Neth. J. Plant Path. 71 (1965): 136–144

THE UNDERGROUND ATTACKS ON *CROCUS* AND *COLCHICUM* BY THE RUSTS *UROMYCES CROCI* AND *UROMYCES COLCHICI* RESPECTIVELY[1]

De ondergrondse aantastingen door de roesten Uromyces croci *en* Uromyces colchici *bij respectievelijk* Crocus *en* Colchicum

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It was proved by inoculation experiments that *Uromyces croci* taken from infected leaves of *Crocus albiflorus* in Switzerland can attack the underground parts of *Crocus* cultivars. The symptoms obtained by inoculating tunics and corms with this material agree with the characteristics of the underground rust on *Crocus* observed in Dutch nurseries since 1955. Conversely the Dutch material of *U. croci* from tunic infections was shown to be capable of attacking leaves also. The methods of cultivation adopted in *Crocus* growing in Dutch nurseries apparently makes above-ground infection almost impossible, but favors instead the underground infections. Furthermore, because of the anatomy of *Crocus*, there seems to be a barrier to infection of the leaves coming from infected tunics or corms. In *Colchicum*, on the other hand, the tunic is the basal part of the leaf sheath of the lowest leaf. This explains why in commercial growing of *Colchicum*, infection by *Uromyces colchici* is not always restricted to tunic infections and systemic leaf infections and secondary above-ground infections occasionally occur.

INTRODUCTION

Since 1956 the *Crocus* rust, *Uromyces croci* Pass. [microtype: only teleutospores, which germinate after a resting period (winter)] has been regularly found in Dutch nurseries on the underground parts of various *Crocus* cultivars (BOEREMA, 1959). Local infections are particularly striking when the corms are harvested early. Teleutosori develop mainly on the inner sides of the tunics. Mycelium of the rust often penetrates deep into the fleshy corm, on which teleutosori may be produced near the centre of the infected area. Another type of attack occurs when the rust mycelium grows directly from the parent corm into the new vegetative corms, giving rise to a typical basal infection. The invading mycelium tends to follow the vascular bundles and may penetrate deep into the flesh of the corm.

In areas of the world where *Crocus* is native, especially the Mediterranean, *Uromyces croci* is recorded as attacking only the leaves. However, leaf infections are not known to occur in the Netherlands. A reference to this type of infection in the Dutch "Tuinbouwgids" of 1944–1957 must have been based on data from foreign literature and not on actual findings in this country.

Underground infections of *Colchicum* rust on *Colchicum* spp. and cultivars have been observed in Dutch nurseries since 1955 (BOEREMA, 1961). The teleutosori of *Colchicum* rust, *Uromyces colchici* Massee (also micro-type) have been found on the inner sides and occasionally also on the outer sides of the corm tunics. Sometimes teleutosori have also been observed on that part of the con-

[1] Accepted for publication 8 July, 1965.

necting leaf sheath which is lacking in chlorophyll. Infections of the corm-flesh of *Colchicum* have not been observed.

Uromyces colchici has been reported to be very rare. It was described from above-ground leaf infections on plants growing in Kew gardens and in Yorkshire, England, at the end of the last century. In the Netherlands, leaf infections of *U. colchici* are occasionally observed (BOEREMA, 1962), but generally the infections are restricted to the corm tunic.

We are grateful for the cooperation received from the Swiss Mycologists Dr. E. MÜLLER and Prof. Dr. CH. TERRIER who made it possible to carry out comparative inoculation experiments in 1963 and 1964 with "above-ground strains" and "underground strains" of *Uromyces croci*. The results of these trials provide a satisfactory explanation of the phenomenon of the underground infections of the rusts on *Crocus* and *Colchicum*.

MATERIALS AND METHODS

1. To check that *Crocus* plants with underground rust infection by *Uromyces croci* do not show symptoms on above-ground parts, many infected corms were planted in the experimental garden of the Dutch Plant Protection Service where the plants were carefully inspected during the growing season for evidence of above-ground rust symptoms. Corms manifesting the following symptoms were used in the trials:

a. corms with tunic infections only,
b. corms with tunic infections and infections in the corm-flesh.

2. From excursions to the mountains in the Swiss cantons of Tessin and Neuchâtel, at "Nante" near Airolo and "Les Sagnettes" near de Boveresse respectively, Dr. MÜLLER and Prof. TERRIER collected plant material of *Crocus albiflorus* with leaf symptoms of *U. croci*, to be examined for underground infections.

3. *Crocus* corms of Dutch origin infected with *U. croci* were planted by Dr. MÜLLER in a trial field in the Swiss mountains at "Nante" in the autumn of 1961 for the purpose of checking whether the ecological conditions would lead to the production of above-ground symptoms of *U. croci* from the underground infections. In the same geographical region above-ground rust infections on *Crocus albiflorus* occur (see above at 2) naturally.

4. *Crocus albiflorus* grown in Switzerland, showing leaf symptoms of *U. croci* but without visible underground corm symptoms, were planted in the trial garden of the Dutch Plant Protection Service in the autumn of 1962 to check whether the corms might harbour the fungus internally.

5. To determine whether above-ground *Crocus* rust can cause underground infections, healthy corms of the susceptible variety 'Remembrance' were inoculated with teleutospores taken from infected leaves of *Crocus albiflorus* from Switzerland. Inoculation was done by mounting infected leaf-fragments containing teleutospores between the tunics and the flesh of the corms. These artificially inoculated corms were then planted in the trial garden of the Plant Protection Service. For comparison, healthy *Crocus* corms were inoculated with teleutospores originating from underground corm infections by preparing the corms in a similar manner with infected tunic-fragments.

6. To find out whether "underground strains" of the rust *Uromyces croci* can also cause above-ground infections, diseased tunic fragments were placed on the turf in which healthy corms of various susceptible *Crocus* varieties e.g. 'Remembrance' and 'Grand Maître' were planted. It was supposed that the primary above-ground infections would most likely come from old teleutospores in the turf. For comparison, infected leaf material from Switzerland was placed on the turf in the same manner except that corms of the susceptible *Crocus* variety 'King of the Striped' were planted.

RESULTS

1. In no case did the plants grown from corms with rust infections show above-ground rust symptoms. From the corms with a heavy infection of the corm-flesh (b), generally only a few leaves developed and some plants even died, probably due to invasion by secondary organisms. Only in those cases where the tunics alone had been infected (a) did normal leaves develop and only from corms with this type of attack were new corms of any reasonable size produced. These newly formed corms were nearly always infected in the tunic and often the corm-flesh was also infected.

2. Inspection of many plants of *Crocus albiflorus* with rust-infected leaves did not reveal infections of the underground parts.

3. From the rust-infected corms of *Crocus* cultivars planted in the Swiss trial field at "Nante" a small number produced normal plants. It seems likely that, as in the corresponding trial in the Netherlands (see above at 1), these were plants grown from corms with tunic infections only. In his examination, Dr. MÜLLER did not find above-ground infections on these plants. However, the new corms were infected in nearly all cases.

4. The corms of *Crocus albiflorus* originating from plants with above-ground infections in Switzerland always produced healthy plants in the Netherlands.

5. From the corms inoculated with teleutospores originating from leaf infections, healthy leaves were always formed. However, approximately 25% of the newly-produced corms showed rust infections on the tunic and sometimes also in the corm-flesh. The symptoms of these rust-attacks agreed with those generally occurring in Dutch nurseries. The corms inoculated with teleutospores from infected tunics also produced healthy leaves. Again in this case the new corms showed the well-known tunic and flesh infections.

6. The above-ground inoculations on *Crocus* cultivars with teleutospores from tunic infections gave rise to a few leaf infections for the first time in 1963. In a repetition of this experiment the next year, many leaf infections appeared (Fig. 1 A, B). On the broad leaves of the *Crocus* cultivars, relatively large sori are produced, often arranged in concentric rings. This conspicuous rust attack on *Crocus* cultivars has not been previously recorded. Similar leaf infections on *Crocus* cultivars were obtained in above-ground inoculation experiments with teleutospores taken from leaf infections of *Crocus albiflorus* from Switzerland (Fig. 1 C).

DISCUSSION AND CONCLUSION

From these results it may be concluded that the *Crocus* rust, *Uromyces croci*, described and known from leaf infections, is not only morphologically identical with that found occurring underground in Dutch nurseries (BOEREMA, 1959), but that it agrees also in parasitism (trial 5, 6). In other words, there are no different phytopathogenic strains involved.

Under natural conditions, *U. croci* apparently does not attack the underground parts of *Crocus* (trial 2). Considering the growth habit of wild *Crocus* species and the depth at which the corms are produced in the soil, an underground attack would seem possible only as a result of a systemic infection. This, however, appears generally not to occur (trial 4). In nature the rust apparently lives over as teleutospores in the debris at soil level.[2]

In Dutch nurseries the underground attack of *Crocus* rust usually occurs as a result of planting corms with infected tunics, or corms contaminated with teleutospores from diseased corms (BOEREMA, 1959). Teleutospores present in the soil from a previous diseased crop can, of course, also become a source of infection, but this possibility will be limited because of the usual crop rotation in the nurseries. It may be assumed that the first underground attack by *Uromyces croci* on *Crocus* in the Netherlands was started by teleutospores from infected leaves (trial 5).

In contrast with the above-ground attack, a modified systemic infection by *U. croci* does occur in the underground attack (BOEREMA, 1959) as we find in typical basal corm injury (N^1 in Fig. 2 C–E). This takes place when the new corm becomes directly infected from the diseased flesh of the mother corm (0^1 in Fig. 2 A–C). Systemic infection of leaves originating from corm-flesh infections is not known (trial 1, 3). To understand this it must be noted that a fleshy corm which is deeply penetrated by rust mycelium becomes so weakened that it is rapidly invaded by secondary organisms and soon dies. As a result, hardly any leaves are developed if bulbs with deep corm-flesh infections are planted (trial 1).

To understand still further why direct leaf infections do not arise from infected tunics of the parent corm, it must be pointed out that in the various growing stages of a *Crocus* plant (Fig. 2) there is no direct contact between the tunics of the parent corm and the developing new leaves, because these leaves are enclosed by membraneous sheaths (ms $^{1-5}$ in Fig. 2B). The underground parts of these membraneous sheaths later become the lowest tunics of the new corm, whereas the above-ground parts die early and become detached. This means that an infection of the leaves from the infected tunics of the parent corm would be possible only if the fungus were able to penetrate these membraneous sheaths. If this were to occur (Fig. 2C→D) the underground parts of the leaves would

[2] We accept the conclusion of Prof. TERRIER who communicated to us the following observations on *Crocus albiflorus:* "Les bulbes se trouvent à une profondeur de 6–8 centimètres et sont séparés de la surface du sol par un feutrage dense constitué par l'entrelacs des racines des graminées parmi lesquelles croissent les *Crocus*. J'ai l'impression que l'infection se produit sur les feuilles au moment où elles arrivent à la surface du sol, à partir des téleutosores qui se trouvent précisément parmi les débris foliaires. Le mycélium d'*Uromyces croci* ne semble pas être systémique et ne descendre jusque dans le bulbe"... "Dans la Nature, il n'est guère possible que les téleutospores parviennent jusqu'aux bulbes. Elles sont retenues en surface par le feutrage dense dont j'ai parlé plus haut".

become infected, but by this time the above-ground parts of the leaves will already be dead (Fig. 2D), leaving the basal parts as the uppermost tunics of the new corm (Fig. 2E). For further details of the development of the underground rust infection see the explanation in Fig. 2.

This explains why in Dutch *Crocus* growing, where underground *Crocus* rust infections occur, infection of the above-ground parts of *Crocus* are never observed (compare trial 1). If, however, leaf infection were to have taken place at any time, spread of the rust to other above-ground parts as occurs under natural conditions would not take place, because of the cultivation methods used in growing *Crocus* corms. It is a common practice to harvest the corm crop each year and maintain a wide rotation program. On the other hand, the growing and handling methods for *Crocus* tend to favour the spread of the rust on the underground corm parts. This occurs particularly when *Crocus* corms are stored together, in which case one infected corm can easily contaminate many healthy corms by the dissemination of spores.

To summarize: 1. The cultivation methods used in the commercial production of *Crocus* bulbs almost exclude the possibility of an above-ground spread of the *Crocus* rust. 2. The ability of *Uromyces croci* to attack the underground parts of *Crocus* corms such as tunics and fleshy parts allows this rust to maintain itself in the nurseries, and even to become widely distributed. One can speak of an adaptation to the prevailing cultivation methods without a genetical mutation. 3. The fact that in commercial growing of *Crocus* there is no extension of the underground attack by *U. croci* to the above-ground parts of the plants can be explained by the anatomy of the *Crocus*.

The question now arises as to how far the above explanations apply to the underground attack on *Colchicum* by the rust *Uromyces colchici*.

From reports in the literature concerning the above-ground attack by this fungus, formerly observed in England only, it was concluded (BOEREMA, 1961) that in the case of this rust it, also, normally maintains itself by means of the resting teleutospores on debris. Furthermore, it appears that extension growth of this rust in *Colchicum* plants takes place via the veins. In the English report on leaf infections it was not stated whether there were tunic infections also. It would seem unlikely that these were present, since the plants, at that time, had been so carefully studied. It may therefore be presumed that in the case of *U. colchici* also, underground infections on *Colchicum* will generally not occur in nature.

The above-ground attack by *U. colchici* on *Colchicum* 'Violet Queen' observed in the Netherlands in 1961 (BOEREMA, 1962), makes it plausible that one and the same strain of *U. colchici* can attack the leaves as well as the corm tunics. Consequently, the "behaviour" of *U. colchici* appears to be comparable to that of *U. croci*. As with *U. croci*, the ability of *U. colchici* to attack the underground parts of its host also, makes it possible for the rust to maintain and spread itself in Dutch nurseries.

There are differences, however, between *U. colchici* and *U. croci* in that, as mentioned earlier, *U. colchici* attacks only the membraneous tunic of the corm. This tunic in *Colchicum* is in fact the well-developed sheath of the lowest leaf (Fig. 3D). The only difference is in the absence of chlorophyll in the sheath

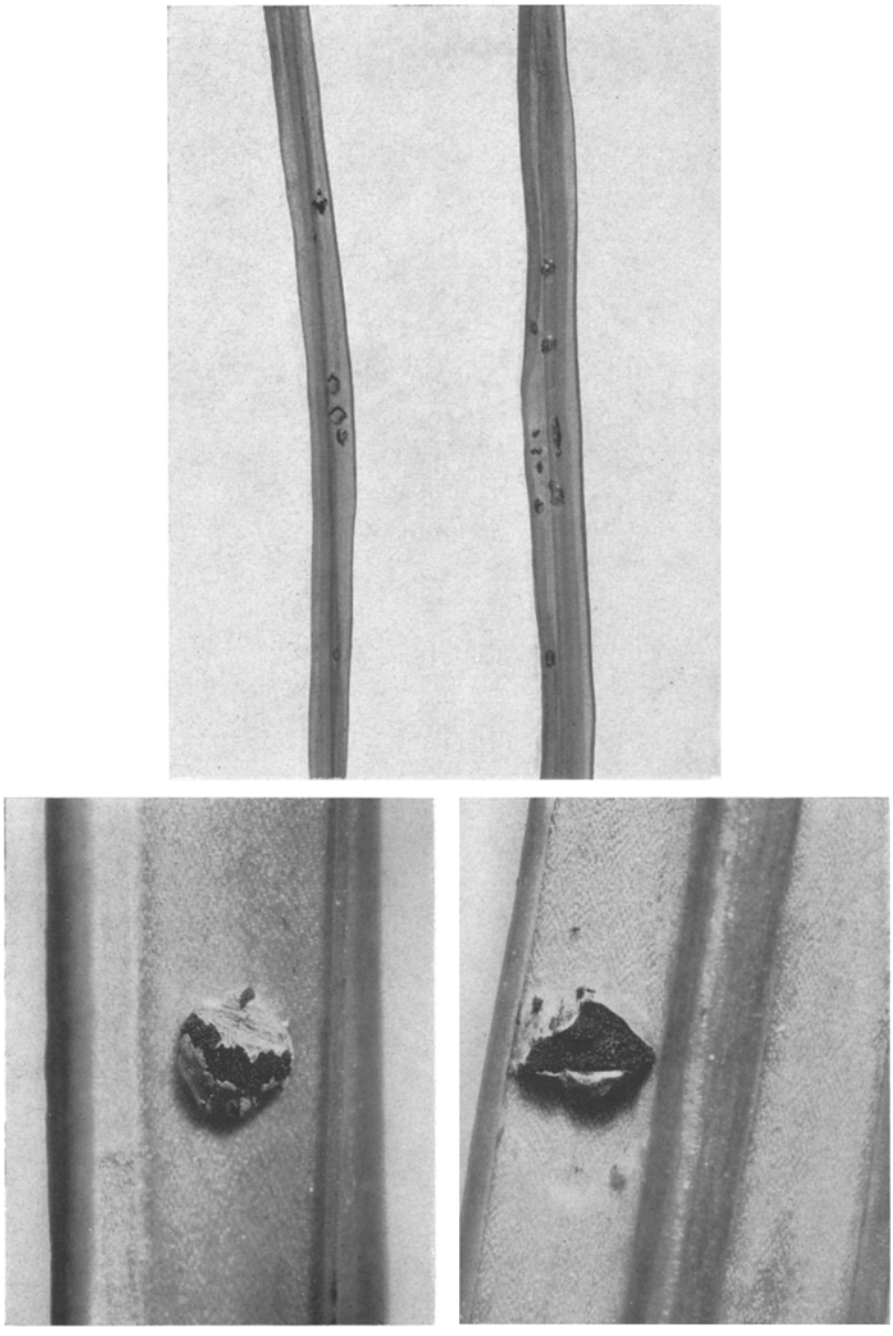

FIG. 1.
Leaf infections of *Uromyces croci* on *Crocus* cultivars obtained by contaminating the turf above the planted corms.
A, B: Teleutosori produced from infection by spores from diseased tunic fragments from Dutch *Crocus* cultivars.
C: Teleutosori produced from infection by spores from leaves of *C. albiflorus* from Switzerland.
Bladaantastingen door Uromyces croci *bij* Crocus-*cultivars, verkregen door besmetting van de grasmat waarin knollen geplant waren.*
A, B: *Teleutosori ontstaan door infectie met sporen van aangetaste rokfragmenten van Nederlandse* Crocus-*cultivars.*
C: *Teleutosori ontstaan door infectie met sporen van bladeren van* C. albiflorus *uit Zwitserland.*

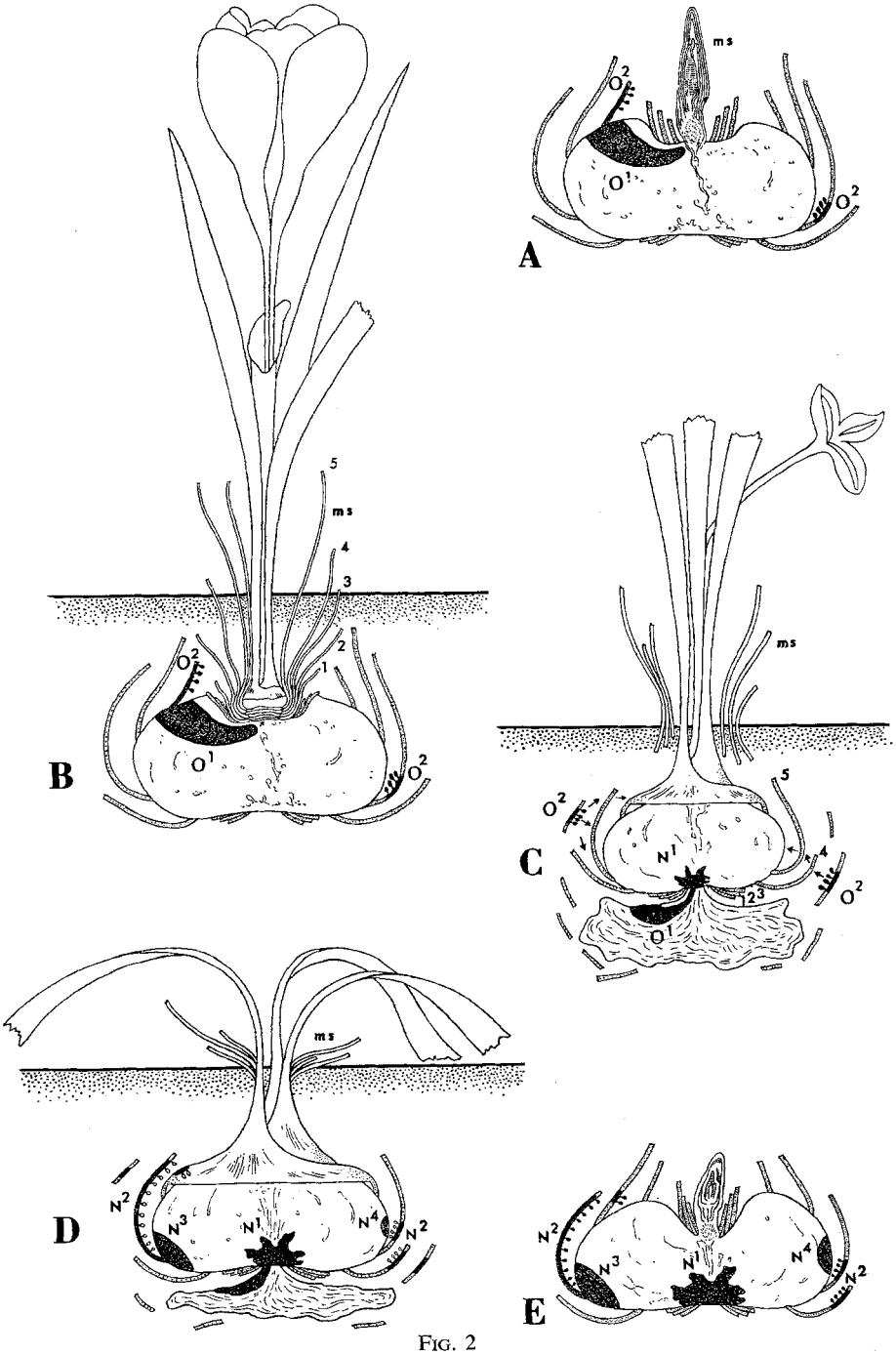
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FIG. 2

(BOEREMA, 1961). Thus, in the case of the underground attack by *U. colchici* on *Colchicum*, there does not exist an anatomic barrier against systemic infection of the lowest leaf. Nevertheless such infections of the lowest leaves are found only occasionally in commercial *Colchicum* growing (BOEREMA, 1962). Possibly in the case of very early infections of the tunic the rust may be capable of systemically penetrating into the leaves. For details of the life-cycle of the underground infection see the explanation of Fig. 3.

Analogous to what has been concluded about the *Crocus* rust, the following can now be said about the *Colchicum* rust: 1. Natural above-ground spread of *U. colchici* is limited in Dutch bulb growing nurseries, as in the case of *Crocus* rust, because of the cultivation methods now in existence. 2. Because of the ability of *U. colchici* to attack the corm tunic as well as the leaves, this rust is capable of adaptation to the Dutch cultivation methods and of becoming widely distributed. 3. Since the corm tunic of *Colchicum* is the basal part of the lowest leaf, an underground attack by *U. colchici* can, under favourable circumstances, pass into above-ground leaf infections.

SAMENVATTING

Dank zij de medewerking van de Zwitserse mycologen Dr. E. MÜLLER en Prof. Dr. CH. TERRIER kon een onderzoek worden ingesteld naar de achtergrond van de sinds 1955–56 op Nederlandse kwekerijen waargenomen ondergrondse aantastingen door de alleen teleutosporen vormende roesten *Uromyces croci* Pass. en *Uromyces colchici* Massee bij respectievelijk *Crocus* cultivars (BOEREMA, 1959) en *Colchicum* species (BOEREMA, 1961).

Bij wilde krokussen in Zwitserland en elders in Zuid-Europa was *U. croci*

◀ FIG. 2.
Diagrammatic representation of the sequence of events in the underground life-cycle of *Uromyces croci*, starting from an attacked corm (A) with one deep flesh infection (0^1) and two teleutosori-bearing tunic infections (0^2). In the spring the developing plant (B) is enclosed at the base by membraneous sheaths (ms^{1-5}) which prevent a direct infection of the leaves by basidiospores from germinating teleutospores. From the flesh infection of the mother corm the rust can penetrate directly into the flesh of the new developing corm (B→C), resulting in a large radial basal infection (N^1). The basidiospores from germinating teleutospores can cause infections of the connected basal parts of the membraneous sheaths which are the lowest tunics of the new corm. Subsequently the rust mycelium can penetrate the underlying tunics including the basal parts of the leaves which are the uppermost tunics of the new corm (C→D). By this time the above-ground parts of the leaves are generally dead (D). From the infected tunics of the new corm (N^2) the rust can also penetrate (D→E) into the flesh of the new corm (N^{3-4}).
Schematische weergave van de gang van zaken bij de ondergrondse levenscyclus van Uromyces croci, *uitgaande van een aangetaste knol* (A) *met één diepe knolvleesinfectie* (0^1) *en twee teleutosori dragende rokinfecties* (0^2). *In het voorjaar is de zich ontwikkelende plant* (B) *aan de basis omgeven door vliezige schedebladeren* (ms^{1-5}), *zodat een directe infectie van de bladeren door basidiosporen van gekiemde teleutosporen wordt voorkomen. Uitgaande van de knolvleesaantasting van de moederknol, kan de roest direct in het vlees van de nieuw gevormde knol* (B→C) *binnendringen en daar een uitstralende basale aantasting teweegbrengen* (N^1). *De basidiosporen van gekiemde teleutosporen kunnen infecties veroorzaken op de aangrenzende basale delen van de vliezige schedebladeren, zijnde de onderste rokken van de nieuwe knol. Vervolgens kan het roestmycelium ook de onderliggende rokken binnendringen inclusief de bladscheden, zijnde de bovenste rokken van de nieuwe knol* (C→D). *Tegen die tijd zijn de bovengrondse delen van de bladeren in het algemeen reeds afgestorven* (D). *Uitgaande van de aangetaste rokken van de nieuwe knol* (N^2) *kan de roest* (D→E) *ook het knolvlees van de nieuwe knol binnendringen* (N^{3-4}).

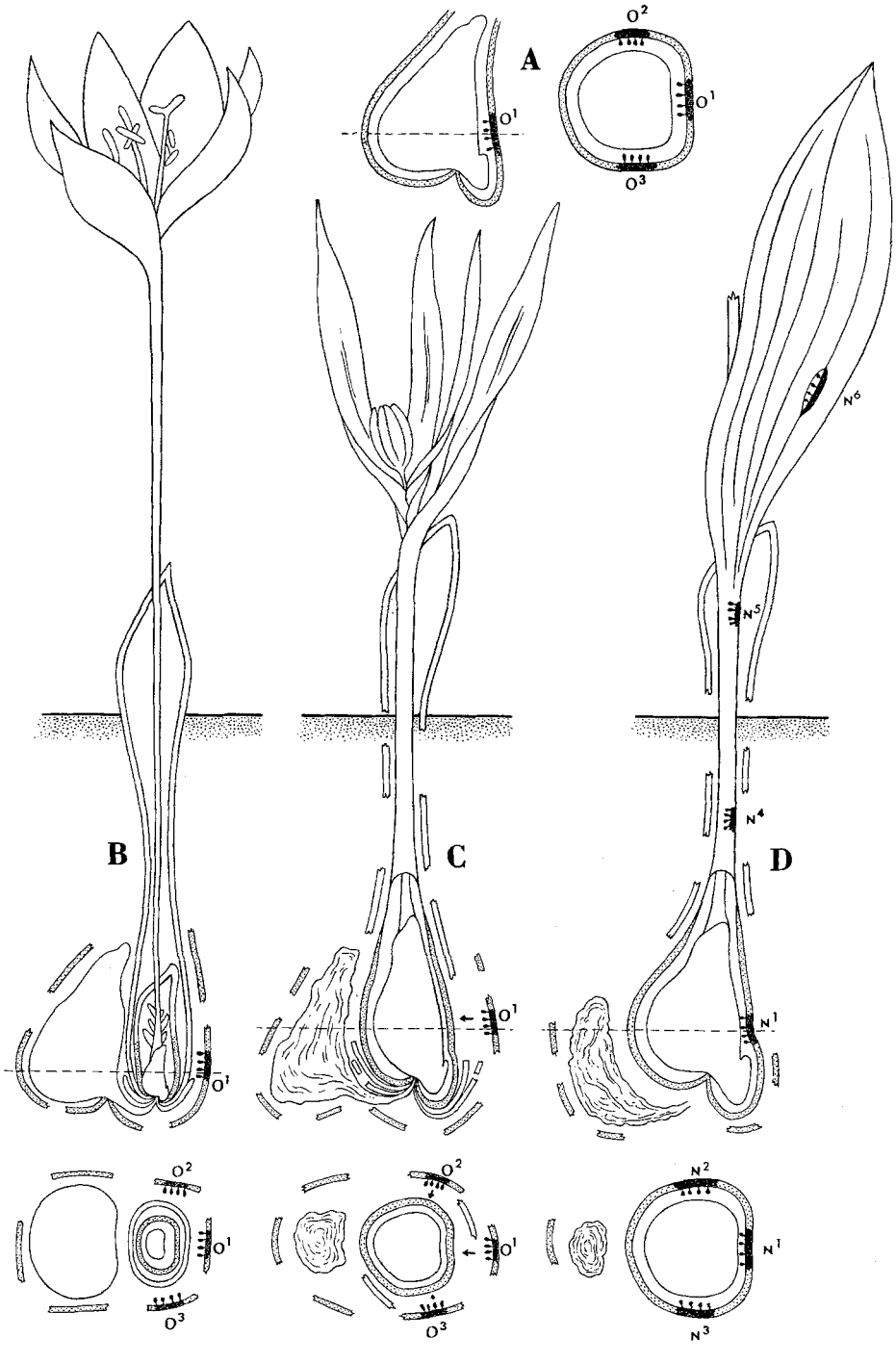
alleen bekend van bladaantastingen. Bij onderzoek van vele bovengronds door roest aangetaste planten van *Crocus albiflorus* werden door de bovengenoemde onderzoekers ook nimmer aantastingen van knolrokken of knolvlees geconstateerd. De bladaantastingen ontstaan hier blijkbaar elk jaar door infecties van basidiosporen, afkomstig van op het grondoppervlak overwinterde teleutosporen. Door de dichte vegetatie waarin de wilde krokussen in het algemeen groeien en de diepte waarop de knollen worden gevormd is een infectie van de rokken en het knolvlees door basidiosporen ook vrijwel uitgesloten, terwijl een systemische infectie van de ondergrondse delen blijkbaar niet plaatsvindt.

Door bladfragmenten van *C. albiflorus* met teleutosori van *U. croci* te monteren tussen de rokken van gezonde knollen van *Crocus*-cultivars werden bij de nieuw gevormde knollen van de laatste de typische (ondergrondse) rok- en knolvlees-aantastingen verkregen. Dit vermogen van *U. croci* om ook de ondergrondse delen van krokussen aan te tasten heeft deze roest de mogelijkheid gegeven zich op de Nederlandse kwekerijen, waar het gebruikelijk is de planten elk jaar te rooien en een ruime vruchtwisseling toe te passen, te handhaven en zelfs sterk uit te breiden (adaptatie zonder erfelijke verandering). Immers de roest kan nu overblijven op de knollen, terwijl bij de bewaring vele gezonde knollen met losse teleutosporen kunnen worden besmet. De „levenscyclus" van de ondergrondse aantasting door *U. croci* is schematisch weergegeven in Fig. 2. Bij het gebruik van knollen, waarvan het knolvlees door de roest is aangetast, kan het roestmycelium de nieuwe knol aan de basis binnendringen. Dat een systemische uitbreiding tot in de bladeren van de nieuwe plant hierbij nooit is waargenomen, hangt waarschijnlijk samen met het feit, dat bij een diepe roestaantasting van het knolvlees vaak de gehele knol door „secundaire" rottingsorganismen te gronde gaat, zodat nauwelijks enig blad wordt gevormd. De anatomie van de krokusplant is verder zodanig, dat de teleutosporen op de rokken via hun basidiosporen alleen infecties van de bladeren kunnen veroorzaken als eerst de vliezige schedebladeren, die de jonge plant omsluiten, zijn aan-

FIG. 3. ▶

Diagrammatic representation of the sequence of events of the underground attack by *Uromyces colchici*, starting from a corm (A) with three teleutosori-bearing tunic infections (0^{1-3}). In autumn, at flowering-time (B), the initial of the new corm with tunic and leaves "*in statu nascendi*" are enclosed by a membraneous sheath. In spring, this sheath becomes ruptured by the outgrowth of the leaves and the moving up of the seed-capsule (C). At that time the basidiospores from germinating teleutospores can cause new infections (N^{1-3}) on the tunic of the new developing corm (C→D). As this tunic is only the basal part of the leaf sheath of the lowest leaf, in an early infection, the rust mycelium can spread to the leaf sheaths and invade the leaves above-ground (N^{4-6}). The development of the new corm with its bulging part against the flat part of the old corm further explains why the underground rust attacks are most often found on the tunic at the lateral sides of the corm (see BOEREMA, 1961).

Schematische weergave van de gang van zaken bij de ondergrondse aantasting door Uromyces colchici, *uitgaande van een knol* (A) *met drie teleutosori dragende rokinfecties* (0^{1-3}). *In de herfst, ten tijde van de bloei* (B), *is de primordiale nieuwe knol met aanleg van rok en bladeren omgeven door een vliezige schede. Door het uitgroeien van de bladeren en het naar boven groeien van de doosvrucht scheurt deze bladschede in het voorjaar* (C). *De basidiosporen van gekiemde teleutosporen kunnen dan* (C→D) *de rok en de nieuwe zich ontwikkelende knol infecteren* (N^{1-3}). *Daar de rok niets anders is dan het basale deel van de bladschede van het onderste blad, kan bij een vroege infectie het roestmycelium zich uitbreiden tot in de bladscheden en ook bovengrondse bladaantastingen veroorzaken* (N^{4-6}). *De ontwikkeling van de nieuwe knol met zijn bolle zijde tegen de afgeplatte zijde van de oude knol verklaart verder dat de ondergrondse roestaantastingen speciaal worden gevonden op de knolrok aan de zijkanten van de knol (zie BOEREMA, 1961).*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getast. Als dit plaatsvindt, zijn de bovengrondse bladdelen in het algemeen echter reeds min of meer afgestorven. Een en ander verklaart dat op de Nederlandse kwekerijen bij de ondergrondse roestaantastingen van krokussen nimmer bovengrondse infecties zijn waargenomen. Dat de teleutosporen, afkomstig van knolrokken, wel degelijk bladaantastingen bij *Crocus*-cultivars teweeg kunnen brengen, werd bewezen door aangetaste rokfragmenten te deponeren in een grasmat, waarin gezonde knollen waren geplant (fig. 1).

Uit de literatuurgegevens over de bovengrondse aantasting door *Uromyces colchici* bij *Colchicum* spp. is af te leiden dat ook deze roest in de natuur zich beperkt tot een aantasting van de bladeren en „overblijft" via teleutosporen op het grondoppervlak (zie BOEREMA, 1961).

Het vermogen van *U. colchici* om ook ondergronds de rok van *Colchicum* te kunnen aantasten, heeft deze roest, evenals *U. croci*, de gelegenheid gegeven zich op de Nederlandse kwekerijen te handhaven en te verspreiden (adaptatie zonder erfelijke verandering). De „levenscyclus" van de ondergrondse aantasting door *U. colchici* is weergegeven in fig. 3. Bij *Colchicum* is de rok in feite niets anders dan het basale deel van de bladschede van het onderste blad. De mogelijkheid van een systemische uitbreiding bovengronds tot in het blad is hier, in tegenstelling met de krokusroest, dan ook direct aanwezig. Bovengrondse bladaantastingen door *U. colchici* zijn op de Nederlandse kwekerijen echter slechts incidenteel waargenomen (BOEREMA, 1962), zodat dit waarschijnlijk alleen plaatsvindt bij een zeer vroege en „hoge" aantasting van de knolrok. Een uitbreiding van de *Colchicum*-roest bovengronds wordt op de kwekerijen voorkomen, doordat het gebruikelijk is elk jaar de planten te rooien en een ruime vruchtwisseling toe te passen.

ACKNOWLEDGEMENTS

The authors are very grateful to Dr. E. MÜLLER of the "Eidg. Technische Hochschule" at Zürich and Prof. Dr. CH. TERRIER of the University of Neuchâtel for their excellent cooperation during this research.

We also express our thanks to Mr. N. G. SANTACROCE, Head, Foreign Site Inspection Section, U.S. Plant Quarantine Division, for his critical review of the manuscript, and for the contributions and kind assistance he has given regarding the underground attacks of *Uromyces croci* and *U. colchici*.

The diagrams were drawn by Mr. A. S. J. NOORDIJK, artist to the Netherlands Plant Protection Service.

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