THE DEVELOPMENT OF *PUCCINIA HORDEI* ON DIFFERENT BARLEY CULTIVARS

by

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ABSTRACT

The development of Puccinia hordei Otth. was examined principally on the four barley cultivars. Deba Abed, Zephyr, Julia and Vada. Some experiments also included the cultivars Midas and Proctor. Most greenhouse experiments were designed to find out why P.hordei grows comparatively well on Zephyr but not on Julia.

Experiments on the first seedling leaves indicated no differences between these cultivars in respect of uredospore deposition on leaves, the germination of uredospores and the frequency with which germ-tubes penetrated stomata, nor in the number of primary hyphae which developed from the substomatal vesicles and the number of pustules formed. The only differences in growth of the fungus on Zephyr and Julia were in the size of pustule formed and amount of spores produced per pustule. Experiments indicated that the fungus behaved similarly on the leaves of mature plants of these cultivars.

Pustule size was also affected by treating plants with maleic hydrazide, with one-quarter strength Long Ashton nutrient solution, by keeping inoculated plants at 10°C or by inoculating leaves of different age. It was concluded from these experiments that, within limits, growth of the fungus could also be determined by the nutrition of the host.

Different amounts of disease developed on the four cultivars in field trials but infection rates of the fungus were similar suggesting that factors other than those demonstrated in the greenhouse experiments were involved. These results are discussed in relation to race-specific and race-non-specific resistance of the cultivars and two hypotheses are suggested both of which could account for the differences in disease development in the field. Both hypotheses assume a local distribution of inoculum and this was established experimentally by vertical sticky rod spore traps.

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INTRODUCTION

Brown rust of barley, caused by the fungus Puccinia hordei Otth., is a disease of somewhat sporadic occurrence and intensity in the U.K. Generally it is present in small amounts within barley grown in the south of England but in some years e.g. 1967 and 1970, it is severe. It is not generally important in any year within crops grown in the north of the country. Perhaps as a result of its infrequent severity relatively little work has been done in this country since that of D'Oliviera in the 1930's (D'Oliviera, 1939a, 1939b). Recently, however, the development of the fungus was studied in detail on the cultivar Zephyr by Simkin & Wheeler (1974a) and its interaction with Erysiphe graminis examined (Simkin & Wheeler, 1974b). While there has been no major effort to incorporate resistance to P.hordei in the barley cultivars presently grown in the U.K., these cultivars do differ in their susceptibility and one, Midas, is not recommended to growers in the south of England because of its susceptibility to brown rust.

The reasons why the fungus develops well on some cultivars but not on others have received little attention but investigation by Clifford (1972) on the cultivars Midas (susceptible) and Vada (relatively resistant) suggest that on the latter the fungus is affected at particular stages in its growth within the leaf. The primary aim of this investigation was to extend this work of Clifford by examining the development of the fungus on several cultivars of differing susceptibility both in the greenhouse and in the field.

REVIEW OF LITERATURE

Brown rust or dwarf leaf rust of barley caused by Puccinia hordei Otth. is a common disease in most areas where barley is grown. In the United Kingdom it occurs mainly on Spring barley crops in the southern parts of the country (James, 1969; Doling & Doodson, 1970).

For a long time the disease was considered to be of little economic importance. In recent years, however, there have been some severe outbreaks, especially in southern parts of the United Kingdom. In 1967 the disease caused an estimated 3% loss in yield in England and Wales (James, 1969) and in 1970 it was the most important foliar disease of Spring barley (King, 1972).

The fungus is obligate) and heterathallic, forming uredosori and teleutosori mainly on cultivated barley and aecidia and spermagonia on species of Ornithogalum e.g. O.pyrenaicum (Wilson & Henderson, 1966). The aecidial state has been found in several countries. Although the aecidial state has been reported once on O.pyrenaicum (Dennis & Sandwith, 1948) in England, Simkin & Wheeler (1974c) could not find this state on O.pyrenaicum on the same site and or in two other localities with relatively abundant O.pyrenaicum in a search in two successive years. It would appear, therefore, that the aecidial state is not an important way in which P.hordei overwinters in the U.K. In these areas there is now abundant evidence that it usually overwinters as uredosori on Winter barley or volunteer plants and also as a dormant uredo-mycelium (Anon, 1921; D'Oliviera, 1939a; Mehta, 1922; Simkin & Wheeler, 1974c).

There have been relatively few studies on the effect of environmental factors on P.hordei but in a recent paper by Simkin & Wheeler (1974a) these were

examined in detail on Zephyr barley.

Relative humidity is mainly important during germination and infection. While D'Oliviera (1939b) suggests that under normal temperatures germination can occur within the range 72.5-100% r.h others found that no germination occurs below 100% r.h (Simkin & Wheeler, 1974a). Some workers also state that a free film of water is needed for germination, penetration and infection in cereal rusts (Polley, 1971; Manners, 1971).

Relatively little work has been carried out on the effects of light on P.hordei though experiments with other Puccinia spp. (e.g. Dillon-Weston, 1932; Sharp etal., 1958; McCracken & Burleigh, 1962) suggest that light could have a direct effect on uredospore germination. D'Oliviera (1939b) suggested that uredospores and aecidiospores germinated equally well in the light or dark but Simkin (1973) found germination to be optimal after a 6-8 hr light period.

Temperature is probably the most important factor in determining the growth of P.hordei in barley leaves following its penetration of the stomata. Hermansen (1968) examined the generation time of P.hordei on barley by placing out pots of inoculated seedlings during 1965 and 1966 in Denmark. He found that generation time - the time from inoculation to eruption of pustules - was 9-11 days in June-July-August and 16-22 days in September-October. He also showed that at 2-4^{o}C the generation time of P.hordei could be as long as 60-65 days. Similar experiments showed that in South-East England generation time in the field was 8 days in mid July and as long as 16 days in May (Onursal, 1972). Effects of temperature, especially in relation to pustule formation have also been studied extensively by Simkin & Wheeler (1974a). They found that in temperature-controlled climatic cabinets

generation time was 6 days at 25°C, 10 days at 15°C, 15 days at 10°C and 60 days at 5°C. They also showed that pustule production can be accelerated on inoculated plants which had been kept at 5°C for some time by transferring them to 20°C. They also found that an initial incubation at 20°C for 24 hrs considerably shortened the generation time (by 23 days) of plants kept at 5°C. The same workers also found that pustule productivity increased with temperature.

Temperature similarly affects the germination of uredospores. Brown (1931) found that uredospore germination occurred within the range tested (5-23°C) and reached optimum levels between 15°C and 20°C. Simkin & Wheeler (1974a) also found that maximum germination occurred at 20°C. D'Oliviera (1939b) found that uredospores were unable to germinate at 28°C and the rust was killed if the host was maintained at 30°C. The storage of uredospores, for experiments, is also affected by temperature. For example, Joshi etal. (1959) found that uredospores remained viable for 9 months if stored at 0-5°C and for 4 months at 9-14°C while Brown & Newton (1929) found that uredospores kept at room temperature remained viable for less than a month. In more recent work, Clifford (1973) found that the germination of fresh spores stored at 2°C fell to 50% in 25 days. The subsequent decline was less rapid, another 25% fall in germination taking a further 80 days. After 30 weeks, germination was approximately 5%. He also found that P.hordei uredospores which were vacuum-dried and stored at 2°C still retained a high germination capacity after 2 years.

Relatively few studies have been concerned with the effect of brown rust on yields of barley. Newton, Peterson & Meredith (1945), by artificially-inoculating plants, found that severe infections not only reduced yields of different barley cultivars but also their malting qualities. Recent trials with fungicide BAS 3170F

suggest that even where there is as little as 5% brown rust, yields may be adversely affected (Simkin & Wheeler, 1974b) and that spraying can result in worthwhile yield increases (Frost, 1973).

No commercial barley cultivar has major-gene resistance against brown rust but cultivars do differ in their susceptibility as the ratings from the N.I.A.B. recommended list indicate (Table 1). That the fungus grows less well on some cultivars e.g. Vada than on others e.g. Midas has been attributed to horizontal, race non-specific, background or field resistance (Van der Plank, 1963) and is considered to be polygenic in nature. Clifford (1972) has studied the development of P.hordei on these two particular cultivars in detail under uniform conditions. Uredospores germinate equally well on both and also form appresoria, enter stomata and form sub-stomatal vesicles (SSV) with similar frequency. However, significantly more monopolar primary infection hyphae (PIH) form in Vada and more bipolar PIH in Midas. Pustules take longer to form on Vada (9 to 14 days) than on Midas (9 days), and there are fewer of them. They are also smaller on Vada and produce fewer spores. These features largely account for the slower development of rust on Vada.

In an extension of this work, Clifford & Clothier (1974) have recently shown that isolates of P.hordei from particular cultivars differ in their infectivity, uredospore collections from a particular cultivar being especially adapted to infect that cultivar.

Table 1. Recommended list of Spring barleys 1973.

Cultivars	Lofa Abed	Julia	Berac	Hassan	Zephyr	Vada	Midas	Gerka	Imber	Proctor	Mazurka	Wing	Universe	Maris Mink	Sultan	Deba Abed
Resistance to brown rust (Higher the figure more resistant to brown rust)	5	5	4	5	3	5	1	3	3	3	3	3	5	4	1	2

I. DEVELOPMENT OF *PUCCINIA HORDEI* ON DIFFERENT CULTIVARS IN THE GREENHOUSE.

MATERIALS AND METHODS

1. Production of Seedlings

For most greenhouse experiments two barley cultivars were used, Zephyr and Julia. Seed, dressed with a standard mercurial fungicide, was obtained from Elsoms of Spalding. This was stored at 5°C and its viability tested regularly.

Seeds were sown in John Innes Potting Compost No.2 either in 12.5 cm diameter or, singly in 6 cm square pots. For the latter seeds were pre-germinated on damp blotting paper in germination trays (Stewart Plastics Ltd.). After sowing all pots were transferred to a spore-free cabinet (Finney, 1973) within a greenhouse maintained at 18$\pm$ 3°C, with a 16 hr photoperiod by six 400 W mercury vapour discharge lamps (Phillips TYP 571359).

2, Production of Uredospores

All uredospores were derived from a collection (Pb 60/3/1,295/21) originally supplied by Dr. R. Johnson of the Plant Breeding Institute and resembling race U.N. 16 of *P.hordei* (Simkin & Wheeler, 1974a).

Seedlings at the first leaf stage were sprayed with distilled water until the leaves were covered with many fine droplets then they were placed within an inoculation chamber (Round, 1975) (See below) into which uredospores mixed with talc as diluent were discharged and allowed to settle on the leaves. The pots of inoculated seedlings were then stood in a tray of water and covered with a polyethylene hood the inside of which was sprayed with water to ensure a high humidity. Pots were transferred into the spore-free cabinets 24 hrs later. Pustules erupted within 7-9 days and from then until the leaves senesced, uredospores were collected every other day with a cyclone collector. (Tervet, Rawson, Cherry & Saxon, 1951).

At the beginning spores were freeze-dried in glass vials which were stored at 1°C until required but these spores lost viability quickly once the glass vial was opened. Subsequently spores were stored in specimen tubes at 5°C. Tests indicated that even after 4 months and repeated transfers to room temperatures over 50% of the spores germinated (Fig.1). Nevertheless, spores which had been stored longer than 3 months were not used in experiments.

3. Assessments of Uredospore Germination

a) In vitro: The method used was essentially similar to that described by Manners & Hossain (1963). Uredospores were deposited on coverslips each of which was fixed by molten wax to small pieces of glass (1.5 mm thick) cemented to the cover of a glass staining block (Gallenkamp, Cat.No.HJ 300). Water was placed in the well of the staining block and the cover sealed to the staining block with Vasalene.

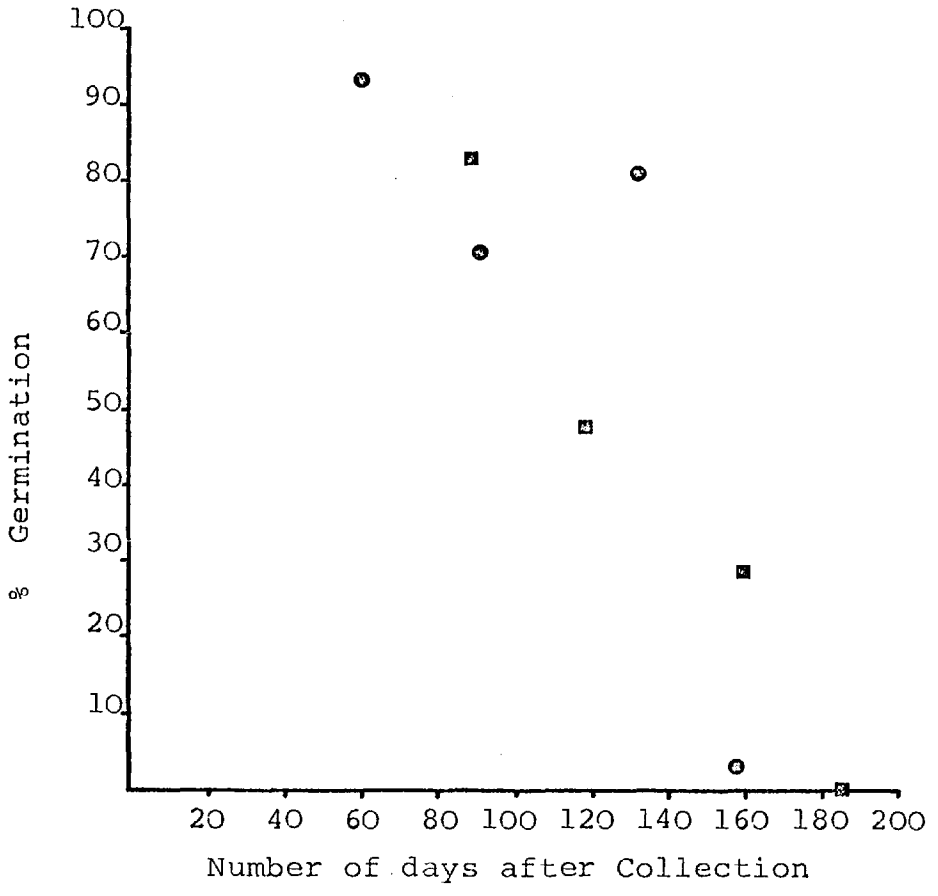
After incubation at 20°C each coverslip was removed and lowered into a drop of lactophenol-cotton-blue on a slide. Assessments of spore germination were made in 10 fields selected at random on each slide. A spore was considered to have germinated if its germ-tube length was at least twice its diameter.

b) On leaf surface: After 24 hrs incubation leaves inoculated with P.hordei were cut at the base and placed on a glass plate. A piece of lassotape was pressed onto the leaf surface and then removed and mounted in lactophenol-cotton-blue on a slide. Another slide was placed on top of it and fastened at the edges by sellotape. Assessments of spore germination were made in 100 microscope fields (x 400) selected at random on each slide.

4. Assessment of further development of the fungus within barley leaf: (Formation of substomatal vesicles, primary infection hyphae, colony growth).

Since the technique described by Shipton & Brown(1962)

Fig.1 % Germination of Uredospores stored in $5^{\circ}C$



did not give satisfactory results, other methods were tried. The following was found to be the most satisfactory. Leaves were cut into 2.5 cm lengths, cleared in methanol for 3 days and then transferred into lactophenol-cotton-blue for 3-4 days. The pieces were washed in distilled water, put into 25 ml. specimen tubes containing 10-15 ml. lactophenol (3-4 pieces into one tube) and heated on a magnetic mixer and heater (Gallenkamp Magnetic stirrer-hotplate) at heating point 2.5 for 15-25 mins. From 15 mins. pieces were removed for examination every 3 mins. until satisfactory clearing and staining was obtained. They were then mounted in 50% glycerine (Plate 1).

5. Inoculation

Several methods of inoculation were tried, including:

a) Puffing the spore/talc mixture onto plants placed within a cardboard cylinder (height 58 cm X diameter 14 cm) with a powder dispenser (DeVilbiss, 36).

b) Applying the spore/talc mixture onto individual leaves by a fine camel hair brush.

c) Spraying the spores in a 10^{-4} Tween 80 solution onto the leaves.

With all these methods variation in pustule number was too high.

Eventually a spore settling tower was used designed by Round (1975). This consisted basically of a metal drum, 90 cm high and 72 cm across with a central tube through which a spore/talc mixture was discharged (Fig.2).

The leaves of seedlings in 12.5 cm diameter pots were flattened by pressing them at the base and were held by holding them onto pots by small rubber weights. Leaves of seedlings in 6 cm square pots were similarly held in a horizontal position by laying the pot on its side and then holding the leaf down on a small polystyrene

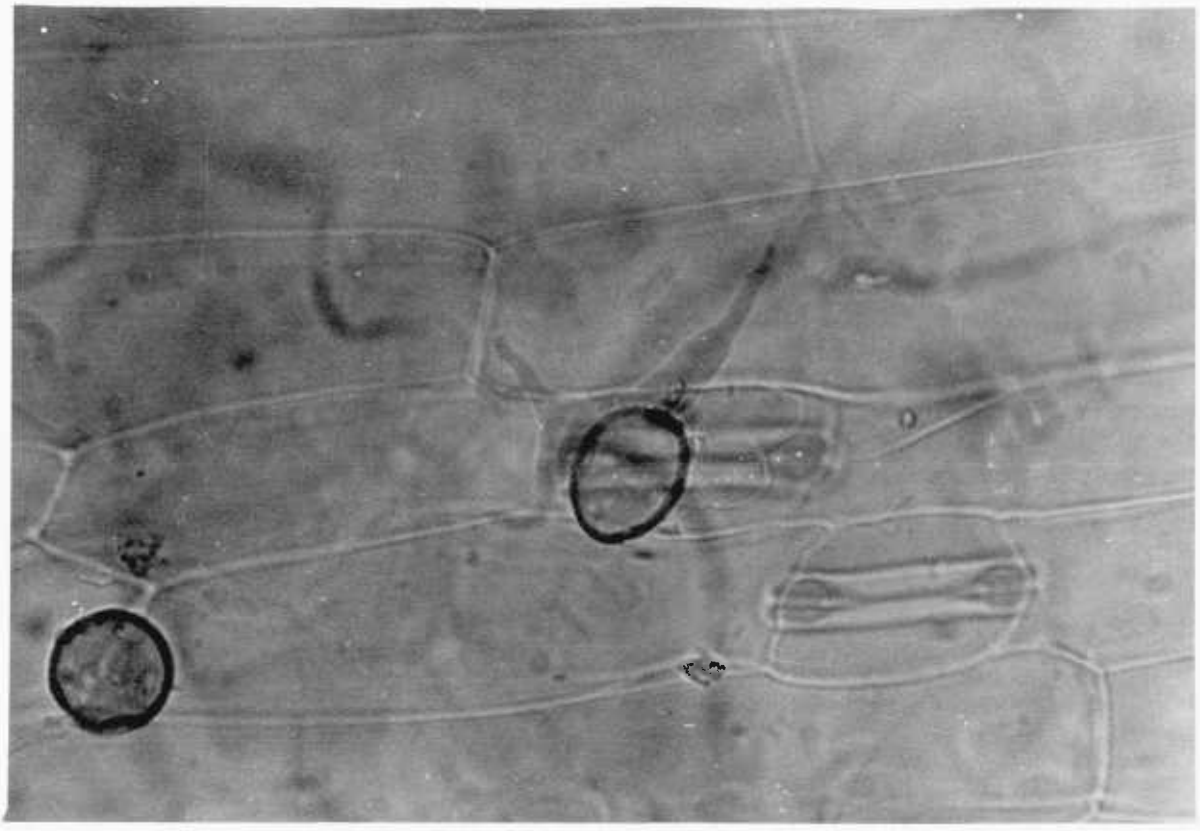
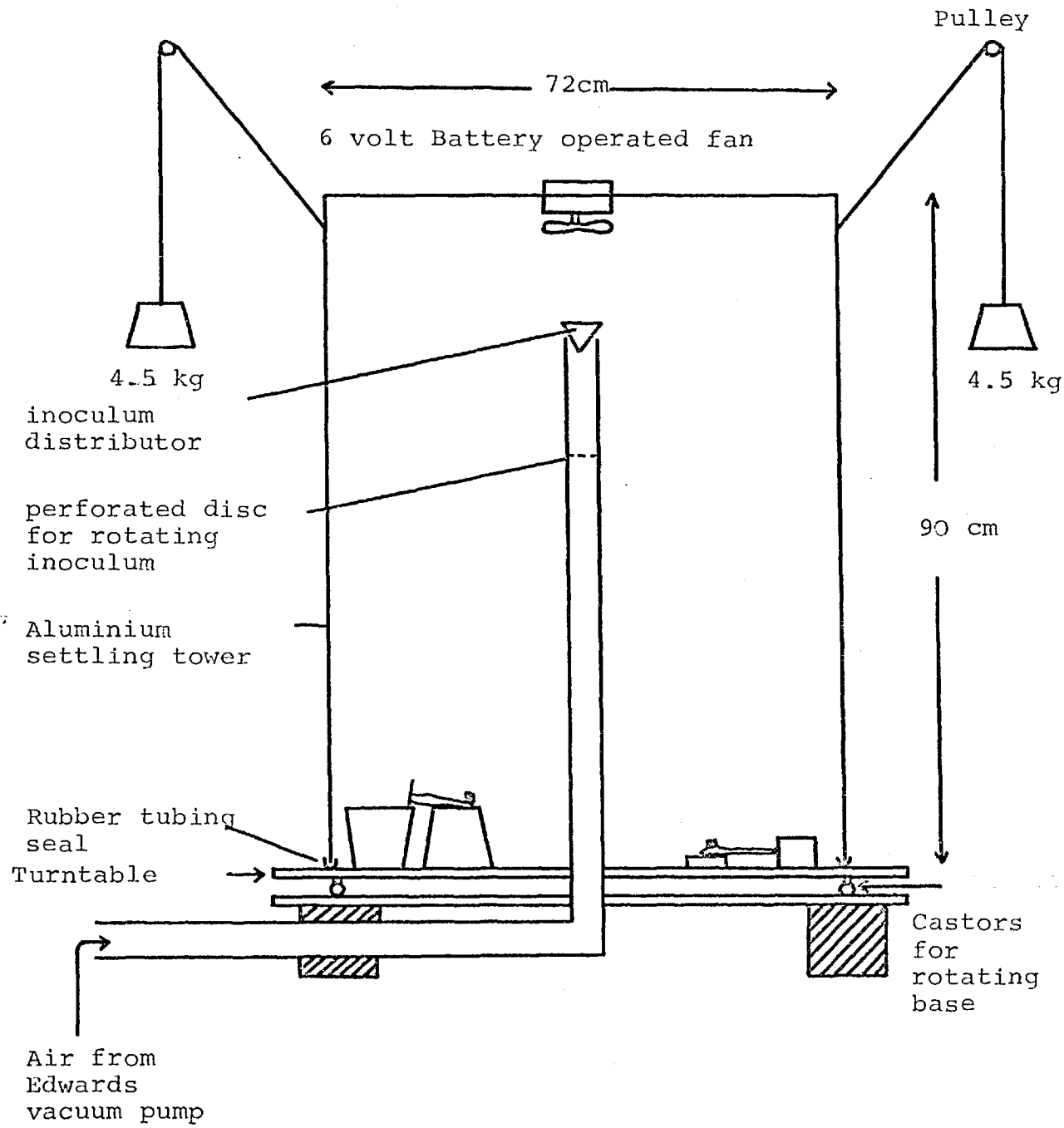


Plate 1. A stomatal infection with primary infection hyphaes (PIH) on a barley seedling leaf.

Fig.2 Inoculation chamber.



box with a rubber bung. By these means only one leaf surface was inoculated.

6. Experiments in controlled environments

These were carried out in Weyco Climatic Cabinets (refrigerated). Plant Growth Type 250 PG.

I - Development of P.hordei on Different Cultivars in the Greenhouse.

A- Development on the first seedling leaf.

1 - On Zephyr, Proctor, Julia and Deba Abed.

Five pots of each cultivar were randomized in blocks. Each pot had seven seedlings with a fully expanded first leaf and had been sown 11 days previously. The leaves were inoculated with a spore/talc mixture and immediately after inoculation two of them were sampled at random from each pot to determine the spore load per unit leaf area. After 24 hrs incubation a further two leaves were picked for an assessment of spore germination. The remaining three leaves in each pot were left until pustules formed.

a) Spore load: An analysis of variance showed that there were no significant difference in the number of spores deposited per unit area on the leaves of the different cultivars (Table 2).

b) Germination: The detailed results of the spore germination test are given in Appendix Table 1. An analysis of this experiment (Table 3) shows that there are no significant differences in uredospore germination on the different cultivars.

c) Pustule Production: When rust pustules were fully developed the remaining three leaves were collected, measured and the numbers of rust pustules counted. There was no significant difference in the numbers of pustules on leaves from different cultivars (Table 4 and Appendix Table 2).

Table 2. Spore Deposition on Different Cultivars
(Figures are means of two leaves).

	No.spores/cm^2				
Blocks	Zephyr	Proctor	Deba Abed	Julia	Block Total
1	190	145	77	202	614
2	167	122	128	108	525
3	157	98	140	125	520
4	117	214	123	116	570
5	150	104	356	193	803
Total	781	683	824	744	

	Degrees of Freedom	Sums of Squares	Mean Squares	Variance ratio	
	(D.F.)	(S.S.)	(M.S.)	(F)	
Cultivars	3	2141.2	713.73	0.158	N.S.
Blocks	4	13531.3	3382.83	0.749	N.S.
Error	12	54204.3	4517.03		
Total	19	69876.8			

Table 3. Percentage Germination of Uredospores
(Figures are based on counts of two leaves).

Blocks	Zephyr	Proctor	Deba Abed	Julia	Blocks Total
1	85.8	89.7	48.6	16.5	240.6
2	80.0	88.7	85.0	77.3	331.0
3	89.7	90.4	87.7	75.0	342.8
4	90.5	89.8	88.5	89.4	358.2
5	92.2	81.3	94.0	91.7	359.2
Total	438.2	439.9	403.8	349.9	
Mean	87.6	88.0	80.8	70.0	

	D.F.	S.S.	M.S.	F.	
Cultivars	3	1064.58	354.86	1.50	N.S.
Blocks	4	2434.71	608.68	2.57	N.S.
Error	12	2841.06	236.76		
Total	19	6340.35			

Table 4. Pustule Production on Different Cultivars

Blocks	Zephyr	Proctor	Deba Abed	Julia	Blocks Total
1	36	23	4	1	64
2	52	28	77	76	233
3	71	77	86	66	300
4	66	52	80	30	228
5	61	13	93	59	226
Total	286	193	340	232	
Mean	57.2	38.6	68.0	46.4	

	D.F.	S.S.	M.S.	F.	
Cultivars	3	2463.70	821.23	2.048	N.S.
Blocks	4	7631.20	1907.80	4.758	*
Error	12	4812.05	401.00		
Total	19	14906.95			

* Significant at 5% level.

S.E. $\pm$ 8.96

2 - On Zephyr, Proctor, Julia, Deba Abed, Sultan & Vada

The above experiment was repeated with the following modifications: Sultan and Vada were included, estimates of spore load were derived from germination counts and the processes of infection were examined in more detail. In this experiment there were four pots of each cultivar, with nine seedlings per pot. Three leaves were taken from each pot for counts of germinated spores 24 hrs after inoculation, two from each pot after 24 hrs for a study of infection and the remaining four leaves were left until pustules formed.

a) Spore load: There were no significant differences in the numbers of spores deposited on leaves of the different cultivars (Appendix Table 3).

b) Germination: As in the previous experiment there were no significant differences in germination of spores on the leaves of the different cultivars (Appendix Table 4).

c) Penetration of Stomata: The penetration of stomata by germ-tubes and establishment of primary infection hyphae in the sub-stomatal cavities were examined in cleared leaves sampled 24 hrs after inoculation. No significant differences were found amongst the cultivars in these respects (Appendix Table 5).

d) Pustule Development: Seven days after inoculation the ratio of erupted pustules to numbers of flecks (un-erupted pustules) was determined on the leaves as a rough measure of the speed of pustule development. The results (Table 5) suggested that pustules developed rapidly on Sultan and least rapidly on Vada but a test of the differences between means based on the method of Tukey (Steel & Terrie,1960) showed that only pustule development on Vada was significantly slower than that on the other cultivars.

e) Pustule Production: Leaves were measured and pustules counted 9 days after inoculation. As in the previous experiment, there were no significant differences in the numbers of pustules formed on different cultivars (Appendix Table 6).

Table 5. Ratio of Erupted Pustules/Flecks, 7 Days After Inoculation.

	Zephyr	Julia	Proctor	Vada	Deba Abed	Sultan
	0.75	0.60	0.80	0.10	0.80	1.00
	0.80	1.00	0.80	0.20	0.80	1.00
	0.75	0.80	1.00	0.10	0.80	0.80
	0.80	0.75	0.80	0.10	0.80	0.80
Total	3.10	3.15	3.40	0.50	3.20	3.60
Mean	0.77	0.78	0.85	0.12	0.80	0.90

Analysis of Variance

	D.F.	S.S.	M.S.	F.
Cultivars	5	1.664	0.332	36.89 ***
Error	18	0.162	0.009	
Total	23	1.826		

To test differences between cultivars (Tukey's method)

$W = q_{\alpha}(p, n_2)\ S\bar{x}$ $\qquad S\bar{x} = \sqrt{S^2/n}$

q_{α} for 5% = 4.49 $\qquad S\bar{x} = 0.0474$

$W_{0.05} = 0.213$

3 - On Zephyr, Vada and Midas

Seeds were germinated on damp blotting paper and then transferred to 6 cm square pots to give ten pots of each cultivar each with a single seedling. When the first seedling leaves had fully expanded the upper surfaces were inoculated with a uredospore/talc mixture (1:33) and the seedlings kept in a humid chamber for 24 hrs. They were then kept on the greenhouse bench. Under these conditions pustules developed on Zephyr and Midas in 8 days and on Vada in 10 days. When the pustules were fully formed, leaves were collected, their areas measured and pustules counted not only on the upper surface but also on the lower surface since the number of infections which grow through the leaf is an important factor in the epidemiology of the disease. Counts of pustules on the lower surface were expressed as a percentage of the main pustules on the upper surface. Tables 6 and 7; Appendix Table 7.

Analysis showed that pustule development, both on the upper and lower surface, was significantly less on Vada ($P \leq 0.01$), than on the other two cultivars.

Table 6. Pustule Development on the Upper Surface of Seedling Leaves.

Cultivar	No. Pustules/cm^2 leaf	Mean
Zephyr	39,39,25,15,71,56,37,31,25,30	36.8
Midas	29,37,12,90,42,15,37,45,23,25	36.5
Vada	15,19,14,10,24,11,22, 3,28, 6	15.2
	S.E. ±	5.26

Table 7. Pustule Development on Lower Surface of Seedling Leaves Inoculated on Upper Surface Only

Cultivar	No. Pustules (As % of No. on Upper Surface)	Mean
Zephyr	75.2, 67.0,74.7,72.8,79.8,70.8 73.9,76.7,58.1	73.1
Midas	79.5,76.9,100.0,81.5,76.1,76.7, 44.5,74.4,94.5,86.0	79.0
Vada	57.4,62.3,72.6,55.1,74.4,54.7, 68.3,45.0,60.1,58.1	60.8
	S.E. ±	3.39

Least Difference between means for significance at $P \leq 0.01$ (Tukey's test).

$$W = q_{\alpha}(p,n_2)\ S\bar{x}$$

$$W_{0.01}\ (3,27) = 4.53 \times 3.39$$

$$= 15.36$$

Vada	Zephyr	Midas
60.8	73.1	79.0

4 - On Zephyr and Julia.

Number of Stomata: P.hordei enters the barley leaf through the stomata, so the number of infection sites available on the leaf could be important. In this experiment the number of stomata on two cultivars, Zephyr and Julia was examined. Fourteen seedling leaves of each cultivar were cleared in methanol, lightly stained in lactophenol-cotton-blue and the number of stomata on each leaf counted in twenty fields of the microscope (x 150), (Appendix Table 8). A student's "t" test (Table 8a) showed that Julia, which is more resistant in the field, has significantly more stomata than Zephyr. So it appears that for these two cultivars the number of stomata does not play a role in susceptibility.

Germination and Initial Penetration:

a) An experiment was set up to see if there were any differences in germination, stomatal infection and primary infection structures on the first seedling leaves of Zephyr and Julia.

There were forty-eight pots of single seedlings (twenty-four of each cultivar) and these were divided in two groups containing twelve pots of each cultivar. Each group was inoculated with a uredospore/talc mixture (1:33) and kept at 100% r.h for 24 hrs. Subsequently one group was used immediately to assess uredospore germination by taking lassotape strips of the leaves. An analysis of the results (Table 8b and Appendix Table 9) showed that spores germinated equally well on both cultivars.

The development of infection structures, 24 hrs after inoculation, was determined by clearing leaves from the second group of plants in methanol, staining and examining 100 microscope fields at random on each leaf. The numbers of infections with sub-stomatal vesicles (SSV), and monopolar and dipolar primary infection hyphae (PIH) were determined but in no instance was there a significant difference between the cultivars in these features (Table 8c and Appendix Table 10).

Table 8. Experiments with Zephyr and Julia.

(a) Number of Stomata on the first Seedling Leaf
(Figures are totals in twenty fields)

Zephyr	335
Julia	364
t-value	3.33 ($P \leqslant 0.01$)
D.F.	26

(b) Uredospore Germination (%)

Zephyr	61.7
Julia	63.7
t-value	0.58 N.S.
D.F.	22

(c) Infection Structures in the first Seedling Leaf, 24 hrs after Inoculation.

	Total No. Infections	SSV	% Infections with Monopolar PIH	Bipolar PIH
Zephyr	16.16	18.5	13.4	68.1
Julia	14.08	23.2	9.6	67.2
t-value	1.34 NS	0.88 NS	1.01 NS	0.18 NS
D.F.	22	22	22	22

b) A similar experiment was set up with Zephyr and Julia to determine number of uredospores deposited on leaves, their germination, formation of infection structures and, finally, number of pustules. Seventy-two seedlings (thirty-six of each cultivar grown singly in 6 cm square pots) were divided into three blocks. Each block of seedlings was inoculated with a 1:33 uredospore/talc mixture and kept for 24 hrs in a saturated atmosphere. Then four pots of each cultivar were selected at random from each block and germination assessed as before. These figures also provided a measure of spore load. All pots were then kept under normal greenhouse conditions. After a further 24 hrs, a similar quantity of plants was selected and infection structures counted as in the previous experiment. The remainder of the plants were left until pustules erupted. These were counted and their size measured.

The number of uredospores deposited on leaves of Zephyr was higher than on leaves of Julia but not significantly so and, as in the previous experiment, there was no significant difference in germination on the two cultivars (Appendix Table 11). Similarly in this experiment there were no significant differences in the formation of the various infection structures nor, indeed, in the number of pustules formed per unit leaf area (Appendix Table 12 and 13). Only in respect of pustule size was there a significant difference ($P \leqslant 0.05$) between the two cultivars, with a mean size on Zephyr of 0.3855 mm^2 and 0.3222 mm^2 on Julia (S.E. $\pm$ 0.002), Appendix Table 14).

The results of the experiment are summarized in Table 9. While in terms of the individual stages only a comparison of pustule size proved significantly different, nevertheless, in several other respects the mean figures for Julia are below those of Zephyr.

Table 9. Development of P.hordei on Seedling Leaves of Zephyr and Julia.

	Zephyr	Julia
Spore load/cm^2	112.20	81.42
% Germination	55.9	58.5
No. of Germinated Spores/cm^2	63.2	45.7
Stomatal Infection/cm^2	31.1	19.0
No. of Pustule/cm^2	20.8	16.0
Pustule size (mm^2)	0.386	0.322

Pustule Productivity

The number of uredospores produced per pustule (pustule productivity) is an important factor in the development of brown rust on a particular cultivar. The productivity of uredosori on Zephyr and Julia was compared in the following experiment.

Sixteen pots (eight to ten plants/pot) of each cultivar were inoculated with a uredospore/talc mixture (1:50) when the first seedling leaf was fully expanded. The inoculated seedlings were then incubated at 18^{o}C and 100% r.h for 24 hrs. The pots were arranged in four rows (blocks) of eight pots (four pots for each cultivar) with the pots completely randomized in each row.

At pustule eruption uredospores were collected, using a cyclone separator, from the eight pots in each row and eight seperate samples thus obtained. Further samples were collected 2, 3, 4 and 5 days after pustule eruption and a final sample on day 7 when leaves started to senesce. The total amounts of uredospores collected were then weighed.

The full details of the numbers of pustules and the amounts of spores collected are given in Appendix Table 15 and on analysis of the results is presented in Table 10. This shows that significantly more uredospores per pustule were produced on Zephyr than on Julia.

Table 10. Pustule Productivity on Zephyr and Julia.

mg. Uredospores/1000 Pustules

Block	Zephyr	Julia	Total
I	7.5	4.1	11.6
II	3.7	1.3	5.0
III	5.7	0.9	6.6
IV	7.5	2.7	10.2
Total	24.4	9.0	

Variance ratios: Cultivars 43.3 **, Blocks 6.9 N.S.

Significance at $P \leq 0.01$ denoted by **

5 - Effect of Maleic Hydrazide on the Development of P.hordei.

Horsfall and Dimond (1957) have attempted to relate disease and sugar content of plant tissue, distinguishing diseases associated with high sugar content, from those associated with low sugar content. Rusts are listed in "high sugar diseases" because some do not develop on plants kept in the dark but can be induced to do so by subsequently floating leaves on sugar solutions (Wood, 1967). Maleic hydrazide increases the sugar content of foliage so, treating leaves with this material should make them more susceptible. Livingston (1953) demonstrated this for leaf rust of wheat. Although plants treated with maleic hydrazide (0.1%) were stunted the size of the rust pustules was increased.

The effect of applications of 0.1% maleic hydrazide on the development of P.hordei on two cultivars, Vada and Midas, was examined in the following two experiments. In both, seed was first germinated on damp blotting paper and then seedlings transferred singly to 6 cm square pots. When the first seedling leaves were fully expanded the plants were inoculated with a 1:33 uredospore/talc mixture and then kept in a humid chamber for 24 hrs, before they were returned to the greenhouse bench.

In the first experiment there were twelve pots of each cultivar and the seedlings in six pots of each were sprayed to run-off with maleic hydrazide 48 hrs after inoculation. There was little stunting of the plants following this treatment and there were no significant differences in pustule number or pustule size between cultivars or treated and untreated plants (Appendix Table 16).

In the second experiment there were the same number of pots of each cultivar but seedlings in six pots (of each cultivar) now received three sprays of maleic hydrazide: 3 days before and at 2 days and 5 days after inoculation. These treated plants became stunted and developed only two leaves during the experimental period compared with four in the controls. At the end of the experiment pustules were counted on the upper (inoculated)

leaf surface and also on the lower surface to give a measure of the number of infections which had grown through the leaf. Analysis of these data showed that whereas treatment with maleic hydrazide had no effect on pustule number on the upper leaf surface it did increase significantly the number of infections growing through the leaf and producing pustules on the lower surface.

After pustule formation had finished, leaves were collected and stained and fifteen pustules measured on each leaf. These measurements indicated that treatment with maleic hydrazide significantly increased pustule size. (Table 11 and Appendix Table 17).

Table 11. Effect of Maleic Hydrazide on Brown Rust Development.

Cultivar	Treatment	Mean Pustule No. Upper Surface	Mean Pustule No. Lower Surface*	Pustule Size (mm^2)
Vada	Control	6.1	43.0	0.113
	Maleic hydrazide	6.1	64.1	0.228
Midas	Control	6.2	57.7	0.125
	Maleic hydrazide	9.2	87.6	0.230
	S.E. $\pm$	1.7	5.6	0.014

* as % of those on upper surface.

6 - Growth of P.hordei on Zephyr and Julia in the Greenhouse and in a Growth Cabinet.

a) Seedlings of Zephyr and Julia, twelve pots of each were,raised to the first-leaf stage in the greenhouse. They were inoculated, 10 days after sowing, with a uredospore/talc mixture (1:50) and kept in a humid atmosphere for 24 hrs to facilitate infection. Then six pots of each cultivar were transferred to a growth cabinet at 10°C with similar light conditions to the greenhouse. The remainder were left in the greenhouse. Pustules erupted in 7 days on plants kept in the greenhouse and in 12 days on those kept in the growth cabinet. Leaves began to senesce 10 and 18 days respectively in the two regimes. Pustules were counted daily and the sizes of pustules determined.

An analysis of the final pustule counts (Appendix Table 18) showed that there were no significant differences in the numbers formed on the two cultivars or between the numbers of pustules formed in the two regimes. However, pustules developed at different rates in the two regimes. This is indicated by expressing pustule numbers as percentages of the final counts (Fig.3 and Appendix Table 19). Additionally in the growth cabinet pustules developed more slowly on Julia than on Zephyr for the first 2 days after pustule eruption. (Table 12).

An analysis of pustule size showed that this not only differed significantly between cultivars but also between regimes. Pustules were larger on Zephyr and correspondingly larger on plants kept in the growth chamber compared with those in the greenhouse (Table 13 and Appendix Table 20).

Fig.3 Development of Pustules on Zephyr (o) and on Julia (●) in the Greenhouse (——) and in a growth cabinet at 10°C (- - -).

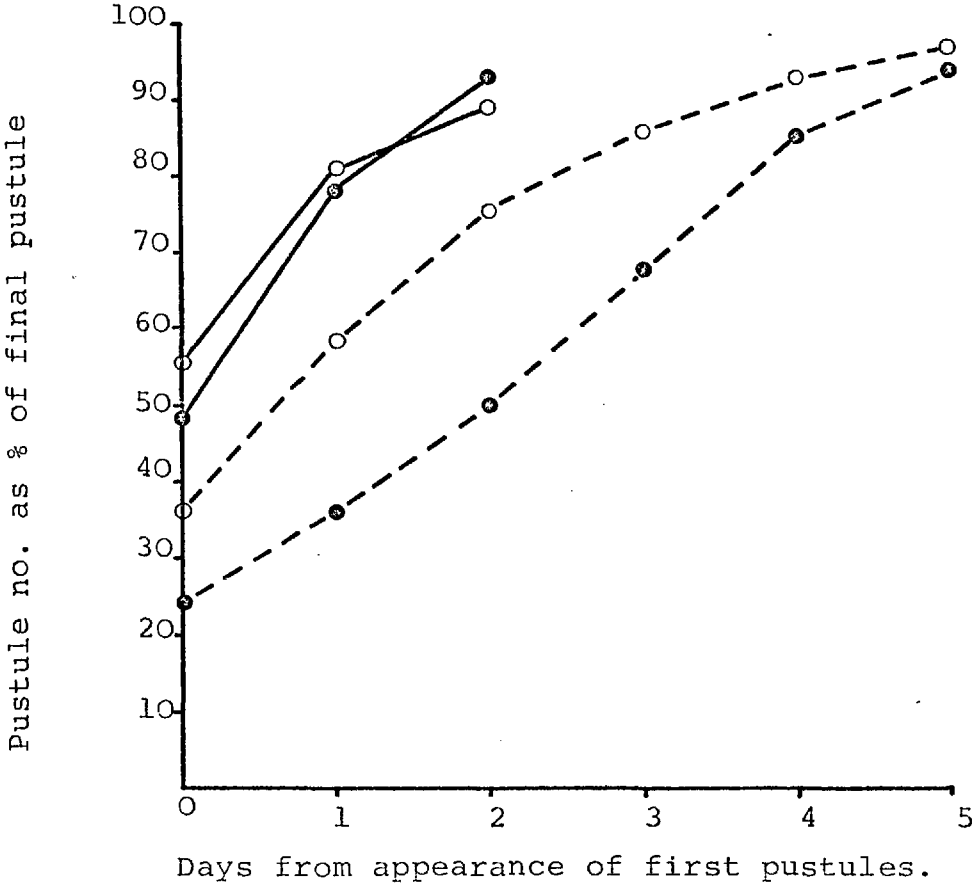


Table 12. Comparison between Pustule Development on Zephyr and on Julia, 2 days after Pustule Eruption.

Mean No. Pustules (As % of Final Count)			
Greenhouse		Growth Cabinet	
Julia	Zephyr	Zephyr	Julia
93.2	89.2	75.4	49.7

Means not underscored by the same line are significantly different ($P \leqslant 0.05$); Duncan's new multiple range test.

Table 13. Mean Pustule Size (mm^2)*: Expt 1

Zephyr		Julia	
Growth Cabinet	Greenhouse	Growth Cabinet	Greenhouse
0.129	0.105	0.102	0.085

* Means of six samples of fifty pustules.

Means not underscored by the same line are significantly different ($P \leqslant 0.05$); Duncan's new multiple range test.

b) The experiment described above was repeated using single seedlings in 6 cm square pots. There were six seedlings per treatment.

There were again no significant differences between the treatments in respect of final pustule number (Appendix Table 21), but the rates of pustule development differed markedly in the two regimes. Also, in the growth cabinet pustules developed more slowly on Julia than on Zephyr (Fig.4 and Table 14 and Appendix Table 22) during the two days following their first appearance. Larger pustules were formed on plants in the growth cabinet (significantly so on Julia) but in this experiment there was no significant difference in the size of pustule formed on the two cultivars (Table 15 Appendix Table 23).

Fig.4 Development of Pustules on Zephyr (o) and on Julia (⊙) in the Greenhouse (——) and in a Growth Cabinet at 10°C (- - -).

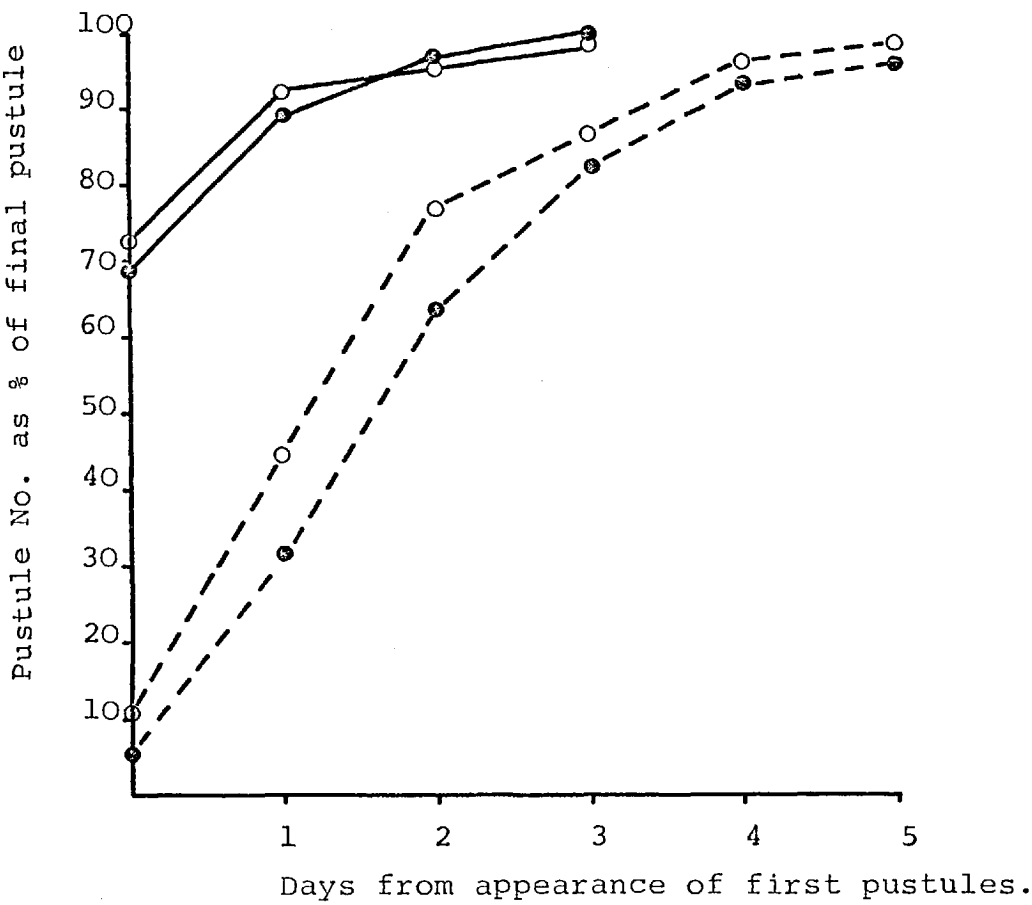


Table 14. Comparison between Pustule Development on Zephyr and on Julia, two days after Pustule Eruption. Expt.2.

Mean No. Pustules (As % of Final Count)			
Greenhouse		Growth Cabinet	
Julia	Zephyr	Zephyr	Julia
96.43	94.97	76.93	63.78

Duncan's new multiple range test; $P \leqslant 0.05$.

Table 15. Mean Pustule Size (mm^2)*: Expt 2.

Growth Cabinet		Greenhouse	
Julia	Zephyr	Zephyr	Julia
0.1091	0.098	0.0858	0.0719

$P \leqslant 0.05$.

* Means of six samples of fifty pustules.

7 - Effect of Leaf Age on the Development of Brown Rust.

a) Using Detached Leaf Pieces.

Three pots of each of the cultivars, Zephyr, Julia, Midas and Vada, were sown in three successive weeks to give first leaves of different ages. When the first leaves had fully expanded on seedlings from the final sowing, all the first leaves were collected and pieces, 6 cm long, were cut from the middle of each leaf. These pieces were floated on 10 ml. of a benzimidazole solution (100 p.p.m.) in small polystyrene boxes and were inoculated with a uredaspore/talc mixture (1:33). After inoculation, the lids of the boxes were sprayed with water, replaced and the boxes incubated at 20°C. There were seven replicates for each treatment.

Pustules took longer to develop (14 days) than on attached leaves and by the time pustules had erupted all the leaf pieces had become chlorotic. However, an analysis of the results (Table 16 and Appendix Table 24) showed that significantly more pustules developed on the oldest leaf pieces. There were also significant differences between cultivars in respect of pustule formation. The number of pustules formed on Midas appeared particularly low considering the susceptibility of this cultivar in the field.

b) Using Attached Seedling Leaves.

The result of the previous experiment conflicted with the general idea that obligate parasites develop better on young tissue so another experiment was carried out using leaves on seedlings. Only two cultivars were used, Zephyr and Julia, and the interval between plantings was decreased to 5 days. There were again three plantings and all plants were inoculated with a uredospore/talc mixture (1:33) when the first leaves were fully expanded on seedlings within the last planting. Inoculated plants were kept in a saturated atmosphere for 24 hrs, and at 20°C throughout. There were three pots for each treatment with four to seven plants in each pot. Pustules were

Table 16. Development of Pustules on Leaf Pieces of Different Age.

a) Total pustules formed on seven leaf pieces.

Sowing Date	Cultivars				Total
	Zephyr	Julia	Midas	Vada	
1	141	70	30	6	247
2	30	4	11	1	46
3	38	1	14	1	54
Total	209	75	55	8	

b) Variance ratios.

Cultivars	21.26 ***
Planting Date	27.79 ***
Cultivars X Planting Date	6.38 **

, *,

Significance at $P \leq 0.01$ and 0.001 respectively.

counted daily from their first appearance (7 days after inoculation) until some of the older leaves began to senesce (10 days after inoculation). Leaves were then collected, cleared in methanol and stained with lactophenol-cotton-blue so that pustule size (of ten pustules per leaf) could be measured.

In this experiment, most pustules developed on the youngest leaves of both cultivars (Table 17 and Appendix Table 25) but there were no differences between cultivars. There were also differences in the rate at which pustules developed as judged by expressing pustule number as a percentage of the final count on that leaf (Fig.5 and Appendix Table 26). Pustules developed most slowly on the oldest leaves. Overall, pustules developed more rapidly on Zephyr than on Julia, the differences between these cultivars being most marked on the oldest leaves. There were also significant differences in pustule size between the treatments. Pustules on Zephyr were generally larger than those on Julia within each sowing, the largest pustules being formed on the youngest leaves (Table 18 and Appendix Table 27).

Table 17. Development of Pustules on Leaves of Different Age. Expt. 2.

a) Mean pustule number per leaf.

Sowing No.	Days After Inoculation 7	8	9	10
		On Zephyr		
1	11.3	50.7	63.4	64.9
2	14.9	49.0	58.5	62.3
3	75.0	207.0	232.6	247.8
		On Julia		
1	1.9	49.6	88.4	101.1
2	10.3	45.4	64.4	71.7
3	50.7	130.1	150.1	150.9

b) Variance ratios.

	7	8	9	10 days after inoculation
Cultivars	3.8 NS	1.7 NS	0.4 NS	0.4NS
Sowing Date	29.9***	14.4**	9.4**	8.3**
Cultivars X Sowing Date	0.8 NS	1.4 NS	1.5 NS	2.0 NS

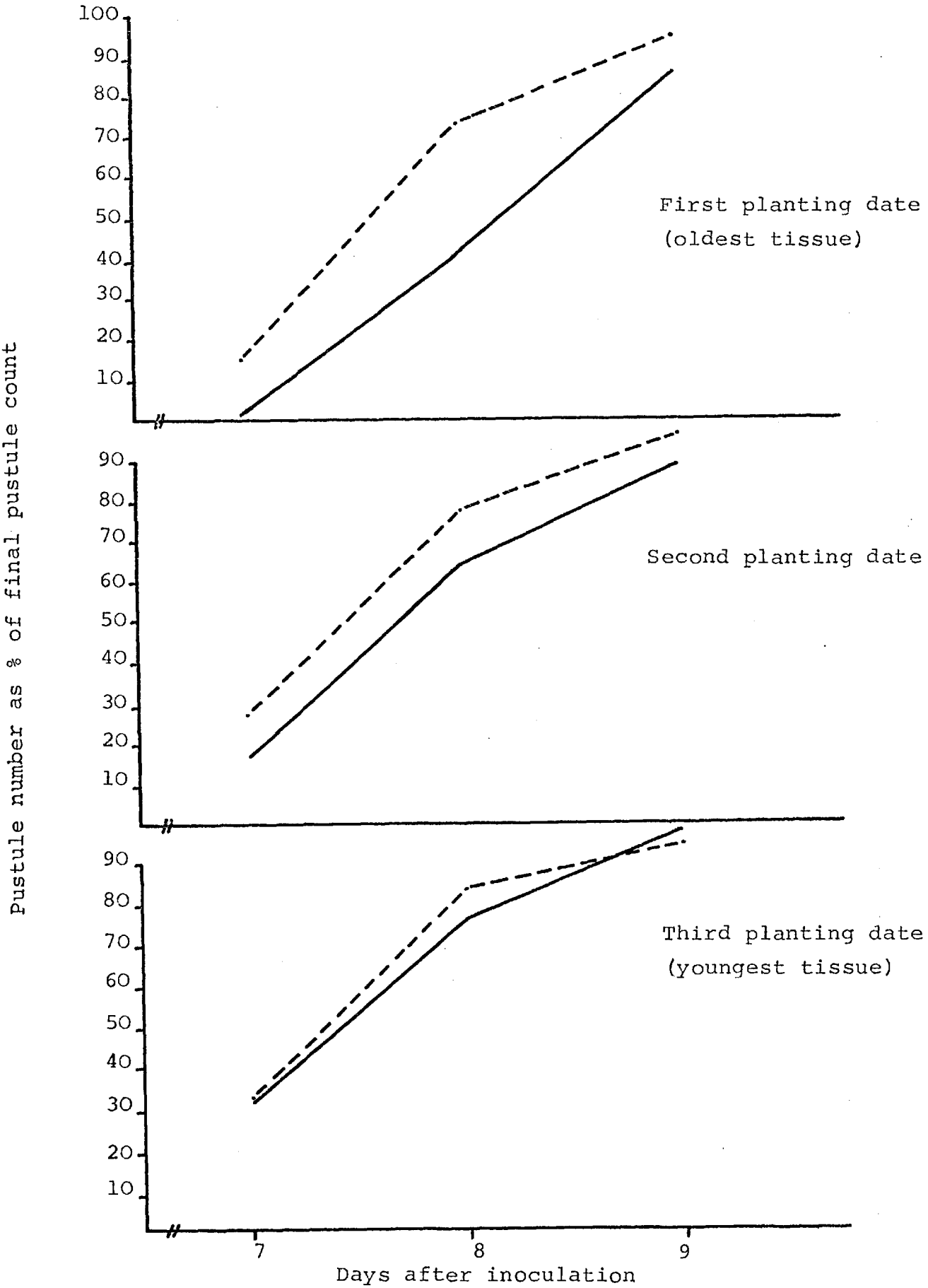


Fig.5 Affect of different aged tissue on pustule production on Zephyr (- - -) and Julia (——)

Table 18. Pustule Size (mm^2) on Leaves of Different Age.

	Cultivar	
Sowing No.	Zephyr †	Julia
1	0.082	0.064
2	0.085	0.074
3	0.091	0.083

Variance ratios:

Cultivars	16.54 **
Planting date	7.04 **
Cu X Planting date	0.98 NS

† Mean of three replicate batches of four to seven leaves.

Significance at $P \leq 0.01$ and 0.001 denoted by ** and *** respectively.

Table 19. Effect of Nutrients on Pustule Development.

	Zephyr			Julia			S.E.±
Strength Long Ashton Solution	1	x¼	x4	1	x¼	x4	
Mean Pustule/ Leaf	39.2	48.4	10.8	39.6	33.6	34.8	16.2
Mean Pustule Size (mm^2)	0.091	0.068	0.083	0.071	0.052	0.072	0.0044

8 - Effect of Nutrients on Development of P.hordei.

Virtually no work has been done on the relationship between the nutrient supply to the barley plant and the development of brown rust. The following experiment was designed to examine this in a preliminary way and to indicate possible further lines of research.

Plants of Zephyr and Julia were grown singly in 6 cm square pots in vermiculite and were top-watered with nutrient solution. There were fifteen plants of each cultivar, divided equally among three nutrient treatments; (1) Long Ashton solution (Hewitt, 1966) at normal strength, (2) ¼ strength and (3) x 4 strength of this solution. Each plant was given 10 ml. of the appropriate solution per day from sowing. When the first leaves had fully expanded all the seedlings were inoculated with a 1:33 uredospore/talc mixture. The plants were kept in a saturated atmosphere for 24 hrs then returned to the greenhouse bench. When pustules erupted they were counted and the size of pustules was determined on cleared leaves.

An analysis of the results (Table 19, Appendix Table 28) showed that there were no significant effects on pustule numbers but there were on pustule size. Pustules were smaller on plants of both cultivars watered with one-quarter strength Long Ashton solution than on those in the other two regimes. Pustules were also larger on Zephyr than on Julia.

B - Development of Brown Rust on Leaves of Mature Plants.

Some barley cultivars which are susceptible to brown rust as seedlings show resistance to this disease at the adult plant stage (Levine & Cherewick, 1956). The susceptibility of adult plants of Zephyr and Julia was examined in the following experiment.

Thirty pots of each cultivar, one to three plants per pot, were raised to heading in the spore-free growth chamber and at ear emergence were inoculated with a uredospore/talc mixture (1:50). To ensure high humidity the sides of the growth chamber were sprayed with water, wet blotting paper was hung in the chamber and the fan ventilation was turned off. These conditions were maintained for 48 hrs and the chamber then returned to its normal running. Infection was subsequently assessed by counting pustules on the flag leaves and the two leaves below the flag leaf and by measuring the size of pustule on the penultimate leaf.

(i) Pustule number: Thirty plants of each cultivar were collected at random. The areas of leaves were measured with a Paton Electronic Planimeter and an average area for the flag leaf and others obtained so that pustules/ cm^2 leaf could be calculated (Appendix Tables 29 & 30). A student's 't' test showed that as with seedling leaves there were no significant differences in the number of pustules/cm^2 between Zephyr and Julia (Table 20).

(ii) Pustule Size: Samples of leaves immediately below the flag leaf (i.e. leaf 2) were collected Zephyr (11 leaves) and from Julia (12 leaves). Fifteen pustules were measured on each leaf and the results analysed (Table 21). Pustules on Zephyr were significantly larger than on Julia, a result similar to that obtained with seedlings of the two cultivars.

Table 20. Pustule Numbers/cm^2 Leaf: Mature Plants of Zephyr and Julia.

	Leaf 1 (flag leaf)	Leaf 2	Leaf 3
Zephyr	6.98	4.05	4.88
Julia	4.17	4.05	6.34
t-value	1.378 NS	0.001 NS	1.053 NS
D.F.	58	53	32

Table 21. Pustule Size (mm^2) on Leaf 2 of Zephyr & Julia.

Zephyr		Julia
0.01396		0.01583
0.01532		0.01995
0.02860		0.01795
0.01544		0.01760
0.03752		0.01556
0.02658		0.01385
0.02504		0.01314
0.02252		0.02292
0.02466		0.01333
0.02662		0.02105
0.02746		0.01224
		0.01378
Mean 0.02397		0.01643
t-value	3.34 $P \leq 0.01$	
D.F.	21	

II. DEVELOPMENT OF *PUCCINIA HORDEI* ON DIFFERENT CULTIVARS IN THE FIELD.

II Development of P.hordei on Different Cultivars in the Field

A - FIELD TRIAL, 1973

MATERIALS AND METHODS

The development of Puccinia hordei on four different barley cultivars - Zephyr, Deba Abed, Julia and Vada - was examined in a trial at Silwood Park in 1973. The trial was sited on a light, sandy, well-drained soil. In an attempt to obtain different (and increasing) levels of rust there were three plantings, on 20 March (S.D.I.), 6 April (S.D.2) and 16 April (S.D.3). There were four replicates (blocks) of each sowing (main plots) and each main plot was split into four sub-plots, each 6 ft x 15 ft (1.8 m x 4.6 m) (Fig.6). Each sub-plot was sown with one of the four cultivars at the rate of 158g/sub-plot. Mildew was controlled by sowing 'Milstem'-dressed seed in all plots but brown rust was not controlled. After crop emergence plots were kept weed-free by hoeing.

Although there were three sowings, all the barley matured at about the same time and all plots were harvested in the second week of August. Individual sub-plots were cut by hand and the barley threshed in a 'Dania' tractor-driven machine - Model T57279. The grain from each sub-plot was bagged and weighed immediately.

Assessments of disease and plant growth were started within the first sowings on 21 May. Ten plants were selected at random from within each sub-plot and taken to the laboratory for examination. Samples were first taken from the second and third sowings one week later and sampling then continued at weekly intervals, until there were no green leaves available.

Rust was assessed on individual leaves using the standard diagrams of the Plant Pathology Laboratory, Harpenden, to give mean values for a sub-plot either as disease per individual leaf or per plant.

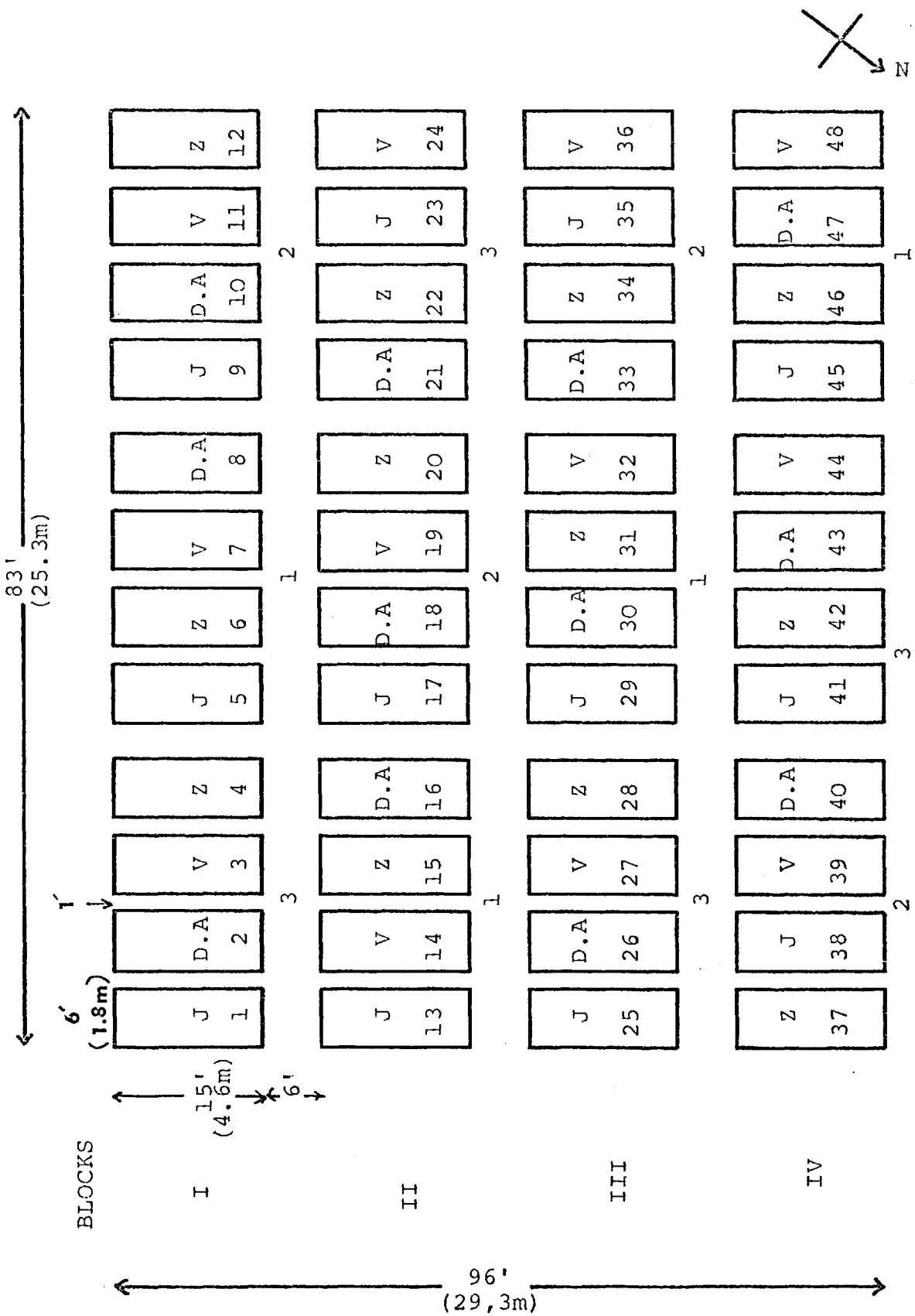
Data were analysed by methods suggested by Van der Plank (1963). Diseased areas were transformed into proportions of infected tissue (x) and the disease progress obtained by plotting $\log_e \left(\frac{x}{1-x}\right)$ against time. Infection

Fig.6 Layout of field trial: Silwood Park 1973

Key:

Sowing Date:
1 20 March
2 6 April
3 16 April

Cultivar:
D.A = Deba Abed
J = Julia
V = Vada
Z = Zephyr



rates over specific periods were also calculated for individual leaves.

A Burkard volumetric 7-day spare trap, sited within the barley trial, was operated continuously from 1 May until 23 July. Each week the revolving drum was removed from the trap and the coated-sticky band cut into seven lengths corresponding to each day. These were mounted individually on microscope slides. The number of rust uredospores deposited were counted within a 460 μ wide traverse of the prepared slides and spare number/m^3 air calculated from which an hourly mean for each day derived.

A leaf surface wetness recorder and a thermohydrograph were also sited within the trial site. Rainfall was recorded at Silwood Park Main Meterological Site, Latitude 51°28'N, C. 200m away and wind speed at Silwood Farm, about 1 km from the trial site.

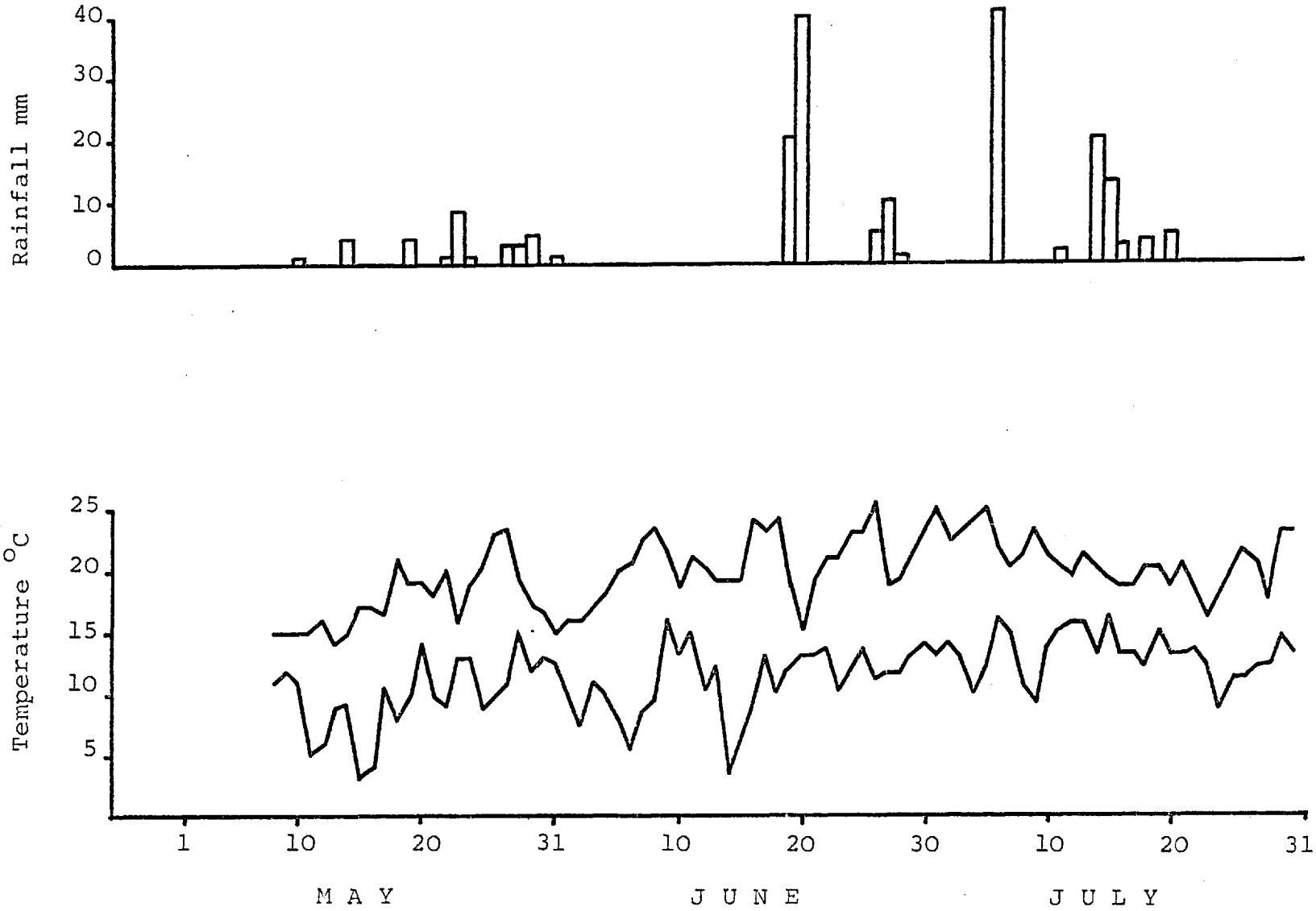
After harvesting the moisture content of grain was determined by drying a 100g sample from each sub-plot at 120°F for 3 days and then reweighing. The figures obtained were used to adjust the yield of each plot to a dry-weight basis.

RESULTS

Crop Development and the Weather: Deba Abed showed a distinctly different growth habit to the rest of the cultivars. In the early stages it tillered more vigorously and covered the soil but began stem extension later than the rest. It also had wider and longer leaves. In the first sowing Zephyr, Julia and Vada entered stem extension about mid-May and Deba Abed in the first week of June. Some leaves remained green on Deba Abed especially within the second and third sowings 8 days or more after those of the other cultivars had completely senesced.

There was a dry period during the first 19 days of June followed by heavy rains which favoured disease development. Minimum daily temperatures also increased during this period (Fig.7).

Fig.7 Meteorological data: Silwood Park 1973.



Disease Development: Rust was first recorded in all sowings in the second week of June. The barley had then grown as follows: first sowing, Zephyr, Julia and Vada Growth Stage (G.S.) 10-10.1 (in boot and first ears just visible), Deba Abed G.S. 7-8 (second node visible - last leaf just visible). Second sowing, Zephyr, Julia and Vada G.S. 9 (ligule of flag leaf just visible) and Deba Abed G.S. 7; third sowing, Zephyr, Julia and Vada G.S. 8-9 and Deba Abed G.S. 6 (first node of stem visible).

Disease development was initially slow. By the first week of July there was less than 1% brown rust in all sowings (Table 22). Subsequently the amount of disease increased substantially, especially within the plantings of Deba Abed and Zephyr.

The overall development of brown rust within each sowing is shown in Fig.8a,b,c where the means of four replicate sub-plots are plotted as $\log_e(\frac{x}{1-x})$ against time (see also Appendix Table 31). Only for the first sowings (Fig.8a) do the slopes of the regression lines for Julia and Vada appear to differ from those of Zephyr and Deba Abed but tests (Steel & Torrie, 1960), indicated that there were no significant differences between the slopes within each sowing (Appendix Table 32). This was supported by a more detailed analysis of apparent infection rates on leaf 2 (Flag leaf =1) between second and third week of July. There were no significant differences in infection rates either between cultivars or between sowings (Table 23 and Appendix Table 33).

These results suggest that the rate of brown rust development was similar on all cultivars yet the amounts of brown rust on the cultivars was clearly different as analysis for rust levels on leaves 1,2,3 and 4 and for total rust at assessment dates first, second and third weeks of July indicate (Table 24 and 25; Appendix Tables 34 and 35). This in turn suggests that the differences between the cultivars are established very early in the development of the crop. The implications will be discussed later. There were also significant differences

Table 22. Development of Brown Rust:1973 Field Trial

(Figures are mean % brown rust/plot)

(a) First Sowing

Assessment date	Cultivar			
	Deba Abed	Julia	Zephyr	Vada
11 June	(0.003)	-	-	(0.004)
18	(0.004)	(0.006)	(0.007)	(0.002)
25	0.04	(0.008)	0.04	(0.007)
2 July	0.22	0.12	0.30	0.08
8	1.31	0.52	1.61	0.52
16	9.14	1.87	12.05	1.09
23	23.44	4.08	16.17	2.50

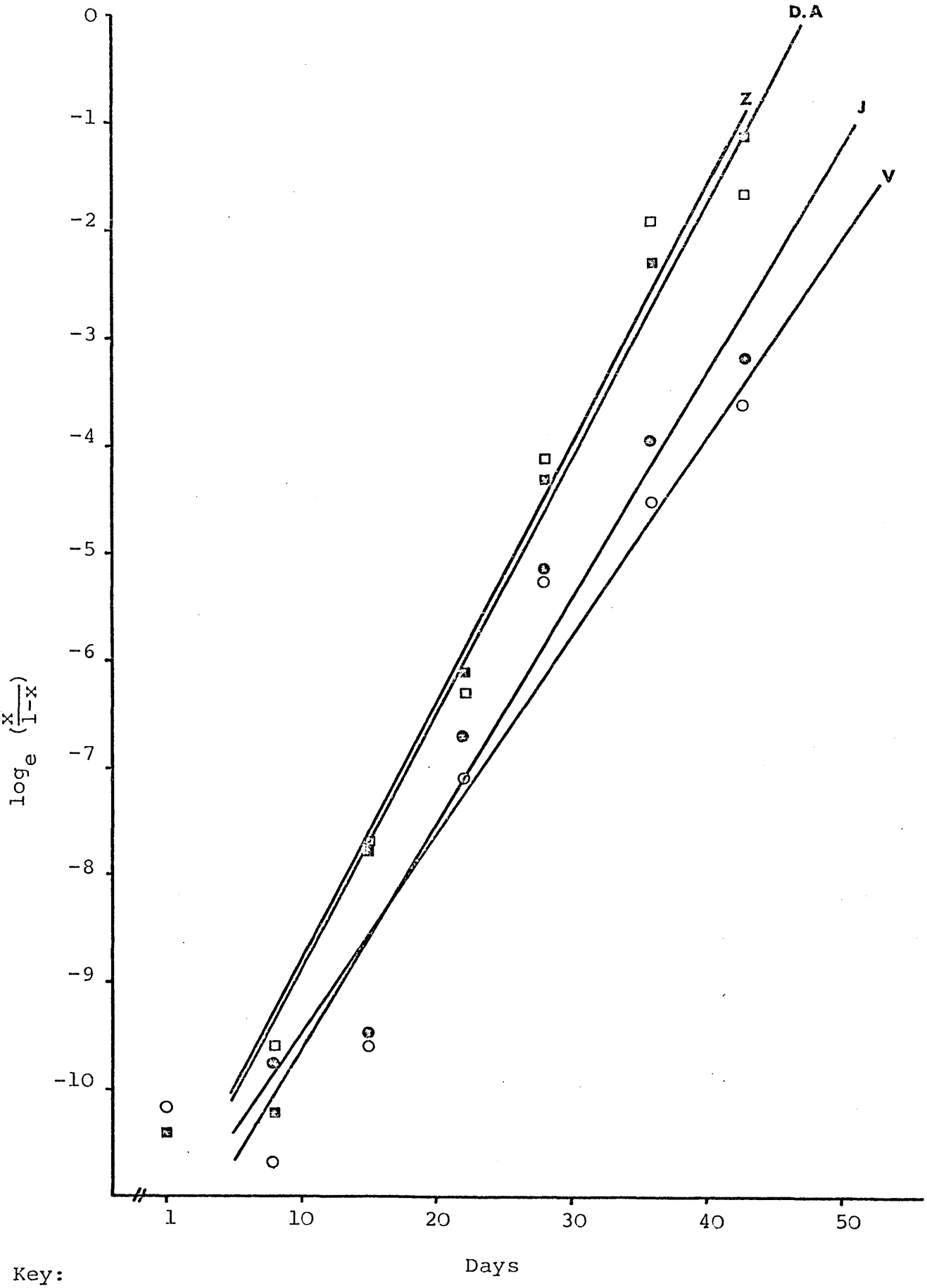
(b) Second Sowing

Assessment date	Cultivar			
	Deba Abed	Julia	Zephyr	Vada
12 June	(0.006)	-	-	-
19	0.02	(0.009)	0.01	(0.002)
26	0.02	0.02	0.03	(0.007)
3 July	0.16	0.10	0.20	0.02
9	1.16	0.50	1.01	0.12
17	5.43	1.78	5.68	1.07
24	18.15	6.33	21.13	2.46
31	39.38			

Table 22 continued.

(c) Third Sowing

Assessment date	Cultivar			
	Deba Abed	Julia	Zephyr	Vada
13 June	-	-	(0.003)	(0.001)
21	0.01	-	(0.003)	-
27	0.02	(0.005)	0.03	(0.008)
4 July	0.28	0.11	0.25	0.02
12	1.75	0.51	1.76	0.58
18	3.38	1.05	4.50	0.73
27	17.25	10.67	17.28	3.93
31	21.67			



Key:

■, D.A = Deba Abed

○, V = Vada

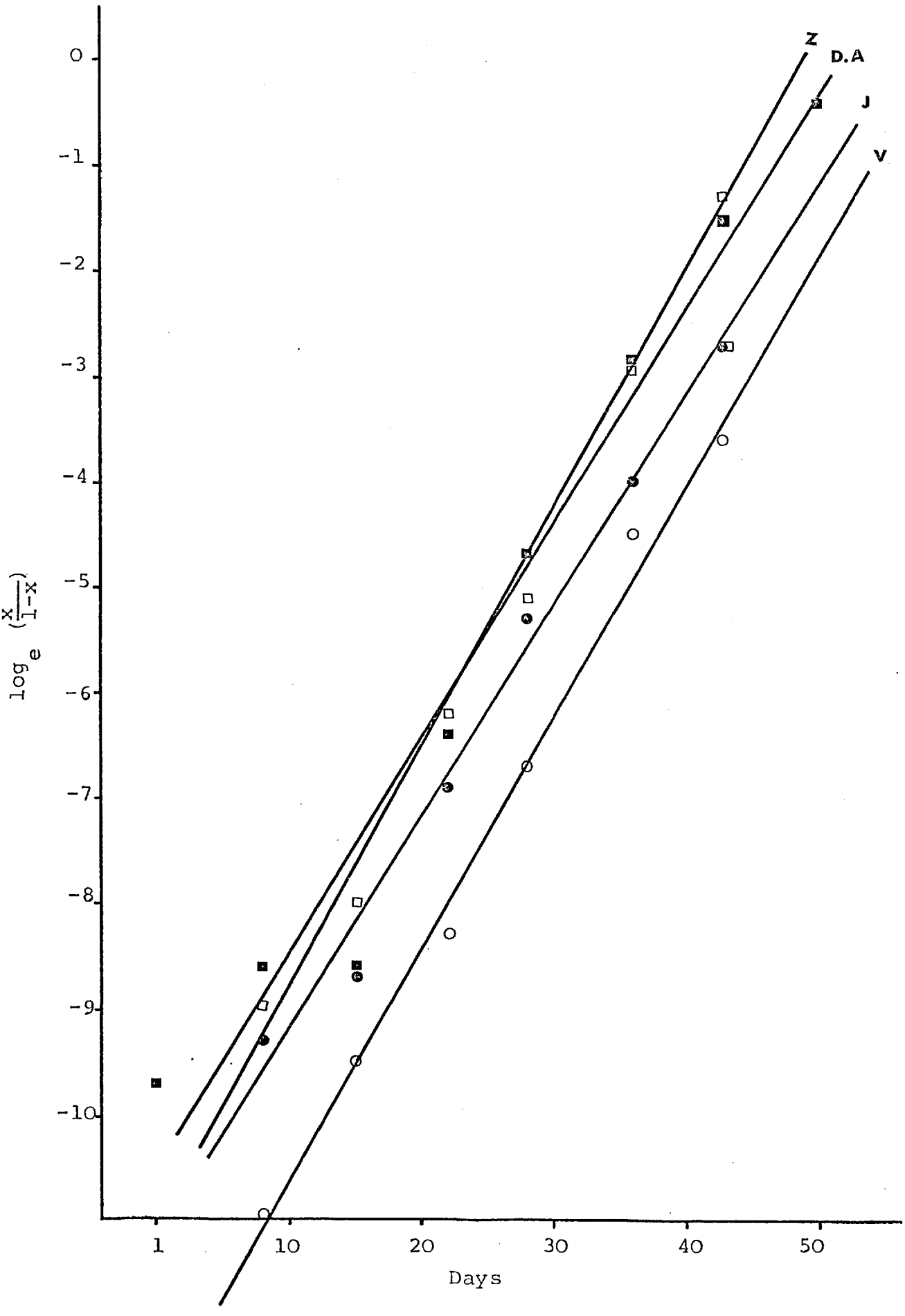
□, Z = Zephyr

◉, J = Julia

Fig.8a Disease progress 1973
First Sowing

Key:

Fig.8b Disease Progress 1973: Second Sowing. See Fig.8a



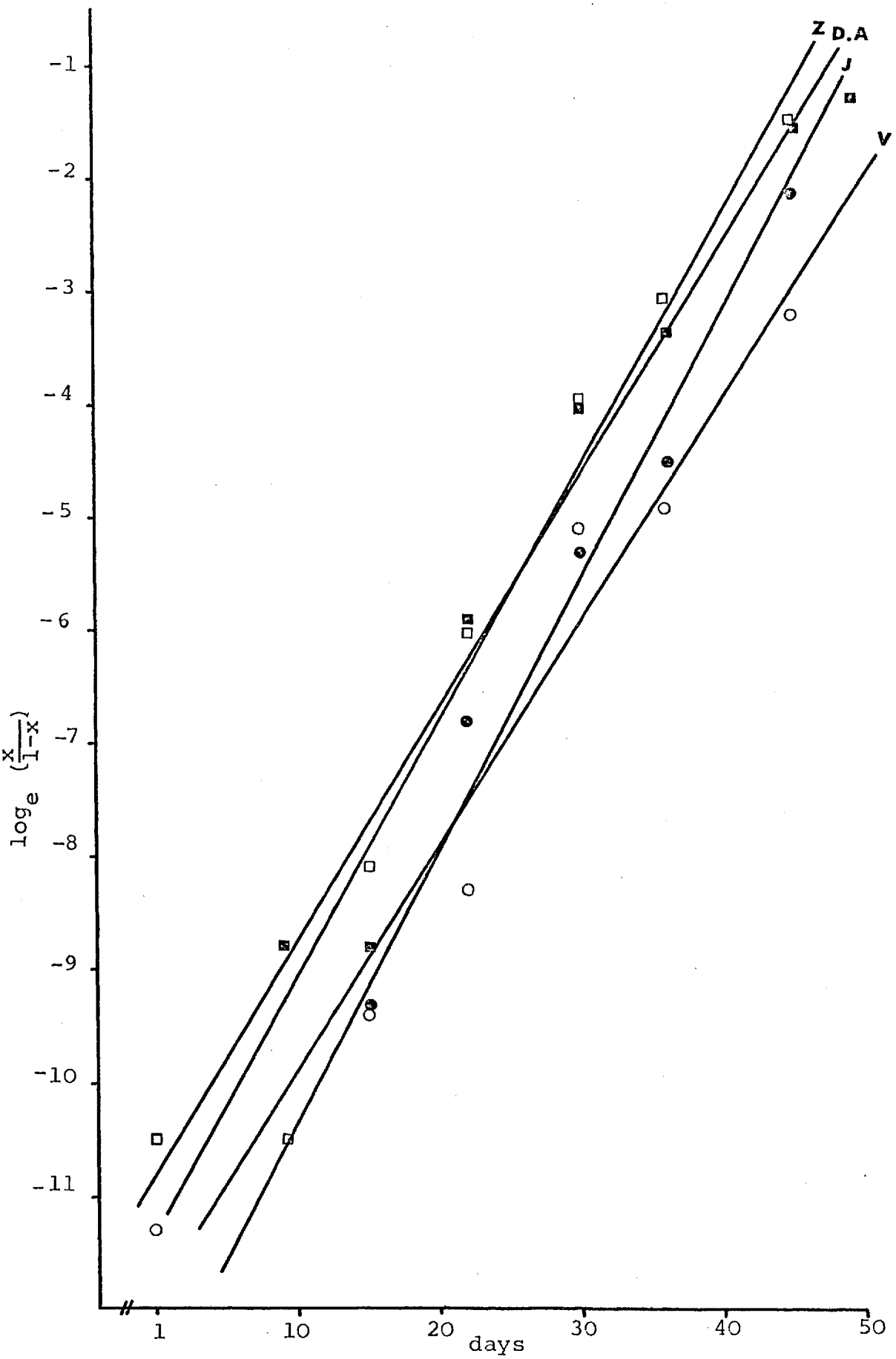


Fig.8c Disease progress 1972: Third Sowing.

Key: See Fig.8a

between the different sowings in the maximum rust recorded on leaves 2,3, and 4 and the mean % rust per plant at assessment at second week of July, indicating that the attempt to build-up rust through different sowings had been partly successful.

Increases in the amount of brown rust were reflected by increasing numbers of uredospores trapped (Fig.9 Appendix Table 36). Thus a 10-fold increase in disease within plots (Table 22) from 1 July was matched by a rapid rise in spores caught. There followed a succession of depressions and peaks in daily uredospore counts sometimes associated with intermittent heavy rains but sometimes with no connection between them. This can be seen especially on 6 July when there was a heavy rain but at the same time a big peak in uredospore count. This suggests that there are other factors affecting spore release. The time of rain and its duration could also be important.

Yields: There were significant differences in the yields of cultivars (Table 26 and Appendix Table 37) but in the absence of plots in which brown rust was controlled it was difficult to assess the effects of the disease on yield pf a particular sowing of a cultivar. Also there did not appear to be any relationship between the yield of a plot and the amount of brown rust present in that plot.

Table 23. Apparent Infection rates of P.hordei on Leaf 2 (flag leaf = 1) Between Second and Third Week of July.

Planting date	Cultivar: Deba Abed	Julia	Zephyr	Vada
1	+0.247	+0.234	+0.236	+0.143
2	+0.204	+0.144	+0.186	+0.299
3	+0.172	+0.222	+0.166	+0.182

Analysis of Variance.

	D.F.	S.S.	M.S.	F.
Main Plots				
Date of Planting	2	0.0076	0.0038	0.43 NS
Blocks	3	0.0421	0.0140	1.59 NS
Error	6	0.053	0.0088	
Sub-Plots				
Cultivars	3	0.0012	0.0004	0.05 NS
Cultivars X date of planting	6	0.0859	0.0143	1.91 NS
Error	25	0.1872	0.0075	

Table 24. Maximum Brown Rust Levels Recorded on Leaves 1,2,3 and 4 (Flag leaf =1):1973 Field Trial.

Cultivar	Mean rust level †(as angular transform of % Infection) Leaf No. 1(flag leaf)	2	3	4
Deba Abed	27.03	23.52	11.05	3.90
Julia	10.00	8.73	2.93	0.15
Zephyr	20.46	14.29	5.78	1.72
Vada	8.47	7.57	3.78	1.03
S.E. Diff.	1.34	1.15	0.70	0.56

† Mean of twelve sub-plots, four per sowing.

Table 25. Brown Rust Recorded on Assessments 4,5, and 6†: 1973 Field Trial.

Cultivar	Mean rust level (as angular transform of % Infection). Assessment No. 4	5	6
Deba Abed	2.59	6.69	13.81
Julia	1.90	4.00	7.14
Zephyr	2.80	6.72	15.18
Vada	0.75	2.95	5.71
S.E. Diff.	0.25	0.55	0.76

† Key:

Assessment No. 4 - 2,3,4 July
5 - 8,9,12 July
6 - 16,17,18 July

Fig.9 Concentration of rust uredospores in the air: Field Trial, Silwood Park 1973.

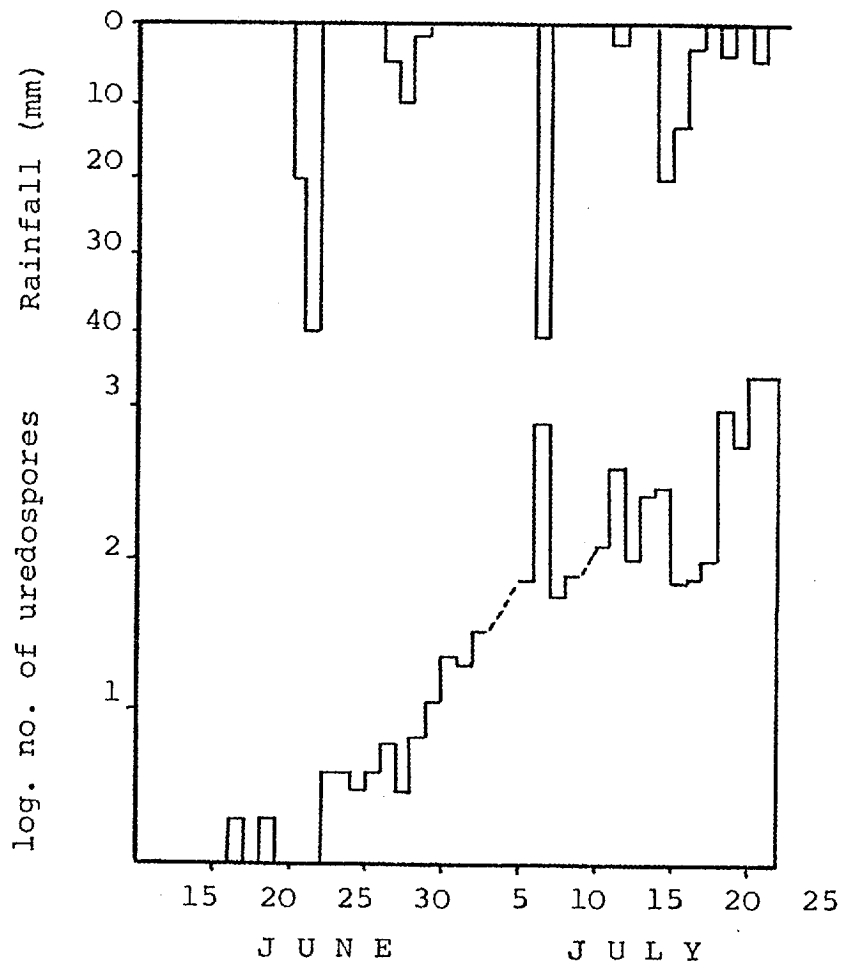


Table 26. Mean Yields (kg Dry Weight)

Planting	Cultivar			
	Deba Abed	Julia	Zephyr	Vada
1	7.319	11.819	10.191	13.149
2	5.385	12.839	12.302	12.789
3	6.395	11.566	9.887	13.545
Mean	6.366	12.075	10.793	13.161
S.E. Diff.	0.133			

B. FIELD TRIAL, 1974

MATERIALS AND METHODS

The development of P.hordei on the four cultivars, Deba Abed, Julia, Zephyr and Vada was again examined in the field during 1974. The layout of this trial is shown in Fig.10. There were four blocks each of eight plots of barley, four of which were kept rust-free by two applications of Mebenil (BASF), on 15 June and 2 July, at a rate of 2.781 kg of a 75% w.p./hectare using a Tudor knapsack sprayer and four plots which were left unsprayed. All these plots were sown with "Milstem"-dressed seed on 8 April. However, in an attempt to encourage the development of brown rust within the site, strips (2 x 15 ft, 0.6 x 4.6 m) were sown between the plots with the brown-rust susceptible cultivar Midas c. 2 weeks earlier, on 26 March. This seed was also dressed with Milstem.

Crop growth and disease were assessed by the methods used in 1973 on six labelled plants per plot in the field. The numbers of rust uredospores in the air were also measured as in 1973 by a Burkard 7-day volumetric spore trap. Additionally, rust uredospores in the air immediately above each unsprayed plot were monitored by vertical sticky cylinder traps of the type suggested by Jenkyn (1974). Each consisted of an aluminium rod, 25 cm long and 0.7 cm diameter, held above the crop by inserting it into a well, 5 cm deep and 0.8 cm diameter, drilled in a wooden stake (4 cm x 4 cm). The sticky surface to trap spores was provided by coating a piece of Cellophane, 25 mm wide with a mixture of Vaseline and paraffin wax (12%) dissolved in toluene. The coated Cellophane was held on the rod by a narrow strip of Twinstick applied to the join, and it was protected from rain by an inverted flower pot saucer (16 cm diameter) held at the top of the rod by rubber bungs (Fig.11). These rod traps were changed each week. Each Cellophane strip was mounted on a microscope slide with

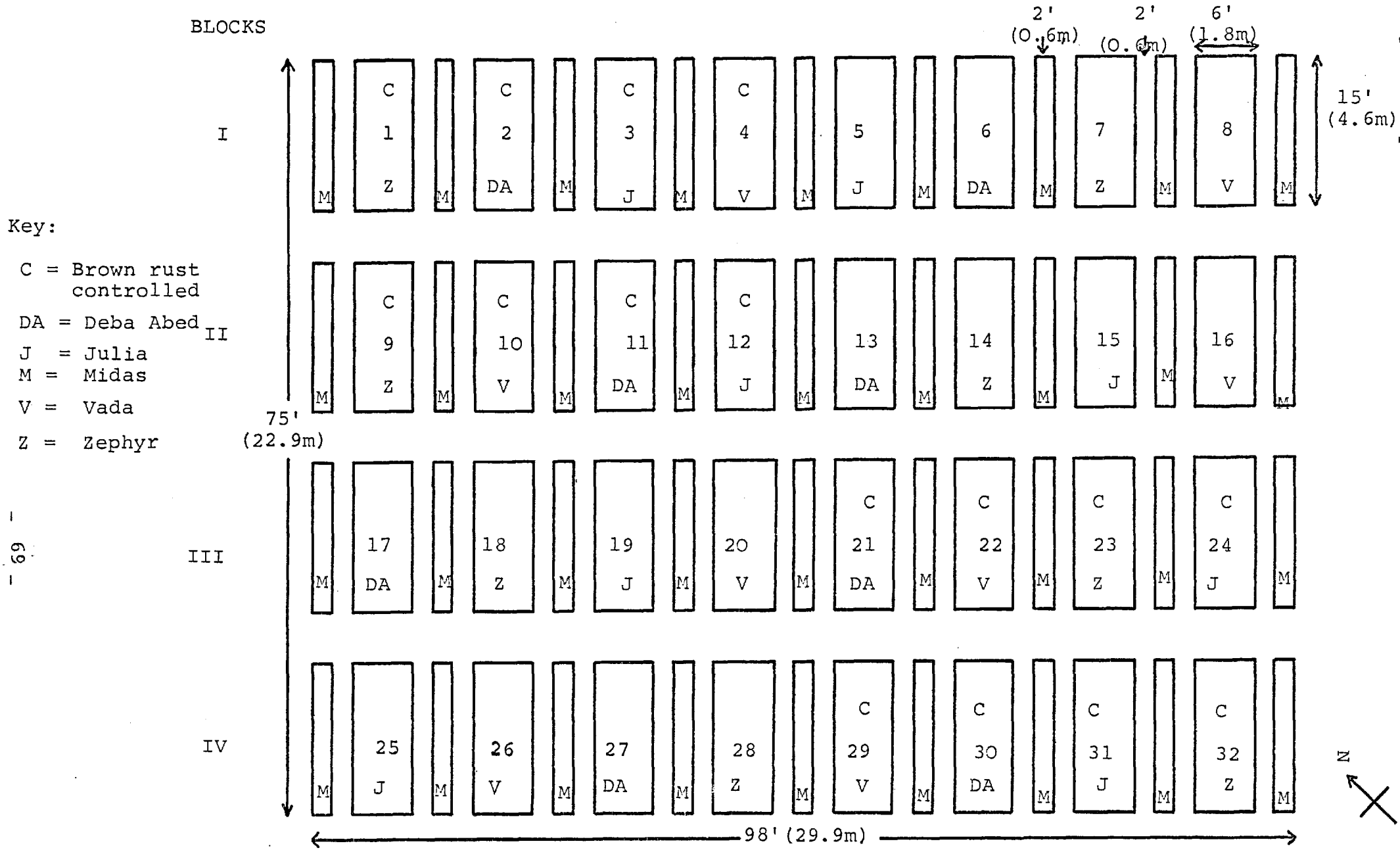
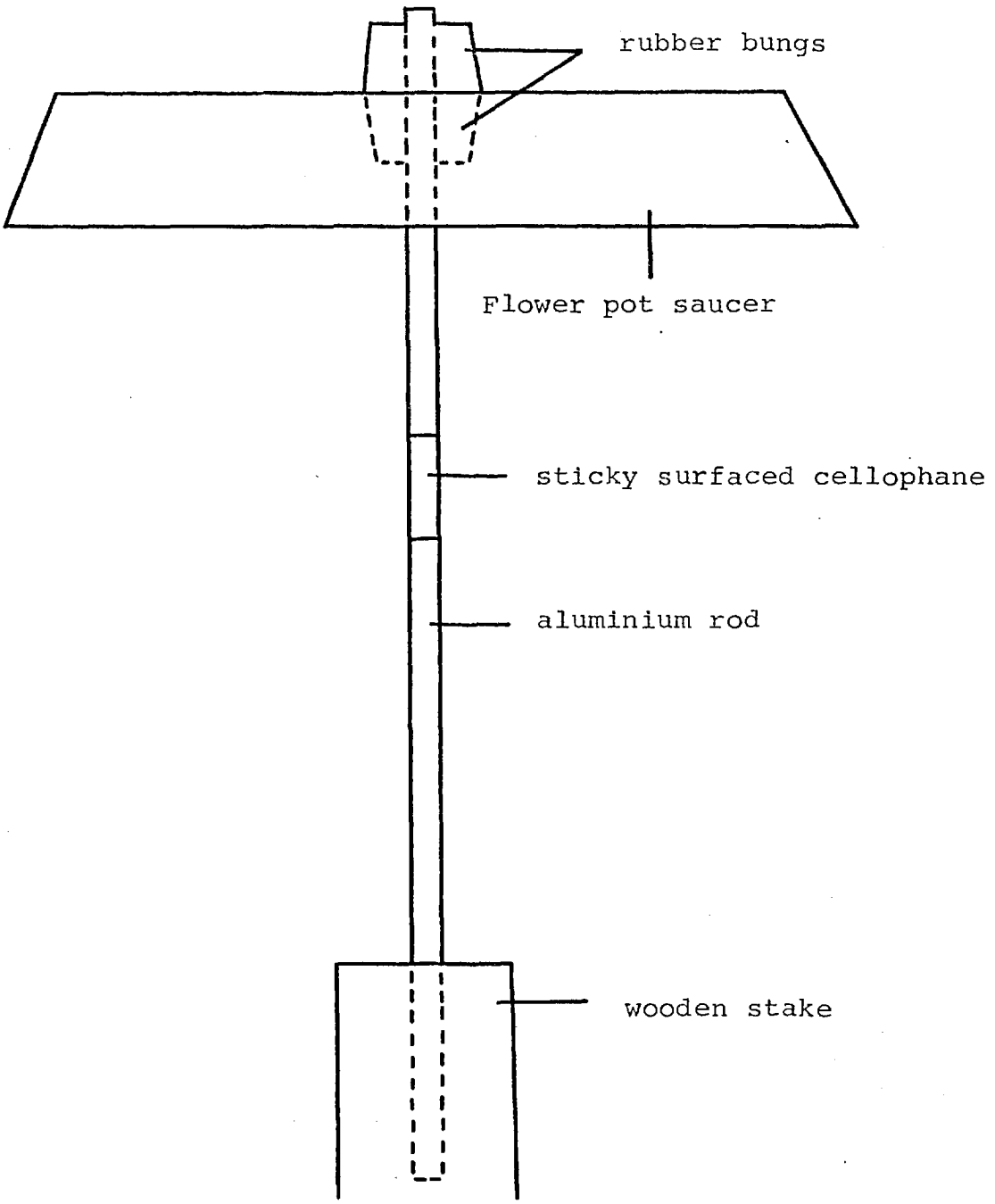


Fig.10 Layout of field trial: Silwood Park 1974

Fig.11 Vertical sticky cylinder trap.



clear nail varnish and then uredospores counted in ten traverses at right angles to the axis of the rod.

As in 1973 temperature, humidity and leaf surface wetness were recorded by instruments within the trial site.

Plots were harvested on 20 August, also using similar methods to 1973 and grain dry wight likewise determined. Sieve tests were also carried out on 100g samples of dried grain from each plot. A stack of three sieves of decreasing mesh size (2.8,2.5,2.2 mm) was placed on a wooden tray and attached to a mechanical shaker. A 100g sample of grain was placed in the top sieve, the lid replaced and the stack secured tightly to the shaker which was then switched on for 3 mins. The grain retained in each sieve was then weighed.

RESULTS

Disease Development:

The weather conditions during the trial are summarised in Fig.12. From May onwards rainy periods alternated with dry, sunny days and both daily maximum and minimum temperatures rose steadily from mid-June. Brown rust was first recorded in the trial on 19 June and thereafter increased steadily to a mean of 7-8% cover per leaf on the susceptible cultivars, Deba Abed and Zephyr by 23 July (Table 27 and Appendix Table 38). Analysis of variance indicated significant differences between the cultivars on all assessment dates, Deba Abed and Zephyr having significantly more brown rust than Julia or Vada. However, when the rate of brown rust development was examined, by converting percentages to proportions brown rust (x) and plotting the mean values as $\log_e (\frac{x}{1-x})$ against time, there appeared to be no significant differences between cultivars and this was confirmed by a homogeneity test on the regression lines obtained (Fig.13 and Appendix Table 39). Differences in the final amount of brown rust within the cultivars appeared to be governed (as in sowings

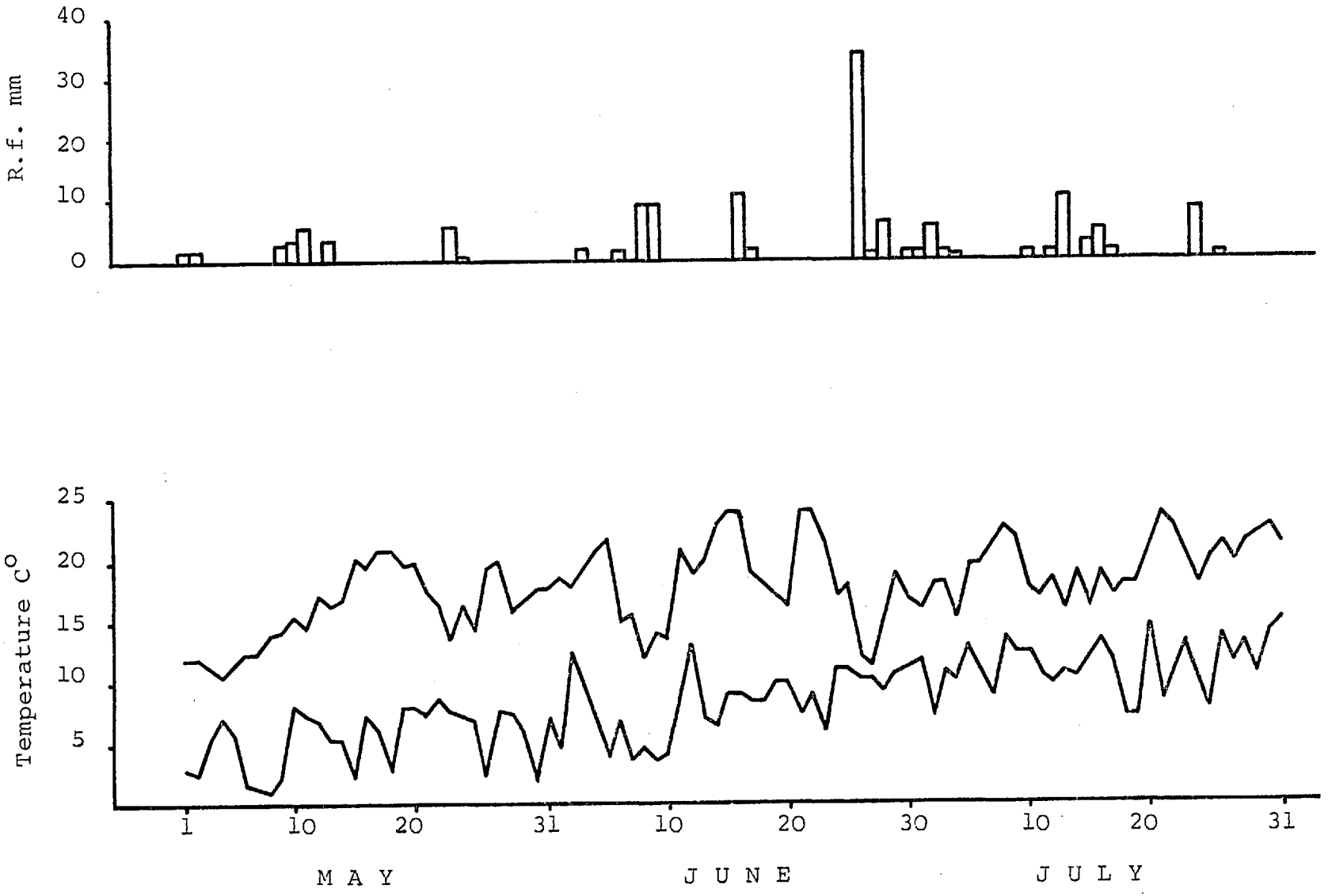


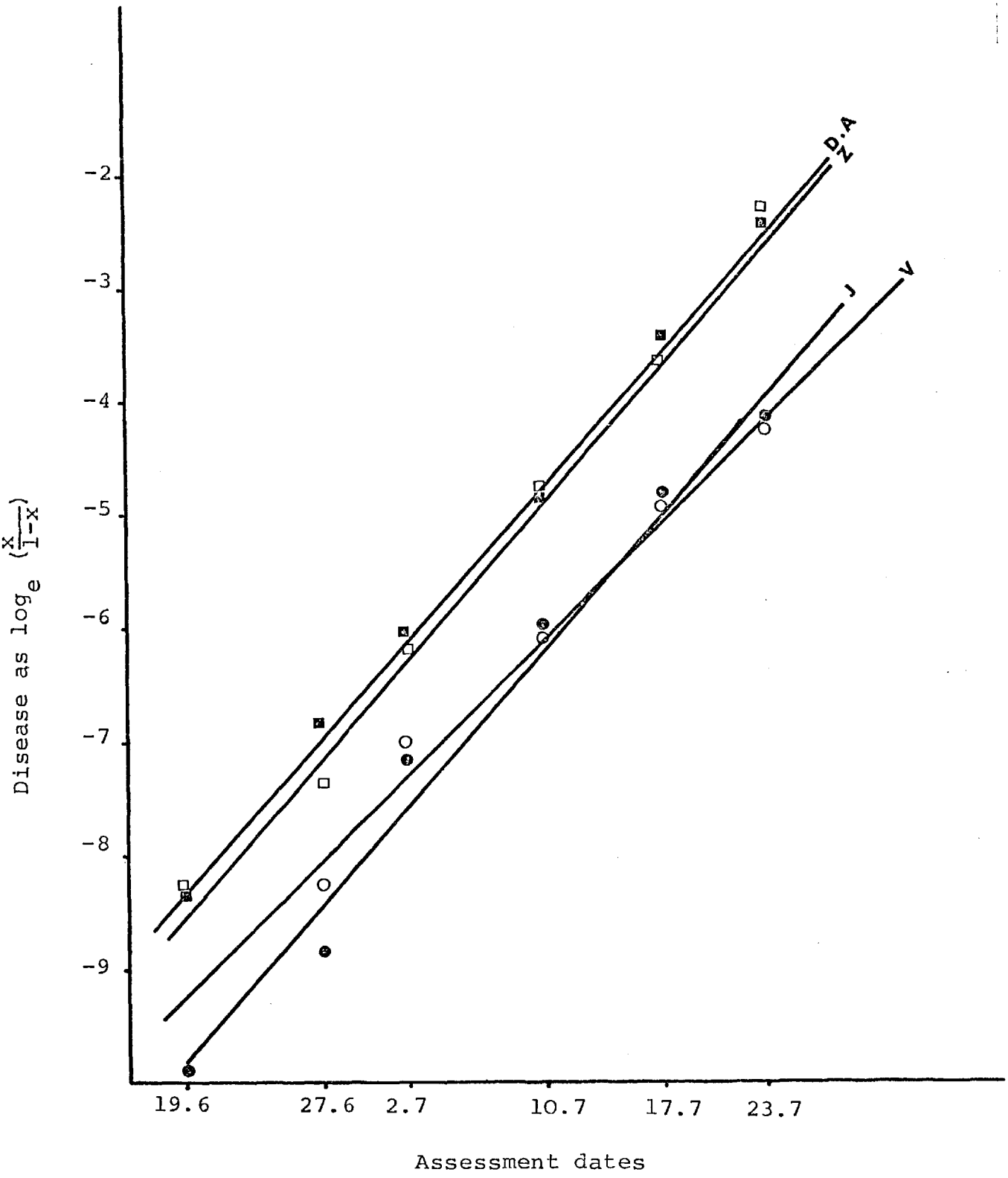
Fig.12 Meteorological data: Silwood Park 1974

Table 27. Brown Rust Development Within the Field Trial,1974

Cultivar	Mean % disease per leaf on					
	19 June	27 June	2 July	10 July	17 July	23 July
Deba Abed	0.02	0.10	0.23	0.78	3.08	7.80
Julia	0.01	0.01	0.08	0.24	0.82	1.53
Zephyr	0.02	0.06	0.20	0.80	2.51	8.94
Vada	0	0.03	0.09	0.20	0.71	1.42
S.E $\pm$	0.006	0.02	0.016	0.16	0.49	1.37
Variance ratios:						
Cultivars	4.02*	3.9*	23.5***	4.0*	6.0*	8.6**
Blocks	1.76	6.3*	8.3***	5.2*	3.5	3.5

Significance at $P \leqslant 0.05$, 0.01 or 0.001 denoted by *,** and *** respectively.

Fig.13 Disease development: 1974



Key:

■, D.A = Deba Abed

●, J = Julia

○, V = Vada

□, Z = Zephyr

2 and 3 of the 1973 trial) by events preceding the first visible appearance of the disease within plots. Further evidence on similarity of rates of development was obtained by analysis of variance on the apparent infection rates (r) derived from successive estimates of disease (Table 28 and Appendix Table 40). In no instance was there a significant difference between cultivars in this respect.

Estimates of Uredospores in the Air: No useful information was obtained from the Burkard trap as the machine failed to function properly after mid-July when brown rust was developing. Counts from the simple vertical traps showed that, although plots were near to strips of Midas on which brown rust developed substantially and not far removed from other plots, the number of uredospores trapped above plots reflected in general the brown rust development within that plot. Thus the regression of spore numbers (as logarithms) against disease (as $\sqrt{\text{percentage disease}}$) during its logarithmic phase (i.e. up to 5% brown rust) for all plots was highly significant (Fig.14 & Appendix Table 41).

Analysis of variance for the spore counts obtained above plots within successive periods also showed some difference between cultivars but these were not so consistent as the differences shown in the previous analysis of disease levels. For example, the total number of spores collected above plots of Deba Abed was significantly greater than that collected above plots of Julia, but there was no significant difference between total spores collected above plots of Zephyr and Vada. A similar result was obtained from an analysis of spore trap data for the periods 27 June-5 July and 18-24 July (Table 29 & Appendix Table 42).

A measure of the rate at which spores were produced within plots of the four cultivars was obtained by plotting $\log_e \left(\frac{x}{1-x}\right)$ against time where x = accumulative number of spores caught as a proportion of the total trapped above each plot. The regression lines obtained from analysis of these data are shown in Fig.15 (Appendix Table 43). From this it can be seen that as with disease increase (Fig.13)

Table 28. Rate of Brown Rust Development Within the Field Trial, 1974.

Cultivar	Mean apparent infection rate (r) during the period				
	19-27 June	27 June-2 July	2-10 July	10-17 July	17-23 July
Deba Abed	+0.152	+0.220	+0.126	+0.212	+0.170
Julia	+0.123	+0.137	+0.125	+0.184	+0.111
Zephyr	+0.091	+0.273	+0.163	+0.178	+0.216
Vada	-	+0.171	+0.091	+0.194	+0.124
S.E.±	-†	-†	0.023	0.019	0.026
Variance ratios:					
Cultivars	-	-	1.6 NS	0.6 NS	3.5 NS
Blocks	-	-	3.5 NS	1.9 NS	1.0 NS

† Analysis not possible because data not available for several plots.

Fig.14 Regression of disease level and spore number trapped above the plot. (Within the logarithmic phase of the disease e.i. up to 5% brown rust).

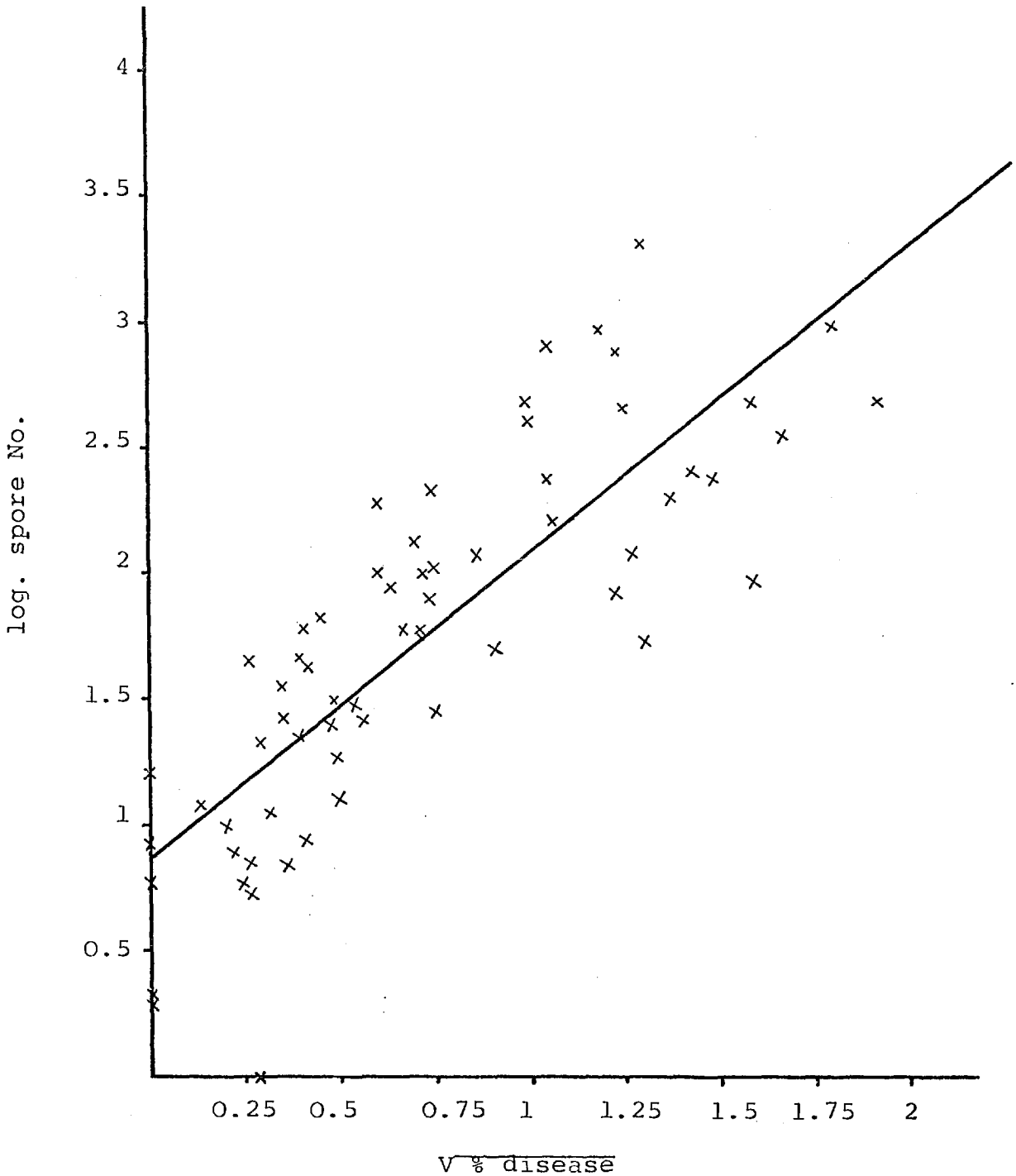


Table 29. Analysis of Variance of Spore Numbers Collected on Sticky Vertical Spore Traps.

Between 27 June - 5 July.

	D.F.	S.S.	M.S.	F.
Cultivars	3	1754.69	584.9	5.35*
Blocks	3	357.19	119.06	1.09 NS
Error	9	983.56	109.28	

differences between cultivars (Tukey's w-procedure-hsd)

Julia	Vada	Zephyr	Deba Abed
10.25	11.5	19	36.5 *

* means not underscored by the same line are significantly different.

Between 5 - 11 July.

	D.F.	S.S.	M.S.	F.
Cultivars	3	21102.25	7034.08	3.31 NS
Blocks	3	18712.25	6237.42	2.94 NS
Error	9	19117.25	2124.14	

Between 11 - 18 July.

Cultivars	3	69290.5	23096.83	1.16 NS
Blocks	3	84441.5	28147.17	1.42 NS
Error	9	178658.0	19850.89	

Table 29 continued.

Between 18 - 24 July.

	D.F.	S.S.	M.S.	F.
Cultivars	3	5015943.5	1671981.17	8.46 **
Blocks	3	888708.5	296236.17	1.5 NS
Error	9	1778998.0	197666.44	

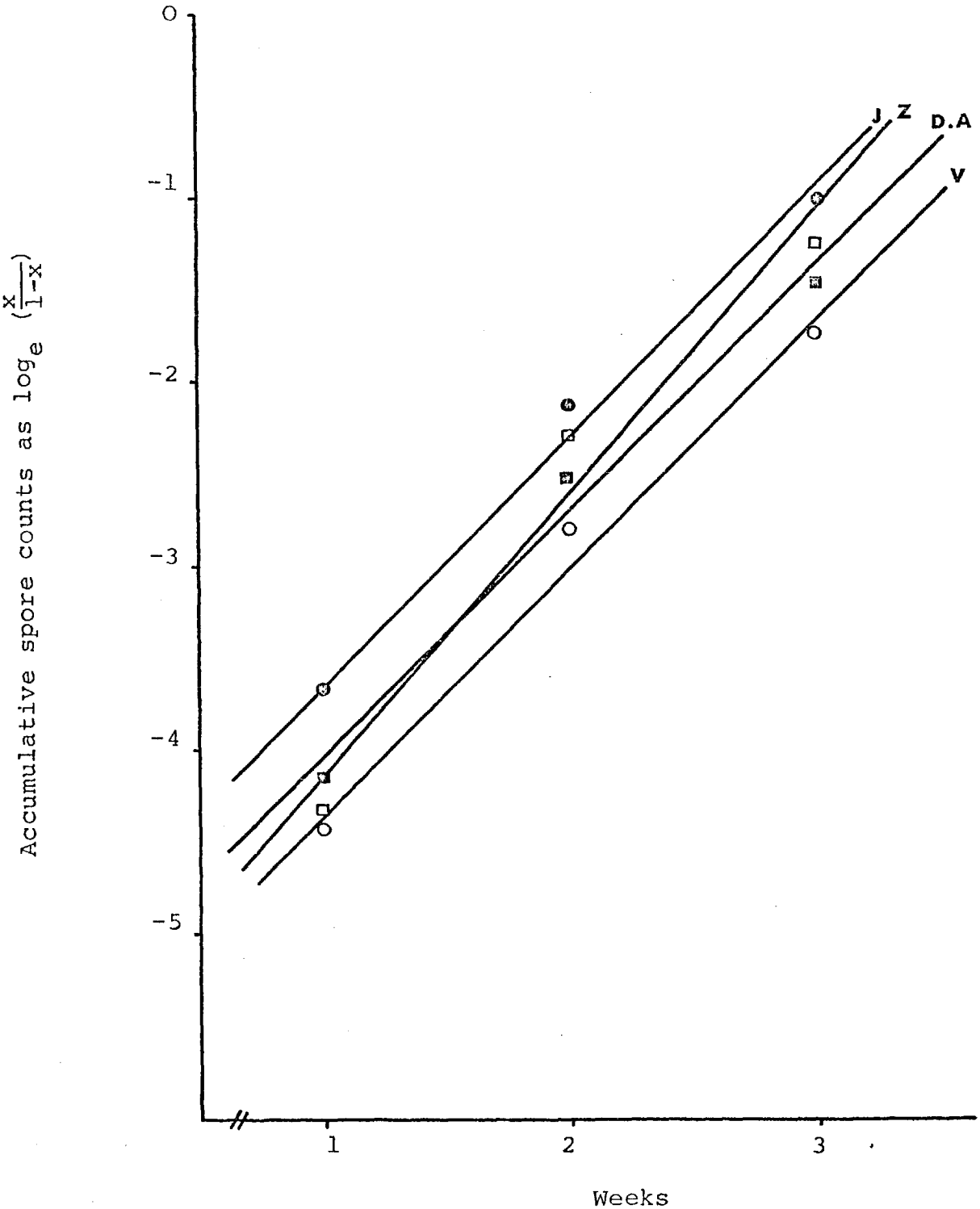
Julia	Vada	Zephyr	Deba Abed
385.5	1120.75	1144.0	1967.75

Total number of Spores

	D.F.	S.S.	M.S.	F.
Cultivars	3	7059627	2353209	7.5**
Blocks	3	1515797	505265.7	1.6 NS
Error	9	2816226	312914	

Deba Abed	Zephyr	Vada	Julia
2401.5	1506.0	1385.8	526.8

Fig.15 Regression lines of accumulative spore counts above the different cultivars (as $\log_e \left(\frac{x}{1-x}\right)$



Key:

■, D.A : Deba Abed

○, V : Zephyr

□, Z : Julia

●, J : Vada

spores appear to be produced at similar rates within plots of the four cultivars. Differences in total spores caught above plots therefore, like the disease levels they reflect, appear to be due to other factors than rate of spore production.

Yield: Growth of the barley in those plots of Blocks 3 and 4 in which brown rust was controlled was very poor. The reason for this was not discovered but it was associated with a marked ridge in this area. Accordingly these plots were not harvested and so consideration can only be given to yields from Blocks 1 and 2. An analysis showed that in these two blocks rust significantly affected grain yield (Table 30). Even small levels of rust on Julia and Vada caused substantial % reduction in yield over that obtained from sprayed plots. This was again reflected in data from sieving tests (Table 31 & Appendix Table 44); rust reduced the amount of large grain in all cultivars (Fig.16).

Table 30. Yields in Blocks 1 and 2 of the Field Trial, 1974

(a)

	Dry Weight Grain (kg/plot)							
	Deba Abed		Julia		Zephyr		Vada	
Block	A	B	A	B	A	B	A	B
1	2.46	2.34	2.84	2.68	3.30	2.96	3.35	3.29
2	2.90	1.94	3.0	1.56	2.79	1.61	3.12	2.32

A = plots sprayed to control brown rust.

B = unsprayed plots.

Analysis of Variance:

	D.F.	S.S.	M.S.	F.
Cultivars	3	0.846	0.282	1.45 NS
Rust	1	1.60	1.60	8.25 *
Interaction	3	0.092	0.03	0.15 NS
Block	1	0.99	0.99	5.10 NS
Error	7	1.366	0.194	

(b) Yield Reduction

	Deba Abed		Julia		Zephyr		Vada	
	A	B	A	B	A	B	A	B
Total yield (Blocks 1 & 2)	5.36	4.28	5.84	4.24	6.09	4.57	6.47	5.61
Reduction (kg)	1.08		1.6		1.52		0.86	
% Reduction	20.1		18.2		25.0		13.3	

Table 31. Result of Sieve Tests (>2.8 and 2.5 to 2.8 Combined).

Block	Deba Abed		Julia		Zephyr		Vada	
	A	B	A	B	A	B	A	B
I	56.56	51.30	67.20	61.64	61.65	53.40	66.59	56.48
II	59.57	62.20	72.16	51.02	73.04	55.37	73.01	55.38
Mean	58.07	56.75	69.68	56.33	67.35	54.39	69.80	55.93

S.E ± 3.54

A = plots sprayed to control brown rust.
B = unsprayed plots.

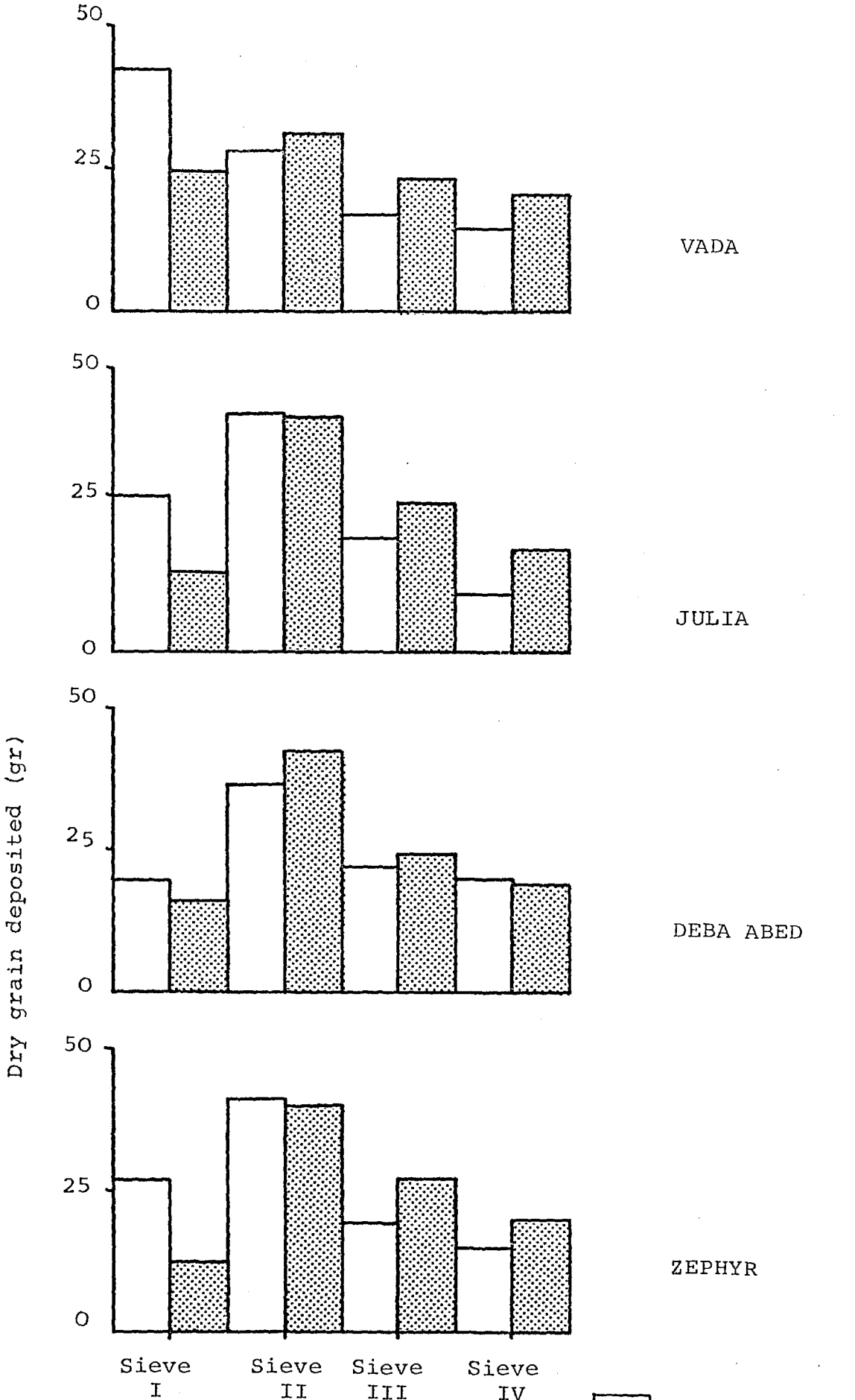


Fig.16 Result of Sieves test.
(as mean of two blocks).

C - Preliminary Analysis of Spore Trap Data

Introduction: Spore traps were placed centrally within a planting of Midas barley in both 1973 and 1974, adjacent to the field trials, but relatively few records were obtained because either the trap did not work properly (1974) or there was little brown rust until late in crop growth (1973). However, from the available slides counts were made of uredospores trapped and from these hourly estimates of spore numbers per m^3 air were derived. Slides were also available from traps placed near field trials in 1971 and 1972 by N.B. Simkin. On these, spores had been counted within a single, longtitudinal traverse and a mean daily concentration of spores per m^3 air calculated (see Simkin, 1973). These slides were also re-examined and hourly estimates derived, as indicated in the account of the 1973 field trial. Brown rust uredospores were identified by comparing them with a prepared 'spore-trap' slide on which uredospores of known P.hordei had been deposited in the laboratory. The spore counts obtained were related to daily records of temperature, rainfall, relative humidity, leaf-surface wetness and wind-speed (2m above the ground) obtained from the appropriate instruments at the Field Station.

Results: The days for which spore counts were available were divided into four categories of weather conditions (Table 32) based on those of Hammett & Manners (1971), viz.

1. No rainfall.
2. Rainfall: predominantly in daytime.
3. Rainfall: predominantly at night.
4. Rainfall: distributed approximately evenly during day and night.

Because the time available for this part of the investigation was limited, it was decided to restrict further consideration of the results to the 1971 data and, in particular, to the period without rain from 29 June to 10 July. The detailed data for 1971 is presented in Appendix Table 45; data for the other years have been

deposited in the Botany Department at Silwood Park.

Examination of the data between 29 June and 10 July showed that uredospore concentrations in the air had a marked diurnal periodicity (Fig.17a & b). While the general pattern of spore release was similar on all days, the numbers of spores and the periodicity of the release varied considerably. On some days substantial numbers of spores were trapped over many hours from early morning onwards (2,3 & 4 July, Fig.17a) on other days very many spores were trapped in one particular hour (7 & 9 July, Fig.17b). In the absence of rain spore release appeared to be associated in a general way with low humidity and high temperature. On rainy days (18,19,25,26,27 & 28 June) generally fewer spores were trapped but there were indications that the onset of rain (e.g. 26 & 28 June, Fig.18) did itself trigger-off some release of uredospores, a feature also found by Hammett & Manners in their study of factors affecting conidial dispersal of Erysiphe graminis. However, prolonged rain (e.g. 18 June, Fig.18) was associated with low spore counts presumably because this washed the spores from the air.

The results suggest that a statistical analysis of the data along the lines indicated by Hammett & Manners might be profitable but more complete data for one season should first be obtained.

Table 32. Days on which brown rust uredospores were trapped in relation to weather conditions.

Weather Category (see text)	1	2	3	4
(a) 1971	June 17,20,21,22 23,24,29,30 July 1,2,3,4,5 6,7,8,9,10	June 26,28	June 19,25	June 18,27
(b) 1972	July 10,12,15,16 17,18,19,22,24 25,26,27,28,29 August 2,3	July 20,23	July 21,31	August 1
(c) 1973	June 30 July 1,2,5,7,8 10,12,13,17,23	July 1,15 16,18,19 20,21	July 6,14	
(d) 1974	July 1,5,6,7 8,9	July 3,4 10,11		July 12

Fig.17a. Uredospore concentration in the air.

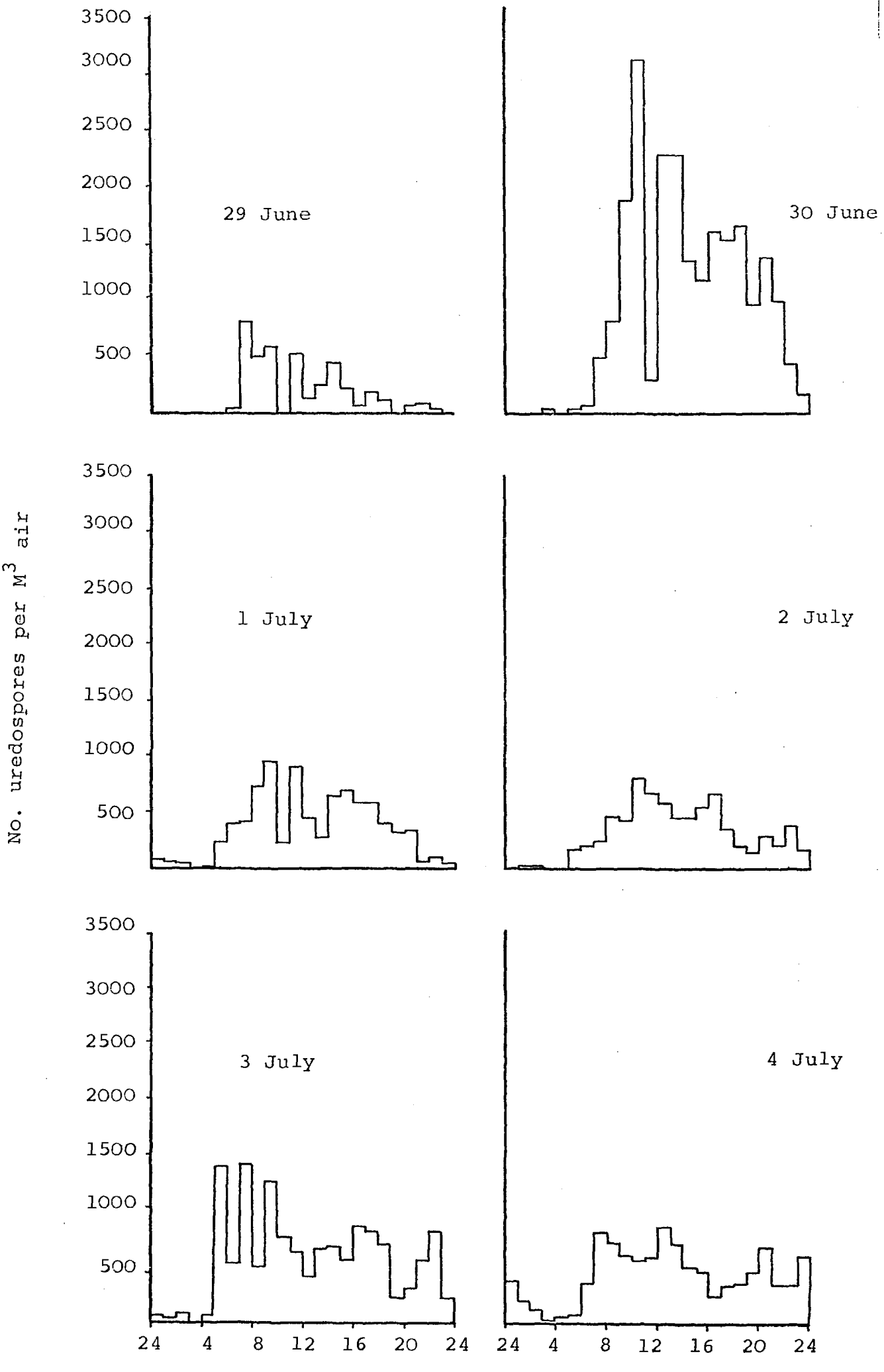


Fig.17b. Uredospore concentration in the air.

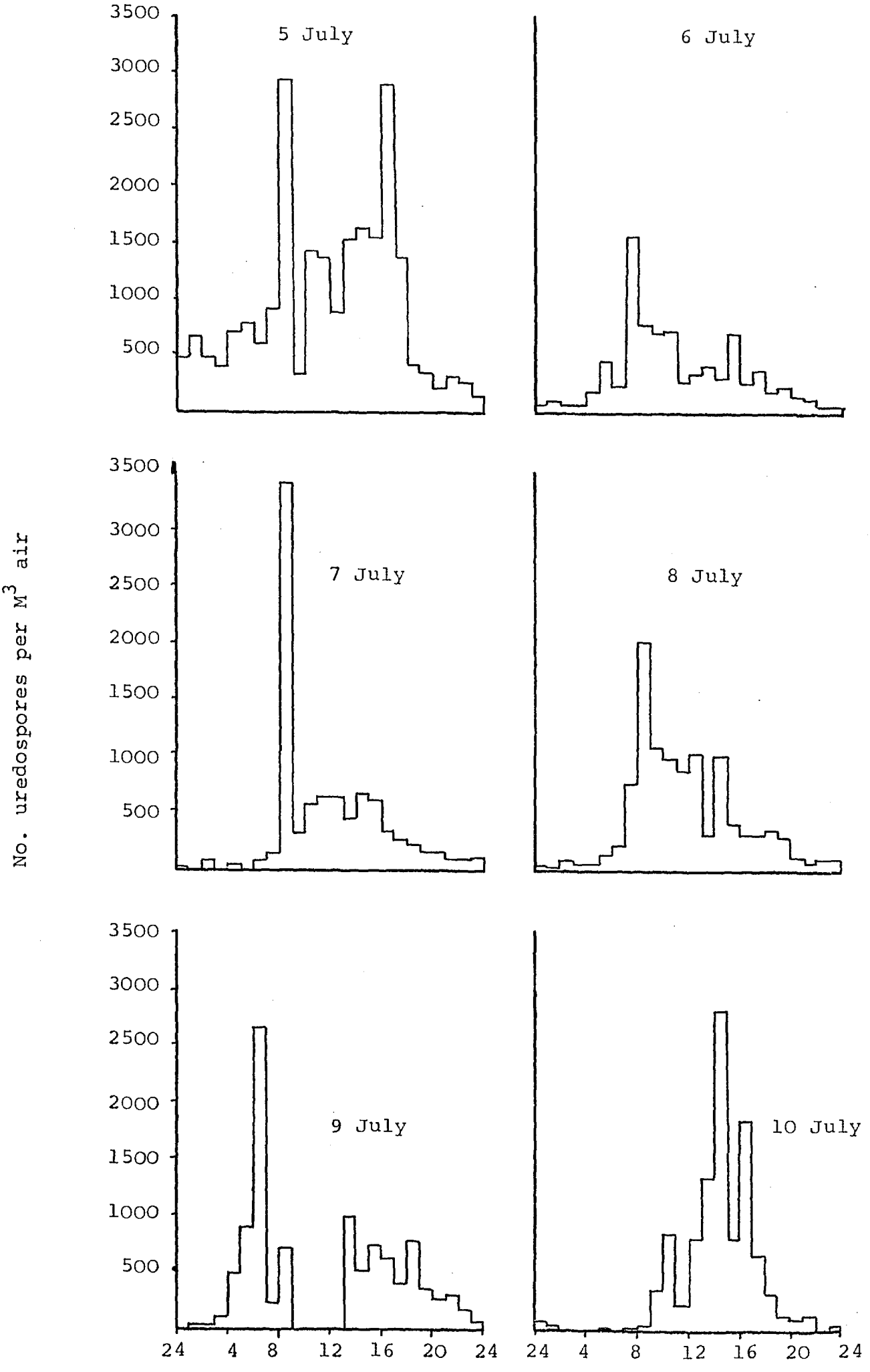
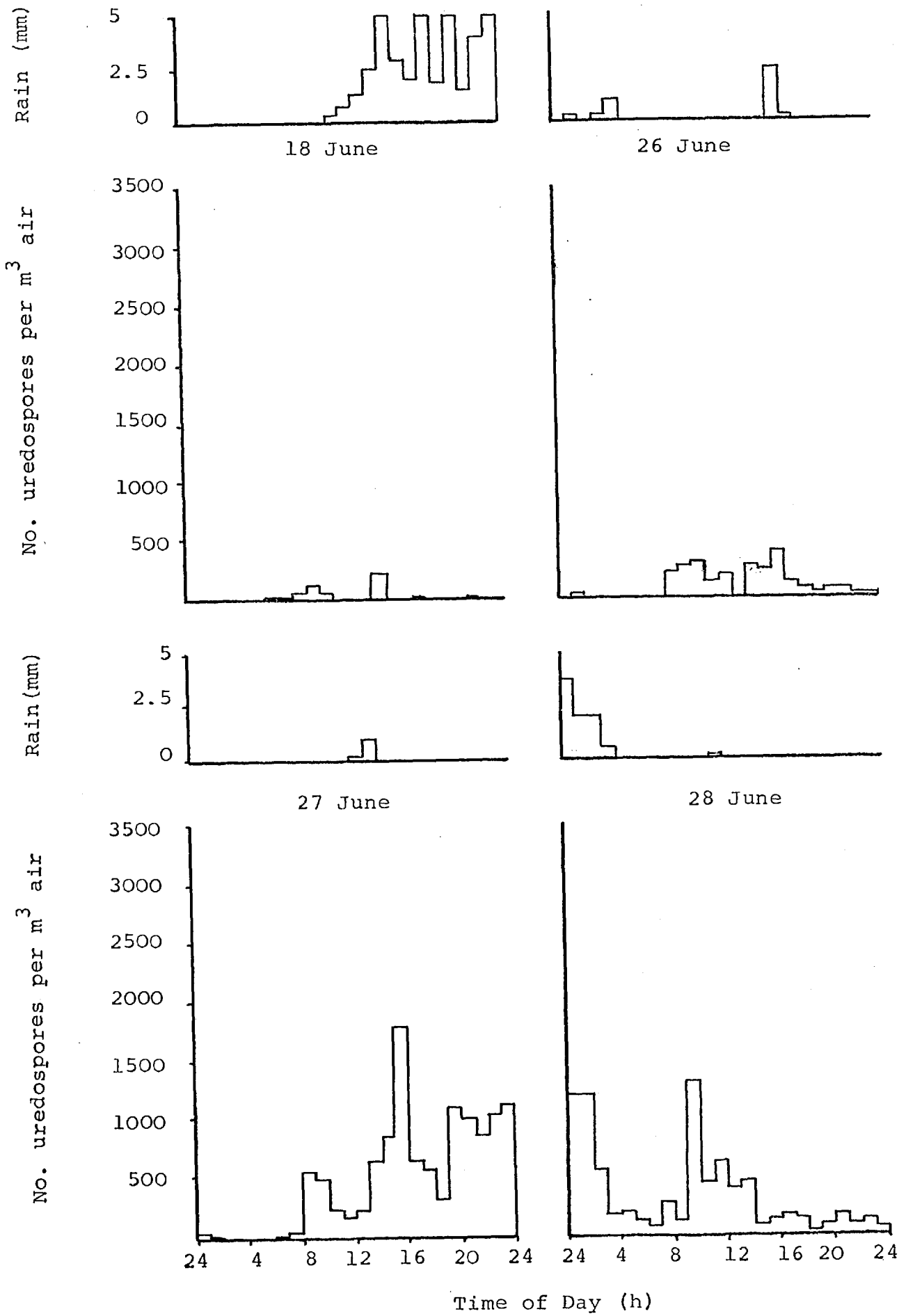


Fig.18 Uredospore concentration in the air.



DISCUSSION

In this investigation the development of P.hordei was examined principally on the four barley cultivars, Deba Abed, Zephyr, Julia and Vada. Some experiments also included the cultivars Midas and Proctor and one included the cultivar Sultan but most experiments were designed to find out why P.hordei grows comparatively well on Zephyr but not on Julia.

The experiments involving inoculations of the first seedling leaf indicated no differences between these cultivars, or others which were examined, in respect of uredospore deposition on leaves, the germination of uredospores and the frequency with which they penetrated stomata or in the numbers of primary hyphae which developed from the substomatal vesicles. Lack of differences in uredospore germination on cultivars of varying susceptibility agree with the results of other workers notably that of Clifford (1972) also with P.hordei, of Zimmer (1965) with Puccinia carthami on safflower and of Hilu (1965) with P.sorghi on seedling corn (Zea mays). However, Clifford (1972) did find differences in the numbers of primary infection hyphae (PIH) formed after 48 hrs on the cultivars Vada and Midas. One possible reason for the difference between these results and those of Clifford is that the inoculation techniques differed. That used in the present investigation, despite many attempts at standardization, did result in considerable variation within replicates of the same treatment and this might have obscured small differences in the behaviour of the fungus on the two cultivars which Clifford's more sophisticated technique of forcibly-injecting spores into a settling tower with air pistol (Eyal, Clifford & Caldwell, 1968) might have detected. Another obvious reason is that different cultivars (Zephyr and Julia) were used and it does not necessarily follow that the differences between these should be attributed to the same factors. In terms of susceptibility these two cultivars are not so different from each other as are Midas and Vada which, respectively, are the most susceptible and most resistant cultivars

commonly planted. Lack of difference in the early stages of host-parasite relationships on susceptible and resistant cultivars has been seen with other rusts and hosts. Hilu (1965) noted that the initial stages of infection, uredospore germination, appresorial formation, stomatal penetration, vesicle formation, intercellular hyphal growth in the mesophyll, and subsequent intracellular haustorial development of P.sorghi in nearly isogenic resistant and susceptible seedling corn were similar.

In most experiments there were some differences between barley cultivars in respect of pustule development. As far as Zephyr and Julia were concerned the most consistent difference between them was pustule size. With few exceptions, pustules were bigger on Zephyr than on Julia, although the sizes of pustules on one cultivar did differ from one experiment to the next. For example, in one experiment the mean pustule size on Julia was c. 0.3mm^2 and in another c. 0.1 mm^2. The reasons for this are not known.

As might be expected from this difference in pustule size (and of underlying fungal tissue), the amount of uredospores produced per pustule was significantly greater on Zephyr than on Julia.

Comparisons involving other cultivars revealed further differences between them in respect of pustule development. For example, pustules took longer to form on Vada than on (Table 5) Zephyr, Proctor, Deba Abed, Julia and Sultan but there were not significant differences in rate of pustule development between these cultivars. In one experiment only significantly fewer pustules formed on Vada than on Midas, confirming in this instance the findings of Clifford (1972). In several experiments significantly more infections grew through leaves of Midas which had been inoculated on their adaxial surfaces and formed pustules on the abaxial (uninoculated) surfaces than did so on Vada. All these results suggest that the fungus grows less well on Vada and in particular that its pustule development is generally restricted to the region

of the leaf which receives the inoculation. In these respects the differences between Vada and Midas are well-defined, as they were in Clifford's experiments and this reflects the fairly wide difference in the respective susceptibilities of these two cultivars. Clearly where there are smaller differences in the overall susceptibilities of the cultivars, as is the case with Zephyr and Julia, it becomes increasingly difficult to demonstrate significant differences in the growth of the fungus at particular stages of its development. Nevertheless, small differences at these stages which do not appear significant because of the variation within an experiment may be important because they have a cumulative effect. Thus, although the only significant differences between Zephyr and Julia were in respect of pustule size and amount of spores produced, it is interesting that the number of spores deposited, the number of spores germinated per cm^2 of leaf, the number of stomata penetrated and the number of pustules formed were all higher on Zephyr than on Julia (Table 9) though not significantly so. If this pattern occurred on successive leaves of the cultivars it could well result in a slower development of the fungus on Julia than on Zephyr in the field. This assumes that the results obtained on the first seedling leaf apply also to all other leaves. Although this was not tested, the results of inoculating mature plants in the greenhouse suggests that this may be true. Here, significant differences between the sizes of pustules on Zephyr and Julia were again demonstrated for the flag leaf, and from this it may be inferred that the amount of spores produced by one leaf and thus available for the infection of the next would be correspondingly smaller on Julia than on Zephyr. This, in turn, suggests that during the later stages of crop growth locally-produced inoculum is most important in the build-up of the fungus within a planting of a particular cultivar. There is evidence to support this from the vertical-rod spore traps. Catches of spores above plots of the different cultivars generally reflected the amount

of disease present within the particular plot. On this basis one might expect that the differences in the levels of the disease on corresponding leaves of the different cultivars, which were clearly seen in the field trials (e.g. Table 22) might be attributed to differences in the overall infection rate of the fungus on these cultivars. However, when this was assessed in both the 1973 and 1974 trials, by plotting $\log_e \left(\frac{x}{1-x}\right)$ where x = proportion of disease against time, as suggested by Van der Plank (1963) the respective regression lines for the various cultivars were approximately parallel and did not differ significantly in slope as would be expected if the differences between cultivars were due to race non-specific resistance or, as defined by Van der Plank (1963), horizontal resistance. Indeed, the results obtained were more indicative of race specific resistance (the vertical resistance of Van der Plank, 1963). However, race-specific resistance of the type involving a hypersensitive reaction is not known in the cultivars planted within the trials. A possible explanation may be derived from the work of Clifford & Clothier (1974). These workers demonstrated a physiologic specialization of P.hordei on barley cultivars with non-hypersensitive resistance. Isolates from the cultivars Julia, Sultan and Vada were differentially more compatible with their cultivar of origin. It could be that in both seasons in which the present trials were conducted, the first inoculum to arrive consisted of a mixture of different types (variants) of P.hordei some of which grew better on some cultivars than on others so that at an early stage in the crop growth different levels of disease were established reflecting differences in the composition of this initial inoculum. These differences in disease were subsequently maintained by local distribution of inoculum within the plots of each cultivar.

There is, however, another possible explanation of the field results. Experiments in the growth chamber showed that at 10°C the development of P.hordei on both Zephyr and Julia was much slower than in the greenhouse and in particular, at the lower temperature differences

in its development on the two cultivars were more pronounced. Other experiments in the laboratory also showed that the fungus grew less rapidly on old seedling leaves and again differences between Zephyr and Julia were more marked in this respect than on young leaves. Differences between disease levels on the cultivars in the field could thus be established from an initial inoculum simply because the lower temperatures prevailing during the early stages of crop growth differentially affected the development of P.hordei on the cultivars. The ability of the fungus to grow better on old seedling leaves of one cultivar than on another might also contribute to this effect, the differences in disease levels thus established being perpetuated by the local distribution of inoculum. This explanation does not necessarily involve a variable composition of the initial inoculum but does not exclude this possibility.

The reason why P.hordei develops better on some cultivars than on others was the major topic of this investigation but other points of interest arrose from the experiments. The most important of these is that factors which alter host nutrition also affect the size of the pustules produced. For example, in the experiment with maleic hydrazide,treated plants had bigger pustules and more rust infections grew through the leaves than on untreated ones. Growing the plants at 10°C also resulted in larger pustules than on plants in the greenhouse and similarly larger pustules developed on young leaves than on old ones. Also larger pustules developed on plants treated with full strength of Long Ashton solution than on those treated with only one-quarter strength.

These results suggest that the nutrition of the host might itself be an important factor in the field development of the disease.

Some information was also obtained on yield but lack of plots in the 1973 trial on which rust controlled limited comparison as did loss of some plots through uneven growth in the 1974 trial.

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A P P E N D I X

Table 1. Uredospore Germination on Seedling Leaves of Different Barley Cultivars.

Cultivars	Blocks	No. counted	No. germinated	% germination
	1	113	97	85.8
	2	115	92	80.0
Zephyr	3	97	87	89.7
	4	63	57	90.5
	5	51	47	92.2
	1	78	70	89.7
	2	62	55	88.7
Proctor	3	52	47	90.4
	4	49	44	89.8
	5	75	61	81.3
	1	72	35	48.6
	2	60	51	85.0
Deba Abed	3	81	71	87.7
	4	61	54	88.5
	5	100	94	94.0
	1	158	26	16.5
	2	97	75	77.3
Julia	3	44	33	75.0
	4	47	42	89.4
	5	60	55	91.7

Table 2. Pustule Production on Seedling Leaves of Different Barley Cultivar.

(Each figure represents mean of three leaves).

Cultivars	Blocks	Area (cm^2)	No.Pustules	No.Pustules/cm^2
	1	4.857	173	36
	2	4.027	210	52
Zephyr	3	3.605	255	71
	4	4.951	326	66
	5	4.340	263	61
	1	5.312	124	23
	2	3.097	87	28
Proctor	3	2.963	228	77
	4	4.047	210	52
	5	3.755	47	13
	1	4.800	19	4
	2	4.160	322	77
Deba Abed	3	3.070	263	86
	4	4.293	344	80
	5	4.063	377	93
	1	4.640	4	1
	2	2.547	194	76
Julia	3	3.425	226	66
	4	3.687	110	30
	5	3.107	184	59

Table 3. No.of Spores Deposited on Leaves of Different Barley Cultivars (Expt.2),(means of three leaves).

Cultivars		Replicate No. 1	2	3	4
	leaf area(cm^2)	1.251	1.305	1.255	1.257
Zephyr	No. Spores	33	29	34	22
	No.Spores/cm^2	26	22	27	18
	leaf area(cm^2)	1.210	1.345	1.270	1.124
Julia	No. Spores	17	24	52	39
	No.spores/cm^2	14	18	41	35
	leaf area(cm^2)	1.204	1.196	1.160	1.146
Proctor	No. spores	17	35	126	33
	No.spores/cm^2	14	29	109	29
	leaf area(cm^2)	1.261	1.307	1.251	1.275
Deba Abed	No.spores	62	44	32	65
	No.spores/cm^2	49	34	26	51
	leaf area(cm^2)	1.248	1.297	1.277	1.188
Sultan	No. spores	40	59	88	48
	No.spores/cm^2	32	45	69	40
	leaf area(cm^2)	1.138	0.991	1.250	1.175
Vada	No. spores	57	15	42	33
	No.spores/cm^2	50	15	34	28

Analysis of Variance.

	D.F.	S.S.	M.S.	F.
Cultivars	5	1890.38	378.07	0.85 NS
Error	18	7957.25	442.06	
Total	23	9847.63		

Table 4. Uredospore Germination (Expt.2) (means of three leaves).

	Zephyr	Julia	Proctor	Vada	Deba Abed	Sultan
	62.07	70.83	68.57	80.00	66.13	79.66
	78.79	82.35	76.47	76.19	38.63	37.50
	47.06	71.15	74.60	49.12	71.88	60.42
	86.36	69.23	81.82	63.64	75.38	70.00
Total	274.28	293.56	301.46	268.95	252.02	247.58
Mean	68.57	73.38	75.37	67.24	63.01	61.90

Analysis of Variance.

	D.F.	S.S.	M.S.	F.
Cultivars	5	584.23	116.84	0.59 NS
Error	18	3523.20	195.73	
Total	23	4107.43		

Table 5. Stomatal Infection/cm^2 (Expt.2).

	Zephyr	Julia	Proctor	Vada	Deba Abed	Sultan
	20.3	14.9	9.4	1.7	3.9	12.8
	9.2	6.7	4.1	21.1	5.1	0.0
	13.5	17.6	12.8	2.8	17.7	7.9
	19.4	11.4	10.7	36.7	28.4	42.0
Total	62.4	50.6	37.0	62.3	55.1	62.7
Mean	15.6	12.7	9.3	15.6	13.8	15.7

Analysis of Variance

	D.F.	S.S.	M.S.	F.
Cultivars	5	127.6	25.52	0.19 NS
Error	18	2431.7	135.09	
Total	23	2559.3		

Table 6. Number of Pustules/cm^2 (Expt.2).

	Zephyr	Julia	Proctor	Vada	Deba Abed	Sultan
	32.94	20.96	6.48	7.48	15.59	34.71
	12.78	42.99	7.76	25.82	5.85	13.31
	22.26	30.93	41.27	5.59	16.50	20.20
	19.18	18.98	18.18	30.15	58.71	49.70
Total	87.16	113.86	73.69	69.04	96.65	117.92
Mean	21.79	28.47	18.42	17.26	24.16	29.48

Analysis of Variance

	D.F.	S.S.	M.S.	F.
Cultivars	5	512.63	102.53	0.43 NS
Error	18	4282.38	237.91	
Total	23	4795.01		

Table 7. Pustule Development on Upper and Lower Surfaces of the Seedling Leaves of Different Cultivars.

	Zephyr
Leaf area (cm^2)	7.80,6.37,6.23,7.63,7.00,7.04,7.43, 7.07,7.14,7.50
Pustules, upper surface	306,249,158,114,499,394,275,218,180, 222
Pustules, lower surface	230,142,118, 83,398,279,226,161,138, 129
	Midas.
Leaf area (cm^2)	4.35,4.55,4.48,4.56,3.92,2.92,3.92,2.94, 4.76,6.30
Pustules, upper surface	127,212, 53,410,163, 43,146,133,109, 157
Pustules, lower surface	101,163, 53,334,124, 33, 65, 99,103, 135
	Vada
Leaf area (cm^2)	8.68,6.37,7.70,6.65,6.72,7.56,4.75, 7.00,6.79,5.60
Pustules, upper surface	129,122,106, 69,164, 86, 104, 20,188, 31
Pustules, lower surface	74, 76, 77, 38,122, 47, 71, 9,113, 18

Analysis of Variance:

No. Pustules/cm^2 Upper Surface

	D.F.	S.S.	M.S.	F.
Cultivars	2	3067.8	1533.9	5.54**
Error	27	7471.7	276.7	
Total	29	10539.5		

No. Pustules/cm^2 Lower Surface (as % of No. on upper surface)

	D.F.	S.S.	M.S.	F.
Cultivars	2	1728.5	864.3	7.54**
Error	27	3096.6	114.7	
Total	29	4825.1		

Significance at $P \leq 0.01$ denoted by **

Table 8. Number of Stomata on Leaves of Zephyr and Julia
(each figure is total of twenty microscope fields)

		Mean
Julia	385,349,332,328,356,415,368,333,374,403	
	350,369,352,378	363.7
Zephyr	339,333,326,340,331,320,392,338,313,330	
	316,346,315,345	334.6

Table 9. Germination of Uredospores on Zephyr and Julia First Seedling Leaves.

Julia			Zephyr		
No.of Spores Germ-inated	No. of Spores Ungerm-inated	% germ-ination	No. of Spores Germ-inated	No. of Spores Ungerm-inated	% Germ-ination
88	67	56.8	55	55	50.0
87	64	57.6	98	98	50.0
83	33	71.6	64	50	56.1
90	55	62.1	109	53	67.3
84	83	50.3	96	77	55.5
132	47	73.7	99	52	65.6
97	53	64.7	133	68	66.2
36	28	56.3	91	38	70.5
84	26	76.4	84	47	64.1
123	39	75.9	126	56	69.2
96	50	66.7	70	33	68.0
94	85	52.5	80	57	58.4

Table 10. Infection Structures, 24hrs After Inoculation

Zephyr

Total No.infection	No.infection with SSV	Monopolar PIH	Bipolar PIH
21	2	5	14
18	3	2	13
20	7	1	12
13	3	2	8
20	3	2	15
16	1	2	13
20	5	3	12
17	3	0	14
13	3	2	8
10	2	3	5
13	1	3	9
13	3	0	10

Julia

18	2	1	15
17	3	2	12
17	4	2	11
12	4	2	6
13	3	1	9
17	3	1	13
6	4	0	2
13	1	2	10
8	2	0	6
14	0	1	13
18	5	6	7
16	4	0	12

Table 11. Number of Spores Deposited and Their Germination on Zephyr and Julia Seedling Leaves.
(100 Microscope fields/replicate)

Blocks	Zephyr			Julia		
	Total No. Spores	No. Spores Germ-inated	% Germ-ination	Total No. Spores	No. Spores Germ-inated	% Germ-ination
	48	28	58.3	35	19	54.3
1	48	21	43.8	8	7	87.5
	64	36	56.3	57	33	57.9
	64	37	57.8	56	38	67.9
2	101	52	51.5	139	61	43.9
	83	44	53.0	46	32	69.6
	135	78	57.8	92	46	50.0
	55	34	61.8	47	25	53.2
	122	83	68.0	66	37	56.1
3	183	101	55.2	7	3	42.9
	108	55	50.9	92	48	52.2
	46	26	56.5	122	81	66.4

Analysis:

Spores Deposited

	D.F.	S.S.	M.S.	F.
Cultivars	1	876.04	876.04	6.46 NS
Blocks	2	2476.20	1238.10	9.13 NS
Error	2	271.08	135.54	
Total	5	3623.33		

Germination

Cultivars	1	10.01	10.01	0.25 NS
Blocks	2	32.99	16.50	0.41 NS
Error	2	79.54	39.77	
Total	5	122.54		

Table 12. Infection Structures, 48 hrs After Inoculation
(100 Microscope Fields/Replicate)

Block	Total No. Infections	No Infections With		
		SSV	Monopolar PIH	Bipolar PIH
Zephyr				
1	15	2	2	11
	25	0	5	20
	27	4	4	19
	7	0	0	7
2	26	1	7	18
	20	2	2	16
	27	4	3	20
	22	4	4	14
3	38	4	6	28
	39	4	5	30
	43	4	4	35
	4	2	0	2
Julia				
1	2	0	0	2
	6	0	1	5
	23	4	4	15
	6	1	1	4
2	24	1	3	20
	26	3	2	21
	24	2	2	20
	28	4	2	22
3	16	2	2	12
	28	0	8	20
	8	1	0	7
	14	1	2	11

Table 12 continued

Analysis:

	D.F.	S.S.	M.S.	F.
Total Infection				
Cultivars	1	80.67	80.67	2.35 NS
Blocks	2	142.56	71.28	2.07 NS
Error	2	68.77	34.39	
Total	5	292.0		
% Infections With SSV				
Cultivars	1	1.042	1.042	0.97 NS
Blocks	2	2.438	1.219	1.14 NS
Error	2	2.145	1.073	
Total	5	5.625		
% Infection With Monopolar PIH				
Cultivars	1	1.153	1.153	0.06 NS
Blocks	2	1.191	0.596	0.03 NS
Error	2	37.665	18.833	
Total	5	40.009		
% Infections With Bipolar PIH				
Cultivars	1	38.811	38.811	1.93 NS
Blocks	2	31.156	15.578	0.77 NS
Error	2	40.216	20.108	
Total	5	110.183		

Table 13. Number of Pustules/cm^2 Formed on Zephyr and Julia.

Block	Zephyr	Julia
1	21.3,6.7,13.2,14.5	12.5,25.5,23.6,3.5
2	50.1,19.8,29.9,16.1	20.3,25.4,10.9,20.6
3	23.3,20.9,8.6,25.4	9.5,11.6,2.5,26.4

Analysis

	D.F.	S.S.	M.S.	F.
Cultivars	1	34.47	34.47	1.7 NS
Blocks	2	98.96	49.48	2.4 NS
Error	2	40.53	20.27	
Total	5	173.15		

Table 14. Pustule Sizes (mm^2) on Leaves of Zephyr & Julia
(Each figure is mean of 15 Pustules)

Block	Zephyr	Julia
1	0.2697,0.4741,0.4199,0.4465	0.4023,0.4037,0.3905,0.2853
2	0.3527,0.3445,0.4659,0.4356	0.3846,0.2956,0.2516,0.2947
3	0.2864,0.3432,0.4192,0.3680	0.3444,0.2125,0.3334,0.2682

Analysis

	D.F.	S.S.	M.S.	F.
Cultivars	1	0.000368	0.000368	19.37*
Blocks	2	0.000292	0.000146	7.68 NS
Error	2	0.000038	0.000019	
Total	5	0.000698		

Significance at $P \leqslant 0.05$ denoted by *

Table 15. The Number of Pustules and Amount of Uredospores Produced (mg).

(Figures are Total of 4 pots)

Blocks	Zephyr		Julia	
	No. of Pustules	Amount of Uredospores (mg)	No. of Pustules	Amount of Uredospores (mg)
I	1342	10.1	557	2.3
II	3393	12.5	1568	2.1
III	3001	17.0	2089	1.8
IV	6020	45.3	2995	8.2

Analysis of Variance (mg. Spare/Pustule)

	D.F.	S.S.	M.S.	F.
Cultivars	1	0.000029	0.000029	43.4 **
Blocks	3	0.000014	0.00000467	7.0 NS
Error	3	0.000002	0.000000667	

Significance at $P \leq 0.01$ denoted by **

Table 16. Effect of Maleic Hydrazide (Expt.1)

Vada		Midas	
Maleic hydrazide	Control	Maleic hydrazide	Control
a) Pustule number/cm^2 upper leaf surface			
22.80	2.07	39.54	32.29
28.17	42.75	15.33	34.10
11.54	40.0	21.48	28.83
24.27	50.53	51.89	46.94
32.37	47.56	27.78	57.18
25.25	23.0	42.0	46.67
b) Pustule Size (mm^2)			
0.071	0.082	0.098	0.080
0.075	0.095	0.085	0.080
0.106	0.074	0.085	0.084
0.101	0.071	0.085	0.100
0.072	0.077	0.094	0.090
0.097	0.074	0.103	0.103

c) Analysis of Variance:

		Pustule No.		Pustule Size	
	D.F.	M.S.	F.	M.S.	F.
Cultivars	1	365.98	2.1 NS	0.00035	2.9 NS
Maleic hydrozide	1	499.59	2.9 NS	0.00016	1.3 NS
Interaction	1	7.62	0.04 NS	0.00005	0.4 NS
Error	20	175.45		0.00012	

Table 17. Effect of Maleic hydrazide on Brown Rust Development (Expt.2).

Vada		Midas	
Maleic hydrazide	Control	Maleic hydrazide	Control
a) No. Pustules/cm^2 Upper leaf Surface			
7.9	5.1	8.9	6.5
8.7	4.2	14.9	1.3
2.1	13.7	7.0	14.7
3.4	2.7	13.6	10.2
4.4	7.2	6.8	1.0
10.0	4.1	4.2	3.6
b) No.Pustules on Lower Surface as % of Those on Upper Surface			
76.1	30.2	86.8	32.3
61.3	25.9	78.8	66.7
60.0	42.7	87.0	66.2
53.6	76.5	87.1	81.0
60.0	32.7	96.8	50.0
73.7	50.0	89.5	50.0
c) Pustule Size (mm^2)			
0.217	0.145	0.234	0.101
0.161	0.131	0.283	0.151
0.201	0.117	0.236	0.129
0.241	0.100	0.218	0.120
0.312	0.061	0.212	0.095
0.235	0.122	0.196	0.151

d) Analysis of Variance:

		Pustule No.					
		Upper Surface		Lower Surface		Pustule Size	
	D.F.	M.S.	F.	M.S.	F.	M.S.	F.
Cultivars	1	15.36	0.84 NS	2194.59	11.71**	0.0003	0.25 NS
Maleic hydrazide	1	12.90	0.70 NS	3914.26	20.9**	0.0729	60.8***
Interaction	1	14.42	0.79 NS	117.49	0.6 NS	0.0001	0.08 N
Error	20	18.21		187.42		0.0012	

,*, Significance at $P \leq 0.01$ and 0.001 respectively.

Table 18. Final Pustule Numbers Formed on Zephyr & Julia in Greenhouse and Growth Cabinet.
(Figures are means of 8-10 leaves)

			Mean
Greenhouse	Zephyr	221,101,25,64,62,336	134.8
	Julia	42, 12,48,15,332,236	114.2
Growth Cabinet	Zephyr	38, 28, 45,146,122,140	86.5
	Julia	44, 36, 83, 43,280, 8	82.3

Analysis of Variance:

	D.F.	S.S.	M.S.	F.
Cultivars	1	925.04	925.04	0.08 NS
Regime	1	9640.04	9640.04	0.84 NS
Cultivars X Regime	1	408.38	408.38	0.04 NS
Error	20	228496.5	11424.83	

Table 19. Daily Pustule Counts as % of Final Pustule Numbers

Days after Inoculation		Mean
	Greenhouse	
	Zephyr	
7	63.6,55.2,24.8,69.1,48.7,73.9	55.9
8	94.3,70.6,52.3,89.9,81.8,99.0	81.3
9	99.5,78.1,75.7,91.9,89.7,100.0	89.2
	Julia	
7	51.0,35.7,38.4,13.9,75.5,78.8	48.9
8	66.7,71.1,79.2,56.7,99.8,98.8	78.7
9	91.9,97.0,83.8,86.2,100.0,100.0	93.2
	Growth Cabinet	
	Zephyr	
12	21.5,47.7,21.7,46.5,49.6,32.4	36.6
13	45.0,62.4,44.6,75.2,67.0,57.1	58.6
14	68.7,73.1,60.2,90.8,84.9,74.6	75.4
15	85.4,82.4,73.4,93.8,95.7,85.8	86.1
16	93.5,88.2,88.2,95.1,98.8,94.3	93.0
17	95.9,96.7,93.2,98.2,100.0,97.9	96.9
	Julia	
12	6.4,18.9,45.0,9.0,61.0,5.1	24.2
13	13.1,28.1,74.7,11.2,81.9,6.8	36.0
14	29.9,40.3,89.9,23.1,98.5,16.2	49.7
15	60.2,58.6,94.6,50.4,98.2,44.8	67.8
16	81.6,77.4,99.0,86.9,99.1,69.6	85.6
17	92.7,91.5,99.5,93.6,99.9,88.1	94.2

Table 20. Pustule size as mm^2 (Figures are means of 50 pustules)

			Means
Green-house	Zephyr	0.o999,0.0966,0.0951,0.1188,0.1154,o.1023	0.1045
	Julia	0.0900,0.0708,0.0793,0.0992,0.0864,0.0815	0.0845
Growth cabinet	Zephyr	0.1171,0.1360,0.1363,0.1322,0.1262,0.1265	0.1290
	Julia	0.1037,0.1024,0.1003,0.1014,0.1026,0.1014	0.1019

Analysis of Variance:

	D.F.	S.S.	M.S.	F.
Cultivars	1	0.0033465	0.0033465	53.7***
Regimes	1	0.0026209	0.0026209	42.1***
CultivarsXRegimes	1	0.0000721	0.0000721	1.2 N.S
Error	20	0.0012476	0.0000623	
Total	23	0.0072871		

Standard error $\pm$ 0.003

*** Significance at $P \leq 0.001$

Table 21. Final Pustule Numbers Formed on Zephyr & Julia in Greenhouse and Growth Cabinet (Expt.2)

			Mean
Greenhouse	Zephyr	101,73,303,109,392,399	229.5
	Julia	122,138,327,219,108,176	181.7
Growth Cabinet	Zephyr	124,164,232,76,258,50	150.7
	Julia	258,270,71,87,210,22	153.0

Analysis of Variance:

	D.F.	S.S.	M.S.	F.
Cultivars	1	1247.04	1247.04	0.09 NS
Regime	1	12376.04	12376.04	0.87 NS
Cultivars X Regime	1	1683.38	1683.38	0.12 NS
Error	20	284675.5	14233.78	

Table 22. Daily Pustule Counts as % of Final Pustule Numbers

Days after inoculation	Zephyr	Mean
	Greenhouse	
7	58.4,76.7,79.5,62.2,78.9,78.6	72.4
8	84.2,94.5,96.4,92.1,88.3,100.0	92.6
9	91.0,97.3,96.4,93.0,92.1,100.0	95.0
10	93.1,97.3,97.0,100.0,100.0,100.0	97.9
	Julia	
7	62.3,79.4,58.4,74.4,72.7,63.9	68.5
8	96.7,87.9,83.2,94.7,84.5,88.9	89.3
9	98.4,100.0,85.8,100.0,100.0,94.4	96.4
10	98.4,100.0,100.0,100.0,100.0,100.0	99.7
	Growth Cabinet	
	Zephyr	
12	8.0,16.5,11.3,0,17.4,10.7	10.7
13	55.2,53.7,42.3,18.4,53.9,46.4	45.0
14	84.0,87.2,72.4,50.0,84.1,83.9	76.9
15	84.0,90.9,79.9,71.1,93.4,100.0	86.6
16	91.2,98.8,96.2,90.8,99.6,100.0	96.1
17	100.0,98.8,100.0,92.1,99.6,100.0	98.4
	Julia	
12	8.9,4.1,5.6,6.9,7.1,0	5.4
13	46.9,27.4,29.6,18.4,30.5,36.4	31.5
14	81.4,55.9,69.0,47.1,65.7,63.6	63.8
15	93.4,75.2,84.5,75.9,77.1,90.9	82.8
16	98.5,84.8,88.7,90.8,95.2,100.0	93.0
17	100.0,93.7,95.8,93.1,95.2,100.0	96.3

Table 23. Pustule Size as mm^2 (Figures are means of 20 Pustules)

			Mean
Green-house	Zephyr	0.0851,0.0879,0.0828,0.0802,0.0771,0.1020	0.0858
	Julia	0.0771,0.0572,0.0731,0.0682,0.0682,0.0877	0.0719
Growth Cabinet	Zephyr	0.0981,0.1161,0.1087,0.0904,0.0913,0.0837	0.0980
	Julia	0.1384,0.1233,0.1217,0.0781,0.0723,0.1213	0.1091

Analysis of Variance:

	D.F.	S.S.	M.S.	F.
Cultivars	1	0.00001	0.00001	0.04 NS
Regimes	1	0.00367	0.00367	14.11**
Cultivars x Regimes	1	0.00094	0.00094	3.62 NS
Error	20	0.00526	0.00026	

Growth Cabinet		Greenhouse	
Julia	Zephyr	Zephyr	Julia
0.1091	0.0980	0.0858	0.0719

Means not underscored by the same line are significantly different ($P \leq 0.01$); Duncan's new multiple range test.

Table 24. Number of Pustules Formed on Leaf Pieces Floating On Benzimidazole Solution.

PLANTING DATE I 25 January'74				PLANTING DATE II 1 February'74				PLANTING DATE III 8 February'74				
MIDAS	VADA	ZEPHYR	JULIA	MIDAS	VADA	ZEPHYR	JULIA	MIDAS	VADA	ZEPHYR	JULIA	
9	0	31	12	0	0	7	2	2	0	14	0	
4	1	7	17	1	1	9	0	0	1	8	0	
1	0	21	12	2	0	6	0	1	0	8	1	
2	4	38	7	7	0	2	2	8	0	3	0	
8	0	11	10	1	0	3	0	1	0	2	0	
2	1	13	5	0	0	2	0	2	0	1	0	
4	0	20	7	0	0	1	0	0	0	2	0	
30	6	141	70	11	1	30	4	14	1	38	1	TOTAL

Table 25. Mean No. of Pustules on Leaves of Zephyr & Julia From Three Sowings.

Sowing No.& Date	Replicate	Days After Inoculation			
		7	8	9	10
Zephyr					
1. 31 May'74	1	1.3	30.2	44.8	48.3
	2	7.1	45.4	60.0	61.9
	3	25.5	76.5	85.5	84.5
2. 5 June'74	1	21.8	65.0	77.8	79.9
	2	12.9	60.4	72.0	79.7
	3	9.9	21.7	25.8	27.4
3. 10 June'74	1	74.1	208.3	239.1	247.3
	2	58.6	132.4	147.4	154.3
	3	92.2	280.2	311.2	341.8
Julia					
1. 31 May'74	1	0.4	12.4	40.5	50.3
	2	4.4	109.4	183.6	205.2
	3	0.8	27.0	41.0	47.8
2. 5 June'74	1	8.8	39.0	46.8	55.8
	2	4.5	62.3	99.5	106.8
	3	17.5	35.0	46.8	52.5
3. 10 June'74	1	22.9	77.1	85.9	89.7
	2	58.1	137.4	158.4	157.0
	3	71.0	175.7	205.9	205.9

Table 25 continued

Analysis of Variance

a) 7 days after inoculation

	D.F.	S.S.	M.S.	F.
Cultivars	1	736.0	736.0	3.8 NS
Sowing Date	2	11443.15	5721.58	29.9***
Cultivars x Sowing Date	2	315.42	157.71	0.8 NS
Error	12	2300.0	191.67	
			S.E. ± 8.0	

b) 8 days After Inoculation

	D.F.	S.S	M.S.	F.
Cultivars	1	3329.28	3329.28	1.7 NS
Sowing Date	2	57457.64	28728.82	14.4**
Cultivars x Sowing Date	2	5562.39	2781.20	1.4 NS
Error	12	24017.28	2001.44	
			S.E. ± 25.8	

c) 9 days After Inoculation

	D.F.	S.S	M.S.	F.
Cultivars	1	1341.62	1341.62	0.42 NS
Sowing Date	2	60760.51	30380.26	9.4**
Cultivars x Sowing Date	2	9848.23	4924.12	1.5 NS
Error	12	38712.24	3226.02	
			S.E. ± 32.8	

d) 10 days After Inoculation

	D.F.	S.S.	M.S.	F.
Cultivars	1	1440.06	1440.06	0.38 NS
Sowing Date	2	62702.11	31351.06	8.3**
Cultivars x Sowing Date	2	14747.44	7373.72	2.0 NS
Error	12	45229.32	3769.11	
			S.E. ± 35.4	

Table 26. Development of Pustules on Leaves of Different Age.

a) Mean No. of pustules as percentage of final counts

Sowing No.	Days After Inoculation 7	8	9
		On Zephyr	
1	2.61,12.18,28.28	61.63,73.0,85.18	89.31,95.97,97.04
2	25.91,17.59,38.26	78.78,79.02,75.42	95.04,91.80,92.40
3	28.48,33.69,27.08	82.95,83.61,81.56	95.87,95.52,91.37
		On Julia	
1	0.85,1.99,0.87	25.02,52.47,44.55	79.92,89.01,88.0
2	14.72,4.23,30.77	72.51,57.41,64.49	88.42,94.22,85.86
3	24.37,38.11,33.74	83.38,74.13,71.73	96.09,99.69,98.69

b) Variance ratios

	7	8	9 days after inoculation
Cultivars	2.68 NS	18.38***	2.70 NS
Sowing Date	9.46**	10.72**	5.41*
Cultivars x Sowing date	1.20 NS	3.84 NS	4.75*

Significance at $P \leqslant 0.05$ denoted by *

Table 27. Mean Pustule Size as mm^2

Sowing No.	Zephyr	Julia
1	0.084,0.079,0.083	0.074,0.054,0.065
2	0.089,0.079,0.088	0.075,0.070,0.078
3	0.096,0.082,0.094	0.087,0.085,0.077

Analysis of Variance

	D.F.	S.S.	M.S.	F.
Cultivars	1	0.00066	0.00066	16.54**
Sowing Date	2	0.000561	0.000281	7.04**
Cultivars x Sowing Date	2	0.000077	0.000039	0.98 NS
Error	12	0.000479	0.0000399	

S.E. $\pm$ 0.0036

Significance at $P \leqslant 0.01$ denoted by **

Table 28. Effect of Nutrients on Pustule Development

a) Pustule Numbers:

Strength Long-Ashton Solution	Zephyr 1	Zephyr X¼	Zephyr X4	Julia 1	Julia X¼	Julia X4
	43	98	4	58	46	32
	144	5	5	11	3	64
	4	87	1	34	16	18
	1	36	1	67	13	31
	4	16	43	28	90	29

Analysis of Variance

	D.F.	S.S.	M.S.	F.
Cultivar	1	76.80	76.80	0.06 NS
Long-Ashton Solution	2	2031.20	1015.6	0.77 NS
Interaction	2	1911.20	955.6	0.73 NS
Error	24	31550.0	1314.58	

b) Pustule Size (mm^2)

Strength Long-Ashton Solution	Zephyr 1	Zephyr X¼	Zephyr X4	Julia 1	Julia X¼	Julia X4
	0.1105	0.0681	0.0837	0.0555	0.0385	0.0797
	0.0795	0.0615	0.0929	0.0631	0.0502	0.0681
	0.0805	0.0831	0.0718	0.0769	0.0587	0.0751
	0.0884	0.0686	0.0812	0.0678	0.0600	0.0629
	0.0939	0.0583	0.0857	0.0895	0.0511	0.0730

Analysis of Variance

	D.F.	S.S.	M.S.	F.
Cultivar	1	0.001882	0.001882	18.9***
Long-Ashton Solution	2	0.002501	0.001251	12.6***
Interaction	2	0.000095	0.000048	0.48 NS
Error	24	0.002387	0.000099	

Significance at $P \leq 0.001$ denoted by ***

Table 29. Leaf Area (cm^2) : Mature Plants of Zephyr & Julia

	Leaf 1 (flag leaf)	leaf 2	Leaf 3
Zephyr			
Total area (cm^2)	261.35	452.27	281.72
No.of Leaves	30	29	20
Mean leaf Area(cm^2)	8.7116	15.595	14.086
Julia			
Total area (cm^2)	471.03	554.87	205.61
No.of leaves	30	26	14
Mean leaf Area(cm^2)	15.701	21.725	14.686

Table 30. No.Pustules/cm^2 : Mature Plants of Zephyr & Julia

	Zephyr
Leaf No.1 (Flag leaf)	3.0,13.4,0,3.2,21.8,0,0,5.9,4.5,0.1,0.2, 6.8,1.0,10.6,3.2,13.4,43.6,24.2,0,0.2,0,0,0, 23.3,11.2,1.8,3.3,6.7,6.4,1.6
Leaf No.2	0.1,9.9,1.3,7.2,1.9,9.7,0.3,5.2,6.2,3.2,5.6, 5.7,1.2,5.1,4.0,7.1,3.3,2.6,5.3,2.3,0.5,3.3,2.9, 6.7,0.2,6.0,2.0,4.2,4.6
Leaf No.3	6.9,1.9,2.9,4.4,12.5,4.3,2.2,7.7,15.0,0.5,2.6, 1.8,2.0,7.5,1.7,3.5,2.7,10.4,2.4,4.7
	Julia
Leaf No.1	0.8,6.6,2.3,1.0,0.7,9.9,2.2,6.2,1.3,0.2,7.0,5.2, 7.7,0.8,6.5,1.9,0.5,15.9,0.1,2.6,21.0,0.8,0.3, 1.4,0,4.8,11.6,0.2,5.6,0.1
Leaf No.2	0.1,0.4,1.7,0.6,1.6,4.3,1.7,4.1,1.4,0.9,3.6,1.1, 1.5,1.5,2.4,15.2,21.3,8.8,10.6,4.5,2.3,1.2,5.0, 3.8,1.0,4.8
Leaf No.3	3.1,7.0,8.7,10.0,1.4,2.7,8.4,8.0,9.1,1.8,4.4,3.5, 16.1,4.6

Note: No. of pustules/leaf can be derived by multiplying each figure in above table by the appropriate mean leaf area of Appendix Table 29.

Table 31. Regressions of Disease Progress (as $\log_e\left[\frac{X}{1-X}\right]$ Based on Mean % Infection of Four Replicate Plots).

Planting date	Assessment Number †							
	1	2	3	4	5	6	7	8
				Deba Abed				
1	-10.41	-10.23	-7.73	-6.11	-4.32	-2.30	-1.18	-
2	-9.69	-8.62	-8.67	-6.45	-4.45	-2.86	-1.51	-0.43
3	—	-8.82	-8.78	-5.87	-4.03	3.35	-1.57	-1.29
				Julia				
1	—	-9.76	-9.50	-6.69	-5.26	-3.96	-3.16	-
2	—	-9.29	-8.73	-6.94	-5.30	-4.01	-2.69	-
3	—	—	-9.86	-6.80	-5.28	-4.54	-2.12	-
				Zephyr				
1	—	-9.60	-7.76	-5.82	-4.12	-1.99	-1.65	-
2	—	-8.99	-8.01	-6.20	-4.59	-2.81	-1.32	-
3	-10.52	-10.48	-8.16	-5.99	-4.02	-3.06	-1.57	-
				Vada				
1	-10.13	-10.68	-9.63	-7.13	-5.25	-4.51	-3.66	-
2	—	-10.96	-9.52	-8.34	-6.71	-4.53	-3.68	-
3	-11.33	—	-9.41	-8.30	-5.17	-4.91	-3.20	-

Table 31 continued

Equations:

	Deba Abed	Julia	Zephyr	Vada
1	y=0.241x-11.300	y=0.209x-11.672	y=0.240x-11.246	y=0.185x-11.320
2	y=0.204x-10.509	y=0.200x-11.217	y=0.228x-11.085	y=0.218x-12.806
3	y=0.205x-10.843	y=0.240x-12.825	y=0.227x-11.381	y=0.195x-11.896

†	Assessment Number							
Sowing	1	2	3	4	5	6	7	8
1	11 June	18 June	25 June	2 July	8 July	16 July	23 July	
2	12 June	19 June	26 June	3 July	9 July	17 July	24 July	
3	13 June	21 June	27 June	4 July	12 July	18 July	27 July	31 July

Table 32. Homogeneity Tests Between Regressions of Disease Development. Silwood Park, 1973

(a) First Sowing

Cultivars	D.F.	Σx^2	Σxy	Σy^2	D.F.	Reduced S.S
Deba Abed	6	1358.86	327.02	80.08	5	1.380
Zephyr	5	851.34	204.62	50.36	4	1.179
Julia	5	851.34	177.55	38.73	4	1.701
Vada	6	1358.86	250.88	50.13	5	3.811
Residuals from individual regressions					18	8.071 = A
Totals for single regressions	22	4420.40	960.07	219.30	21	10.785 = B
Difference for homogeneity of regressions					3	2.71 = B-A

$$F=\frac{(B-A)/(t-1)}{A/(\Sigma n_i-2t)}$$ with $t-1$ and Σn_i-2t D.F.

F= 2.01 N.S (with 3 and 18 D.F.)

(b) Second Sowing

Cultivars	D.F	Σx^2	Σxy	Σy^2	D.F.	Reduced S.S
Deba Abed	7	2051.88	418.42	87.72	6	2.396
Zephyr	5	851.34	193.73	44.31	4	0.225
Julia	5	851.34	169.94	34.41	4	0.487
Vada	5	851.34	185.27	40.68	4	0.361
Residuals from individual regressions					18	3.469 = A
Totals for single regressions	20	4605.90	962.46	207.11	21	3.939 = B
Difference for homogeneity of regressions					3	0.470 = B-A

F= 0.81 N.S. (with 3 and 18 D.F.)

Table 32. continued

(c) Third Sowing

Cultivars	D.F.	Σx^2	Σxy	Σy^2	D.F.	Reduced S.S
Deba Abed	6	1349.71	276.46	58.59	5	1.963
Zephyr	6	1445.71	328.06	76.71	5	2.267
Julia	4	549.20	131.82	32.85	3	1.210
Vada	5	1230.83	240.01	48.39	4	1.588
Residuals from individual regressions					17	7.028 = A
Totals for single regressions	24	4575.45	976.35	216.54	20	8.198 = B
Difference for homogeneity of regressions					3	1.17 = B-A

F= 0.92 N.S. (with 3 and 17 D.F)

Table 33. Infection rates on 8th Leaves Between Second and Third Week of July.

Planting Date	Cultivars	Blocks 1	2	3	4	Totals
1	Zephyr	+0.1958	+0.3218	+0.2750	+0.1531	0.9457
	Deba Abed	+0.2695	+0.2685	+0.2627	+0.1861	0.9868
	Julia	+0.3013	+0.2826*	+0.1597*	+0.1920	0.9356
	Vada	+0.0989	+0.3018	+0.0779	+0.0939	0.5725
Totals		+0.8655	1.1747	0.7753	0.6251	3.4406
2	Zephyr	+0.1802	+0.1213	+0.3155	+0.1259	0.7429
	Deba Abed	+0.3307	+0.1567	+0.1988	+0.1287	0.8149
	Julia	+0.0926	+0.0794	+0.2247	+0.1790	0.5757
	Vada	+0.1597	+0.3315	+0.3673	+0.3373	1.1958
Totals		0.7632	0.6889	1.1063	0.7709	3.3293
3	Zephyr	+0.2902	+0.2479	+0.1099	+0.0179	0.6659
	Deba Abed	+0.0708	+0.2560	+0.1506	+0.2094	0.6868
	Julia	+0.1095	+0.3479	+0.2967	+0.1338	0.8879
	Vada	+0.2693	+0.1211	+0.2047	+0.1338	0.7289
Totals		0.7398	0.9729	0.7619	0.4949	2.9695
Blocks Total		2.3685	2.8365	2.6435	1.8909	9.7394

* missing plot.

$$Y_1 = \frac{4(0.4933)+4(0.8921) - 2.9983}{3(3)} = 0.2826$$

$$Y_2 = \frac{4(0.6156)+4(0.4933)-2.9983}{3\ (3)} = 0.1597$$

Table 34a. Max.Rust Levels on Flag Leaf = Leafl(as angular Transforms of Mean Percentage Infection.)

Planting Date	Cultivars	Blocks 1	2	3	4
1	Zephyr	14.77	16.22	25.03	22.46
	Deba Abed	31.50	29.73	31.76	28.32
	Julia	6.29	8.53	9.10	10.47
	Vada	8.72	5.13	9.28	8.53
Totals		61.28	59.61	75.17	69.78
2	Zephyr	22.06	25.77	22.95	25.70
	Deba Abed	28.59	27.42	31.69	26.92
	Julia	12.11	8.13	16.54	11.83
	Vada	5.74	9.63	7.27	9.97
Totals		68.50	70.95	78.45	74.42
3	Zephyr	18.24	24.73	19.73	7.92
	Deba Abed	20.00	27.20	23.89	17.36
	Julia	12.38	8.13	5.74	10.78
	Vada	7.49	9.63	9.10	11.09
		58.11	69.69	58.46	47.15
Total		187.89	200.25	212.08	191.35

Table 34a continued

Planting Date	Zephyr	Deba Abed	Julia	Vada	Total
1	78.48	121.31	34.39	31.66	265.84
2	96.48	114.62	48.61	32.61	292.32
3	70.62	88.45	37.03	37.31	233.41
Total	245.58	324.38	120.03	101.58	791.57

Main Plots	D.F.	S.S.	M.S.	F.
Date of Planting	2	108.8184	54.40	3.68 NS
Blocks	3	29.1414	9.71	0.66 NS
Error	6	88.5817	14.76	-
Sub Plots				
Cultivars	3	2800.9876	933.66	86.23***
Cultivars x planting date	6	163.0244	27.17	2.51*
Error	27	292.3475	10.827	-
Total	47	3482.901		

*,***, Significance at $P \leq 0.05$ and 0.001 respectively.

Table 34b. Max. Rust Levels on Leaf 2(flag leaf=1) (as angular transforms of mean percentage infection).

Planting Date	Cultivars	Block 1	2	3	4
1	Zephyr	6.29	12.11	10.14	23.42
	Deba Abed	22.63	19.82	25.84	24.35
	Julia	7.49	4.05	5.44	11.54
	Vada	5.13	2.56	8.13	8.13
		41.54	38.54	49.55	67.44
2	Zephyr	15.89	9.80	14.18	9.80
	Deba Abed	21.39	19.37	19.00	23.26
	Julia	9.97	7.49	9.10	5.44
	Vada	4.44	8.13	6.29	7.27
		51.69	44.79	48.57	45.77
3	Zephyr	15.79	21.05	17.95	15.00
	Deba Abed	26.35	27.27	28.32	24.65
	Julia	6.80	10.47	11.54	15.45
	Vada	9.28	9.46	10.78	11.24
		58.22	68.25	68.59	66.34
Total		151.45	151.58	166.71	179.55

Table 34b. continued

Planting Date	Zephyr	Deba Abed	Julia	Vada	Total
1	51.96	92.64	28.52	23.95	197.07
2	49.67	83.02	32.00	26.13	190.82
3	69.79	106.59	44.26	40.76	261.40
Total	171.42	282.25	104.78	90.84	649.29

Main Plots	D.F.	S.S.	M.S.	F.
Date of planting	2	190.8114	95.40	5.43*
Blocks	3	45.8041	15.27	0.87 NS
Error	6	105.3728	17.56	-
Sub.Plots				
Cultivars	3	1907.1880	635.73	79.87***
Cultivar x Planting date	6	16.0378	2.67	0.34 NS
Error	27	215.0365	7.96	-
Total	47	2480.2506		

*,***, Significance at $P \leqslant 0.05$ and 0.001 respectively.

Table 34c. Max.Rust Levels on Leaf 3(flag leaf=1) (as angular Transforms of Mean Percentage Infection).

Planting Date	Cultivars	Block			
		1	2	3	4
1	Zephyr	1.81	1.81	1.81	9.28
	Deba Abed	5.13	3.14	8.13	8.72
	Julia	1.81	0	0	3.63
	Vada	4.44	1.81	3.63	2.56
		13.19	6.76	13.57	24.19
2	Zephyr	4.44	4.80	4.05	3.63
	Deba Abed	11.39	11.39	7.92	11.09
	Julia	2.56	1.81	2.56	1.81
	Vada	1.81	2.56	2.56	3.14
		20.20	20.56	17.09	19.67
3	Zephyr	8.13	9.97	6.80	12.79
	Deba Abed	14.30	16.32	13.44	21.64
	Julia	5.74	6.02	3.14	6.02
	Vada	3.63	3.63	6.29	9.28
		31.80	35.94	29.67	49.73
Total		65.19	63.26	60.33	93.59

Table 34c continued

Planting Date	Cultivars				
	Zephyr	Deba Abed	Julia	Jada	Total
1	14.71	25.12	5.44	12.44	57.71
2	16.92	41.79	8.74	10.07	77.52
3	37.69	65.70	20.92	22.83	147.14
Total	69.32	132.61	35.10	45.34	282.37

Main Plots	D.F.	S.S.	M.S.	F.
Date of planting	2	275.7730	137.88	22.46**
Blocks	3	59.1307	19.71	3.21 NS
Error	6	36.8546	6.14	-
Sub.Plots				
Cultivars	3	478.7663	159.59	54.65***
Cultivars x Planting date	6	68.8878	11.48	3.93**
Error	27	78.7347	2.92	-
Total	47	998.1471		

,* Significance of P$\leq$ 0.01 and 0.001 respectively.

Table 34d. Max.Rust Levels on Leaf 4 (flag leaf=1) (as angular transforms of mean percentage infection).

Planting Date	Cultivars	Block 1	2	3	4
1	Zephyr	0	0	0	0
	Deba Abed	0	0	1.81	4.44
	Julia	0	0	0	0
	Vada	0	0	0	0
		0	0	1.81	4.44
	Zephyr	0	1.81	0	0
	Deba Abed	1.81	1.81	1.81	2.56
	Julia	0	0	0	0
	Vada	0	0	0	1.81
		1.81	3.62	1.81	4.37
	Zephyr	1.81	5.74	2.56	8.72
	Deba Abed	8.53	6.80	4.44	12.79
	Julia	0	1.81	0	0
	Vada	1.81	2.56	2.56	3.63
		12.15	16.91	9.56	25.14
	Total	13.96	20.53	13.18	33.95

Table 34d continued

Planting Date	Variety				
	Zephyr	Deba Abed	Julia	Vada	Total
1	0	6.25	0	0	6.25
2	1.81	7.99	0	1.81	11.61
3	18.83	32.56	1.81	10.56	63.76
Total	20.64	46.80	1.81	12.37	81.62

Main Plots	D.F.	S.S.	M.S.	F.
Date of planting	2	126.1615	63.08	22.77**
Blocks	3	23.1018	7.70	2.78 NS
Error	6	16.6304	2.77	-
Sub.Plots				
Cultivars	3	92.2572	30.75	16.44***
Cultivars x Planting date	6	52.535	8.75	4.68**
Error	27	50.4005	1.87	-

,*, Significance at $P \leqslant 0.01$ and 0.001 respectively.

Table 35a. Rust Levels at Assessment Date 4† (as angular transform of mean % infection).

†for actual dates see Table 26.

		Block				
Planting	Cultivar	1	2	3	4	Total
1	Deba Abed	2.56	2.56	2.56	3.14	10.82
	Julia	1.81	1.81	1.81	3.14	8.57
	Zephyr	3.14	2.56	2.56	4.05	12.31
	Vada	1.81	1.81	1.81	1.81	7.24
Total		9.32	8.74	8.74	12.14	38.94
2	Deba Abed	1.81	1.81	3.14	1.81	8.57
	Julia	2.56	0.0	1.81	1.81	6.18
	Zephyr	1.81	1.81	3.14	3.14	9.90
	Vada	0.0	0.0	0.0	0.0	0.0
Total		6.18	3.62	8.09	6.76	24.65
3	Deba Abed	3.63	2.56	3.63	1.81	11.63
	Julia	2.56	1.81	1.81	1.81	7.99
	Zephyr	2.56	3.14	2.56	3.14	11.40
	Vada	0.0	0.0	0.0	1.81	1.81
Total		8.75	7.51	8.0	8.57	32.83
Blocks Total		24.25	19.87	24.83	27.47	96.42

	Cultivar				
Planting	Deba Abed	Julia	Zephyr	Vada	Total
1	10.82	8.57	12.31	7.24	38.94
2	8.57	6.18	9.90	0.0	24.65
3	11.63	7.99	11.40	1.81	32.83
Total	31.02	22.74	33.61	9.05	96.42

Table 35a. continued

Analysis of Variance:

	D.F.	S.S.	M.S.	F.
Main Plots		11.828		
Planting	2	6.426	3.213	6.58*
Blocks	3	2.484	0.828	1.70 NS
Error	6	2.918	0.488	
Sub.Plots		40.429		
Cultivar	3	30.556	1.185	3.23*
Planting x Cultivar	6	3.447	0.575	1.57 NS
Error	27	9.906	0.367	

Significance at $P \leqslant 0.05$ denoted by*.

Table 35b. Rust Levels at Assessment Date 5 (as angular transform of mean % infection).

		Block				
Planting	Cultivar	1	2	3	4	Total
1	Deba Abed	5.74	7.27	5.74	7.27	26.02
	Julia	2.56	5.13	4.44	3.63	15.76
	Zephyr	5.74	5.44	6.02	10.63	27.83
	Vada	4.80	1.81	5.74	3.14	15.49
Total		18.84	19.65	21.94	24.67	85.10
2	Deba Abed	4.05	6.29	6.02	7.92	24.28
	Julia	5.13	4.05	3.63	3.14	15.95
	Zephyr	4.44	5.13	6.02	7.03	22.62
	Vada	1.81	2.56	1.81	1.81	7.99
Total		15.43	18.03	17.48	19.90	70.84
3	Deba Abed	9.63	6.80	6.29	7.27	29.99
	Julia	5.44	3.14	3.63	4.05	16.26
	Zephyr	6.29	7.71	7.27	8.91	30.18
	Vada	3.14	2.56	2.56	3.63	11.89
Total		24.50	20.21	19.75	23.86	88.32
Blocks Total		58.77	57.89	59.17	68.43	244.26

	Cultivars				
Planting	Deba Abed	Julia	Zephyr	Vada	Total
1	26.02	15.76	27.83	15.49	85.10
2	24.28	15.95	22.62	7.99	70.84
3	29.99	16.26	30.18	11.89	88.32
Total	80.29	47.97	80.63	35.37	244.26

Table 35b continued

Analysis of Variance:

	D.F.	S.S.	M.S.	F.
Main Plots				
Planting	2	10.818	5.409	5.36*
Blocks	3	6.098	2.033	2.01
Error	6	6.062	1.01	
Sub.Plots				
Cultivar	3	132.008	44.003	24.31***
Planting x cultivar	6	8.017	1.336	0.74
Error	27	48.865	1.81	

*,***, Significance at $P \leq 0.05$ and 0.001 respectively.

Table 35c. Rust Levels at Assessment Date 6 (as angular transform of mean % infection).

Block

Planting	Cultivar	1	2	3	4	Total
1	Deba Abed	16.74	20.70	16.43	16.22	70.09
	Julia	8.13	8.33	7.03	7.92	31.41
	Zephyr	14.77	22.95	20.27	22.46	80.45
	Vada	4.44	6.55	7.03	5.74	23.76
	Total	44.08	58.53	50.76	52.34	205.71
2	Deba Abed	14.30	12.11	15.56	11.54	53.51
	Julia	8.72	6.80	8.53	6.55	30.60
	Zephyr	10.30	9.46	18.05	15.34	53.15
	Vada	4.44	6.55	6.02	6.55	23.56
	Total	37.76	34.92	48.16	39.98	160.82
3	Deba Abed	10.47	10.30	9.97	11.39	42.13
	Julia	5.74	5.44	7.03	5.44	23.65
	Zephyr	13.69	13.56	10.63	10.63	48.51
	Vada	4.44	4.80	5.13	6.80	21.17
	Total	34.34	34.10	32.76	34.26	135.46
Blocks	Total	116.18	127.55	131.68	126.58	501.99

Cultivar

Planting	Deba Abed	Julia	Zephyr	Vada	Total
1	70.09	31.41	80.45	23.76	205.71
2	53.51	30.60	53.15	23.56	160.82
3	42.13	23.65	48.51	21.17	135.46
	165.73	85.66	182.11	68.49	501.99

Table 35c. continued

Analysis of Variance:

	D.F.	S.S.	M.S.	F.
Main Plots				
Planting	2	158.194	79.097	11.73**
Blocks	3	10.686	3.562	0.53 NS
Error	6	40.465	6.744	
Sub.Plots				
Cultivar	3	805.043	268.348	78.40***
Planting x Cultivar	6	99.703	16.617	4.85**
Error	27	92.409	3.423	

,* Significance at $P \leqslant 0.01$ and 0.001 respectively.

Table 36. Daily Spore Trap Counts per m^3 Air, 1973.

Date	No. Uredospores	log. No.Uredospores
16 June	2	0.3010
17	0	-
18	2	0.3010
19	0	-
20	0	-
21	0	-
22	4	0.6021
23	4	0.6021
24	3	0.4771
25	4	0.6021
26	6	0.7782
27	3	0.4771
28	7	0.8451
29	12	1.0792
30	24	1.3802
1 July	20	1.3010
2	35	1.5441
5	75	1.8751
6	844	2.9263
7	60	1.7782
8	77	1.8865
10	127	2.1038
11	424	2.6304
12	104	2.0170
13	276	2.4409
14	311	2.4928
15	70	1.8451
16	77	1.8865
17	104	2.0170
18	1015	3.0064
19	572	2.7574
20	1718	3.2350
21	1639	3.2146
23	17	1.2304

Table 37. Brown Rust Trial : Silwood 1973.

Plot Yields (kg.) on Dry Weight Basis

Planting Date	Cultivar	Block 1	2	3	4
1	Zephyr	2.425	3.107	2.768	1.891
	Deba Abed	1.822	2.598	1.731	1.168
	Julia	3.684	3.373	3.010	1.752
	Vada	3.358	3.578	3.399	2.814
		11.289	12.656	10.908	7.544
2	Zephyr	2.874	3.505	3.288	2.635
	Deba Abed	1.524	1.583	1.548	0.730
	Julia	2.955	3.762	3.424	2.698
	Vada	3.291	3.385	4.011	2.102
		10.644	12.235	12.271	8.165
3	Zephyr	2.828	3.080	3.052	0.927
	Deba Abed	1.782	1.999	1.558	1.056
	Julia	3.090	3.441	2.916	2.119
	Vada	3.613	4.093	3.390	2.449
		11.313	12.613	10.916	6.551
	Total	33.246	37.504	34.095	22.260

Table 37 continued.

Planting Date	Cultivar: Zephyr	Deba Abed	Julia	Vada	Total
1	10.191	7.319	11.819	13.149	42.478
2	12.302	5.385	12.839	12.789	43.315
3	9.887	6.395	11.566	13.545	41.393
	32.380	19.099	36.224	39.483	127.186
Mean (kg. dry weight)	10.793	6.366	12.075	13.161	

	D.F.	S.S.	M.S.	F.
Main Plots				
Date of Planting	2	0.1161	0.058	0.563 NS
Blocks	3	10.4795	3.493	33.913 ***
MP Error	6	0.6219	0.103	-
Sub. Plots.				
Variety	3	20.0210	6.674	63.02 ***
Variety x Planting	6	1.5154	0.252	2.38 NS
SP Error	27	2.8603	0.1059	-
Total	47	-	-	

Significance at $P \leqslant 0.001$ denoted by ***.

Table 38. Disease Levels as Mean % Disease per Leaf in a Plot.

Assessment Date	Cultivar	BLOCKS I	II	III	IV	Mean
19.6.74	Deba Abed	0.019	0.022	0.029	0.019	0.023
	Zephyr	0.056	0	0.019	0.020	0.024
	Julia	0.021	0	0	0	0.005
	Vada	0.00	0	0	0	0
27.6.74	Deba Abed	0.261	0.068	0.042	0.040	0.103
	Zephyr	0.114	0.083	0.031	0.020	0.062
	Julia	0.056	0	0	0	0.014
	Vada	0.063	0.042	0	0	0.026
2.7.74	Deba Abed	0.286	0.239	0.211	0.167	0.226
	Zephyr	0.298	0.238	0.163	0.118	0.204
	Julia	0.111	0.083	0.056	0.063	0.078
	Vada	0.102	0.143	0.050	0.066	0.090
10.7.74	Deba Abed	1.882	0.488	0.408	0.350	0.782
	Zephyr	1.611	0.571	0.512	0.517	0.803
	Julia	0.515	0.181	0.162	0.118	0.244
	Vada	0.237	0.355	0.153	0.069	0.204
17.7.74	Deba Abed	6.353	2.056	2.764	1.125	3.075
	Zephyr	3.662	2.188	2.500	1.679	2.507
	Julia	1.500	0.733	0.542	0.500	0.819
	Vada	0.794	1.015	0.571	0.438	0.705
23.7.74	Deba Abed	15.292	7.042	5.643	3.212	7.7973
	Zephyr	15.750	7.100	5.750	7.167	8.942
	Julia	2.500	1.000	1.536	1.083	1.530
	Vada	1.389	1.667	1.111	1.500	1.417

Table 38 Continued:

Analysis of Variance

Assessment Date

		19.6.1974		27.6.1974		2.7.1974		10.7.1974		17.7.74		23.7.1974	
	D.F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
Cultivars	3	0.000573	4.02*	0.006373	3.9*	0.023198	23.5***	0.43249	4.0*	5.71	6.0*	64.3	8.6**
Blocks	3	0.000251	1.76NS	0.010176	6.3*	0.0082	8.3**	0.55667	5.2*	3.35	3.5NS	26.5	3.5 NS
Error	9	0.000142		0.001616		0.000988		0.10787		0.956		7.5	
S.E±		0.006		0.02		0.016		0.16		0.49		1.37	

Table 39.

a) Disease Development as $\log_e(\frac{x}{1-x})$; Figures are means of four plots.

	Assessment Dates					
Cultivars	19.6.'74	27.6.'74	2.7.'74	10.7.'74	17.7.'74	23.7.'74
Deba Abed	-8.377	-6.877	-6.090	-4.843	-3.451	-2.470
Zephyr	-8.335	-7.385	-6.193	-4.817	-3.661	-2.321
Julia	-9.903	-8.874	-7.155	-6.013	-4.797	-4.165
Vada	-	-8.255	-7.012	-6.193	-4.948	-4.242

b) Homogeneity of Regression Coefficients

Cultivars	D.F.	Σx^2	Σxy	Σy^2	D.F.	Reduced S.S
Deba Abed	5	811.33	140.041	24.200	4	0.028
Zephyr	5	811.33	144.840	26.011	4	0.154
Julia	5	811.33	142.849	25.629	4	0.478
Vada	4	450.80	67.499	10.259	3	0.152
Residuals from individual regressions					15	0.812 = A
Totals for single regressions	19	2884.79	495.229	86.099	18	1.084 = B
Difference for homogeneity of regressions					3	0.272 = B-A

F= 1.68 N.S. (with 3 and 15 D.F.)

Table 40. Apparent Infection Rates, 1974.

Block	Cultivars	Assessment Dates: 19 June-27 June	27 June-2 July	2-10 July	10-17 July	17-23 July
1	Deba Abed	+0.327	+0.018	+0.237	+0.180	+0.163
	Zephyr	+0.089	+0.192	+0.212	+0.120	+0.265
	Julia	+0.123	+0.137	+0.192	+0.154	+0.087
	Vada	-	+0.096	+0.105	+0.173	+0.094
2	Deba Abed	+0.141	+0.251	+0.089	+0.207	+0.214
	Zephyr	-	+0.211	+0.110	+0.194	+0.205
	Julia	-	-	+0.097	+0.200	+0.052
	Vada	-	+0.245	+0.114	+0.151	+0.084
3	Deba Abed	+0.046	+0.323	+0.083	+0.276	+0.124
	Zephyr	+0.061	+0.332	+0.143	+0.229	+0.144
	Julia	-	-	+0.133	+0.173	+0.175
	Vada	-	-	+0.140	+0.189	+0.112
4	Deba Abed	+0.092	+0.286	+0.093	+0.183	+0.178
	Zephyr	0.0	+0.355	+0.185	+0.170	+0.251
	Julia	-	-	+0.078	+0.207	+0.130
	Vada	-	-	+0.006	+0.264	+0.207

Table 40 continued

Analysis of Variance:

		2-10 July		10-17 July		17-23 July	
	D.F.	M.S.	F.	M.S.	F.	M.S.	F.
Cultivars	3	0.00339	1.6NS	0.00086	0.6 NS	0.00910	3.5NS
Blocks	3	0.00730	3.5NS	0.00276	1.9 NS	0.00249	1.0NS
Error	9	0.00208		0.00144		0.00263	

Table 41 Correlation of log.no. of Spores, Collected Above Plots, to Disease Level as $\sqrt{\text{percentage}}$.

OBS†	$\sqrt{\%}$ disease x	log.spore No. y	OBS	x	y	OBS	x	y
1	0.000	0.930	23	0.378	1.342	45	0.638	1.959
2	0.000	0.778	24	0.223	0.903	46	0.591	2.000
3	0.333	0.845	25	0.256	0.700	47	1.433	2.405
4	0.288	1.322	26	0.486	1.279	48	1.662	2.545
5	0.236	0.778	27	0.595	2.272	49	1.060	2.193
6	0.250	0.845	28	0.391	1.663	50	1.792	2.985
7	0.717	1.447	29	0.262	1.653	51	0.288	0.000
8	0.425	1.820	30	0.891	1.699	52	0.141	1.079
9	0.402	1.633	31	1.007	2.683	53	0.545	1.431
10	0.343	1.544	32	0.755	2.021	54	0.487	1.114
11	1.224	1.914	33	0.661	1.778	55	0.403	0.954
12	0.856	2.086	34	1.178	2.963	56	0.343	1.431
13	0.736	1.898	35	1.291	3.299	57	1.269	2.072
14	0.707	1.740	36	1.054	2.919	58	0.755	2.324
15	1.581	2.673	37	1.224	2.872	59	0.715	1.778
16	1.000	2.589	38	0.200	1.000	60	0.719	2.009
17	1.239	2.643	39	0.534	1.477	61	1.913	2.683
18	1.040	2.386	40	0.488	1.491	62	1.479	2.369
19	0.000	0.301	41	0.459	1.398	63	1.581	1.978
20	0.000	1.204	42	0.408	1.778	64	1.295	1.716
21	0.000	0.301	43	1.371	2.305			
22	0.319	1.041	44	0.698	2.121			

Correlation = 0.825

t = 11,49 ***

F = 132,09 ***

Equation y = 0.874 + 1.216x

† Observation

Table 42. Spore Counts on Sticky Vertical Spore Traps.

Cultivar & Plot No.	DATES 19.6.74/27.6.74	27.6.74-5.7.74	5.7.74-11.7.74	11.7.74-18.7.74	18.7.74-24.7.74	Total
Plot 5 JULIA	0	7	28	82	471	588
Plot 6 DEBA ABED	0	30	202	293	2441	2966
Plot 7 ZEPHYR	0	27	118	482	1003	1630
Plot 8 VADA	0	11	19	50	918	998
Plot 13 DEBA ABED	0	31	132	254	1969	2386
Plot 14 ZEPHYR	1	13	211	234	898	1357
Plot 15 JULIA	0	21	66	122	388	597
Plot 16 VADA	2	22	187	482	1991	2684
Plot 17 DEBA ABED	0	25	91	351	2494	2961
Plot 18 ZEPHYR	0	9	60	95	1608	1772

Table 42 Continued.

Cultivar & Plot No.	DATES 19.6.74/27.6.74	27.6.74-5.7.74	5.7.74-11.7.74	11.7.74-18.7.74	18.7.74-24.7.74	Total
Plot 19 JULIA	8	6	43	79	440	576
Plot 20 VADA	16	8	46	105	829	1004
Plot 25 JULIA	6	7	35	55	243	346
Plot 26 VADA	2	5	45	60	745	857
Plot 27 DEBA ABED	10	60	100	156	967	1293
Plot 28 ZEPHYR	12	27	107	52	1067	1265

Table 43. $\log_e \left(\frac{x}{1-x}\right)$ of Accumulative Spore Count.

Blocks	Cultivars	Weeks		
		1	2	3
	Deba Abed	-4.585	-2.463	-1.537
	Zephyr	-4.082	-2.326	-0.470
1	Julia	-4.419	-2.760	-1.393
	Vada	-4.499	-3.473	-2.440
	Deba Abed	-4.330	-2.613	-1.552
	Zephyr	-4.565	-1.616	-0.671
2	Julia	-3.311	-1.769	-0.619
	Vada	-4.713	-2.462	-1.055
	Deba Abed	-4.771	-3.199	-1.675
	Zephyr	-5.273	-3.207	-2.282
3	Julia	-3.693	-2.208	-1.174
	Vada	-3.710	-2.591	-1.555
	Deba Abed	-2.861	-1.888	-1.087
	Zephyr	-3.449	-2.037	-1.685
4	Julia	-3.242	-1.826	-0.858
	Vada	-4.795	-2.739	-1.895

Equations:

Deba Abed	$y = 1.3369\ x - 5.3871$
Zephyr	$y = 1.5327\ x - 5.7038$
Julia	$y = 1.3276\ x - 4.9279$
Vada	$y = 1.3465\ x - 5.6869$

Table 44. Result of Sieve Tests, Deposits in Each Sieve (gr).

Plot No.	Cultivar	Sieve I 2.8	Sieve II 2.5	Sieve III 2.2	less than 2.2
1	Zephyr	18.92	42.73	24.45	13.90
2	Deba Abed	15.75	40.81	23.41	20.03
3	Julia	23.89	43.31	21.39	11.41
4	Vada	34.09	32.50	19.46	13.95
5	Julia	20.66	40.98	22.57	15.79
6	Deba Abed	14.79	36.51	26.72	21.98
7	Zephyr	13.86	39.54	27.43	19.17
8	Vada	23.28	33.20	24.58	18.94
9	Zephyr	33.50	39.54	15.39	11.57
10	Vada	51.33	21.68	13.56	13.43
11	Deba Abed	24.15	35.42	20.34	20.09
12	Julia	31.02	41.14	19.23	8.61
13	Deba Abed	18.31	43.89	22.67	15.13
14	Zephyr	14.04	41.33	28.15	16.48
15	Julia	7.93	43.09	28.94	20.04
16	Vada	25.25	30.13	22.59	22.03

Analysis of Variance:

	D.F.	S.S.	M.S.	F.
Cultivar	3	81.667	27.222	1.09 NS
Brown Rust	1	430.457	430.457	17.19 **
Cultivar x Brown Rust	3	109.826	36.609	1.46 NS
Block	1	45.326	45.326	1.81 NS
Error	7	175.327	25.047	

** Significant at $P \leqslant 0.01$.

Table 45. Weather Conditions and Spore Counts, 1971

Key: TP = trapping period, viz. 1=10.00-11.00 h, 2=11.00-12.00 B.S.T., and so on.
Spores = number uredospores per m^3 air.
^oC = Temperature.
R = Rainfall in mm.
r.h. = % relative humidity.
s.w. = surface wetness in arbitary unit from 1 (dry) to 10 (wet)..
wind = wind speed, 2 m above ground, in meter in second.

Cont'd. Table 45.

TP	Spores	°C	R	r.h.	s.w.	Wind
	17 June'71					
1	18	12	0	66	8	1.5
2	18	12.5	0	58	5	2.0
3	9	13.5	0	50	2	2.0
4	9	14	0	48	1	2.5
5	27	15.5	0	48	1	2.0
6	27	15	0	46	1	2.5
7	9	14.5	0	48	1	2.5
8	0	14	0	48	1	3.0
9	0	13.5	0	50	1	2.0
10	0	13	0	54	1	1.5
11	9	12	0	63	1	0.0
12	0	11	0	67	1	1.0
13	0	10	0	68	1	0.5
14	0	10	0	69	1	0.0
15	0	9.5	0	72	1	0.5
16	9	9	0	75	1	1.0
17	0	8.5	0	81	1	0.5
18	0	8	0	80	2	1.0
19	0	8	0	84	2	0.5
20	0	8.5	0	85	2	1.0
21	36	9.5	0	82	2	1.0
22	27	10.5	0	80	2	1.5
23	109	11.5	0	76	2	1.5
24	172	12.5	0	76	1	2.0

TP	Spores	°C	R	r.h.	s.w.	Wind
	18 June'71					
1	63	12.5	0	69	1	2.0
2	18	12	0.4	82	1	3.0
3	18	11	0.7	82	2	2.5
4	27	11	1.3	87	6	1.5
5	226	10.5	2.5	87	7	2.0
6	0	10	5.0	90	8	2.5
7	9	10	3.0	90	10	2.5
8	27	10	2.0	90	10	2.5
9	9	10	5.0	90	10	2.5
10	0	10.5	2.0	90	10	3.0
11	0	11	5.0	90	10	1.5
12	18	11	1.5	90	10	2.0
13	0	11.5	4.0	90	10	2.0
14	0	11.5	5.0	90	10	2.0
15	0	12	3.0	90	10	1.5
16	0	12.5	4.2	90	10	2.0
17	0	12.5	0	88	10	3.0
18	0	12.5	0	88	10	4.0
19	0	12.5	0	87	10	4.0
20	18	12.5	0	87	10	3.5
21	0	13	0	80	10	3.0
22	0	14	0	76	10	3.0
23	36	14	0	76	10	4.0
24	18	15.5	0	70	3	3.5

Cont'd. Table 45

	19 June'71					
TP	Spores	°C	R	r.h.	s.w.	Wind
1	0	16	0	70	2	3.5
2	9	15.5	0	72	1	3.0
3	0	15.5	0	70	1	2.5
4	0	16	0	63	1	2.0
5	9	16	0	62	1	1.5
6	36	16	0	62	1	1.5
7	36	16	0	64	1	1.0
8	0	16	0	70	1	0.0
9	0	16	0	73	1	0.0
10	0	15.5	0	75	1	0.0
11	0	15.5	0	80	1	0.0
12	0	14.5	0	84	1	0.0
13	0	14.5	0	85	1	0.0
14	0	14	0.8	88	1	0.5
15	0	13.5	1.2	90	8	0.5
16	0	12.5	2.3	90	8	1.0
17	0	12	4.0	90	8	2.0
18	0	12	2.4	90	9	2.0
19	0	12	0	88	10	2.5
20	0	12.5	0	88	10	2.5
21	9	12.5	0	87	10	2.0
22	0	13	0	87	10	2.5
23	0	14	0	83	10	2.0
24	91	15	0	82	9	2.5

	20 June'71					
TP	Spores	°C	R	r.h.	s.w.	Wind
1	163	15.5	0	78	7	2.5
2	127	15.5	0	77	4	2.5
3	72	15.5	0	68	2	2.5
4	72	16	0	65	1	3.0
5	54	16	0	62	1	3.0
6	0	16	0	62	1	3.0
7	45	15.5	0	62	1	3.0
8	81	15.5	0	63	1	3.0
9	9	15.5	0	63	1	2.0
10	9	15	0	68	1	1.5
11	9	13.5	0	73	1	1.5
12	9	11	0	80	1	0.0
13	0	11	0	82	1	0.0
14	0	10	0	85	2	0.0
15	0	9	0	88	3	0.0
16	0	8.5	0	88	4	0.0
17	0	8	0	88	5	0.0
18	27	8	0	90	3	0.0
19	0	8	0	91	7	0.0
20	0	8	0	92	7	1.0
21	9	8.5	0	92	7	1.0
22	27	9	0	91	8	1.0
23	136	11	0	82	8	1.0
24	109	14	0	73	7	1.5

Cont'd. Table 45

21 June'71							22 June'71						
TP	Spores	°C	R	r.h.	s.w.	Wind	TP	Spores	°C	R	r.h.	s.w.	Wind
1	72	14.5	0	68	4	1.5	1	18	14.5	0	55	1	2.5
2	380	14.5	0	62	3	2.5	2	54	15.5	0	55	1	3.0
3	145	15.5	0	57	1	2.5	3	63	16	0	53	1	2.5
4	81	15.5	0	58	1	2.5	4	27	16.5	0	52	1	2.5
5	226	15	0	58	1	2.5	5	9	17	0	50	1	2.0
6	190	15.5	0	58	1	3.0	6	18	18	0	47	1	1.5
7	109	15.5	0	58	1	3.0	7	27	18.5	0	45	1	1.5
8	81	15	0	61	1	3.5	8	0	19	0	46	1	1.5
9	54	14.5	0	68	1	3.0	9	27	18.5	0	46	1	1.5
10	0	13.5	0	71	1	2.5	10	9	18.5	0	48	1	1.5
11	0	13	0	72	1	2.5	11	9	16.5	0	58	1	0.0
12	36	13	0	78	1	3.0	12	0	14	0	72	1	0.0
13	9	12	0	84	1	3.5	13	0	12	0	78	1	0.0
14	0	12	0	85	1	3.0	14	0	12	0	82	2	0.0
15	0	12	0	87	1	3.0	15	0	10	0	86	3	0.0
16	0	12.5	0	88	1	2.0	16	0	9.5	0	88	4	0.0
17	0	12.5	0	86	1	2.5	17	0	9	0	89	4	0.0
18	0	12.5	0	83	1	2.0	18	0	9	0	90	5	0.0
19	9	12	0	82	1	2.5	19	0	9	0	90	5	0.0
20	9	12	0	80	2	2.0	20	18	8.5	0	90	5	0.0
21	18	12.5	0	68	2	2.0	21	9	9	0	90	6	0.0
22	27	13	0	62	2	2.5	22	18	11	0	80	6	0.0
23	380	14	0	58	2	2.5	23	27	13	0	74	6	0.0
24	63	14	0	57	2	3.0	24	244	18	0	58	5	1.0

Cont'd. Table 45

	23 June'71						24 June'71					
TP	Spores	°C	R	r.h.	s.w.	Wind	Spores	°C	R	r.h.	s.w.	Wind
1	272	18	0	55	3	1.5	453	19	0	62	2	1.0
2	253	18	0	52	1	1.5	109	20	0	46	1	2.0
3	317	18.5	0	50	1	1.5	253	21	0	46	1	2.0
4	235	19	0	48	1	1.5	362	21.5	0	42	1	2.5
5	262	19.5	0	48	1	1.5	462	21.5	0	40	1	2.5
6	190	20	0	45	1	1.5	362	21.5	0	38	1	2.5
7	416	20	0	52	1	2.0	416	22	0	40	1	2.5
8	272	20	0	51	1	2.0	371	21.5	0	46	1	2.5
9	118	19.5	0	51	1	1.5	661	21	0	51	1	2.5
10	190	18	0	58	1	1.0	299	20	0	58	1	2.0
11	154	17	0	60	1	0.0	344	18	0	67	1	1.5
12	109	16	0	64	1	0.0	181	16	0	71	1	1.5
13	0	15.5	0	72	1	0.0	208	14.1	0	76	1	1.5
14	0	14.5	0	80	1	0.0	163	13	0	80	2	1.0
15	9	13.5	0	82	2	0.0	154	11.5	0	84	2	0.0
16	9	13	0	83	2	0.0	45	11	0	84	3	0.5
17	45	13	0	81	2	0.0	9	10.5	0	85	3	0.5
18	27	11.5	0	86	2	0.0	9	10.5	0	86	4	0.0
19	27	11	0	88	3	0.0	0	10	0	88	5	0.0
20	63	11	0	88	3	0.0	18	10.5	0	86	6	0.0
21	54	13	0	76	4	0.0	63	11.5	0	82	6	1.0
22	154	14	0	74	4	1.0	154	12.5	0	76	6	1.5
23	100	16	0	70	3	1.0	353	14	0	70	6	2.0
24	525	18	0	66	3	1.5	869	15	0	70	5	2.5

Cont'd. Table 45

TP	25 June'71 Spores	°C	R	r.h.	s.w.	Wind	26 June'71 Spores	°C	R	r.h.	s.w.	Wind
1	850	17	0	65	3	2.0	290	14	0	75	2	2.0
2	235	17	0	64	1	2.5	127	15	0	74	1	3.0
3	634	17.5	0	62	1	3.0	208	15.5	0	70	1	3.0
4	606	17.5	0	65	1	3.0	36	15.5	0	68	1	3.5
5	552	17	0	71	1	3.0	281	16	0	68	1	4.0
6	507	17	0	70	1	3.5	236	16.5	0	68	1	4.0
7	335	16	0	76	1	3.0	399	14	2.4	68	1	4.0
8	262	16	0	74	1	2.5	127	14	0.2	84	1	2.0
9	91	16	0	74	1	3.0	91	14	0	82	10	1.5
10	127	16	0	74	1	3.0	45	14	0	80	10	1.0
11	54	15.5	0	76	1	2.5	72	14	0	80	10	0.0
12	81	14.5	0	84	1	1.5	54	13.5	0	84	10	0.0
13	36	14	0	84	1	2.0	36	12.5	0	84	10	0.0
14	27	14	0.3	86	2	2.0	45	12	0	84	10	1.0
15	27	14	0	85	2	2.0	45	12	0	84	10	1.0
16	45	14	0.2	88	7	2.0	27	11	0	84	10	1.0
17	9	13.5	1.0	90	7	2.5	0	10.5	0	86	10	1.5
18	9	13.5	0	89	8	2.0	9	10	0	87	10	1.5
19	0	13	0	86	8	1.5	0	10	0	88	10	1.5
20	18	12.5	0	80	7	2.0	9	10	0	84	10	1.5
21	0	12.5	0	80	7	1.5	27	11	0	78	10	1.5
22	9	13	0	76	7	1.5	63	12	0	72	10	2.0
23	235	14	0	76	6	2.0	562	13	0	64	10	3.0
24	272	14	0	70	4	2.5	507	14	0	60	6	2.5

Cont'd. Table 45

TP	Spores	°C	R	r.h.	s.w.	Wind
		27 June'71				
1	236	14.5	0	58	1	2.5
2	172	15	0	56	1	2.5
3	236	14.5	0.1	57	1	2.5
4	652	14	1.0	66	2	1.5
5	852	13	0	80	4	2.5
6	1758	14	0	72	10	2.0
7	661	15	0	64	8	2.0
8	580	15	0	55	5	2.5
9	326	15	0	55	2	3.0
10	1105	14	0	65	1	2.5
11	1024	13	0	69	1	1.5
12	852	12.5	0	78	1	0.5
13	1051	12.5	0	78	1	1.5
14	1142	12	0	82	1	1.5
15	1214	11	3.8	86	1	1.0
16	1232	10	2.0	88	10	1.0
17	562	9.5	2.0	89	10	1.0
18	181	8.5	0.5	90	10	0.0
19	208	8.5	0	91	10	0.0
20	145	8.5	0	91	10	0.0
21	81	9	0	86	10	0.0
22	290	10	0	81	10	1.0
23	136	11.5	0	78	10	1.5
24	1305	14	0	66	9	2.0

TP	Spores	°C	R	r.h.	s.w.	Wind
		28 June'71				
1	453	14	0	66	4	2.0
2	643	12.5	0.2	72	2	2.5
3	408	15.5	0	65	1	2.5
4	480	16.5	0	46	6	3.0
5	100	17	0	42	2	3.5
6	127	17.5	0	40	1	3.5
7	190	17	0	54	1	3.0
8	154	17	0	50	1	2.5
9	45	17	0	45	1	2.5
10	100	17	0	44	1	2.5
11	181	15	0	50	1	1.5
12	100	13	0	74	1	0.5
13	136	12	0	80	1	1.0
14	63	11	0	83	2	1.0
15	0	10	0	86	3	0.5
16	9	9	0	88	4	0.0
17	9	8	0	90	4	0.0
18	18	8	0	90	5	0.0
19	0	8	0	90	6	0.0
20	0	9	0	88	7	0.0
21	45	10	0.3	86	7	0.5
22	806	11	0	82	9	0.0
23	507	12.5	0	80	9	0.5
24	607	13	0	76	8	1.5

Cont'd. Table 45

TP	Spores	°C	R	r.h.	s.w.	Wind
		29 June'71				
1	0	15	0	70	6	2.0
2	525	15	0	65	3	2.0
3	127	15	0	65	1	1.5
4	254	16.5	0	60	1	2.0
5	453	16	0	62	1	2.0
6	236	16	0	62	1	1.5
7	72	16	0	62	1	1.5
8	190	16.5	0	62	1	2.0
9	109	16	0	70	1	2.0
10	18	15.5	0	74	1	2.0
11	63	15	0	74	1	1.0
12	91	14.5	0	82	1	1.0
13	45	14	0	85	1	1.0
14	18	14	0	87	1	0.5
15	0	14	0	88	1	1.0
16	9	14	0	86	1	1.0
17	9	13.5	0	87	1	0.5
18	45	13.5	0	86	1	0.5
19	18	13	0	88	1	1.0
20	45	12.5	0	84	1	1.0
21	81	12.5	0	80	2	0.5
22	498	13.5	0	74	2	1.5
23	824	14.5	0	66	2	1.5
24	1884	17	0	60	2	2.0

TP	Spores	°C	R	r.h.	s.w.	Wind
		30 June'71				
1	3126	17	0	58	1	2.0
2	299	17.5	0	52	1	1.5
3	2301	19	0	50	1	2.0
4	2292	19.5	0	53	1	0.5
5	1341	19	0	54	1	0.0
6	1160	19	0	50	1	0.0
7	1631	19.5	0	54	1	1.0
8	1549	19.5	0	54	1	1.0
9	1649	19.5	0	52	1	0.0
10	960	19.5	0	64	1	0.0
11	1377	19	0	70	1	0.0
12	997	18.5	0	78	1	0.0
13	435	17	0	76	1	0.0
14	163	17	0	78	1	0.0
15	81	17	0	80	1	0.0
16	63	17	0	84	1	0.0
17	54	16	0	84	1	0.0
18	9	16	0	83	1	0.0
19	18	16	0	84	1	0.0
20	245	16	0	85	1	0.0
21	408	16	0	83	1	0.5
22	426	16.5	0	81	1	0.5
23	743	18	0	75	1	0.5
24	970	19.5	0	72	1	0.5

Cont'd. Table 45

	1 July'71						2 July'71					
TP	Spores	°C	R	r.h.	s.w.	Wind	Spores	°C	R	r.h.	s.w.	Wind
1	227	20	0	72	1	1.0	788	22	0	71	2	1.0
2	924	20	0	72	1	1.0	670	23.5	0	65	1	1.5
3	444	20.5	0	70	1	1.5	589	24.5	0	58	1	1.5
4	272	20.5	0	72	1	1.5	444	24.5	0	55	1	1.5
5	661	21	0	70	1	1.5	444	23.5	0	66	1	0.5
6	689	22	0	67	1	1.5	553	23.5	0	68	1	0.0
7	580	23	0	63	1	1.5	670	23.5	0	68	1	1.5
8	598	23	0	62	1	1.5	353	23.5	0	69	1	1.5
9	408	23	0	62	1	1.0	245	22.5	0	68	1	2.0
10	326	22.5	0	18	1	1.0	190	21.5	0	73	1	1.5
11	344	20	0	80	1	0.0	290	20	0	74	1	1.0
12	54	19.5	0	84	1	0.0	208	19.5	0	78	1	0.0
13	100	18.5	0	86	2	0.0	381	18.5	0	83	1	0.0
14	45	17.5	0	86	2	0.0	172	17	0	83	1	0.0
15	0	17.5	0	88	3	0.0	72	15.5	0	88	2	0.0
16	27	17	0	88	3	0.0	45	15	0	89	2	0.0
17	36	16	0	89	3	0.0	91	14	0	90	3	0.0
18	18	15.5	0	90	3	0.0	18	14	0	90	3	0.0
19	18	15.5	0	90	4	0.0	63	14	0	90	4	0.0
20	172	16	0	90	4	0.0	1404	14	0	90	5	0.0
21	208	16	0	88	4	0.0	525	14.5	0	84	5	0.5
22	254	17	0	85	4	0.0	1422	14.5	0	84	5	1.5
23	471	19.5	0	80	4	0.0	489	15	0	84	4	1.5
24	426	21.5	0	74	3	0.5	1259	17	0	78	4	1.5

Cont'd. Table 45

TP	3 July'71 Spores	°C	R	r.h.	s.w.	Wind	4 July'71 Spores	°C	R	r.h.	s.w.	Wind
1	752	17	0	77	3	1.5	562	20	0	70	1	1.5
2	634	19	0	60	1	1.5	589	22	0	62	1	1.5
3	435	20.5	0	57	1	2.0	852	24	0	57	1	2.0
4	670	21	0	57	1	2.0	707	24	0	57	1	1.5
5	689	21.5	0	57	1	2.0	498	24	0	56	1	1.0
6	553	21.5	0	58	1	2.5	462	25	0	53	1	1.0
7	861	21.5	0	50	1	2.5	254	24.5	0	54	1	1.5
8	806	21	0	64	1	2.5	344	24.5	0	58	1	1.5
9	598	20	0	68	1	2.5	362	24	0	60	1	1.5
10	227	19	0	74	1	2.0	444	23	0	64	1	0.5
11	308	17	0	80	1	2.0	670	22	0	65	1	0.5
12	571	16	0	84	1	1.0	344	20.5	0	75	1	0.0
13	815	15	0	86	1	1.5	344	19	0	84	1	0.0
14	227	15	0	87	1	1.5	652	17.5	0	86	1	0.0
15	381	15	0	86	2	1.5	471	17	0	90	1	0.0
16	199	15	0	86	2	1.0	661	16	0	90	2	0.5
17	127	15	0	87	2	1.5	471	16	0	90	3	0.5
18	27	15	0	87	2	1.5	381	16	0	88	3	1.0
19	63	15	0	87	2	1.0	698	16	0	87	4	0.5
20	81	15	0	88	2	1.0	779	16	0	86	4	1.0
21	362	15	0	86	1	1.5	598	16	0	84	3	1.0
22	797	16	0	82	1	1.5	906	16.5	0	82	3	1.0
23	725	17.5	0	76	1	1.5	2926	17.5	0	78	2	2.0
24	607	19	0	74	1	1.5	308	18.5	0	74	2	1.5

Cont'd. Table 45

TP	5 July'71 Spores	°C	R	r.h.	s.w.	Wind	6 July'71 Spores	°C	R	r.h.	s.w.	Wind
1	1413	19	0	74	4	2.0	725	17.5	0	72	1	2.0
2	1169	19.5	0	72	4	2.0	281	19	0	69	1	2.0
3	852	20	0	70	1	2.0	344	20.5	0	62	1	2.5
4	1504	20.5	0	70	1	2.5	408	21.5	0	59	1	2.5
5	1613	20.5	0	70	1	2.0	299	23	0	55	1	2.5
6	1531	21	0	66	1	1.5	707	23	0	53	1	2.5
7	2872	21.5	0	66	1	1.5	245	23.5	0	53	1	2.5
8	1359	21.5	0	64	1	1.5	381	23	0	56	1	2.0
9	408	21.5	0	64	1	1.5	172	23	0	58	1	1.5
10	344	21	0	70	1	1.5	217	21	0	64	1	1.5
11	208	19.5	0	74	1	0.5	127	19	0	70	1	1.0
12	299	18	0	75	1	1.0	109	17.5	0	82	1	0.0
13	254	17	0	78	1	0.5	54	16.5	0	85	1	0.0
14	127	16	0	82	1	0.0	54	15.5	0	87	1	1.0
15	63	15	0	86	2	0.0	18	14.5	0	88	2	0.0
16	91	14	0	89	3	0.0	9	14	0	90	3	0.0
17	63	13.5	0	89	4	0.0	72	14	0	89	4	0.0
18	63	13	0	89	4	0.0	18	14	0	88	4	0.5
19	190	13.5	0	90	5	0.0	45	14	0	88	4	1.0
20	444	13.5	0	90	5	0.5	0	14	0	88	4	1.0
21	227	14	0	88	6	1.5	81	14.5	0	88	4	1.0
22	1549	14.5	0	85	5	1.5	145	15	0	84	3	1.0
23	770	15.5	0	80	4	1.5	3416	16	0	80	3	1.5
24	689	17	0	76	3	2.0	317	17.5	0	74	2	1.5

Cont'd. Table 45

TP	7 July'71 Spores	°C	R	r.h.	s.w.	Wind	8 July'71 Spores	°C	R	r.h.	s.w.	Wind
1	553	20	0	68	1	2.0	535	22	0	66	2	1.0
2	652	22.5	0	58	1	2.0	426	24.5	0	54	2	1.0
3	661	23.5	0	54	1	2.5	580	25.5	0	52	1	1.0
4	462	24.5	0	46	1	3.0	317	27	0	40	1	1.0
5	680	25	0	45	1	3.0	571	27.5	0	42	1	1.5
6	616	25	0	39	1	3.5	408	28.5	0	40	1	1.5
7	371	25	0	36	1	3.5	308	28.5	0	42	1	1.0
8	272	24.5	0	37	1	3.5	326	28.5	0	42	1	1.0
9	236	24	0	40	1	3.5	362	27.5	0	54	1	0.0
10	154	23	0	42	1	3.0	290	25.5	0	60	1	0.0
11	145	20	0	52	1	2.0	109	24.5	0	68	1	0.0
12	91	17	0	70	1	1.5	63	22.5	0	68	1	0.0
13	81	16.5	0	78	1	0.5	91	21.5	0	68	1	0.5
14	109	16	0	84	1	1.0	100	20.5	0	76	2	0.0
15	45	14.5	0	86	2	0.0	36	18	0	84	2	0.0
16	27	14.5	0	89	2	0.0	54	17.5	0	85	2	0.0
17	91	13	0	90	3	0.0	45	17	0	87	3	0.0
18	54	12.5	0	90	4	0.0	118	16.5	0	88	3	0.0
19	45	13	0	90	4	0.0	507	16.5	0	88	3	0.0
20	127	13	0	90	5	0.0	915	16.5	0	88	4	0.0
21	227	14	0	90	5	0.0	2673	17	0	84	4	0.0
22	770	15	0	88	4	0.5	236	20	0	70	4	0.0
23	2039	16.5	0	84	4	0.5	707	22.5	0	60	4	0.5
24	1096	19	0	76	3	1.0	0	24	0	56	2	1.5

Cont'd. Table 45

TP	9 July'71 Spores	°C	R	r.h.	s.w.	Wind
1	0	26	0	45	1	1.5
2	0	26.5	0	46	1	1.5
3	0	27	0	45	1	2.0
4	997	27.5	0	42	1	2.0
5	516	27.5	0	43	1	2.0
6	734	27.5	0	44	1	2.0
7	625	27.5	0	47	1	2.0
8	408	27	0	52	1	2.0
9	761	25.5	0	58	1	2.5
10	353	23.5	0	70	1	1.5
11	281	21.5	0	78	1	2.0
12	308	19.5	0	82	1	2.0
13	181	18.5	0	84	1	2.0
14	72	18	0	82	1	2.0
15	81	17.5	0	84	1	1.5
16	45	17	0	84	1	1.5
17	18	16.5	0	84	1	1.5
18	9	16.5	0	82	1	1.0
19	0	16.5	0	82	1	1.5
20	27	16.5	0	82	1	1.0
21	9	16.5	0	84	1	1.5
22	27	17	0	82	1	1.5
23	45	17.5	0	80	1	1.5
24	362	18	0	74	1	1.5

TP	10 July'71 Spores	°C	R	r.h.	s.w.	Wind
1	879	19	0	74	1	2.5
2	227	20	0	72	1	2.0
3	806	21	0	66	1	1.5
4	1341	22	0	60	1	2.0
5	2818	23.5	0	58	1	1.5
6	815	25	0	50	1	1.5
7	1839	26	0	44	1	1.0
8	652	26	0	44	1	2.0
9	308	25	0	46	1	2.5
10	127	24	0	54	1	2.0
11	109	21.5	0	64	1	1.0
12	127	19.5	0	74	1	0.0
13	18	18.5	0	76	2	0.0
14	45	17	0	84	2	0.5
15	27	15.5	0	86	2	0.0
16	36	14.5	0	90	3	0.0
17	27	13.5	0	90	3	0.0
18	54	12	0	90	4	0.0
19	100	12	0	90	4	0.0
20	172	11.5	0	90	4	0.0
21	91	13	0	90	5	0.0
22	834	16	0	86	5	0.0
23	426	19	0	74	5	0.5
24		22.5	0	64	3	0.5