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SOME DISEASES OF SUNFLOWERS IN THE UNITED STATES — THEIR OCCURRENCE, BIOLOGY, AND CONTROL

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Sunflowers are native species to the Western Hemisphere and many species probably evolved within the confines of the United States (2). Pathogenic fungi probably evolved along with sunflowers, thus it is not surprising that fungal diseases play an important role in the cultivation of domestic sunflowers in the United States, perhaps of greater significance than in any other country. Thirty some different species of fungi are known to attack annual sunflowers in the United States (1) and the presence of others are suspected. Fortunately, only six of these fungi cause losses of sufficient magnitude to be considered serious threats to the successful establishment of sunflowers as a major agricultural commodity in the Red River Valley area of North Dakota and Minnesota where over 90% of the total U.S. sunflower acreage has historically grown.

DOWNY MILDEW

Downy mildew caused by the complex fungus species, *Plasmopara halstedii,* is the most serious disease on the heavy clay soils in the Red River Valley. Downy mildew infection may manifest itself as damping off, basal stem infection, and systemic symptoms. During years when the planting season is permeated by frequent periods of heavy precipitation 50% or more of the plants in some fields exhibit systemic symptoms (7).

Field and greenhouse studies have shown that sunflower seedlings are prone to systemic infection for only a few days during the germination and emergence process (table 1). The period of proneness varied somewhat depending upon the method of inoculation. This period of maximum proneness also depends upon soil temperatures and may be relatively short, 6 days at greenhouse temperatures of 20—25°C, or relatively long, 15 days or more at early seeding dates in the field

Table 1

Percentage of plants with systemic downy mildew which resulted from the inoculation of seedlings at different ages and by three methods

Seedling age (days after seeding)	Inoculation method[1]		
	Soil drench	Foliage spray[2]	Whole seedling method
3	100	—	100
4	100	—	100
5	87	100	98
6	12	98	85
7	3	91	51
8	0	14	3
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0

[1] Data averaged over three experiments. Each experiment contained 100 seedlings.
[2] Seedlings did not emerge until 5 days after seeding, thus foliage inoculation was not possible until after that time.

where mean air temperatures are about 15°C. At later dates of planting when soil and air temperatures were higher (June 15, 1973) seedlings were already beyond the stage of proneness when heavy precipitation occurred on the 13th and 14th days following seedling. If heavy precipitation occurs during the period of proneness and the causal fungus is present, a high incidence of systemically infected plants is likely (figure 1). If, on the other hand, this period is relatively free of precipitation systemically infected plants are rare.

Many of the fields in the Red River Valley are heavily infested with *P. halstedii*. Sunflowers are normally grown in a 4-year rotation scheme. Sunflowers volunteer profusely and a high percentage of the volunter plants are severely infected with downy mildew. A 4-year rotation pathologically speaking is only a 3-year rotation and is not long enough to eliminate the causal fungus from the soil.

Field surveys during 1971—1972 revealed abundant sporulation of *P. halstedii* occurring on volunteer seedlings coinciding with the emergence of sunflowers in neighboring fields. This observation, coupled with the incidences of systemic mildew occurring in several fields never previously planted to sunflowers, suggest hat wind-borne zoosporangia may play a more important role in dessimenation than heretofore realized. Downy mildew zoosporangia are thin-walled, but under cool humid conditions that prevail some years during the planting season, zoosporangia could be carried several miles, be deposited during rain showers on the surface of fields seeded to sunflowers and germinate producing zoospores which infect the emerging seedlings. We have demonstrated that zoosporangia seeded on the soil surface retain viability for at least 10 days at 20—25°C.

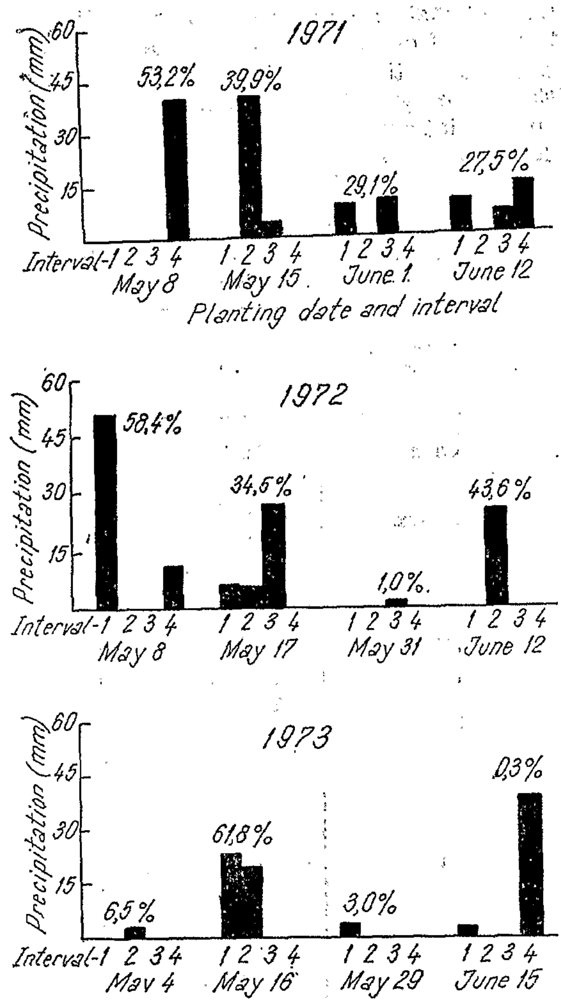

Figure 1—The percentage of systemically downy mildew infected plants which resulted from planting on heavily infested land at four dates during each of three years and its relationship to the amount of precipitation which occurred at four 3-day intervals following planting. Interval 1=3rd—5th day after planting, interval 2=6th—8th day after planting, interval 3=9th—11th day after planting, interval 4=12th—14 th day after planting.

The short-term corp rotations preferred by American sunflower growers, the flat topography of the major sunflower producing area, the heavy clay soils, the frequency of heavy rain showers during the planting season, and the abundance of soil-borne and wind-borne inoculum makes it highly unlikely that losses from downy mildew will be greatly reduced in the U.S. by management and cultural practices. Management and cultural practices have been effective in reducing losses in areas of Eastern Europe. Developing varieties resistant to downy mildew offers an attractive means of reducing losses and is major objective of sunflower breeders in the Unitade States.

Only the Pl_2 gene conditions resistance to the Red River race of downy mildew. The other genes (Pl and Pl_3) reported (5,8) to be effective against the races of downy mildew in Europe are not effective in the U.S. Comparative field trials in Eastern Europe and the U.S. have established that varieties developed for resistance to downy mildew in Europe may not be resistant in the U.S. (table 2). Experimental lines and varieties resistant to the Red River race have shown resistance to downy mildew.

Table 2

Differential response of sunflower lines *(H. annuus)* to downy mildew *(P. halstedii)* in European and U. S. trials.

Country of origin	Line	Reported reaction in European trials	Reaction in U.S. trials[2]	
			Greenhouse	Field
Canada	CM 29-1	R	0	0
	CM 90 RR	R	96	54
	S 37-388 RR	R	96	54
France	CA 73	R	98	—
	HIR-34	R	0	0
	P 1014	R	96	—
	29-3	R	2	—
	307-1	R	96	—
Romania	AD 66	R	100	52
Soviet Union	Peredovik (Control)	S	98	48
United States	HA 60	R	88	36
	HA 61-1	R	0	0
	RHA 265	R	98	62
	RHA 266	R	100	52
	RHA 271	R	2	1
	RHA 273	R	0	0
	RHA 274	R	0	0
Yugoslavia	CM 1-6-1	R	96	46
	CR 1-2-1	R	100	44
	CR 7-2-2	R	100	40
	CV 4-2-3	R	100	48
	NO 23-1	R	98	60
	SR 2-2-1	R	94	42
	SR 3-6-1	R	96	44
	SR 5-6-1	R	100	48
	SR 9-9-1	R	100	60

[1] R = resistant, S = susceptible
[2] Percentage of plants with systemic symptoms. Based on 50 plants in the greenhouse trials and about 200 in the field.

The introduction of the Red River race of downy mildew into areas of the world where it does not presently occur could have serious consequences. As proposed by Leppik (3) action should be taken to eliminate the possibility of the by-chance introduction of the virulent Red River race into areas of the world where it does not presently occur.

The group immunity lines developed by interspecific hybridization at the Pustovoit Institute at Krasnodar, USSR unfortunately have not been evaluated for resistance to the Red River race of downy mildew. We have, however, secured several such lines from the Agricultural Institute at Novi Sad, Yugoslavia and much to our dismay found most of them to be highly downy-mildew susceptible. It may well be that the advance lines of Madam Pustovoit, so envied by all who have viewed them, may be highly susceptible to the Red River race of downy mildew, and consequently, of little value for the development of downy mildew-resistant varieties for the United States. Cooperative tests should be set up to evaluate group immunity lines for resistance to the Red River race.

Several thousand hectares of downy mildew resistant hybrids are being grown for the first time in the U.S. in 1974. Such hybrids have as male parents the downy mildew resistant restorer lines RHA 271 or RHA 274. Resistance of both these restorer lines trace to HA 61 and is conditioned by the Pl_2 gene. Efforts to combine the Pl_2 gene with the R_1 for rust resistance has been unsuccessful because of tight repulsion linkage. No difficulty, however, has been encountered in combining the R_2 gene for rust resistance and the Pl_2 gene. The linkage between the R_1 locus and the Pl_2 locus coupled with the reported linkage of the Pl and the R_1 gene (6) suggests that the Pl_2 and the Pl genes may be multiple alleles or closely linked. If so, then difficulty could be encountered in attempting to develop varieties carrying both the Pl and Pl_2 gene.

RUST

Rust incited by the fungus, *Puccinia helianthi*, has perhaps been the most serious disease of non-oil varieties in the United States. Rust has at times caused yield losses in excess of 50%. Rust not only reduces yield but also reduces seed size, test weight, and nut meat to hull ratio which are all important attributes for marketing.

For the most part the oilseed varieties of Eastern European origin have considerable field resistance to rust and can normally be grown without fear of significant yield losses; however, under severe rust conditions they also show some loss. Both the R_1 and R_2 genes described by Putt and Sackston (4) impart excellent resistance against the predominant races of rust occurring in the Red River Valley area of North Dakota and Minnesota. These genes have been widely used by U.S. sunflower breeders to develop rust-resistant hybrid oilseed varieties.

Sundak, the first rust-resistant large-seeded non-oil variety suitable for the confectionery market, was released in 1973. Sundak possesses the R_1 gene for resistance and since its release has rapidly replaced the previous rust-susceptible varieties as the preferred large-seeded variety.

P. helianthi completes the sexual cycle each spring, thus maximum opportunity exists for the recombination of recessive virulent genes and the development of new virulent races. We have found wild, annual sunflowers in the principle sunflower growing region of the U.S. to frecuently be heavily rusted. Wild sunflowers furnish a breeding sanctuary in the absence of susceptible domestic varieties for the development of new races. The widespread distribution of wild annual sunflowers in the principal sunflower producing area of the U.S. and the heavy rust occurring on them suggests that the development of monogenic rust-resistant varieties with long-term resistance will be difficult. Under these circumstances it would be wise to utilize other types of resistance.

Seven wild *Helianthus* species occur in the principal sunflower producing area of the United States including the annual species *H. annuus* and *H. petiolaris,* and the perennial species, *H. grosseserratus, H. maximiliani, H. nuttallii, H. rigidus* and *H. tuberosus.* Rust has been observed on all these species. We have demonstrated that the rust occurring on the perennial species is in general specific to the perennial species and rust occurring on the wild annual species is specific to the annual species. There is some evidence for specialization within the rust occurring on the various perennial species and rust occurring on the two wild annual species. It appears that the wild annual species, *H. annuus* and *H. petiolaris* which occur in the major sunflower producing area of the United States, play a more significant role in rust epiphytotics of domestic sunflower than the rust occurring on the perennial species.

Whether sunflower varieties developed by interspecific hybridization in Eastern Europe will demonstrate rust resistance in the U.S. where natural races of rust occur which attack the perennial species is not known. Our studies to date indicate that a multitude of races of *P. helianthi* occur on the wild species, and that through recombination via the sexual cycle on a mutually susceptible host, races capable of attacking multiple species could perhaps be produced.

WHITE MOLD *(SCLEROTINIA SCLEROTIORUM)*

White mold of sunflowers, incited by the fungus *Sclerotinia sclerotiorum (Whetzelinia sclerotiorum)* has been increasing each year as sunflower cultivation intensifies in the Red River Valley area. This has been particularly evident in areas where sunflowers are grown in rotation with other white mold susceptible crops, such as edible beans and rape. Basal stem infection presumably resulting from mycelium growing for over-wintering sclerotia is the predominant disease phase in the Red River Valley. Upper stem and head infection presumed to result from wind-borne ascospores discharged from apothecia produced by germinating sclerotia are not as prevalent in the U.S. as in some European countries. The reason for this is not known but it may be that conditions highly favorable for apothecial formation do not occur as frequently in the U.S. as in some other countries.

We have tested several diverse sunflower lines in hopes of locating sources of resistance to basal stem infection, and have been unsuccessful. Even the perennial species appear to have little if any resistance to basal stem infection. Resistance to ascosporic infection of the upper stem and the head was suggested by artifical stem and head inoculation and may be attainable, but at this time, we feel that losses from basal stem infection may have to be controlled entirely by management practices.

ALTERNARIA LEAF AND STEM SPOTS

Alternaria leaf and stem spots, incited by perhaps several species including *A. zinniae* and *A. leucanthemi,* are sporadic diseases occurring at serious levels only during years when sunflowers are exposed to prolonged hot-humid weather during or after flowering. Although Alternaria primarily occurs on the leaves it may under highly favorable conditions attack all above ground portions of the plant. Alternaria leaf spot was particularly severe in some fields in 1973 and caused significant yield losses. Alternaria leaf spot is considered a limiting factor to successful sunflower production in some areas of Yugoslavia and may become progressively more severe in the U.S. as sunflower culture intensifies.

Sunflower breeding lines vary in response to *A. leucanthemi.* Some lines are extremely susceptible while others are only moderately susceptible. The lines with moderate levels of resistance may be of value in efforts to develop resistant or tolerant varieties. Efforts to develop a greenhouse technique for screening seedlings have been relatively unsuccessful. All lines behave much alike when inoculated in the seedling stage under greenhouse conditions, thus suggesting that using seedling response as a mesure of mature plant resistance in the field may not be possible.

We were encouraged when we demonstrated that some of the perennial *Helianthus* species exhibited resistance to *A. leucanthemi* when inoculated under greenhouse conditions. Particularly worthy of note was the excelent resistance exhibited by *Helianthus rigidus, H. tuberosus,* and *H. macrophyllus.* Although our results are limited, it appeans that these species may provide resistance that can be incorporated into *H. annuus* by interspecific hybridization.

VERTICILLIUM WILT

Verticillium wilt incited by *Verticillium albo-atrum* occurs primarily on the lighter soils on the fringes of the Red River Valley. The large-seeded confectionery varieties of U.S. and Canadian origin are highly susceptible and frequently are moderately to severely damaged. Peredovik, and other varieties of Russian origin have shown some resistance. However, on land heavily infested with *V. albo-atrum* they also show some loss. An exceptionally high level of wilt resistance has been found in inbreds HA 89, HA 124, and P-21 VR1. The resistance of these inbreds is conditioned by a single dominant gene which may be different from the V_1 gene identified by Putt in the Canadian line CM 144.

Most of the U.S. hybrid varieties produced by the cytoplasmic sterility and fertility restoration route have wilt resistance derived from HA 89 or related inbreds.

PHOMA BLACK STEM

Phoma black stem incited by the fungus, *Phoma oleracea,* has occurred with increasing intensity the past three years. Phoma black stem much like Alternaria leaf spot is favored by recurring periods of precipitation at or after flowering. Unlike lesions caused by *Alternaria* sp., the large black lesions produced by *P. oleracea* are normally associated with the axil of the petiole.

The intensity of Phoma black stem was sufficiently great in some areas of the Red River Valley in 1973 to suggest the need to screen breeding lines, varieties and related *Helianthus* species for resistance. In preliminary trials we were encouraged when we found that some of the perennial species including *H. tomentosus, H. grosseserratus, H. rigidus, H. macrophyllus* and *H. tuberosus* were resistant in greenhouse trials when *H. annuus, H. petiolaris,* and several cultivated varieties were fully susceptible.

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