INSTITUTE OF SOIL SCIENCE AND PLANT CULTIVATION
STATE RESEARCH INSTITUTE
Czartoryskich 8 st., 24-100 Pulawy (Poland)

BREEDING FOR RESISTANCE TO HOP POWDERY MILDEW IN POLAND

Urszula Skomra

Powdery mildew caused by *Podosphaera macularis* is one of the most dangerous fungal diseases of hop. First symptoms are observed on leaves in the form of scattered, isolated, white colonies (fot. 1). Infection of the flowers and young cones causes deformations which result in loss of yield and quality (fot. 2).

conidiophores

ascomas

Fot. 1. Symptoms of hop powdery mildew on leaves

Fot. 2. Symptoms of hop powdery mildew on cones

Table 1. The occurrence of powdery mildew symptoms on cones of three hop cultivars

Cultivar	Infected cones (%)		Infection coefficient (%)	
	Mean 2001-2007	Variability range	Mean 2001-2007	Variability range
Marynka	16.6 b*	2.0 – 23.6	5.0 b	0.5 – 8.3
Lubelski	9.8 a	4.0 – 14.8	3.0 a	1.1 – 5.0
Magnum	22.9 c	18.0 – 28.4	7.6 c	4.8 – 12.8
$LSD_{0.05}$	3.9		1.4	

*means followed by the same letter are not significantly different (P = 0.05) according to Tukey's statistic

Studies on the occurrence of powdery mildew on commercial hop gardens in Poland revealed that disease appeared every year but symptoms severity was different in particular vegetation seasons and hop cultivars. Susceptibility of hop cultivars expressed as infection coefficient, was determined in the technological maturity stage on the basis of the number of infected cones and symptoms severity. The least susceptible Polish cultivar, Lubelski showed a relatively low infection coefficient, ranging from 1.1 to 5.0%, but for the most susceptible Magnum cv. it ranged from 4.8 to 12.8% (tab.1).

The most effective way to control the powdery mildew is breeding for resistance. The first step of work was the evaluation of effectiveness of currently known sources of resistance on the basis of artificial inoculation tests conducted in controlled conditions using the mixture of powdery mildew isolates occurring in Poland. These analyses showed that only resistances based on R1 and R2 genes from the English cultivars Zenith and Wye Target are still effective. Strong resistance was observed also in the case of First Gold cv. These cultivars exhibited effective resistance to hop powdery mildew also in the field, that is why, they are used in breeding program in Poland. Resistances based on the action of major genes are easily overcome by new virulent races of pathogen, therefore, we should start looking for new sources of resistance to hop powdery mildew. Wild male accessions collected from different regions of Poland were multiplied by softwood cuttings. Young plants were artificially inoculated by a mixture of powdery mildew isolates occurring in Poland. Field tests were also conducted. We identified 7 very promising wild males. Some of them have been used as crossing components in our breeding program.

Fot.3. Hop seedlings healthy (left) and strongly infected by *Podosphaera macularis* (right).

Hop seedlings obtained by hybridization of appropriate parental components were tested for resistance to powdery mildew using artificial inoculation in controlled conditions. The most promising were two progenies obtained by crossing Zenith cv. with susceptible males (NSzH 3/18 and NSzH 11/6). They showed almost 100% of resistance to powdery mildew (tab. 2). The lowest percentage of resistant plants (17.8) was found within progeny of Wye Target × SzM 2/5.

Plants from progenies of parents Wye Target × SzM2/5 and Wye Target × SzM3/39 were planted to the field, where they have been evaluated for resistance under natural infection pressure. Their susceptibility to hop powdery mildew was estimated on the basis of cone's damages in technological maturity stage. Almost 85% of plants recognized as resistant in artificial inoculation test, exhibited resistance to hop powdery mildew also in the field conditions. Remaining 15% showed a very slight severity of symptoms (infection coefficient did not exceed 0.25%). Plants evaluated as susceptible under artificial infection usually showed stronger symptoms of powdery mildew in the field (mean infection coefficient of cones was 3.5%) (tab.3).

Artificial inoculation at the first stage of selection is a very useful method, which permit to reduce number of plants evaluated in the field conditions. Wild males identified as resistant to powdery mildew, seem to be valuable genetic sources of this trait. Their breeding value in relation to other properties (e.g. yield potential, brewing quality) will be assessed in F_1 populations.

Table 2. Evaluation of hop powdery mildew resistance under artificial inoculation of seedlings

Progeny from crosses	No. of seedlings	Resistant (%)	Susceptible (%)
♀ Wye Target (R) × ♂ SzM2/5	101	17.8	82.2
♀ Wye Target (R) × ♂ SzM3/39	93	30.1	69.9
♀ Wye Target (R) × ♂ NSzH3/18	41	80.5	19.5
♀ Wye Target (R) × ♂ NSzH16/47	47	80.9	19.1
♀ Zenith (R) × ♂ NSzH3/18	44	97.7	0.3
♀ Zenith (R) × ♂ NSzH11/16	89	100.0	0.0
♀ First Gold (R) × ♂ NSzH3/18	42	26.2	73.8
♀ First Gold (R) × ♂ NSzH14/9	231	39.8	60.2
♀ First Gold (R) × ♂ NSzH8/12	78	33.3	66.7
♀ Iunga × ♂ NSzH10/52 (R)	62	33.9	66.1
♀ Iunga × ♂ D11(R)	72	43.1	56.9
♀ Sybilla × ♂ NSzH10/52 (R)	61	37.7	62.3
♀ Sybilla × ♂ D11(R)	97	64.9	35.1

Table 3. Comparison of powdery mildew evaluation under artificial inoculation of hop seedlings and field assesment of cone's damages

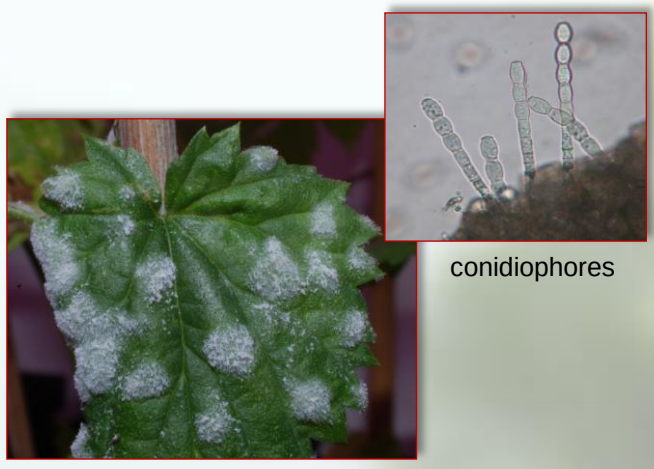
Seedling score under artificial inoculation	Infection coeficient of cones in the field (%)	
	Variability range	Mean
Resistant	0 – 0.25	0.08
Susceptible	0 – 8.30	3.50

BREEDING FOR RESISTANCE TO HOP POWDERY MILDEW IN POLAND

Urszula Skomra

Instytut Uprawy Nawożenia i Gleboznawstwa w Puławach
Państwowy Instytut Badawczy

Powdery mildew caused by *Podosphaera macularis* is one of the most dangerous fungal diseases of hop. First symptoms are observed on leaves in the form of scattered, isolated, white colonies (fot.1). Infection of the flowers and young cones causes deformations which result in loss of yield and quality (fot.2).



Fot. 1. Symptoms of hop powdery mildew on leaves

conidiophores

ascomas

Fot. 2. Symptoms of hop powdery mildew on cones

Table 1. The occurrence of powdery mildew symptoms on cones of three hop cultivars most popular in Poland

Cultivar	Infected cones (%)		Infection coefficient (%)	
	Mean 2001-2007	Variability range	Mean 2001-2007	Variability range
Marynka	16.6 b*	2.0 – 23.6	5.0 b	0.5 – 8.3
Lubelski	9.8 a	4.0 – 14.8	3.0 a	1.1 – 5.0
Magnum	22.9 c	18.0 – 28.4	7.6 c	4.8 – 12.8
$LSD_{0.05}$	3.9		1.4	

*means followed by the same letter are not significantly different (P = 0.05) according to Tukey's statistic

Studies on the occurrence of powdery mildew on commercial hop gardens in Poland revealed that disease appeared every year but symptoms severity was different in particular vegetation seasons and hop cultivars. Susceptibility of hop cultivars expressed as infection coefficient, was determined in the technological maturity stage on the basis of the number of infected cones and symptoms severity. The least susceptible Polish cultivar, Lubelski showed a relatively low infection coefficient, ranging from 1.1 to 5.0%, but for the most susceptible Magnum cv. it ranged from 4.8 to 12.8% (tab.1).

The most effective way to control the powdery mildew is breeding for resistance. The first step of work was the evaluation of effectiveness of currently known sources of resistance on the basis of artificial inoculation tests conducted in controlled conditions using the mixture of powdery mildew isolates occurring in Poland. These analyses showed that only resistances based on R1 and R2 genes from the English cultivars Zenith and Wye Target are still effective. Strong resistance was observed also in the case of First Gold cv. These cultivars exhibited effective resistance to hop powdery mildew also in the field, that is why, they are used in breeding program in Poland. Resistances based on the action of major genes are easily overcome by new virulent races of pathogen, therefore, we should start looking for new sources of resistance to hop powdery mildew. Wild male accessions collected from different regions of Poland were multiplied by softwood cuttings. Young plants were artificially inoculated by a mixture of powdery mildew isolates occurring in Poland. Field tests were also conducted. We identified 7 very promising wild males. Some of them have been used as crossing components in our breeding program.

Fot.3. Hop seedlings healthy (left) and strongly infected by *Podosphaera macularis* (right).

Hop seedlings obtained by hybridization of appropriate parental components were tested for resistance to powdery mildew using artificial inoculation in controlled conditions. The most promising were two progenies obtained by crossing Zenith cv. with susceptible males (NSzH 3/18 and NSzH 11/6). They showed almost 100% of resistance to powdery mildew (tab. 2). The lowest percentage of resistant plants (17.8) was found within progeny of Wye Target SzM 2/5.

Plants from progenies of parents Wye Target SzM2/5 and Wye Target SzM3/39 were planted to the field, where they have been evaluated for resistance under natural infection pressure. Their susceptibility to hop powdery mildew was estimated on the basis of cone's damages in technological maturity stage. Almost 85% of plants recognized as resistant in artificial inoculation test, exhibited resistance to hop powdery mildew also in the field conditions. Remaining 15% showed a very slight severity of symptoms (infection coefficient did not exceed 0.25%). Plants evaluated as susceptible under artificial infection usually showed stronger symptoms of powdery mildew in the field (mean infection coefficient of cones was 3.5%) (tab.3).

Artificial inoculation at the first stage of selection is a very useful method, which permit to reduce number of plants evaluated in the field conditions. Wild males identified as resistant to powdery mildew, seem to be valuable genetic sources of this trait. Their breeding value in relation to other properties (e.g. yield potential, brewing quality) will be assessed in F_1 populations.

Table 2. Evaluation of hop powdery mildew resistance under artificial inoculation of seedlings

Progeny from crosses	No. of seedlings	Resistant (%)	Susceptible (%)
♀ Wye Target (R) × ♂ SzM2/5	101	17.8	82.2
♀ Wye Target (R) × ♂ SzM3/39	93	30.1	69.9
♀ Wye Target (R) × ♂ NSzH3/18	41	80.5	19.5
♀ Wye Target (R) × ♂ NSzH16/47	47	80.9	19.1
♀ Zenith (R) × ♂ NSzH3/18	44	97.7	0.3
♀ Zenith (R) × ♂ NSzH11/16	89	100.0	0.0
♀ First Gold (R) × ♂ NSzH3/18	42	26.2	73.8
♀ First Gold (R) × ♂ NSzH14/9	231	39.8	60.2
♀ First Gold (R) × ♂ NSzH8/12	78	33.3	66.7
♀ Iunga × ♂ NSzH10/52 (R)	62	33.9	66.1
♀ Iunga × ♂ D11(R)	72	43.1	56.9
♀ Sybilla × ♂ NSzH10/52 (R)	61	37.7	62.3
♀ Sybilla × ♂ D11(R)	97	64.9	35.1

Table 3. Comparison of powdery mildew evaluation under artificial inoculation of hop seedlings and field assesment of cone's damages

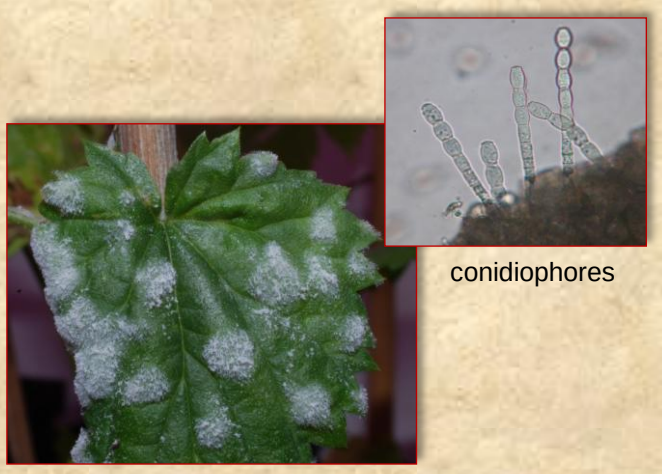
Seedling score under artificial inoculation	Infection coeficient of cones in the field (%)	
	Variability range	Mean
Resistant	0 – 0.25	0.08
Susceptible	0 – 8.30	3.50

BREEDING FOR RESISTANCE TO HOP POWDERY MILDEW IN POLAND

Urszula Skomra

Instytut Uprawy Nawożenia i Gleboznawstwa w Puławach
Państwowy Instytut Badawczy

Powdery mildew caused by *Podosphaera macularis* is one of the most dangerous fungal diseases of hop. First symptoms are observed on leaves in the form of scattered, isolated, white colonies (fot.1). Infection of the flowers and young cones causes deformations which result in loss of yield and quality (fot.2).



Fot. 1. Symptoms of hop powdery mildew on leaves

conidiophores

ascomas

Fot. 2. Symptoms of hop powdery mildew on cones

Table 1. The occurrence of powdery mildew symptoms on cones of three hop cultivars most popular in Poland

Cultivar	Infected cones (%)		Infection coefficient (%)	
	Mean 2001-2007	Variability range	Mean 2001-2007	Variability range
Marynka	16.6 b*	2.0 – 23.6	5.0 b	0.5 – 8.3
Lubelski	9.8 a	4.0 – 14.8	3.0 a	1.1 – 5.0
Magnum	22.9 c	18.0 – 28.4	7.6 c	4.8 – 12.8
$LSD_{0.05}$	3.9		1.4	

*means followed by the same letter are not significantly different (P = 0.05) according to Tukey's statistic

Studies on the occurrence of powdery mildew on commercial hop gardens in Poland revealed that disease appeared every year but symptoms severity was different in particular vegetation seasons and hop cultivars. Susceptibility of hop cultivars expressed as infection coefficient, was determined in the technological maturity stage on the basis of the number of infected cones and symptoms severity. The least susceptible Polish cultivar, Lubelski showed a relatively low infection coefficient, ranging from 1.1 to 5.0%, but for the most susceptible Magnum cv. it ranged from 4.8 to 12.8% (tab.1).

The most effective way to control the powdery mildew is breeding for resistance. The first step of work was the evaluation of effectiveness of currently known sources of resistance on the basis of artificial inoculation tests conducted in controlled conditions using the mixture of powdery mildew isolates occurring in Poland. These analyses showed that only resistances based on R1 and R2 genes from the English cultivars Zenith and Wye Target are still effective. Strong resistance was observed also in the case of First Gold cv. These cultivars exhibited effective resistance to hop powdery mildew also in the field, that is why, they are used in breeding program in Poland. Resistances based on the action of major genes are easily overcome by new virulent races of pathogen, therefore, we should start looking for new sources of resistance to hop powdery mildew. Wild male accessions collected from different regions of Poland were multiplied by softwood cuttings. Young plants were artificially inoculated by a mixture of powdery mildew isolates occurring in Poland. Field tests were also conducted. We identified 7 very promising wild males. Some of them have been used as crossing components in our breeding program.

Fot.3. Hop seedlings healthy (left) and strongly infected by *Podosphaera macularis* (right).

Hop seedlings obtained by hybridization of appropriate parental components were tested for resistance to powdery mildew using artificial inoculation in controlled conditions. The most promising were two progenies obtained by crossing Zenith cv. with susceptible males (NSzH 3/18 and NSzH 11/6). They showed almost 100% of resistance to powdery mildew (tab. 2). The lowest percentage of resistant plants (17.8) was found within progeny of Wye Target SzM 2/5.

Plants from progenies of parents Wye Target SzM2/5 and Wye Target SzM3/39 were planted to the field, where they have been evaluated for resistance under natural infection pressure. Their susceptibility to hop powdery mildew was estimated on the basis of cone's damages in technological maturity stage. Almost 85% of plants recognized as resistant in artificial inoculation test, exhibited resistance to hop powdery mildew also in the field conditions. Remaining 15% showed a very slight severity of symptoms (infection coefficient did not exceed 0.25%). Plants evaluated as susceptible under artificial infection usually showed stronger symptoms of powdery mildew in the field (mean infection coefficient of cones was 3.5%) (tab.3).

Artificial inoculation at the first stage of selection is a very useful method, which permit to reduce number of plants evaluated in the field conditions. Wild males identified as resistant to powdery mildew, seem to be valuable genetic sources of this trait. Their breeding value in relation to other properties (e.g. yield potential, brewing quality) will be assessed in F_1 populations.

Table 2. Evaluation of hop powdery mildew resistance under artificial inoculation of seedlings

Progeny from crosses	No. of seedlings	Resistant (%)	Susceptible (%)
♀ Wye Target (R) × ♂ SzM2/5	101	17.8	82.2
♀ Wye Target (R) × ♂ SzM3/39	93	30.1	69.9
♀ Wye Target (R) × ♂ NSzH3/18	41	80.5	19.5
♀ Wye Target (R) × ♂ NSzH16/47	47	80.9	19.1
♀ Zenith (R) × ♂ NSzH3/18	44	97.7	0.3
♀ Zenith (R) × ♂ NSzH11/16	89	100.0	0.0
♀ First Gold (R) × ♂ NSzH3/18	42	26.2	73.8
♀ First Gold (R) × ♂ NSzH14/9	231	39.8	60.2
♀ First Gold (R) × ♂ NSzH8/12	78	33.3	66.7
♀ Iunga × ♂ NSzH10/52 (R)	62	33.9	66.1
♀ Iunga × ♂ D11(R)	72	43.1	56.9
♀ Sybilla × ♂ NSzH10/52 (R)	61	37.7	62.3
♀ Sybilla × ♂ D11(R)	97	64.9	35.1

Table 3. Comparison of powdery mildew evaluation under artificial inoculation of hop seedlings and field assesment of cone's damages

Seedling score under artificial inoculation	Infection coeficient of cones in the field (%)	
	Variability range	Mean
Resistant	0 – 0.25	0.08
Susceptible	0 – 8.30	3.50