POWDERY MILDEW OF CEREAL CROPS — A REVIEW

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Summary

A brief account of the characteristics and life cycle of *Erysiphe graminis* is given. The review indicates the economic significance of the disease although quantitative information is lacking both in New Zealand and overseas. Possible control measures are considered, along with methods available for assessing the amount of cereal mildew in trial work.

INTRODUCTION

THE CAUSAL AGENT of powdery mildew of cereal crops is the fungus *Erysiphe graminis* DC. It is a member of the Erysiphaceae, a family of obligatory parasitic ascomycetous fungi, characterized by superficial hyaline mycelium, haustoria in the epidermal cells of the host, production of large hyaline air-borne conidia, and formation of dark cleistothecia during sexual reproduction.

Erysiphe graminis is not only world-wide in distribution, but also possesses a large host range, attacking over one hundred genera of Gramineae (Kapoor, 1967).

BIOLOGY

The life-cycle of *E. graminis* consists of three separate phases. In the vegetative and asexual stages, primary mycelium develops from germinating conidia on the leaf or stem, resulting in mycelial patches, elongate to ellipsoidal in shape, and grey-white in colour. In the epidermal cells of the host, haustoria, adorned with characteristic finger-like projections, are formed, which absorb cellular material to satisfy the nutritional requirements of the pathogen, and thereby damage the host. Short conidiophores arise from the primary mycelium, and ellipsoidal, hyaline conidia are produced in long unbranched chains. These are shed readily and disseminated by wind.

According to Smith and Blair (1950) the cycle from conidium germination to conidium formation may take only six days. The resultant build-up of inoculum in an infected crop is therefore extremely rapid under suitable environmental conditions.

Chlorotic spots, or large areas of chlorosis, are seen at this stage of mildew infestation. Under heavy infestation, stunting of cereal plants will occur.

Erysiphe graminis is able to survive and reproduce under a wide variety of climatic conditions (Tapke, 1951). This may be explained by the fact that the pathogen does not require free water for conidial germination (Yarwood, 1957), since the conidia themselves have a water content of up to 70% as compared with about 10% for other air-borne spores (Somers and Horsfall, 1966).

Relative humidity has a marked effect on conidial germination although conflicting reports occur. Tapke (1951) and Cherewick (1944) found conidia germinated readily between 0% and 100% R.H. Conversely, Clayton (1942) and Grainger (1947) reported low germination at 90% R.H., increasing as R.H. reached 100%.

Temperatures within the range 0 to 35°C allow germination with a maximum response between 15 and 20°C (Cherewick, 1944).

The bulk of evidence suggests that development of *E. graminis* is favoured by relatively dry weather, although mildew outbreaks may occur under almost all climatic conditions.

The asexual cycle continues throughout the spring and summer at a time when cereal crops are passing through a period of rapid growth. Crop damage is intense at this stage of rapid cycling of pathogen generations.

During late summer as the host plants begin to yellow-off, secondary mycelium is formed. Initially this is white in colour but later becomes grey to brown and has a fluffy nature. Cleistothecia which are globular, thick walled, dark brown structures, develop in the secondary mycelium.

Sexual reproduction occurs within the cleistothecia, resulting in formation of several asci, each containing eight ascospores. These sexually produced spores were once considered to be used for overwintering, but more recently Turner (1956) has envisaged them as bridging the gap between ripening of one host in the early autumn and development of a new host in late autumn.

As a result of sexual reproduction, a marked degree of physiological specialization is displayed by *E. graminis*. Several distinct "biological forms" have been distinguished on the basis of host specificity—e.g., there are specific strains for wheat and barley, namely *E. graminis* f. sp. *tritici* on wheat, and *E. graminis* f. sp. *hordei* on barley. Within each of these biological groupings there are many individual races of *E. graminis* each one genetically different from the other.

Two races of *E. graminis* f. sp. *tritici* were detected in New Zealand in a survey by Smith and Blair (1950) while Dingley (1969) reported on the possibility of two further races.

ECONOMIC SIGNIFICANCE

Brooks (1970) considered that powdery mildew of cereal crops is a chronic disease rather than an acute one, and for this reason estimates of losses due to *E. graminis* have generally been underestimated. Little information regarding economic losses caused by cereal mildew has been published.

Jensen (1951) reported on the work done by Butler in the U.S.A. in 1937-9. He showed that, using sulphur to control *E. graminis* on several trial plots, he was able to estimate reduction in barley yields of between 7% and 15%. Jensen considered these estimates to be conservative as he estimated yield losses of up to 40% due to *E. graminis*.

Losses in British cereal crops caused by *E. graminis* were not reported until Last (1955) showed his results using spring-sown barley and lime-sulphur sprays for mildew control. Yield reductions of 13% and 22% for early and late sowings, respectively, were measured. That sowing date altered the effect of *E. graminis* on yield loss was also shown by Last (1957) when the percentage yield loss was greater in later sown crops. Other publications by Large and Doling (1962) and James (1969) give evidence of yield reductions of 15% to 18% due to *E. graminis*.

Smith (1949) reported on yield losses in New Zealand wheat crops caused by *E. graminis* f. sp. *tritici*, but no figures are available.

That *E. graminis* causes economic losses to cereal crops is clearly shown by these reports. Actual damage is difficult to estimate, but is reflected in size of cereal grains, the amount of grain in each ear, and often the number of heads of grain formed.

CONTROL

Erysiphe graminis may be controlled by three methods, cultural practice, breeding resistant varieties, and application of fungicides.

Cultural practice is of minor significance and involves the removal of the ascospore source of inoculum by burning or ploughing in the crop stubble. Desiccant herbicides may also be used.

Genetically based resistance occurs and resistant varieties have been bred but in almost all cases resistance has broken down within a few years owing to the appearance of new physiological races of *E. graminis*. In New Zealand development of severe field infection of "mildew resistant" Hilgendorf 61 and Cross 7 61 occurred in some localities in the year of commercial release (Smith and Smith, 1970).

The application of fungicides appears to be the most successful method of controlling *E. graminis*. As indicated above, repeated application of sulphur dust and lime-sulphur has given a high degree of control in field trials, while Kent (1949), Smith (1949) and Jackson (1968) have reported successful use of lithium compounds in glasshouse pot trials.

Following World War 2, several antibiotics obtained from *Streptomyces* sp. were shown to effectively control *E. graminis* when plants were sprayed with filtrates containing the antibiotic, or their roots placed in antibiotic solutions (Powers, 1958). However, the use of antibiotics for mildew control on a field scale is not economically feasible.

In recent years research has been directed mainly at the use of organic protectant fungicides and systemic fungicides for powdery mildew control in the field.

Drazoxalon and dinocap, two organic protectants, have been successfully used to control *E. graminis*. Kirby (1966) reported that dinocap at 50 ppm gave 65 to 95% control of *E. graminis* f. sp. *hordei* when used as a foliar spray on barley, while Rosser (1969) reported that in European trials drazoxalon sprays gave increases in both barley yields and grain quality.

Protectant fungicides suffer from severe limitations due mainly to their usage as surface applications. Systemic fungicides are absorbed and translocated upwards within the plant vascular system enabling them to protect new plant growth and once absorbed are protected from environmental degradation.

Several systemic compounds have been used for mildew control in recent years. One of the earliest, ethirimol, a pyrimidine compound developed in 1964 (Brooks, 1970), has been shown to give up to 10 to 20% yield increases of spring barley, when applied as a seed dressing (Kruger, 1971). Spray applications are generally not as effective as seed applications.

A benzimidazol derivative, benomyl, also controls *E. graminis*, when used as a foliar spray or seed dressing. Several other systemic compounds, cyclomorph, tridemorph, biforomylchlorazin, and triarimol, have been used to control *E. graminis* in both field and glasshouse trials in Europe and Great Britain.

Systemic fungicide usage for powdery mildew control in New Zealand has been limited to experimental work carried out by commercial firms and government institutions. Little information is available regarding results of this work, although ethirimol, tridemorph, benomyl and triarimol have controlled *E. graminis* in New Zealand field trials.

METHODS FOR ASSESSING INCIDENCE IN CEREAL CROPS

When investigating plant diseases it is necessary to assess the incidence of the pathogen for several reasons:

- (1) To check the rate of progress of the disease.
- (2) To provide a basis for estimating crop losses.
- (3) To test the efficiency of control measures.

Furthermore it is essential to use standard methods of assessment in order that results from many sources may be accurately compared.

This involves several steps:

(1) *Defining the stage of growth of the plant at which mildew occurs or estimates are made.* By modifying the Feekes growth scale for wheat, Large (1954) produced growth stage diagrams providing a standard for reading the stages at which the incidence of powdery mildew in cereal crops occurs.

(2) *Distinguishing between yellowing and death of plant leaves caused by mildew and that caused by natural senescence.* Following detailed studies over a three-year period, Large and Doling (1962) found that at any one growth stage no more than four leaves are operative in photosynthesis. By measuring the incidence of mildew on the top four leaves only, confusion of the mildew symptoms with natural physiological process, is overcome.

(3) *Estimating the amount of tissue affected by powdery mildew.* Early records of mildew assessment were based on the Cobb scale first published in 1892. Although originally used to measure leaf rust (*Puccinia recondita* Rob. ex Desm.), modifications to the scale have enabled it to be used for assessing powdery mildew of cereals (Smith, 1949). Grainger (1947) also adapted the Cobb scale to obtain a leaf index method for measuring the incidence of *E. graminis* on oats.

Currently two further modifications are in general use. These are:

- (a) *Standard Key Diagrams:* These were developed by Large and Doling (1962) and they enable the physiological state of each leaf together with the amount of mildew on it to be recorded by simply comparing leaves with key diagrams. The method is useful in field surveys for making quick estimates of the mildew present but is of greater use in comparing mildew incidence on plants grown in glasshouse pot trials.
- (b) *Standard field keys:* These have been developed for many diseases including powdery mildew. The "key" is compiled in such a way as to provide easy recognition of the category of any diseased specimen in the field. Adequate descriptions of disease conditions obviate the need for diagrams. The percentage of the combined area of the upper four leaves which is covered by mildew pustules or yellowed by mildew is estimated.

(4) *Standardizing sampling methods in field trials.* When carrying out assessments, plants must be selected at random in order for true comparisons to be made. Selection methods vary, depending on plot size, but wherever possible a standard pattern of selection is necessary. One useful method suggested by Moore (1943), is to make two diagonal traverses of a plot or field, taking ten samples on each traverse. Each sample should contain one metre length of drill row.

CONCLUSIONS

Most aspects of the biology of *Erysiphe graminis* are well known, although conflicting reports have occurred regarding some aspects of its life-cycle. The disease of powdery mildew has been shown to be of great economic significance and several control measures have been developed. Breeding for resistance is an extremely long process, and the resulting immunity does not appear to last very long. Chemical control, therefore, is the best method of combating the disease. Advances in the study of systemic fungicides should enable successful control of *E. graminis* in the future.

There is a need for the use of standard methods for disease assessment throughout the world. The standard "key diagram" and "field key" are adequate for this work. Modifications to these systems will occur, but workers should continue to use standard methods to enable comparison of disease control methods.

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