

Sakr N, 2009. Components of quantitative resistance to downy mildew (*Plasmopara halstedii*) in sunflower (*Helianthus annuus*). Journal of Plant Protection Research, 49 (3): 297-301.

Components of quantitative resistance in sunflower (Helianthus annuus) to Plasmopara halstedii, the pathogen causing downy mildew, were investigated. Percentage infection, latent period, sporulation density and reduction of hypocotyl length were compared on two sunflower lines showing different levels of quantitative resistance in the field infected with different P. halstedii strains of races 100, 300, 710 and 714 in controlled conditions. The inbred line BT, rather susceptible in the field, showed a higher percentage infection, a higher sporulation density, a shorter latent period and less reduced hypocotyl length than inbred line FU, which showed a greater resistance in the field. The very good resistance of inbred line FU observed in the field was confirmed by the measurements of quantitative resistance criteria described in this study. Percentage infection of FU was 1.4% less than BT, latent period of BT was 12.4% less than FU, sporulation density of FU was 22.3% less than BT and reduced hypocotyl length of BT was 15.3% less than FU. It seems that the criteria such as latent period, sporulation density and reduction of hypocotyl length may be used to measure quantitative resistance in sunflower to P. halstedii.

Sakr N, 2009. Variation in aggressiveness of *Plasmopara halstedii* (sunflower downy mildew). J.Plant Dis.Protect, 116 (6): 247-251.

Variability in aggressiveness was studied in seven Plasmopara halstedii (sunflower downy mildew) parental isolates of races 100, 300, 304, 314, 704, 710 and 714 using five single zoosporangium isolates per parental isolate. Aggressiveness criteria, including latent period and sporulation density, were analysed in one sunflower inbred line showing a high level of quantitative resistance. Analysis of five single zoosporangium isolates of each parental isolate showed variability within parental isolate for the two aggressiveness criteria, but not for all parental isolates. The parental isolates of races 100, 300, 304 and 314 had a shorter latent period and greater sporulation density than the parental isolates of races 710, 704 and 714. Consequently, parental isolates of races 100, 300, 304 and 314 were significantly more aggressive than the parental isolates of races 710, 704 and 714.

Sakr N, 2010. Can enhance durable resistance against *Plasmopara halstedii* (sunflower downy mildew). Journal of Plant Protection Research, 50 (1): 15-21.

Sunflower downy mildew caused by Plasmopara halstedii is one of the most potentially important diseases. So far, a complete, major gene resistance (PI) has been used successfully, but with the appearance of eight races in France since 2000, research on more durable resistance was undertaken. In this study, we present new results concerning the evolution of pathogenicity of P. halstedii under conditions of re-enforced infection and different PI gene selection pressures. Moreover, we imagine the evolution of virulence and aggressiveness of P. halstedii under a mixture model of sunflower inbred lines carrying the two types of resistance which may enhance durable resistance against it. Examples of host-parasite interactions including the influence of plant mixture models against pathogens are equally presented to understand how the pathogen develops its pathogenicity.

Sakr N, 2010. A plant mixture model against *Plasmopara halstedii* (sunflower downy mildew). Journal of Plant Protection Research, 50 (2): 125-129.

Sunflower downy mildew caused by Plasmopara halstedii is one of the most potentially important diseases. So far, a complete, major gene resistance (PI) has been used successfully. But, with the appearance of eight races in France since 2000, research on more durable resistance was undertaken. In this study, we presented new results concerning the evolution of pathogenicity in P. halstedii under conditions of re-enforced infection and different PI gene selection pressure. Moreover, we studied the evolution of virulence and aggressiveness of P. halstedii under a mixture model of sunflower inbred lines carrying the two types of resistance (qualitative and quantitative). This sunflower model may enhance durable resistance against P. halstedii.

Sakr N, 2010. Trade-off between Virulence and Aggressiveness in *Plasmopara halstedii* (Sunflower Downy Mildew). J Phytopathol, doi: 10.1111/j.-1439-0434.2010.01733.x

The Journal of Phytopathology has retracted a 2010 article by a French researcher who apparently misled editors about her role in preparing the manuscript.

Sakr N, 2010. Studies on pathogenicity in *Plasmopara halstedii* (sunflower downy mildew). Int J Life Sci, 4: 48-59.

Studies on morphological and genetic variabilities as well as alterations in pathogenicity were carried out in Plasmopara halstedii (sunflower downy mildew) isolates of several races. Aggressiveness was analyzed in one sunflower inbred line showing a high level of quantitative resistance. Viability analyses were performed on oval and spheric zoosporangia. Genetic relationships were detected between the pathogen isolates using 12 EST-derived markers. There were significant differences between pathogen isolates for aggressiveness criteria. Based on virulence and aggressiveness reaction for P. halstedii to D3 line of sunflower, there were two groups as more aggressive and less virulent isolates of 100 and 3xx races, and less aggressive and more virulent isolates of 7xx races. The oval zoosporangia for more aggressive isolates of races 100 and 3xx produced more zoospores than the oval ones for less aggressive isolates of races 7xx. The isolates of races 714, 704 and 314 had an intermediary genetic position between the two isolates of races 100 and 710. It is concluded that the relationship between aggressiveness and oval zoosporangia viability may be established in P. halstedii. No correlation was detected between pathogenicity traits and EST genotypes.

Sakr N, 2011. Aggressiveness in *Plasmopara halstedii* (sunflower downy mildew). Plant Pathol. J., 27 (2): 110-15.

Aggressiveness was studied in seven Plasmopara halstedii (sunflower downy mildew) pathotypes: 100, 300, 304, 314, 704, 710 and 714. Aggressiveness criteria including percentage infection, latent period, sporulation density and reduction of hypocotyl length (dwarfing) were analysed in one sunflower inbred line showing a high level of quantitative resistance. Genetic relationships were detected between the seven pathotypes using 12 ESTderived markers. Pathotypes 100, 300, 304 and 314 were characterized with shorter latent period and higher sporulation density than pathotypes 710, 704 and 714. All pathotypes showed high percentage infection values and caused a large reduction in seedling size except for pathotype 314 involved in dwarfing. Pathotypes 714, 704 and 314 had an intermediary genetic position between the pathotypes 100 and 710. No correlation was detected between aggressiveness traits and EST genotypes.

Sakr N, 2011. Can percentage infection and dwarfing be used to differentiate aggressiveness in *Plasmopara halstedii*? Archives of Phytopathology and Plant Protection, 44 (14), 1365-1374.

Aggressiveness was studied in seven *Plasmopara halstedii* (sunflower downy mildew) parental isolates of races 100, 300, 304, 314, 704, 710 and 714 using five single zoosporangium isolates per parental isolate. Aggressiveness criteria, including percentage infection and dwarfing (reduction of hypocotyl length), were analysed in one sunflower inbred line showing a high level of quantitative resistance. Analysis of five single zoosporangium isolates of each parental isolate showed variability within parental isolate for the two aggressiveness criteria, but not for all parental isolates for percentage infection and vice versa for the reduction of hypocotyl length. Percentage infection showed high values irrespective of the parental isolate used. However, all the parental isolates caused a large reduction in seedling size except for the isolate of race 314. Although percentage infection and reduction of hypocotyl length could be used to differentiate aggressiveness in *P. halstedii*, it seems that these criteria played a limited role to define *P. halstedii* isolates according to their aggressiveness.

Sakr N, 2011. Evolution of pathogenicity in *Plasmopara halstedii* (sunflower downy mildew). Archives of Phytopathology and Plant Protection, 44 (15), 1432-1437.

Comprehension of the processes of co-evolution between the pathogen and its host plant is very important, particularly in the case of obligate pathogen as *Plasmopara halstedii* which cannot develop only on sunflower. The influence of selection pressure exercised by qualitative resistance in sunflower plants on evolution of pathogenicity was analysed in pathogenic populations of *P. halstedii*. This selection pressure led a new virulence to appear in *P. halstedii* isolates carrying several levels of aggressiveness. It seems that the qualitative resistance selection pressure plays an important role in the evolution of this pathogen, and these changes on the level of pathogenicity may help to a better adaptation of *P. halstedii* in the presence of intensive use of qualitative resistance.

Sakr N, 2011. Relation between virulence and aggressiveness in *Plasmopara halstedii* (sunflower downy mildew). Archives of Phytopathology and Plant Protection, 44 (15), 1456-1461.

Relationship between virulence and aggressiveness was studied in seven *Plasmopara halstedii* (sunflower downy mildew) pathotypes including five progeny pathotypes of races 300, 304, 314, 704 and 714 arising from two parental pathotypes of races 100 and 710. Aggressiveness criteria including percentage infection, latent period, sporulation density and reduction of hypocotyl length were analysed in one sunflower inbred line showing a high level of quantitative resistance. There were significant differences between *P. halstedii* pathotypes for all aggressiveness criteria. Pathogenicity of progeny pathotypes as compared with parental ones (relationship between virulence and aggressiveness) seems to be positive, negative or uncorrelated. Hypothesis explaining these cases are discussed.

Sakr N, 2011. Genetic origin of progeny isolates in a local *Plasmopara halstedii* (sunflower downy mildew) population. Archives of Phytopathology and Plant Protection, 44 (15), 1512-1518.

Genetic origin of five progeny *Plasmopara halstedii* (downy mildew) isolates of races 300, 304, 314, 704 and 714 obtained after 5 years of sunflower mono-culture infected with two parental isolates of races 100 and 710 was studied using 12 EST-derived markers. The isolates of races 714, 704 and 314 had an intermediary genetic position between the two parental isolates of races 100 and 710. The three isolates of races 100, 300 and 304 were localised in the same genetic clade. Two mechanisms could explain the emergence of new virulence in *P. halstedii* as recombination between races and mutations in a clonal lineage.

Sakr N, 2011. Relationship between aggressiveness and zoosporangia viability in *Plasmopara halstedii* (sunflower downy mildew). Archives of Phytopathology and Plant Protection, 44 (16), 1585-1594.

Relationship between aggressiveness and zoosporangia viability was studied in seven *Plasmopara halstedii* (sunflower downy mildew) isolates of races 100, 300, 304, 314, 710, 704 and 714. Aggressiveness criteria including latent period and sporulation density were analysed on sunflower inbred line showing a high level of quantitative resistance. There were significant differences between pathogen isolates for the two aggressiveness criteria. Viability analyses were performed on oval and spheric zoosporangia. The number of zoospores released from oval zoosporangia was significantly higher than those released from spheric ones. The oval zoosporangia for more aggressive isolates of races 100 and 3xx produced more zoospores than the oval ones for less aggressive isolates of races 7xx. There was a significant correlation between aggressiveness criteria and the number of zoospores released from oval zoosporangia and vice versa for zoospores released from spheric ones. It is concluded that the relationship between aggressiveness and oval zoosporangia viability may be established in *P. halstedii*.

Sakr N, 2011. Pathogenic groups identified among *Plasmopara halstedii* isolates belonging to several races. Archives of Phytopathology and Plant Protection, 44 (12), 1225-1231.

Pathogenic variation was studied in 19 *Plasmopara halstedii* isolates belonging to races 100, 300, 710 and 714. Based on the reaction for the *P. halstedii* isolates to four sunflower hybrids H1 to H4 differing only in their downy mildew resistance genes, there were differences in virulence spectrum in pathogen isolates. All sunflower hybrids were resistant to isolates of races 100 and 300 and sensible to isolate of the race 714, H1 was only sensible to isolates of race 710. Regarding aggressiveness criteria on two sunflower inbred lines showing different levels of quantitative resistance, there were significant differences in aggressiveness for *P. halstedii* isolates. The index of aggressiveness (sporulation density/latent period) varied between 8.1 and 23.6. There was a significant correlation ($r = -0.456$) between the two aggressiveness criteria at $p < 0.05$.

Sakr N, 2012. Virulence cost in *Plasmopara halstedii* (sunflower downy mildew). Archives of Phytopathology and Plant Protection, 45 (6): 646-651.

Virulence cost (trade-off between virulence and aggressiveness) was studied in seven *Plasmopara halstedii* (sunflower downy mildew) isolates of races 100, 300, 304, 314, 710, 704 and 714. The seven isolates were divided, according to their virulence and aggressiveness, into two main groups as more aggressive isolates of the 100 and 3xx races that do not overcome the sunflower differential host D3, and less aggressive isolates of 7xx races that can overcome D3. Consequently, the 100 and 3xx avirulent races had a virulence cost measured by differences in aggressiveness (from 58.3 to 78.2%) compared to 7xx virulent races carrying unnecessary virulence gene.

Sakr N, 2013. Pathogenic, morphological and genetic diversity in *Plasmopara halstedii*, the causal agent of sunflower downy mildew. Acta Scientiarum, Agronomy, 35 (1): 9-19.

Pathogenic, morphological and genetic variation was studied in 35 Plasmopara halstedii (sunflower downy mildew) isolates of different races. Virulence spectrum was analyzed in sunflower hybrids carrying effective Plgenes. Aggressiveness was analyzed in one sunflower inbred line showing a high level of quantitative resistance. There were differences in virulence spectrum for pathogen isolates. Index of aggressiveness was calculated for each isolate and two groups were revealed as more aggressive isolates of 100 and 3xx races, and less aggressive isolates of 7xx races. Significant morphological differences were found in zoosporangia and sporangiophores morphology. Genetic relationships were detected between the pathogen isolates using 12 EST-derived markers. Five multilocus genotypes (MLG) were identified among 35 P. halstedii isolates. Our results did not show a correlation between pathogen variation and both morphological and genetic characteristics.

Sakr N, 2013. Diversity in *Plasmopara halstedii*, the causal agent of sunflower downy mildew. Cryptogamie, Mycologie, 33 (4): 463-480.

Diversity of level of morphological, pathogenic and genetic characteristics was studied in seven Plasmopara halstedii isolates of seven races namely 100, 300, 304, 314, 710, 704 and 714. All analyses were carried out by using five single zoosporangium isolates per pathogen isolate. Morphological analyses were performed on zoosporangia for P. halstedii single zoosporangium isolates. Aggressiveness criteria were analysed in one sunflower inbred line showing a high level of quantitative resistance. Genetic relationships were detected between the single zoosporangium isolates using 12 EST-derived as SNPs markers. Based on the aggressiveness reaction for the P. halstedii single zoosporangium isolates, there were significant intra and inter-race differences for all criteria studied. Isolates of race 100 and 3xx were less virulent and more aggressiveness than isolates of race 7xx. There was no relation between morphology of zoosporangia and pathogenic characteristics for 35 single zoosporangium isolates. There was no intra-race genetic variation, but five genetically-identified groups were detected among pathogen isolates of all races. No correlation was detected between EST genotypes on the one hand and both pathogenic traits and morphological characteristics on the other.