EFFECTS OF ENVIRONMENT ON BIOLOGY OF
PUCCINIA HELIANTHI AND ON DEVELOPMENT
OF RUST ON SUNFLOWERS

by

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A

thesis

submitted to

The

FACULTY OF GRADUATE STUDIES AND RESEARCH

in partial fulfilment of

the requirements for the Degree of

MASTER OF SCIENCE

in

PLANT PATHOLOGY

McGill University,
Montreal, Quebec. January, 1966
SHORT TITLE

BIOLOGY OF SUNFLOWER RUST

by

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ACKNOWLEDGEMENTS

The writer expresses her sincere gratitude to Professor W.E. Sackston, Department of Plant Pathology, for suggesting this project and for his direction during the investigations and in the completion of the manuscript. She is also sincerely grateful to Dr. J.G. Coulson, Professor Emeritus of Plant Pathology, for his help and encouragement in the preparation of the manuscript, and to Mr. Theo Boerboom, for technical assistance.

The financial support of the National Research Council of Canada and of the Quebec Agricultural Research Council is gratefully acknowledged.
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I. INTRODUCTION

Atmospherical environmental factors have long been known to affect rust development on green plants. Environmental conditions subsequent to infection usually have more effect than conditions prior to infection. Moisture, temperature, and light have been shown to be most significant of the atmospheric factors. These factors may affect: a) inoculum efficiency, as appraised by the density of uredial pustules formed, b) length of incubation period, c) reaction type, d) germinability of uredospores produced, and e) formation and infectivity of teliospores. The effects may vary with the race-variety combination of pathogen and host. Knowledge of the significance of the various components of the environment, singly and in combination, on the development of parasitic diseases is extremely important to epidemiologists and to plant breeders attempting to produce disease-resistant varieties of plants.

The studies, reported herein, are of a preliminary nature. They are concerned with sunflower rust (*Puccinia helianthi* Schw) which possesses the capability of causing severe and damaging epidemics on *Helianthus annuus* L. They were undertaken to explore the significance of atmospheric factors upon the development of its sporophytic stage beginning with uredospore inoculum. The time available restricted the research to a consideration of two factors, temperature and light, which it was thought might provide
the most useful and interesting data. While the moisture factor is extremely important, its role in the development of the sporophytic stages of rust fungi is likely to be more simple in its action and more readily conjectured from knowledge of studies on other rust fungi than are the influences of either temperature or light.
II. REVIEW OF SELECTED LITERATURE

The literature selected for review is not intended to be exhaustive but rather to illustrate the different known aspects of the influence of temperature and light upon the course of development of foliage rusts and upon the reaction types induced in infected hosts.

Most investigators have conducted their experiments under the unnatural condition of constant temperatures while only a few have probed the effects of fluctuating temperatures such as the more or less rhythmical day and night changes which occur during a twenty-four-hour period. In this review, the temperatures given are constant unless it is stated that temperature fluctuations are involved.

A. TEMPERATURE EFFECTS

In general, it appears that temperature affects pathogens and host responses to them to about the same degree. The effects of constant temperatures will be mentioned first followed by those caused by fluctuating temperatures.

1. Intensity of Infection

Intensity of infection can be judged, though not always with strict accuracy, from the number of pustules per unit area of leaf surface following inoculation of plants.
Peltier (1923) placed three varieties of wheat inoculated with *Puccinia graminis tritici* at 15°, 20°, 25°, and 30°C, with optimum moisture conditions. There was a sharp optimum at 25°C for density of pustules, contrasted to a broad optimum, 10° to 28°C, for spore germination.

The optimum temperature for infection of beans by *Uromyces phaseoli* is 18° to 21°C, whereas for spore germination and germ tube elongation it is 12° to 18°C (Shands and Schein, 1962).

The significance of temperatures for infectivity is illustrated by the data of Lange et al. (1958) who found that infection of wheat by 7 strains of *P. graminis tritici* fell off by about 10% for each degree below the optimum of 75 ± 1°F (24°C) and at a slightly faster rate for each degree above the optimum. The minimum for infection was near 60°F (15.6°C) and the maximum was 85°F (29.4°C).

The studies of Sharp et al. (1958) and of Emge (1958) demonstrated that the highest infectivity of uredospores of *P. graminis tritici* was promoted by temperatures within the range of 60-75°F (15.6-23.9°C) during germination, growth of germ tube and appressorial formation while post-appressorial development was best at 85°F (29.4°C). In nature, during the rust season, temperature is often quite low during a large portion of a dew period and this is followed by higher temperatures after the sun rises. The results of Sharp et al. (1958) indicate a close adaptation of stem rust to take advantage of these diurnal temperature changes.
Preinoculation temperatures may also be important. Mohamed (1961) observed more infection centers of stem rust on inoculated wheat seedlings exposed for some days to 85°F (29.4°C) than on those similarly exposed to 75°F (23.9°C) previous to inoculation.

2. Incubation Period

The length of incubation refers to the time elapsing from application of inoculum to appearance of symptoms or sometimes in the case of rusts to the appearance of uredospores which follows in one to a few days (often depending upon prevailing temperatures) after the beginning of symptom expression.

As temperatures are increased above or reduced below the optimum, the incubation period progressively lengthens (Dimock and Baker, 1951, Lange et al., 1958, Naoumova, 1935, Schein, 1961, Stakman and Levine, 1919, Stakman and Harrar, 1957, and Zimmer and Schafer, 1961). Stakman and Levine (1919) found that stem rust of wheat developed best between 66.5°F and 70°F (19.1°C and 21.1°C). They observed a retardation in the time of fruiting of 1 day for every rise in temperature of 10 degrees above 70°F (21.1°C) and of 1 day for every fall of 5 degrees below 66.5°F (19.1°C). At this temperature (19.1°C – 21.1°C) most flecks appeared in from 5 to 7 days and uredinia developed within another day or two.
Depending on temperature, the time required for commencement of uredospore production by the wheat stem rust fungus on a susceptible variety can vary from 5 days to 3 months. The incubation period for *P. coronata* is 5 to 6 days at 25°C; 9 days at 20°C; 13 to 15 days at 15°C; and 15 days at 13°C (Stakman and Harrar, 1957).

Invasion of host tissues by *P. triticina* and the onset of fruiting are favoured by fluctuations in temperature (cool nights and warm days) as reported by Chester (1946).

Naoumova (1935) studied the influence of temperature on the incubation period of *P. triticina*. She showed that the day temperature fluctuations between 15.6°C and 23.6°C and between 18°C and 29°C did not appreciably affect the growth of the intramatrical mycelium, but temperatures above 30°C for several hours significantly lengthened the incubation period. Great fluctuations of the day temperature between 35°C and 55°F (1.67°C and 12.8°C) seemed to stimulate the development of the internal mycelium.

According to Dimock and Baker (1951), *P. antirrhini*, snapdragon rust develops more vigorously and sporulation is definitely more luxuriant in plants exposed to fluctuating temperatures in the greenhouse than in plants held at constant temperatures. In 1961b, Schein demonstrated that diurnal temperature changes during the colonization and fruiting periods of *U. phaseoli* can influence symptom development and
sporulation. Symptom expression was more rapid at 80°F-70°F (26.7°C - 21.1°C) day-night temperatures than at 70°F-60°F (21.1°C-15.6°C) day-night temperatures. The coolest environment employed (21.1°C-15.6°C) retarded the appearance of symptoms by one day and the attainment of full sporulation by 2 days. A 90°F-60°F (32.2°C-15.6°C) regime completely inhibited symptom development. The data show the fallacy of using mean temperatures to characterize the influence of temperature upon this rust under artificial or field conditions.

3. **Classes and Infection Reaction or Types**

The leaf reaction classes and infection types within each class are employed for the detection of different degrees of host resistance and the identification of physiologic races of cereal rust (Stakman, Stewart and Loegering, 1962). Phenotypic variability in the infection types, especially in cereals attacked by rusts has often been reported in the literature. Temperature and light have especially strong ability to alter host resistance, particularly when it is either type 2 or X.

Among the first to give attention to the temperature influence was Peltier (1923) and Peturson (1930), who showed that postinoculation temperature influenced the types of infection produced by physiologic forms of *P. coronata avenae* on varieties Green Mountain and White Tartar. In 1935, Murphy observed that oat varieties Green Russian, Hawkeye, Anthony, Sunrise, Green Mountain and White Tartar were
resistant to form 7 at 550°F (12.8°C) but susceptible at 850°F (29.4°C), while at an intermediate temperature a mesothetic reaction was produced on all these varieties. Other varieties, such as Red Rustproof, Sterisel, Belar, Glabrota, Victoria, Bond and Markton did not change from resistant to susceptible, or vice versa, but exhibited only a small decrease in resistance or a small increase in susceptibility as the temperature became higher. In 1937, Wei demonstrated that the reaction type of the susceptible and resistant bean varieties to rust is very stable and influenced very little, if at all, by variation in the temperature factor. It was found that at low temperatures (6.11°-21.1°C) the Kenya variety 318 A.J.4-A-1 of wheat was resistant to 11 races of P. graminis tritici, but at higher temperatures (18.3°-34.4°C) it became susceptible to 6 of the races; four other wheat varieties did not show this varying reaction (Joshi, 1962).

Changes in reaction type are usually quite small. This is illustrated well by the responses of inbred lines of corn to specific lines of P. sorghi at different temperatures as reported by Syamanandra and Dickson (1959). Most of the temperature-induced changes were from one susceptible type to a very similar one. A suboptimal temperature of 16°C brought about a change from the fully susceptible type 4 reaction to the highly resistant necrotic fleck reaction type 0; when inbred corn line Pop 35 was inoculated with rust lines 921 and 925. Zimmer and Schafer (1961) reported a shift in reaction
from type 0 at 60°F (15.6°C) to type 3 at 80°F (26.7°C) in the case of *P. coronata* on an oat variety; Schein (1961a) reported an alteration in reaction of Pinto lima beans to *U. phaseoli* from the normally susceptible type to a highly resistant necrotic one when inoculated plants were held for 7 days after inoculation at 32°C.

In 1961a, Bromfield studied the effect of temperature on a mixed reaction (mesothetic or X type) on wheat in response to *P. graminis tritici* which was characteristically produced on a temperature sensitive variety of wheat subjected to a post-inoculation temperature of 72°-74°F (22.2°-23.3°C). At temperatures below these values, the reaction was in the resistant class and at temperatures above, in the susceptible class. Similar findings were reported by Wei (1937) for bean rust.

Precise temperature control has demonstrated that differences of only 2° or 3°F may shift reactions from one class to another. The susceptibility developed at high temperatures or the resistance at low temperatures were not retained when the temperature sensitive varieties were subsequently exposed for a sufficient length of time to a sufficiently low or high temperature (Bromfield, 1961b, Zimmer and Schafer, 1961).

The time required for the temperature to alter the reaction seems to be a few days. Diurnal temperature changes are probably unimportant. When the host is subjected to the week to week changes in temperature which might occur during
its growth period, the macroscopic appearance of the resulting pustules may be strongly influenced by the value of the temperature and the length of exposure at any given time of their development (Bromfield, 1961b). According to Straib, (1939), summer resistance of wheat to P. glumarum develops principally under the influence of rising summer temperatures which may make a variety virtually immune from yellow rust during the main growing part of the summer; the same variety may bear a great deal of pustules of a susceptible type in the cooler spring or autumn.

By altering the temperature at various stages after penetration of stem rust of a temperature sensitive wheat variety, Silverman (1959) was able to show that the temperature effect came into play about when symptom development and spore formation commences. At this time, the effect of high temperature made the host more susceptible.

High temperature during pustule formation promoted a susceptible reaction while low temperature promoted a more resistant reaction of oats to stem rust. Roberts (1963) observed that the variety Rodney was resistant to race 7 and 3 at 75°F (23.9°C) but susceptible at 85°F (29.4°C). The expression of resistance or susceptibility depended upon the stage of rust development at the time of exposure to high or low temperature and the duration of exposure. Plants transferred to 85°F (29.4°C) before flecking were susceptible, those
transferred at flecking were mesothetic, and those transferred afterwards were resistant. The minimum exposure to either temperature was 4 days although fluctuations in temperature were cumulative in effect. Preinoculation exposure to high temperatures did not affect the reaction. The temperature effect was a localised reaction. New sources of resistance to oat stem rust were differentiated by rust reactions at both high and low temperatures.

In 1960, Mohamed demonstrated that the preinoculation temperature to which wheat seedlings are exposed, may also alter their reaction to stem rust. More infection centers were produced and reaction was shifted to a more susceptible type, if the preinoculation temperature was 85°F (29.4°C) than if it was 70°F (21.1°C). The longer the inoculated seedlings of certain wheat varieties were kept at higher temperatures after inoculation and the higher the temperature up to a certain degree of temperature, the larger were the uredia; this was most pronounced with temperature sensitive varieties. Sharp (1962) found that preinoculation temperature was often critical in determining rust reaction types induced by P. striiformis. Several wheat varieties, including Omar and Idaed were susceptible when grown at 15°C prior to inoculation, but resistant when grown at 24°C in the preinoculation period. Other varieties such as Webster and Holzapfels Früh were susceptible when preconditioned at 24°C and resistant when
preconditioned at 15°C. Many varieties exhibited identical rust reaction types after being grown at 15°C or 24°C. In 1965, Sharp reported that the dark-period temperatures during both the preinoculation and postinoculation phases were critical in determining infection type.

Studies on the effects of temperature on expression of infection type are most complete with wheat stem rust. The results of this work may be briefly summarized as follows; (1) the reaction of most varieties of wheat is essentially constant over a wide range of temperature but there are varieties whose infection types in response to certain strains of the pathogen may vary from susceptible to more resistant or vice versa, depending upon the postinoculation or even the preinoculation temperature; (2) host reactions 2 and X are the most readily altered ones and types 0,0; and 4 are the most stable. Type X may become only a susceptible or a resistant type under the influence of temperature; (3) shifts in reaction are usually very narrow, from one type to the next one above or below, but a few cases of a highly resistant reaction changing into a highly susceptible type or vice versa have been reported; (4) it appears to take a fairly long time of exposure (a few days) for the temperature to bring about a shift in reaction so that diurnal changes in temperature are not likely to be important in this connection; (5) a shift in reaction response is not permanent but is lost by exposure
of the host to the original temperature for a few days; and
(6) a shift in reaction of a host variety may be induced to
one or more strains but not to other strains.

4. **Germinability of Uredospores**.

In 1939, Straib observed that the temperature at which
uredospores of *P. glumarum*, yellow rust of wheat, are
produced determine their germinability. Those produced at
20°-25°C germinated more quickly and over a wider range of
temperatures than did those produced at 8°-10°C.

5. **Teliospore Formation**

One of the many interesting phenomena in the life
history of a rust is the formation of the teliospores, which
commonly takes place in the sori that previously had produced
uredospores. Many investigators have studied the effect of
environmental factors, especially temperature, light and
moisture on teliospore formation.

Eriksson (1898) suggested that only the teliospores
produced in the late autumn succeed in germinating in the
following spring (Johnson, 1931). Melander (1935) observed
that the production of telia by *P. graminis* on wheat, oats
and rye was stimulated at a low temperature (0° to 1°C).
Peturson (1930) however, studied the effect of different
environmental conditions on the formation of telia of crown
rust and concluded that telia formed more readily at moderately
warm temperatures than at cool temperatures. Simons (1954)
found that telia of *P. coronata avenae* were produced earlier and in greater abundance at 25°C, in most cases; this difference was greatest with the more resistant varieties.

Johnson (1931) studied telial formation in physiologic forms of *P. graminis tritici*. He found that relatively high temperatures favoured rapid teliospore formation, but there were inherent differences also between forms in respect to their telial development. He observed also that most rapid telial development occurred at the nodes of the plants. In other words, environmental factors, constitution of the fungus mycelium and specific host tissues had some effect on teliospore formation.

From a study of the telial development of several rust fungi, Waters (1928) concluded that factors such as light, temperature and moisture may influence the metabolism of the host that the fungus reacts by changing from the uredinial to the telial stage. That is, environmental factors are of importance, but are indirect in their action. Gassner (1915) found that the development of teliospores of the cereal rusts occurred when the host plant reaches a certain stage of maturity, and that telial development is independent of external conditions (Johnson, 1931).

6. *Sunflower Rust*

The only references in the literature on the temperature relations of *P. helianthi* that could be found, were those of Bailey (1922, 1923). Both teliospores and uredospores germinate through a rather wide range of temperature, 6°C to 28°C, with an optimum at 18°C. Infection by uredospores is
very heavy by the end of an incubation period of twenty-four hours but some infection can occur in 6 hours. Uredia do not develop below 10°C but the mycelium will remain dormant in infected leaves for at least a month at this temperature and uredia will subsequently develop when the plants are transferred to higher temperatures.

B. LIGHT EFFECTS

In contrast to temperature, which apparently affects both host and parasite about equally, light as a rule affects the host more than the pathogen. Light intensity and quality and length of day may be significant. In general lack of light for normal photosynthetic activity due to too short exposure or too low intensity of light tends to weaken the host making it more susceptible to facultative parasites and more resistant to obligate ones (Gaumann, 1950).

1. Intensity of Infection

Since the uredospores penetrate through the stomata much consideration has been given to the significance of the opening and closing of stomata under the influence of light as a factor in determining inoculum efficiency. In general, this appears to be a factor of little or no significance and most workers use light-tight containers as moist chambers and obtain good infection (Caldwell and Stone, 1936, Chester, 1946 and Hart and Forbes, 1935). Hart and Forbes (1935) demonstrated that leaf rust of wheat, crown rust of oats and snapdragon
rust could enter their hosts in darkness as well as in light while darkness could inhibit infection by the wheat stem rust fungus and bean rust but only slightly influenced infection of corn and sunflower rust. Sharp et al. (1958) obtained maximum inoculum efficiency with the uredospores of P. graminis tritici at all light intensities below 300 foot-candles (and within an accompanying temperature range of 15.6°C to 23.9°C) up to the completion of appressoria formation followed by light intensities over 500 foot-candles (and higher temperatures).

2. The Incubation Period.

The length of incubation period may be strongly affected by light. In general relatively high light intensity and long days are most favourable for rapid invasion and abundant sporulation. Wheat stem rust develops well under light intensities ranging from 500 to 10,000 ft-c. The incubation period is likely to shorten and sporulation to increase with increasing light (Stakman and Harrar, 1957). Uredia of Melampsora lini, flax rust, appeared 9 days after inoculation under normal light, in 6.5 days under continuous light and in 14 days under reduced light intensity (Hart, 1926). The incubation period of P. glumarum was twice as long at low light intensities as it was at 960 ft-c and 9 days longer when infected barley was exposed to 6-hour days than when it was exposed to 12-hour days (Bever, 1934). While increase in
light from suboptimal to optimal amounts shortens the incubation period, Scheibe found that increases above an optimum amount may cause an extension of this period, (Chester, 1946).

3. **Infection Class and Types**

   Not only is the incubation period influenced by light but the type of rust reaction may be altered. Light is not, in general, as effective as temperature and host nutrition in altering reactions. There are many records, however, of reactions being changed from susceptible to more resistant or vice versa by changes in the light factor when temperature is maintained constant (Chester, 1946, Gaumann, 1950, Stakman and Harrar, 1957).

   In 1941, Newton and Johnson tested 7 rust races on 7 differential wheats during 3 months of different light intensities, and light duration at 60° and 75°F (15.6°-23.9°C). Many changes from a resistant to a more susceptible type as light intensity or day length was increased were observed. This was expressed to a greater or lesser degree by all varieties toward one or more races and by all races toward one or more varieties. Varieties normally expressing extreme resistance or susceptibility were less affected than those expressing moderate resistance or susceptibility. It was further seen that temperature was more influential in changing reaction types than was light; a significant temperature
alteration was observed in cases in which light produced only a slight effect. The normal seasonal variation in the light factor brought about alterations in reactions.

Bever (1934) observed that susceptible varieties of wheat tended to show a more resistant type of infection towards *P. glumarum* when exposed to day lengths of more than 12 hours. According to Hart and Zaleski (1935) the development of race 21 of wheat stem rust on Hope wheat is depressed by high light intensity while it is normal at lower intensities.

Resistance can be altered by light without a change in infection type. Daly (1964) reported that transfers from incandescent-fluorescent light before inoculation to fluorescent light immediately after incubation increased pustule numbers, whereas the opposite transfer markedly inhibited pustule formation by *P. graminis tritici*. Transfers following the infection period had the opposite but not so marked effect. He interpreted the data as indicating a major influence of light on the biochemical and physiological factors of the host prior to incubation and on the first day after inoculation.

The increase in resistance of hosts to rusts under inadequate light is generally regarded as being due to the lowered photosynthesis of the host and this contention is supported by the fact that rusts develop on leaves in the dark if they are fed sugar (Chester, 1946).
4. **Uredospore Germinability**

Uredospores of *P. coronata* were not viable if they developed on plants lacking sufficient light (Hobbs, 1962).

5. **Teliospore Formation**

Cereal rusts change from production of uredospores to teliospores when days became short. The uredial stage of *U. phaseoli* continues to develop when daylight hours equal or exceed the hours of darkness but when nights became longer than the day, then, only the telial stage appears; in Florida the telial stage never appears (Chupp and Sherf, 1960).

6. **Sunflower Rust**

Bailey (1923) found that light had a marked influence on the rapidity of the development of sunflower rust. Reduced light increased the length of the incubation period by about 2 days and a further reduction of the light intensity appeared to prolong it indefinitely.
III MATERIALS AND METHODS

Sunflower rust races 1 and 3 (Sackston, 1962) were used in these studies. Two varieties of sunflower plants were used: S37-388, which is susceptible to all collections of rust from Helianthus annuus so far tested; and CM90RR which is resistant to race 1 but susceptible to race 3. Seed of these two varieties was supplied by Dr. E.D. Putt, Canada Department of Agriculture Experimental Farm, Morden, Manitoba.

Seedlings were grown in 4-inch pots in a greenhouse maintained at 70°F (21.1°C) in winter, fluctuating temperatures in spring and summer. Six to seven seeds were sown in each pot. When the first pair of true leaves were fully expanded, three to five plants in each pot were chosen for uniformity of size and vigor and the rest were discarded. In most experiments, seedlings were inoculated when the second pair of leaves was well unfolded.

Plants were inoculated with uredospores suspended in distilled water with 0.1% Tween-80 to reduce surface tension, sprayed from a DeVilbiss atomizer. After inoculation, plants were incubated in a saturated light-tight moist chamber kept at approximately 20° to 23°C for 24 hours. At the end of 24 hours, plants were incubated in controlled environment chambers.

Uredospores were collected when the rust pustules reached full development by shaking the leaves with tweezers into petri dishes. Germinability of fresh spores produced
under different conditions was determined on spores collected. The remainder was kept in the freezer (-16°C to -20°C) for several weeks before being used, to determine the effect on germinability of stored spores. Spores were distributed uniformly on 1% water agar either on standard slides or in 9 cm petri dishes by means of an aspirator, as shown in Figure 1. They were incubated at room temperature in darkness. Results were recorded 24 hours after inoculation. The spores were covered with a drop of lactophenol and cotton blue and a coverslip deposited before counting. The germination percentage data were analyzed statistically using the Arcsin transformation (Steel and Torrie, 1960).

The reaction types were classified by size and vigor of sporulation of uredia as indicated by Sackston (1962):

0; - Hypersensitive flecks.
1 - Very resistant, producing very small, very weakly sporulating uredia.
2 - Moderately resistant, producing small, less strongly sporulating uredia.
3 - Moderately susceptible, producing medium-sized, vigorously sporulating uredia.
4 - Very susceptible, producing large, vigorously sporulating uredia.

The statistical design used for most experiments was the randomized complete block. For the individual analyses of treatments, Duncan's new multiple-range test was used (Steel and Torrie, 1960).
Fig. 1. Aspirator for uniform distribution of rust spores to determine germinability.
IV. EXPERIMENTAL RESULTS

A. TEMPERATURE EFFECTS

On August 8, 1964, two varieties of sunflower plants (S37-388 and CM90RR) were sown in 4-inch pots and grown in the greenhouse. Twenty-four pots of each variety, each with 3 plants, were selected according to the uniformity of the plants. Random groups of pots of each variety were placed in each of 4 controlled environment chambers maintained at 15°C, 20°C, 25°C, and 30°C respectively, with 8 pots at 15°C and 20°C, and 4 pots at 25°C and 30°C. The plants in each chamber were illuminated with 1500 ft-c of white fluorescent light with photoperiod of 16 hours. At the end of 3 days the plants were removed from the chambers. Half of the pots of each variety from each chamber were inoculated with race 1 and the other half were inoculated with race 3. The spore mass was suspended in 0.1% Tween 80, with 4 mg of spores per ml. After inoculation the plants were placed in a light-tight moist chamber at room temperature (21°C) for 24 hours. At the end of this period, 2 pots of each race-variety combination were exposed to the following regimes:

<table>
<thead>
<tr>
<th>Pre-inoculation temperature</th>
<th>Post-inoculation temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°C</td>
<td>15°C</td>
</tr>
<tr>
<td>15°C</td>
<td>20°C</td>
</tr>
<tr>
<td>20°C</td>
<td>15°C</td>
</tr>
<tr>
<td>20°C</td>
<td>20°C</td>
</tr>
<tr>
<td>25°C</td>
<td>25°C</td>
</tr>
<tr>
<td>30°C</td>
<td>25°C</td>
</tr>
</tbody>
</table>
The experimental results, unfortunately, were not recorded properly, and the concentration of spore suspension proved to be too high. However, it was observed that the density of pustules was greater and the reaction type developed better under the 15°C pre-inoculation and 20°C post-inoculation temperature regime than at 15° and 15°C, 20° and 20°C, and 20° and 15°C respectively. Pre-inoculation temperature of 30°C and post-inoculation 25°C gave better results than the 25° and 25°C regime.

The following experiments were designed to provide data on the influence of constant temperatures, varying day-night temperatures, and various pre- and post-inoculation temperature regimes on sunflower rust development.

1. Constant Post-infection Temperatures

An experiment was designed to provide data upon the effects of constant post-infection temperatures upon
(a) inoculum efficiency as appraised by the density of rust pustule development, (b) the length of the incubation period or time from inoculation to appearance of rust symptoms, (c) type of pustule, (d) uredospore germinability, and (e) telial formation.

Sunflowers of two varieties (S37-388 and CM90RR) were sown on February 1st, 1965, and grown in the greenhouse. Twenty-four pots of each variety (each with 3 plants with second pair of leaves fully developed) were selected for
uniformity of plants and inoculated on March 4th, 1965. Twelve pots of each variety were uniformly inoculated with a uredospore suspension of race 1, and the remaining 12 pots of each variety were inoculated with race 3. One ml of suspension contained approximately 2 mg of fresh spores.

The inoculated plants were placed in a light-tight moist chamber in a room kept at 21° - 23°C. After 24 hours, 3 pots of each variety-race combination were transferred to each of four controlled environment chambers maintained at 15°, 20°, 25°, and 29°C, respectively. The light period was 16 hours per day, at 1500 foot candles. The plants were observed daily for 15 days.

a) Inoculum efficiency as determined by density of pustules

The density readings (number of rust pustules per square centimeter of leaf surface) were made 15 days after inoculation. The averages of 3 random readings for each set of three plants are recorded in Table 1.

The data were analyzed statistically. There was no significant difference between older and younger leaves (Appendix Table I, II and III). When S37-388 inoculated with race 1 the interaction between leaf age and temperature was very highly significant. Duncan's multiple-range test was applied to the data for infection on leaves of two ages at the various temperatures. The younger leaves (second pair) were more sensitive than older leaves to the influence of temperature.
TABLE 1. Effect of constant post-infection temperature on density of rust pustules per cm² of leaf surface (No.) and on host reaction type (Type) of sunflowers.

| Variety   | Temperature °C | Race 1 (1st leaves) | | Race 1 (2nd leaves) | | Race 3 (1st leaves) | | Race 3 (2nd leaves) |
|-----------|----------------|---------------------|---|--------------------|---|--------------------|---|
|           |                | No. | Type | No. | Type | No. | Type | No. | Type |
| S37-388   | 15°            | 19.7| 2⁻,2 | 7.3 | 2⁺,3 | 14 | 2⁻,2 | 16 | 3⁻,3 |
|           | 20°            | 16  | 3⁻,3 | 15  | 3⁻ to 4 | 13 | 3.4  | 15.7| 3.4  |
|           | 25°            | 16.7| 3⁻ to 4 | 15.7| 3.4  | 16.7| 3⁻ to 4 | 16 | 3⁻ to 4 |
|           | 29°            | 13.7| 3⁻,3 | 7.3 | 3⁻ to 4 | - | - | - | - |
| CM90RR    | 15°            | 0   | 0; 0; | 0   | 0; 0; | 12 | 1⁺,2 | 10.7| 1⁺ to 2⁺ |
|           | 20°            | 0   | 0; 0; | 0   | 0; 0; | 15.7| 3   | 18.3| 3⁻ to 4 |
|           | 25°            | 0   | 0; 0; | 0   | 0; 0; | 21  | 3.4  | 22.7| 3⁻ to 4 |
|           | 29°            | 0   | 0; 0; | 0   | 0; 0; | 9   | 2⁺,3⁻ | 6.3 | 2⁻ to 3 |

1) Average readings for the leaves of 9 plants (3 pots, 3 plants per pot).
There were no significant differences in pustule density at various temperatures of either pair of leaves of S37-388 inoculated with race 3 (Figures 2 and 3). Pustule density on younger leaves inoculated with race 1 was significantly greater at 20° and 25°C than at 15° and 29°C (Appendix Tables I-a and I-b).

On CM90RR inoculated with race 3, pustule density was significantly higher on older leaves at 25°C than at 29°C (Fig. 4, Appendix Tables II-a and II-b). On younger leaves density was significantly higher at 20° and 25°C than at 15° and 29°C (Fig. 5).

\[\text{b) Length of incubation period}\]

The effect of the four post-infection temperatures upon the length in days of the incubation period or time from inoculation to earliest appearance of symptoms is shown in Fig. 6. The incubation period was shortest at 25°C for both races on the two varieties. The incubation periods for both races were consistently somewhat shorter on variety CM90RR than on S37-388 at 15°, 20° and 25°C but at 29°C they were practically the same.

The length of time required for sporulation of both races on variety S37-388 and of race 3 on CM90RR at 15°, 20°, 25° and 29°C was 10, 7-8, 7, and 7 days respectively.

\[\text{c) Type of pustule}\]

Data concerning the influence of the four post-infection temperatures upon host reaction type are included in Table 1.
Fig. 2 Effect of constant temperature on first leaves of S37-388 inoculated with race 3. From left to right 25°, 20°, and 15°C, respectively.

Fig. 3 Effect of constant temperature on second pair of leaves of S37-388 inoculated with race 3. From left to right 25°, 20°, and 15°C, respectively.
Fig. 4  Effect of constant temperature on first leaves of CM90RR inoculated with race 3. No. 1, 2, 3 and 4 indicates 29°, 25°, 20° and 15°C respectively.

Fig. 5  Effect of constant temperature on second pair of leaves of CM90RR inoculated with race 3. No. 1, 2, 3 and 4 indicates 29°, 25°, 20° and 15°C respectively.
Fig. 6  Effect of constant post-infection temperature upon the length of incubation period of *Puccinia helianthi*, races 1 and 3 on varieties S37-388 and CM90RR.
Temperature had no influence on the resistant reaction (type 0;) resulting from race 1 on CM90RR. The susceptible 3 and 4 type reactions induced by race 1 and 3 on S37-388, and race 3 on CM90RR, proved to be influenced by temperature variation. They showed some, usually small, difference in reaction type as the temperature varied. Rather striking difference in reaction type on the first leaves from 3 and 4 at 25° to 1+ and 2 at 15°C occurred with race 3 on CM90RR (Fig. 4). In general changes in reaction type were more pronounced on lesions on the upper leaf surface than on the lower surface. Differences among reaction types under various conditions tended to get less with time, approximately 20 days after inoculation.

d) Uredospore germinability

Spores produced by race 1 on S37-388 and by race 3 on CM90RR at 15°, 20°, 25° and 29°C were collected for germinability tests 12 days after inoculation. Half the volume of spores was used to determine germinability of the freshly harvested spores at room temperature on 1% water agar while the remaining half was stored at -16°C for 60 days and then subjected to a similar germinability test.

The data for germination of freshly harvested spores are given in Appendix Tables IV and V. In Figure: 7 it can be seen that spores of race 1 gave very high germination irrespective of temperature of production. The statistical analyses of these data given in Table 2 reveal no significant differences in the germination percentages. The percentage
Fig. 7  Effect of conditions during spore production on germinability of fresh and stored uredospores of *Puccinia helianthi* race 1.

Unshaded portion of bar in each case represents fresh spores, shaded portion spores stored 60 days at -16°C.
Fig. 8 Effect of conditions during spore production on germinability of fresh and stored uredospores of *Puccinia helianthi* race 3.

Unshaded portion of bar in each case represents fresh spores, shaded portion spores stored 60 days at -16°C.
TABLE 2. Duncan's new multiple-range test for the effect of post-infection temperatures in which uredospores were produced upon the percentage germination of fresh uredospores.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Race 1 on Variety S37-388</th>
<th>Race 3 on Variety CM90RR</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°C</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>20°C</td>
<td>100</td>
<td>97</td>
</tr>
<tr>
<td>25°C</td>
<td>99</td>
<td>89</td>
</tr>
<tr>
<td>29°C</td>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>

1) Any two means underscored by the same line are not significantly different.

2) Any two means not underscored by the same line are significantly different.
germination of spores of race 3 produced at 20°C was significantly higher than those produced at 25°C and 29°C. Not enough spores of race 3 were produced at 15°C to determine germination percentage (Fig. 8).

The data for the germination of the stored spores are given in Appendix Tables VI and VII. The storage conditions reduced markedly the germinability of the spores of both races. The reduction was more pronounced with race 3 than with race 1. The statistical analyses presented in Table 3 show that the spores of race 1 produced at 20°C and 25°C retained significantly higher germination values than did those produced at 15°C and 29°C. On the other hand, the spores of race 3 produced at 15°C retained a significantly higher capacity to germinate than did those produced at the other 3 temperatures. Germination of spores produced at 29°C fell to very low levels.

e) Teliospore formation and infectivity

As soon as sporulation began, spores were harvested daily by lightly scraping different pustules each day with the moistened blade of a scalpel. The spores were suspended in distilled water and examined under the microscope for the occurrence of teliospores.

Table 4 gives the length of time it took the teliospores of race 1 to form on variety S37-388 and of race 3 on variety CM90RR whereas those of race 3 on S37-388 were not recorded. It can be seen that, at all temperatures, race 1 on S37-388 formed teliospores earlier than race 3 on CM90RR. Teliospores of both races occurred earliest at 15°C.
TABLE 3. Duncan's new multiple-range test for the effect of post-infection temperature in which uredospores were produced upon the percentage germination of stored spores.

Race 1 on Variety S37-388

<table>
<thead>
<tr>
<th>Temperature</th>
<th>25°C</th>
<th>20°C</th>
<th>15°C</th>
<th>29°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of percentage germination</td>
<td>81</td>
<td>77</td>
<td>63</td>
<td>55</td>
</tr>
</tbody>
</table>

Race 3 on Variety CM90RR

<table>
<thead>
<tr>
<th>Temperature</th>
<th>15°C</th>
<th>25°C</th>
<th>20°C</th>
<th>29°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of percentage germination</td>
<td>37</td>
<td>25</td>
<td>24</td>
<td>3</td>
</tr>
</tbody>
</table>
TABLE 4. The effect of post-infection temperature on formation of teliospores on sunflower rust.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Race</th>
<th>15°C</th>
<th>20°C</th>
<th>25°C</th>
<th>29°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>S37-388</td>
<td>1</td>
<td>16</td>
<td>16-17</td>
<td>18-19</td>
<td>19-20</td>
</tr>
<tr>
<td>CM90RR</td>
<td>3</td>
<td>17</td>
<td>17-18</td>
<td>21-22</td>
<td>23-24</td>
</tr>
</tbody>
</table>
Teliospore formation was more abundant at 15° and 20°C than at 25° and 29°C.

Approximately 1 month after inoculation rusted leaves bearing teliospores produced at various temperatures were harvested and stored at 6°C to maintain the vitality of the teliospores as well as to break spore dormancy. After 25 days, leaves were removed from cold storage and alternately soaked all day and dried overnight for 3 or 4 times to induce germination. The treated telia-bearing leaves were then used for inoculating healthy sunflower plants. This was accomplished by placing a leaf on a moist filter paper in the bottom of a petri dish which was then inverted and placed as a cover on the top of a lamp chimney positioned on a flower pot so as to enclose the 6 sunflower plants growing in it. Three pots of plants were inoculated with teliospores of each race produced on the two varieties at each of four temperatures. The pots were placed in a light-tight moist chamber for 48 hours at 20°C. The plants were then removed, uncovered, and placed in a controlled-environment chamber maintained at 20°C and illuminated with 1500 ft-c at plant level for a period of 16 hours per day.

The number of pycnia on all plants was recorded 20 days after inoculation (Table 5). Teliospores of races 1 and 3 on S37-388 and of race 3 on CM90RR produced at 15°C induced numerous infections. Those produced at 20°C induced few infections. No infections were induced by the teliospores produced under the other conditions.
TABLE 5. The effect of temperature at which teliospores were formed on their infectivity.

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>S37-388</th>
<th>CM90RR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Race 1</td>
<td>Race 3</td>
</tr>
<tr>
<td>15°</td>
<td>16</td>
<td>37</td>
</tr>
<tr>
<td>20°</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>25°</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>29°</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
2. **Varying Day-Night Post-infection Temperatures**

This experiment was carried out to study the effects of various artificial day and night temperature regimes or profiles, (simulating, at least to some degree, the range of natural diurnal temperature changes) upon (a) inoculum efficiency as determined by the density of pustule development, (b) the length of the incubation period, and (c) type of pustule formed.

Plants for this experiment were sown April 7 and inoculated May 4 in the routine way. The spore suspension contained approximately 1 mg of spores (collected and stored on April 19, 1965) per ml. After incubation for 24 hours in a moist chamber in the dark, 3 pots of each variety inoculated with each race were placed in controlled environment chambers with 1500 ft-c illumination for 16 hours per day (6 a.m. to 10 p.m.) and the following temperature programs:

<table>
<thead>
<tr>
<th></th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>25°C</td>
<td>25°C</td>
</tr>
<tr>
<td>2.</td>
<td>25°C</td>
<td>18°C</td>
</tr>
<tr>
<td>3.</td>
<td>33°C</td>
<td>23°C</td>
</tr>
<tr>
<td>4.</td>
<td>28°C 6 a.m. - 10 a.m.</td>
<td>33°C 10 a.m. - 6 p.m.</td>
</tr>
<tr>
<td></td>
<td>33°C 10 a.m. - 6 p.m.</td>
<td>28°C 6 p.m. - 10 p.m.</td>
</tr>
<tr>
<td></td>
<td>25°C 10 p.m. - 6 a.m.</td>
<td></td>
</tr>
</tbody>
</table>

The temperature mechanisms of these chambers were very efficient and adjusted the air temperature from one level to another in
15 minutes or less depending upon the magnitude of the change required. The stepwise temperature regime (4) was included to approach more closely the gradual and rather long drawn out diurnal cycle of temperature changes occurring under natural conditions.

a) **Inoculum efficiency as determined by density of pustules**

The number of pustules on half of each leaf surface was counted 14 days after inoculation. The results are shown in Table 6.

The data were analyzed statistically (Appendix Tables VIII, IX and X). Differences due to temperature were not significant for race 1 on S37-388, highly significant for race 3 on S37-388, and significant at the 5% level for race 3 on CM90RR. Differences due to age of leaves were significant at the 5% level (race 1 on S37-388) or the 1% level (race 3 on S37-388 and on CM90RR). There was a significant interaction between age of leaves and temperature regime in S37-388 inoculated with race 1, and CM90RR inoculated with race 3. Duncan's multiple range test was applied to the means for individual variety-race combinations exposed to the various temperature regimes (Appendix Tables VIII-a, VIII-b, IX-a, IX-b, X-a, and X-b). Age of leaves of S37-388 inoculated with race 1 was significant only in the 25°C-25°C and 28°C-33°C-28°C-25°C regimes (Appendix Table VIII-c). Age of leaves of CM90RR was significant in all temperature regimes (Appendix Table X-c).
TABLE 6.

Effect of varying post-infection temperature on density of rust pustules per half leaf (No.) and on host reaction type (Type) on sunflowers.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Day-night Temperatures °C</th>
<th>Race 1</th>
<th></th>
<th></th>
<th>Race 3</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1st leaves</td>
<td>2nd leaves</td>
<td>1st leaves</td>
<td>2nd leaves</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No.</td>
<td>Type</td>
<td>No.</td>
<td>Type</td>
<td>No.</td>
<td>Type</td>
</tr>
<tr>
<td>S37-388</td>
<td>25° - 25°</td>
<td>95.6</td>
<td>2 to 4</td>
<td>67.8</td>
<td>3(^-) to 4</td>
<td>89.0</td>
<td>2 to 4</td>
</tr>
<tr>
<td></td>
<td>25° - 18°</td>
<td>78.8</td>
<td>2(^-) to 4</td>
<td>64.5</td>
<td>3(^-) to 4</td>
<td>95.2</td>
<td>2 to 3</td>
</tr>
<tr>
<td></td>
<td>33° - 23°</td>
<td>56.6</td>
<td>1 to 2(^-)</td>
<td>53.1</td>
<td>2(^-) to 3</td>
<td>63.9</td>
<td>1(^+) to 2</td>
</tr>
<tr>
<td></td>
<td>28°-33°-28°-25°</td>
<td>96.8</td>
<td>1(^+) to 3</td>
<td>73.4</td>
<td>2 to 4</td>
<td>78.8</td>
<td>2(^-) to 2(^+)</td>
</tr>
<tr>
<td>CM90RR</td>
<td>25° - 25°</td>
<td>1</td>
<td>2</td>
<td>0.2</td>
<td>2</td>
<td>77.9</td>
<td>3(^-) to 4</td>
</tr>
<tr>
<td></td>
<td>25° - 18°</td>
<td>1</td>
<td>2(^-)</td>
<td>0.3</td>
<td>2(^-)</td>
<td>99.8</td>
<td>2(^-) to 4</td>
</tr>
<tr>
<td></td>
<td>33° - 23°</td>
<td>0.1</td>
<td>2(^+)</td>
<td>0.1</td>
<td>2</td>
<td>52.8</td>
<td>1(^+) to 2</td>
</tr>
<tr>
<td></td>
<td>28°-33°-28°-25°</td>
<td>0.4</td>
<td>2(^+)</td>
<td>0</td>
<td>-</td>
<td>83.4</td>
<td>2(^-) to 3</td>
</tr>
</tbody>
</table>

1) Average readings for the leaves of 12 plants (3 pots, 4 plants per pot)
b) Length of incubation period

The effect of the four day-night post-infection temperature regimes upon the length in days of the incubation period is shown in Fig. 9. The incubation period is 5 days at 25°C day-night for both varieties infected with either of the two races. At 33°C day and 23°C night temperatures the incubation period is 6 days for these race-variety combinations. At 25°C day and 18°C night, the incubation period on CM90RR inoculated with either race was 1 day shorter than on 33-388 inoculated with either race. Under the stepwise temperature regime (28°C-33°C-28°C-25°C) the incubation period for race 1 was 1 day shorter than for race 3 on 33-388, and 1 day longer than for race 3 on CM90RR.

Sporulation of both races on variety 33-388 and of race 3 on variety CM90RR at 33°C day and 23°C night occurred 2 days after flecks appeared. Under all other conditions sporulation occurred 1 day after the appearance of flecks.

c) Type of pustule

The effect of day-night post-infection temperature regimes upon the type of pustules is shown in Table 6. The day-night temperature regimes had no marked influence on the resistant reaction of variety CM90RR infected by race 1. The susceptible type 3 and 4 reactions on 33-388 infected with either race, and on CM90RR infected with race 3 appeared to be affected more by the day-night temperature variations (Figs. 10,
Fig. 9. Effect of day-night post-infection temperature upon the length of incubation period of *Puccinia helianthi* races 1 and 3 on varieties S37-388 and CM90RR.
Fig. 10 Effect of day-night temperature on first pair of leaves of S37-388 inoculated with race 1. From left to right 25°-18°C, 25°-25°C, 28°-33°-28°-25°C, and 33°-23°C respectively.

Fig. 11 Effect of day-night temperature on second pair of leaves of S37-388 inoculated with race 1. From left to right 25°-18°C, 25°-25°C, 28°-33°-28°-25°C, and 33°-23°C respectively.
Fig. 12 Effect of day-night temperature on first pair of leaves of CM90RR inoculated with race 3. From left to right 25°-18°C, 25°-25°C, 28°-33°-28°-25°C and 33°-23°C, respectively.

Fig. 13 Effect of day-night temperature on second pair of leaves of CM90RR inoculated with race 3. From left to right 25°-18°C, 25°-25°C, 28°-33°-28°-25°C and 33°-23°C respectively.
Young leaves of S37-388 inoculated with race 1 showed strikingly less chlorosis under the 33°-23°C regime than under the other conditions (Fig. 11).

The reaction type of both races on variety S37-388 is lowest at 33°C day with 23°C night. Race 3 on CM90RR induced some flecks at all temperature conditions, though many type 3 and 4 reactions were present on the same leaf surface.

At all times, rust pustules were more numerous and larger on the lower leaf surfaces than on the upper ones, of both the first and second pairs of leaves. The reaction types on the lower leaf surfaces were usually a class higher (more susceptible) than those on the upper surfaces.
3. **Pre-inoculation and Post-inoculation Temperatures**

This experiment was an attempt to provide data on the effects of pre-inoculation and post-infection temperatures upon (a) inoculum efficiency as determined by density of pustules, (b) the length of the incubation period and (c) type of pustule.

On February 17, 1965, seeds of the two varieties, S37-388 and CM90RR were sown in 4-inch pots. On March 19 when the second pair of leaves had attained their full expansion, 14 pots of S37-388 and 28 pots of CM90RR were selected for uniformity of the plants. Four pots of S37-388 and 8 of CM90RR were placed in each of 3 controlled environment chambers maintained at 15°, 20°, and 29°C respectively. Two pots of S37-388 and 4 of CM90RR were placed in a chamber operating constantly at 24°C. The temperature variations in these chambers did not exceed ±1°C. The plants in each chamber were illuminated with 1500 ft-c of white fluorescent light; the photoperiod was 16 hours. At the end of 3 days the plants were removed from the chambers. S37-388 was inoculated with race 1; half of the pots of CM90RR from each chamber were inoculated with race 1, and the other half from each chamber with race 3. The spore suspension used as inoculum contained 1 to 1.5 mg of uredospores (collected and stored on January 29, 1965) per ml. After inoculation the plants were placed in a light-tight moist chamber at room temperature (21°-23°C) for 24 hours. Upon removal from the moist chamber, 2 pots of each variety inoculated
with each race were returned to the chambers in which they had been conditioned prior to inoculation. Another 2 pots of each variety-race combination were placed under new conditions, as follows:

<table>
<thead>
<tr>
<th>Pre-inoculation temperature</th>
<th>Post-inoculation temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°C</td>
<td>24°C</td>
</tr>
<tr>
<td>20°C</td>
<td>29°C</td>
</tr>
<tr>
<td>29°C</td>
<td>15°C</td>
</tr>
</tbody>
</table>

The plants were observed daily.

a) **Inoculum efficiency as determined by density of pustules**

The number of pustules per square centimetre of leaf surface was counted 13 days after inoculation. The average readings for each set of 2 pots (8 plants) of S37-388 inoculated with race 1 and CM90RR with race 3 are presented in Table 7. Plants of CM90RR inoculated with race 1 showed only flecks under all conditions; no pustules were produced.

The analyses of variance of the data for S37-388 inoculated with race 1 are shown in Appendix Table XI. Differences due to age of leaves and to pre-inoculation and post-infection temperatures were not significant. Furthermore, the interaction between age of leaves and pre- and post-inoculation temperature was also non-significant.

Analysis of the data for CM90RR inoculated with race 3 (Appendix Table XII) showed no significant differences due to temperatures or to age of leaves, but a significant interaction
TABLE 7.  Effect of pre-inoculation and post-inoculation temperatures on density of rust pustules per cm² of leaf surface (No.) and on host reaction type (Type) of sunflowers.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Temperature</th>
<th>Race 1</th>
<th>Race 3</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1st leaves</td>
<td>2nd leaves</td>
<td></td>
<td>1st leaves</td>
<td>2nd leaves</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-inoc.</td>
<td>Post-inoc.</td>
<td>Type</td>
<td>No.</td>
<td>Type</td>
<td>No.</td>
<td>Type</td>
</tr>
<tr>
<td>S37-388</td>
<td>15°</td>
<td>15°</td>
<td>17.2</td>
<td>1+ to 2</td>
<td>15.7</td>
<td>2, 2+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20°</td>
<td>20°</td>
<td>10.8</td>
<td>2+ to 3</td>
<td>19.0</td>
<td>3, 3+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24°</td>
<td>24°</td>
<td>12.7</td>
<td>3-, 3</td>
<td>14.3</td>
<td>3- to 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15°</td>
<td>24°</td>
<td>11.3</td>
<td>3, 3+</td>
<td>15.0</td>
<td>3, 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20°</td>
<td>29°</td>
<td>11.5</td>
<td>3-, 3</td>
<td>17.3</td>
<td>3-, 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>29°</td>
<td>15°</td>
<td>15.2</td>
<td>1+ to 2</td>
<td>10.5</td>
<td>2-, 2</td>
<td></td>
</tr>
<tr>
<td>CM90RR</td>
<td>15°</td>
<td>15°</td>
<td>11.3</td>
<td>1+ to 2</td>
<td>25.8</td>
<td>2, 2+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20°</td>
<td>20°</td>
<td>20.7</td>
<td>2+ to 3</td>
<td>16.7</td>
<td>3-, 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24°</td>
<td>24°</td>
<td>15.2</td>
<td>2+ to 3</td>
<td>11.5</td>
<td>3, 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>29°</td>
<td>29°</td>
<td>2.8</td>
<td>2, 2+</td>
<td>6.8</td>
<td>3- to 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15°</td>
<td>24°</td>
<td>19.8</td>
<td>3, 4</td>
<td>17.2</td>
<td>3, 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20°</td>
<td>29°</td>
<td>8</td>
<td>3-, 3</td>
<td>6.8</td>
<td>3-, 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>29°</td>
<td>15°</td>
<td>10.5</td>
<td>1+, 2-</td>
<td>6.7</td>
<td>1+, 2-</td>
<td></td>
</tr>
</tbody>
</table>

1) Average readings for the leaves of 8 plants (2 pots, 4 plants per pot).
between leaf age and temperature regime. When Duncan's new multiple-range test was applied to the data (Appendix Tables XII-a and XII-b), there was no significant difference in pustule densities on the first (older) leaves exposed to the 20°-20°C, 15°-24°C, and 24°-24°C regimes, but the 20°-20°C and 15°-24°C regimes gave significantly higher pustule densities than the other temperature combinations. Pustule densities were lowest on first leaves of plants exposed to the 290-290°C regime. On the younger second leaves, highest pustule densities developed in the 15°-15°C regime, and the lowest in 290-15°C, 290-290°C, 20°-290°C and 24°-24°C regimes.

b) **Length of incubation period**

The effect of the pre-inoculation and post-infection temperatures on length of the incubation period is shown in Figure 14. There were no differences in incubation period attributable to host variety or rust race in any temperature sequence.

The shortest incubation period, 4 days, was observed in plants exposed to the sequences 24°-24°C, and 20°C-29°C. The longest incubation period, 7 to 8 days, was observed in the sequence 15°-15°C (which gave the highest density of rust pustules on second leaves of CM90RR inoculated with race 3 - Table 7).
Fig. 14. Effect of pre- and post-inoculation temperature upon the length of the incubation period of *Puccinia helianthi*, race 1 on variety S37-388 and races 1 and 3 on variety CM90RR.
c) **Type of pustule**

The effect of pre-inoculation and post-infection temperatures on reaction types is shown in Table 7. S37-388 gave susceptible reactions to race 1 and CM90RR to race 3, on the second pair of leaves, when post-infection temperatures were 20°C or higher. The older (first pair) leaves gave susceptible reactions over a narrower range of temperatures. Varying temperature regimes did not affect the resistant reaction of CM90RR inoculated with race 1.
B. POST-INFECTION LIGHT EFFECTS

1. Day Length and Light Intensity

The effects of post-infection day length and light intensity upon sunflower rust were investigated in the same way as the effects of temperature. In the studies of temperature, the light factor was maintained constant at 1500 ft-c at plant level, while in these studies the temperature factor was maintained constant at $20^\circ \pm 1^\circ C$.

Sunflower plants of the varieties S37-388 and CM90RR sown January 6th, 1965 and grown in the greenhouse were selected and inoculated on February 9th, 1965. Sixteen pots variety S37-388 with 5 plants in each pot were inoculated with race 1 and 16 of variety CM90RR were inoculated with race 1 and race 3 respectively. The spore suspension contained 1.5 mg of uredospores (collected and stored on January, 29 1965) per ml.

After inoculation plants were incubated in a moist chamber for 24 hours. At the end of this period, 4 pots of each variety-race combination were transferred to each of 4 controlled environment chambers with day length and light intensities as follows:

<table>
<thead>
<tr>
<th>Day length</th>
<th>Light intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 hr</td>
<td>1200 ft-c</td>
</tr>
<tr>
<td>10 hr</td>
<td>1200 ft-c</td>
</tr>
<tr>
<td>16 hr</td>
<td>600 ft-c</td>
</tr>
<tr>
<td>10 hr</td>
<td>600 ft-c</td>
</tr>
</tbody>
</table>
The illumination in the chambers was provided by V.H.O. cool-white fluorescent tubes.

The effects of light factor upon (a) inoculum efficiency as determined by the density of pustules, (b) the length of the incubation period, (c) type of pustule, and (d) infectivity of teliospores, were studied.

a) **Inoculum efficiency as determined by density of pustules**

The number of pustules per square centimeter of leaf surface was determined on several randomly distributed areas of every leaf. The averages of the density readings from each set of 4 pots (24 plants) are shown in Table 8.

Statistical analyses of the data are shown in Appendix Tables XIII and XIV. Differences were not significant.

b) **Length of incubation period**

The effect of the day length and light intensity upon the length in days of the incubation period is shown as follows:

<table>
<thead>
<tr>
<th></th>
<th>S37-388 Race 1</th>
<th>S37-388 Race 3</th>
<th>CM90RR Race 1</th>
<th>CM90RR Race 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200 ft-c</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 hr</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>1200 ft-c</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 hr</td>
<td>5.5-6</td>
<td>5.5-6</td>
<td>5.5-6</td>
<td>5.5-6</td>
</tr>
<tr>
<td>600 ft-c</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 hr</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>10 hr</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>
TABLE 8. Effect of day length and light intensity upon numbers of rust pustules per cm² of leaf surface (No.) and host reaction type (Type) of 2 sunflower varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Environment</th>
<th>Race 1</th>
<th></th>
<th>Race 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1st leaves</td>
<td>2nd leaves</td>
<td>1st leaves</td>
<td>2nd leaves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No.</td>
<td>Type</td>
<td>No.</td>
<td>Type</td>
</tr>
<tr>
<td>CM90RR</td>
<td>1200 ft-c. 16 hr</td>
<td>0</td>
<td>0;</td>
<td>0</td>
<td>0;</td>
</tr>
<tr>
<td></td>
<td>1200 ft-c. 10 hr</td>
<td>0</td>
<td>0;</td>
<td>0</td>
<td>0;</td>
</tr>
<tr>
<td></td>
<td>600 ft-c. 16 hr</td>
<td>0</td>
<td>0;</td>
<td>0</td>
<td>0;</td>
</tr>
<tr>
<td></td>
<td>600 ft-c. 10 hr</td>
<td>0</td>
<td>0;</td>
<td>0</td>
<td>0;</td>
</tr>
<tr>
<td>S37-388</td>
<td>1200 ft-c. 16 hr</td>
<td>26.1</td>
<td>3, 4</td>
<td>22.1</td>
<td>3, 4</td>
</tr>
<tr>
<td></td>
<td>1200 ft-c. 10 hr</td>
<td>23.1</td>
<td>2+, 3-</td>
<td>24.6</td>
<td>2+, 3-</td>
</tr>
<tr>
<td></td>
<td>600 ft-c. 16 hr</td>
<td>20</td>
<td>3</td>
<td>21.9</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>600 ft-c. 10 hr</td>
<td>16.6</td>
<td>2+</td>
<td>21.4</td>
<td>2+</td>
</tr>
</tbody>
</table>

1) Average readings for the leaves of 24 plants (4 pots, 6 plants per pot).
It can be seen that day length exerts a slight effect on the incubation period of both races on either variety. However, a light intensity seems to have little or no effect.

c) Type of pustule

Data concerning the effect of the day length and light intensity upon the type of pustule are given in Table 8. The reaction type of race 1 on S37-388 and race 3 on CM90RR is highest under 1200 ft-c light intensity and 16 hr day length, and lowest under 600 ft-c and 10 hr day length. The difference due to the effect of day length is larger than due to the effect of light intensity.

d) Infectivity of teliospores

The procedures of the storage and inoculation of teliospores were the same as described in Experiment 1, except that teliospores were collected on February 11 and used in inoculations on March 12, 1965.

The number of pycnia on all plants was recorded 18 days after inoculation, as shown in Table 9. Most numerous infections were induced by teliospores of race 3 on CM90RR produced under 1200 ft-c, and fewer under 600 ft-c. Day length had little apparent effect. Teliospores of race 1 on S37-388 gave rise to relatively few pycnial infections. There was little apparent effect of day length or light intensity, except that spores produced under 1200 ft-c and 16 hr day length induced fewest pycnial infections. No experiment was done with race 3 on S37-388.
TABLE 9. The effect of day length and light intensity at which teliospores were formed on their infectivity.

<table>
<thead>
<tr>
<th>Environment</th>
<th>Number of pycnia 18 days after inoculation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S37-388 Race 1</td>
</tr>
<tr>
<td>1200 ft-c 16 hr</td>
<td>5</td>
</tr>
<tr>
<td>1200 ft-c 10 hr</td>
<td>26</td>
</tr>
<tr>
<td>600 ft-c 16 hr</td>
<td>21</td>
</tr>
<tr>
<td>600 ft-c 10 hr</td>
<td>21</td>
</tr>
</tbody>
</table>
2. **Day Length**

Further experiments were designed to study the possible effect of day length on sunflower rust in greater detail. On April 5, 1965, 12 pots of S37-388 and 24 pots of CM90RR were selected for uniformity of plants, from sunflower plants which had been sown on March 9 in 4-inch pots and grown in the greenhouse. The second pair of leaves was fully expanded. There were 5 plants in each pot.

Twelve pots of each variety were inoculated with race 1 and the remaining 12 pots of CM90RR with race 3. The inoculum contained 1 to 2 mg of spores (collected and stored on March 12, 1965) per ml. After inoculation in a moist chamber, 3 pots of each variety-race combination were transferred to each of 4 controlled environment chambers. The illumination in the chambers was provided by V.H.O. cool white fluorescent tubes giving 1500 ft-c at plant level. The photoperiods were 24, 16, 12, and 6 hours respectively.

The plants were examined daily to appraise (a) inoculum efficiency as determined by density of pustules, (b) length of incubation period, and (c) type of pustule. Germinability of uredospores was also determined.

a) **Inoculum efficiency as determined by density of pustules**

The density of pustules per square centimeter of leaf surface was determined. The average density readings from each set of 3 pots (15 plants) are shown in Table 10.
TABLE 10. Effect of day length upon numbers of rust pustules per cm² of leaf surface (No.) and host reaction type (Type) of 2 sunflower varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Race 1</th>
<th>Race 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st leaves</td>
<td>2nd leaves</td>
</tr>
<tr>
<td>CM90RR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hr</td>
<td>7.0 2⁻, 2</td>
<td>1.1 1⁺, 2⁻</td>
</tr>
<tr>
<td>18 hr</td>
<td>2.5 1⁺, 2⁻</td>
<td>0.1 1⁺, 2⁻</td>
</tr>
<tr>
<td>12 hr</td>
<td>3.4 1⁺, 2⁻</td>
<td>0.1 1⁺, 2⁻</td>
</tr>
<tr>
<td>6 hr</td>
<td>2.0 1⁺, 2⁻</td>
<td>0.2 1⁺, 2⁻</td>
</tr>
<tr>
<td>S37-388</td>
<td>24.3 3⁻ to 4</td>
<td>16.0 3⁻ to 4</td>
</tr>
<tr>
<td></td>
<td>18 hr</td>
<td>20.2 3⁻ to 4</td>
</tr>
<tr>
<td></td>
<td>12 hr</td>
<td>14.6 3⁻ to 4</td>
</tr>
<tr>
<td></td>
<td>6 hr</td>
<td>13.1 2⁺ to 4</td>
</tr>
</tbody>
</table>

1) Average readings for the leaves of 15 plants (3 pots, 5 plants per pot).
The statistical analyses are shown in Appendix Tables XV, XVI, and XVII. The effect of day length was highly significant, but the effect of age of leaves on density of rust pustules was even more pronounced. The first pair of leaves showed a significantly greater density of uredial pustules than did the second pair, under all the photoperiods. The interaction between age of leaves and photoperiods was not significant. When the data were analyzed by Duncan's multiple range test, pustule density of race 1 on S37-388 was found to be reduced by decreases in day length. Density of race 3 on CM90RR was apparently greater under shorter day lengths, but the pattern of response was not consistent for the first and second pairs of leaves.

b) Length of incubation period

Day length had no effect upon the length of the incubation period. It took 6 days for flecks to make their appearance in all cases. It was further observed that uredospores began developing 1 day after flecking appeared under all the different sets of conditions. However, under the 6-hr photoperiod sporulation was observed to be less abundant than under the other periods, which seemed to be about equal in their effect on sporulation.

c) Type of pustules

The host reaction types under the different photoperiods are given in Table 10. There was little evidence of photoperiodic effects. The very abnormal photoperiods of 24 and 6 hours induced minor differences in reaction types in some race-
variety combinations from those produced under the other photoperiods. The reaction types 1 and 2 induced by race 1 on CM90RR in this experiment were unusual; in most other experiments only "0" and "0;" reactions were observed. This experiment differed from many others also in the intensity of chlorosis around the rust pustules. Chlorosis was least pronounced on leaves in the 6 hour photoperiod, and progressively more intense with increasing length of day (Figs. 15 and 16).

d) **Uredospore germinability**

Uredospores produced by race 1 on S37-388 and by race 3 on CM90RR under 24, 18, 12 and 6 hours of illumination were collected 15 days after inoculation. The germinability of the freshly harvested spores and of spores stored at -16°C for 27 days, was determined.

The percentage germination of the freshly harvested spores is given in Appendix Tables XVIII and XIX. The statistical analyses of the data, as shown in Table 11 indicate that the fresh spores of race 1 produced at 18 and 12 hour day lengths gave higher germination values than did the spores produced under 6 and 24 hour day lengths. Those produced under the 24 hour photoperiod gave the lowest germination. Fresh spores produced by race 3 under 18 hours of light showed the highest percentage germination. The spores produced under 6, 24, and 12 hours of light gave progressively lower values. Some drying of the agar film or insufficient thickness of the
Fig. 15. Effect of day length on second pair of leaves of S37-388 inoculated with race 1. From left to right 24, 18, 12 and 6 hr, respectively.

Fig. 16. Effect of day length on second pair of leaves of CM90R inoculated with race 3. From left to right 24, 18, 12 and 6 hr, respectively.
TABLE 11. Duncan's new multiple-range test for the effect of photoperiods under which sunflower rust spores were produced upon the percentage germinability of uredospores.

<table>
<thead>
<tr>
<th>Freshly Collected Spores</th>
<th>Race 1 on Variety S37-388</th>
<th>Race 3 on Variety CM90RR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day length</strong></td>
<td>18 hr</td>
<td>12 hr</td>
</tr>
<tr>
<td><strong>Average percentage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1) germinability</strong></td>
<td>87.2</td>
<td>85.8</td>
</tr>
</tbody>
</table>

Spores Stored 27 days at -16°C

<table>
<thead>
<tr>
<th>Race 1 on Variety S37-388</th>
<th>Race 3 on Variety CM90RR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day length</strong></td>
<td>6 hr</td>
</tr>
<tr>
<td><strong>Average percentage</strong></td>
<td></td>
</tr>
<tr>
<td><strong>1) germinability</strong></td>
<td>46.1</td>
</tr>
</tbody>
</table>

1) Any two means not underscored by the same line are significantly different. Any two means underscored by the same line are not significantly different.
agar layer on which the 12-hr spores were germinating during the test may have reduced their germination.

The percentage germination of the stored spores is given in Appendix Tables XVIII and XIX. Storage conditions reduced markedly the germinability of both races, particularly race 3. From the statistical analyses of the data presented in Table 11 it can be seen that spores of both races produced under a 6-hr day gave the highest percentage of germination. Spores of race 1 produced under 12 and 18 hours of light gave the lowest values, and those produced under 12-hr day length germinated slightly better than those produced under a 24-hr day.
3. **Light Intensity**

The effects of light intensities upon (a) inoculum efficiency as determined by the density of pustules, (b) the length of the incubation period, (c) type of pustule, and (d) uredospore germinability, were studied.

Sunflower plants of the varieties S37-388 and CM90RR sown April 20th, 1965 and grown in the greenhouse were selected and inoculated on May 21st, 1965. Twelve pots of each variety were inoculated with a suspension of race 1 containing approximately 1.5 mg of uredospores (collected and stored on April 19, 1965) per ml, and 12 pots of each variety with race 3.

After incubation for 24 hours in a dark moist chamber in a room kept at 23°C, 3 pots of each variety-race combination were transferred to each of 4 controlled environment chambers. Each chamber was set to give a constant temperature of 20°C ± 1°C and a day length of 16 hours. V.H.O. cool white fluorescent tubes were used to give light intensities at plant level of 500, 1200, 2000, and 2800 ft-c respectively, in the four chambers.

a) **Inoculum efficiency as determined by density of pustules**

The number of pustules of half of each leaf surface was counted 15 days after inoculation. The average readings for each set of 4 plants are given in Table 12.
TABLE 12.  Effect of light intensities on density of rust pustules per half leaf (No.) and on host reaction type (Type) of two sunflower varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Light Intensity ft-c</th>
<th>Race 1 1st leaves</th>
<th>Race 2 2nd leaves</th>
<th>Race 3 1st leaves</th>
<th>Race 4 2nd leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. 1) Type</td>
<td>No. 1) Type</td>
<td>No. 1) Type</td>
<td>No. 1) Type</td>
<td>No. 1) Type</td>
</tr>
<tr>
<td>S37-388</td>
<td>2800</td>
<td>17.2 2+ to 4</td>
<td>17.5 2+ to 4</td>
<td>5.9 2+ to 4</td>
<td>1.5 2+ to 4</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>56.5 2+ to 4</td>
<td>23.1 2+ to 4</td>
<td>41.9 2+ to 4</td>
<td>16.2 2+ to 4</td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td>57 2+ to 4</td>
<td>31.5 2+ to 4</td>
<td>84.9 2+ to 4</td>
<td>34.1 2+ to 4</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>31 2 to 4</td>
<td>12 2+ to 4</td>
<td>25.1 2 to 4</td>
<td>9 2+ to 4</td>
</tr>
<tr>
<td>CM90RR</td>
<td>2800</td>
<td>0 0; 0; 0; 90, (5) 2)</td>
<td>0; 2+ to 4</td>
<td>46, (30) 0; 2+ to 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>0 0; 0; 0; 98.1</td>
<td>0; 2+ to 4</td>
<td>60, (25) 0; 2+ to 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td>0 0; 0; 64.5</td>
<td>2 to 4</td>
<td>16, (8) 0; 2+ to 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>0 0; 0; 71.0</td>
<td>2 to 3</td>
<td>58.8 0; 2+ to 3</td>
<td></td>
</tr>
</tbody>
</table>

1) Average readings for the leaves of 12 plants (3 pots, 4 plants per pot).

2) Number inside the bracket indicates the number of flecks.
The analyses of variance of the data are given in Appendix Tables XXII, XXIII, and XXIV. Differences due to light intensity were not significant. In all combinations, the interactions between age of leaves and light intensities showed highly significant differences (Appendix Table XXV). When the data for race 1 on S37-388 were subjected to Duncan’s test (Appendix Tables XXII-a and XXII-b), it was found that for the first pair of leaves light intensities of 1200 and 2000 ft-c were most favorable for rust development, while 2800 ft-c was least favorable. However, for the second pair of leaves light intensity of 1200 ft-c was optimal and 500 and 2800 ft-c were least favorable (Fig. 17). On S37-388 inoculated with race 3, on both the first and second pairs of leaves, the light intensity of 1200 ft-c was found to be the most favorable for rust development, while 2800 ft-c was least favorable, as shown in Figs. 18 and 19 as well as in Appendix Tables XXIII-a and XXIII-b. It was observed that leaves incubated under 500 ft-c were much darker that the others, and that they showed least chlorosis around the pustules.

Different results were obtained on variety CM90RR inoculated with race 3 (Appendix Tables XXIV-a and XXIV-b). For the first pair of leaves, light intensities of 2000 and 2800 ft-c were best for rust development and light intensities of 500 and 1200 ft-c were unfavorable. However, for the second pair of leaves, light intensities of 2000 and 500 ft-c were
Fig. 17. Effect of light intensity on second pair of leaves of S37-388 inoculated with race 1. From left to right 500, 1200, 2000 and 2800 ft-c respectively.
Fig. 18. Effect of light intensity on first pair of leaves of S37-388 inoculated with race 3. From left to right 500, 1200, 2000 and 2800 ft-c respectively.

Fig. 19. Effect of light intensity on second pair of leaves of S37-388 inoculated with race 3. From left to right 500, 1200, 2000 and 2800 ft-c respectively.
the most favorable, and 1200 ft-c was the least favorable (Figs. 20 and 21). There was least chlorosis on leaves incubated at 500 ft-c.

b) Incubation period

The time required for the appearance of symptoms tended to be 6 days under all light conditions. Light intensity apparently did not influence the length of incubation period.

c) Type of pustule

Data concerning the effect of the light intensities upon the type of pustule are given in Table 12.

The reaction type on the first pair of leaves of S37-388 inoculated with either race was slightly higher at 1200, 2000, and 2800 ft-c than at 500 ft-c. On CM90RR inoculated with race 3 numerous flecks appeared on the younger second leaves at 1200, 2000, and 2800 ft-c, and a few on the first leaves at 2800 ft-c. The flecks were more numerous at the higher light intensities. The reaction type on older leaves tended to be slightly higher (more susceptible) under the higher light intensities than under lower ones.

Variations in light intensity did not affect the resistant (0;) reaction of CM90RR to race 1.

Under all conditions, rust developed better on the lower leaf surface than on the upper one, though the difference was not so obvious under 500 ft-c as under the three other conditions of illumination.
Fig. 20. Effect of light intensity on first pair of leaves of CM90RR inoculated with race 3. From left to right 500, 1200, 2000 and 2800 ft-c respectively.

Fig. 21. Effect of light intensity on second pair of leaves of CM90RR inoculated with race 3. From left to right 500, 1200, 2000 and 2800 ft-c respectively.
d) *Uredospore germinability*

Spores were collected and tested for their germinability on June 9th, 1965. The germinability of only freshly collected spores was determined. As in the previous experiments the spores used in this study were race 1 produced on variety S37-388 and race 3 on CM90RR.

Percentage germination is given in Appendix Tables XXVI and XXVII. When these data were subjected to Duncan's new multiple-range test it was found, as shown in Table 13, that spores of race 1 produced under 2000 ft-c gave the highest germination while those produced under 2800 ft-c gave the lowest. On the other hand, the light intensity had no significant effect on the germinability of spores of race 3, which was much lower than that of race 1.
TABLE 13. Duncan's new multiple-range test for the effect of light intensities under which uredospores were produced upon the percentage germination of fresh uredospores.

<table>
<thead>
<tr>
<th>Race 1 on Variety S37-388</th>
<th>Light intensities</th>
<th>2000</th>
<th>1200</th>
<th>500</th>
<th>2800</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
<td></td>
</tr>
<tr>
<td>Average of percentage 1)</td>
<td>germination</td>
<td>86.6</td>
<td>77.2</td>
<td>70.8</td>
<td>53.0</td>
</tr>
</tbody>
</table>

| Race 3 on Variety CM9ORR |
|--------------------------|-------------------|------|------|------|------|
| Light intensities        | 500               | 1200 | 2800 | 2000 |
| ft-c                     | ft-c              | ft-c | ft-c |
| Average of percentage 1) | germination       | 21.6 | 20.2 | 15.3 | 15.1 |

1) Any two means not underscored by the same line are significantly different. Any two means underscored by the same line are not significantly different.
V. DISCUSSION AND CONCLUSIONS

Preliminary experiments in the series on which this thesis is based indicated a broad range of environmental conditions which should be investigated for their effects on biology of the sunflower rust pathogen, and on the development of rust on sunflowers. Because of some unforeseen difficulties, time did not permit repetition of critical experiments. The discussion and conclusions which follow are therefore based on limited experimental evidence, and may need to be revised when the results of additional experiments are available.

The density of pustules on inoculated leaves was affected by the constant post-infection temperatures to which the plants were exposed. The influence of temperature was dependent on the host variety, the rust race, and on the age of the leaves inoculated. Race 3 on S37-388, the "universal susceptible" gave essentially the same results at the temperatures tested both on the first and second pair of leaves. On CM90RR, resistant to race 1 but susceptible to 3, race 3 gave highest pustule densities at 20°C and 25°C respectively, both on the first and second leaves. Race 1 on S37-388 gave highest pustule densities at 15°C, slightly lower density at 20°C and 25°C, and the lowest density at 29°C on the first leaves. On the second pair of leaves, density was highest at 20°C and 25°C, and much lower at 15°C and 29°C. This sort of variation in reactions is difficult to explain. It may be wisest to attribute it to
unobserved variations in inoculation technique, until the experiments are repeated several times with much larger numbers of plants and the inoculation process mechanized and carefully regulated to reduce the possibility of chance variations.

Diurnal fluctuations in post-infection temperatures, with higher temperature during the day than during the night, had relatively little effect on pustule density of race 1 on second leaves of S37-388, but did influence density on the first leaves. Highest densities were obtained on plants exposed to 25°C both day and night, and to those given a range of daytime temperatures from 28°C to 33°C to 28°C, with 25°C at night. Daytime temperatures of 25°C and night-time 18°C gave somewhat lower pustule density, and daytime temperature 33°C and night temperature 23°C gave the lowest density. It is possible that in the first case 18°C at night slowed down either host or rust development, or both, because results were better in both regimes involving 25°C night temperature. Presumably 16 hours exposure to 33°C during the day had an unfavourable effect greater than the advantage of 23°C (very close to the apparently favourable 25°C) night temperature. Exposure to 33°C for eight hours in the variable daytime temperature regime apparently had no deleterious effect.

Race 3 on both S37-388 and CM90RR gave the highest pustule density on plants exposed to 25°C during the day and 18°C during the night, although the values were not very much higher than those for plants exposed to 25°C during the night. It will require more detailed study to determine whether it
is day temperature or night temperature which is critical for
rust development, as well as to define more precisely the
temperature regimes which give optimum development.

Experiments on the pre-conditioning effect of pre-
inoculation temperatures were too limited to be conclusive.
Pre-conditioning may well be significant in rust development,
and should be investigated more fully.

Statistically significant interactions between age of
leaves and temperatures as they affect pustule density are
difficult to explain. The younger leaves of S37-388 appeared
to be more sensitive than older leaves to the influence of
temperature when inoculated with race 1. The same effect was
observed on CM90RR inoculated with race 3. It was not observed,
however, on S37-388 inoculated with race 3. It is important
that similar studies be carried on to determine if the
differences observed are obtained consistently. If they are,
it may indicate that the susceptible reaction of a given
combination of host variety and rust race may depend on
different inter-relationships in each case.

The effect of two light intensities at each of two day
lengths was studied in one experiment. In another, four
different day lengths were studied at one light intensity
(1200 ft-c) and four different light intensities at one day
length (16 hours). In the first experiment, there was very
little apparent influence of variation in day length and light
intensity on development of race 3 on CM90RR, either on first
or second leaves. Decreasing light intensities and day lengths apparently resulted in decreasing intensity of infection by race 1 on first leaves of S37-388, but had little effect on the younger second leaves. Decreasing day lengths under constant light intensity apparently increased pustule density of race 3 under CM90RR on the first leaves, but had relatively little effect on second leaves. Pustule density of race 1 on S37-388 decreased with decreasing day length, both on first and second leaves.

Density of rust pustules of race 3 on CM90RR was greater on plants exposed to 2800 and 2000 ft-c than at 1200 or 500 ft-c on first leaves, but the pattern was erratic on second leaves. Pustule density of race 3 on S37-388 was highest at 1200 ft-c, lower at 2000, and lowest at 2800 and 500 ft-c on both first and second leaves. Race 1 on S37-388 gave highest densities at 1200 and 2000 ft-c, and lower densities at 2800 and 500 ft-c, both on first and second leaves.

Sunflower rust will develop quite well at light intensities from 1200 - 2000 ft-c and day lengths of 12-18 hours. In order to discover optimum conditions, however, it would be necessary to vary day lengths and light intensity simultaneously in a greater number of combinations than was possible in these experiments, with a definite possibility of finding different optima for various host-race combinations.

It has been observed by numerous investigators working with cereal rusts particularly, but also with sunflower rust,
that the best infections and clearest reaction types occur under greenhouse conditions from late February to early April. It was hoped that these experiments would indicate if temperature, day length, or light intensity were the critical factors responsible for good results during the spring. No clear-cut answers have yet been obtained. It is possible that the apparently ideal spring-time conditions in the greenhouse can be duplicated and analysed only by programming diurnal variations in each of these three factors simultaneously.

In the experiment on the effects of light intensity, many flecks were observed on leaves of CM90RR inoculated with race 3 and incubated at 2800 and 2000 ft-c, particularly on the younger second leaves. It is possible that the high light intensity interfered with normal development of some of the rust infections. This does not seem very probable, however, as the number of well-developed uredial pustules was as high or higher at 2800 and 2000 ft-c than at 1200 or 500 ft-c.

The incubation period, defined as the length of time between inoculation and the appearance of earliest symptoms or flecking, did not vary greatly with changes in the environmental conditions studied, within the ranges used. Other criteria appeared to be more important in determining the influence of environment on sunflower rust.

Reaction type, although it is expressed in numerals, is essentially a qualitative indication of the inter-action of host and rust pathogens. Cereal rust investigators have long
known that the definitely resistant and definitely susceptible reaction types are relatively stable and are not usually affected markedly by minor changes in environmental conditions. Intermediate reaction types, such as moderately susceptible or moderately resistant, however, can more readily be changed by changing environmental conditions. In some host-pathogen combinations, exceeding a critical temperature may change a highly resistant to a highly susceptible reaction. If plants are exposed to extreme temperature conditions, even highly susceptible varieties may fail to show symptoms of infection.

When planning the experiments reported above, it was not thought worth while to include environmental extremes beyond the limits likely to be encountered by sunflower plants either in the field or under usual greenhouse conditions. Within the range of temperatures studied, no dramatic changes in reaction type were observed. A temperature of 33°C continuing throughout a 16-hour day was unfavourable for rust development, resulting in moderately resistant reaction types in host-pathogen combinations that appeared susceptible under more favourable conditions. The resistance of CM90RR to race 1 was not reduced by any of the conditions studied. Variations in day length and light intensity had relatively little effect on reaction type in any of the variety-race combinations.

Germinability of fresh spores of race 1 was not influenced by the temperature at which they were produced. Effects of temperature under which the spores were produced on
germinability of fresh uredospores of race 3 were statistically significant, but as the germination ranged only from 99 - 89%, the effect was not very striking. The temperature under which uredospores were produced apparently had much greater effect on their longevity in storage in the deep freezer. It has been reported (Sackston, 1960) that uredospores of P. helianthi survived storage at -10° to -22°C for five years with no apparent loss of germinability or ability to infect plants. In the experiments reported here, storage at -16°C for only 60 days reduced germinability very markedly. Spores of race 1 produced at 25° and 20°C retained significantly higher germinability than those produced at 15° and 29°C. Spores of race 3 produced at 15° appeared more resistant to storage than those produced at higher temperatures. It is not known how the temperature at which the spores are produced affects their longevity in storage. It is quite probable that spores produced in the greenhouse or in controlled environment cabinets may be much less resistant to storage than the field-produced spores used in the earlier work.

Teliospores are essential for the over-wintering of the rust organism and for the initiation of new infections in the spring for an autoecious rust such as P. helianthi, which is dependent on local inoculum for survival in most areas. In order to make genetic studies on the rust pathogen, it is essential to be able to produce teliospores under experimental conditions, and to be able to induce them to germinate and infect test plants.
The conditions which induce telial formation and affect the germinability and infectivity of the teliospores are not well understood. It has been suggested that environmental factors may influence the metabolism of the host and thus initiate the formation of telia rather than uredia by the pathogen (Waters, 1928).

Teliospores of both races formed earlier on sunflower plants kept at 15°C and 20°C than at 25°C or 29°C. Teliospores were also more abundant at the lower temperatures. Teliospores formed at 15°C germinated readily after storage for about a month and induced numerous pycnial infections on test plants. Teliospores formed at 20°C induced relatively few pycnial infections. Those produced at 25°C and 29°C failed to induce any pycnial infections. Although no previous work has been reported with teliospores of *P. helianthi*, Johnson (1931) found that the temperature under which teliospores of wheat stem rust are formed affects their germinability.

The effect on germinability of the day length and light intensity under which teliospores were produced was studied. The plants were grown at a constant temperature of 20°C, which although not optimum was satisfactory for teliospore production. Teliospores of race 3 produced on CM90RR at 1200 ft-c and either 16 or 10 hours day-length gave rise to approximately twice as many pycnial infections as those
produced at 600 ft-c and either 16 hours or 10 hours day-length. Teliospores of race 1 on S37-388 produced relatively few pycnial infections. There was very little apparent effect of day length or light intensity under which the teliospores were produced on their subsequent infectivity.

Unfortunately, it was not possible to compare the effects of specific environmental conditions on germinability of teliospores and of uredospores, as samples for the various germinability tests were taken from different experiments. Teliospore formation and infectivity seem to be favoured by temperatures slightly below those which are optimum for uredospore production. Temperatures which were too high for best uredial production inhibited germination of teliospores completely.

Observations in other experiments have indicated that teliospores formed in early spring in the greenhouse may germinate better than those formed at other times. It will be necessary to repeat experiments with more combinations of temperature, light intensity, and day length, to determine conditions which are optimum both for teliospore formation and for their subsequent germinability.

As indicated earlier, limitations of time prevented desirable repetition and amplification of these experiments. The results obtained indicate that temperature within the range studied has a greater effect on rust development than either day length or light intensity.
VI. SUMMARY

The effect of various temperatures, light intensities, and day length on the development on sunflower rust in controlled environment cabinets was measured by determining density of pustules on inoculated leaves, reaction types, germinability of freshly harvested uredospores and of spores stored in a deep-freezer, production of teliospores, and infectivity of stored teliospores.

The rust races used were 1 and 3. The sunflower varieties studied were S37-388, susceptible to both rust races, and CM90RR, resistant to race 1 and susceptible to race 3.

The effect of constant post-infection temperatures of 15°, 20°, 25°, and 29°C on pustule density varied with rust race, host variety, and age of leaves inoculated (first or second pair of leaves). Density tended to be higher at 25°C than at the other temperatures. Differences in reaction type were slight. Percentage germination of fresh spores of race 3 was highest for spores produced at 20°C; no differences were obvious among the other samples. Percentage germination of stored spores was highest for race 1 produced at 20° and 25°C, and for race 3 at 15°C.

Race 1 formed teliospores sooner than did race 3, and more abundantly at 15° and 20°C than at 25° and 29°C. Teliospores produced at 15°C gave numerous pycnia infections, those produced at 20°C fewer, and those at 25° and 29°C, none.
Effects of varying day-night post-infection temperatures were studied with constant day length and light intensity using the following regimes: Day temperature (D) 25°C, night temperature (N) 25°C; D-25°C, N-18°C; D-33°C, N-23°C; and D changing from 28°C to 33°C to 28°C, N-25°C. The effect of various temperature regimes on pustule density varied with host rust race, host variety, and age of leaves. Lowest pustule density resulted from exposure to day temperature of 33°C and night temperature of 23°C. Reaction types also were lowest on plants under these conditions. Race 1 appeared to give best results when night temperature was 25°C, and race 3, 18°C.

Differences in pustule density and infection type attributable to varying the pre-inoculation and post-inoculation temperatures were not statistically significant. Interactions between temperature and leaf age were significant in some cases.

The effects of day lengths of 24, 18, 12, and 6 hours respectively varied with rust race and host variety. Pustule density of race 1 on S37-388 was reduced by decreasing day length, but race 3 on CM90RR was apparently higher under shorter days. Fresh spores germinated best if produced under 18 or 12 hour days.

Effects of light intensities of 2800, 2000, 1200, and 500 foot candles respectively on pustule density were not significant. There were highly significant differences attributable to interactions between light intensity and age of leaves. On S37-388 results tended to be best at 1200 or 2000 ft-c, on CM90RR at 2000 ft-c.
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Controlled inoculation of wheat seedlings with urediospores of *Puccinia graminis* var. *tritici*. Phytopathology 47: 650-655.

Effect of dew evaporation rates on infection of wheat by *Puccinia graminis* var. *tritici*. Phytopathology 47: 30. (Abstr.)

Effect of certain environmental conditions on infection of wheat by *Puccinia graminis*. Phytopathology 48: 371-376.

Forms and races of *Puccinia helianthi* Schw. Phytopathology 46: 25. (Abstr.)


Samborski, D.J. and M. Shaw. 1956.  
The physiology of host-parasite relations. II. The effect of *Puccinia graminis tritici* Eriks. and Henn. on the respiration of the first leaf of resistant and susceptible species of wheat. Can. J. Botany 34: 601-619.


Schein, R.D. 1961b.
Some effects of temperature during the colonization period of bean rust. Phytopathology 51: 674-680.


Influence of temperature and light upon substomatal vesicle formation in *Puccinia graminis var tritici*. Phytopathology 47: 30. (Abstr.)

Time-temperature interactions of *Uromyces phaseoli* during spore germination and elongation. Phytopathology 52: 27. (Abstr.)

Effects of preinoculation and postinoculation host temperature on infection of wheat seedlings by *Puccinia striiformis*. Phytopathology 52: 751-752 (Abstr.)

Prepenetration and postpenetration environment and development of *Puccinia striiformis* on wheat. Phytopathology 55: 198-203.


Influence of temperature and light on the infection process of *Puccinia graminis var tritici*. Phytopathology 47: 31. (Abstr.)


Silverman, W. 1959.
The effects of variations in temperature on the necrosis associated with infection type. Phytopathology 49: 827-830.

Simons, M.D. 1954.
The relationship of temperature and stage of growth to the crown rust reaction of certain varieties of oats. Phytopathology 44: 221-223.


Ward, H.M. 1902.

Waterhouse, W.L. 1929.

Waters, C.W. 1928.

Wei, C.T. 1937.

Weston, W.A.R. Dillon. 1931.


Relation of temperature to reaction type of Puccinia coronata on certain oat varieties. Phytopathology 51: 202-203.
Note on Appendix Tables

In the analyses of variance, the significance of the "f" values for the interactions was determined in each analysis. Where the interactions were significant, the interaction mean squares were used to calculate "f" values for the main treatments. Where the interactions were not significant, the error mean squares were used to calculate "f" values for the main treatments.
VIII. APPENDIX TABLES

APPENDIX TABLE 1. Analysis of variance for the data of the effect of post-infection constant temperature on the density of pustules on variety S37-388 inoculated with race 1.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>3.7</td>
<td>10.13</td>
<td>34.12</td>
</tr>
<tr>
<td>Temperature</td>
<td>3</td>
<td>0.9</td>
<td>9.28</td>
<td>29.46</td>
</tr>
<tr>
<td>Age of leaves x Temperature</td>
<td>3</td>
<td>5.46*</td>
<td>3.24</td>
<td>5.29</td>
</tr>
<tr>
<td>Error</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE I-a: Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>3.26</td>
<td>3.39</td>
<td>3.47</td>
</tr>
<tr>
<td>LSR</td>
<td>5.64</td>
<td>5.86</td>
<td>6.00</td>
</tr>
</tbody>
</table>

Temperature

<table>
<thead>
<tr>
<th>Temperature</th>
<th>15°C</th>
<th>25°C</th>
<th>20°C</th>
<th>29°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of pustule density(^1)</td>
<td>19.7</td>
<td>16.7</td>
<td>16</td>
<td>13.7</td>
</tr>
</tbody>
</table>

\(^1\) Any two means underscored by the same line are not significantly different. Any two means not underscored by the same line are significantly different.
APPENDIX TABLE I-b  
Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>3.26</td>
<td>3.39</td>
<td>3.47</td>
</tr>
<tr>
<td>LSR</td>
<td>4.99</td>
<td>5.19</td>
<td>5.31</td>
</tr>
</tbody>
</table>

Temperature  
- 25°C  
- 20°C  
- 15°C  
- 29°C

Average of pustule density  
- 15.7  
- 15   
- 7.3  
- 7.3
APPENDIX TABLE II. Analysis of variance for the data of the effect of post-infection constant temperature on pustule density on variety CM90RR inoculated with race 3.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>0.006</td>
<td>4.49</td>
<td>8.53</td>
</tr>
<tr>
<td>Temperature</td>
<td>3</td>
<td>13.9*</td>
<td>3.24</td>
<td>5.29</td>
</tr>
<tr>
<td>Age of leaves x Temperature</td>
<td>3</td>
<td>0.6</td>
<td>3.24</td>
<td>5.29</td>
</tr>
<tr>
<td>Error</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE II-a  Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>3.26</td>
<td>3.39</td>
<td>3.47</td>
</tr>
<tr>
<td>LSR</td>
<td>8.88</td>
<td>9.22</td>
<td>9.44</td>
</tr>
</tbody>
</table>

Temperature  

<table>
<thead>
<tr>
<th></th>
<th>25°C</th>
<th>20°C</th>
<th>15°C</th>
<th>29°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of pustule density</td>
<td>21</td>
<td>15.7</td>
<td>12</td>
<td>9</td>
</tr>
</tbody>
</table>
APPENDIX TABLE II-b  Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>3.26</td>
<td>3.39</td>
<td>3.47</td>
</tr>
<tr>
<td>LSR</td>
<td>6.32</td>
<td>6.58</td>
<td>6.73</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>25°C</th>
<th>20°C</th>
<th>15°C</th>
<th>29°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of pustule density</td>
<td>22.7</td>
<td>18.3</td>
<td>10.7</td>
<td>6.3</td>
</tr>
</tbody>
</table>
APPENDIX TABLE III. Analysis of variance for the data of the effect of post-infection constant temperature on pustule density on variety S37-388 inoculated with race 3.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>0.24</td>
<td>4.75</td>
<td>9.33</td>
</tr>
<tr>
<td>Temperature</td>
<td>2</td>
<td>0.22</td>
<td>3.89</td>
<td>6.93</td>
</tr>
<tr>
<td>Age of leaves x Temperature</td>
<td>2</td>
<td>0.16</td>
<td>3.89</td>
<td>6.93</td>
</tr>
<tr>
<td>Error</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX TABLE IV. Percentage germinability of fresh uredospores of race 1 produced on variety S37-388 at four different constant temperatures.

<table>
<thead>
<tr>
<th>Determinations</th>
<th>Temperature 15°C</th>
<th>Temperature 20°C</th>
<th>Temperature 25°C</th>
<th>Temperature 29°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>100</td>
<td>97</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>98</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td>5</td>
<td>98</td>
<td>100</td>
<td>100</td>
<td>95</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td>100</td>
<td>97</td>
<td>95</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>100</td>
<td>97</td>
<td>100</td>
</tr>
<tr>
<td>9</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Average: 100 100 99 99
APPENDIX TABLE V. Percentage germinability of fresh uredospores of race 3 produced on variety CM90RR at three different constant temperatures.

<table>
<thead>
<tr>
<th>Determination</th>
<th>Temperature 20°C</th>
<th>Temperature 25°C</th>
<th>Temperature 29°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>97</td>
<td>94</td>
</tr>
<tr>
<td>3</td>
<td>97</td>
<td>98</td>
<td>92</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>97</td>
<td>93</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>97</td>
<td>96</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>100</td>
<td>91</td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td>100</td>
<td>81</td>
</tr>
<tr>
<td>8</td>
<td>98</td>
<td>97</td>
<td>87</td>
</tr>
<tr>
<td>9</td>
<td>100</td>
<td>96</td>
<td>81</td>
</tr>
<tr>
<td>10</td>
<td>98</td>
<td>96</td>
<td>79</td>
</tr>
<tr>
<td>Average</td>
<td>99</td>
<td>97</td>
<td>89</td>
</tr>
</tbody>
</table>
APPENDIX TABLE VI. Percentage germinability of stored uredospores of race 1 produced on variety S37-388 at four different temperatures.

<table>
<thead>
<tr>
<th>Determination</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15°C</td>
</tr>
<tr>
<td>1</td>
<td>72</td>
</tr>
<tr>
<td>2</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>52</td>
</tr>
<tr>
<td>5</td>
<td>59</td>
</tr>
<tr>
<td>6</td>
<td>56</td>
</tr>
<tr>
<td>7</td>
<td>74</td>
</tr>
<tr>
<td>8</td>
<td>45</td>
</tr>
<tr>
<td>9</td>
<td>70</td>
</tr>
<tr>
<td>10</td>
<td>67</td>
</tr>
</tbody>
</table>

Average 63 77 81 55
APPENDIX TABLE VII. Percentage germinability of stored uredospores of race 3 produced on variety CM90RR at four different temperatures.

<table>
<thead>
<tr>
<th>Determinations</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15°C</td>
</tr>
<tr>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>3</td>
<td>54</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>39</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>41</td>
</tr>
<tr>
<td>9</td>
<td>31</td>
</tr>
<tr>
<td>10</td>
<td>29</td>
</tr>
<tr>
<td>Average</td>
<td>37</td>
</tr>
</tbody>
</table>
APPENDIX TABLE VIII. The analysis of variance for the data of the effect of day-night post-infection temperature on the density of pustules on variety 337-388 inoculated with race 1.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>10.2*</td>
<td>10.13</td>
<td>34.12</td>
</tr>
<tr>
<td>Temperature</td>
<td>3</td>
<td>6.3</td>
<td>9.28</td>
<td>29.46</td>
</tr>
<tr>
<td>Age of leaves x Temperature</td>
<td>3</td>
<td>2.89*</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 5%
APPENDIX TABLE VIII-a  Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>12.88</td>
<td>13.50</td>
<td>13.90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Day</th>
<th>25°C</th>
<th>25°C</th>
<th>25°C</th>
<th>33°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night</td>
<td>33°C</td>
<td>25°C</td>
<td>18°C</td>
<td>23°C</td>
<td></td>
</tr>
</tbody>
</table>

| Average of pustule density | 96.8 | 95.6 | 78.8 | 56.6 |
APPENDIX TABLE VIII-b  Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>13.11</td>
<td>13.74</td>
<td>14.14</td>
</tr>
</tbody>
</table>

Temperature

<table>
<thead>
<tr>
<th></th>
<th>Day</th>
<th>Day</th>
<th>Day</th>
<th>Night</th>
<th>Night</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25°C</td>
<td>25°C</td>
<td>25°C</td>
<td>33°C</td>
<td>25°C</td>
<td>18°C</td>
</tr>
<tr>
<td></td>
<td>13°C</td>
<td>18°C</td>
<td>23°C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average of pustule density

|       | 73.4 | 67.8 | 64.5 | 53.1  |
APPENDIX TABLE VIII-c  "T" test for the influence of leaf age on effect of day-night post-infection temperatures on the density of pustules on variety 337-388 inoculated with race 1.

<table>
<thead>
<tr>
<th>Day-night Temperature ± 1°C</th>
<th>t value obtained</th>
<th>Tabulated 5%</th>
<th>Tabulated 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>25°C - 18°C</td>
<td>1.78</td>
<td>2.14</td>
<td>2.98</td>
</tr>
<tr>
<td>25°C - 25°C</td>
<td>4.86*</td>
<td>2.14</td>
<td>2.98</td>
</tr>
<tr>
<td>25°C - 33°C</td>
<td>5.12**</td>
<td>2.14</td>
<td>2.98</td>
</tr>
<tr>
<td>33°C - 23°C</td>
<td>0.54</td>
<td>2.14</td>
<td>2.98</td>
</tr>
</tbody>
</table>

* Significant at 5%
** Significant at 1%
APPENDIX TABLE IX. The analysis of variance of the data of the effect of day-night post-infection temperature on the density of pustules on variety 837-388 inoculated with race 3.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>37.3**</td>
<td>4.00</td>
<td>7.08</td>
</tr>
<tr>
<td>Temperature</td>
<td>3</td>
<td>24.6**</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Age of leaves x Temperature</td>
<td>3</td>
<td>2.52</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE IX-a  Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>13.25</td>
<td>13.89</td>
<td>14.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Day</th>
<th>25°C</th>
<th>25°C</th>
<th>25°C</th>
<th>33°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Night</td>
<td>18°C</td>
<td>25°C</td>
<td>33°C</td>
<td>23°C</td>
</tr>
</tbody>
</table>

| Average of pustule density | 95.2 | 89.0 | 78.8 | 63.9 |
APPENDIX TABLE IX-b  Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>11.98</td>
<td>12.56</td>
<td>12.93</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>25°C</td>
<td>25°C</td>
</tr>
<tr>
<td>Night</td>
<td>18°C</td>
<td>33°C</td>
</tr>
</tbody>
</table>

Average of pustule density: 86, 65.5, 57.6, 42.8
APPENDIX TABLE X. The analysis of variance of the data of the effect of day-night post-infection temperature on the density of pustules on variety CM90RR inoculated with race 3.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>45.7**</td>
<td>10.13</td>
<td>34.12</td>
</tr>
<tr>
<td>Temperature</td>
<td>3</td>
<td>12.9*</td>
<td>9.28</td>
<td>29.46</td>
</tr>
<tr>
<td>Age of leaves x Temperature</td>
<td>3</td>
<td>3.28*</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 5%
** Significant at 1%
APPENDIX TABLE X-a  Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>ISR</td>
<td>13.25</td>
<td>13.89</td>
<td>14.30</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day</td>
<td>25°C</td>
<td>25°C</td>
<td>25°C</td>
</tr>
<tr>
<td>Night</td>
<td>18°C</td>
<td>33°C</td>
<td>25°C</td>
</tr>
<tr>
<td>Average of pustule density</td>
<td>99.8</td>
<td>83.4</td>
<td>77.9</td>
</tr>
</tbody>
</table>
APPENDIX TABLE X-b  Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>9.69</td>
<td>10.15</td>
<td>10.45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25°C</td>
<td>18°C</td>
</tr>
<tr>
<td></td>
<td>25°C</td>
<td>33°C</td>
</tr>
<tr>
<td></td>
<td>25°C</td>
<td>25°C</td>
</tr>
<tr>
<td></td>
<td>33°C</td>
<td>23°C</td>
</tr>
</tbody>
</table>

| Average of pustule density | 61.4 | 58.5 | 30.5 | 24.8 |
APPENDIX TABLE X-c "T" test for the influence of leaf age on effect of day-night post-infection temperatures on the density of pustules on variety CM90RR inoculated with race 3.

<table>
<thead>
<tr>
<th>Day-night post-infection Temperature 1°C</th>
<th>t value</th>
<th>Obtained</th>
<th>Tabulated 5%</th>
<th>Tabulated 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>25°C - 18°C</td>
<td>5.89**</td>
<td>2.14</td>
<td>2.98</td>
<td></td>
</tr>
<tr>
<td>25°C - 25°C</td>
<td>10.37**</td>
<td>2.14</td>
<td>2.98</td>
<td></td>
</tr>
<tr>
<td>25°C - 33°C</td>
<td>3.89**</td>
<td>2.14</td>
<td>2.98</td>
<td></td>
</tr>
<tr>
<td>33°C - 23°C</td>
<td>5.72**</td>
<td>2.14</td>
<td>2.98</td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE XI. Analysis of variance for the data of the effect of preinoculation and post-inoculation temperature upon the density of pustules on variety S37-388 inoculated with race 1.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>1.50</td>
<td>4.00</td>
<td>7.08</td>
</tr>
<tr>
<td>Temperature</td>
<td>6</td>
<td>1.32</td>
<td>2.25</td>
<td>3.12</td>
</tr>
<tr>
<td>Age of leaves x Temperature</td>
<td>6</td>
<td>1.43</td>
<td>2.25</td>
<td>3.12</td>
</tr>
<tr>
<td>Error</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>83</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX TABLE XII. Analysis of variance for the data of the effect of preinoculation and post-inoculation temperatures upon the density of pustules on variety CM90RR inoculated with race 3.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>0.49</td>
<td>5.99</td>
<td>13.75</td>
</tr>
<tr>
<td>Temperature</td>
<td>6</td>
<td>3.28</td>
<td>4.28</td>
<td>8.47</td>
</tr>
<tr>
<td>Age of leaves x Temperature</td>
<td>6</td>
<td>5.03**</td>
<td>2.25</td>
<td>3.12</td>
</tr>
<tr>
<td>Error</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>83</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE XII-a  Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.86</td>
<td>3.01</td>
<td>3.10</td>
<td>3.17</td>
<td>3.22</td>
<td>3.27</td>
</tr>
<tr>
<td>LSR</td>
<td>6.69</td>
<td>7.04</td>
<td>7.25</td>
<td>7.42</td>
<td>7.53</td>
<td>7.65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Pre-</th>
<th>Post-</th>
<th>Pre-</th>
<th>Post-</th>
<th>Pre-</th>
<th>Post-</th>
<th>Pre-</th>
<th>Post-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20°C</td>
<td>15°C</td>
<td>24°C</td>
<td>15°C</td>
<td>29°C</td>
<td>20°C</td>
<td>29°C</td>
<td>29°C</td>
</tr>
<tr>
<td></td>
<td>20°C</td>
<td>24°C</td>
<td>24°C</td>
<td>15°C</td>
<td>15°C</td>
<td>29°C</td>
<td>29°C</td>
<td>29°C</td>
</tr>
</tbody>
</table>

| Average of pustule density | 20.7 | 19.8 | 15.2 | 11.3 | 10.5 | 8    | 2.8  |
APPENDIX TABLE XII-b Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of F</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.86</td>
<td>3.01</td>
<td>3.10</td>
<td>3.17</td>
<td>3.22</td>
<td>3.27</td>
</tr>
<tr>
<td>LSR</td>
<td>4.98</td>
<td>5.24</td>
<td>5.39</td>
<td>5.52</td>
<td>5.60</td>
<td>5.69</td>
</tr>
</tbody>
</table>

Temperature

<table>
<thead>
<tr>
<th>Pre-</th>
<th>15°C</th>
<th>15°C</th>
<th>20°C</th>
<th>24°C</th>
<th>20°C</th>
<th>29°C</th>
<th>29°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-</td>
<td>15°C</td>
<td>24°C</td>
<td>20°C</td>
<td>24°C</td>
<td>29°C</td>
<td>29°C</td>
<td>15°C</td>
</tr>
</tbody>
</table>

Average of pustule density

| 25.8 | 17.2 | 16.7 | 11.5 | 6.8 | 6.8 | 6.7 |
APPENDIX TABLE XII-c "T" test for the influence of leaf age on effect of preinoculation and postinoculation temperatures on the density of pustules on variety CM90RR inoculated with race 3.

<table>
<thead>
<tr>
<th>Pre- and Post-inoculation Temperatures °C</th>
<th>t value Obtained</th>
<th>Tabulated 5%</th>
<th>Tabulated 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°C - 15°C</td>
<td>4.63**</td>
<td>2.23</td>
<td>3.17</td>
</tr>
<tr>
<td>15°C - 24°C</td>
<td>0.86</td>
<td>2.23</td>
<td>3.17</td>
</tr>
<tr>
<td>20°C - 20°C</td>
<td>0.90</td>
<td>2.23</td>
<td>3.17</td>
</tr>
<tr>
<td>20°C - 29°C</td>
<td>0.53</td>
<td>2.23</td>
<td>3.17</td>
</tr>
<tr>
<td>24°C - 24°C</td>
<td>1.19</td>
<td>2.23</td>
<td>3.17</td>
</tr>
<tr>
<td>29°C - 15°C</td>
<td>1.95</td>
<td>2.23</td>
<td>3.17</td>
</tr>
<tr>
<td>29°C - 29°C</td>
<td>2.44*</td>
<td>2.23</td>
<td>3.17</td>
</tr>
</tbody>
</table>

* Significant at 5%

** Significant at 1%
APPENDIX TABLE XIII. Analysis of variance for the data of the effect of day length and light intensity upon the density of pustules on variety 337-388 inoculated with race 1.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>0.49</td>
<td>10.13</td>
<td>34.12</td>
</tr>
<tr>
<td>Light</td>
<td>3</td>
<td>2.70</td>
<td>9.28</td>
<td>29.46</td>
</tr>
<tr>
<td>Age of leaves x Light</td>
<td>3</td>
<td>1.48</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX TABLE XIV. Analysis of variance for the data of the effect of day length and light intensity upon the density of pustules on variety CM90RR inoculated with race 3.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>0.47</td>
<td>10.13</td>
<td>34.12</td>
</tr>
<tr>
<td>Light</td>
<td>3</td>
<td>1.04</td>
<td>9.28</td>
<td>29.46</td>
</tr>
<tr>
<td>Age of leaves × Light</td>
<td>3</td>
<td>0.99</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX TABLE XV. Analysis of variance for the data of the effect of post-infection photoperiods upon the density of pustules on variety S37-388 inoculated with race 1.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>8.69**</td>
<td>4.00</td>
<td>7.08</td>
</tr>
<tr>
<td>Day length</td>
<td>3</td>
<td>8.21**</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Age of leaves x Day length</td>
<td>3</td>
<td>0.97</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE XV-a. Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.86</td>
<td>3.01</td>
<td>3.10</td>
</tr>
<tr>
<td>ISR</td>
<td>6.84</td>
<td>7.19</td>
<td>7.41</td>
</tr>
</tbody>
</table>

Day length 24 hr 18hr 12hr 6hr

Average of pustule density 24.3 20.2 14.6 13.1
APPENDIX Table XV-b.

Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSR</td>
<td>2.86</td>
<td>3.01</td>
<td>3.10</td>
</tr>
<tr>
<td>LSR</td>
<td>4.52</td>
<td>4.76</td>
<td>4.90</td>
</tr>
</tbody>
</table>

Day length

<table>
<thead>
<tr>
<th></th>
<th>18hr</th>
<th>24hr</th>
<th>12hr</th>
<th>6hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of pustule density</td>
<td>16.9</td>
<td>16</td>
<td>12.8</td>
<td>9.6</td>
</tr>
</tbody>
</table>
APPENDIX TABLE XVI. Analysis of variance of the data of the effect of post-infection photo-periods upon the density of pustules on variety CM90RR inoculated with race 3.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>99.59**</td>
<td>4.00</td>
<td>7.08</td>
</tr>
<tr>
<td>Day length</td>
<td>3</td>
<td>8.64**</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Age of leaves x Day length</td>
<td>3</td>
<td>2.08</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE XVI-a. Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.86</td>
<td>3.01</td>
<td>3.10</td>
</tr>
<tr>
<td>ISR</td>
<td>5.63</td>
<td>5.93</td>
<td>6.12</td>
</tr>
</tbody>
</table>

Day length  
6hr  | 12hr | 24hr | 18hr |

Average of pustule density  
26.5  | 25.9  | 20.6  | 15.9  |


APPENDIX TABLE XVI-b. Duncan's new multiple-range test for the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.86</td>
<td>3.01</td>
<td>3.10</td>
</tr>
<tr>
<td>LSR</td>
<td>3.78</td>
<td>3.97</td>
<td>4.09</td>
</tr>
</tbody>
</table>

Day length: 12hr 6hr 24hr 18hr

Average of pustule density: 13.5 10.3 9.8 7.9
APPENDIX TABLE XVII. Analysis of variance of the data of the effect of post-infection photoperiods upon the density of pustules on variety CM90RR inoculated with race 1.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>37.4*</td>
<td>4.00</td>
<td>7.08</td>
</tr>
<tr>
<td>Day length</td>
<td>3</td>
<td>6.28**</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Age of leaves x Day length</td>
<td>3</td>
<td>2.72</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE XVII-a. Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>3.04</td>
<td>3.19</td>
<td>3.29</td>
</tr>
</tbody>
</table>

Day length: 24hr, 12hr, 18hr, 6hr

Average of pustule density: 7, 3.4, 2.5, 2
APPENDIX TABLE XVII-b. Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>0.78</td>
<td>0.82</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Day length | 24hr | 6hr | 12hr | 18hr |
--- | --- | --- | --- | --- |
Average of pustule density | 1.12 | 0.25 | 0.12 | 0.00 |
APPENDIX TABLE XVIII  Percentage germinability of fresh uredospores of race 1 produced on variety S37-388 under four different photoperiods.

<table>
<thead>
<tr>
<th>Determinations</th>
<th>24hr</th>
<th>18hr</th>
<th>12hr</th>
<th>6hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>68</td>
<td>89</td>
<td>84</td>
<td>73</td>
</tr>
<tr>
<td>2</td>
<td>56</td>
<td>85</td>
<td>81</td>
<td>71</td>
</tr>
<tr>
<td>3</td>
<td>61</td>
<td>93</td>
<td>80</td>
<td>73</td>
</tr>
<tr>
<td>4</td>
<td>65</td>
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<td>87</td>
<td>62</td>
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<tr>
<td>5</td>
<td>55</td>
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<td>86</td>
<td>72</td>
</tr>
<tr>
<td>6</td>
<td>68</td>
<td>80</td>
<td>92</td>
<td>75</td>
</tr>
<tr>
<td>7</td>
<td>63</td>
<td>85</td>
<td>88</td>
<td>75</td>
</tr>
<tr>
<td>8</td>
<td>57</td>
<td>89</td>
<td>88</td>
<td>71</td>
</tr>
<tr>
<td>9</td>
<td>59</td>
<td>85</td>
<td>87</td>
<td>63</td>
</tr>
<tr>
<td>10</td>
<td>53</td>
<td>90</td>
<td>85</td>
<td>75</td>
</tr>
</tbody>
</table>

Average     60.5  87.2  85.8  71.0
APPENDIX TABLE XIX  Percentage germinability of fresh uredospores of race 3 produced on variety CM90RR under four different day lengths.

<table>
<thead>
<tr>
<th>Determinations</th>
<th>24hr</th>
<th>18hr</th>
<th>12hr</th>
<th>6hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54</td>
<td>84</td>
<td>28</td>
<td>69</td>
</tr>
<tr>
<td>2</td>
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<td>82</td>
<td>50</td>
<td>67</td>
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<tr>
<td>3</td>
<td>53</td>
<td>89</td>
<td>40</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>79</td>
<td>88</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>5</td>
<td>72</td>
<td>84</td>
<td>50</td>
<td>85</td>
</tr>
<tr>
<td>6</td>
<td>57</td>
<td>96</td>
<td>32</td>
<td>86</td>
</tr>
<tr>
<td>7</td>
<td>39</td>
<td>90</td>
<td>33</td>
<td>65</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
<td>86</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>83</td>
<td>27</td>
<td>71</td>
</tr>
<tr>
<td>10</td>
<td>55</td>
<td>88</td>
<td>25</td>
<td>57</td>
</tr>
</tbody>
</table>

Average 59.0 87.0 32.8 72.2
APPENDIX TABLE XX  Percentage germinability of stored  
uredospores of race 1 produced on variety  
S37-388 under four different day lengths.  

<table>
<thead>
<tr>
<th>Determinations</th>
<th>24hr</th>
<th>18hr</th>
<th>12hr</th>
<th>6hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53</td>
<td>13</td>
<td>24</td>
<td>55</td>
</tr>
<tr>
<td>2</td>
<td>42</td>
<td>34</td>
<td>26</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>25</td>
<td>12</td>
<td>48</td>
</tr>
<tr>
<td>4</td>
<td>41</td>
<td>28</td>
<td>24</td>
<td>45</td>
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<tr>
<td>5</td>
<td>24</td>
<td>15</td>
<td>26</td>
<td>36</td>
</tr>
<tr>
<td>6</td>
<td>42</td>
<td>13</td>
<td>17</td>
<td>39</td>
</tr>
<tr>
<td>7</td>
<td>32</td>
<td>6</td>
<td>13</td>
<td>45</td>
</tr>
<tr>
<td>8</td>
<td>28</td>
<td>19</td>
<td>33</td>
<td>66</td>
</tr>
<tr>
<td>9</td>
<td>45</td>
<td>7</td>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td>10</td>
<td>32</td>
<td>13</td>
<td>23</td>
<td>50</td>
</tr>
</tbody>
</table>

Average 36.3  17.3  21.3  46.1
APPENDIX TABLE XXI  Percentage germinability of stored  
uredospores of race 3 produced on variety  
CM90RR at four conditions of different  
day length.

<table>
<thead>
<tr>
<th>Determinations</th>
<th>24hr</th>
<th>18hr</th>
<th>12hr</th>
<th>6hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
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<td>21</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
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<td>0</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
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<td>6</td>
<td>48</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>26</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>18</td>
</tr>
</tbody>
</table>

Average 1 0.3 6.8 18.5
APPENDIX TABLE XXII  Analysis of variance of the data of the effect of light intensities upon the density of pustules on variety S37-388 inoculated with race 1.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>7.30</td>
<td>10.13</td>
<td>34.12</td>
</tr>
<tr>
<td>Light intensity</td>
<td>3</td>
<td>3.42</td>
<td>9.28</td>
<td>29.46</td>
</tr>
<tr>
<td>Age of leaves x Light intensity</td>
<td>3</td>
<td>12.3**</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE XXII-a  Duncan's new multiple-range test
for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>8.93</td>
<td>9.36</td>
<td>9.64</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Light intensity</th>
<th>1200</th>
<th>2000</th>
<th>500</th>
<th>2800</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
</tr>
</tbody>
</table>

| Average of pustule density | 57   | 56.5 | 31   | 17.2 |


APPENDIX TABLE XXII-b  
Duncan's multiple-range test for 
the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>7.77</td>
<td>8.14</td>
<td>8.39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Light intensity</th>
<th>1200</th>
<th>2000</th>
<th>2800</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
</tr>
</tbody>
</table>

| Average of pustule density | 31.5 | 23.1 | 17.5 | 12  |
APPENDIX TABLE XXIII  Analysis of variance of the data of the effect of light intensity upon the density of pustules on variety S37-388 inoculated with race 3.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>6.04</td>
<td>10.13</td>
<td>34.12</td>
</tr>
<tr>
<td>Light intensity</td>
<td>3</td>
<td>5.85</td>
<td>9.28</td>
<td>29.46</td>
</tr>
<tr>
<td>Age of leaves x</td>
<td>3</td>
<td>26.8***</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Light intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1%
APPENDIX TABLE XXIII-a  Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>9.80</td>
<td>10.28</td>
<td>10.58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Light intensity</th>
<th>1200 ft-c</th>
<th>2000 ft-c</th>
<th>500 ft-c</th>
<th>2800 ft-c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of pustule density</td>
<td>84.9</td>
<td>41.9</td>
<td>25.1</td>
<td>5.9</td>
</tr>
</tbody>
</table>
APPENDIX TABLE XXIII-b  Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>5.10</td>
<td>5.35</td>
<td>5.51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Light intensity</th>
<th>1200</th>
<th>2000</th>
<th>500</th>
<th>2800</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average of pustule density</th>
<th>34.1</th>
<th>16.2</th>
<th>9</th>
<th>1.5</th>
</tr>
</thead>
</table>
APPENDIX TABLE XXIV Analysis of variance of the data of the effect of light intensities upon the density of pustules on variety CM90RR inoculated with race 3.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>F</th>
<th>5%</th>
<th>1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of leaves</td>
<td>1</td>
<td>19.2*</td>
<td>10.13</td>
<td>34.12</td>
</tr>
<tr>
<td>Light intensity</td>
<td>3</td>
<td>4.1</td>
<td>9.28</td>
<td>29.46</td>
</tr>
<tr>
<td>Age of leaves x Light intensity</td>
<td>3</td>
<td>7.1**</td>
<td>2.76</td>
<td>4.13</td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 5%
** Significant at 1%
APPENDIX TABLE XXIV-a  Duncan's new multiple-range test for the data of the first pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>13.48</td>
<td>14.14</td>
<td>14.55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Light intensity</th>
<th>2000</th>
<th>2800</th>
<th>500</th>
<th>1200</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
<td>ft-c</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average of pustule density</th>
<th>98.1</th>
<th>90</th>
<th>71</th>
<th>64.5</th>
</tr>
</thead>
</table>
APPENDIX TABLE XXIV-b  Duncan's new multiple-range test for the data of the second pair of leaves.

<table>
<thead>
<tr>
<th>Value of P</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSR</td>
<td>2.90</td>
<td>3.04</td>
<td>3.13</td>
</tr>
<tr>
<td>LSR</td>
<td>11.40</td>
<td>11.95</td>
<td>12.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Light intensity</th>
<th>2000 ft-c</th>
<th>500 ft-c</th>
<th>2800 ft-c</th>
<th>1200 ft-c</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Average of pustule density</th>
<th>60.0</th>
<th>58.8</th>
<th>46.0</th>
<th>16</th>
</tr>
</thead>
</table>
APPENDIX TABLE XXV. "T" test for the influence of leaf age on effect of light intensities on density of pustules on variety S37-388 inoculated with races 1 and 3 and CM90RR inoculated with race 3.

<table>
<thead>
<tr>
<th>Light intensities</th>
<th>S37-388</th>
<th></th>
<th></th>
<th>CM90RR</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Race 1</td>
<td>Race 3</td>
<td></td>
<td>Race 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>t value</td>
<td>t value</td>
<td></td>
<td>t value</td>
<td>t value</td>
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<tr>
<td></td>
<td>Obtained</td>
<td>5%</td>
<td>1%</td>
<td>Obtained</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>500 ft-c</td>
<td>4.69**</td>
<td>2.14</td>
<td>2.98</td>
<td>5.69**</td>
<td>2.14</td>
<td>2.98</td>
</tr>
<tr>
<td>1200 ft-c</td>
<td>5.21**</td>
<td>&quot;</td>
<td>&quot;</td>
<td>10.10**</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>2000 ft-c</td>
<td>8.07**</td>
<td>&quot;</td>
<td>&quot;</td>
<td>5.27**</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>2800 ft-c</td>
<td>0.098</td>
<td>&quot;</td>
<td>&quot;</td>
<td>4.21**</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

* Significant at 5%
** Significant at 1%
APPENDIX TABLE XXVI. Percentage germinability of fresh uredospores of race 1 produced on variety S37-388 under four different light intensities.

<table>
<thead>
<tr>
<th>Determinations</th>
<th>500 ft-c</th>
<th>1200 ft-c</th>
<th>2000 ft-c</th>
<th>2800 ft-c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67</td>
<td>92</td>
<td>75</td>
<td>42</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>61</td>
<td>84</td>
<td>58</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
<td>76</td>
<td>88</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>61</td>
<td>71</td>
<td>92</td>
<td>49</td>
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<tr>
<td>5</td>
<td>75</td>
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<td>78</td>
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</tr>
<tr>
<td>6</td>
<td>72</td>
<td>83</td>
<td>97</td>
<td>52</td>
</tr>
<tr>
<td>7</td>
<td>73</td>
<td>76</td>
<td>92</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>65</td>
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<td>81</td>
<td>59</td>
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Average 70.8 77.2 86.6 53.0
APPENDIX TABLE XXVII. Percentage germinability of fresh uredospores of race 3 produced on variety CM90RR under four different light intensities.

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<th>Determinations</th>
<th>500 ft-c</th>
<th>1200 ft-c</th>
<th>2000 ft-c</th>
<th>2800 ft-c</th>
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Average: 21.6  20.2  15.1  15.3