Some observations on breeding for resistance to *Phytophthora infestans*

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SOME OBSERVATIONS ON BREEDING FOR RESISTANCE TO *PHYTOPHTHORA INFESTANS*

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INTRODUCTION

Since the occurrence of potato blight in 1845 breeders have made a more or less conscious selection with a view to obtaining optimum field resistance to *Phythophthora infestans* (MONT.) DE BARY. A fair measure of success has been achieved with late maturing varieties, but early varieties are usually very susceptible to the disease. It must be assumed that there is a connection between early maturing and susceptibility to *Phytophthora* (TOXOPEUS, 1958).

For some decades breeders have used wild Mexican species, mainly *Solanum demissum*, for crossing with the existing cultivated varieties in order to introduce hypersensitivity. Although hopes ran high to begin with, they have gradually given way to a certain disappointment. Many breeders have come to the conclusion that in addition to the hypersensitivity resistance, which can apparently be overcome by the fungus, a substantial degree of field resistance is required. Consequently attention is being focussed once again on field resistance. An important question is what degree of resistance is required and it is remarkable that little is said on this subject. One gains the impression that too heavy demands are sometimes made.

In this paper a few observations will be made on the biology of the fungus and the problem of field resistance will be discussed.

WHAT DEGREE OF RESISTANCE IS REQUIRED?

Recent investigations have demonstrated that in North America and Western Europe *Phytophthora* probably overwinters only in diseased potato tubers (BONDE & SCHULTZ, 1943; HIRST, 1955; VAN DER ZAAG, 1956, a.o.). The fungus is capable of growing upward from the tuber into a stem and sporulating on the young stems above ground under favourable weather conditions. In this way a primary focus is formed. These foci spread, particularly in the prevailing direction of the wind. As soon as the foci begin to overlap the disease becomes epidemic. The time taken is determined by the number of primary foci and the rate at which these foci spread. Both factors largely depend on weather conditions and the degree of susceptibility of the variety.

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TABLE 1. Relationship between the susceptibility of tuber and haulm and the percentage of diseased plants derived from diseased tubers. Experiment in a heated glasshouse at a mean temperature of approx. 18°C; 40 tubers per treatment (VAN DER ZAAG, 1956)

Variety / *Sorte* / *Variété*	Susceptibility rating according to: *Anfälligkeit nach:* *Sensibilité d'après:* HOGEN ESCH/ZINGSTRA (1954)[1]		Diseased plants derived from diseased tubers *Aus kranken Knollen aufgegangene kranke Pflanzen* *Plantes malades issues de tubercules malades*	
	Tuber *Knolle* *Tubercule*	Haulm *Kraut* *Feuillage*	Number *Zahl* *Nombre*	Percentage *Prozentsatz* *Pourcentage*
Saskia	5	4	8	20
Eigenheimer	3	5	4	10
Furore	5	7,5	3	8
Koopmans Blauwe	8	4	3	8
Voran	6,5	7	0	0
Noordeling	8	7,5	0	0

[1] Low number denotes very susceptible – *Niedrige Zahl bedeutet grosse Anfälligkeit – Chiffre bas signifie très sensible.*

TABELLE 1. *Zusammenhang zwischen Knollen- und Krautanfälligkeit und dem Prozentsatz an aus kranken Knollen aufgegangenen kranken Pflanzen. Versuch in einem Warmhaus bei etwa 18°C Durchschnittstemperatur. Von jeder Sorte 40 Knollen* (VAN DER ZAAG, 1956)

TABLEAU 1. *La relation entre la sensibilité du tubercule et du feuillage et les pourcentages des plantes malades issues de tubercules malades. Essai dans une serre chauffée à environ 18°C; 40 tubercules par traitement* (VAN DER ZAAG, 1956)

TABLE 2. Relationship between susceptibility of tuber and haulm and percentage of diseased plants derived from diseased tubers. Experiment in the field at a mean soil temperature of approx. 10°C (VAN DER ZAAG, 1956)

Variety / *Sorte* / *Variété*	Susceptibility rating according to: *Anfälligkeit nach:* *Sensibilité d'après:* HOGEN ESCH/ZINGSTRA (1954)[1]		Number of tubers planted *Zahl der gepflanzten Knollen* *Nb. de tubercules plantés*	emergence % *% aufgelaufener Pflanzen* *% de plantes émergées*	Diseased plants derived from diseased tubers as % of *Aus kranken Knollen aufgegangene kranke Pflanzen in % der* *Plantes malades issues de tubercules malades en % des*	
	Tuber *Knolle* *Tubercule*	Haulm *Kraut* *Feuillage*			Tubers planted *gepflanzten Knollen tubercules plantés*	Plants emerged *aufgelaufenen Pflanzen plantes émergées*
Eersteling	3	3	200	61	6	10
Saskia	5	4	270	63	7	11
Eigenheimer	3	5	300	64	3	4
Furore	6	7,5	300	62	2	3
Koopmans Blauwe	8	3	300	97	3	3
Voran	6,5	7	300	39	0	0
Noordeling	8	7,5	300	95	0	0

[1] Low number denotes very susceptible – *Niedrige Zahl bedeutet grosse Anfälligkeit – Chiffre bas signifie très sensible.*

TABELLE 2. *Der Zusammenhang zwischen Knollen- und Krautanfälligkeit und dem Prozentsatz an aus kranken Knollen aufgegangenen kranken Pflanzen. Feldversuch bei einer durchschnittlichen Bodentemperatur von etwa 10°C* (VAN DER ZAAG, 1956)

TABLEAU 2. *La relation entre la sensibilité du tubercule et du feuillage et les pourcentages des plantes malades issues de tubercules malades. Essai au champ, température du sol environ 10 degrés C* (VAN DER ZAAG, 1956)

Artificially inoculated tubers of several varieties were planted in a glasshouse and in the open in order to gain an idea of the significance to be attached to the susceptibility of tuber and foliage in the development of diseased plants from diseased seed (TABLES 1 and 2). In both experiments the number of diseased plants derived from diseased tubers was determined by the degree of resistance of the tuber as well as of the haulm. In practice in seed tubers of a variety as *Koopmans Blauwe*, which has considerable tuber resistance, fewer blighted tubers will occur than in a variety as *Furore*. For this reason greater importance is to be attached to the resistance of the tubers in preventing primary foci than would appear from these tables.

According to these tables a degree of resistance of tuber and leaves designated by 7 (HOGEN ESCH & ZINGSTRA, 1954) would be sufficient to suppress the development of diseased plants from diseased seed potatoes to a great extent, if not altogether.

The rate at which the fungus spreads from the first diseased plant is largely determined both by weather conditions and the susceptibility of the foliage. The experiment described below affords an idea of the importance to be attached to the latter.

In 1955 five leaflets of the varieties *Eersteling*, *Eigenheimer* and *Noordeling* were artificially infected at four different positions in the field, at a time when the disease was not occurring naturally. The spread of the fungus was ascertained after 12 days by counting the number of newly infected leaflets. The average was 180, 30 and 1 respectively (TABLE 4). A primary focus in the variety *Eersteling* is several times more dangerous than in the variety *Eigenheimer*. Under the prevailing conditions, in a rather resistant variety as *Noordeling*, a primary focus could hardly maintain itself.

It follows from what has been said that, in order to bring about a substantial delay of an epidemic, or to suppress it entirely, a degree of resistance of 7 for tuber and foliage is sufficient, both in the case of the development of diseased plants from diseased seed tubers and extension of a primary focus.

Normally a blight epidemic starts and develops in the more susceptible varieties. Under favourable conditions the enormous quantity of sporangia developing in this material is probably the main source of infection for the more resistant varieties in the vicinity. It is highly probable that the damage done to the latter would be much less, if susceptible varieties were not present and the epidemic had to start and develop from foci within the resistant material itself.

From this it follows that the damage done by *Phytophthora infestans* could be restricted by preventing the planting of highly susceptible varieties. That will be possible only, when breeders produce satisfactory substitutes for these very susceptible varieties, with a higher degree of resistance. Breeding work, therefore, should be especially focussed on obtaining early varieties with a resistance of 6–7, which is probably sufficient to retard the development of the epidemic.

By doing so, however the fungus may be offered wide possibilities to adapt itself to the more resistant material as explained by TOXOPEUS (1956). Therefore, it is wellnigh impossible to predict exactly the ultimate effect of this exclusion of the susceptible material.

AN ANALYSIS OF FIELD RESISTANCE

As was stated in the introduction it is much more difficult to raise an early variety with a high degree of resistance than a late one. Not many attempts have so far been made to find a solution to this problem. To do so will first of all necessitate a close study of the phenomenon of field resistance. An attempt of this kind, which was merely an introductory study of the problem (VAN DER ZAAG, 1956), will be discussed here.

Field resistance can be divided into 3 main components:

1. the chance of infection, viz. the chance of a spore penetrating the leaf.
2. the rate at which the mycelium spreads in the leaf tissue.
3. The rate at which sporangia are formed and the number of sporangia formed per unit leaf area.

A further important factor is the rate at which affected cells become necrotic, but this is not taken into account since in this respect there is probably not much difference between the usual cultivated varieties. Moreover it is already partly reflected in the second component.

These three components can be determined and compared for different varieties in the following manner:

1. Chance of infection. Leaflets are inoculated by dipping in a very dilute zoospore suspension. After about three days at a high atmospheric humidity and 20 °C the relative chance of infection can be determined from the number of patches.
2. Rate of growth of the mycelium. Leaflets are inoculated at the top with a drop of a zoospore suspension. To prevent the drop from spreading over the leaf, the following method is recommended:
   A small patch of filter paper is dipped in a zoospore suspension and placed on the top of the leaf. After six days at a high atmospheric humidity and 20 °C the extension of the discoloured portion is measured in the direction of the leaf base.
3. Sporulation. Leaflets are inoculated by dipping in a concentrated zoospore suspension; the concentration should be high enough for the entire leaf to be uniformly infected. The leaflets are placed in a high humidity and 20 °C. After five days and again after a further two days they are rinsed in a given amount of water. From this it is possible to determine the number of sporangia per leaflet. When leaflets of about the same size are taken from each variety these numbers may be compared. Summing the values found after five and seven days respectively, provides an index for the intensity of sporulation and the rate at which sporangia are formed.

These three components were determined in four varieties, using ten leaflets in each case. The test was carried out twice. The highly susceptible variety *Eersteling* was used as a control and the value 10 assigned to each component in this variety. There was little difference in the results of the two tests, therefore, the averages are given in TABLE 3. The degree of resistance is calculated from the figures for the 3 components.

The degree of resistance can also be directly determined. Leaflets taken from different varieties are inoculated with an equal amount of a very dilute zoospore suspension.

TABLE 3. The susceptibility of four different potato varieties (VAN DER ZAAG, 1956)

Variety *Sorte* *Variété*	Chance of infection *Infektionswahrscheinlichkeit* *Chances d'infection*	Rate of extension *Verbreitungsgeschwindigkeit* *Rapidité de propagation*	Sporulation *Sporulation* *Sporulation*	Susceptibility acc. to the 3 components *Durch Multiplizierung berechnete Anfälligkeit* *Sensibilité d'après les 3 composantes*	Susceptibility determined directly *Direkt bestimmte Anfälligkeit* *Sensibilité déterminée directement*	Susceptibility rating acc. to: *Anfälligkeit nach:* *Sensibilité d'après:* HOGEN ESCH/ ZINGSTRA (1954)[1]
Eersteling	10	10	10	1000	1000	3
Eigenheimer	4	6	10	240	232	5
Voran	2	6	2	24	55	7
Noordeling	2	5	1–2	15	17	7,5

[1] Low number denotes very susceptible – *Niedrige Zahl bedeutet grosse Anfälligkeit – Chiffre bas signifie très sensible.*

TABELLE 3. *Die Anfälligkeit von vier Kartoffelsorten* (VAN DER ZAAG, 1956)
TABLEAU 3. *La sensibilité de quatre variétés de pommes de terre différentes* (VAN DER ZAAG, 1956)

TABLE 4. Comparison between the rate of spread in the field and susceptibility according to greenhouse determination (TABLE 3) (VAN DER ZAAG, 1956)

Variety *Sorte* *Variété*	Mean number of diseased leaflets (in the field) *Durchschnittszahl kranker Blättchen (im Felde)* *Nombre de folioles malades (au champ)*	Susceptibility determined in greenhouse *Im Gewächshaus bestimmte Anfälligkeit* *Sensibilité déterminée en serre*	The same as column 3 when Eersteling = 180 *Wie in Spalte 3 wenn Eersteling = 180* *Comme colonne 3 quand Eersteling = 180*
Eersteling	180	1000	180
Eigenheimer	30	240	43
Noordeling	1	15	3

TABELLE 4. *Vergleich zwischen der Verbreitungsgeschwindigkeit im Felde und der auf Grund von Gewächshausbestimmungen berechneten Anfälligkeit* (TABELLE 3) (VAN DER ZAAG, 1956)
TABLEAU 4. *Comparaison entre la rapidité de propagation au champ et la sensibilité d'après la détermination en serre* (TABLEAU 3) (VAN DER ZAAG, 1956)

After 5 days and again after a further 2 days the sporangia are counted. Care should be taken to prevent the patches from overlapping to any extent, so that all 3 components are able to exert their effect.

This experiment was also done twice, each time using 10 leaflets from each variety. In TABLE 3 the figures obtained are set beside those calculated from the 3 components separately. The two sets of figures are in good agreement (only the variety *Voran* showing a slight divergence). The data from the List of Potato Varieties (HOGEN ESCH & ZINGSTRA, 1954) are shown in the last column for comparison.

The experiment described on page 280 shows how rapidly *Phytophthora* spreads in the open from a number of infected leaflets. The rate of spread is a measure of the

degree of susceptibility. It may be questioned whether the susceptibility determined under glass in excised leaflets (TABLE 3) agrees with the degree of resistance determined in the open in the manner described above (TABLE 4).

TABLE 4 shows that the susceptibility according to greenhouse determination is somewhat greater in the varieties *Eigenheimer* and *Noordeling* than might have been anticipated from the field determination. Two reasons for this may be advanced:

1. In the variety *Eersteling* there were probably a number of diseased leaflets of the second generation, so that the figure 180 in the second column is rather too high.
2. In the greenhouse the figures are obtained under ideal conditions for the fungus. Although the relative atmospheric humidity in the field was fairly high during the experiment, there was no question of conditions being optimum. In surroundings less favourable to the parasite differences in susceptibility between varieties increase.

Of considerable importance is the indication that in the varieties investigated, the relationship between the components of field resistance varies from variety to variety. For instance, according to the data obtained, the varieties *Eigenheimer* and *Voran* show the same rate of spread of mycelium in the leaf, whereas in *Voran*, the chance of a zoospore penetrating is only half that in *Eigenheimer*, and sporulation is only one-fifth as great. Hence the difference in susceptibility between *Eigenheimer* and *Voran* is due to a smaller chance of infection in the latter, and especially to reduced sporulation. *Eersteling* and *Eigenheimer*, on the other hand, differ in chance of infection and in the spread of the mycelium.

DISCUSSION

The main object of potato blight control should be to prevent the occurrence of epidemics. Theoretically it might be possible to achieve a great deal by means of drastic phyto-sanitary measures, but these are fairly difficult to carry out so that little can be expected from them. Hence it will still be necessary to enlist the aid of breeders and it is desirable that phytopathologists and breeders should co-operate closely in this field in particular. Breeders will also have to carry out their work with the same object in view, viz. delaying the rise of epidemics.

As early and mid-early varieties are the main source of inoculum for the development of an epidemic, such varieties should be bred with a fairly high degree of resistance in the tubers as well as in the foliage (e.g. 6–7). In breeding work it seems to be very difficult to combine earliness and a reasonable degree of field resistance and therefore fundamental studies should be made of the phenomenon of field resistance.

The results of some preliminary experiments indicate that field resistance of the foliage is a composite character and that the components vary widely and to all appearances independently of each other. If rapid methods of testing were developed, studies of the inheritance could be made, and on the basis of the knowledge gained, the breeding program could be placed on a firm basis. Provided the values for the resistance of a large number of commercial varieties were known, the breeder could

make a well-founded choice as regards the parent varieties to be used in his crosses.

A fair degree of tuber resistance might be even more important for the prevention of epidemics than resistance of the haulm. Unfortunately, not much attention has been paid by the breeders to these characters. A thorough phytopathological analysis of tuber resistance followed by genetical work would be of great value.

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SUMMARY

Epidemics of blight start and develop mainly in highly susceptible varieties. It is assumed that if, in a certain region, only varieties were grown which had a resistance rating of 7 or more, blight would present no problem at all. Breeding work should therefore, be concentrated on the replacement of very susceptible varieties with new ones having the mentioned level of resistance. However, it seems very difficult to combine earliness and a reasonable degree of leaf resistance. Some preliminary experiments are made on field resistance of the foliage. This resistance can be split up into at least 3 components, which vary widely and to all appearance, independently of each other. Further studies of the field resistance of the foliage as well as of the tubers would enable breeders to make a well-founded choice of parent varieties to be used in their crosses.

Should it be possible to combine earliness and resistance, potato breeders would have made a valuable contribution towards preventing the development of blight epidemics.

ZUSAMMENFASSUNG

BEMERKUNGEN ZUR ZÜCHTUNG AUF RESISTENZ GEGEN *Phytophthora infestans* BEI KARTOFFELN

Die Züchtung der Kartoffel auf Resistenz gegen *Phytophthora infestans* muss als ein Mittel zur Verhinderung des epidemischen Auftretens dieser Krankheit betrachtet werden. Da der Pilz vor allem in den sehr anfälligen Kartoffelsorten überwintert, und sich darin auch im Sommer stark verbreiten kann, muss ein Ersatz dieser Sorten durch solche mit einer ziemlich guten Knollen- und Krautresistenz (TABELLE 1, 2 und 4, 2. Spalte) angestrebt werden. In einer Sorte mit einer Kraut- und Knollenresistenz von ca. 7 (HOGEN ESCH & ZINGSTRA, 1954), überwintert der Pilz nicht oder kaum. Ein einmal in diesen Sorten entstandener Herd breitet sich nur langsam aus. Um die Entstehung einer Epidemie zu verzögern, sollten die sehr anfälligen Sorten durch solche mit leidlicher Resistenz (6–7) ersetzt werden. Da man aber annimt, dass Frühreife und Resistenz sich schwer kombinieren lassen, muss die Feldresistenz eingehender untersucht werden.

In einem Orientierungsversuch wurde nachgewiesen, dass die Anfälligkeit der normalen *Solanum tuberosum*-Sorten in mindestens drei Komponenten aufzuteilen ist, nämlich:

1. die Infektionswahrscheinlichkeit, d.h. der Wahrscheinlichkeitsgrad, dass eine Zoospore in das Blatt eindringt,
2. die Verbreitungsgeschwindigkeit des Myzels im Blattgewebe,
3. die Geschwindigkeit der Sporangien-Erzeugung und die Sporangienzahl, welche pro Blatteinheit gebildet wird.

Die besagten Komponenten wurden mit Hilfe von zehn abgeschnittenen Blättchen von etwa gleicher Grösse wie folgt bestimmt:

1. Impfung mit gleichen Mengen einer sehr verdünnten Schwärmsporen-Suspension. Nach drei

Tagen wurde die Anzahl schwarzer Fleckchen auf jedem Blättchen festgestellt.
2. Impfung an der Spitze der Blättchen. Die verfärbte Oberfläche wurde in der Richtung der Blattbasis nach sechs Tagen gemessen.
3. Impfung mit einer konzentrierten Schwärmsporen-Suspension. Nach fünf Tagen und wiederum zwei Tage später wurde die Anzahl Sporangien auf den Blättchen festgestellt, indem diese Blättchen mit einer bestimmten Menge Wasser abgespült und dann die Sporangien in einer Anzahl Tropfen gezählt wurden. Die zwei errechneten Zahlen wurden zusammengezählt.
Nach jeder Impfung wurden die Blättchen bei 20 °C in hoher Luftfeuchtigkeit aufbewahrt. Der Versuch wurde zweimal mit vier Sorten durchgeführt. Die Durchschnittszahlen sind in TABELLE 3 zusammengefasst (*Eersteling* erhielt die Zensur 10).
Durch Impfung abgeschnittener Blättchen mit der gleichen Menge einer verdünnten Schwärmsporen-Suspension hat es sich als möglich erwiesen, die Anfälligkeit in ihrer Gesamtheit zu bestimmen. Die kranken Stellen dürfen aber zum Zeitpunkt in dem die Beobachtungen durchgeführt werden müssen, einander nicht oder kaum berühren. Nach fünf Tagen und abermals zwei Tage später wurde die Anzahl Sporangien gezählt, indem die Blättchen mit einer bestimmten Menge Wasser abgespült wurden. Die zwei errechneten Zahlen wurden zusammengezählt (TABELLE 3, 6. Spalte).
Um die Anfälligkeit einiger Sorten im Felde festzustellen, wurden fünf Blättchen der Sorten *Eersteling*, *Eigenheimer* und *Noordeling* an vier verschiedenen Stellen im Felde künstlich geimpft. Nach zwölf Tagen wurde die Anzahl erneut infizierter Blättchen gezählt (TABELLE 4, 2. Spalte). Die auf diese Weise festgestellten Zahlen werden in TABELLE 4 mit der im Warmhaus bestimmten Anfälligkeit (errechnet aus den drei Komponenten) verglichen. Es besteht eine gute Übereinstimmung.
Für die Züchtung ist es wichtig, dass das Verhältnis zwischen diesen Komponenten bei den geprüften Sorten verschieden ist. Durch Bestimmung dieser Komponenten bei sämtlichen wichtigen Geniteuren wird zu untersuchen sein, ob es möglich ist, die Geniteure so zu wählen, dass eine Frühsorte mit ziemlich niedrigen Werten für diese Komponenten und somit ziemlich guter gesamter Krautresistenz gezüchtet werden kann. Da ausserdem die Knollenresistenz von grosser Wichtigkeit ist, werden auch darüber weitere Forschungen notwendig sein. So könnte man vielleicht Frühsorten züchten, die dem Pilz erschwerte Überwinterungsbedingungen bieten und in denen er sich nur langsam verbreiten kann.

RÉSUMÉ

OBSERVATIONS SUR L'AMÉLIORATION DE LA POMME DE TERRE EN CE QUI CONCERNE SA RÉSISTANCE AU *Phytophthora infestans*

L'amélioration de la pomme de terre en ce qui concerne sa résistance au *Phytophthora infestans* doit être considérée comme un moyen pour éviter l'éruption de cette maladie sous forme d'une épidémie. Du fait que le champignon hiverne surtout dans les variétés les plus sensibles et qu'il s'y propage considérablement en été, il importe d'essayer de remplacer les variétés très sensibles par celles qui ont une résistance raisonnable dans les tubercules et le feuillage (TABLEAUX 1, 2 et 4, 2 me colonne). Dans une variété à résistance d'environ 7 dans le feuillage et les tubercules (HOGEN ESCH & ZINGSTRA, 1954) le champignon n'hiverne pas ou guère. Un foyer une fois déclaré dans ces variétés ne se propage que lentement. Pour ralentir la manifestation d'une épidémie il importe que les variétés très sensibles soient remplacées par celles ayant une résistance raisonnable (6–7). Puisqu'on admet que la maturité précoce et la résistance se combinent difficilement, plus de recherche est nécessaire sur la résistance au champ.
Un essai d'orientation a prouvé que la sensibilité des variétés normales de *Solanum tuberosum* se laisse diviser en trois composantes au moins, savoir:
1. la chance d'infection, c.à.d. la chance qu'une zoospore pénètre dans la feuille,
2. la rapidité de la propagation du mycélium dans le tissu de la feuille,
3. la rapidité de la production des sporanges et le nombre qui est formé par unité de feuille.

Les trois composantes furent déterminées à l'aide de dix folioles coupées de la même grandeur comme suit:

1. Inoculer avec des quantités égales d'une suspension de zoospores très diluée. Au bout de trois jours fut déterminé le nombre des taches noires par foliole.
2. Inoculer au sommet des folioles. Au bout de six jours la surface décolorée fut mesurée dans le sens de la base de la feuille.
3. Inoculer avec une suspension concentrée de zoospores. Au bout de cinq jours, et ensuite deux jours plus tard fut déterminé le nombre des sporanges sur les folioles par lavage de ces folioles dans une certaine quantité d'eau, après quoi les sporanges furent comptés dans un certain nombre de gouttelettes. Les deux chiffres ainsi obtenus furent additionnés.

Aprés chaque inoculation les folioles furent conservées à une température de 20 °C et dans une atmosphère humide. L'essai fut entrepris deux fois avec quatre variétés. Les indices moyens sont consignés au TABLEAU 3 (*Eersteling* a été fixée à 10).

Par inoculation des folioles coupées avec la même quantité d'une suspension diluée de zoospores, il s'est avéré possible de déterminer la sensibilité dans son entier. Toutefois, les endroits malades ne doivent pas ou guère se toucher au moment, où les observations doivent être effectuées. Au bout de cinq jours, et puis deux jours plus tard le nombre des sporanges fut compté par lavage des folioles dans une certaine quantité d'eau. Les deux chiffres ainsi obtenus furent additionnés (TABLEAU 3, 6me colonne).

Pour étudier la sensibilité de certaines variétés au champ, cinq folioles des variétés *Eersteling*, *Eigenheimer* et *Noordeling* furent inoculées artificiellement sur quatre endroits différents en plein champ. Au bout de douze jours on compta le nombre des folioles nouvellement infectées TABLEAU 4, 2me colonne). Les données ainsi obtenues sont comparées au TABLEAU 4 à la sensibilité telle qu'elle a été déterminée en serre (calculée sur la base des trois composantes). Ces données s'accordent bien.

Pour l'amélioration il importe que chez les variétés examinées la relation entre ces composantes soit variée. En déterminant ces composantes de tous les géniteurs importants, on devra examiner s'il est possible de choisir les géniteurs de telle sorte qu'une variété hâtive se crée, ayant des valeurs assez basses pour ces composantes, de sorte que la résistance totale du feuillage soit raisonnable. Comme en outre la résistance de tubercules est d'une grande importance on devrait amplement examiner cette matière. De cette façon on pourrait peut-être créer des variétés hâtives, dans lesquelles le champignon hiverne difficilement et ne peut se propager que lentement

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