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Methods of evaluating tomato susceptibility to late blight (*Phytophthora infestans* (Mont.) de Bary) under field conditions

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Abstract

The purpose of the investigations carried out in 1983-1985 was to assess the usefulness of natural and artificial infections under field conditions for evaluating tomato resistance to late blight in Poland. It was found, that the degree of natural infection by this fungus was a better indicator of tomato resistance than the degree of artificial infection obtained under field conditions.

INTRODUCTION

The opinion is commonly held that the best method of assessing the resistance or susceptibility of plants to most pathogenes is observing natural infections in the field. In addition to this, in the process of resistance breeding, artificial infections are carried out under field and laboratory conditions. A detailed evaluation of the advantages and shortcomings of various laboratory methods has been presented in a previous paper (Horodecka, 1986). Observations on the natural infection of tomatoes by late blight are usually conducted systematically over the whole period of vegetation. In those years when the disease is not widespread, artificial field infections are done by spraying either whole plants (Dorozhkin and Strel'skaya 1966; Eggert, 1970; Turkensteen, 1973) or their parts (individual shoots, clusters) isolated from the rest of the plant with polyethylene bags (Dorozhkin and Strel'skaya, 1966), with suspensions of spores. Laterrot (1975) conducted field infections using the method of intensified natural infection. This method was devised by Messiaen et al. (1968).

In the opinion of Pietkiewicz (1976), the evaluation of the infection of plants achieved as the result of artificial field infection only allows for an approximate determination of resistance and laboratory tests are needed for more precise understanding of this phenomenon and its elements. Turkensteen (1973) expressed a similar opinion, stating that field tests, insomuch as they are relatively simple, inexpensive and permit observation of the utilitarian traits of the studied crops, are useful in resistance breeding, but insufficient for determining the type and elements of resistance.

In spite of the fact that studies on the resistance of tomatoes to potato blight have been going on for many years, there is still no agreement as to the mutual relationship of the resistance of leaves and fruit. Grummer et al. (1969) found in field studies using cvs. Atom (resistant), Marglobe (little resistant) and their crosses with other varieties, that there is a strict relationship between the degree of infection of the leaves and of the fruit. Later, Günther, et al. (1970) stated that this relationship is not always so clear, e.g. the leaves of cv. Fanal are very susceptible, while the fruit is relatively resistant. The lack of a clear tie between the susceptibility to potato blight of leaves and that of fruit is supported by the observations on natural field infections of a collection of varieties carried out by Czyżewska and Białkowska (1973). In many lines said to be partially resistant (West Virginia 36, West Virginia 700, Genewa 11, Ottawa 30, Ottawa 31, Red Cherry 25/7) no correlation was found between the resistance of the leaves and of the fruit, while one was found in susceptible varieties (Dorozhkin et al. 1979). These conclusions were supported by other studies on different material (Shirko, 1963; Kravchenko and Kovbashenko, 1979). According to Dorozhkin and Strel'skaya (1966), the most important factor in the resistance of varieties is the resistance of the fruit, while according to Dorozhkin et al. (1982) hypersensitivity and horizontal resistance of leaves in association with a moderate degree of fruit resistance is the most significant factor.

The aim of the studies conducted in 1983-1985 was to assess the usefulness of natural and artificial field infections for evaluating the resistance of tomatoes to potato blight in this contury.

MATERIAL AND METHODS

The investigations were conducted on varieties, lines and wild species of tomato. Part of the plants were artificially infected; the control plants were at risk of only natural infection. In 1983, 40 objects in 2 replications of 20 plants each were studied. The experiment was repeated in 1984 on 17 objects in 2 repetitions of 10 plants each, and in 1985 on 21 objects in 4 repetitions of 5 plants each.

The tomato plants were grown in an experimental field of the Department of Breeding and Genetics in Reguły on agricellous podzol soil formed on clay loam. The field was first sown with legumes which were plowed under at blooming. The use of mineral fertilizers in spring was dependent on the results of chemical analyses of the soil. The plants were fertilized with the mixture MIS-4 (250 kg/ha) during fruit formation.

Tomato seeds disinfected with seed's Mordant T and sodium triphosphate were planted at the beginning of April in crates and kept in a greenhouse. Seedlings with 1-2 leaves were transplanted into hotbeds. The transplants were set out in the field in the third decade of May. From 20 to 30 plants, as necessary, were planted spaced at 50 × 80 or 80 × 100 cm (wild species, varieties which do not self-terminate). The plants were allowed to grow without cutting, supports or chemical protection. The infected plants were set 5 m away from the controls.

INFECTION OF PLANTS UNDER FIELD CONDITIONS

Artificial infection in the field was done depending on the weather conditions on the following dates: 1983 – July 1 and September 1 and 15; 1984 – July 17, 1985 – July 19.

In 1983 and 1984 the infection was carried out by placing on the petioles tomato fruits containing fungus spores. The fruit used for the infections was inoculated in the laboratory with either race 0 or 1 ten days prior to the infection date. The field plants infected with race 0 were isolated from those infected with race 1 using plastic foil. In 1985 the artificial infection was done by spraying the plants with a mixture of isolates having various, previously determined pathogenicities. This mixture was prepared from cultures of 30 isolates obtained from different varieties of tomatoes naturally infected by the fungus. The cultures were rinsed with distilled water to wash away the sporangia. The concentration of the inoculum was brought to a standard of $50 \times 10^3/1\ cm^3$ of suspension. The plants were isolated with plastic bags which were removed after 3 days. The infection was conducted on a cool evening when the temperature did not exceed 18°C.

The following scale was used to visually evaluate the natural and artificial infections during vegetation from the moment symptoms of disease became apparent:

0 – lack of infection,
1 – small spots without visible condidiophores,
2 – small spots with sporulation,
3 – necrosis of less than 1/2 of the leaf blade without visible condiophores,
4 – necrosis of less than 1/2 of the leaf blade with sporulation,
5 – necrosis of the greater part of the leaf blade.

The infection of stems was evaluated visually by determining the average area of the stem showing signs of infection. The final assessment of infection of the fruit was made upon harvesting, taking into account the number of diseased fruits among the total number of fruits and calculating the percentage of infected fruit.

METEOROLOGICAL CONDITIONS

The data on the temperature and rainfall during the experimental periods are given on the basis of the observations of the Brwinów Meteorological Station. They are presented on Figures 1 and 2.

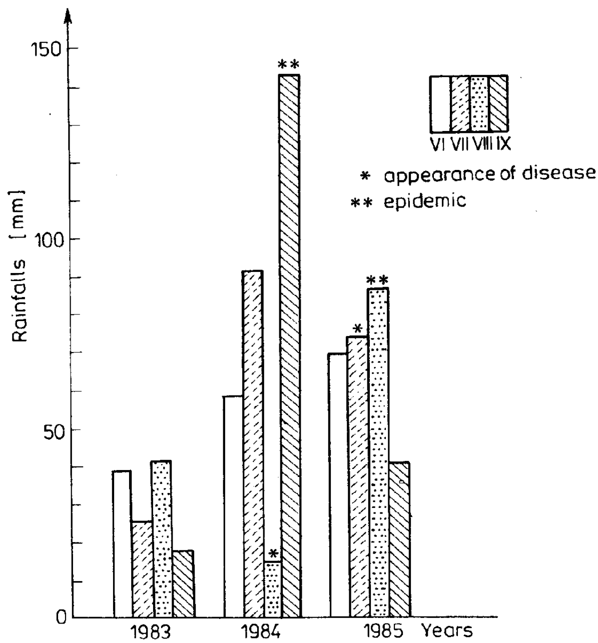

Fig. 1. Sum of monthly rainfalls

RESULTS

The field infections carried out in 1983-1985 resulted in the disease developing only in 1984 and 1985. The weather conditions in 1983 were unfavourable for the development of the fungus, and artificial infections conducted several times during the vegetative season were not successful in making the plants succumb to the disease. Prolonged keeping of the plants under plastic covers to increase the humidity of the air around them promoted the development of a variety of fungal and bacterial diseases and significant weakening of the plants, which totally distorted the picture of infection with potato blight.

In 1984 the course of the disease in plants infected artificially and naturally in the field was similar. The correlation and regression between the results of natural and artificial infection of fruit under field conditions were statistically

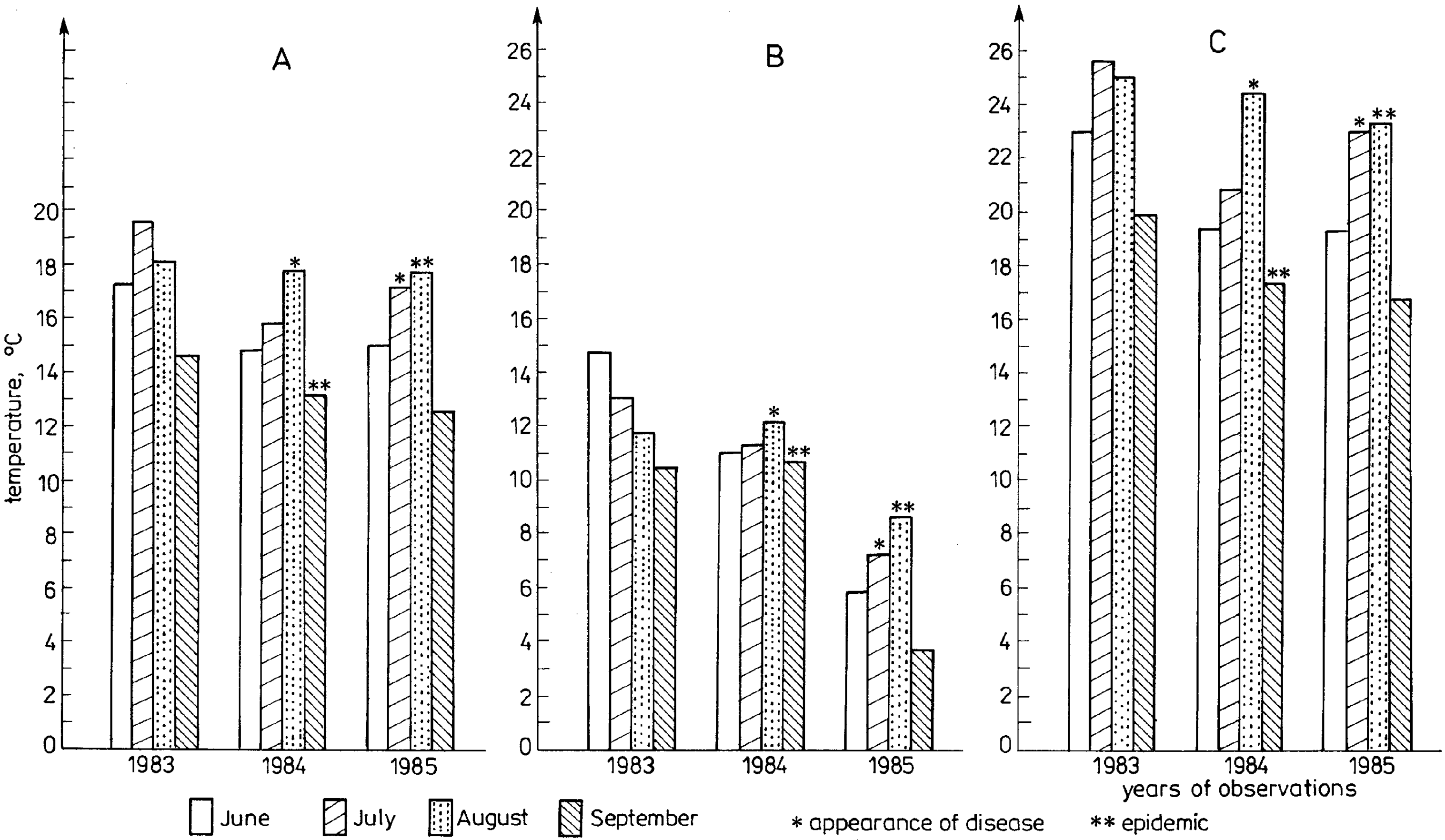

Fig. 2. Monthly temperatures: A — average of twenty-four hours, B — minimum, C — maximum

significant ($r = 0.51$ at $R_{tab.} = 0.48$). Significant correlation and regression between natural and artificial infections was also found in 1985, but pertained only to leaves and stems (Table 1). In contrast to the previous year, in 1985 no

Table 1

Correlations between natural and artificial infection in the field conditions in 1985 ($R_{tab.} = 0.43$)

Correlated features	Coefficient of correlation	Regression equation
Mean degree of infection of leaves	0.81*	y = 1.20 + 1.02x
Percent of infected leaves	0.81*	y = 11.53 + 1.35x
Mean percent of stem infection	0.87*	y = 5.15 + 2.02

* Significant.

statistically significant relations between natural and artificial infection of fruit was found. The infection of leaves, stems and fruit resulting from artificial infection in the years favourable for the development of the disease (1984-1985) was greater than the results of natural infection (Table 2).

Table 2

Statistical characterization of infection of plants through natural and artificial infection in the field: 1984-1985

Infection	Mean degree of infection of leaves	S	V%	Mean percent of infected leaves	S	V%	Mean percent of stem infection	S	V%	Mean percent of fruits infection	S	V%
Natural	2.28	1.17	51.32	23.89	15.13	63.33	4.28	7.97	186.21	2.97	3.04	102.36
Artificial	3.52	1.47	41.77	43.81	25.14	57.40	13.81	18.57	134.45	9.74	8.38	86.03

S – standard deviation; V – coefficient of variation.

No plants completely resistant to the races of *Phytophthora infestans* occurring in Poland were found among the studied field and greenhouse tomato varieties, breeding lines or wild species. The studied tomatoes showed different degrees of infection, but almost all of them were more susceptible than the partially resistant line, West Virginia 700 (Table 3). In respect to the health

Table 3

Mean infection of varieties and lines of tomatoes by late blight in 1984-1985

Variety Line Models	Provenance of seeds country – firm	Admitted to resistant by	Natural infection	
			Mean degree of infection of leaves	Disease fruits in percent of total yield
Atom	England – Hurst	Goodman (1957)	1.10	7.85
Goniec 13	USSR – WIR	Shirko, Glushchenko (1973)	3.33	13.21
Heline	France – INRA	Laterrot (1975)	3.81	11.33
Kirys (Przemysłowy)	Poland – IW	Potaczek (1979)	3.00	10.81
Najwcześniejszy	Poland – ZNRiO	Chroboczek (1966)	3.10	28.10
New Hampshire	Holland – IVT	Rick, Yeager (1957)	1.10	15.25
New Yorker	Canada – Stokes	Robinson et al. (1968)	4.00	15.25
Pieraline	France – INRA	Laterrot (1975)	4.00	16.57
Szkarłatna Kula	Poland – IW	Potaczek (1979)	3.00	11.36
Genewa T-5	Canada – Stokes	Dorozhkin et al. (1979)	1.33	5.72
Genewa 11	"	"	1.66	10.00
No. 62/74	Poland – IW	Horodecka	2.00	4.67
No. 155/84	"	"	1.66	5.33
No. 246/72	"	"	1.66	7.42
Ottawa 30	Holland – IVT	Drozhkin et al. (1979)	1.22	8.55
Ottawa 31	"	"	2.00	6.33
West Virginia 700	"	Gallegly (1955)	1.33	0.72
Moneymaker	USA – Ferry Morse Seed Co.	–	4.66	36.10
Rutgers	"	–	2.67	26.99

West Virginia 700 – model of resistance; Moneymaker, Rutgers – model of susceptibility.

of leaves, only the varieties Atom and New Hampshire stood out – their average degree of infection was 1.10 (for West Virginia 700 – 1.33). The breeding lines, with the exception of No. 62/74 and Ottawa 31, whose degree of leaf infection equalled 2.0, had similar degrees of leaf infection as West Virginia 700. In contrast to the degree of leaf infection, fruit of the varieties Atom and New Hampshire was infected much more than that of West Virginia. Evaluation of the health of the fruit revealed that under conditions of natural field infection, the percentage of diseased fruit in all of the tested varieties and lines was higher than in West Virginia, but lower than in the standard susceptible varieties. In respect to the health of fruit under field conditions, lines No. 62/64, No. 155/84 and Genewa T-5 (Table 3) stood out. The correlation between infection of leaves and stems was found to be significant both under conditions of natural and artificial infection (Table 4). The

Table 4

Statistical characterization of infection of tomato leaves and stems in field conditions

Infection	Mean degree of infection of leaves	S	$V\%$	Mean percent of infection of stems	S	$V\%$	Coefficient of correlation for leaves and stems	
							degree	percent
Natural	2.28	1.17	51.32	4.28	7.97	186.21	0.51*	0.65*
Artificial	3.52	1.47	41.77	13.81	18.57	134.45	0.44*	0.52*

$R_{tab.}$ = 0,43; S – standard deviation; V – coefficient od variation; * Significant.

correlation between infection of leaves and fruit both in the initial phase of the epidemic and its intensification were not significant. This pertains both to natural as well as artificial infection – the correlation coefficient r equalled $0.23 \div 0.42$ at $R_{tab.}$ -0.43. No correlation between infection of stems and fruit was also found – the correlation coefficient equalled $0.14 \div 0.30$ at $R_{tab.} = 0.43$.

DISCUSSION

In contrast to the opinions of some researchers, such as Turkensteen (1973) and Pietkiewicz (1978), who consider artificial field infection as pointless, the conducted studies show that both methods of natural and artificial infection complement each other. The main drawback in using artificial infection is, of course, the high dependence of the development of a potato blight epidemic on external conditions (humidity and temperature) which are hard to regulate under field conditions. Providing the appropriate conditions would entail the use of special experimental techniques such as, e.g.

field incubation chambers, which were not available when these experiments were conducted. The usefulness of artificial infections is shown by the significant correlations and regressions between the natural and artificial infection of leaves, stems and fruit. Only in 1985 were such relations in fruit not found. This can be explained by the fact that in 1985, under natural conditions, potato blight attacked leaves and stems, rarely fruit, while the inoculum used for artificial infection contained isolates infecting entire plants. The classification of many varieties and lines listed in Table 3 does not agree with that of other authors who consider them resistant or partially resistant. These objects were infected rather seriously under field conditions in 1984-1985. Upon studying the infection of the individual above-ground plant parts, statistically significant correlations between the infection of leaves and stems were found, while no such relationships were seen between the infection of leaves and fruit or stems and fruit. Grummer et al. (1969) were of an opposite opinion claiming that there is a strict relationship between the infection of leaves and fruit. The differences in the evaluation of these correlations may result from different properties of the fungus races occurring in Poland and Germany or from the selection of the varieties in the experiment. The cited authors found a correlation in studying only extreme varieties — resistant (Atom) and susceptible (Marglobe). Later, Günther et al. (1970) when taking into account also varieties of moderate resistance (Fanal) reported that the correlation between the infection of leaves and fruit is not very distinct. The findings presented here support the earlier results of studies by Czyżewska and Białkowska (1973) conducted in the same vicinity — Reguły — and abroad (Dorozhkin et al. 1979; Shirko, 1963; Kravchenko and Kovbashenko, 1979).

CONCLUSIONS

1. Observations on natural infection of tomatoes with potato blight are a good test of resistance or susceptibility of tomatoes under the condition that a severe epidemic of the disease occurs. Artificial infection of plants under field conditions may be treated as a supplementary method.

2. The resistance of particular plant parts is probably regulated by different factors, which is indicated by the non-significant correlations between the infection of leaves and fruit and stems and fruit.

3. When assessing the resistance of tomatoes, their leaves, stems and fruit should be assessed independently of each other.

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Ocena odporności pomidorów na zarazę ziemniaka wywoływaną przez *Phytophthora infestans* (Mont.) de Bary w warunkach polowych

Streszczenie

Celem badań prowadzonych w latach 1983-1985 było określenie przydatności naturalnych i sztucznych zakażeń polowych do oceny odporności pomidorów na zarazę ziemniaka w naszym kraju. Stwierdzono:

1. Obserwacje naturalnego porażenia zarazą ziemniaka są dobrym sprawdzianem odporności lub wrażliwości pomidorów na tę chorobę.

2. Sztuczne zakażenia w warunkach polowych są niecelowe przy testowaniu odporności pomidorów na zarazę ziemniaka.

3. Odporność poszczególnych części rośliny jest prawdopodobnie warunkowana różnymi czynnikami, o czym świadczą nieistotne korelacje między porażeniem liści i owoców oraz łodyg i owoców.

4. Oceniając odporność pomidorów należy oceniać niezależnie od siebie ich liście, łodygi i owoce.