H.sativum and F.culmorum. Scientific Agriculture 22, 688-697, (1942).

LEDINGHAM R.J. ATKINSON T.G. HORRICKS J.S. MILLS J.T. PIENING L.J. TINLINE R.D. Wheat losses due to common root rot in the Prairie Provinces of Canada 1969-71. Canadian Plant Disease Survey 53, 113-123 (1973).

LOISELLE R. Note on additional sources of resistance to H.sativum. Canadian Journal Plant Science 42, 368-369, (I962).

LOISELLE R. Inheritance of resistance to root rot and seedling blight of barley caused by H.sativum Canadian Journal Plant Science 45, 238-240, (I965).

LUDWIG R.A. CLARK R.V. JULIEN J.B. ROBINSON D.B. Studies on the seedling disease of barley caused by H.sativum. Canadian Journal Botany 34, 653-673, (I956).

LUTTRELL E.S. A taxonomic revision of H.sativum and related species. American Journal of Botany 42, 57-68, (I955).

MACHACEK J.E. An estimate of loss in Manitoba from common root rot. Scientific Agriculture 24, 70-77 (I943).

MACHACEK J.E. GREANEY F.J. Studies on control of root rot diseases of cereals. 3. Effect of seed treatment. Scientific Agriculture I5, 607-620 (1935).

MACHACEK J.E. WALLACE H.A. MEAD H.W. BROADFOOT W.C. A study of some seed borne diseases of cereals in Canada 3. Effect of rate of seeding, percentage of infested kernels and weeds on the yield of plots sown withtreated and untreated seed. Canadian Journal of Agricultural Science 34, 240-25I (I954).

MAKELA K. Leaf spot fungi in Finland. Suomen Maataloustieteellisan Seuran Julkaisuja 124, I-23, (I972).

MEAD H.W. Environmental relationships in a seed-borne disease of barley caused by H.sativum. Canadian Journal Research C 20, 525-538, (1942).

MEAD H.W. Host-parasite relationships in a seed-borne disease caused by H.sativum. Canadian Journal Research C 20, 501-523, (1942).

MICHALIZOVA Occurrence of O,graminis and H.sativum on Wheat. Pol'nohospoda rstvo 18, 1062-1069, (1972).

McKENZIE H. ATKINSON T.G. Inheritance of Thatcher type resistance to common root rot in spring wheat. Canadian Journal Plant Science 48, 479-486, (1968).

McKINNEY H.H. Influence of soil temperature and moisture on infection of wheat seedlings by H.sativum. Journal of Agricultural Research 26, 195-217, (1923).

McKINNEY H.H. DAVIS J. Influence of soil temperature and moisture on infection of young plants by O.graminis. Journal of Agricultural Research 9, 827-840, (1925).

MITRA M. A comparative study of species and strains of Helminthosporium on ceratain Indian cultivated crops. Transactions of British Mycological Society 15, 254-293, (1930).

MITRA M. Saltation in the genus Helminthosporium. Transactions of British Mycological Society 16, 127-157, (1931).

MOORE W.C. Report on fungal, bacterial and other diseases on crops in England and Wales for the years 1933-1942. Ministry of Agriculture, Fisheries and Food Bulletin 126, (1945).

MOORE W.C MOORE C. Cereal Diseases. Ministry Agriculture, Fisheries and Food Bulletin 129, 44, (1950).

MUKEWAR P.M. NATH R. LAMBAT A.K. Interception of a virulent isolate of <u>H.sativum</u>. Indian Phytopathology 26, 167-169, (1973).

MULLER H.E.H. Die verbreitung von <u>H.sativum</u> in Bayern und seine beteutung als krankheitserreger in gerste und weizen. Jb. bayer landw, 33, 610-640, (1956).

NEMA K.G. JOSHI L.M. Symptoms and diagnosis of 'spot blotch' and leaf blight of wheat. Indian Phytopath 24, 418-419, (1971).

NEMA K.G. JOSHI L.M. Flag leaf susceptibility of wheat to <u>H.sativum</u> in relationship to grain weight. Indian Phytopathology 24, 526-532, (1972).

PAMMEL L.H. KING C.M. BAKKE A.L. Two barley blights, with comparison of species of <u>Helminthosporium</u> upon cereals. Bulletin of Iowa Agricultural Experimental Station 116, (1910).

PAXTON G.E. Consistent mutation of <u>H.sativum</u> on a no-nitrogen medium. Phytopathology 23, 617-619, (1932).

PERSON C. SAMBORSKI D.J. FORSYTH F.R. Effect of benzimidazole on detached wheat leaves. Nature Lond. 180, 1294-1295, (1957).

PETERSON E.A. KATZNELSON H. Studies on the nutrition of H.sativum and certain related species. Canadian Journal Microbiology I, 190-197, (1954).

PETERSON E.A. KATZNELSON H. The effect of trace elements on growth of H.sativum and several related species. Canadian Journal Microbiology 2, 441-446, (1956).

PIENING L.J. Differential yield response to 10 barley cultivars to common foot rot. Canadian Journal Plant Science 53, 763-764, (1973).

PURSS G.S. Resistance to common root rot (C.sativus) in wheat in Queensland. Australian Journal Experimental Agriculture and Animal Husbandry 10, 497-501, (1970).

RICHARDSON L.T. Some effects of insecticides and herbicides applied to soil on the development of plant diseases. I. The seedling disease of barley caused by H.sativum. Canadian Journal Plant Science 37, 196-204, (1956).

RICHARDSON M.J. Meeting of Federation of Plant Pathologists London 1975.

RUSSELL T.A. Observations on foot-rot diseases of cereals. Transactions of British Mycological Society, 16, 253-269, (1932).

SALLANS B.J. Methods of inoculation of wheat with H.sativum. Scientific Agriculture 13, 515-527, (1933).

SALLANS B.J. Recovery in wheat from early infections by H.sativum and F.culmorum. Canadian Journal Plant Science 39, 187-193, (1959).

SALLANS B.J. LEDINGHAM R.J. An outbreak of common root rot in south-western Saskatchewan in 1942. Scientific Agriculture 23, 589-597, (1943).

SALLANS B.J. TINLINE R.D. Pathogenicity tests of isolates of H.sativum on wheat varieties. Proceedings of Canadian Phytopathology Society 17, 16, (1950).

SALLANS B.J. TINLINE R.D. Resistance of wheat to C.sativus - a cause of common root rot. Canadian Journal Plant Science 45, 343-351, (1965).

SANDFORD G.B. CORMACK M.W. Variability in association effects of the other soil fungi on the virulence of H.sativum on wheat seedlings. Canadian Journal of Research C, 18, 562-565, (1940).

SHANDS H.L. DICKSON J.G. Variation in hyphal-tip cultures from conidia of H.gramineum. Phytopathology 42, 480, (1952).

SHOEMAKER R.A. Biology, cytology, and taxonomy of C.sativus Canadian Journal Botany 29, 467-478, (1955).

SIMMONDS P.M. Dominion Botanist Canadian Department of Agriculture, 98-112, (1927).

SIMMONDS P.M. A review of the investigations in W.Canada on root rots of cereals. Scientific Agriculture 19, 565-582, (1939).

SIMMONDS P.M. Root rots of cereals. Botanical Review, 7, 308-332, (1941).

SIMMONDS P.M. Root rots of cereals 2. Botanical Review 19, 131-146, (1953).

SIMMONDS P.M. SALLANS B.J. Testing wheat seedlings for resistance to H.sativum. Scientific Agriculture, 26, 25-33, (1946).

SIMMONDS P.M. SCOTT G.A. Seed treatments for the control of seedling blight in cereals. Scientific Agriculture, 8, 502-511, (1928).

SIMMONDS P.M. SALLANS B.J. LEDINGHAM R.J. The occurrence of *H.sativum* in relation to primary infections in common root rot of wheat. Scientific Agriculture 30, 407-417, (1950).

SKOU J.P. Conidial stages of *C.sativus* as a pathogen and a cause of a disguised disease in Denmark. Friesia 8, 57-75, (1966).

STAKMAN L. A *Helminthosporium* disease of wheat and rye. Bulletin of Minnesota Agriculture Experimental Station 191, (1920).

STAKMAN L. HENRY A.W. CURRAN G.C. CHRISTOPHER W.N. Observations on the spore content of the upper air. Phytopathology 12, 44, (1922).

STEVENS F.L. The *Helminthosporium* foot rot of wheat, with observations on the morphology of the fungi and on the occurrence of saltation in the genus. Bulletin Illinois Natural History Survey 14, 77-185, (1922).

TINLINE R.D. Studies on the perfect stage of *H.sativum*. Canadian Journal of Botany 29, 467-478, (1951).

TINLINE R.D. *C.sativus* 5. Heterokaryosis and parasexuality Canadian Journal of Botany, 40, 425-437, (1962).

TYNER L.E. BROADFOOT W.C. Field trials of the differential reaction of wheat varieties to root rot. Scientific Agriculture 24, 153-163, (1943).

VIR D. Efficiency of fungicides - Seed disinfection in relation to black point disease of wheat. Pesticides 6, I5-I6, (I972).

WOOD L.S. *H.sativum* becomes destructive on hitherto resistant varieties. Phytopathology 44, 5II, (I954).

WOOD L.S. Relation of variation in *H.sativum* to seedling blight in small grains. Phytopathology 52, 463-467, (I962).

## 6. Appendix.

Table Ia. Detached Leaf Method of Varietal Response.

Spore conc. $IO^5$ spores/ml.

| Source. | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 23 | 4.835 | 0.2I02 | 3.98I *** |
| Errors | I20 | 6.336 | 0.0528 | |
| Total | I43 | II.I7I | | |

$F_{0.005,23,I20}$ = 2.089 from tables

Therefore varieties SIG at 0.005 level.

Table Ib.

Spore conc. 4 x $IO^5$ spores/ml.

| Source. | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 23 | 8.722 | 0.379 | 6.35I7 *** |
| Errors | I20 | 7.I69 | 0.0597 | |
| Total | I43 | I5.89I | | |

$F_{0.005,23,I20}$ = 2.0890 from tables

Therefore varieties SIG at 0.005 level.

Table 2a. Detached Leaf Method of Varietal Response.

Spore conc. $IO^5$ spores/ml.

| Source. | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 25 | 4.8I6 | 0.I926 | 8.875 *** |
| Errors | I30 | 2.82I | 0.02I7 | |
| Total | I45 | 7.637 | | |

$F_{0.005,25,I30}$ = 2.0890 from tables

Therefore varieties SIG at 0.005 level

Table 2b.

Spore conc. $5 \times 10^5$ spores/ml.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Varieties | 25 | 3.485 | 0.139 | 6.168 | *** |
| Errors | 130 | 3.493 | 0.023 | | |
| Total | 155 | 6.978 | | | |

$F_{0.005,25,130} = 2.089$ from tables

Therefore varieties SIG at 0.005 level

Table 3a. Detached Leaf Method of Varietal Response.

Spore conc. $5 \times 10^5$ spores/ml.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Varieties | 25 | 8.290 | 0.332 | 24.38 | *** |
| Errors | 130 | 1.769 | 0.014 | | |
| Total | 155 | 10.059 | | | |

$F_{0.005,25,130} = 2.089$ from tables

Therefore varieties SIG at 0.005 level

Table 3b.

Spore conc. $3 \times 10^5$ spores/ml

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Varieties | 25 | 2.762 | 0.1104 | 18.4 | *** |
| Errors | 130 | 0.780 | 0.006 | | |
| Total | 155 | 3.542 | | | |

$F_{0.005,25,130} = 2.089$ from tables

Therefore varieties SIG at 0.005 level

Table 4.

Spore conc. $10^5$ spores/ml

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Varieties | 7 | 37.17 | 5.31 | 6.852 | *** |
| Errors | 40 | 31.00 | 0.77 | | |
| Total | 47 | 68.17 | | | |

Table 4 (cont.)

$F_{0.005,7,40}$ = 3.5088 from tables

Therefore varieties SIG at o.005 level

Table 5a. Greenhouse Experiment of Varietal Response.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 23 | 0.812 | 0.0353 | 16.809 *** |
| Replicates | 1 | 0.002 | 0.0020 | 0.952 N.S. |
| Errors | 23 | 0.047 | 0.0021 | |
| Total | 47 | 0.861 | | |

For Varieties $F_{0.005,23,23}$ = 3.0208 from tables

Therefore varieties SIG at 0.005 level

For Replicates $F_{0.05,1,23}$ = 4.2793 from tables

Therefore Replicates NOT SIG.

Table 5b.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 23 | 0.7096 | 0.0309 | 7.923 *** |
| Replicates | 1 | 0.0046 | 0.0046 | 1.179 N.S. |
| Errors | 23 | 0.0902 | 0.0039 | |
| Total | 47 | 0.8044 | | |

For Varieties $F_{0.005,23,23}$ = 3.0208 from tables

Therefore varieties SIG at 0.005 level

For Replicates $F_{0.05,1,23}$ = 4.2793 from tables

Therefore replicates NOT SIG at 0.05 level.

Table 6a. 1974 Field Experiment of Varietal Response.

Percentage Infection.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 23 | 1.36 | 0.0591 | 0.945 N.S. |
| Errors | 24 | 1.50 | 0.0625 | |
| Total | 47 | 2.86 | | |

Table 6a.(cont.)

$F_{0.05,23,24}$ = I.9838 from tables

Therefore varieties NOT SIG

Table 6b.

Foot Rot Rating.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 23 | 0.821 | 0.0357 | 2.196 * |
| Errors | 24 | 0.390 | 0.0163 | |
| Total | 47 | I.2II | | |

$F_{0.05,23,24}$ = I.9838 from tables

Therefore varieties SIG at 0.05 level

Table 6c. Percentage infection - contol plots v inoculated.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | I | 21392.69 | 21392.69 | 50.64 *** |
| Errors | 44 | 18584.53 | 422.375 | |
| Total | 45 | 39977.22 | | |

$F_{0.005,I,44}$ = 8.8278 from tables

Therefore treatments SIG at 0.005 level

Table 7a. I975 Field Trials of Varietal Response.

After 2I days - percentage infection by Fusarium spp

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | II | 0.I20 | 0.0I09 | 0.7032 N.S. |
| Errors | I2 | 0.I86 | 0.0155 | |
| Total | 23 | 0.306 | | |

$F_{0.05,II,I2}$ = 2.75 from tables

Therefore varieties NOT SIG at 0.05 level.

Table 7b. Percentage infection - C.sativus after 21 days.

| Source. | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | II | 0.6748 | 0.06134 | I.II9 N.S. |
| Errors | I2 | 0.6582 | 0.0548 | |
| Total | 23 | I.333 | | |

$F_{0.05,II,I2}$ = 2.75 from tables

Therefore varieties NOT SIG at 0.05 level

Table 7c. Percentage infection - Fusarium spp after 63 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | IO | 743.42 | 74.34 | 0.I267 N.S. |
| Errors | II | 6450.09 | 586.3 | |
| Total | 2I | 7193.5I | | |

$F_{0.05, IO,II}$ = 2.853 from tables

Therefore varieties NOT SIG at0.05 level.

Table 7d. Percentage infection - C.sativus after 63 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | IO | I.6939 | 0.I6939 | I2.5846 *** |
| Errors | II | 0.I48I | 0.0I346 | |
| Total | 2I | I.842 | | |

$F_{0.005,IO,II}$ = 7.92 from tables

Therefore varieties SIG at 0.005 level.

Table 7e. Fusarium spp.infection in CON and INOC plots after 63 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatment | I | 2849.II8 | 2849.II8 | II.5I **** |
| Errors | I6 | 3959.I4 | 247.44 | |
| Total | I7 | 6808.26 | | |

$F_{0.005,I,I6}$= IO.575 from tables

Therefore treament SIG at 0.005 level

Table 8a. Foot Rot Rating - C.sativus and Fusarium spp. after 21 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 11 | 0.143 | 0.013 | 4.643 ** |
| Errors | 12 | 0.034 | 0.0028 | |
| Total | 23 | 0.177 | | |

$F_{0.01, 11, 12}$ = 4.30 from tables

Therefore varieties SIG at 0.01 level

Table 8b. Foot Rot Rating - C.sativus after 63days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 10 | 0.151 | 0.0151 | 4.14 * |
| Errors | 11 | 0.077 | 0.007 | |
| Total | 21 | 0.367? | | |

$F_{0.05, 10, 11}$ = 2.85 from tables

Therefore varieties SIG at 0.05 level

Table 8c. Foot Rot Rating - Fusarium spp after 63 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Varieties | 10 | 0.1511 | 0.0151 | 0.491 N.S. |
| Errors | 11 | 0.3389 | 0.0308 | |
| Total | 21 | 0.4899 | | |

$F_{0.05, 10, 11}$ = 2.85 from tables

Therefore varieties NOT SIG at 0.05 level

Table 8d. Fusarium spp.infection in CON and INOC plots after 63 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatment | 1 | 0.099 | 0.099 | 5.5 * |
| Errors | 14 | 0.252 | 0.018 | |
| Total | 15 | 0.351 | | |

$F_{0.05, 1, 14}$ = 4.60 from tables

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Table 9a. Plant Vigour after 21 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatment | I | 0.089 | 0.089 | 4.238 N.S. |
| Errors | 20 | 0.420 | 0.021 | |
| Total | 21 | 0.509 | | |

$F_{0.05,I,20}$ = 4.353 from tables

Therefore treatment NOT SIG.

Table 9b. Number of Tillers after 63 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatment | I | I.043 | I.043 | 0.224 N.S. |
| Errors | 20 | 92.98 | 4.649 | |
| Total | 21 | 94.03 | | |

$F_{0.05,I,20}$ = 4.353 from tables

Therefore treatment NOT SIG.

Table IO. Correlation between varietal response using the detached leaf method and greenhouse tests.

Test Statistic = 4.7009

$T_{0.005,6}$ = 3.707 from tables.

Therefore Correlation present at 0.005 level.

Table IIa. British Isolates v Barley I6°C

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 6 | 83.54 | I3.923 | 0.8859 | N.S. |
| Errors | I33 | 2090.2I | I5.7I6 | | |
| Total | I39 | 2173.74 | | | |

$F_{0.05,6,I33}$ = 2.I75 from tables

Therefore Isolates NOT SIG

Table IIb Netherlands Isolates v Barley I6°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 2 | I.034 | 0.5I7 | 0.0369 | N.S. |
| Errors | 57 | 797.950 | I3.999 | | |
| Total | 59 | 798.984 | | | |

$F_{0.05,2,57}$ = 3.I5 from tables

Therefore Isolates NOT SIG

Table IIc. Indian Isolates v Barley I6°C

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | I | 0.625 | 0.625 | 0.3823 |
| Errors | 38 | 62.I50 | I.635 | |
| Total | 39 | 62.775 | | |

$F_{0.05, I,38}$ = 4.085 from tables

Therefore Isolates NOT SIG

Table IId. Canadian Isolates v Barley I6°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 4 | 288.46 | 72.II5 | 5.007 | *** |
| Errors | 95 | I368.05 | I4.40I | | |
| Total | 99 | I656.5I | | | |

$F_{0.005,4,95}$ = 4.I39 from tables

Therefore Isolates SIG at 0.005 level.

Table 11e. Representatives of Groups v Barley 16°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 8 | 159.85 | 19.981 | 2.359 * |
| Errors | 171 | 1448.15 | 8.468 | |
| Total | 179 | 1608.0 | | |

$F_{0.05,8,171} = 2.016$ from tables.

Therefore Isolates SIG at 0.05 level.

Table 12a. British Isolates v Wheat 16°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 6 | 31.743 | 5.2905 | 1.571 N.S. |
| Errors | 113 | 447.80 | 3.367 | |
| Total | 119 | 479.543 | | |

$F_{6,113,0.05} = 2.175$ from tables

Therefore Isolates NOT SIG

Table 12 b. Netherlands Isolates v Wheat 16°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 2 | 0.234 | 0.117 | 0.148 N.S. |
| Errors | 57 | 45.174 | 0.792 | |
| Total | 59 | 45.198 | | |

$F_{0.05,2,57} = 3.15$ from tables

Therefore Isolates NOT SIG

Table 12 c .Indian Isolates v Wheat 16°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 1 | 0.900 | 0.900 | 0.084 N.S. |
| Errors | 38 | 405.6 | 10.674 | |
| Total | 39 | 406.5 | | |

$F_{0.05,1,38} = 4.08$ from tables.

Therefore Isolates NOT SIG.

Table I2d. Canadian Isolates v Wheat I6°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 4 | 576.I4 | I44.78 | 34.2I0 | *** |
| Errors | 95 | 402.I0 | 4.232 | | |
| Total | 99 | 98I.24 | | | |

$F_{0.005,4,95}$ = 3.9207 from tables.

Therefore Isolates SIG at 0.005 level.

Table I2e. Representatives of Groups v Wheat I6°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 6 | 56.I86 | 9.364 | 3.574 | *** |
| Errors | I33 | 348.50 | 2.620 | | |
| Total | I39 | 440.686 | | | |

$F_{0.005,6,133}$ = 3.28 from tables.

Therefore Isolates SIG at 0.005 level.

Table I3a. British Isolates v Oats I6°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 5 | I9.3 | 3.86 | I2.532 | *** |
| Errors | 24 | 7.4 | 0.308 | | |
| Total | 29 | 26.7 | | | |

$F_{0.005,5,24}$ = 4.48 from tables

Therefore Isolates SIG at 0.005 level.

Table I3 b. Netherlands Isolates v Oats I6°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 2 | 0.I4 | 0.07 | 0.II6 | N.S. |
| Errors | I2 | 7.20 | 0.60 | | |
| Total | I4 | 7.34 | | | |

$F_{0.05,2,12}$ = 3.88 from tables

Therefore Isolates NOT SIG.

Table I3c. Indian Isolates v Oats 16°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | I | 0.I | 0.I | 0.4 | N.S. |
| Errors | 8 | 2.0 | 0.25 | | |
| Total | 9 | 2.I | | | |

$F_{0.05,I,8}$ = 5.3177 from tables

Therefore Isolates NOT SIG.

Table I3 d. Canadian Isolates v Oats 16°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 4 | 166.56 | 41.64 | 49.57 | *** |
| Errors | 20 | 16.80 | 0.84 | | |
| Total | 24 | 183.36 | | | |

$F_{0.005,4,20}$ = 5.1743 from tables

Therefore Isolates SIG at 0.005 level.

Table I3e. Representatives of Groups v Oats 16°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 6 | 13.2 | 2.2 | 9.05 | *** |
| Errors | 28 | 6.8 | 0.243 | | |
| Total | 34 | 20.0 | | | |

$F_{0.005,6,28}$ = 4.019 from tables

Therefore Isolates SIG at 0.005 level.

Table I4a. British Isolates v Barley 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 6 | 62.19 | 10.365 | 0.785 | N.S. |
| Errors | 133 | 1754.50 | 13.193 | | |
| Total | 139 | 1816.69 | | | |

$F_{0.05,6,133}$ = 2.175 from tables

Therefore Isolates NOT SIG.

Table I4b. Netherlands Isolates v Barley 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 3 | 41.54 | 13.846 | 3.05 | * |
| Errors | 76 | 339.65 | 4.528 | | |
| Total | 79 | 381.19 | | | |

$F_{0.05,3,76} = 2.758$ from tables

Therefore Isolates SIG at 0.05 level.

Table I4c. Indian Isolates v Barley 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | I | 2.025 | 2.025 | 2.743 | N.S. |
| Errors | I8 | 13.350 | 0.742 | | |
| Total | I9 | 15.375 | | | |

$F_{0.05,1,18} = 4.41$ from tables

Therefore Isolates NOT SIG.

Table I4d. Canadian Isolates v Barley 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 4 | 23.80 | 5.95 | I.709 | N.S. |
| Errors | 95 | 330.95 | 3.48 | | |
| Total | 99 | 354.75 | | | |

$F_{0.05,4,95} = 2.525$ from tables.

Therefore Isolates NOT SIG.

Table I4e. Representatives of Groups v Barley 25°C.

| Source | D/F | S/S | M/S | Fobs. | |
|---|---|---|---|---|---|
| Isolates | 5 | 475.842 | 95.168 | 12.262 | *** |
| Errors | II4 | 884.75 | 7.761 | | |
| Total | II9 | 1360.592 | | | |

$F_{0.005,5,114} = 3.548$ from tables

Therefore Isolates SIG at 0.005 level.

Table 15a. British Isolates v Wheat 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 6 | 37.9 | 6.316 | 8.908 | *** |
| Errors | 133 | 94.35 | 0.709 | | |
| Total | 139 | 132.25 | | | |

$F_{0.005,6,133}$ = 3.087 from tables

Therefore Isolates SIG at 0.005 level.

Table 15b. Netherlands Isolates v Wheat 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 3 | 10.584 | 3.528 | 3.681 | * |
| Errors | 56 | 54.000 | 0.964 | | |
| Total | 59 | 64.584 | | | |

$F_{0.05,3,56}$ = 2.758 from tables

Therefore Isolates SIG at 0.05 level.

Table 15c. Indian Isolates v Wheat 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 1 | 124.033 | 124.033 | 26.122 | *** |
| Errors | 28 | 132.934 | 4.748 | | |
| Total | 29 | 256.967 | | | |

$F_{0.005,1,28}$ = 4.196 from tables

Therefore Isolates SIG at 0.005 level.

Table 15d. Canadian Isolates v Wheat 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 4 | 240.546 | 60.136 | 18.705 | *** |
| Errors | 70 | 225.041 | 3.215 | | |
| Total | 74 | 465.587 | | | |

$F_{0.005,4,70}$ = 4.1399 from tables

Therefore Isolates SIG at 0.005 level.

Table 15e. Representatives of Groups v Wheat 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 8 | 494.26 | 61.782 | 24.546 *** |
| Errors | 126 | 317.14 | 2.517 | |
| Total | 134 | | | |

$F_{0.005,8,126}$ = 3.933 from tables

Therefore Isolates SIG at 0.005 level.

Table 16a. British Isolates v Oats 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 6 | 7.43 | 1.238 | 1.3004 N.S. |
| Errors | 21 | 20.0 | 0.952 | |
| Total | 27 | 27.43 | | |

$F_{0.05,6,21}$ = 4.393 from tables.

Therefore Isolates SIG at 0.005 level.

Table 16b. Netherlands Isolates v Oats 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 3 | 2.8 | 0.933 | 3.732 * |
| Errors | 16 | 4.0 | 0.25 | |
| Total | 19 | 6.8 | | |

$F_{0.05,3,19}$ = 3.127 from tables

Therefore Isolates SIG at 0.05 level.

Table 16c. Indian Isolates v Oats 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 1 | 3.6 | 3.6 | 6.0 * |
| Errors | 8 | 4.8 | 0.6 | |
| Total | 9 | 8.4 | | |

$F_{0.05,1,8}$ = 5.3177 from tables

Therefore Isolates SIG at 0.05 level.

Table 16d. Representatives of Groups v Oats 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 5 | 1.1 | 0.22 | 0.402 N.S. |
| Errors | 19 | 10.4 | 0.547 | |
| Total | 24 | 11.5 | | |

$F_{0.05,5,19} = 2.7401$ from tables

Therefore Isolates NOT SIG .

Table 17a. Pot Sown Experiment 1974.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 3 | 193.5 | 64.5 | 3.909 | N.S. |
| Blocks | 1 | 84.5 | 84.5 | 5.121 | N.S. |
| Errors | 3 | 49.5 | 16.5 | | |
| Total | 7 | 327.5 | | | |

$F_{0.05,3,3} = 9.276$ from tables

Therefore Treatments NOT SIG

$F_{0.05,1,3} = 10.128$ from tables

Therefore Blocks NOT SIG.

Table 17b Percentage Germination after 6 weeks.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 3 | 118 | 39.33 | 1.372 |
| Blocks | 1 | 2 | 2.00 | 0.0697 |
| Errors | 3 | 86 | 28.66 | |
| Total | 7 | 206 | | |

$F_{0.05,3,3} = 9.2766$ from tables

Therefore NOT SIG

$F_{0.05,1,3} = 10.128$ from tables

Therefore Blocks NOT SIG.

Table 17c. Percentage infection after 3 weeks.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatment | 3 | 9872.629 | 3290.87 | 46.013 | ** |
| Blocks | 1 | 2.959 | 2.959 | 0.041 | N.S. |
| Errors | 3 | 214.565 | 71.521 | | |
| Total | 7 | 10090.153 | | | |

$F_{0.01,3,3}$ = 29.457 from tables

Therefore Treatments SIG at 0.01 level.

$F_{0.05,1,3}$ = 10.128 from tables

Therefore Blocks NOT SIG.

Table 17d. Percentage infection after 6 weeks.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatment | 3 | 1280.978 | 426.992 | 9.3439 | * |
| Blocks | 1 | 337.998 | 337.998 | 7.3965 | N.S. |
| Errors | 3 | 137.091 | 45.697 | | |
| Total | 7 | 1756.067 | | | |

$F_{0.05,3,3}$ = 9.2766 from tables

Therefore Treatments SIG at 0.05 level.

$F_{0.05,1,3}$ = 10.128 from tables

Therefore Blocks NOT SIG.

Table 17e. Foot Rot Rating after 6 weeks.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatment | 3 | 0.1569 | 0.0523 | 98.679 | *** |
| Blocks | 1 | 0.0104 | 0.0104 | 19.622 | |
| Errors | 3 | 0.0016 | 0.00053 | | |
| Total | 7 | 0.1689 | | | |

$F_{0.005,3,3}$ = 47.467 from tables.

Therefore Treatments SIG at 0.005 level.

$F_{0.05,I,3}$ = I0.I28 from tables.

Therefore Blocks SIG at 0.05 level.

Table I8a. Field Sown Experiment - % infection after 3 weeks.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatment | 3 | I3599.I88 | 4533.06 | II0.732 | *** |
| Blocks | I | I.563 | I.56 | 0.038 | N.S. |
| Treatment/Block | 3 | 48.687 | I6.22 | 0.396 | N.S. |
| Errors | 8 | 327.500 | 40.937 | | |
| Total | I5 | I3976.94 | | | |

$F_{0.005,3,8}$ = 9.5965 from tables.

Therefore Treatments SIG at 0.005 level.

$F_{0.05,I,8}$ = 5.3I77 from tables

Therefore Block effect NOT SIG.

$F_{0.05,3,8}$ = 4.0662 from tables

Therefore Interaction NOT SIG.

Table I8b. Percentage Infection after 35 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatment | 3 | 6I24.75 | 204I.58 | I8.947 | *** |
| Blocks | I | I2.25 | I2.25 | 0.II4 | N.S. |
| T/B Interaction | 3 | 84.75 | 28.25 | 0.262 | N.S. |
| Errors | 8 | 862.00 | I07.75 | | |
| Total | I5 | 7083.75 | | | |

$F_{0.005,3,8}$ = 9.5965

Therefore Treatments SIG at 0.005 level.

$F_{0.05,I,8}$ = 5.3I77 from tables

Therefore Blocks NOT SIG.

$F_{0.05,1,8}$ = 4.0662 from tables.

Therefore Interaction NOT SIG.

Table I8c. Foot Rot Rating after 42 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatment | 3 | 0.4507 | 0.I502 | 2I.457 *** |
| Block | I | 0.00I | 0.00I | 0.I428 N.S. |
| Interaction | 3 | 0.0I | 0.0033 | 0.47I4 N.S. |
| Error | 8 | 0.0567 | 0.007 | |
| Total | I5 | 0.5I84 | | |

$F_{0.005,3,8}$ = 9.5965 from tables.

Therefore Treatments SIG at 0.005 level.

$F_{0.05,1,8}$ = 5.3177 from tables

Therefore Blocks NOT SIG.

$F_{0.05,3,8}$ = 4.066 from tables.

Therefore Interaction NOT SIG.

Table I9a. Percentage Infection - C.sativus after 2I days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatment | I4 | 0.6226 | 0.04447 | II.258 *** |
| Errors | 30 | 0.II84 | 0.00395 | |
| Total | 44 | 0.74I0 | | |

$F_{0.005,14,30}$ = 3.0057 from tables.

Therefore Treatments SIG at 0.005 level.

Table I9b. Percentage Infection - C.sativus after 35 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatment | I4 | I.2495 | 0.08925 | 9.8946 *** |
| Errors | 30 | 0.2707 | 0.00902 | |
| Total | 44 | I.5202 | | |

$F_{0.005,14,30}$ = 3.0057 from tables

Therefore Treatments SIG at 0.005 level.

Table I9c. Percentage Infection - C.sativus after 49 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | I4 | I.244 | 0.0888 | I2.869 *** |
| Errors | 30 | 0.207 | 0.0069 | |
| Total | 44 | I.45I | | |

$F_{0.005,14,30}$ = 3.0057 from tables.

Therefore Treatments SIG at 0.005 level.

Table I9d. Percentage Infection - C.sativus after 63 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | I4 | I.460 | 0.I04 | 4.727 *** |
| Errors | 30 | 0.656 | 0.022 | |
| Total | 44 | 2.II6 | | |

$F_{0.005,14,30}$ = 3.0057 from tables

Therefore Treaments SIG at 0.005 level.

Table 20a. Percentage Infection - F.culmorum after 2I days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | I4 | 4I6.426 | 29.744 | 3.4I05 *** |
| Errors | 30 | 2I6.632 | 8.72I | |
| Total | 44 | 678.058 | | |

$F_{0.005,14,30}$ = 3.0057 from tables.

Therefore Treatments SIG at 0.005 level.

Table 20b. Percentage Infection - F.culmorum after 35 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | I4 | 0.468 | 0.033 | 4I.25 *** |
| Errors | 30 | 0.279 | 0.0093 | |
| Total | 44 | 0.5I7 | | |

$F_{0.005,14,30}$ = 3.0057 from tables

Therefore Treatments SIG at 0.005 level.

Table 20c. Percentage Infection - F.culmorum after 49 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 14 | 0.238 | 0.0318 | 3.419 *** |
| Errors | 30 | 0.279 | 0.0093 | |
| Total | 44 | 0.517 | | |

$F_{0.005,14,30}$ = 3.0057 from tables

Therefore Treatments SIG at 0.005 level.

Table 20d. Percentage Infection - F.culmorum after 63 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 14 | 0.269 | 0.0192 | 2.400 * |
| Errors | 30 | 0.244 | 0.008 | |
| Total | 44 | 0.513 | | |

$F_{0.05,14,30}$ = 2.0148 from tables

Therefore Treatments SIG at 0.05 level.

Table 21a. Foot Rot Rating - C.sativus + Fusarium spp.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatment | 14 | 0.1609 | 0.01149 | 5.3943 *** |
| Errors | 39 | 0.0639 | 0.00213 | |
| Total | 44 | 0.2248 | | |

$F_{0.005,14,30}$ = 3.0057 from tables.

Therefore Treatments SIG at 0.005 level.

Table 21b. Foot Rot Rating - C.sativus after 35 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatment | 14 | 0.403 | 0.02878 | 29.670 *** |
| Errors | 30 | 0.0293 | 0.00097 | |
| Total | 44 | 0.4323 | | |

$F_{0.005,14,30}$ = 3.0057 from tables

Therefore Treatments SIG at 0.005 level.

Table 21c. Foot Rot Rating - Fusarium spp. after 49 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 14 | 0.7134 | 0.05095 | 4.5409 | *** |
| Errors | 30 | 0.3367 | 0.01122 | | |
| Total | 44 | 1.0501 | | | |

$F_{0.005,14,30}$ = 3.0057 from tables.

Therefore Treatments SIG at 0.005 level.

Table 21d. Foot Rot Rating - Fusarium spp. after 49 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 14 | 0.0707 | 0.00505 | 2.2544 |
| Errors | 30 | 0.0673 | 0.00224 | |
| Total | 44 | 0.1308 | | |

$F_{0.05,14,30}$ = 2.0148 from tables.

Therefore Treatments SIG at 0.05 level.

Table 22a. Plant Vigour after 21 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 14 | 0.108 | 0.0077 | 0.6696 | N.S. |
| Errors | 30 | 0.347 | 0.0115 | | |
| Total | 44 | 0.455 | | | |

$F_{0.05,14,30}$ = 2.0148 from tables.

Therefore Treatments NOT SIG.

Table 22b. Plant Vigour after 35 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 14 | 0.085 | 0.00614 | 1.189 | N.S. |
| Errors | 30 | 0.155 | 0.00516 | | |
| Total | 44 | 0.241 | | | |

$F_{0.05,14,30}$ = 2.0148 from tables

Therefore Treatments NOT SIG.

Table 22c. Number of Tillers after 63 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 14 | 2.956 | 0.2111 | 1.088 | N.S |
| Errors | 30 | 5.820 | 0.194 | | |
| Total | 44 | 8.776 | | | |

$F_{0.05,14,30}$ = 2.0148 from tables

Therefore Treatments NOT SIG .

Table 23a. Mean Weight of Heads at harvest.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 14 | 30.977 | 2.2126 | 35.232 | *** |
| Plots | 30 | 1.341 | 0.0413 | 0.657 | N.S. |
| Rows | 45 | 2.828 | 0.0628 | | |

$F_{0.005,14,45}$ = 2.7811 from tables

Therefore Treatments SIG at 0.005 level

$F_{0.05,30,45}$ = 1.744 from tables.

Therefore Plots NOT SIG.

Table 23b. Analysis of Yield Weights at harvest.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 14 | 11.0129 | 0.7866 | 2.5909 | * |
| Plots | 30 | 22.296 | 0.7432 | 2.4479 | * |
| Rows | 45 | 13.6637 | 0.3036 | | |

$F_{0.05,14,45}$ = 1.924 from tables

Therefore Treatments SIG at 0.05 level.

Also Plots SIG at 0.05 level.

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Table 23c Analysis of Number of Tillers at harvest.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 14 | 5.453 | 0.3995 | 1.5598 | N.S. |
| Plots | 30 | 13.884 | 0.4628 | 1.8534 | N.S. |
| Row | 45 | 11.237 | | | |
| Total | 89 | 30.574 | | | |

$F_{0.05,14,45}$ = 1.9245 from tables.

Therefore Treatments NOT SIG.

$F_{0.05,30,45}$ = 1.7444 from tables.

Therefore Plots SIG at 0.05 level.

Table 24a. Percentage infection - C.sativus after 25 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 118.141 | 23.628 | 3.2168 * |
| Errors | 12 | 88.405 | 7.345 | |
| Total | 17 | 206.546 | | |

$F_{0.05,5,17}$ = 3.1059 from tables

Therefore Treatments SIG at 0.05 level.

Table 24b. Percentage infection - C.sativus after 37 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 94.72 | 18.944 | 1.618 | N.S. |
| Errors | 12 | 140.50 | 11.708 | | |
| Total | 17 | 235.22 | | | |

$F_{0.05,5,12}$ = 3.1059 from table.

Therefore Treatments NOT SIG.

Table 24c. Percentage infection - C. sativus after 55 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 429.889 | 85.977 | 5.296 | ** |
| Errors | I2 | 194.795 | 16.232 | | |
| Total | I7 | 624.684 | | | |

$F_{0.005,5,I2}$ = 5.0643 from tables.

Therefore Treatments SIG at 0.005 level.

Table 25a. Percentage infection - Fusarium spp. after 25 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 512.830 | 102.566 | 3.972 | * |
| Errors | I2 | 309.872 | 25.822 | | |
| Total | I7 | 822.702 | | | |

$F_{0.05,5,I2}$ = 3.I059 from tables.

Therefore Treatments SIG at 0.05 level.

Table 25b. Percentage Infection - Fusarium spp. after 37 days.

| Source | D/F | S/S | M/S | Fobs. | |
|---|---|---|---|---|---|
| Treatments | 5 | 695.86 | I39.I7 | I0.2338 | *** |
| Errors | I2 | I63.I83 | I3.59 | | |
| Total | I7 | 859.I83 | | | |

$F_{0.005,5,I2}$ = 6.07II from tables.

Therefore Treatments SIG at 0.005 level.

Table 25c. Percentage Infection - Fusarium spp. after 55 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 2800.978 | 560.I95 | I5.I94 | *** |
| Errors | I2 | 442.428 | 36.869 | | |
| Total | I7 | 3243.406 | | | |

$F_{0.005,5,I2}$ = 6.07II from tables.

Therefore Treatments SIG at 0.005 level.

Table 26a. Foot Rot Rating - C.sativus after 25 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 0.001886 | 0.000377 | 12.7796 | *** |
| Errors | 12 | 0.000354 | 0.0000295 | | |
| Total | 17 | 0.0024 | | | |

$F_{0.005,5,12}$ = 6.0711 from tables

Therefore Treatments SIG at 0.005 level.

Table 26b. Foot Rot Rating - C.sativus after 37 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 0.004808 | 0.000816 | 6.133 | *** |
| Errors | 12 | 0.00160 | 0.000133 | | |
| Total | 17 | 0.00568 | | | |

$F_{0.005,5,12}$ = 6.0711 from tables

Therefore Treatments SIG at 0.005 level.

Table 26c. Foot Rot Rating - C.sativus after 55 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 0.01437 | 0.00287 | 5.8215 | ** |
| Errors | 12 | 0.00591 | 0.000493 | | |
| Total | 17 | 0.02028 | | | |

$F_{0.01,5,12}$ = 5.0643 from tables.

Therefore Treatments SIG at 0.01 level.

Table 27a. Foot Rot Rating - Fusarium spp. after 25 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 0.00339 | 0.000678 | 3.9882 | * |
| Errors | 12 | 0.00205 | 0.00017 | | |
| Total | 17 | 0.00544 | | | |

$F_{0.05,5,12}$ = 3.1059 from tables.

Therefore Treatments SIG at 0.05 level

Table 27b. Foot Rot Rating - Fusarium spp. after 37 days.

| Source | D/F | S/S | M/S | Fobs. | |
|---|---|---|---|---|---|
| Treatments | 5 | 0.009104 | 0.00182 | 9.100 | *** |
| Errors | 12 | 0.00240 | 0.0002 | | |
| Total | 17 | 0.11504 | | | |

$F_{0.005,5,12}$ = 3.1059 from tables.

Therefore Treatments SIG at 0.005 level.

Table 27c. Foot Rot Rating - Fusarium spp. after 55 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 0.0718 | 0.0144 | 12.00 | *** |
| Errors | 12 | 0.0145 | 0.0012 | | |
| Total | 17 | 0.0863 | | | |

$F_{0.005,5,12}$ = 6.0711 from tables

Therefore Treatments SIG at 0.005 level.

Table 28a. Plant Vigour after 37 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 0.32 | 0.064 | 2.406 | N.S. |
| Errors | 12 | 0.32 | 0.0266 | | |
| Total | 17 | 0.64 | | | |

$F_{0.05,5,12}$ = 3.1059 from tables.

Therefore Treatments NOT SIG.

Table 28b. Number of Heads at Harvest.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 1.533 | 0.3066 | 5.84 | ** |
| Errors | 12 | 0.630 | 0.0525 | | |
| Total | 17 | 2.163 | | | |

$F_{0.01,5,12}$ = 5.0643 from tables.

Therefore Treatments NOT SIG.

**Table 29a.** Analysis of Average Weight of Heads .

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 0.243 | 0.0486 | 1.658 | N.S. |
| Errors | 12 | 0.351 | 0.0293 | | |
| Total | 17 | 0.594 | | | |

$F_{0.05,5,12} = 3.1059$ from tables.

Therefore Treatments NOT SIG.

**Table 29b.** Analysis of Mean Weight of heads/plant.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 11.459 | 2.2918 | 3.139 | * |
| Errors | 12 | 8.760 | 0.730 | | |
| Total | 17 | 20.219 | | | |

$F_{0.05,5,12} = 3.1059$ from tables

Therefore Treatments SIG at 0.05 level.

**Table 30a.** Percentage Infection - C.sativus after 23 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 244.784 | 48.957 | 4.9031 | * |
| Errors | 12 | 195.797 | 16.316 | | |
| Total | 17 | 440.581 | | | |

$F_{0.05,5,12} = 3.1059$ from tables

Therefore Treatments SIG at 0.05 level.

**Table 30b.** Percentage Infection - C.sativus after 39 days.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Treatments | 5 | 324.996 | 64.999 | 5.48 | ** |
| Errors | 12 | 142.306 | 11.859 | | |
| Total | 17 | 467.302 | | | |

$F_{0.01,5,12} = 5.0463$ from tables.

Therefore Treatments SIG at 0.01 level.

Table 30c. Percentage Infection - C.sativus after 60 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 607.458 | 121.492 | 3.939 * |
| Errors | 12 | 367.788 | 30.649 | |
| Total | 17 | 975.246 | | |

$F_{0.05,5,12} = 3.1059$ from tables

Therefore Treatments SIG at 0.05 level.

Table 31a. Percentage Infection - Fusarium spp. after 23 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 518.16 | 103.632 | 40.26 *** |
| Errors | 12 | 30.892 | 2.574 | |
| Total | 17 | 549.052 | | |

$F_{0.005,5,12} = 6.0711$ from tables

Therefore Treatments SIG at 0.005 level.

Table 32b. Percentage Infection - Fusarium spp. after 39 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 741.006 | 148.201 | 21.948 *** |
| Errors | 12 | 81.038 | 6.753 | |
| Total | 17 | 822.036 | | |

$F_{0.005,5,12} = 6.0711$ from tables

Therefore Treatments SIG at 0.005 level.

Table 32c. Percentage Infection - Fusarium spp. after 60 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 965.816 | 193.163 | 2.619 N.S. |
| Errors | 12 | 885.020 | 73.752 | |
| Total | 17 | 1850.836 | | |

$F_{0.05,5,12} = 3.1059$ from tables.

Therefore Treatments NOT SIG.

Table 32a. Foot Rot Rating - C.sativus after 23 days.

| Source | D/F | S/S | M/S | Fobs. |
|---|---|---|---|---|
| Treatments | 5 | 0.000345 | 0.000069 | 0.25 N.S. |
| Errors | 12 | 0.003243 | 0.00027 | |
| Total | 17 | 0.003588 | | |

$F_{0.05,5,12}$ = 3.1059 from tables

Therefore Treatments NOT SIG.

Table 32b. Foot Rot Rating - C.sativus after 39 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 0.00869 | 0.00174 | 2.685 N.S. |
| Errors | 12 | 0.00777 | 0.000648 | |
| Total | 17 | 0.01646 | | |

$F_{0.05,5,12}$ = 3.1059 from tables

Therefore Treatments NOT SIG.

Table 32c. Foot Rot Rating - C.sativus after 60 days.

| Treatments | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 0.03138 | 0.00627 | 4.9031 * |
| Errors | 12 | 0.01542 | 0.00128 | |
| Total | 17 | 0.04680 | | |

$F_{0.05,5,12}$ = 3.1059 from tables

Therefore Treatments SIG at 0.05 level

Table 33a. Foot Rot Rating - Fusarium spp. after 23 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 0.001361 | 0.000272 | 1.2 N.S. |
| Errors | 12 | 0.002721 | 0.000227 | |
| Total | 17 | 0.004082 | | |

$F_{0.05,5,12}$ = 3.1059 from tables.

Therefore Treatments NOT SIG.

Table 33b. Foot Rot Rating - Fusarium spp. after 39 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 0.025215 | 0.005003 | 2.195 N.S. |
| Errors | 12 | 0.02735 | 0.002279 | |
| Total | 17 | 0.0525 | | |

$F_{0.05,5,12}$ = 3.1059 from tables

Therefore Treatments NOT SIG.

Table 33c. Foot Rot Rating - Fusarium spp. after 60 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 0.021869 | 0.00437 | 1.2734 N.S. |
| Errors | 12 | 0.041214 | 0.00343 | |
| Total | 17 | 0.063083 | | |

$F_{0.05,5,12}$ = 3.1059 from tables

Therefore Treatments NOT SIG.

Table 34a. Plant Vigour after 39 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 0.73 | 0.146 | 4.290 * |
| Errors | 12 | 0.41 | 0.034 | |
| Total | 17 | 1.14 | | |

$F_{0.05,5,12}$ = 3.1059 from tables

Therefore Treatments SIG at 0.05 level.

Table 34b. Plant Vigour within Infected Clermont plots.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 2 | 0.07 | 0.035 | 0.875 N.S. |
| Errors | 6 | 0.24 | 0.04 | |
| Total | 8 | 0.31 | | |

$F_{0.05,2,6}$ = 5.1433 from tables.

Therefore Treatments NOT SIG.

Table 34c. Plant Vigour within Uninfected Clermont plots

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 2 | 0.06 | 0.03 | I.07 N.S. |
| Errors | 6 | 0.I7 | 0.028 | |
| Total | 8 | 0.23 | | |

$F_{0.05,2,6}$ = 5.I433 from tables.

Therefore Treatments NOT SIG.

Table 34d. Plant Vigour - Infected v Uninfected plots.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | I | 0.6 | 0.60 | I7.6 *** |
| Errors | I6 | 0.54 | 0.034 | |
| Total | I7 | I.I4 | | |

$F_{0.005,I,I7}$ = I0.384 from tables.

Therefore Treatments SIG at 0.005 level.

Table 34e. No.Tillers after 60 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 3.39 | 0.678 | 5.086 ** |
| Errors | I2 | I.60 | 0.I33 | |
| Total | I7 | 4.99 | | |

$F_{0.0I,5,I2}$ = 5.0643 from tables.

Therefore Treatments SIG at 0.0I level.

Table 34f. No. tillers within Infected Clermont after 60 days.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Seed lot | 2 | 0.30 | 0.I5 | 0.72 N.S. |
| Errors | 6 | I.25 | 0.208 | |
| Total | 8 | I.55 | | |

$F_{0.05,2,6}$ = 5.I433 from tables.

Therefore Seed lot NOT SIG.

Table 34 g. No. Tillers within Untreated plots.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 2 | 0.63 | 0.315 | I.4 N.S. |
| Errors | 6 | I.35 | 0.225 | |
| Total | 8 | I.98 | | |

$F_{0.05,2,6}$ = 5.I433 from tables.

Therefore Treatments NOT SIG.

Table 34h. No. Tillers Infected v Uninfected.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Seed lots | I | I.46 | I.46 | 6.63 * |
| Errors | I6 | 3.53 | 0.22 | |
| Total | I7 | 4.99 | | |

$F_{0.05,I,I6}$ = 5.I433 from tables.

Therefore Seed lots SIG at 0.05 level.

Table 34i. No. Tillers within Infected Seed at harvest.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 2 | 0.54 | 0.27 | 3.698 N.S. |
| Errors | 6 | 0.44 | 0.073 | |
| Total | 8 | 0.98 | | |

$F_{0.05,2,6}$ = 5.I433 from tables.

Therefore Treatments NOT SIG.

Table 34j. No.Tillers within Uninfected seed at harvest.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 2 | 0.06I | 0.0305 | 0.5258 N.S. |
| Errors | 6 | 0.350 | 0.058 | |
| Total | 8 | 0.4II | | |

$F_{0.05,2,6}$ = 5.I433 from tables.

Therefore Treatments NOT SIG.

Table 34k. No. tillers infected v uninfected.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Seed lots | I | 0.339 | 0.339 | 3.89 N.S. |
| Errors | I6 | I.39I | 0.087 | |
| Total | I7 | I.730 | | |

$F_{0.05,I,I7}$ = 4.45I3 from tables.

Therefore Seed lots NOT SIG.

Table 35a. Average Weight of heads at harvest.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 0.055 | 0.0II | 0.733 N.S. |
| Errors | I2 | 0.I82 | 0.0I5 | |
| Total | I7 | 0.237 | | |

$F_{0.05,5,I2}$ = 3.I059 from tables.

Therefore Treatments NOT SIG.

Table 35b. Mean Weight of heads /plant.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Treatments | 5 | 5.246 | I.0492 | 2.767 N.S. |
| Errors | I2 | 4.503 | 0.375 | |
| Total | I7 | 9.749 | | |

$F_{0.05,5,I2}$ = 3.I059 from tables.

Therefore Treatments NOT SIG.

Table 36a. British, Netherlands Isolates v P.D.A. I6°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 8 | 329.86 | 4I.232 | 3.936 *** |
| Errors | 27 | 282.83 | I0.475 | |
| Total | 35 | 6I2.69I | | |

$F_{0.005,8,27}$ = 3.687 from tables

Therefore Isolates SIG at 0.005 level.

Table 36b. British, Netherlands isolates on P.D.A. 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 8 | 1080.65 | 135.081 | 13.575 | *** |
| Errors | 27 | 268.67 | 9.951 | | |
| Total | 35 | 1349.32 | | | |

$F_{0.005,8,27}$ = 3.6875 from tables.

Therefore Isolates SIG at 0.005 level.

Table 36c. British, Netherlands isolates on P.D.A. 30°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 8 | 974.145 | 121.768 | 35.697 | *** |
| Errors | 27 | 92.103 | 3.411 | | |
| Total | 35 | 1066.25 | | | |

$F_{0.005,8,27}$ = 3.6875 from tables.

Therefore Isolates SIG at 0.005 level.

Table 36d. Canadian Isolates on P.D.A. 16°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 4 | 1410.85 | 352.713 | 109.518 | *** |
| Errors | 15 | 48.12 | 3.208 | | |
| Total | 19 | 1458.975 | | | |

$F_{0.005,4,15}$ = 5.8029 from tables.

Therefore Isolates SIG at 0.005 level

Table 36e. Canadian Isolates on P.D.A. 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 4 | 1524.61 | 381.152 | 63.78 | *** |
| Errors | 10 | 59.76 | 5.976 | | |
| Total | 14 | 1583.93 | | | |

$F_{0.005,4,10}$ = 7.3428 from tables.

Therefore Isolates SIG at 0.005 level.

Table 36f. Canadian Isolates on P.D.A. 30°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 4 | 7878.10 | 1969.52 | 138.17 *** |
| Errors | 35 | 498.88 | 14.25 | |
| Total | 39 | 8376.98 | | |

$F_{0.005,4,35}$ = 4.6233 from tables.

Therefore Isolates SIG at 0.005 level.

Table 36g. Indian Isolates on P.D.A. 16°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 1 | 72.25 | 72.25 | 65.266 *** |
| Errors | 14 | 15.50 | 1.107 | |
| Total | 15 | 87.75 | | |

$F_{0.005,1,14}$ = 11.060 from tables

Therefore Isolates SIG at 0.005 level.

Table 36h. Indian Isolates on P.D.A. 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 1 | 1105.57 | 1105.57 | 72.639 *** |
| Errors | 6 | 91.37 | 15.22 | |
| Total | 7 | 1196.94 | | |

$F_{0.005,1,7}$ = 18.635 from tables.

Therefore Isolates SIG at 0.005 level.

Table 36i. Indian Isolates on P.D.A. 30°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 1 | 1235.15 | 1235.15 | 50.745 *** |
| Errors | 6 | 146.08 | 24.34 | |
| Total | 7 | 1381.23 | | |

$F_{0.005,1,6}$ = 18.635

Therefore Isolates SIG at 0.005 level.

Table 37a. British, Netherlands Isolates on Czapek Dox 16°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 8 | 353.06 | 44.133 | 11.541 *** |
| Errors | 27 | 103.24 | 3.824 | |
| Total | 35 | 456.30 | | |

$F_{0.005,8,27}$ = 3.687 from tables.

Therefore Isolates SIG at 0.005 level.

Table 37b. British, Netherlands Isolates on Czapek Dox 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 8 | 1703.50 | 212.90 | 51.796 *** |
| Errors | 27 | 111.00 | 4.111 | |
| Total | 35 | 1814.50 | | |

$F_{0.005,8,27}$ = 3.687 from tables.

Therefore Isolates SIG at 0.005 level.

Table 37c. British, Netherlands Isolates on Czapek Dox 30°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 8 | 843.765 | 105.345 | 26.099 *** |
| Errors | 27 | 108.98 | 4.036 | |
| Total | 35 | 951.748 | | |

$F_{0.005,8,27}$ = 3.687 from tables.

Therefore Isolates SIG at 0.005 level.

Table 37d. Canadian Isolates on Czapek Dox 16°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 5 | 156.80 | 31.36 | 10.079 *** |
| Errors | 24 | 74.67 | 3.111 | |
| Total | 29 | 231.47 | | |

$F_{0.005,5,24}$ = 4.4857 from tables.

Therefore Isolates SIG at 0.005 level.

Table 37e. Canadian Isolates on Czapek Dox 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 5 | 14757.53 | 2951.506 | 262.03 *** |
| Errors | 24 | 270.34 | 11.262 | |
| Total | 29 | 15027.87 | | |

$F_{0.005,5,24}$ = 4.4857 from tables.

Therefore Isolates SIG at 0.005 level.

Table 37f. Canadian Isolates on Czapek Dox Agar 30°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 5 | 1814.46 | 362.892 | 10.992 *** |
| Errors | 24 | 793.34 | 33.014 | |
| Total | 29 | 2606.80 | | |

$F_{0.005,5,24}$ = 4.4857 from tables.

Table 37g. Indian Isolates on Czapek Dox 16°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | I | 56.33 | 56.33 | 10.694 *** |
| Errors | 10 | 52.67 | 5.267 | |
| Total | II | 109.00 | | |

$F_{0.005,I,IO}$ = 12.826 from tables.

Therefore Isolates SIG at 0.01 level.

Table 37h. Indian Isolates on Czapek Dox 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | I | 225.33 | 225.33 | 5.66 * |
| Errors | 10 | 397.67 | 39.76 | |
| Total | II | 623.00 | | |

$F_{0.05,I,IO}$ = 4.9646 from tables.

Therefore Isolates SIG at 0.05 level.

Table 37i. Indian Isolates on Czapek Dox 30°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | I | 5.33 | 5.33 | 3.995 | N.S |
| Errors | IO | I3.34 | I.334 | | |
| Total | II | I8.67 | | | |

$F_{0.05,I,IO}$ = 4.9646 from tables.

Therefore Isolates NOT SIG.

Table 38a. British, Netherlands Isolates on V - 8,I6°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 8 | I09.I4 | I3.642 | 7.499 | *** |
| Errors | 27 | 49.I2 | I.8I9 | | |
| Total | 35 | I58.26 | | | |

$F_{0.005,8,27}$ = 3.6875 from tables.

Therefore Isolates SIG at 0.005 level.

Table 38b. British, Netherlands Isolates on V - 8 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 8 | 843.86 | I05.48 | 42.426 | *** |
| Errors | 27 | 67.I3 | 2.486 | | |
| Total | 35 | 9I0.99 | | | |

$F_{0.005,8,27}$ = 3.6875 from tables.

Therefore Isolates SIG at 0.005 level.

Table 38c. British, Netherlands Isolates on V - 8 25°C.

| Source | D/F | S/S | M/S | Fobs | |
|---|---|---|---|---|---|
| Isolates | 8 | 842.76 | I05.345 | 26.099 | *** |
| Errors | 27 | I08.983 | 4.036 | | |
| Total | 35 | 95I.748 | | | |

$F_{0.005,8,27}$ = 3.6875 from tables.

Therefore Isolates SIG at 0.005 level.

Table 38d. Canadian Isolates on V - 8 I6°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 4 | 377.II | 94.277 | 26.602 *** |
| Errors | 25 | 88.36 | 3.544 | |
| Total | 29 | 465.47 | | |

$F_{0.005,4,25}$ = 4.835I from tables.

Therefore Isolates SIG at 0.005 level.

Table 38e. Canadian Isolates on V - 8 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 4 | 3107.65 | 776.912 | I8.92I *** |
| Errors | 25 | I026.52 | 4I.06I | |
| Total | 29 | 4I34.I7 | | |

$F_{0.005,4,25}$ = 4.835I from tables.

Therefore Isolates SIG at 0.005 level.

Table 38f. Canadian Isolates on V - 8 30°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 4 | 3407.092 | 85I7.73 | I20.75 *** |
| Errors | 25 | I76.34 | 7.053 | |
| Total | 29 | 3583.43 | | |

$F_{0.005,4,25}$ = 4.835I from tables.

Therefore Isolates SIG at 0.005 level.

Table 38g. Indian Isolates on V - 8 I6°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | I | I62.565 | I62.565 | 75.787 *** |
| Errors | I4 | I2.875 | 2.I45 | |
| Total | I5 | I75.440 | | |

$F_{0.005,I,I4}$ = II.060 from tables.

Therefore Isolates SIG at 0.005 level.

Table 38h. Indian Isolates on V - 8 25°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 1 | 551.25 | 551.25 | 10.038 * |
| Errors | 18 | 180.70 | 10.038 | |
| Total | 19 | 731.95 | | |

$F_{0.05,1,18}$ = 4.4139 from tables.

Therefore Isolates SIG at 0.05 level.

Table 38i. Indian Isolates on V - 8 30°C.

| Source | D/F | S/S | M/S | Fobs |
|---|---|---|---|---|
| Isolates | 1 | 3781.25 | 3781.25 | 729.548 *** |
| Errors | 18 | 93.30 | 5.183 | |
| Total | 19 | 3874.55 | | |

$F_{0.005,1,18}$ = 10.218 from tables.

Therefore Isolates SIG at 0.005 level.