EUCARPIA FODDER CROPS SECTION

Report of Meeting held at the Max-Planck-Institute
for Plant Breeding Research, Køln-Vogelsang, Germany
September 20th and 21st 1967.

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Preface

During 1966 the Board of the Fodder Crops Section of Eucarpia sent questionaires to its members with the aim of collecting information as to the fields of interests and wishes regarding new activities of the section.

A great number of the members responded to the questionaire and a majority expressed their interest in two distinct fields of research: **1) the breeding for disease-resistance in grasses** and **2) day length reaction in relation to the breeding of herbage plants.**

As a result, the Board decided to arrange a meeting where these subjects could be discussed. Following the kind invitation of Dr. Walther Hertzsch the meeting was held at the Max Planck Institute for Plant Breeding Research in Köln-Vogelsang, Germany, on the 20th and 21st of September 1967.

A total of 37 members attended the meeting, in the course of which Dr. Hertzsch and his co-workers presented the work at the Fodder Plant Department of the Max Planck Institute.

The meeting concluded in the formation of working groups for the two subjects mentioned above. As chairmen of the two groups were elected:

> 1) Dr. F. Wit, Wageningen, Holland
> 2) Dr. G. Julén, Svaløf, Sweden

On behalf of the Board I wish to express our sincere thanks to the Max-Planck-Institute for all facilities offered and for great hospitality shown to the participants. Special thanks are due to Dr. Walter Hertzsch and his co-workers for their kind and efficient assistance in all the local arrangements for the meeting.

Øtoftegård, April 1968

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Common Grass Diseases in Europe and Their Importance

by

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Introduction

You might well assume from the fact that I am addressing you today on the subject of grass diseases that I am an expert on phytopathology. You would be mistaken, however, because I am a plant breeder, and the only reason I am speaking is that I was not resistant enough to the organising committee's friendly but urgent request to read an introductory paper on this topic.

Although I feel somewhat uncertain as regards the subejct I am comforted by the reflection that a plant breeder certainly has many opportunities of observing diseased plants. Work with monocultures of single-spaced plants provides good opportunities of noticing pathological spectra. As the season goes on all manner of discolorations may be observed in nursery plants, the incidence varying from one year to another. One may see yellow to violet discolorations, leaf flecks of various hues, stripes and mosaic formations. Sometimes the plant is visibly affected by the disease and even dies, or it may suffer little harm and after being harvested it shows up again like new in the next cut.

The first thing I can do is to discuss with you which pathogens are involved in these infections. In this connection I am greatly indebted to the literature of the subject. Apart from many detailed papers in particular K. Sampson and J.H.Western's »Diseases of British Grasses and Herbage Legumes» and F.Mühle's »Die Krankheiten und Schädlinge der zur Samengewinnung angebauten Futtergräsern» were very usefull books. The same is true of Mr. Drew Smith's book about fungal diseases of turf grasses.

Now I was asked to speak to you about the common diseases, so I need not deal with the 40 or more pathogens described by the British authors, and still less with the 400 grass parasites which according to Mühle are described in the literature. And I do not think it necessary to treat my subject in such detail as to discuss the 50 species of detrimental fungi which according to a Finnish writer are to be found on timothy in Finland, or attempt to trace the 125 species of rust stated by the American author Fischer (1953) to attack

grasses. If all these parasites were such important factors probably no more grass would grow.

But even if we ignore scarce pathogens we are still left with a fairly large number of diseases. In order to arrive at a list of a manageable size I thought it advisable to confine my attentions to diseases that are clearly widespread and attack important grasses. I have also left out of account the soil-borne fungi which infect young plants in particular from the soil. The animal parasites, although they are numerous and occasionally dangerous, also come outside the scope of my paper.

A further difficulty is that I was asked to speak about diseases that occur in Europe. Now it would be quite untrue to say that Europe can be considered as a single unit as regards climate and soil conditions. A disease which is of general occurence in one area of Europe may be unknown in another. And I am sure that you will not think I was able to gather information on the grass diseases from every corner of Europe, so I have taken the liberty of interpreting Europe as »Holland and its surroundings» and ask you to forgive this rather chauvinistic approach to the subject.

Common diseases

The remaining diseases that may be described as common I have classified as diseases of the inflorescence and diseases of the rest of the plant, although I realise this is not an altogether clear-cut division. I shall also try to indicate the chief hosts, but this will be an easier task for some countries than for others.

Table 1. Diseases of the inflorescence.

Latin name	Common name	Main Hosts	Older name or synonym
Claviceps purpurea	Ergot	General	
Gloeotinia temulenta	Blind seed	Lolium sp.	Phialea temulenta
Epichloe typhina	Choke	Phleum, Dactylis	

Claviceps pupurea and Gloeotinia temulenta prevent the growth of healthy seeds, and Epichloe wholly or partly prevents the appearance of the inflorescence.

Rusts are caused by Puccinia and Uromyces, e.g. Puccinia coronata of Lolium, Puccinia graminis of timothy and cocksfoot, and Uromyces of cocksfoot.

Mildew and leaf flecks caused by Mastigosporium, Helminthosporium and Heterosporium are also of frequent occurrence. The virus diseases seem to grow increasingly common.

The last group of diseases is particularly common in lawns and playing fields, i.e. under

Table 2. Diseases not specific to the inflorescence

Latin name	Common Name	Main Hosts	Older name or synonym
Puccinia spec.)	Rust	General	
Uromyces)	Rust	General	
Erysiphe graminis	Mildew	General	
Mastigosporium rubricosum	Leaf fleck	Dactylis, Festuca	
Helminthosporium spec.	Leaf spot, Foot rot	Lolium, Festuca, Poa	
Heterosporium phlei	Leaf spot	Phleum	
Virus	Yellow dwarf, mottle streak, mosaiec	Lolium, Dactylis, Phleum	
Calonectria graminicola	Snow mould or fusarium patch	Agrostis, Festuca	Fusarium nivale
Fusarium roseum	Root rot	Agrostis, Festuca	Fusarium culmorum
Corticium fuciforme	Red thread or pink patch	Festuca	
Sclerotinia homoeocarpa	Dollar spot	Festuca	
Gäumannomyces graminis	Take-all	Agrostis	Ophiobolus graminis

conditions of frequent, close cutting. The group also includes Helminthosporium vagans which may become an important disease under intense mowing conditions.

For a more detailed description of the pathogens and symptoms I must refer you to the literature I already mentioned. I now wish to concentrate on the damage that may be done by the grass diseases.

Harmful effects of diseases have often been described in general terms. The diseases reduce the yield and quality. Infected or dead foliage has less nutritive value and is not so palatable to livestock. Diseases destroy seeds. And lastly, diseased plants have less resistance to such unfavourable conditions as drought and frost.

It is also known that in special circumstances the damage done may be very extensive. According to the Roumanian writer Radulescu, 1935, in 1932, a rust epidemic year, 26 resistant clones of timothy produced an average of 4.1 to 9.2 kg of green mass per clone in his nursery, whereas 26 susceptible clones only managed to produce 1 to 3.7 kg per clone.

Are losses sustained at this level under practical conditions? Grasses may be used in three different ways, i.e. for seed growing, for hay and pasture, and for lawns and playing fields. I will try to give some definite information on damage for each of these three groups.

Seed growing

The diseases that cause damage in seed growing are in the first instance those that attack the inflorescence. Claciceps purpurea is still an important disease that constantly occurs in seed crops. Fortunately all diseases do not occur with the same severity every year, but this makes it difficult to assess the average damage as the literature usually reports the result of a peak year and provides no information about the regular occurence of the disease.

During the period 1919 to 1925 60 % of all seed samples in Finland were contaminated by Claviceps (Mühle 1953). Seedmen have told me that in Holland the seed-growing diseases do not present any great problem but that Claviceps is the most serious, especially in smooth-stalked meadowgrass (Poa pratensis), and in particular in the American variety Merion. In one special year the loss in seed crop was 30 % - 40 % in this variety.

The disease may not only affect the seed crop but be a hazard to livestock, since the sclerotia are poisonous. I do not know whether such poisoning still occurs today.

Blind seed disease of Lolium is chiefly found in areas with a heavy rainfall and comparatively low temperature. In New Zealand, for example, it is particularly troublesome. In Europe it occurs in Ireland, which has a rainy climate, and in some years it is also encountered in other countries. Since the infected seeds are not misshaped, as they are when attacked by Claviceps, it is possible that the disease is the cause of low germinative power of the seed, the disease not being recognised. In 1946 the bred varieties of perennial ryegrass had a germinative capacity of 50 % in Northern Ireland, but the damage was far less severe in Irish

Commercial. The disease does not usually give much trouble in Holland. In the wet year 1965 infection of the awned ryegrasses resulted in an average damage of 19 % (de Tempe 1966). Losses were greatest in the coastal provinces.

In Ireland, Wright 1967 after assessing 5000 ryegrass found 4 plants which were resistant to blind seed disease and these have been incorporated in a breeding programme. Genes governing resistance were for the most part dominant. Many genes were involved.

The third inflorescence disease I mentioned was *Epichloe typhina*. This is a very widespread infection which is often found on roadsides and the like (Kohlmeyer 1956, Sampson 1932). It is, however, only a minor factor to be considered in growing seed, although severe damage of timothy is sometimes reported, as in Denmark in 1904, and some years earlier in Sweden were the seed crop was reduced by a third, According to Bontea (1962) Epichloe typhina caused considerable damage to cocksfoot seed fields in the years 1928, 51, 54 and 58, and in 1949 to the timothy seed fields.

In the U.K. Holland and Rumania the disease occurs locally in pastures, but no damage has ever been reported, so that the toxicity mentioned by some writers need not be taken too seriously. Varietal differences with respect to Epichloe of timothy have been described. (Mühle 1963).

The damage caused by these inflorescence diseases is directly reflected in the seed crop. Of course, this does not mean that the seed yield cannot be affected by other diseases, − in fact any disease capable of severely weakening the plant is a hazard to the crop.

The impression I have gained from a study of the literature and conversations with seed growers is that rust is considered to be the most dangerous of the remaining diseases. In Holland 1959 was the only year in which rust caused noticeable damage to the seed crop: it was estimated that smooth-stalked meadowgrass (Poa pratensis) suffered 15 % damage in the year in question. 1959 was a very dry year.

In contrast in Germany Mühle (1942) reports much damage to smooth-stalked meadow grass after a long period of wet weather, first to the seed yield and afterwards to the regrowth. In 1938 many fields wanted ploughing. In 1952 in Rumania (Bontea 1962) a severe Puccinia graminis attack before heading reduced the seed yield of Lolium perenne by 50 %.

Hardly any important economic damage is reported on mildew although the disease is extremely widespread. The disease sometimes cause damage to Cocksfoot, perennial ryegrass and smooth brome at the most areas of Rumania (Bontea 1962).

Obviously severe damage must by expected whenever virus diseases gain a foothold in the seed Crops, particularly the forms of disease that reduce the number of stalks. The virus diseases also endanger the germinative power. Catherall found that cocksfoot streak virus reduced the germinative power of the seed of seperate plants by about 50 %. But I have no information about severe damage to commercial seed fields.

Lastly, seed crop diseases involve additional cleaning work. In some cases the infected seeds are extremely difficult to remove, e.g. those attacked by blind seed disease. The chief diseases transmitted by the seed are Claviceps purpurea and Gloetinia, Epichloe typina of Festuca rubra (Sampson 1932) Helminthosporium species of Lolium, Festuca and Poa (Andersen 1959, de Tempe 1964, Christensen 1922). Opinions differ as regards the virus diseases, and no doubt Mr. Carr will be able to give us some better information later in the morning.

Grazing and haymaking

The situation is not so complicated in seed growing because the damage is expressed in the form of a lower weighed crop. But even in this case we are not so well-informed as we should like to be about the actual damage. The situation becomes more involved when the grass is used for grasing or haymaking. I can, however, pass on to you what figures are available about the damage suffered in hayfields and pastures.

The German writer von Oetingen (1932) reports cases of very great damage; in his view rust is responsible for the poor crop in the second cut in 50 % of the cases. A loss of 60 % to 70 % is to be anticipated for the total harvest. In seed growing the losses are even higher, and a situation of this kind would be considered a disastrous in arable farming.

His alarming figures, however, are not confirmed by other German authors, (eg. Buhl 1962, Mühle 1962).

Lancashire and Latch's measurements 1966 are more recent. Although these are not European but New Zealand experiments the results are too interesting to ignore. In their experiments with perennial ryegrass they kept half the plots free from disease by spraying them with chemicals, the other half being infected with rust. The damage measured was 36 % in the fresh crop, 30 % in L.A.I., and 20 % in the number of tillers. The percentage of yellow foliage also rose to 91 %.

In the States Elliot (1962) made several measurements of the percentage of leaf surface covered by disease symptoms in the course of the year. The figures he found were 14.8 % for Poa pratensis, 9.9 % for Dactylis glomerata, 11.4 % for Bromus inermis, and only 3.2 % for Phleum pratense.

It is interesting to note that timothy is the most popular pasture crop in West Virginia where the experiments were carried out. This might indicate that farmers really appreciate a healthy grass crop.

Returning to Europe, we have Carr and Catherall's (1963) figures showing that Mastigosporium rubricosum of cocksfoot varieties covered 1 % to 9 % of the leaf surface with flecks.

One interesting feature is that Carr and Catherall were able to demonstrate that some pathogens have a marked effect on the metabolism. A leaf surface of 9 % Mastigosporium was

accompanied by a 50 % drop in the content of water-soluble carbohydrates. Another disease that reduced the content of water-soluble carbohydrates was Puccinia of cocksfoot, and Helminthosporium leaf spot of Festuca pratensis had no such effects. Cocksfoot plants high in water soluble carbohydrates proved to be more prone to rust.

It seems to me that we can combine these data with certain other experiences. It has been found in experiments with oats that rust resistance and Helminthosporium resistance are to some extrent mutually exclusive, although not altogether so. In this context rust is termed a high-sugar disease and Helminthosporium a low-sugar disease (van Andel 1959).

Experience gained by Dutch breeders with Poa pratensis in particular shows that it is difficult but not impossible to combine rust resistance and Helminthosporium resistance.

In his breeding work with Lolium Wit (1966) found a positive correlation between susceptibility to Puccinia coronata and resistance to cold. Although in this case no measurements were made of the carbohydrate content, it is conceivable that the cold-resistant plants were the same as those that had a higher carbohydrate content. If this theory is correct we arrive at the same situation as Carr found with Puccinia of cocksfoot.

Lastly, U.S. workers have found that grasses attacked by rust have a higher protein content (Fischer 1953); this may correspond to a reduced carbohydrate content.

I may have wandered a little from my subject in giving you these correlated data, but I considered this advisable inasmuch as it focuses attention on certain important aspects of the problem. In the first instance, the Mastigosporium case shows that even a comparatively slight infection may have a marked physiological effect. Secondly, the data may be taken as a warning that breeders should not adopt a too one-sided approach in resistance breeding. For instance in breeding for rust resistance they should also be careful not to neglect cold resistance and resistance to other diseases, especially to Helminthosporium.

Much recent literature deals with the damage done by virus diseases. The British workers Carr and Catherall 1963, Catherall 1966, Catherall and Griffith 1966, experimented with simulated swards established by close planting of single tillers or seedlings. In such swards healthy cocksfoot plants outyielded streak virus infected plants by 60 %. In swards with healthy and diseased plants it was found that under frequent cutting the healthy constituents gave some compensation in growth, but not when cutting was occasional. In simulated swards of Lolium perenne, plants infected with barley yellow dwarf yielded 20 % less than swards of healthy plants. In mixed swards no compensation in growth occured from the healthy plants.

Thus in these experiments the damage inflected by virus diseases is very high. I have no information as to whether cases of damage are also found under practical conditions, although it is reported that considerable damage may be suffered by 2nd and 3rd year leys of cocksfoot.

So much for the figures I have found in the literature and which may give you some idea of the damage to quality and yield that may be caused by grass diseases. But nearly all these figures were obtained from rows or swards of a single species, whereas the mixed sward is the usual method of growing grasses. In my opinion the results of mixing species are somewhat conflicting as regards the incidence of grass diseases.

Mixtures

In the first place, when species are mixed the diseases cannot spread to the same extent, so that the effects of diseases are somewhat moderated. This obvious phenomenon is mentioned by several writers. The American workers Carter and Ahlgren (1951) showed by experiments that the spreading of two diseases of Smooth Brome, i.e. bacterial blight and brown leaf spot, was reduced when the smooth brome plants grew together with lucerne and were therefore more widely distributed over the field. Beard (1965) obtained similar results in mixtures of turf grasses.

Interspecific competition is another important factor to be remembered in mixtures. If a given variety is weakened by diseases its competitive power will decrease. Carr's experiments prove that in simulated swards of perennial ryegrass was attacked by barley yellow dwarf virus. The same was observed on cocksfoot clover leys at Hurley when the cocksfoot plants had been attacked by cocksfoot streak virus (Catherall 1966). The Dutch workers van den Bergh and Elberse (1962) also reports that in pot experiments on the competition between perennial ryegrass and Authoxanthum odoratum, the competitive power of ryegrass was reduced by a virus infection. In an unaggressive species weakening of the plant by disease may prove fatal in the struggle for existence.

Since shading is an important factor in competition, the data assembled by the American worker Beard (1965) are of some importence. He found that with heavy shading (5 % of the incident light) several turf grasses including Poa pratenses and Festuca rubra did not die from lack of light but through diseases. It may perhaps be inferred from these experiments that in cases where there is severe competition for light, prononess to diseases increases in the repressed plant.

Thus although on the one hand mixing of species counteracts the spread of diseases, it should not be forgotten that competition may have an adverse effect on the incidence and trend of the diseases. But we have not yet sufficient information on the interaction of disease and interspecific competition.

Under practical conditions, however, the situation is not only complicated by the use of mixtures; we are also faced with the problem of the reponse of livestock to diseased grass. Practically all that is known for certain is that livestock will ingest diseased herbage less readily than healthy herbage; it is diffucult to assess the degree of damage caused by diseases under grazing conditions, and it would be a step forward of we only knew what diseases were likely to be encountered in pasture.

The diseases one hears most about are the rusts, especially Puccinia coronata of Lolium perenne. Puccinia coronata occurs under practical conditions and reduces palatibility. Uromyces dactylidis is also mentioned in Rumania (Bontea 1962).

Mastigosporium rubricosum probably also occurs in cocksfoot pastures. A case of Corticium fuciforme in poor pastures is reported for North West Germany (Richter 1961).

Another important question is whether grass diseases have an adverse effect on the health of livestock. The best known is the above-mentioned Claviceps purpurea poisoning. Whether this is still important at the present day I am unable to say. Adverse effects are sometimes attributed to rusts as well, and these might be the causative factor of pulmonary disease in livestock. (Margadant 1952). Others report rust as being the cause of metritis and abortion, (Mühle 1953), but there is no proven evidence of such case. It is known, however, that grass diseases may sometimes indirectly affect the health of livestock. A fungus Pithomyces chartaran, which is the cause of facial eczema of sheep and cattle, develops on dead foliage in New Zealand, for instance as a result of a rust infection. (Lancashire and Latch 1966).

Lawns

The third form of grassland cultivation I mentioned was lawns and playing fields. In this case owing to the system of intense mowing and heavy wear, the diseases have more opportunities of killing the plant. On the other hand, there is more opportunity for a practical and economic use for chemical fungicides (Couch 1962, Kort 1962, Lefebre et al. 1953, Mankin 1955/56, Smith 1959).

A very good example of the effect of frequency of cutting on the trend of a disease is afforded by Helminthosporium vagans of Poa pratenses. With infrequent mowing Helminthosporium causes leaf flecks but the plant does not suffer to any considerable extent. With frequent mowing the disease spreads rapidly, attacks the sheath and roots and is fatal to the plant (Dreksler 1930).

Of the remaining diseases it can be stated that they cause flacks in the sward by killing or discolouring grass plants. It is precisely in this sector that users demand a uniform green sward.

It is difficult to assess the economic damage done in the lawn and playing field sector. It may vary from disfiguring the lawn to destroying the sward of a playing fields, from ruining the home gardener's hobby to bedevilling good relations in a sports club. As an illustration of the latter, here is a quotation from the American writer Couch's book (1962) on turf grass diseases: – Viz.

»The author knows personally of several instances in which, after a season of disease-ridden turf, the golf-course superintendent was offered by the Greens Committee as a living sacrifice to appease the wrath of the angry club membership».

Conclusion:

I have tried to give you some idea of the damage that may be caused by grass diseases. There is not sufficient information available to enable me to express the average damage in clear-out figures, and all I have been able to do is to try and discover the most generally widespread diseases and to indicate what degree of damage may be caused. The data given warrant the very general conclusion that grass diseases clearly increase the production risk in seed growing and may ruin the sward of lawns and playing fields. Of pastures it is at any rate true to say that grass diseases sometimes reduce palatability and nutritive value. Both in pastures and playing fields grass diseases may influence botanical composition. Unfortunately we have little information about crop losses in mixtures and the effects on inter-specific relationships.

For the present I cannot go beyond these general conclusions, but I hope you don't mind my making some brief remarks on the control of grass diseases.

Although good grassland management may sometimes prevent or retard diseases, and in some cases (for instance, lawns) they may be controlled by chemical agents, the safest kind of control is to breed resistant varieties.

Resistances, or at any rate varietal differences have been described for practically every disease. Although, according to Rebischung (1958), the frequency of resistant types is generally low. So, in principle it is possible to breed resistant varieties. In fact this has already been done for some diseases.

In my opinion, breeders should first concentrate on the disease that cause serious damage in practice. Examples of diseases known to inflict widespread damage in practice are Helminthosporium vagans of Poa pratensis and Puccinia coronata of Lolium perenne. But even here some differences occur. So far as I know, Helminthosporium is always a potential danger where Poa pratensis is frequently cut, and a highly resistant variety in America shows the same resistance in Europe. But in Holland and England northern varieties of Lolium perenne may sometimes be extremely susceptible to Puccinia coronata, whereas such a situation is unknown, or practically unknown in the country of origin. Consequently if a grower wishes to export his seeds he must be acquainted with the situation obtaining both in his own country and that in which his varieties are used.

The possible occurence of physiological races of pathogens is also important in this connection (Lefebre et al. 1053). Such physiological races have been described for a number of diseases, (Carr 1960, Couck and Bedford 1966, Latch 1966, Mastenbroek en Oort 1941, Mühle 1942, Nelson en Kline 1962, Rebischung 1958) and they probably occur in others.

It is possible that the arable farmer has more to fear from the new physios than has the grass grower. Since the susceptible genotypes of the cultivated grass species will always continue to abound under natural conditions, there is probably less risk than in other crops that a

given physiological race of a pathogen will begin to dominate. Moreover the most grass species are cross fertilizers and grown in mixtures, wnich will also hamper the dominance of a special race of the pathogen.

Finally, I have already mentioned that breeders should realise that one-sided selection for resistance may have drastic effects on the plant's physiological and chemical properties. Likewise, one-sided selection for resistance to one disease may enhance its prononess to another. It is therefore the grower's task not only to discover the resistances to the principal diseases, but to combine them, together with all the plant's useful characteristics.

References

van Andel, O.M.
Physiologisch-chemische achtergrond van de resistentie van planten tegen schimmels en bacteriën. From: Resistentie in de Landbouw, Wageningen 1959 pp 16-36.

Andersen, A.H.
Helminthosporium catenarium Drechs på græser i Denmark. Tidskrift for Planteavl 63 (1959): 710-736.

Beard, J.B.
Factors in the adaptation of turfgrasses to shade. Agronomy Journal 57 (1965): 457-459.

van den Bergh, J.P. and Elberse, W.Th.
Competition between Lolium perenne L. and Anthoxanthum odoratum L. at the two levels of Phosphate and Potash. J. Ecology 50 (1962): 87-95.

Bontea, V.
Die hauptsächlichsten Krankheiten an Futtergräsern in der Rumänischen Volksrepublik. Heft 8 Karl Marx Universität Leipzig 1962: 23-33.

Buhl, C.
Die Phytopathologische Situation bei Futtergräsern in der Deutschen Bundesrepublik. Heft 8. Karl Marx Universität Leipzig 1962: 13-22.

Carr, A.J.H.
The significance of virus diseases in herbage crops. Proc. 8th international grassland congress 1960: 200-204.

Carr, A.J.H. and Catherall, P.L.
The assessment of disease in herbage crops. Report Welsh Plant Breeding Station 1963: 94-100.

Carter J.F. and Ahlgren H.L.
Forage yields and disease devolopment of two varieties of smooth Bromegrass, Bromes inermis Leyss, grown under various conditions in the field. Agronomy Journal 43 (1951) 166-171.

Catherall P.L. and Griffiths, E.
Influence of cocksfoot streak virus on the growth of cocksfoot swards. Ann. appl. Biology 57 (1966): 149-154.

Catherall P.L.
The significance of virus diseases for the productivity of Grassland. Journal British Grassland Society 21 (1966): 116-122.

Christensen J.J.
Studies on the parasitism of Helminthosporium sativim. Technical Bull. 11 (1922). The university of Minnesota.

Couch, H.B.
Diseases of turfgrasses. New York, London 1962 pp. 289.

Couch H.B. and Bedford E.R.
Fusarium blight of turfgrasses. Phytopathology 56 (1966): 781-786.

Drechsler C.   Leaf spot and foot rot of Kentucky Bluegrass caused by Helmin-
thosporium vagans. Journal Agricultural Research 40 (1930): 447-456.

Elliot, E.S.   Disease damage in forage grasses. Phytopathology 52 (1962): 448-551.

Fischer, G.W.   Some of the 125 rusts of grasses. From: Plant Diseases, the yearbook
of agriculture. 1953: 276-280.

Kohlmeyer, J.   Beobachtungen über die Lebensweise von Epichloe typhine (Pers.) Tul.
Ber. dtsch. bot. Ges. 69 (1956): 149-157.

Kort, H.   Schimmelziekten van gazongras. Tijdschrift der Ned. Heidemaatschappij
9 (1962): 261-265.

Laneashire, J.A. and Latch, G.C.M.
Some effects of crown rust (Pucciniae coronata Corda) on the growth
of two ryegrass varieties in New Zealand, New Zealand Journ. Agric.
Res. 9 (1966): 628-640.

Latch, G.C.M.   Fungous diseases of ryegrasses in New Zealand, I. Foliage diseases.
N.Z.J. agric. Res. 9 (1966): 394-409.

Lefebre C.L., Howard F.L., and Gran F.V. How to keep turf grass healthy. Plant Diseases.
The Yearbook of Agriculture 1953: 285-291.

Mankin, C.J. and Ross J.G.
Grass Diseases. Agric. Research in South Dakota 69 Annual Report
1955/1956 P. 102-105.

Margadant, W.D.   Parasitaire schimmels van weidegrassen. Verslag C.I.L.O. over 1951.
Wageningen 1952 pp. 42-44.

Mastenbroek, C. en Oort A.J.P.
Het voorkomen van moederkoren (Claviceps) op granen en grassen en
de specialisatie van de moederkorenschimmel. Tijdschrift over planten-
ziekten 47 (1941): 165-185.

Mühle E.   Die Rostpilze der wichtigsten zur Samengewinnung angebauten Futter-
gräser. Phytopathol. Zeitschrift 14 (1942): 83-101.

Mühle E.   Die Krankheiten und Schädlinge der zu Samengewinnung angebauten
Futtergräser. Leipzig 1953 pp. 167.

Mühle E.   Krankheiten und Schädlinge der Kulturgräser. Pflanzenschutz 10 (1958):
109-111.

Mühle E.   Allgemeines zum Auftreten von Krankheiten und Schädlingen an
Futtergräsern. Heft 8 Karl Marx Universität Leipzig. 1962: pp 5-12.

Nelson, R.R. en Kline, M.
Intraspecific variation in pathogeneticy in the genus Helminthosporium
to gramineous species. Phytopathology 52 (1962): 1045-1049.

von Oettingen, H.   Phytopathologische Probleme des Grünlandes. Mitteilungen des Vereins
zur Förderung der Moorkultur im Deutschen Reiche. 50 (1932): 20-24.

Ohmann–Kreutzberg, G.
Ein Betrag zur Analyse der Gramineenvirosen in Mitteldeutschland. Das
Streifenmosaikvirus der Gerste. Phytopathologische Zeitschrift 45
(1962): 260-288.

Rădulescu, E.　Die Bedeutung der Züchtung des Liechsgrases (Timothee) auf Rost-resistenz. Der Züchter 7 (1935): 324-326.

Rebischug, J.　Breeding for Disease-resistance in forage grasses. 1958 (mimeographed).

Richter W.　Grasnarbenschäden durch Corticium fuciforme (Berk) Warkef In Nord-west Deutschland. Nachrichtenblatt des Deutschen Pflanzenschuts-dienstes 13 (1961): 54-58.

Sampson, Kathleen　The systemic infection of grasses by Epichloe typhina (pers). Tul. Trans. Brit. Micological Society 18 (1932): 30-47.

Sampson, K. and Western, J.H.
　Diseases of British grasses and Herbage Legumes. Cambridge 1954.

Smith, J.D.　Fungual diseases of turf grasses. Yorkshire 1959 pp. 90.

de Tempe, J.　De blinde zaden-ziekte van raaigras in Nederland. De zaad-contrôle in 1965/1966 Mededeling R.P.v.Z. no. 18-december 1966.

de Tempe J.　Helminthosporium-infecties van graszaden. Med. Ned. Alg. Keurings-dienst landbouwzaden en aardappelpootgoed 21 (1964): 48-50.

Wit, F.　Winterhardheid bij grassen. Ontwikkeling in de plantenveredeling Wageningen 1966: 174-181.

Wright, C.E.　Blind seed disease of ryegrass. Euphytica 16 (1967): 122-130.

Preliminary results from a method of inoculation of cultivars of Italian rye-grass (Lolium multiflorum and S/SP) with Puccinia Coronata CDA, for testing the rust susceptibility of these cultivars

by

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Natural contaminations in breeding nurseries of Italian Rye-grass are subject to numerous factors of heterogeneity which make the detection of genotypes resistant to Puccinia coronata Cda difficult. We are trying to perfect a method of incculation which will allow a rapid and sure selection of plants resistant to this rust.

At the begining we endeavoured to find out the influence of the age and developmental stages of the plant to its susceptibility to Crown Rust.

Secondly we compared the results of artificial inoculations on living plants growing in boxes and on leaves which had been detached and kept alive in Petri dishes.

I INFLUENCE OF THE AGE AND DEVELOPMENTAL STAGES OF THE PLANT

1 INFLUENCE OF AGE

In 1965, we transplanted, in a nursery 70 cm apart, plants with the age of four leaves, on four dates at intervals of one month (29 April, 26 May, 29 June, 27 July). These plants belonged to three cultivars of Italian Rye-grass.

Motterwitzer *   : susceptible
Fat   : fairly susceptible
Tetrone   : almost resistant

4.800 plants were placed in split plots in six repetitions of twelve elementary plots.

The infections were natural. They began at the end of June and reached their maximum in October.

Notation took place from the thirteeth October to the twenty-fifth October 1965, the intensity of the attack on each plant being evaluated on a scale ranging from zero to five.

Scale used		Correspondance to the general European scale of recording data applied to the susceptibility to Rust
marks	Explanation of marks	
0	No Rust	1
1	A few pustules per plant	2
2	A few pustules on a few leaves	3
3	Less than half the plant covered with pustules	4-5
4	Half the plant and less than three quarters covered with pustules	6,7,8
5	Three quarters and more of the plant covered with pustules	9

The results are expressed by the average of the marks of each elementary plot.

We noted that:
— the three cultivars are significantly different from one another
— the plants of the last date of transplanting are significantly less attacked than the three others. There is no significant differences between these last
— there is no interaction between the dates of planting out and the classification

2 INFLUENCE OF THE DEVELOPMENTAL STAGE OF THE PLANT

One cultivar of non alternative Italian Rye-grass, Tetrone, was artificially inoculated on the sixteeth February 1967 at three different developmental stages.

At the moment of inoculation each plant had a comparable leaf volume. The test apparatus comprised 210 plants in seven repetitions.

Notation took place on the second and seventeeth March and the second April 1967, according to the above scale of 0 to 5.

The data are expressed as an average of the marks per elementary plot.

We obtained:

Stage of the plants of the Tetrone cultivar at the time of inoculation on the 16 february 1967	Dates on which the Rust was noted					
	2-3-67		17-3-67		2-4-67	
	developmental stage	Average marks	Developmental stage	Average marks	Developmental stage	Average marks
End of montaison	Flowering	0.81	End of Flowering (17% regrowth)	1.52	Maturity 57% regrowth	2.23
Vernalised plants presenting the vegetative stage S, with elongated apex (i.e. when the internodes appear)	Motaison	2.19	ear emergence	1.94	end of flowering Maturity (62% regrowth)	2.74
Non-vernalised plants not yet presenting the vegetative stage A.	Vegetative appearance	1.95	vegetative appearance	2.81	vegetative appearance	3.84
S. D. (P = 0,5)		0,52		0,57		0.61

3 CONCLUSION
— The age of the plants has influence on the classification on the three Motterwitzer, Fat and Tetrone cultivars. On the other hand, the general intensity of the attack is weaker on the youngest plants.
— The plants become more resistant at the period of ear emergence.

II ARTIFICIAL INOCULATIONS

We tried to perfect and compare:
— a technique of inoculation on living plants growing in seed boxes
— a technique of inoculation of cut leaves kept alive in Petri dishes.

A Inoculation in boxes
1 DISCRIPTION OF THE TECHNIQUE
a Gathering and preservation of spores
— The spores are collected by means of a small glass cyclone attached to a laboratory aspirator
— The spores are preserved in a refrigerator kept at $7^o - 11^o$ C.
This method of preservation permits a germination
— of 98 % after one month
— of 25 % after three months
— of 3 % after eight months

b Contamination

We sprayed the leaves of the plants growing in seed boxes with water, and dusted them with a mixture of ordinary talc and the spores. With spores aged one month the inoculum was made up of 1 cc of uredospores for 50 cc of talc.

c The penetration of the Rust

In order to avoid the evaporation of the water necessary for the germination of the spores, and for the penetration into the host plant, the boxes are covered for forty-eight hours with transparent polyane bags.

d Notation

Every plant is noted from 0 to 5 according to the scale described above.

2 THE RESULTS: VALUE OF THE TECHNIQUE OF INOCULATION IN BOXES

Disadvantages

a Consequences of the temperature and the light during the germination of the spores and the penetration into the host.

— During this period the boxes are covered with a transparent polyane bag. An intensity of 8.000 to 10.000 lux is necessary outside these bags. Smaller plants recieve less light than the bigger ones and their infection is reduced.

— Contamination is difficult at a temperature constantly above about thirty degrees centigrade.

— In summer it is necessary to shade the boxes in order to lower the temperature beneath this maximum level.

b Importance of the handling of the boxes

The boxes have to be handled in order to obtain the most favourable environment factors during the contamination, and this takes up much time. This drawback will disappear by using a growth-room.

c Long notations

In order to give marks, the experimenter has to isolate each plant by hand. In fact, the plants are entangled.

d The space taken up is not negligeable

Ten plants grow in a box 45 x 15 x 15 cm.

Advantages

a The method is rapid

At temperatures of 20º to 25º Centigrade the period of incubation is eleven days.

b The correlation with natural infection is excellent
– 12 ecotypes, each comprising about sixty plants, put in a nursery on the 1st March 1966, were naturaly infected by Crown Rust and were noted on the 16th October 1966.

– On the other hand, seeds of the same ecotypes were sown in boxes in hot house on the 29th September 1966. The plants were artificially inoculated on the 18th November 1966 when they had 8 to 10 leaves and were noted on the 30th November 1966.
– The test comprised 1.080 plants in nine repetitions.
– The coefficient of correlation between the averages of the marks given in the nursery and in seed boxes is 0.758. It is significant at a level of 0.01.

B Inoculation in Petri dishes

In order to avoid the disavantages of inoculation in seed-boxes, we tried to perfect an inoculation of cut leaves kept alive in Petri dishes.

1 DISCRIPTION OF THE TECHNIQUE

– Two leaves of n - 1 category of each plant are detached and immediately floated in water containing benzimidazol in Petri dishes.
– Contamination. This is carried out by spraying the leaves with water, then dusting them with a mixture of talc and spores.
– Infection is noted. On each leaf, according to a scale from 0 to 6, taking into account both the stage of development of the Rust and the leaf surface taken up by the Rust.

0   no infection
0;   chlorotic spots
1   a few weakly dehiscent pustules
2   a few very powdery pustyles
3   less than half the leaf is taken up by pustules which are faintly deshiscent or not at all
4   less than half the leaf is taken up by very powdery pustules
5   more than half the leaf surface is covered by pustules which are faintly powdery or not at all
6   more than half the leaf surface is covered by very dehiscent pustules

2 The results

a Factors acting on the drying up of the leaves
The temperature. We observed ten days after inoculation of the leaves of Tetrone cultivar, floating on water containing 60 ppm of benzinmidazol

Temperatures		% of leaves
Extremes	Averages	dried up
13o - 19o	17o	7 %
15o - 22o	19o	19 %
20o - 22o	21o	30 %

The »length of survival» of leaves

By inoculating leaves of Tetrone and using a concentration of 60 ppm of benzinmidazol, and the temperature between 13o and 19o (average 17o) we obtained:

Number of days in survival	% of leaves dried up
10 days	7 %
14 days	14 %
21 days	49 %

The cultivar

At the end of twelve days with a temperature varying from 18o to 30o C (an average of 24o), we observed on the inoculated leaves, floating on the water containing 60 ppm of benzimidazol:

Cultivar	% of leaves dried up
Tetrone	32 %
Motterwitzer	75 %

The concentration of benzimidazol

Leaves detached from four cultivars of Rye-grass were floated on four different concentrations of benzimidazol and inoculated. Fourteen days after inoculation, at temperatures between 13 and 21 degrees (an average of 17o), we obtained out of 216 leaves for each concentation.

Concentration of benzimidazol	% of leaves dried up
60 ppm	21 %
120 ppm	8 %
180 ppm	12 %
240 ppm	13 %

This indicates
there is no significant difference between the treatments 120, 180, and 240 ppm.
the treatment at 60 ppm is significantly different from the three others.

b Inhibiting action of benzimidazol on the rust Puccinia ceronata Cda.
In the experiment just mentioned the rotation of intensivy of infection
expressed as an arc sin $\sqrt{\%}$ marks of 0 plus 0; shows that benzimidazol has an
inhibiting action on the Rust.

Concentration of benzimidazol	Average marks Arc sin $\sqrt{\%}$ marks (0–0;)	S.D. P = 0.05
60 ppm	32.4	
120 ppm	52.9	
180 ppm	76.7	4.105
240 ppm	77.1	

c Correlation between the inoculations in Petri dishes and artifichal contamination
in seed boxes or natural contamination in nursery.
By using a concentration of benzimidazol of 60 ppm, we obtained a significant
correlation between the infections obtained in Petri dishes on the one hand, and
in nursery on the other. Two tests wer carried out:

First test
Method

Nine cultivars of Italian Rye-grass, sown in seed-boxes in a hot-house on the 1st
July 1966 were inoculated according to two techniques:

On the 20th August 1966 the plants were contamined in seed-boxes. The
experiment comprised seven repetitions on nine seed-boxes of ten plants.
Notation took place on the 12th September 1966.

On the 20th August 1966 leaves were detached from the same plants growing in
seed boxes, not yet inoculated, two leaves of category n - 1 per plant.

The experiment comprised 1.242 leaves, 6 per 10 cm Petri dish. The Petri
dishes were placed on the laboratory bench in six repetitions. The light was
natural, and the temperature varied from 15⁰ to 34⁰ (an average of 24⁰).
Notation took place on the 1st September 1966; at this date 49,4 % of the
leaves were dried up.

The results

The intensity of infection is estimated by the averages of the marks given to the the plants growing in the seed-boxes and by the log. of the average of the marks given to the leaves in the Petri-dishes. In this case, the logarithmic transformation is necessary in order to eliminate the average – variance connexion. We observed:

a coefficient of correlation of 0.8398, significant at the level of 0.01, between the marks given to the plants growing in seed-boxes and to leaves kept alive in Petri dishes.

a comparable classification of the cultivars

Cultivars	Inoculation in seed boxes Average of marks	Inoculation in Petri dishes Log. of average of marks
Tetrone	2,88	0.366
Rina	2.91	0.493
Tiara	2.95	0.467
Fat	3.37	0.477
Rita	3.57	0.566
Motterwitzer	3.91	0.696
Melle	4.01	0.570
S K 7	4.06	0.585
Westerwold Billion	4.13	0.630
S.D. (P = 0.05)	0.41	0.096

Second test

Method. We compared:

the artificial infection carried out in seed-boxes on the 18th November 1966 on 12 ecotypes.

the natural infection on the same material which took place in the fields.

an inoculation in Petri dishes. On the 14th January 1967 we detached two leaves from the healthy regrouths of each plant growing in seedboxes (Two leaves of n - 1 category).

The experiment comprised seven repetions of 36 dishes each one containing six leaves. It was carried out under artificial light, under a light intensity varying between 3.000 and 10.000 lux.

The temperature varied between 15º and 22º and the average was 19º C. Notation took place on the 3rd February 1967. At this date, 22 % of the leaves had dried up.

The results

a Correlations between the infections in seed-boxes, in the nursery, and in Petri dishes.

By expressing the results of the marks given in the Petri dishes seed boxes and from the nursery, by means of uncorrected averages; we obtained.

Coefficient of correlation between the averages of the marks of the inoculation in Petri dishes and:	The average of the marks given on the 30-11-66 to the plants inoculated in seed-boxes on the 18-11-66	The average of the marks given on the 17-10-66 to the plants naturally contaminated in the nursery
	0.7435	0.5018
Significance	Significant at a level of 0.01	Not significant at a level of 0.05

By expressing the results of the inoculation in Petri dishes as Arc sin $\sqrt{\%}$ of marks 0, and those of the inoculations in seed-boxes and in the nursery by means of uncorrected averages, we obtained:

Coefficient of correlation between Arc sin $\sqrt{\%}$ marks 0 of the inoculation in Petri dishes and:	The average of marks given on the 30-11-66 to the plants inoculated in seed-boxes on the 18-11-66	The average of marks given the 17-10-66 to the plants inoculated naturally in the nursery
	− 0.7347	− 0.6601
Significance	Significan at a level of 0.01	Significant at a level of 0.05

b Comparable classifications of the average susceptibility of the ecotypes

Ecotypes	Inoculation in seed-boxes on the 18-11-66	Inoculation in Petri dishes the 14-1-67	Inoculation in Petri dishes 14-1-67
	Averages of marks (uncorrected) given on the 30-11-66	Log $(1-x)$ of the averanges of the marks given the 3-2-67	Arc $\sin\sqrt{\%}$ marks 0 given the 3-2-67
45	1.91	0.036	80.6
52	2.55	0.240	53.4
10	2.93	0.211	48.9
69	2.95	0.154	50.5
61	3.10	0.411	13.5
84	3.21	0.276	39.1
73	3.31	0.440	25.7
72	3.47	0.346	29.6
81	3.48	0.370	28.7
48	3.54	0.348	38.3
20	3.57	0.354	50.7
63	3.74	0.314	28.5
S.D.(P=0.05)	0.40	0.173	14.2

3 CONCLUSION AND PRESENT METHOD OF TECHNIQUE FOR INOCULATION IN PETRI DISHES

The correlations obtained between the infections in Petri dishes on the one hand, and, on the other, the corresponding infections in seed-boxes and in the nursery, encourage us to pursue experiments in order to improve the technique of inoculation in Petri dishes.

One of the conditions essential for success is to be able to work with homogeneous and controlled factors of temperature, light and humidity.

In the present state of the progress of our experiments we propose the following conditions for proper inoculation in Petri dishes.

a Concentration of benzimidazol: 60 ppm of benzimidazol in tap water.

b Preparation of the leaves: One, or preferable two leaves on n - 1 category per plant are detached and floated immediately in 10 cm Petri dishes, six leaves per Petri dish. The non adaxial part of the leaves is places in contact with the liquid.

c Inoculation: This is carried out by dusting a mixture of talc and spores on the leaves, previously sprinkled with droplets of water.

    d Conservation of the water on the surface of the leaves until the rust penetrates the host.

       In order to avoid the evaporation of the water from the surface of the leaves prior th tho penetration by the rust into the host, we light up the Petri dishes 24 hours after contamination.

    e Heat and light conditions in order to obtain an acceptable hatching twenty days after contamination with 30 % of the leaves dried up.

       Temperature :   17 degrees C
       Light   :   10.000 lux

       In fact, the homogeneity of light seems to be more important than a heavy intensity. A 2.000 lux, the infection seems to be of a degree close to that 10.000 lux at the same temperature.

III   DISCUSSION AND CONCLUSION

When one compares the susceptibility of Crown Rust of Italian Rye-grass cultivars, it is essential to use plants of the same age and developmental stage.

The classification of the cultivars can be carried out easily at the vegetative stage, as soon as the plants have 5 to 6 leaves.

With the two techniques of inoculation we can classify the cultivars of Rye-grass according to their susceptibility to Crown Rust.

But, if in seed-boxes we can detect individually the resistant genotypes, it is not yet possible in Petri dishes.

We have to state that there is an absolute parallelism between the susceptibility of each plant and that of the corresponding detached leaf. In order to arrive at this, factors of heterogeneity other than those studied above must be eliminated:

The water must be regularly spread over all the leaves and be maintained until germination of the spores and the penetration by the germinative tube into the host.

The spraying of water must be constant from one Petri dish to another, in order to avoid differences, however slight, of the concentration of benzimidazol.

It is necessary to diminish the concentration of benzimidazol below 60 ppm in order to obtain an absolute concordance between the susceptibility of the living plants and that of the corresponding detached leaf. And that, while decreasing the number of dried up leaves in order to improve the precision of the result.

The study and determination of the physiological strains of Puccinia coronata Cda sp Lolii is necessary.

SUMMARY

Several experiments have been carried out following infections of Italian Rye-grass cultivars Puccinia coronata Cda.

The age of the plant has no influence on the classification, according to susceptibility, of three Italian Rye-grass cultivars. In this test, and using natural inoculations, the youngest plants were attacked the least.

The plant becomes less susceptible at the emergence of the ear.

The technique of inoculation of living plants growing in seed-boxes allows a classification of the cultivars, but does not yet allow the detection of resistant genotypes.

BIBLIOGRAPHIE

Hooker (A.L) and Yarwood (C.E)
>Culture of Puccinia sorghi on detached leaves of corn and *Oxalis corniculata.* Phytopathology, t 56, 5, 536 - 539 1966.

Leath (K.T) and Stewart (D.M)
>A method for the separation of isolates of *Puccinia graminis.* Plant Dis Rep. t 50, 5, 312 1966.

Mansat P.
>Variation de la longueur de tige et realisation d'un de developpement chez les graminées fourrageres. Ann. Amelior. Plantes 1965 15(1) 53 - 60.

Person C., Samborski D.J., and Frosyth F. R (1957)
>Effect of benzimidazol on detached wheat leaves Nature (Lond.) 180.1294. 1294.

Pozsar (B.I.) and Kiraly (Z.)
>Phloem-Transport in rust infected plants and the cytokimin-directed long-distance movement of nutrients. Phytopathol. Z. t 56, 2, 298 – 309 1966.

Pozsar (B.I.) and Kiraly 1966 and M.E.L. Hammady
>Cytokimin activity in Rust infected plant. Juvenility and senescence in deseased leaf tissues. Acta Phytopathologica Academiae Scientiarum Hungaricae vol 1 Number 1 - 2 pp 29 - 38.

Quick (W.A) and Shaw (M)
>The Physiology of host parasite relations XIV. The effet of rust infection On the nucleic acid content of wheat leaves Can. J. Botany 42 1531 - 1540.

Quick (W.A) and Shaw (M)
>The physiology of host parasite relations XVII. Acide soluble nucleotides in rust infected and senescing wheat leaves Canad. J. Bot t 44, 6, 777 - 788. 1966.

Shaw M, and Srivastana Bis 1964
>Purine like substances from coconut endosperm and their effect on senescence on excised cereal leaves. Plant Physiol. 29, 528 - 532.

Shaw (M) and Srivastana Bis 1964
> Chlorophyll, protein and moleic acid level in detached senescing wheat leaves. Canad. J. Bot. t 43, 6, 739 - 746 1965.

Tervet, Ian W, A J. Rawson, E. Cherry and R. B. Saxon 1951
> A method for the collection of microscopic particles phytopathology 41 282 - 285.

Wolfe (M.S.I.) and Macer (R.C.F.)
> The use of kinetin in the detached leaf cultur of *Puccinia strriformis* Cereal Rust conf. Cambridge 58 - 63 1964.

Some data on susceptibility to rusts (genus PUCCINIA) of several cultivars of tall fescue (Festuca arundinacea Schreb.), and cocksfoot (Dactylis glomerata L.) in the south of france

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Data have been recorded by the »Station d'Amelioration des Plantes de Montpellier» France, on the susceptibility of several cultivars of Tall Fescue *(Festuca arundinacea Schreb.)* and of cocksfoot *(Dactylis glomerata L.)* to cryptogamic diseases, mainly rusts (genus *Puccinia).*

Material and Methods:

On Tall Fescue plants, notations have been gathered in the fall, of the last three years: 1964, 1965 and 1966, on the susceptibility to *Puccinia coronata* (the most important cryptogamic disease on Fescues) of several cultivars registered in the »Catalogue Officiel francais des Especes et Varietes cultivees», used ordinarily as varieties of reference in the pre-registration nurseries. Observations concerned also selections of *Festuca arundinacea* submitted to the examination in view of registration in the above-mentioned Catalogue. Among these, two cultivars selected by the »Station de Montpellier» into populations coming from Mediterranean Basin Area, named respectively *»Gazelle»* (from Israel) and *Grombalia* (from Tunisia), showed complete resistance to any *Puccinia* kind during the three seasons of studies. According to this character, they seem to be able to furnish a material valuable for an hybridization breeding work, with varieties from other origins.

The notation scale used is the one proposed, some years ago, by the Dr. VON LOCHOW, of the Methods and Technics Section, in view of standardizing the presentation of the results obtained by EUCARPIA'S different sections.

This scale range from 1 to 9, the first number agreeing with »notrace» of rust, the number 9 with the maximum of attack possible.

The average, by variety and by year, representative of the susceptibility to the disease, is obtained by making the product of the plant number in each notation class, by the coefficient concerned to this last one, then by summing up, and finally dividing by the total number of plants observed.

The formula is:

$$\overline{x}\ V_A = \frac{\Sigma\left[(np1 \times C_1) + (np2 \times C_2) + \ldots (np9 \times C9)\right]}{N_p}$$

$\overline{x}\ V_A$ is the average of susceptibility by variety, by year.

$np1, np2 \ldots$ the number of plants in each class of notation.

$C_1, C_2 \ldots$ the coefficients concerned to every class

N_p the total number of plants

Results

The averages of the cultivar *Manade* (early type) were the following ones: in 1964 = 3,09; in 1965 : 4,65; in 1966 : 2.39
and those of the cultivar *S. 170* (semi-early type)
in 1964 = 4,92; in 1965 : 5,20; in 1966 : 2,55.

Diagram 1 shows the distribution of the number of plants between the classes of notation, and also the averages of susceptibility to the disease by variety and by year.

One can see that in the beginning of autumn 1965, the averages of attacks by *Puccinia coronata* rank distinctly above those recorded in 1964 and in 1965, reaching for the two cultivars *Manade* and *S 170* exactly twice the level observed in 1966, and 20 p. cent above 1964.

Regarding cocksfoot, data are referred to the black rust *(Puccinia graminis)*, in autumn of two years, 1965 and 1966 only, on the varieties used as checks in the »pre-registration» to »Catalogue Officiel» nurseries, in the same manner as previously for Tall fescues.

The cultivars studied were belonging to three main groups:
- 1st Very early and early : Montpellier, Aries, Germinal
- 2d semi-early : Floreal, Chantemille
- 3rd Late: Prairial, Taurus, Frode, Barenza.

The general average of susceptibility for all the cultivars, in 1965: 2,26 is higher than the 1966 one: 1,82. The same fact has been recorded on tall fescues towards *Puccinia coronata* attack, but at a slighthy lower level.

According to the group of earliness, character in connection in some degree, with the re-growing strength in autumn, the averages of susceptibility are the following ones:

1965   very early and early types of cocksfoot : 2,01; semi-early 2,10; late : 2,65.
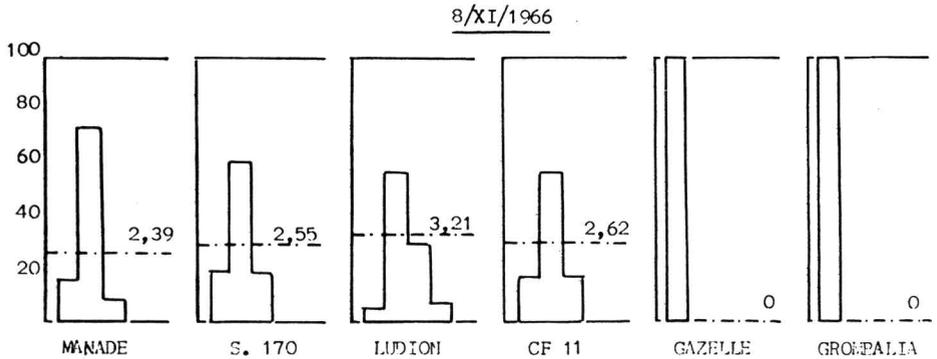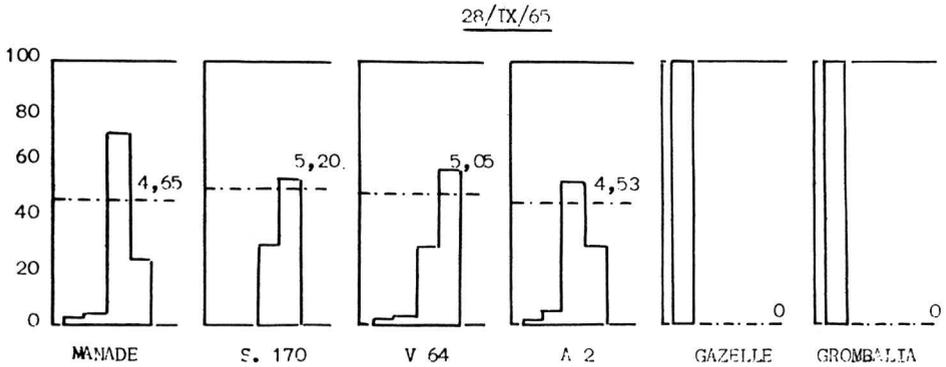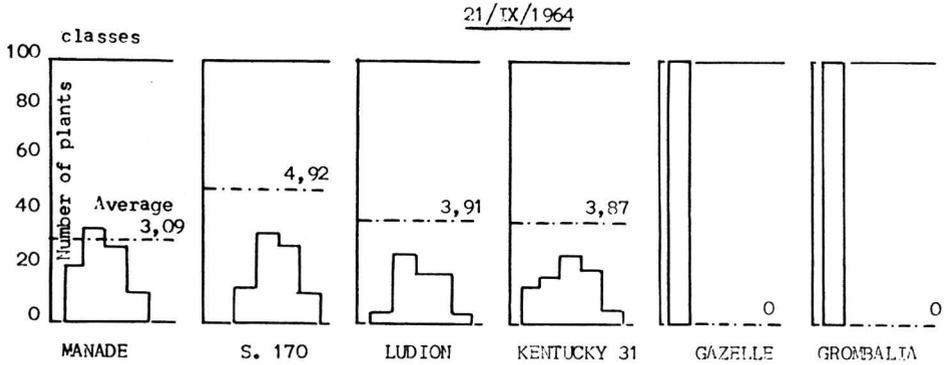
1964   very early and early types : 1,43; semi-early 1,82; late : 2,21.

The second diagram shows the data related to the distribution of the number of plants between the classes of notation, and the averages of susceptibility to the disease by variety and by year.

On a general level, for the two rusts studied, and in relation with meteorological environment in the fall of 1965, (when the most severe attacks by rusts appeared on tall fescues as well as on cocksfoots) rainfalls were not high in August and in September, but on the other hand mean temperatures fall distinctly under the normal. Mean minima temperature were respectively : 12º. 9 C in August and 11º, 4 C in September 1965, versus 18º, 4 C and 14º, O.C. in 1964, and 13º, 5 C and 13º. O.C. in 1966.

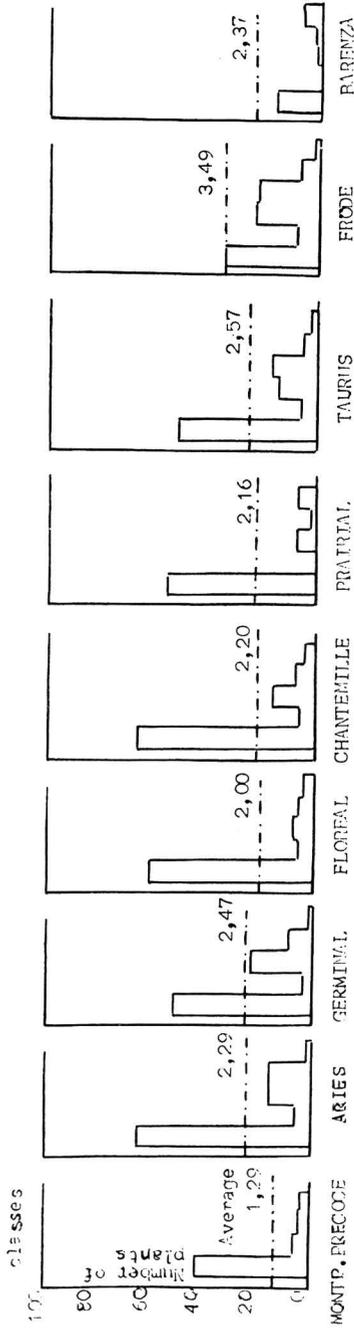The observations concerning rust attacks on the same two kinds of graminaceae are carried on in 1967.

STATION D'AMELIORATION DES PLANTES DE MONTPELLIER

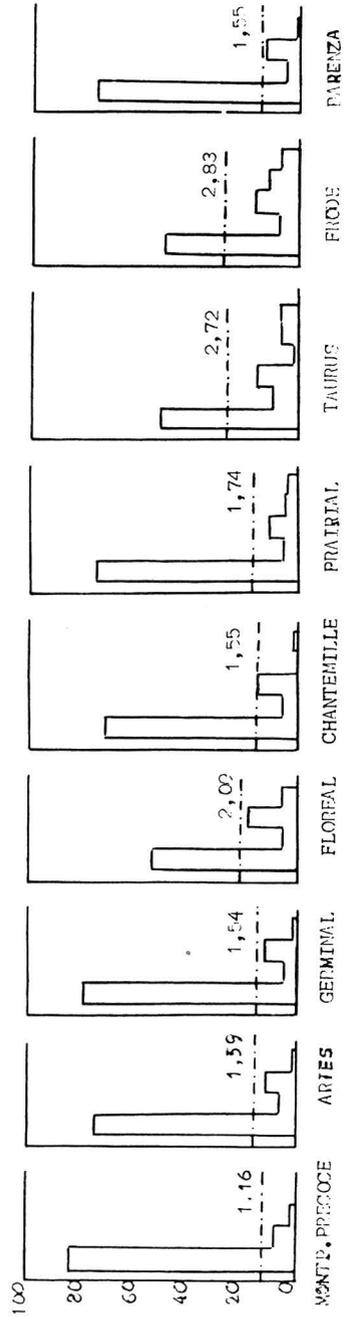1°. PUCCINIA CORONATA/FESTUCA ARUNDINACEA

21/IX/1964

28/IX/65

8/XI/1966

STATION D'AMELIORATION DES PLANTES DE MONTPELLIER

2° PUCCINIA GRAMINIS/DACTYLIS GLOMERATA

28/IX/1965

8/XI/1966

Über recente Blattfleckenkrankheiten an Futtergräsern als mögliche Hemmfaktoren für den künftigen Futtergrasbau

von

E. Siebs

Die landläufige Meinung in der Grünlandpraxis über das Auftreten von Blattfleckenkrankheiten an Futtergräsern besagt, dass sie ähnlich wie die Krankheitsschäden an anderen Grasorganen eine zwangsläufige Begleiterscheinung ungünstiger Anbaujahre sind, wobei neben der Sortenbeschaffenheit, der lokalen Anbaulage, den Pflegemassnahmen und dem Alter des Grasbestandes auch der Witterungscharakter des Vegetationsjahres eine wesentliche Rolle spielt, denn ausgesprochen niederschlagsreiche Jahre begünstigen naturgemäss den Zugriff der verschiedensten pilzlichen Parasiten und Saprophyten auf den Grasbestand, worunter sich selbstverständlich auch manche Erreger von Blattfleckenkrankheiten befinden, und in überwiegend trockenen Jahren hat man in vielen Anbaulagen das Auftreten von Rost, Brand oder Mehltau als Erreger von Blattfleckenkrankheiten zu befürchten. Solche witterungsmässigen Extremjahre sind deshalb meistens auch Krankheitsjahre. Vielfach erfolgt die Ausbreitung einer sichtbar gewordenen Mykose über die Anbaufläche derartig geschwind, dass Abwehrmassnahmen verspätet eingesetzt werden und daher häufig nichts mehr nützen. Besonders gefährdet sind in dieser Hinsicht die der Grassamengewinnung dienenden Bestände von Reinsaaten, i denen als Monokultur nach Art des Getreidebaus eine Mykose die günstigste Ausbreitungsmöglichkeit findet. Die Bedeutung der hier zu betrachtenden Krankheitsbilder besteht in der bis zu möglicher Vernichtung reichenden Schädigung der Blattmassen, des bekanntlich wertvollsten Bestandteiles des Grünfutters und in dementsprechender Ernteminderung. Die Zahl pilzlicher Blattfleckenkrankheitserreger an Futtergräsern ist der Darstellung von Mühle in seinem Futtergräserkrankheitslehrbuch 1953 zufolge beachtlich hoch. Zum Glück ist ein grosser Teil der dort behandelten parasitischen Pilze sicher nicht in jedem Jahr und in jedem Anbaugebiet zu finden, sofern er überhaupt schon stärker aufgetreten ist. Das ändert jedoch nichts an der Tatsache einer ständigen Bedrohung der Futtergrasernten durch Blattfleckenkrankheiten, zumal dann nicht, wenn man sich der weiteren Ansicht der Grünlandwirte anschliesst, dass mit der angestrebten züchterischen Veredlung verschiedener Gras-arten die die Krankheitsanfälligkeit der in gewünschter Richtung verbesserten Zuchtprodukte wahrscheinlich zunehmen wird aufgrund sattsamer Erfahrungen mit vielen anderen Nutzpflanzen.

In einer zeitlich und räumlich zwar nicht ausgedehnten, dennoch aufschluss-reichen Studie hat Elliott 1960 an Poa pratensis, Dactylis glomerata, Phleum pratense und Bromus inermis die im Laufe einer Vegetationsperiode aufgetretenen Blattflecke verursachenden Pilze graphisch registriert. Obwohl der Autor aus seiner angewandten Versuchsmethode Fehler für die statistische Erhebung ableitet, glaubt er doch Graphiken über die jahreszeitliche Aufeinanderfolge, Überschneidung und Befallsstärke von blattparasitären Pilzen erarbeitet zu haben, deren grösserer Teil für bestimmte Futtergräser in einigen Anbaugebieten West-Virginias, wo die Untersuchungen stattfanden, repräsentativ ist. Die hier dargestellten Ermittlungen gelten natürlich nur für ihren Ortsbereich in West-Virginia. Viele der dort beobachteten Pilze interessieren im westeuropäischen Raum überhaupt nicht. Im übrigen soll hier aber auch nicht von den für den mittel- und westeuropäischen Futtergrasbau schwerwiegenden, biologisch, wirtschaftlich und als bekämpfungsschwierig hinreichend bekannten Puccineen, Ustilagineen und Erysipheen die Rede sein. Sie würden gesonderte Diskussionskapitel erfordern. Den Ermittlungen Elliotts zufolge, ist an Poa pratensis Helminthosporium vagans und an Bromus inermis H. bromi relativ stark aufgetreten, ja, beide scheinen von sämtlichen Ermittlungen an den 4 Grasgattungen allein gravierend zu sein. Eine Durchsicht der jüngsten phytopathologischen Weltliteratur hat überdies eine beträchtliche Fülle an Beobachtungen und Untersuchungen von Helminthosporiosen an Futtergräsern ergeben, so dass man daraus einen ortsweise alarmierenden Eindruck gewinnt. Es soll daher zunächst über einige wichtige Helminthosporien als Erreger von recenten Blattfleckenkrankheiten an Futtergräsern gesprochen werden.

Bekanntlich hat in der Systematik der Imperfektengattung Helminthosporium bis vor wenigen Jahren eine ziemliche Verwirrung geherrscht. Sie ist inzwischen von mehreren Autoren, u.a. Shoemaker 1959, 1962, Wehmeyer 1961 und von Ammon 1963 revidiert und neu geordnet worden.

Von Ammon (1963) wurden in Infektionsversuchen hinsichtlich des Wirtspflanzenkreises 14 Gramineen-arten mit 14 Helminthosporium-arten kreuzweise beimpft. Dabei ergab sich aus betrachteter Tabelle, dass Pyrenophora graminea keinen Wirt und P. teres wesentlich nur die Gerste befiel. Beide Spezies sind in der Natur als Blattfleckenkrankheitserreger für Gerste specifisch. Alle anderen geprüften Helminthosporium -arten haben auf mehreren Gramineen-arten Blattflecke hervorgerufen. Die dabei aufgetretenen Krankheitssymptome konnten nur bei Pyrenophora teres und in einem günstigen Fall bei P. graminea auf Gerste zur Identifizierung der Erreger dienen. In allen anderen Fällen hat es sich um ein unspezifisches Krankheitsbild gehandelt, das von mehreren Helminthosporien verursacht werden kann. Die Keimlingsinfektionen hatten bei erheblich mehr Gramineen-arten zu einem Befall geführt im Vergleich zu den Blattinfektionen. Die aufgetretenen Symptome an Wurzel und der Fusskrankheiten sind nicht typisch für einen bestimmten Erreger. Blattinfektionen sind bei Pyrenophora lolii auf Lolium multiflorum und Pyrenophora dactylidis auf Dactylis glomerata bei Temperaturen von 4 bis 30º C möglich, die stärkste Erkrankung erfolgte bei etwa 20º C. Keimlingsinfektionen hafteten ebenso bei Temperaturen von 4 bis 30º C; bei tiefen Temperaturen war die Krankheitsentwicklung jedoch vergleichsweise zu höheren verzögert.

Ammon hat in seinen Helminthosporientestungen eine Spezies nicht geprüft, die vorzüglich Bromus inermis befällt und welche seit 6-7 Jahren den Grünlandwirten in vielen Gras-anbau-gebieten diesseits und jenseits des Oceans zunehmend Sorge bereitet: Pyrenophora bromi= Helminthosporium bromi. Obwohl dieses an sich hochwertige Futtergras in unseren humiden Breiten unter den bevorzugt kultivierten Futtergräsern nicht an erster Stelle steht, liegt hier andererseits ein gut erforschtes Modell einer recenten Blattfleckenkrankheit vor, das zugleich einigen anderen Helminthosporiosen ähnelt und aus diesen Gründen hier betrachtet werden soll. In Deutschland hat sich namentlich Frauenstein (1962) mit der Biologie von Pyren-ophora bromi, von ihr Pleospora bromi bezeichnet, und der diesbezüglichen Pathologie von Bromus inermis intensiv beschäftigt.

An Blattspreiten, seltener an Blattscheiden von Bromus inermis erscheinen etwa 1 mm grosse schokoladenbraune Flecke, umgeben von einem schmalen blass-grünen Hof, der sich bald intensiv gelb färbt; die Flecke wachsen auf $\pm$ 2 - 4 x 6 - 10 mm heran. Im weiteren Verlauf der Erkrankung verlieren die Blätter ihre frisch grüne Farbe und vergilben von der Spitze her. Auf den vergilbten Blättern sind schliesslich nur noch die samtartig dunkel-braunen Zentren der ursprünglichen Flecke erkennbar. Zwischen ihnen ist die abgestorbene Blattpartie $\pm$ dicht mit kaum sichtbaren schwarzen, kugeligen Fruchtkörpern des Pilzes besetzt, die ihn zur Ascomycetengattung Pyrenophora bromi gehörig kennzeichnen. In stark verseuchten Beständen können auch die Blütenstände und Deckspelzen braune Flecke zeigen. Die Ährchen bleiben z.T. taub. An den Samen werden nur gelegentlich Fruchtkörper des Pilzes gefunden. Innerhalb des Bestandes tritt die Krankheit in verhältnismässig gleicher Stärke auf. Der erste Aufwuchs des jeweiligen Jahres behält auch bei stärkerem Befall noch seine frisch grüne Farbe, wobei sich aber die ersten braunen Blattflecke mit ihren gelben Höfen von der grünen Blattmasse schon deutlich abheben. Der zweite Aufwuchs zeigt während der Sommermonate in der Regel weniger ausgeprägte Symptome als der erste. In Zeiten gehäufter Niederschläge bei abnehmenden Temperaturen nimmt die Anzahl der Blattflecke rasch zu, so dass im Herbst allgemein der stärkste Befall zu verzeichnen ist. In dieser Jahreszeit vergilben die erkrankten Pflanzen sehr schnell und sterben von den Blatt-spitzen her ab. Ein stark befallener Bestand erscheint jetzt im Gesamtbild stumpf braun und welk. Obwohl künstliche Infektionen an jungen Pflanzen leichter gelingen als an älteren, so kann doch nach Ermittlungen des Befalls an älteren Trespen nicht von Altersresistenz gesprochen werden. Die Vermutung, dass von allen Nährstoffen des grünen Blattes der wechselnde Gehalt an N die Anfälligkeit der Pflanzen gegenüber diesem typischen Blatt-fleckenpilz am stärksten beeinflussen könnte, hat sich experimentell nicht bestätigen lassen. Unter natürlichen Bedingungen werden alle Pflanzenteile von Bromus inermis ausser den Wurzeln befallen. Die Infektion kann auf beiden Blattseiten in gleicher Weise stattfinden. Der Infektions-vorgang entspricht dem echter blattparasitierender Pilze. Der Pilz verbleibt mit seinem Nyzel in unmittelbarer Nähe der Infektionsstelle. Die Inkubationszeit beträgt entsprechend den Temperaturverhältnissen 2 - 8 Tage. Pyrenophora bromi bildet in 6 - 7 Wochen nach der Infektion bei genügend Feuchtigkeit die Konidien aus. Die Konidienbildung beginnt ab Ende April und hält bis Ende November/Anfang Dezember an. Sie erreicht während der Vegetationsperiode 2 Höhepunkte: Ende Mai und Ende August/Anfang

September. Die Konidienbildung erfolgt vorwiegend auf den abgestorbenen Blatteilen. Die Grössenmasse der Konidien betragen durchschnittlich 114-117 μ x 22-23 μ —Die Ausbildung der Pseudothecienanlagen, der Hauptfruchtform, beginnt Anfang Juni und zieht sich über die ganze Vegetationperiode hin. Ab Oktober beginnt bei Temperaturen zwéischen 0 und 12° C die innere Differenzierung der Fruchtkörper. Die Ausschleuderung der Ascosporen geschieht Ende März bis Mitte Mai. Die Streuweite der Ascosporen beträgt im allgemeinen bis zu 4 m innerhalb eines dichten Bestandes. Reife Ascosporen haben die durchschnittlichen Grössenmasse 76,5 x 30,8 μ Der durch sie hervorgerufene Frühjahrsbefall führt nicht zu Pflanzenschäden, hat aber für die Bildung von Primärherden grossen Bedeutung. Die Konidien besitzen unter den erwähnten Verhältnissen eine Streuweite bis zu 16 m. Die durch sie verursachten Infektionen können zur starken Erkrankung der Trespen führen. — Seinen vollständigen Entwicklungsgang durchläuft der Pilz ausschliesslich auf Bromus erectus, B. inermis B. inermis var. aristatus. - - Über die Befallsmöglichkeiten der Gramineen- gattungen, speziell der Gattung Bromus durch Pyrenophora bromi liegt eine Fülle von Unter- suchungen durch Autoren verschiedener Länder vor, wovon hier nur einige schlüssige Ergebnisse mitgeteilt werden können. An 15 Futtergras-arten der bekanntesten Gattungen und den 4 wesentlichen Getreide-arten hat Mühle 1959 nach Beimpfung keinen Befall festgestellt. Siebzehn von 30 geprüften Bromus-arten wurden nicht oder nur sehr schwach befallen, darunter Bromus villosus, B. japonicus, B. mollis, B. secalinus, B. sterilis und B. tectorum. Auf 10 weiteren geprüften Arten konnte sich der Pilz schwach bis mässig stark ausbreiten und auch Konidien bilden. Jedoch gelang es ihm in keinem Falle, Fruchtkörper und damit gleichzeitig Uberwinterungsorgane zu entwickeln. Diese Bromus-arten haben damit wohl für die Übersommerung, jedoch nicht für die Überwinterung des Pilzes Bedeutung. Auf Bromus inermis, B. inermis var. aristatus und B. erectus hingegen konnte der Pilz reichlich fruktifizieren, d.h. Pseudothecienbilden. 64 Zuchtstämme von Bromus inermis und die beiden Sorten »Ostland» und »von Kamekes» waren unter Feldbedingungen ausnahmslos für den Pilz sehr anfällig. Versuche zur Resistenzzüchtung von B. inermis kön- nen demzufolge nur durch Einkreuzungen mit den zuerst genannten kaum anfälligen Arten unternommen werden. —Zu ähnlichen Ergebnissen ist auch Frauenstein 1962 gelangt :Von 23 infizierten Bromus-arten hatten sich 20 Arten ± anfällig erwiesen; Ausserdem wur- den 58 Zuchtstämme und die beiden vorhin erwähnten Sorten verhältnismässig stark von dem Pilz befallen. —Aus Norwegen berichtet Hansen 1964 über das 1962 erstmalig dort beobachtete Auftreten von Pyrenophora bromi an Bromus inermis und B. inermis x B. pumpellianus. Klonetestungen der Spezies und des Bastards hatten unterschiedliche Be- fallsgrade ergeben, aufgrund deren man aber keines der beiden Gräser hinsichtlich der gewünschten Krankheitsresistenz bevorzugen könnte. —Braverman (1964) hat 41 Spezies aus 5 Sektionen der Gattung Bromus geprüft. Alle eingeführten Herkünfte von B.inermis waren hoch anfällig, und in der Sektion Bromopsis waren nur B. auleticus aus Argentinien, B. cappadocicus aus Belgien und B. ciliatus aus New Hampshire (USA) schwach bis mässig resistent. Variierende Grade von Resistenz wurden in Sektionen von unkrautartigen Ein- jährigen gefunden. Lediglich B. macrostachys aus Afghanistan war vollresistent. Diese wenigen Beispiele müssen hier genügen, um darauf hinzuweisen, in welcher Gefahr der

Anbau dieses wertwollen Futtergrases durch eines Tages mögliche Epidemien seitens dieses recenten Blattfleckenkrankheitserregers Pyrenophora bromi zu schweben scheint. –Aus diesem Grunde ist man manchen Orts auch um die Erarbeitung von Abwehrmassnahmen bemüht. Eine pilzresistente Form von Bromus inermis dürfte den hiesigen Darlegungen zufolge noch ein züchterisches Fernziel sein. Für Präventivmassnahmen muss man vor allem die im Frühjahr erscheinenden Infektionskeime sicher kenne. Da die Konidien wegen ihrer kurzen Lebensdauer von maximal 11 Tagen keine Bedeutung für die Über-winterung des Pilzes haben, sind in erster Linie die Ascosporen für die Frühjahrsinfek-tionen verantwortlich. In vergleichenden Untersuchungen haben Kaufmann, Drolsom & Nielsen (1961) überdies nachgewiesen, dass im Gewächshaus die aus Ascosporenmyzel resultierenden Läsionen stärker und ausgeprägter waren als die durch Konidienmyzel verursachten. Sinngemäss hat Frauenstein 1962 zwei Verfahren angegeben, die es anhand von lokalen Temperatur- und Niederschlagswerten als Voraussage für Mitte Februar ermöglichen, hinweise auf den etwaigen Beginn des Ascosporenfluges zu erlangen und die mit Hilfe mikroskopischer Untersuchungen eine exakte Kontrolle des Reifungsverlaufes der Asci gestatten. - - Die chemische Bekämpfung dieser Krankheit ist bisher weder präparativ noch anwendungsmässig gesichert. Von 10 im Labor getesteten Fungiziden hat, nach Frauenstein (1962), nur Defusit 50 eine völlige Abtötung der Ascosporen bewirkt. Dabei sind bei einer 0,5 % igen Anwendung im Gewächshaus Pflanzenschäden aufgetreten; zudem werden die Pseudothecien und das in dem Blättern befindliche Myzel nicht abgetötet. Die Wirkung der organischen Fungizide ist im allgemeinen besser als die der anorganischen. Die zur Zeit des Ascosporenfluges in Form einer 5 maligen Spritzung durchgeführten Feldversuche haben keinen befriedigenden Erfolg gebracht. Die besten Ergebnisse zeigten Defusit 50 und Kupfer-Defusit bei 600 l/ha. Pflanzenschäden traten hierbei nicht auf. Durch sogenanntes Totspritzen des Pilzes mit Defusit 50 in 1 % iger Anwendung bei einer Auf-wandmenge von 1000 l/ha vor dem Austrieb der Trespe konnte in Verbindung mit einer mechanischen Bekämpfung die Infektionsrate stark gesenkt werden.

Der hiermit vorgestellte Krankheitsfall ist, wie engangs betont, zugleich ein gegenwärtig naheliegendes Beispiel für einige ähnlich geartete andere Helminthosporiosen an Futter-gräsern. Auf detaillierte Darstellungen jener soll hier deshalb verzichtet werden. Aus den eingangs betrachteten Kreuzinfektionsergebnissen Ammons ist das Vorkommen vieler Helminthosporiosen an Futtergräsern auch in der Natur ja von vornherein wahrscheinlich. Poa pratensis hat in feuchten Sommern regelmässig unter verschiedenen Helminthosporiosen mehr oder weniger zu leiden. Es wurden folgende Spezies von diesem Gras isoliert: Helmin-thosporium triseptatum, H. dictyoides, H. sativum, H. giganteum und H. vagans. Dieser letztere in Mitteldeutschland wiederhold nachgewiesene Pilz greift das Innere der Blattscheide und den von ihr umschlossenen jungen Halm mit Blütenstand an, so dass das Schossen gehemmt und die Rispe nach Art von Weissährigkeit partiell zerstört wird. Die häufig zusammenfliessenden Blattflecke vertrocknen und werden dann spröde und rissig. Es werden im Freiland vorwiegend weich- und breitblätterige Rispengrastypen von H. vagans besiedelt, die Schmalblätteringen praktisch gar nicht. Die Konidien können sowohl die Samen als auch

unmittelbar die Blätter infizieren, im Gegensatz zu H. gramineum, dessen Krankheitsbild sonst dem hiesigen ähnelt. Nach Mühle scheint H. vagans mittels Myzel und Konidien auf ausdauernden und abgestorbenen Pflanzenteilen, vor allem den Blättern zu überwintern. Die Bekämpfung des Pilzes im Bestande und im Boden mit chemischen Mitteln ist schwierig, wogegen das Saatgut durch Beizung vor dem Zugriff des Pilzes geschürzt werden kann. – Weitere Helminthosporium-arten an Futtergräsern sind vor allem aus den USA und Canada bekannt geworden, und zwar einerseits das für die Grasgattungen Agrostis, Bromus, Festuca, Phalaris, Phleum, für Poa bereits erwähnte polyphage H. giganteum, andererseits H. erythrospilum auf Agrostis alba, H. dictyoides auf Festuca pratensis, H. phlei auf Phleum pratense, H. siccans auf Lolium-arten und H. catenarium auf Festuca pratensis und auf Lolium-arten. Eine vollständige Aufzählung der Helminthosporien auf Futtergräsern kann hier nicht angestrebt werden. Es geht aus den gegebenen Beispielen auch ohnedies genügend hervor, dass diese eine Pilzgattung Helminthosporium mit vielen Spezies nahezu alle wichtigen Futtergras-arten durchsetzt hat. Dabei kommt noch die Infektionsmöglichkeit einer Wirtspflanze durch gleichzeitig mehrere Helminthosporium-spezies von unterschiedlicher Virulenz, sowie die meist unmögliche morphologische Unterscheidung ihrer Schadensherde erschwerend hinzu. So hat Bean (1964) Poa pratensis zugleich von 3 Spezies befallengefunden, von denen zwei: Helminthosporium dictyoides und H. triseptatum aus Keimlingsinfektion und Curvularia pallescens -aus einer der Ascomycetengattung Cochliobolus eng verwandten Gattung aus direkter Blattinfektion hervorzugehen pflegen.

Diese Darlegungen mögen wohl für die Feststellung genügen, dass die Gattung Helminthosporium mit vielen Arten und verschiedenen Angriffsmethoden sozusagen ständig auf der Lauer liegt, um bei Zusammentreffen günstiger Umweltbedingungen einen gegen manche unserer Futtergräser gerichteten, womöglich katastrophalen Schlag zu führen, dem vor allem mehrjährige Bestände ausgesetzt sind. Aus diesem Grunde wird man den Helminthosporien eines Tages sicher die selbe Aufmerksamkeit schenken müssen wie beispielsweise den Rost- oder den Brandpilzen.

Bei Durchmusterung der vorhin aufgezählten von Helminthosporium betroffenen Gras-arten wurde Dactylis glomerata nicht erwähnt, und scheint es daher, dass dieses Futtergras nicht sehr unter Helminthosporiosen zu leiden hat. Dafür ist gerade an ihm in den letzten Jahren in Norddeutschland aber eine andere recente Blattfleckenkrankheit verstärkt aufgetreten, die das Interesse der dortigen Grünlandwirte und einiger Phytopathologen erregt hat und die darum auch hier kurz betrachtet zu werden verdient: die Mastigosporiose des Knaulgrases. Im Herbst 1962 wurde an verschiedenen Standorten in Schleswig-Holstein Dactylis glomerata und in einem Falle Agrostis alba von einer bis dahin nicht beobachteten Blattfleckenkrankheit befallen, deren Erreger Mastigosporium rubricosum ist. Die Krankheitserscheinungen und -auswirkungen in jenen Befallgebieten bestanden in Vergilben und Vertrocknen der Blätter bereits zur Zeit des ersten Schnittes, in einem zunächst grünen, sodann gelblich braun verfärbten Nachwuchs bei Abnahme des Ertrages beim zweiten Schnitt und schliesslich in einer infolge der gleichen zunehmenden Erscheinungen offensichtlichen Unwirtschaftlichkeit des dritten Schnittes. Der in Europa und Nordamerika seit

langem bekannte, in den Formenkreis Dilophia graminis *Fuckel* gehörende Pilz wurde ausser am Knaulgras an Dactylis aschersoniana, Agrostis spp., Calamagrostis spp., Phleum pratense, Ph. nodosum und Trisetum cernuum nachgewiesen. Nach Sprague (1938,1950) und Bollard (1950) ist die von M.rubricosum verursachte Blattfleckenkrankheit (eye spot, frog eye spot) an Dactylis glomerata und Agrostis in einzelnen Gebieten der USA und in Grossbritannien allgemein verbreitet und hat dort in feuchten Jahren bzw. Lagen zu bemerkenswerten Schäden geführt. –Die Krankheitssymptome sind folgende: An 30 bis 40 cm hohen Pflanzen von D. glomerata erscheinen auf den Blättern purpur bis schwarzbraune, länglich elliptische, seitlich von den Blattadern begrenzte, 1-8 mm grosse Flecke. Später wird in denselben meist ein blass bräunliches oder aschfarbenes Zentrum erkennbar. Mit fortschreitender Erkrankung vergilbt das Blattgewebe im Umkreis der Flecke. Unter Ausbreitung der Verfärbung vertrocknet schliesslich das ganze Blatt häufig von der Spitze her. Seltener werden auf den Blattscheiden und gar nicht auf den Halmen und Blütenständen Flecke gebildet. – Auf Agrostis werden grössere, hellbraune, elliptische Blattflecke mit blasser Mitte sichtbar, die später gegen das gesunde Gewebe durch einen rötlich gelben oder roten Saum abgegrenzt sind. Auf Phleum pratense entstehen ähnlich bräunliche, weinrot umrandete Blattflecke. Im Zentrum von meist grösseren, älteren Flecken erscheint ein sehr zarter, makroskopisch noch soeben sichtbarer weissglänzender Belag bei hoher Luftfeuchtigkeit: das Konidienlager. Die Konidien sind hyalin, zylindrisch, an den Polen abgerundet, meist 4-zellig, an den Septen eingeschnürt, 29-60 x 9-17 μ gross und sitzen einzeln an sehr kurzen, einfachen Konidienträgern. – Die Infektion verläuft nach Schneider und Meyer (1963) im wesentlichen folgendermassen: Bei hoher Luftfeuchte und Wassertropfen auf den Blättern keimen die Konidien innerhalb weniger Stunden. Der Konidienkeimschlauch durchbohrt die Kutikula und durchwächst die Epidermis in Richtung auf das Mesophyll. Die Symptome erscheinen frühestens nach 3-4 Tagen. Nach durchschnittlich 7-12 Tagen erscheinen die Konidien auf den jungen Flecken. Erwähnungsgemäss ist jedenfalls hoher Wassergehalt in der Umgebung des Pilzes Voraussetzung fur die Ausbreitung desselben auf den Gräsern, da die Konidien in trockener Luft schnell absterben. Die Temperaturansprüche des Pilzes sind noch nicht geklärt; es wird vermutet, dass Entwicklung und Wachstum durch Temperaturen um 15-20º C gefördert und um 0º und oberhalb 25º C verhindert werden. Die Übersommerung bzw. Überwinterung von M. rubricosum erfolgt möglicherweise im befallenen, aber noch lebenden Blattgewebe. Nach Sprague (1938) und Bollard (1950) sind innerhalb der Art wahrscheinlich mehrere auf einen engen Wirtsbereich spezialisierte Formen anzunehmen. Sprague's Ergebnissen zufolge, haben sich zwei Isolate von Dactylis glomerata im Infektionsversuch nicht auf andere Gräserarten übertragen lassen, wogegen ein von Agrostis alba isolierter Stamm ausser an der eigenen Wirtspflanze und zwei weiteren Agrostis-arten auch noch an Dactylis glomerata pathogen war.

Buhl und Lange (1963) haben nun für Schleswig-Holstein festgestellt, dass solche Knaulgrasbestände den geringsten Mastigosporiumbefall zeigten, die kurz gemäht und beweidet in den Winter gegangen waren, wohingegen diejenigen, die mit wiel Blattmasse überwinterten, bereits am Neuaustrieb deutliche Mastigosporium-Symptome aufweisen. Demnach dürften abgestorbene Blätter die wesentliche Infektionsquelle sein. Mit Ansteigen der Temperaturen

in der ersten Junihälfte, vor allem nach reichlichen Niederschlägen nahm der Befall rasch zu. Wie Carr (1961) angegeben hat, ist die Intensität der Infektionen mit der Frühzeitigkeit des Ährenschiebens korreliert, wobei die frühzeitigeren Varietäten anfälliger waren. Nach den Ermittlungen von Buhl und Lange war der Befall in überdüngten, dichten Beständen, in Bodensenken und feuchten Lagen am stärksten. Die Bodenart ist aufgrund des Krankheitsvorkommens auf ganz verschiedenen Böden offenbar nicht befallsbestimmend. Nur Knaulgrasreinsaaten werden von M. rubricosum stärker befallen, Mischsaaten seltener oder nur schwach. Für die Befallsstärke sind Witterung, Nutzungsart und Düngung ausschlaggebend. Auf intensiv genutzten Anbauflächen mit hohen Düngergaben (bis 200 kg/ha) ist das Befallsbild besonders deutlich und sterben gelegentlich ganze Horste ab. Nur in den Fällen von reichlicher Kaliversorgung der Pflanzen scheinen diese weniger unter dem Befall zu leiden. Der Einfluss des Kalis auf die Befallsstärke des Knaulgrases soll noch geklärt werden. – Hinsichtlich des Nährstoffentzuges im Blatt von Dactylis glomerata durch Mastigosporium rubricosum hat Carr gezeigt, dass eine Reduktion der gesamten löslichen Kohlenhydrate auf 50 % des Niveaus der Kontrollen schon bei dem verhältnismässig niedrigen Infektionsgrad von 9 % infizierter Blattfläche eintreten kann. Ausserdem hat er in vitro eine auffällige Abhängigkeit der Verwertung von organischem N, wie Pepton durch den Pilz von der Höhe des Zuckerspiegels erkannt. Demnach dürfte dieser Pilz in besonderem Masse auf ausgiebige Versorgung mit Kohlenhydraten angewiesen sein. –– Die wirtschaftliche Auswirkung eines Mastigosporium-befalles ist auf solchen Knaulgrasflächen am stärksten, die als Grünfutter genutzt werden, da nur die Blattmasse von dem Pilz vernichtet wird. Sicherlich werden damit infolge von Unterernährung auch die Fruchtstände in Mitleidenschaft gezogen.– Mit zwei Infektionsverfahren wurden 7 gängige Knaulgrassorten in 4 maliger Wiederholung auf Resistenz gegen Mastigosporium geprüft.Es zeigte sich, dass keine Sorte gegen diesen Pilz resistent ist, wohl aber Befallsunterschiede unter ihnen bestehen: »von Kameke» hatte die höchste, die Sorten »Baraula» und »Iris» die geringste Anfälligkeit besessen. Ähnlich war das Ergebnis einer weiteren Resistenzprüfung anderes Orts mit den Sorten »von Kameke», »N.F.G.» und »Holstenkamp», wo die erstgenannte Sorte wiederum am stärksten befallen war. Die Befallsgrade der beiden anderen betrugen 46,7 % bzw. 38,8 %, besogen auf »von Kameke» = 100. Ergebnissen von Feld-infektionsversuchen mit 20 anderen Gras-arten und den 4 Hauptgetreidearten zufolge, wird ausser Dactylis glomerata auch Alopecurus pratensis und Lolium perenne, wenn auch nur mässig, befallen; die übrigen Gräser sowie die Getreidearten waren befallsfrei geblieben. – Die durchgeführten Bekämpfungsmassnahmen zur Gesunderhaltung der Knaulgrasbestände haben sich, nach Buhl und Lange, im ganzen nicht bewährt: Wiederholter Schnitt im Frühjahr zwecks Verzögerung und Schwächung des Erstbefalles war erfolglos und ist überdies auch undwirtschaftlich. Von 3 eingesetzten Pflanzenschutzmitteln hatte Kupferoxychlorid (45-50 % Cu, 6 kg/ha) die Befallsmöglichkeit des Pilzes vergleichsweise zwar deutlich reduziert, scheidet jedoch wegen phytotoxischer Nebenwirkung in der Art von Berostungen der Blätter für die Praxis aus. Eine Erhöhung des Kaligehaltes auf Kosten gleicher Menge N-Anteils Könnte die Gesunderhaltung des Knaulgrases vielleicht begünstigen. – Obwohl aus den bisher vorliegenden Veröffentlichungen und Mitteilungen über diese Mastigosporiose noch nicht deutlich her-

vorgeht, ob die Krankheit mit jährlicher Regelmässigkeit wiederkehrt, wie beispielsweise die Roste oder der Mehltau, oder ob es sich bei ihr nur um gelegentliche, saisonbedingte Epidemien handelt, so ist sie doch wegen ihres pandemischen Auftretens sicher ernst zu nehmen.

Möglicherweise würde mancher unter den Hörern noch diesen oder jenen Blattfleckenkrankheitserreger aus persönlicher Begegnung und Erfahrungen gerne beachtet wissen. Macht man sich jedoch die Reihe der Publikationen in der phytopathologischen Literatur über dieses Thema zur eigenen Meinung, so sind die betrachteten Helminthosporiosen und die Mastigosporiose unter den recenten Blattfleckenkrankheiten gewiss die gewichtigsten, die als mögliche Hemmfaktoren für den künftigen Futtergrasbau erschienen sind.

Investigations on virus Diseases of Grass

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The nature and properties of the viruses.

Since Smith (1952) first described cocksfoot streak virus at least 8 other viruses attacking grasses in Britain have been recorded (Table 1). The table omits those viruses exclusive to cereals, those which are known in Europe but which have not yet been descovered in Britain (e.g., brome grass mosaic and Festuca necrosis viruses), and the nematode-transmitted tomato black ring virus which, although infecting perennial ryegrass, shows few obvious symptoms.

Some of the viruses (e.g., CSV & LMV) are restricted to a few, or even only one, host, while others (e.g., BYDV & BSMV) can infect most grasses and cereals. Vectors, where known, include aphids, beetles, jassids, eryophyid mites and possibly nematodes. Only BSMV has been shown conclusively to be seed and pollen-borne. Most of the grass viruses are sap-transmitted and non-persistent in their vectors. Others, such as the aphid-transmitted BYDV and the jassid-transmitted EWSMV, are non-sap-transmissible and persistent. Particles, where observed, have been shown to be either rods (generally long and flexuous, but short and rigid in BSMV) or spheres, of generally similar dimensions. Insects with sucking mouthparts tend to transmit the rod-type viruses, while viruses with spherical particles commonly have vectors with biting mouthparts. Antisera, which have been prepared for many of these viruses, afford the best means of indentification.

Taken in conjunction, the properties listed are adequate to identify each individual virus, although few can be identified on the basis of symptoms or host-range alone, particularly in mixed infections which commonly occur. Thus, although CFMV may be separated from CSV on transfer to wheat, and CSV from RMV on transfer to cocksfoot, electron microscopy is required to determine from particle shape the possibility of mixed infection.

Epidemiological considerations

With viruses which attack both grasses and cereals (BYDV, EWSMV, BSMV) the grass crop can provide a perennial reservoir of virus for subsequent infection of the cereal crop. A recent survey (Doodson, 1967) has shown that 93 % of perennial ryegrass seed crops examined were infected with BYDV. Catherall (1963) found strains of this virus in ryegrass which had a severe effect on cereals and some of these strains had only a mild effect on the

Table 1. Some important viruses infecting grasses and cereals

Virus	Symptoms	Main hosts	Transmission	Particle	Antiserum?
Cocksfoot mottle (CFMV)	mottle browning death	cocksfoot wheat	sap & cereal leaf beetle (Lema melanopa)	sphere, c. 30 mμ	yes
Cocksfoot streak (CSV)	pale streak	cocksfoot ryegrass	sap & aphid (M. persicae, S. avenae, H. humulis)	rod, c. 750 mμ	yes
Barley yellow-dwarf (BYDV)	stunting chlorosis bronzing	most grass & cereal spp.	persistent aphid (e.g., R. padi, M. dirhodum, S. avenae, S. fragariae, etc.)	sphere, c. 30 mμ?	no
Ryegrass mosaic (RMV)	mosaic	ryegrass fescue oats	sap & eryophyid mites (Abacarus hystrix)	rod, c. 720 mμ	yes
Lolium mottle (LMV)	mottle chlorosis	ryegrass	sap: no known vector	sphere, c. 30 mμ	no
Anthoxanthum mosaic (AMV)	pale mosaic, necrotic in cereals	sweet vernal grass cereals	sap: no known vector	rod, c. 750 mμ	no
Phleum mottle (PMV)	pale mottle	timothy Agrostis spp.	sap & cereal leaf beetle	sphere, c. 30 mμ	yes
European wheat striate mosaic (EWSMV)	chlorotic stripe	cereals ryegrass	persistent jassid (J. pellucida)	not known	no
Barley stripe mosaic (BSMV)	chlorotic & necrotic stripe	most grass & cereal spp.	sap, pollen & seed no known vector	rigid rod, c. 125 mμ	yes

ryegrass host. Thus, ryegrass can serve to maintain isolates of BYDV which, owing to their severity, would be self-eliminating from the cereal crop.

AMV provides an interesting example of a virus which, were there a natural vector or should one develop in sufficient frequency, would constitute a potential threat to cereal production. In our experiments this virus, which caused mild symptoms only and no loss of vigour in *Anthoxanthum odoratum,* caused a 40 % reduction in height in many oat varieties when manually inoculated to them. Barley varieties were more variable in reaction, some being highly susceptible, some immune and others tolerant. Clearly, therefore, whatever is done to provide amelioration of virus effects in the grass crop, and the way in which this is done, will have influence also on the cereal crop.

Effect of the viruses on the grass crop
The main objectives of work with the grass viruses at the W.P.B.S. has been, to determine effects on growth and productivity of grasses both as single spaced plants and also under the competitive conditions which exist in swards. BYDV, CSY, RMV and CFMV in particular have been investigated in this way. BYDV, although not generally lethal in perennial ryegrass, causes pronounced stunting and loss of yield, with some increase in the number of vegetative tillers but a marked decrease in the number of fertile tillers (Catherall, 1966a). By contrast, CSV in cocksfoot has little effect on plant height but reduces tiller number drastically although increasing the ratio of fertile to vegetative tillers (Catherall & Griffiths, 1966a). Thus, BYDV tends to cause plants to assume a »pasture-type» habit and CSV a »hay-type». This analogy receives further support from data on the effect of management: maximum yield reduction occurred on repeated defoliation of BYDV-infected perennial ryegrass plants, but with occasional (hay and aftermath) defoliation of CSV-infected cocksfoot plants. Maximum differences in productivity between healthy and CSV-infected cocksfoot plants occurred at high nitrogen levels, infected plants appearing not to respond to increased nitrogen application. RMV behaved similarly to CSV in reducing the tillering capacity of its hosts but not their height, and caused a 20 % reduction in the yield of single plants. CFMV drastically reduced the height and the tiller number of single cocksfoot plants and was so lethal that no yield data could be taken (Catherall, 1965; 1966b).

Since BYDV and RMV had virtually opposite effects in the same host species, whether inoculated singly or in combination, there is a clear indication that such effects are a function of specific viruses and are not attributable to the particular host species. Further evidence for this is afforded by the similarity in effect of BYDV on growth habit of different species: Italian ryegrass, perennial ryegrass, tall fescue and timothy. In all cases, height but not tillering capacity was affected. Additionally, Italian ryegrass, which exhibited the most severe leaf reaction, suffered the least reduction in yield, whereas timothy was virtually symptomless yet had the highest yield loss. Thus the severity of symptom expression har proved unrealiable as a criterion of yield losses in the various host virus combinations.

Effects of these viruses under sward conditions have been investigated by planting healthy and pre-infected tillers at 2 in spacing to produce 3 types of »simulated sward»: completely

healthy, 50 % and 100 % infected. Using this technique, Catherall (1965, 1966a, 1966b) and Catherall and Griffiths (1966b) have shown that 50 % CSV-infected cocksfoot swards yielded equally as well as completely healthy swards, although the yield from fully infected swards was drastically reduced. By contrast, the yield from 50 % BYDV-infected perennial ryegrass swards was not only much lower than that of completely healthy swards but was also very little better than the yield of completely infected swards. The precise yield of 50 % infected swards compared with that of the completely healthy, control plots was affected by the virus involved and the management given. Thus, with CSV infection, yield losses of cocksfoot were greater with occasional than with frequent cutting, while with BYDV infection higher yield losses of perennial ryegrass were sustained with frequent than with occasional defoliation.

A plausible explanation of the differential effects of CSV and BYDV on their respective hosts is that, in partially infected swards, the effect on growth habit influences the extent of growth by healthy plants to compensate for loss of productivity by infected plants. Since the effect of CSV is solely on tillering and height is unaffected such compensation would be maximal and little yield loss should result at normal levels of infection. RMV might be expected to behave similarly to CSV in this respect. However, since the effect of BYDV is on height an not markedly on tillering, lateral competition for ground space by infected plants would be high although such plants would contribute little to vertical yield. BYDV therefore provides an example of the type of virus where compensation would be minimal and yield losses would be proportional to the extent of infection of the sward. Repeated cutting, which tends to increase the tillering capacity of BYDV-infected plants, would increase their competitive ability and so increase yield losses. The effect of CFMV in pure, single species stands, would be dependent on the level of infection. Compensation would operate at low levels, but at higher levels death could take place more rapidly than compensation by healthy plants. In mixed stands, particularly in those with white clover, competition is more likely to be between the companion species and the infected plants, with a resultant change in sward composition. This occurred at the Grassland Research Station, Hurley, in 1958 where, following a heavy CFMV infection in cocksfoot/white clover leys, the grass died out and was replaced almost entirely by white clover.

Inplications for plant breeding
It is clear that the 3 types of virus investigated, lethal, compensating and non-compensating, require different plants breeding approaches for their amelioration under sward conditions. Non-compensating viruses such as BYDV necessitate the development of resistent or tolerant varieties of their host species. It should, however, be realised that the production of tolerant varieties capable of becoming infected although showing little symptom development or yield loss will not reduce the reservoir of virus available for infection of the cereal crop, but will improve only the yielding ability of the grass crop. Preliminary investigation has shown that varieties of perennial ryegrass have differential tolerance to BYDV, ranging from a 10 % to a 60 % loss in yield following infection. This suggests that the level of tolerance to this virus could be raised by selection and breeding. Compensating viruses such as CSV and RMV

may require a different approach, aimed at reducing the level of tolerance rather than increasing it, so that compensation by un-infected plants in the sward is enhanced, as envisaged for clover phyllody virus (Carr, 1965). Breeding procedures for the amelioration of diseases due to lethal viruses such as CFMV would be determined largely by agricultural usage. In single-species swards at typically sub-epidemic levels of infection greater amelioration might be achieved by lowering the general level of tolerance and thus allowing maximum compensation. However, in view of the more common use of these grasses in mixtures it would probably be of more general value to breed, as for non-compensating viruses, for enhanced resistance or tolerance.

Bibliography

Carr, A.J.H. (1965) Clover phyllody virus. *Rep. Welsh Pl. Breed. Sta. 1964, 97-98.*
Catherall, P.L. (1963)
> Transmission and effect of barley yellow-dwarf virus isolated from perennial ryegrass. *Pl. Path.* 12, 157-160.

Catherall, P.L. (1965).
> Competition and compensation in virus infected grassland swards. *J. agric. Soc. Univ. Coll. Wales,* Aberystwyth 46, 4-9.

Catherall, P.L. (1966a).
> Effects of barley yellow-dwarf virus on the growth and yield of single plants and simulated swards of perennial ryegrass. *Ann. appl. Biol.* 57, 155-162.

Catherall, P.L. (1966b).
> The significance of virus diseases for the productivity of grassland. *J. Br. Grassld Soc.* 21, 116-122.

Catherall, P.L. & Griffiths, Ellis (1966a).
> Influence of cocksfoot streak virus on the growth of single cocksfoot plants. *Ann. appl. Biol.* 57, 141-148.

Catherall, P.L. & Griffiths, Ellis (1966b).
> Influence of cocksfoot streak virus on the growth of cocksfoot swards. *Ann. appl. Biol.* 57, 149-154.

Doodson, J.K. (1967).
> A survey of barley yellow dwarf virus in S. 24 perennial ryegrass in England and Wales, 1966. *Pl. Path.* 16, 42-45.

Smith, K.M. (1952). A virus disease of cocksfoot. *Pl. Path.* 1, 118.

Vide also various short articles on this subject under »Plant Pathology» in the Annual Reports of the Welsh Plant Breeding Station.

Winter-killing fungi in Scandinavia

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A considerable part of cultivated area in Scandinavia is sown with wintering plants. The yield obtained from this area is highly dependent upon the ability of the plants to survive during the winter.

One important characteristic of winter weather conditions in Scandinavia is the fact that both the thermal winter and the period when the ground is covered with snow are very long. With the exception of the coastal regions, the snow cover is usually also very thick.

A snow cover which forms early and disappears late offers good protection to plants against frost injuries. However, if the soil has not been able to freeze before a lasting snow cover is established the microclimate under the snow cover is favourable to winter killing fungi and they tend to cause great damage, especially when the period of snow cover is long. The investigations have shown that in regions of abundant snow cover the poor overwintering of field crops is mainly due to winter-killing fungi, which are capable of damaging and destroying plants at relatively low temperatures and therefore are also called low-temperature parasitic fungi (YLIMÄKI 1962).

The diseases caused by these fungi are significant to all overwintering plants and they have been studied rather intensively for the past several years. In Sweden EKSTRAND (1955) has started investigations concerning overwintering of plants as early as in 1930's and in Finland these problems has been studied from 1940's under the supervision of JAMALAINEN (1956). The pathogens are species belonging to three different genera: *Fusarium*, *Sclerotinia* and *Typhula*. They differ in their relation to environment, as their different distribution also attest.

Fusarium nivale (Fr.) Ces. called also snow mould or pink snow mould, is among the winter killing fungi the best known. It is found in all winter cereals and grasses. The characteristic of the pathogen indicates adaption to a wide range of environmental conditions. The temperature conditions have been found to be 0-30º C with the optimum at about 22º C. The fungus does the greatest damage under the snow, when the ground is unfrozen, i.e. at about the freezing point. The minimum point for the vegetation of the fungus lies

below − 5o C. At the low temperatures it forms plenty of aerial mycelium and therefore it is very capable of causing contamination of the neighbour plants. It is known that seed infection of *Fusarium nivale* is of great importance. Sometimes the attack is so strong that the germ is destroyed at an early stage.

Fusarium nivale thus infects the underground parts of the plants either from the seed or the soil and from there it grows upwards in the plants and from the upper parts may also spread laterally.

The infection of *Typhula* species, on the contrary, takes place in addition through the basidiospores and therefore the attack usually begins on the leaves and shoots and from there the fungus grows downwards to the lower parts of the plants.

The *Typhula* fungi are most easily to be seen in spring after the melting of the snow when there ist an abundance of sclerotia on the plants. The leaves damaged by the fungi are grey and flat to begin with, later becaming shrivelled and stringy and often enclosing the sclerotia. In particular the sclerotia of *Typhula incarnata* Lasch ex Fr. (syn. *T. itoana* Imai) are often located at the base of the stalk between the leaf and the sheath. Besides *Typhula incarnata* there is *Typhula ishikariensis* Imai (syn. *Typhula idahoensis* Remsb.) which causes the same symptoms and in the field it frequently is very difficult to distinguish from *Typhula incarnata*. Especially when severe, the disease caused by *Typhula incarnata* is similar in gross aspects to the *Typhula ishikariensis*. The former is, however, distinguished from the later by fewer sclerotia on the leaves, and by the fact that the sclerotia are reddish brown, larger, and more irregular in shape. *Typhula incarnata* is more often found below ground. Sclerotia are common on upper parts of roots, particularly between the leaf sheats of the crown below the soil surface.

After the end of a dormance-period from the sclerotia of *Typhula* fungi fruit bodies are developed in the fall. They are clavate with a sterile stalk. The sclerotia germinate independent of light conditions but sporophores develop, however, only by exposure to ultraviolet radiation.

Optimum mycelial growth was obtained at 5-7o C, minimum about − 5o C and maximum at 20-23o C. Development of sclerotia increases, when the factors influencing mycelial growth become unfavourable. Under unaerobic conditions the mycelial growth is inhibited, by darkness it is stimulated.

There is a difference of opinion in the main source of infection. Some authors have found that the main source of infection are the sclerotia and mycelia, the others have the view that the infection of *Typhula* species takes place mainly through the basidiospores. According to our observations the infection takes place in both ways. It obviously depends on conditions which way each time is most significant.

The *Typhula* species are perthophytes and presuppose for an infection weakened and injured plants. The success of the infection thus depends decisively on the host disposition.

A particularly interesting winter-killing fungus is *Sclerotinia borealis* Bubak & Vleugel which occurs in the northern parts of Norway, Sweden and Finland and has been found in addition only in northern regions in Canada, Alaska, Japan and Soviet Union.

This fungus attacks the winter cereals and most of the cultivated grasses and has not been found on other that graminaceous plants. It likely requires lower temperatures for its development than the other parasitic winter fungi. The growth optimum lies at about $5-10^\circ$ C, the minimum is under -5° C and the maximum a little above 20° C. It may grow well and do damage under 0° C.

Sclerotinia borealis injures the seedlings in autumn and spring as well as partially also during the winter under the snow cover. The damage is best seen in spring, when gaps appear in the stand. The leaves of the dead plants are grey and withered. The sclerotia form in the crowns and at the bases of leaves. The black sclerotia are larger and more irregular than those of the *Typhula* species. Fruit bodies form in fall and ascospores released from them are important sources of infection.

Clover rot *(Sclerotinia trifoliorum)* has hitherto been regarded as the most common and damaging infective disease of all field legumes in Scandinavia and in all places these crops are grown. Under conditions favourable for the causal fungus clover rot may really reach epidemic proportions and inflict heavy damage especially in young clover leys. When clover rot disease in very prevalent no strains escape damage, though strains differ in their resistance. Domestic strains, especially many local clovers, have proved to be most resistant. Some tetraploid red clover varieties have also proved highly resistant to clover rot.

In recent years we have studied in Finland a clover disease which has repeatedly been observed in clover during other clover investigations — clover root rot (YLIMÄKI 1967). This disease is caused by several fungi but chiefly by *Fusarium-, Cylindrocarpon-* and *Rhizoctonia*-species.

We have found that root rot is a more serious and complicated problem on leys than clover rot, since it is found every year and in all localities in contrast to clover rot, which occurs injurious only in certain years and localities although occasionally quite total.

The injuries of root rot develop throughout the entire growing season and they are much more difficult to observe. The damping off form of this disease which may cause severe damage to seedlings, is completely overlooked in newly established leys. Besides directly killing clover plants, root rot also causes yield losses by decreasing the productive capasity of diseased plants. From the overall point of view, root rot is considerably more damaging than clover rot.

Clover root rot is not primarily a winter disease. Under the climatic conditions in Scandinavia there is however a close correlation between winter injury to clover and root rot. The sites of fungal entrance are wounds in the tap root and severed ends of the secondary roots. Mechanical damage to clover roots during the winter is caused mainly by soil frost disruption due to abrupt fluctuations in temperature, which may break or otherwise injure the roots.

The most important means of controlling damage from winter-killing fungi is to use as resistant varieties or strains of overwintering plants as possible. It is, however, evident that the degree of resistance possessed by existing varieties of different plants is always not sufficient to provide a reliable means of controlling damage from parasitic fungi. For that reason we have in Finland attempted to control such damage by treating stands with fungicides before the snowfall in the autumn. According to the numerous trials performed the compounds quintozene (or pentachloronitrobenzene) are really effective in controlling all winter-killing fungi besides clover root rot fungi. Despite the relatively high cost of fungicides (about 6 pounds/hectare), several farmers in Finland have begun to use this control method for treating red clover an winter wheat stands and have proved it very profitable. Decisive significance this method scarcely will have in future. The increasing of resistance of overwintering plants will be more important.

The are indeed many significant differences in resistance to winter-killing fungi in different varieties and strains of all overwintering plants.

The reliable results obtained in growing timothy *(Phleum pratense)* and its popularity in Scandinavia especially in Finland can be attributed to its resistance to both cold and parasitic fungi. Other species which are relatively resistant to winter-killing fungi are *Festuca pratensis, Poa pratensis* and *Alopecurus pratensis.* The resistance of *Dactylis glomerata* is considerably weaker. The fact that *Lolium perenne* is not widely grown in Finland is due to its susceptibility to these fungi and to other winter injuries too. The strain Valinge is highly resistant and is therefore well suited to Scandinavian conditions. Indigenous Finnish grass strains as well as also clover varieties have, in general, proved fairly resistant to injuries from winter-killing fungi compared with imported strains.

Information on the susceptibility of strains of grasses used as breeding material to different winter-killing fungi are, however incomplete since they are almost solely based on field observations.

The experiences and observations received from field tests are certainly useful and important. This method is, however, very slow and also uncertain in seasons when the fungi do not develop in the field at all, or only in a minimal amount. For that reason the resistance requires to be studied also under more controlled conditions. Such investigations has been carried out in Finland in many years. Several inoculation methods with all winter-killing fungi have been initially tested. The main characteristics of the most suitable and reliable testing method used by us will be here given. The idea is by no means new, but the realization is a modification of many earlier testing methods.

Since immune plants are unknown, the testing procedure must differentiate susceptible plants from somewhat resistant plants. In studies like these it is of little value to kill all the plants or have them all alive. The relative resistance of plants is most important. It can be best studied in the controlled low temperature chambers or cooling rooms.

The diseases caused by winter-killing fungi normally develops in plants that have been gradually hardened under changing environmental conditions in the late fall. Although most of these fungi grow best at temperatures 10-15° C they also develop well at 0° C and cause damage only at low temperatures. For that reason incubation in tests has been adjusted at 0-2° C. At 15-20° C grown plants can be hardened 2-3 weeks under the lights in cold chambers at 2-4° C or in the late fall outdoors.

The favourable moist conditions required for disease development are maintained by snow cover in nature. Snow favours the pathogens by maintaining required humidity for abundant mycelial growth over plant and soil surface. Snow promotes contact between older leaves and the soil surface increasing the possibilities for the soil-borne inoculum to encounter host tissue. A saturated atmosphere, however, is unfavourable for the development of all fungi. Under low temperatures during incubation plants use only very little water. The pots are in tests placed in moistened peat soil for sub-irrigation. A favourable humidity was maintained by covering all pots with a moist absorbent cellulose mat.

At 6-7 weeks depending on pathogens and other factors susceptible plants are usually dead. After incubation the cellulose mats can be removed and the temperature risen to 10-15° C for 2-3 weeks to check survival and recovery. After this time the disease index can be calculated.

The bulk inoculum is grown on a sterilized medium of equal volumes of wheat and barley moistened with water or a sterilized mixture of moistened oat hulls and wheat (in the ratio of 1:2). Inoculum was distributed over the surface of the soil in each pot.

Diseases develop faster in chambers trials than in the field. The rapid pathogenesis in the chambers is due to constant maintenance of conditions favourable for pathogen development and to higher inoculum levels. The different rates of diseases in the field and chambers do not lessen anyway the value of the field tests.

For the present we have not discontinued the field tests but in addition we are carrying out tests in chambers too.

Concerning the field tests the plants often are killed irregular, in patches in the rows. Therefore it is useful to add fungus inoculum over the surface of the test area. It should be most practical to devide the whole test area into two plots, from which we one half every-other year use for testing and the other half we grow a susceptible plant on purpose to increase the inoculum potential in the soil.

The limits of the cultivated grasses as well as winter cereals towards the north are mainly determined by winter-killing fungi. Therefore the breeding of these plants should take place in the right way to produce winter hardiness not only by attention being paid to resistance to cold, but primarily to resistance to the various parasitic winter fungi. In breeding winter hardy varieties special attention must be paid to their place of origin. The overwintering of new varieties should therefore be tested under the natural conditions

for which they are intended. Seed nursing must take place also within the prospective cultivation areas.

References

Ekstrand, H. 1955. Höstsädens och vallgräsens övervintring. Summary: Overwintering of winter cereals and forage grasses. Stat. Växtskyddsanst. Medd. 67: 1-125.

Jamalainen, E.A. 1956.
Overwintering of plants in Finland with respect to damage caused by low-temperature pathogens. Publ. Finn. Stat. Agric. Res. Board 148: 5-23.

Ylimäki, A 1962. The effect of snow cover on temperature conditions in the soil and overwintering of field crops. Ann. Agric. Fenn. 1: 192-216.

Ylimäki, A 1967. Root rot as a cause of red clover decline in leys in Finland. Ibid. 6, Suppl. 1: 1-59.

Day-length reaction of red clover and its relation to plant breeding.

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1. Rate of development of different types of red clover

If we take a local red clover variety from the Mediterranean area, one from Denmark or Southern Sweden and one from Northern Scandinavia and compare them under South Swedish conditions, we will find that they behave very differently. The South European types start their growth in the spring, have early elongation of the internodes and early development of buds and flowers. If they are cut at the early flowering stage, which will be round about the 15th of June they develope very quickly a second growth and will flower again in the beginning of August. They can also produce a third set of flowering sprouts in the fall. The production of vegetative parts is all the time rather poor and the main production consists of the fertile sprouts.

The South Scandinavian types start their spring growth somewhat later. They develope a great amount of leaves before the stem elongation starts. Bud and flower development comes a fortnight later than in the Mediterranian types. If they are cut in the early flowering stage just after midsummer the development of the regrowth is rather slow and consists mainly of leaves. Fertile sprouts are rather few and they do not come into flower until the end of August. If they are cut again there will be only leaf formation.

The North Scandinavian types start their spring development very late and remain on the leafy stage until the end of June and do not start flowering until the middle of July. If they are cut at that time the regrowth is very slow and new flowering sprouts will hardly develope.

These three types are designated as early, medium late and late clover. On the continent one speaks normally only about two types, the dubbel-cut and single-cut types. The dubbel-cut corresponds to the early clover and the single-cut clover include the medium late as well as the late type. The different types behave differently in different areas. Thus if a medium late variety from Southern Sweden is grown under North Scandinavian conditions it will behave more like an early clover does in Southern Sweden only with the differences caused by the shorter vegetation period. Many varieties, which in Central Europe are classified as single-cut clover, will in Sweden not be classified as medium late but as early

clovers. The variety Aberystwyth S 123 which is a single-cut clover or the local variety Montgomery which is the origin of S 123 are in England and Wales regarded as extremely late varieties but when they are grown in Southern Sweden they are definitely earlier than the South Swedish medium late varieties.

2. Day-length reaction

The main difference between these different types of red clover is their day-length reaction and the difference in their behaviour on different latitudes can be explained by changes in their development caused by differences in day-length. Physiologically red clover is a long-day plant. It requires a certain day-length in order to change over from the vegetative to the generative face or to be more correct the unbroken dark period must nor exceed a certain critical maximum length, if the generative parts shall be able to develope. The minimum day-length required is, however, different in different types. Early clovers adapted to more Southern conditions require shorter days than the late clovers developed under more northern conditions. The more the day-length exceeds the critical minimum requirement the quicker the clover will develope and the sooner the change over from the vegetative to the genrative face will take place. When the day-length is much longer than the critical day-length the plants are forced in their development and the stem elongation and the flowering will take place without hardly any vegetative development at all. In my own investigations I found that if South European red clover was exposed to continuous light the plants were forced to develope flowering sprouts already at the five leaf stage. The plants were at that time very weak but they flowered. Under the same treatment a late clover remained in the rosette stage until a large number of vegetative sprouts had developed.

Chmelar and *Mostovoj* (1932) and *Itzerott* (1938) found that continuous light treatment was a quick method to differentiate between early and late clover. Chmelar and Mostovoj found in their investigations that after a treatment with continuous light during a fortnight only 2,9 per cent of the Danish variety Ötofte medium late had developed fertile sprouts, while at the same time 77,8 per cent of the plants from the most extrem early clover had developed such sprouts. It is here of interest to find that two local varieties from Mähren and Böhmen, which were classified as late clover, developed fertile sprouts in 38.5 and 33.3 per cent of their plants. These varieties which are classified as late clovers behave more like the early type than those Scandinavian varieties which in their home country are classified as medium late.

Schulze in 1957 published the results from an investigation where the day-length reaction in various types of clover is extremely nicely demonstrated. In comparing the German variety Steinacher with the Norwegian variety Molstad he found after different day-length treatment that material sown in the spring flowered at following dates:

Day length	Steinacher	Molstad
12 hours	No	No
15 —	3/7	No
18 —	20/6	25/7
21 —	12/6	14/7
24 —	10/6	6/7

The longer the day-length has been the earlier have both varieties changed over from the vegetative to the generative face. At all day-length treatments Steinacher has come into flower nearly one month earlier than Molstad, but Molstad has when treated with continuous light flowered at the same time as Steinacher in 15 hours day length. Also the flowering intensity has been influenced. In Steinacher the largest number of flowers was obtained at 15 and 18 hours day, while Molstad produced the highest number of flowers at continuous light.

Not only the flowering time and flowering intensity has been influenced by the day-length byt also the development of vegetative parts. Thus Steinacher gave the highest total yield of dry matter in leaves, stalks and flowers at 15 hours day length and the yield at 24 hours day length was only about 40 per cent of that obtained at 15 hours. Highest yield of Molstad was obtained after 18 hours day length but the difference between the yield at 18 and 24 hours day length is only 2 per cent and hardly significant. Thus the long days has forced the early clover Steinacher into flowering at a very early stage and has prevented the normal development of vegetative parts resulting in a low total yield. This is exactly the behaviour of an early clover grown in northern areas with long days.

Interaction of temperature, day-length and light intensity on plant development

Under natural conditions, not only the day-length, is of importance for the development of the plant, but also water supply, temperature and light intensity.

Water supply as such seems not to have any influence on the rate of development and on the time for the change over from the vegetative to the generative face. In my own investigations I have compared irrigated and not irrigated red clover. Under fairly dry conditions the irrigated clover naturally developed much more luxuriously than the not irrigated. The time for flowering was, however, the same in both treatments. (JULÉN and WIKLUND, 1955).

Light intensity. It has often been suggested that it might be possible that increased light intensity should compensate for shorter day-length. In years with what we call poor weather with lots of rain and cloudiness and a low number of hours of sun-shine, red clover comes into flower much later than in sunny years. The same result has been obtained in experiments with shading the clover and comparing the time for flowering with unshaded

material (JULÉN and NILSSON-LEISSNER, 1945). As, however, it is the length of the unbroken dark period, which is of importance for the change over from the vegetative to the generative face and as the light intensity necessary to bring about this change over, is very low, it seems very unlikely that during the day period the variation in light intensity on a level, which is in any case one thousand times higher than the critical light intensity, could have any influence on the day-length reaction. As, however, increased light intensity mostly is combined with an increased temperature it is more likely that it is the difference in temperature that effects the rate of the development of the plants.

Temperature. Red clover starts its development at about 5⁰ C. Low temperature prevents development of fertile sprouts even if the day-length is sufficient. Tenperature therefore is the limiting factor in the early spring. If there is a minimum temperature requirement and if in that case this is different in different types of clover is not known. If so, it is under Scandinavian conditions in any case surpassed by the end of May and the long days now forces the early clovers to a rapid development, while this still goes much slower in the medium late and late types In the fall the temperature is much higher than in spring periods with the same day-length and the temperature has no limiting influence on the flowering. Therefore the day-length is at this time of the year controlling the development. Late types are prevented from flowering while early types are continuously developing fertile sprouts until night frost or other sudden drops of the temperature brings the growth to a stop.

To what degree high temperature can compensate for the short day-length is discussed. The difference in flowering time between various years with different climatic conditions, which probably are due to temperature differences, has already been mentioned. *Walle* and *Garrison* (1959) has been able to produce seed of Tammisto red clover in California, where the day-length is so short that if all other factors had been the same as in Finland this late variety had certainly not been able to produce any flowers at all. It is most likely that it is the higher temperature which has counteracted the effect of the long nights.

Day-length reaction and winterhardiness

It is a well known fact that the early clover types are less winterhardy than the later ones, It is evident that the continuous development of fertile sprouts weakens the plants and prevents them from storing large amounts of nutrient reservs in the roots. These root reservs are, however, necessary to make it possible for the plants to survive during the winter and to be in good condition in the spring. If now through short day treatment plants of early types are prevented from flowering in the autumn, their winter hardiness is increased considerably, which have been demonstrated by among others, *Schultz* (1949) and *Pohjakallio* (1960). If the increased root size and the larger amount of nutrient reservs in the roots are the only reasons for this increased winterhardiness, is not definitely clarified even if these factors undoubtly have very great influence. *Umaerus* (1963) in her investigations found that long day treated plants were much more attacked by root rot and she puts forward the assuption that this increased susceptibility to root rot might be an important cause for the killing of the plants during the winter. If this is the case there must, however, be some

physiological reason behind these increased attacks and any explonation for this is not yet given.

Breeding aspects

With the very strong influence from the day-length reaction on the general development, the productivity, and the winterhardiness of red clover it is evident, that this character must be taken into consideration in the breeding work. As red clover is a cross pollinating species, the selection pressure from day-length and from the winter climate can cause considerable changes in the composition of a population when it is moved from one climatic area to another. Red clover originates from the Mediterranian area and Southwestern Asia and all the various types of red clover now spred over almost all parts of the temperate zone must have developed from the original populations adapted to areas with fairly short days. When red clover is moving towards the North the natural selection pressure from day length and winter climate can force the development into two directions.

A. If the clover is moving as a wild plant it is necessary for the population if it shall be able to survive that flowering and seed ripening comes so early in the season that there is time enough for the seed to germinate and develope plants which are strong enough to overwinter. The further to the North it comes, the shorter the summer will be and the earlier the flowering must take place. Under such conditions the productivity of vegetative parts is of no importance for the plant itself. Further the species can survive as an annual type and winterhardiness will be of no specific importance. It is likely that the wild clover existing in Northern Russia and in Northern Scandinavia has developed in this way. The wild clover in these areas is characterized by very early flowering and low productivity and it is not sepcificly winterhardy (*Wexelsen*, 1937, *Gupalo*, 1953).

B. If the clover is spred as a cultivated plant it will not be able to reseed itself and especially if the seed is harvested in the second or the third year there will be a selection for winterhardy plants, that is those which do not develop any fertile sprouts in the later part of the summer. This will lead to more and more winterhardy and at the same time late types. This is the way in which probably the local varieties of cultivated clover in the Northern part of the red clover growing area have developed.

Thus changes in the rate of development take place if a variety is moved from one area to another. For instance the early clover variety Tystofte nr 40 from Denmark was about 1935 imported to Sweden and multiplied there for a number of generations. A remarkable change took place and to-day the aftercultivated population has become so late that it can almost be classified as a medium late clover. It is now marketed under the name of Bara clover and this local variety is not only later but much more winterhardy and also more productive under Swedish conditions that the original Tystofte nr 40. It is not always that such selection is an improvement of the variety and especially if a variety is grown for seed production in an area, which is climatically more favourable than that area in which the variety is to be used as forage crop. Under such conditions it might happen that the variety becomes less winterhardy and perhaps also less productive.

If it now is possible that all the various types of wild and cultivated redclover have developed from red clover populations originating from the Mediterranean area or Southwestern Asia and this development has occured through natural selection mainly based on the day-length reaction, we may ask if it also is possible through systematic artificial selection to develop new varieties with combinations of characters more suitable for our requirements than now existing cultivated varieties. Is it for instance possible to produce varieties with early flowering and rapid regrowth under long day conditions which in spite of this are sufficiently winterhardy to survive under the climatic conditions prevailing in Northern Europe? Through intensive selection at the Swedish Seed Association in Svalöf it has been possible to produce a type which flowers only a few days after natural early clover but without any production of fertile sprouts in the late autumn and with and winterhardiness comparable with medium late clover. It is still not known if this type is extremely sensitive to changes in the day-length and therefore very quickly turns over from the vegetative to the generative stage as soon as the day length is sufficient for this change or if this type has another temperature requirement for the development of the fertile sprouts. In any case this type is an example on the possibility to produce types which differs from those developed by the nature itself.

Another problem of interest is if it is possible to select new late types from early clover under artificially arranged day-length conditions and if in that case these late types will be adapted for northern conditions. Experiments to clarefy this problem are under way but the results are not yet available.

The wide variation in the existing red clover populations makes it however, reasonable to believe that all genes necessary for the development of winter hardy late clover must have been available already in the original populations grown under short day conditions. If this is true the now existing red clover population in the Southern areas must be a valuable gene pole for breeding clover also for Northern conditions. Also in the South there are areas for instance in the Anatolian Plateau in Turkey or in Southern Russia where the winters are very strong and where we can expect the red clover to carry genes for very good winter-hardiness. These genes for winterhardiness will, however, not show up when these types are grown in the North due to the very strong influence of the day-length reaction. The problem is, however, how to find them and how to utilize these and other valuable genes in these Southern populations for the breeding work in the North.

Literature cited

Chmelar, C. and Mostovoj, K. 1932.
(Eine Laboratoriumsmethode zur Unterscheidung von ein- und zwei-schüringen Rotklee nach dem Wachstum bei verlängertem Tage.) Vestn. Ces. Acad. Zem., 8, 734-741.

Gupalo, P.I. 1953. (Physiological characteristics of morphobiotypes of red clover.) Doklady Akad. Nauk. SSSR. 91:4, 965-968.

Itzerot, H. 1938. Das photoperiodische Verhalten von Früh- und Spätklee, Prakt. Bl. Pflanzenb. 16, 130-136.

Julén, G. och Nilsson-Leissner, G. 1945.
Miljöns inverkan på rödklöverns morfologiska utveckling och kemiska sammansättning. Sv. Vall- o. Mosskilt, fören. Kvartalsskr. 7, 177-194.

Julén, G. och Wiklund, K. 1955.
Effekt av bevattning och beskuggning på halt av råprotein, växttråd och karotin hos några vall- och grönfoderväxter. Sv. Uts. fören. Tidskr. 65:5, 357-381.

Krjacov, I.S. 1936 (Photo-stage in red clover). Selekzia i Semenovodstvo 3, 15-20.

Mirosnikov, V.N. 1943.
(The winter hardiness of Trifolium pratense). Sovet. Bot. 3-14.

Pohjakallio, O. et al. 1960.
Effect of daylength on winter hardiness of clover. Maatal. ja Koetoim. 14, 104-11.

Schulze, E. 1957.
Photoperiodische Versuche an mehrjährigen Futterpflanzen. 1. Mitteilung. Z. Acker- und Pflanzenbau. 103, 198-226.

Schulz, G.E. 1949. (The significance of the long summer northern day in lowering winter hardiness of red clover.) Doklady Akkad. Nauk. SSSR. 66, 743-4.

Smith, D. 1957.
Flowering Response and Winter Survival in Seedling Stands of Medium Red Clover. Agr.J. 49, 126-129.

Umaerus, Magnhild, 1963.
Influence of Photoperiod Treatment on the Overwintering of Red Clover. Zeitschr. Pfl. zücht. 50:2, 167-193.

Valle, O. and Garrison, C.S. 1959.
Seed production of Finnish single-cut Tammisto red clover at different latitudes and the influence of these environmental conditions on varietal performance.
Suomalaisen Tiedeakatemian Toimituksia Annales Academiae Scientiarum Fennicae. IV. Bilogica. 45, 1-20.

Wexelsen, H. 1937. Undersökelser over norsk rödklöver. Variasjonen innenfor stammene. Tdsk. Norsk. Landbr. 44, 135-149, 161-183.

Photoperiodic response and vernalization in grasses

by

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The growth and development of forage grasses show a wide variation in the adaptability of species and varieties to various factors of the plant environment. The length of periods of active growth or of dormancy, the time of flowering and seed ripening as well as the regulations of seed germination by dormancy may express such adaptations to specific clamatic conditions or even to ecosystems developed by the dominant influence of grazing or other practices of forage utilization.

There are numerous physiological mechanisms and their interactions upon which such adaptibility may be based, Two of those, the reaction to photoperiod and to vernalization, will be discussed in this paper.

Photoperiodism plays a fundamental role for numerous morphogentic processes in plants and is especially well known in controlling the induction and development of flowers. Vernalization by low temperature is known as a physiological process essential in the flower induction of many biennial and perennial plant species native to the more temperate regions of the world. Therefore discussing both pgysiological mechanisms for forage grasses we have to deal at first with the flowering process and in the second line with other plant characters which may be influenced too.

1.) The flowering process

Before any visible sign of inflorescence initiation may be observed on the apex of a grass shoot parts of the apex tissue must have reached physiological conditions which are called flower induction. Its nature is still unknown on the molecular level of cell physiology and is morphologically and histologically not detectable. If an apex is induced to flowering may be judged only with the first inflorescence differentiation, the so-called double ridge stage. This inflorescence initiation continues after sufficient flower induction to the full differentiation of the inflorescence.

1. 1 Flower induction and temperature

In numerous grass species of the temperate climatic regions flower induction is favoured by a period of low temperature and may be even impossible in many grasses without it.

This induction process of low temperature, which is called vernalization, effects the plants normally during fall, winter or even early spring. All grass species known to have a vernalization requirement belong to the subfamily Festucoideae and are photoperiodically adapted to long days for inflorescence initiation and development. (EVANS 1964).

Besides winterannual species many perennial grasses have a pronounced vernalization requirement. Among these are forms of Agrostis tenuis, Bormus inermis, Alopecurus pratensis, Dactylis glomerata, Festuca pratensis, F. rubra, Lolium perenne and Poa pratensis. But other perennial grasses of the temperate region like Phleum pratense, P. palustris and Trisetum flavescens are independent on the influence of low temperature in their flower induction process (BOMMER 1961 a, COOPER and CALDER 1964).

The embryo of the imbibed seed may be already sensitive for vernalization in winterannual and on some perennial species like L. perenne, Hordeum bulbosum and Agropyrum intermedium. But the majority of the perennial species show an unsensitive juvenile phase up to the development of some leaves before vernalization by low temperature is possible. In addition an increase of the sensitivity with the tiller age is typical for some species like F. pratensis, P. pratensis (BOMMER 1963), and L. perenne (MCCOWN and PETERSON 1964).

The classic experiments of PURVIS and GREGORY with winter rye showed that the vernalization effect is localised in the tiller apex and may persist there over a long time even under conditions unfavourable for the flowering process. Devernalisation is possible if incomplete vernalization is followed by high temperature.

The stabilisation of the vernalized condition in species like Arrhenatherum elatius seems not to be reached until short before inflorescence initiation (BOMMER 1964).

Effective temperatures for vernalization ranges from -6° to 14° C with the optimum between 0° and 10° C (EVANS 1964). Plants become vernalized too when cool night temperatures change with moderate day temperatures especially if day temperatures are accompanied by high light intensities. So, cool nights during March and April may be sufficient to vernalize spring born tillers of plants with a low vernalization requirement.

The localisation of the vernalization effect in the apex of the single shoot implies that tillers formed after the time of effective vernalization remain vegetative, and perennial grasses have to be vernalized each year again for a new crop of flower tillers (FEDOROV 1964). It was suggested that vernalization may be translocated to lateral buds. This is unlikely to be true. Lateral buds will get the vernalization stimulus during the vernalization of the mother shoot. They have probably no or a diminished juvenile stage. The observation of flower tillers in the aftermath growth may be explained in this way or by subsequent vernalization with low spring temperatures. In species and varieties which have a pronounced vernalization reqirement the spring and summer born tillers remain vegetative and depend in their flowering behaviour on the vernalization during the following fall and winter.

1. 2 Flower induction and day length

The forage grasses of the temperate region are long day plants in their day length reaction. Flower induction is completed when the cycles of the daily dark decrease below a critical length. But in a number of species with a vernalization requirement this applies only to the last part of the induction period.

Short day conditions with a minimal length of the daily dark period may have a pronounced influence during or before the vernalization period with low temperatures. In some species it becomes doubtful if the flower induction during winter depend more an low temperature or on short day conditions. According to the grass species short day conditions during flower induction may replace or supplement the low temperature effect or may be even necessary for its effectiviness. In L.perenne vernalization takes place in short day and warm temperature. But short day in addition to low temperature is without any effect (COOPER 1960). In Arrhenatherum elatius short day during the vernalization with low temperature prevents the elongation of culm internodes before the completion of the induction. Consequently flower induction is most effectful in low temperature together with short day conditions (BOMMER 1964). Low temperature together with short photoperiodes are necessary for flower induction of Poa pratensis (LINDSEY and PEERSON 1964). Short day conditions alone are effective in Agrostis canina, A. alba and A. stolonifera showing no reaction to vernalization with low temperatures (COOPER and CALDER 1964). The same is true for forms of Dactylis glomerata (CALDER 1964 b) which are already induced with a daily dark period of 7 hours. Their induction is inhibited by continous light. The effective dark period for other forms of orchard grass seems to be much longer with 11 1/2 hours (GARDNER and LOOMIS 1953).

Studies in Iowa showed that the influence of photoperiod for flower induction of D. glomerata could be eliminated with the length and temperature range of vernalization. In long photoperiods longer vernalization with lower temperature was needed as in short photoperiods (JUTRAS 1965).

Day length may be of influense to flower induction not only during but also before a vernalization treatment (BOMMER 1963). Plants of Festuca pratensis showed the most effective induction if 6 weeks of vernalization by 4o C together with a 18 hours day length were preceded by 8 hours photoperiod during the warm temperature of the prevernalisation period. Longer photoperiods inhibited and continous light prevented the following vernalization. The effect of the vernalization itself and likewise that of the preceding photoperiod showed a pronounced interaction with the age of the tillers.

As already mentioned the flower induction of temperate grasses is in its last part very much stimulated by long day conditions in warm temperature. Flower initiation is accelerated under these conditions. It is typical for many long day reactions to be accelerated by decreasing daily dark periods showing the most advanced rate in continous light. The interruption of the inhibiting dark period by a light break may have the same effect as continous light.

Usually the long day effect starts after passing the so called »critical day length». Various genotyps of the same species may considerably differ in the length of the critical photoperiod. It may vary between 9 and 16 hours for L. perenne and between 11 and 16 hours for Ph. pratense. The optimum of the long day effect may be apparently reached in some species with a photoperiod of 18 to 20 hours. In this case continous light develops a more or less inhibiting effect. Such observations were made in P. pratensis (LINDSEY and PETERSON 1964) and in Dactylis glomerata (CALDER 1964 b) and may be similar to the ambiphoto-periodism discribed for Setaria verticillata (MATHON 1961).

Relative low light intensities are photoperiodically effective and judging day length under field conditions have to take into account the civil twilight.

The necessary duration of the long day induction to initiate inflorescences even in a following non inductive photoperiod may vary between 1 day (genotyp of L. temulentum, EVANS 1960) and several weeks. KEINENDORST and SONNEVELD 1965 reportet 3 days for an early flowering strain of L. perenne.

In some species, especially anuals, the coleoptile or the first leaf are already sensitive in the long day treatment while in many perennials the sensitivity is reached at a later stage corresponding to their juvenile phase. In L. temulentum the photoperiodical sensitivity increases in ontogenetic younger leaves (EVANS 1960).

In spite of the acceleration by warm temperature of the long day affected flower induction and initiation high temperatures especially high night temperatures may prevent flower induction. Then in some species the long day reaction becomes visible with the elongation of internodes and the development of sterile culms. This is true for instance with Ph. pratense which is described as having no vernalization requirement. Possibly this phenomenon may be also explained with a vernalization requirement similar to Arrhenatherum elatius. This last species is induced to flower initiation and development under long day if 10° C night temperatures coincide with day temperatures of 30° C. If the night temperature is raised to 15° C only sterile culms are developed, but flower culms occur when a sufficient long period of cool temperature and short days preceds the long day treatment (BOMMER 1964). Short periods of high temperatures after the flower induction seem to be responsible for a reduced inflorescence production of P. pratensis in the central valley of California (LINDSEY and PETERSON 1962).

1. 3 Inflorescence initiation and development, internode elongation

The initiation and following differentiation of the inflorescence as well as the elongation of the culm internodes are accelerated with increasing day length and with warm temperatures in long day grasses. Inhibiting conditions as short days or a slowly increasing day length as well as low temperature have a retarding effect. In connection with these an increasing enlargement of the apex with additional initiation of leaf primordia is observed. This may cause substantial enlargements of the inflorescences especially in ear bearing grasses. In comparison a quick inflorescence initiation in favourable day length and temperatures

leads to small inflorescences with fewer spikelets and florets. In an experiment with Lolium hybrids in California clon plants grown under natural day length headed 1 1/2 month later but produced inflorescences with an increase of 16 spikelets in the average than plants of the same clons in an artificially elongated day length of 18 hours (BOMMER 1966).

In some long day grasses inflorescence initiation may take place very much retarded under short day conditions without a long day induction. Similarly the length of the critical photoperiod may be reduced by prolonged vernalization. So, Poa pratensis initiats inflorescences during the time of the shortest day length in the field on our latitudes (BOMMER 1959). If sufficient vernalized with cool temperature and short days this species develops flower heads in all length but is accelerated in its flower reaction by long day conditions. P. annua shows a similar behaviour. In A. elatius inflorescence initiation may be observed in short day too after a prolonged period of vernalization. But the differentiation of the inflorescence stops apparently at an early stage (BOMMER 1964). Lolium species have in comparison a more pronounced dependence of their inflorescence initiation on long day conditions.

The further development of the inflorescence of the most long day grasses is adapted to longer photoperiods at the initiation (EVANS 1964, CALDER 1964 a). Because an increasing temperature beside the day length speeds up the development, the date of heading in spring is very much influenced by the prevailing temperatures. The observation of various species and varieties in the field at Giessen showed the time of inflorescence initiation spread over a period of 7 month while heading of the same material occured in between 2 month (BOMMER 1959). This corresponds with observations that the same varieties come to heading earlier in low land than on high altitudes and heading is earlier in the mediterranean climate than in other parts of France (JACQUARD 1961). As with the inflorescence initiation all conditions accelerating the development like higher temperatures and long photoperiods counteract to some degree the size of the developing inflorescence. The number of florets per spikelets and per ear are higher if the inflorescence development of L. perenne takes place in 13 instead of 23° C and in photoperiods not very much longer than the critical one (RYLE 1965). High temperature ($15/25^{\circ}$ C) during the inflorescence development of tall oat grass reduced the number of spikelets per panicle compared to lower temperature ($5/15^{\circ}$ C). Specific effects of various environmental factors upon particular steps of the inflorescence development may be espected with more detailed studies. The change from stimulating to inhibiting factors during the inflorescence development, for instance the reduction in day length and temperature during late summer and fall causes frequently a reversion in the differentiation to vegetative organs in the inflorescence which expresses various forms of proliferation. The elongation of culm internodes normally synchronized with the inflorescence development appears as a separate process as shown in experimental studies. So, culm elongation may occur in a number of grass species without inflorescence initiation in the form of sterile culms. A. elatius, Ph. pratense and Elytricia repens are well known examples for that (BOMMER 1964). At the contrary the development of an inflorescence without culm elongation was observed in

L. multiflorum under specific conditions (BLONDON 1964). In A. elatius internode elongation seems to be more dependent on the long day reaction than the inflorescence initiation.

1. 4 The influence by other factors

In between the frame which is given by the temperature and day length conditions controlling flower induction, inflorescence initiation and development the general growth conditions notably net assimilation and nutrition of the plant respectively of the single tiller determine to what extent the flowering processes may be expressed or not. The occurence of a juvenile stage in various grass species points to the fact, that the energy substrate in the young plants may be insufficient besides the possibility of the action of specific inhibitors. Low light intensity, nutrient deficiencies of different kinds especially of nitrogen may reduce or prevent flower initiation and development. The reduced production of inflorescences in old dense stands of P. pratensis and F. rubra is probably to explain with the deficiendies in the nutrition of the single tiller. Likewise the increasing competition between the plants in a dense stand and between the tillers in heavy bunches of grasses as F. pratensis and D. glomerata may be responsible for the percentage reduction of flower tillers (LAMBERT 1963, LEWIS 1963).

It is important for the yield components of grass seed stands fall borne tillers produce the largest inflorescences and the main seed yield in the following summer. This was shown for L. perenne, Ph. pratense, D. glomerata and F. pratensis (LAMBERT 1963, RYLE 1963, 1964). These tillers pass through a cycle of enviromental factors favourable for large inflorescences with a long duration of the induction and slowly increasing photoperiod. The order of tiller origin has also an influence on the size of the tiller and its apex as well as on the size of the developing inflorescence. Tillers of tertiery or quartery order bear smaller inflorescences demonstrating some of the less known interactions between tillers on a single grass plant. Fertilization notably with nitrogen may overcome these differences (RYLE 1963).

2.) Relation of vernalization and photoperiod with other morphogenetic and physiological processes.

As shown in the discussion on the flowering process the influence of vernalization or temperature in general and of photoperiods shows manyfold interaction with other environmental and internal factors. This applies to a much larger degree for all effects on other morphogenetic processes like leaf growth, tillering and root development. In addition to the interaction of environmental factors the development of flower tillers may interfer the expression of the vegetative plant characters. Therefore the analysis of the influence of a single factor is rather complicated.

The number of leaves developed on a single tiller is determined by the time the initiation of inflorescence structurs on the apex terminates the further initiation of leaves. Increasing temperature enhances in a wide range up to values of about 25° C (ANSLOW 1966) the

rate of the appearance of leaves on a tiller. It seems to be tha last morphogenetic process inhibited if high temperatures reduce the net assiminlation rate. A lower leaf appearence rate during low temperature conditions is probably to understand in connection with flower induction by the vernalization process. But a specific effect of vernalization upon leaf appearance does not seem to exist. The optimum temperature for the rate of leaf appearance depends on the species. Tropical species have a higher optimum temperature than grasses from temperate regions (more detailed discussion in ANSLOW 1966).

The effect of photoperiod have to be separated from that of total light radiation. If approximately equal daily amounts of radiation were used increasing day length reduced the rate of leaf appearance in several grass species (TEMPLETON et al. 1961, COOPER 1964, RYLE 1966 a). Long day conditions increased at the same time leaf length and sometimes width, so that the rate of the production of new leaf area was increased with increasing day length (RYLE 1966 a).

Tillering is in close relation to the leaf appearance rate in so far each leaf axel bears a tiller bud. But the meristematic activity of the buds is under the control of one or more systems of correlations in the plant. With sufficient total radiation warmer temperature increases tillering especially under short photoperiods (BOMMER 1961 b, v.AMSBERG 1965). With increasing temperature the activation of tiller buds slow down compared with leaf development whereas in lower temperature the tiller zone is closer to the youngest leaf on a tiller. This retardation by warm temperature may be changed to a sudden increase in tillering by changing the plants from high to low temperature (BOMMER 1962).

But »the effect of temperature on tillering cannot be considered in isolation from other environmental factors, notably light intensity» (LANGER 1963).

The development of flower culms always inhibits the activation of axilary leaf buds resulting in a total stop or a more or less pronounced diminishing of the rate of tillering. This inhibition extends not only to the buds on the elongated parts of the culms but also to lower originated ones. The development of elongated culms without flower initiation in A. elatius inhibits bud growth in a sililar way but not so severe. Because internode elongation in long day grasses is a long day response increasing photoperiode affection culm elongation have always a reducing effect on tillering. But without any culm elongation and flower induction a reduction of tillering by long photoperiodes was frequently observed   (P. pratensis. BOMMER 1963, D. glomerata, F. pratensis und L. perenne, RYLE 1966 a, b).

In root growth and development it is even more difficult to analyse a direct effect of vernalization and photoperiod. The number of roots is closely correlated to the number of tillers on a grass plant. But the inhibition of buds by various factors must not inhibit the root development in the same way. The total root mass is very much dependent on the ligth intensity and the temperature which both affects the net assimilation rate and the latter the distribution of assimilates between the above plant parts and the roots. The top : root ratio was not affected by photoperiod in F. arundinacea (TEMPLETON et al. 1961) but increased with the production of flower or sterile culms in A. elatius (BOMMER 1961 b).

Top plant growth is usually increased with the formation of flower tillers. The growth rate of these tillers is higher than that of vegetative tillers (SILSBURY 1965). But without the development of flower culms and with comparable total light energy the total dry matter production of D. glomerata, F. pratensis and L. perenne was higher under long day than under short day conditions (RYLE 1966 a).

Persistency, a very important character for all perennial grasses, is very often discussed in relation to vernalization and photoperiodic response. In some species especially of the genus Lolium a close correlation seems to exist between a low vernalization requirement, a short critical photoperiod and a short living habit of plants. In this case early and profuse elongation of many induced tillers continues over a long period in spring and early summer resulting in a severe reduction of tillering and rooting. The difference in the survival between the annual and the longer living forms of L. multiflorum as well as the low persistency of many early cultivars of L. perenne may be explained in this way. But some studies have shown that a high vernalization requirement and the dependence on long photoperiods for flowering must not be correlated in L. perenne and that a separate selection for both characters is possible (SILSBURY 1964, BOMMER 1966). Moreover a profuse elongation of tillers during a long time of favourable photoperiods and temperature must not be a character of low persistency as demonstrated by such species as A. elatius. Ph. pratense and T. flavescens. One of the important characters of a persistent grass seems to be the existence of enough axilary buds which are able to retain their viability during a long time and inspite of the inhibition and competition by a sometimes large number of elongation or even flowering tillers. Otherwise a large number of tillers originating in summer and remaining vegetative until flower induction during the following fall and winter favours the persistency of a plant as the prevention of flowering in annual grasses prolongs their life time. An example for no correlation between late flowering and persistency may be given from observations in F. pratensis. Plants collected from old pastures near the sea coast in North-Germany showed in the average a 17 days later heading than a medium German cultivar (Wehrdaer). But stand losses of the late flowering metarial after the second winter averaged 64 % compared with 28 % of the cultivar.

To understand the complex nature of persistency in grass plants more detailed studies are needed including not only the reactions to vernalization and daylength but also resistance to various meteorogenic factors and to diseases, studies on the rooting habit, on intraplant competition and so on.

One of the most important indirect effects of vernalization and photoperiod via the production of flower culms is upon the change in nutritive value of the forage grasses. This effect is to well known to discuss it in detail here. A change in the chemical composition by day length or temperature may not be caused only through a shift in the ratio of leaves to culms but also directly as shown in D. glomerata and B. inermis (BOWMAN and LAW 1964). T'HART 1967 suggests the influence of temperature and total radiation as more important than the genetic variability.

The possibilities of selection for the plant breeder in vernalization and photoperiodic response of forage grasses as well as the importance for forage and seed production is left to the discussion of this meeting.

Literature

Amsberg, H.J.v., 1965:
Floral vegetative development in Dactylis glomerata as influenced by different temperature levels and durations. Diss. Abstr. *26*, 1271.

Anslow, R.C., 1966:
The rate of appearance of leaves on tillers of Gramineae. Herb. Abstr. *36*, 149-155.

Blondon, F., 1964: Contribution a l'etude du developpement des graminees fourrageres: Ray-grass et dactyle. Thesis Fac. Sci. Univ. Paris.

Bommer, D., 1959: Über Zeitpunkt und Verlauf der Blütendifferenzierung bei perennierenden Gräsern. Z. Acker-und Pflbau 109,95-118.

Bommer, D., 1961a:Vernalisationsbedürfnis und photoperiodisches Verhalten der Futtergräser und ihre Bedeutung für Anbau und Züchtung. In: Neue Erkenntnisse futterbaulicher Forschung, Frankfurt, S. 120-132.

Bommer, D., 1961b:
Die generative und vegetative Entwicklung des Glatthafers, Arrhenatherum elatius (L.) J. et. Pr. Ein Beitrag zur Entwicklungsphysiologie ausdauernder Gräserarten. Habilitationsschrift, Landw. Fak. Univ. - Giessen.

Bommer, D., 1962: Experiments on the physiology of tillering in perennial grasses. Crop. Sci. Abstr. Ann. Meet. Western Soc. Crop Sci., Bozeman, Montana, p. 19-20.

Bommer, D., 1963: Neue Ergebnisse über die Entwicklungsphysiologie von Futtergräsern aus USA. Tgber. DLG-Aussch. Züchtung und Saatguterzeugung Kleearten und Gräser, Fulda, S. 96 - 105.

Bommer, D., 1964: Die generative und vegetative Entwicklung des Glatthafers, Arrhenatherum elatius (L.) J. et Pr. I. Generative Entwicklung.

Bommer, D., 1966: Untersuchungen zur Blütenbildung spätblühender Weidelgrasformen. Wirtshaftseigene Futter *12*, 325-336.

Bowmann, D.E., and A.G. Law, 1964:
Effects of temperature and daylength on the development of lignin, cellulose and protein in Dactylis glomerata L. and Bromus inermis Leyss. Agron. J. *56*,177-179.

Calder, D.M., 1964 a:
Flowering behaviour of populations of Dactylis glomerata under field conditions in Britain. J. appl. Ecol. 1, 307-320.

Calder, D.M., 1964 b:
Stage development and flowering in Dactylis glomerata. Ann.Bot. *28*, 187-206.

Cooper, J.P., 1960: Short-day and low-temperature induction in Lolium. Ann. Bot. *24*, 232-246.

Cooper, J.P., 1964: Climatic variations in forage grasses. 1. Leaf development in climatic races of Lolium and Dactylis. J. appl. Ecol. 1, 45-61

Cooper, J. P. and D.M. Calder, 1964:
The inductive requirements for flowering of some temperate grasses. J. Brit. Grassl. Soc. 19, 6-14.

Evans, L.T., 1960: Inflorescence initiation in Lolium temulentum L. 1. Effect of plant age and leaf area sensitivity tp photoperiodic induction. Aust. J. biol. Sci. 13, 123-131.

Evans, L.T., 1964: Reproduction. In: Barnard, C.: Grasses and Grasslands London, Melbourne, New York, S. 126-153.

Fedorov, A.K., 1964:
(Differences in shoot development between annual and perennial Gramineae.) Bot. Zh. SSSR 49, 974-979; ref.: Herb. Abstr. 35: 837.

Gardner, F.P. and W.E. Loomis, 1953:
Floral induction and development in orchard grass. Pl. Physiol.28, 201-217.

t'Hart, M.L., 1967: Über den Einfluss von Klima, Düngung, Alter und genetischer Herkunft auf die chemische Zusammensetzung von Gras. Z. Acker-u. Pflbau 125, 47-56.

Jacquard, P., 1961: Bull. tech. Ing. Serv. agric., 877-887.

Jutras, M.W., 1965: Photo-termoperiodic responses of orchard grass. Diss. Abstr. 25, 4895.

Lambert, D.A., 1963:
The influence of density and nitrogen in seed production stands of S 37 cocksfoot (Dactylis glomerata). J. agric. Sci. 61, 361-373.

Kleinendorst, A. and A. Sonneveld, 1965:
Influence of the number of days in continuous light, after vernalization, on shooting and morphology of the inflorescences of two types of perennial ryegrass (Lolium perenne L.). Jaarb. Inst. biol. scheik. Onderz. LandbGewass. 1965, 41-48.

Langer, R.H.M. 1963:
Tillering in herbage grasses. Herb. Abstr. 33, 141-148.

Lewis, J. 1963: Fertile tiller production and seed yield in meadow fescue (Festuca pratensis L.). 1. Time of sowing.

Lindsey, K.E. and M.L. Peterson, 1962:
High temperature suppression of flowering in Poa pratensis L. Crop. Sci. 2, 71-74.

Lindsey, K.E. and M.L. Peterson, 1964:
Floral induction and development in Poa pratensis L. Crop. Sci. 4, 540-544.

Mathon, C.C., 1961:
Effects de la temperature de l'energie et de la qualite de l'eclairement sur la mise a fleur de l'espece ambiphotoperiodique: Setaria verticillata Beauv. C.R. Acad. Sci. 253, 2102.

Mccown, R.L. and M.L. Peterson, 1964:
Effects of low temperature and age of plants on flowering in Lolium perenne L. Crop. Sci. 4, 388-391.

Ryle, G.J.A., 1963: Studies in the physiology of flowering of timothy (Phleum pratense L.). 4. Effects of shoot age and nitrogen level on the size of the inflorescence. Ann. Bot. 27, 467-479.

Ryle, G.J.A., 1964: The influence of date of origin of the shoot and level of nitrogen on ear size in three perennial grasses. Ann. appl. Biol. 53, 311-323.

Ryle, G.J.A., 1965: Effects of daylength and temperature on ear size in S 24 perennial ryegrass. Ann. appl. Biol. 55, 107-114.

Ryle, G.J.A., 1966a: Effects of photoperiod in the glasshouse on the growth of leaves and tillers in three perennial grasses. Ann. appl. Biol. 57, 257-268.

Ryle, G.J.A., 1966b: Effects of photoperiod in growth cabinets on the growth of leaves and tillers on three perennial grasses. Ann. appl. Biol. 57, 269-279.

Silsbury, J.H., 1964: Tiller dynamics, growth and persistency of Lolium perenne L. and of Lolium rigidum Gaud. Aust. J. agric. Res. 15, 9-20.

Templeton, W.C., G.O. Mott and R.J. Bula, 1961: Some effects of temperature and light on growth and flowering of tall fescue, Festuca arundinacea Schreb. 1. Vegetative development. Crop. Sci. 1, 216-219.

Some remarks about methods in pasture grass breeding

by

J. W. Luckamp

Choise of basic material

It seems to me as if the choise of basic material is yet more important for grasses than for cereals, or potatoes. Of course it must be generally accepted that no breeder can isolate from his material more or better than it contains. But the chance for unexpected favourable transgressions is without doubt less in grasses, with its wild and uncontrolled cross pollination than in other cultivated crops with the same or related genotype.

If we distinguish between improving and selection in its proper sense, the emphasis in grass breeding is more on selecting, while in other crops we are more engaged in creating and fixation of new and hidden gene combinations, which did not exist before. In grass-breeding in most cases we select already existing genotypes and afterwards we try to find the best possible combination among them by well known and well experienced methods.

In other crops as cereals and potatoes we start with a restricted number of plants and after crossing them an infinite number of plants is born, out of which we select the best genotypes in a fixed constitution.

In grasses we start with a very great number of plants, and after narrowing this number we end with a restricted number of plants, but nearly never with one genotype.

Only in the last years, especially with crossing of different species we are nearer to the breeding system of cereals and then our general view must be adapted to this other system.

Evaluation of basic material

Therefore I think it can be stated that choise of good basic material in grasses is extremely important. Where shall we find this material? Grasses are, compared with other cultivated crops, yet always wild children of nature and left without the care of farmers they still continue their own life in full competition with the environment and in contrast with other cultivated crops they keep their rights.

The results of this character are that anywhere in westen Europe we can find very vital and amazingly uniform ecotypes of grasses adapted to the conditions under which they are living since many decades, even since centuries. It is our task to investigate the conditions, under which we think that out future varieties must live and then we must observe in the

grass areas of western Europe where we find these circumstances already realised. I am inclined to believe with many others, that western Europe is a gene centre for pasture grasses. There we collect the ecotypes necessary as basic material. As the correlation between individual grass plants and their behaviour in a grassland population in competition with other species, under all kinds of management is very unclear, I have been always hesitating in evaluating individual grassplants, cultivated in a breeding garden in space planting, under quite abnormal conditions. Therefore, without doing any preselection I started with sowing in replications, preferably on two places with different circumstances, the collected ecotypes after having isolated them for seed production.

This trial field looks like a normal grassland and it is left three or four years under normal farmers management of grazing, haymaking, silagemaking. After these years a definite choise may be made among the ecotypes. It was always my opinion and till now I hold this, that for practical use no more work should be done than multiplying these ecotypes for selling to the farmer. Of course the danger exists that many generations of multiplication may cause a shift to earlier of later flowering individuals within an ecotype.

Selection for a specific aim.

The question may arise whether it is possible by this method to select for a specific aim. My answer is yes. That depends on the method of management. In Holland every grassland is used for all aims, grazing, haymaking, silage. But if a special aim is needed it can all be found in the management and the ecotypes will show their behaviour.

The objection may be made that although the general character of the ecotype may be amazingly uniform, still an exact examination of the individual plants in this ecotype show a wide range of different types. To my opinion this is only an advantage for the practical use, for it is favourable for the adaptation to many changing circumstances of water supply, drought, fertilizer application and management.

Complications under the new law of uniformity required for breeders rights.

Since last years however there is a snag in it. And this snag is not set free by agriculturists but by lawyers. The regulations for breeders right suppose high uniformity. And these cause a reselection, perhaps better for the breeder than for the farmer.

This reselection must be done by grouping the individual plants of an ecotype in such combinations that they resemble each other, with the danger that a certain level of heterosis is lost.

The polycross method

The polycross method may be used for evaluating the plants belonging to each group to the best combination among them.

The objection to the general custom of removing a great number of individual plants by mere visual selection before the real polycrosstest can be performed with a much smaller number does not hold now. In general it seems illogical to remove so many plants when it is assumed that only a polycrosstest could give a good indication for the combining ability of the plants. Only practical need could justify this elimination.

But now we have a good excuse. There is no need any more to argue against scientifical objections. We are forced to do so by the lawyers and science has to be silent.

Still it must be kept in mind that the polycross test of Wellensiek and the polycross method of Tysdall and Frandsen, although the same in construction, do not lead to the same decision. The polycrosstest of Wellensiek finds its aim in detecting genotypes, the polycross method leads to a new combination of those individuals or clones, whose progenies born with the help of the a pollen mixture, proved to be the best.

Good correlations between polycross, topcross and diallel crossings have lead to this system.

But here we must make some observations

There must be some reasons, why we may expect a good correlation.

We must be aware of the fact, that in the polycross method we measure the effect of the crossing between a motherclone and an indefinite pollenmixture. If this effects is good, it should be logical to imitate this effect, by multiplying both partners separately and performing the effect in the last crossing before creating the variety.

The more both partners are of different origin, the more we may expect that the result will be good on a high level of heterosis.

As far as we know, this conclusion of the polycrosstest has not often been drawn, but it seems to be the most logical and direct. By recurrent and even reciprocal recurrent selection a new and probably higher level may be reached in the next cyclys.

In the case that we combine together the motherclones with a good progeny, trusting upon the mentioned correlations we must take into account that exactly in one specific combination this may escape out of the correlation, for this is never absolute. This may be one reason of deception.

There are more. Good correlation may be expected in the following case.
1o   When the genetic variance is mainly additive, where the acting genes are localized at different loci, that is in the case of dominance or intermediarity.
2o   When the times of flowering are the same.
3o   When the polycross-system is such, that complete panmixis is effected.
4o   When there are no differences in affinity of fertilization.

But we may expect deceptions when

1° Overdominance is the cause of good combining ability between the motherclones and the general pollen mixture. In this case the polycrossmethod will be non-effective. Selecting will be always towards the alleles that are in a minority position. And repeated selection will bring the breeder into an oscillating system.

2° When after some cycli in the polycrossmethod, where the variance is partially additive, partially non-additive, nearly all aditive variance is employed. The polycross-test becomes them more and more ineffective.

3° When the features and characters for which the selection is performed are important parts of the fittness of the plants; it is a generally accepted fact that the fittness of plants in a cross fertilizing population is often determined by over-dominance.

4° When the number of active clones in a polycross scheme must be so much limited to fullfill the condition of complete panmixis, that previous visual selection in fact is the most important selection.

We think that a complementary method may be found in selffertilizing of the many clones in isolated chambers to get an impression of the total behaviour of the first inbreeding generation. This general impression might give a good idea of the additive genetical variance of such a progeny and in consequence of this, also of the breeding value of a clone.

According to my experience the general appearance of the first inbred generation of the grassplants may give a valuable supplementary estimation of the combining ability with other plants in a group. And these two methods should be applied if we do not want to make our reselection on a lower level than we started. But I am still convinced that this reselection is often not necessary for the farmer who will use our varieties. There is a good chance that it would be better for him if we did not. But the laws and the committees for registration will have the power and the last word.