Reactions of Jerusalem Artichoke Genotypes to Two Rusts and Powdery Mildew

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ABSTRACT

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Thirty-six commercial and plant-introduction genotypes of Jerusalem artichoke (*Helianthus tuberosus*) were grown near Athens, Georgia, to determine their reactions to *Puccinia helianthi, Coleosporium helianthi,* and *Erysiphe cichoracearum.* Tuber characteristics and yields were also determined. The genotypes varied from highly susceptible to highly resistant to each of the three pathogens. Generally, genotypes that were highly susceptible to *P. helianthi* were mostly resistant to *C. helianthi.* The reverse was also true. The genotypes that had the largest and most desirable tubers and the inherent potential for high-tuber yield were often the most susceptible to *P. helianthi.* These studies show levels of resistance to these foliar pathogens within the germ plasms of *H. tuberosus* that could possibly be used to improve disease resistance in both this crop and sunflower.

Additional keywords: fructose, *Helianthus* spp., host resistance, inulin

Jerusalem artichoke (*Helianthus tuberosus* L.), long considered to be both a minor food crop (10,13) and a weed pest (10,14) in the United States, has received increased attention in recent years as a potential crop for inulin (10), fructose (1,10), and fuel-alcohol production (3,11). In addition to its possible commercial value, the species is useful as a source of disease-resistance genes for transfer to commercial sunflower (*Helianthus annuus* L.). Russian workers (7–9) developed immunity in sunflower to the rust caused by *Puccinia helianthi* Schwein., and to other diseases, through interspecific hybridization with *H. tuberosus.* Lipps and Herr (2) suggested that *H. tuberosus* may be useful in interspecific crosses to develop sunflower cultivars highly resistant to *Alternaria helianthi* (Hansf.) Tubaki & Nishihara.

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In Georgia, *P. helianthi* was one of the most important pathogens limiting production of Jerusalem artichoke, causing tuber-yield losses of 29% on the Mammoth French White cultivar during an epidemic year (5). Later, we observed (*unpublished*) that genotypes differed in their susceptibility to *P. helianthi* and that genotypes that were highly resistant or immune to *P. helianthi* were often susceptible to *Coleosporium helianthi* (Schwein.) Arth. However, little coleosporium rust was observed on genotypes that were highly susceptible to *P. helianthi.* Powdery mildew, caused by *Erysiphe cichoracearum* DC., was also severe on some genotypes (5). Although foliar diseases of Jerusalem artichoke can be controlled chemically (5), development of commercial varieties with genetic resistance seems to be a more economical means of control. Few studies were found in which germ plasms of *H. tuberosus* were tested for resistance to foliar pathogens in the United States. The purpose here is to report on the reaction of a collection of *H. tuberosus* genotypes to *P. helianthi, C. helianthi,* and *E. cichoracearum.* A portion of this work appeared in an abstract (4).

MATERIALS AND METHODS

Plot location and establishment. Plots were located at the University of Georgia Horticultural Research Farm near Athens. Conventional land preparation (turning, disking) practices were used, and the soil was fertilized based on soil test results. Weeds were controlled with trifluralin (Treflan, 1.2 L/ha) and by tiller and hand cultivation. Sprinkler irrigation was used as needed to prevent damaging moisture stress. Whole tubers were hand-planted 10 cm deep and 30 cm apart in raised beds that were 25 cm high and 45 cm wide. Beds were spaced 0.96 to 1.2 m apart. Plots were established between 1 and 10 June each year, and four replications were arranged in randomized complete block design. Each replication consisted of a single row of eight to 12 plants.

Procurement and maintenance of planting stock. In 1983, tuber stocks of eight experimental and commercial genotypes were obtained from the Agriculture Canada Research Station, Morden, Manitoba, Canada, and the Reichert Corporation, Edina, Minnesota. These tuber stocks were increased in 1983 and were used in replicated tests in 1984 and 1985. In 1988, tubers of 28 plant-introduction (PI) lines were obtained from the North Central Regional Plant Introduction Station, Iowa State University, Ames. These lines were increased in 1988 and were used in replicated tests in 1989, 1990, and 1991. Each year, tubers for planting the following year were harvested at first frost, washed free of adhering soil, and stored in dry vermiculite in polyethylene bags at 5 C.

Description of experiments. In 1984 and 1985, the eight genotypes (Table 1) were planted to determine disease reactions and yields. In 1984, five plants each of eight sunflower hybrids (Jacques J 503, Texas Triump 241A, SeedTech

S 315, Northrup King NK 265, Interstate IS 3107 and IS 7101, and Dahlgrein DO 705 and DO 167) were also planted at the end of each replication to determine whether the two rust pathogens that had commonly occurred on Jerusalem artichoke would attack sunflower hybrids representing a wide genetic base. The sunflowers were planted 3 wk after the Jerusalem artichoke.

In 1989, 1990, and 1991, the 28 genotypes of Jerusalem artichoke (Table 2) were planted, and disease readings and yield data were taken. In 1990 and 1991, eight sunflower genotypes (S 37-388, CM 29-3, CM 90-RR, HAR-1, HAR-2, HAR-3, P 386, and Hysun 33), used as rust (*P. helianthi*) differentials (6, 12,15,16), were also planted. S 37-388, CM 29-3, and CM 90-RR are differentials developed by Sackston (12) in Canada. S 37-388 is the "universal host." CM 29-3 is resistant to races 1 and 3 and susceptible to races 2 and 4. CM 90-RR is resistant to races 1 and 2 and susceptible to races 3 and 4. The HAR lines and P 386, when released, were reported (6,15,16; T. J. Gulya, *personal communication*) to have resistance to all four North American sunflower races of

Table 1. Disease reaction and yield of selected Jerusalem artichoke genotypes grown near Athens, Georgia

	Disease index[b]						Harvest 1984[c]	
	Puccinia helianthi		*Coleosporium helianthi*		*Erysiphe cichoracearum*			
Genotype[a]	1984	1985	1984	1985	1984	1985	Yield/plant (kg)	Mean tuber wt (g)
NC 10-40	0.50	1.10	3.06	3.25	3.56	3.85	1.09	8.4
NC 10-60	0.25	0.80	2.69	3.70	3.63	3.50	0.93	9.3
NC 10-77	1.06	2.10	1.25	1.10	1.13	1.65	1.07	10.0
NC 10-84	2.62	3.20	0.25	0.28	2.56	2.90	1.08	21.6
NC 10-42	2.60	3.00	0.68	0.37	3.31	3.25	1.16	17.1
NC 10-39	3.06	4.30	0.25	0.22	1.06	1.07	1.24	10.1
Columbia	3.56	3.30	0.20	0.16	3.00	3.45	1.33	13.1
Mammoth French White	2.88	3.60	0.15	0.14	2.56	2.05	1.64	38.4
LSD ($P = 0.05$)	0.90	0.96	0.70	0.84	0.92	1.02	0.30	6.2

[a] Tubers were provided by the Agriculture Canada Research Station, Morden, Manitoba, Canada, and the Reichert Corporation, Edina, Minnesota.
[b] Rust readings are based on a 0–5 scale where 0 = no disease, 1–5 = increasing percentage of leaf area infected, with a 5 rating indicating 30–40% of leaf area covered with lesions. Powdery mildew ratings are based on a 0–5 scale where 0 = no disease, 1–5 = increasing percentage of leaf area covered with fungal growth, with a 5 rating indicating near 100% coverage. Ratings were made on 26 September 1984 and 30 September 1985.
[c] Harvest was made on 11–12 December.

Table 2. Disease reactions, yields, and tuber characteristics of 28 Jerusalem artichoke genotypes grown near Athens, Georgia

			Disease reaction[b]															
			Puccinia helianthi				*Coleosporium helianthi*				*Erysiphe cichoracearum*				Yield/plant[c] (kg)			
Tuber characteristics	Genotype[a]	Origin	1989	1990	1991	Mean	1989	1990	1991	Mean	1989	1990	1991	Mean	1989	1990	1991	Mean
Medium to large size, round, non-branching, white	PI 461518	Argentina	4.44	2.42	3.75	3.54	0.02	0.02	0.07	0.04	2.38	1.80	1.38	1.85	1.51	2.03	0.66	1.40
	PI 458544	Germany	3.50	2.15	3.38	3.01	0.36	0.15	0.69	0.40	1.94	1.40	1.00	1.45	1.95	1.99	0.96	1.63
	PI 357304	USSR	4.06	2.95	3.63	3.55	0.00	0.00	0.16	0.05	2.06	1.42	0.88	1.45	1.56	1.95	0.89	1.47
	PI 357303	USSR	4.01	2.25	4.00	3.42	0.05	0.10	0.16	0.10	1.88	1.68	2.19	1.92	1.22	1.12	0.51	0.95
	PI 357299	USSR	5.00	2.72	4.00	3.91	0.06	0.01	0.06	0.04	1.63	1.64	2.13	1.80	1.39	1.61	0.91	1.30
	PI 357300	USSR	4.83	2.40	4.50	3.91	0.06	0.04	0.19	0.10	1.88	1.61	2.00	1.83	1.12	1.61	0.70	1.14
	PI 357298	USSR	3.88	2.50	3.25	3.21	0.03	0.02	0.00	0.02	2.50	2.10	1.75	2.12	1.15	1.67	0.85	1.22
	PI 357301	USSR	3.75	2.10	3.33	3.06	0.08	0.04	0.10	0.07	1.06	1.00	0.17	0.74	1.27	1.38	0.80	1.15
	PI 357302	USSR	4.12	2.42	3.50	3.35	0.05	0.20	0.13	0.13	0.94	0.84	0.50	0.76	1.58	1.58	0.78	1.31
Medium size, slightly elongated, nonbranching, white	PI 503263	USA	0.00	0.00	0.05	0.02	3.31	2.10	2.06	2.49	3.31	2.69	2.63	2.88	0.78	0.49	0.69	0.65
	PI 503275	USA	0.38	0.25	2.10	0.91	0.75	0.15	0.28	0.39	3.50	3.50	3.88	3.63	1.56	0.45	0.67	0.89
Medium size, slender, non-branching, white	PI 274517	USSR	2.75	1.52	3.68	2.65	0.09	0.02	0.16	0.09	1.19	1.05	1.13	1.12	0.86	0.62	0.70	0.73
	PI 274518	USSR	3.25	1.62	4.18	3.02	0.11	0.10	0.37	0.19	1.94	1.86	1.38	1.73	0.84	0.86	0.67	0.79
	PI 357297	USSR	3.13	2.18	4.13	3.15	0.24	0.20	0.75	0.40	1.38	1.56	1.19	1.38	1.01	0.74	0.81	0.85
Small size, moderately branched, white	PI 503280	USA	1.47	0.90	1.44	1.27	1.44	0,84	0.88	1.05	4.44	3.54	3.88	3.95	0.55	0.40	0.39	0.45
	PI 503279	USA	1.62	0.75	2.38	1.58	0.14	0.06	0.10	0.10	0.94	0.80	0.22	0.65	0.37	0.15	0.22	0.25
Large size, markedly branched, pink	PI 503268	USA	2.06	1.20	2.00	1.75	0.41	0.00	0.13	0.18	4.31	3.46	3.06	3.61	1.16	0.87	0.62	0.88
	PI 503277	USA	0.47	0.25	2.61	1.11	2.62	0.95	0.30	1.29	4.25	3.31	2.63	3.40	0.72	0.83	0.87	0.81
Medium size, markedly branched, pink	PI 503271	USA	0.09	0.34	0.75	0.39	2.56	0.94	1.10	1.53	4.25	3.86	4.13	4.08	0.48	0.32	0.57	0.46
	PI 503269	USA	2.06	0.78	2.19	1.68	0.88	0.32	2.13	1.11	2.44	1.42	0.28	1.38	0.37	0.22	1.00	0.53
	PI 503276	USA	0.13	0.09	0.63	0.28	2.30	1.14	1.13	1.52	3.88	3.24	2.69	3.27	0.51	0.28	0.48	0.42
	PI 503272	USA	0.22	0.12	1.63	0.66	2.00	1.11	0.69	1.27	4.44	3.85	2.94	3.74	0.71	0.37	0.30	0.46
Small size, slender, rootlike or stringy, white	PI 503278	USA	2.56	1.14	2.50	2.07	0.19	0.10	0.35	0.21	1.75	2.15	2.50	2.13	0.28	0.27	0.69	0.41
	PI 503266	USA	1.22	0.85	1.30	1.12	0.38	0.64	0.68	0.57	0.00	0.00	0.47	0.16	0.13	0.35	0.34	0.27
	PI 503265	USA	4.03	3.25	3.94	3.74	0.03	0.05	0.25	0.11	3.00	2.13	2.94	2.69	0.48	0.29	0.38	0.38
	PI 503264	USA	2.38	1.50	2.31	2.06	0.19	0.11	0.47	0.26	3.00	2.38	1.69	2.36	0.81	0.63	0.36	0.60
	PI 503262	USA	0.00	0.00	0.06	0.02	3.94	2.56	3.56	3.35	2.31	2.10	2.63	2.35	0.57	0.21	0.28	0.35
	PI 503254	USA	0.06	0.00	0.00	0.02	3.78	2.64	3.50	3.31	3.06	2.06	2.63	2.58	0.47	0.29	0.32	0.36
LSD ($P = 0.05$)			0.69	0.38	0.58	...	0.31	0.38	0.26	...	0.95	1.05	1.10	...	0.32	0.36	0.23	...

[a] Tubers of all entries were obtained from the North Central Regional Plant Introduction Station, Ames, Iowa.
[b] Rust readings are based on a 0–5 scale where 0 = no disease, 1–5 = increasing percentage of leaf area infected, with a 5 rating indicating 30–40% of leaf area covered with lesions. Powdery mildew ratings are based on a 0–5 scale where 0 = no disease, 1–5 = increasing percentage of leaf area covered with fungal growth, with a 5 rating indicating near 100% coverage. Ratings were made 3 October 1989, 10 October 1990, and 7 October 1991.
[c] Tuber weights are a mean of four replications, each consisting of 8 (1989 and 1990) or 12 (1991) plants. Harvest dates were 6 November 1989, 14 November 1990, and 18 November 1991.

P. helianthi. Hysun 33 is a differential used in Australia (15; T. J. Gulya, *personal communication*) for races there. These genotypes were planted adjacent to (1990) or adjacent to and within (1991) the Jerusalem artichoke plots. Four (1990) or five (1991) replications were arranged in a randomized complete block design, each replication consisting of five plants.

Disease readings and yield determination. Severity of the rusts and powdery mildew on the Jerusalem artichoke genotypes was recorded once in late September and again in early October each year. Rust severity was recorded on 0 to 5 scale where 0 = no disease, T = a trace or a few lesions present, and 1 to 5 = an increasing percent of leaf area infected, with a 5 rating indicating 30 to 40% of the leaf area covered with lesions. Powdery mildew ratings were based on a 0 to 5 scale where 0 = no disease, T = a trace or a few isolated colonies, and 1 to 5 = an increasing percent of leaf area covered with fungal growth, with a 5 rating indicating near 100% coverage. The sunflower genotypes were observed weekly throughout the growing season for the presence of lesions caused by *P. helianthi* or *C. helianthi.*

Yields of Jerusalem artichoke were determined each year (except 1985) by digging the tubers after first frost, by hand or with a tractor-mounted plow, and weighing them. When significant amounts of soil adhered to the tubers, they were washed and air-dried before weighing. Tuber characteristics were also recorded. Harvest dates were 11 December 1984, 6 November 1989, 14 November 1990, and 18 November 1991.

RESULTS

The three diseases occurred on Jerusalem artichoke in each of the 5 yr of the experiments. The eight genotypes evaluated in 1984 and 1985 varied greatly in their reactions to the two rust diseases and powdery mildew (Table 1). Two genotypes, NC 10-40 (also called cv. Comber) and NC 10-60 (a selection from Comber), were highly resistant to *P. helianthi* but were the most susceptible of all eight genotypes to *C. helianthi.* Genotype NC 10-77 was moderately resistant to both rust pathogens. The other five genotypes were moderately to highly susceptible to *P. helianthi* but had few lesions caused by *C. helianthi.* Two genotypes, NC 10-77 and NC 10-39, had significantly less powdery mildew in both 1984 and 1985 than did the other six genotypes. The genotypes also differed significantly in tuber yield (Table 1). Mammoth French White had both the highest yield and the largest tubers of the eight genotypes tested. There were no lesions caused by *P. helianthi* or *C. helianthi* on any of the eight sunflower cultivars growing near heavily diseased Jerusalem artichoke plants in 1984 (*unpublished*).

Fig. 1. Abaxial sides of leaves of Jerusalem artichoke infected with *Coleosporium helianthi* (left, PI 503263) and *Puccinia helianthi* (right, PI 357299). PI 503263 was highly susceptible to *C. helianthi,* but rarely had lesions caused by *P. helianthi.* PI 357299 was highly susceptible to *P. helianthi,* but highly resistant to *C. helianthi.*

The 28 genotypes of Jerusalem artichoke tested from 1989 to 1991 also differed markedly in their disease reactions, tuber characteristics, and yields (Table 2). Each year, reactions to *P. helianthi* ranged from a few isolated lesions on genotypes such as PI 503254, PI 503262, and PI 503263, to very heavy infections on most of the genotypes that originated outside the United States. Some genotypes were intermediate in their reaction to *P. helianthi.* Generally, the genotypes that had high levels of *P. helianthi* had little or no *C. helianthi*; genotypes that had the most severe infection with *C. helianthi* usually had low levels of *P. helianthi* (Table 2, Fig. 1). However, some of the genotypes had low to moderate levels of both pathogens. Although the severity of the two rust pathogens varied among the 3 yr of the tests, the relative reactions of the genotypes remained fairly constant over time. Less puccinia and coleosporium rust occurred in 1990 than in 1989 and 1991.

Some genotypes remained mostly free of powdery mildew every year, whereas others had most of their foliage covered with fungal growth by early October (Table 2, Fig. 2). Many genotypes were intermediate in their reactions to powdery mildew.

Fig. 2. Adaxial sides of leaves of Jerusalem artichoke genotypes highly resistant (left, PI 503266) and highly susceptible (right, PI 503271) to *Erysiphe cichoracearum.*

Tuber size, shape, color, and yield varied significantly among the 28 genotypes (Table 2). Generally, the highest-yielding genotypes with the largest, most desirable tubers were the ones that originated outside the United States. Some of the genotypes, such as PI 503254 and PI 503262, had excellent resistance to *P. helianthi* but produced low yields of small, stringy tubers.

In 1990, the eight sunflower-rust differentials planted adjacent to the Jerusalem artichoke plots matured before *P. helianthi* or *C. helianthi* developed, so no readings were possible. In 1991, later plantings of the same sunflower differentials allowed adequate time for the two rusts to develop. However, only a few rust lesions were observed despite severe occurrence of both *P. helianthi* and *C. helianthi* on susceptible Jerusalem artichoke genotypes only a few meters away. *P. helianthi* caused a few lesions on plants in one replication each of the S 37-388, CM 29-3, CM 90-RR, and HAR-3 differentials. A few lesions caused by *C. helianthi* developed on all five replications of S 37-388, on two replications of CM 90-RR, and on one replication of HAR-1. No *C. helianthi* lesions developed on CM 29-3. There were no lesions of either *P. helianthi* or *C. helianthi* on the HAR-2, Hysun 33, or P 386 differentials.

DISCUSSION

The 36 commercial and experimental lines of Jerusalem artichoke evaluated varied greatly in tuber yield and characteristics, as well as in susceptibility to the three foliar pathogens studied. Levels of resistance to the three pathogens in some of the PI lines seemed to be high enough and stable enough, at least in the location of these tests, to be useful in cultivar-improvement programs, should Jerusalem artichoke ever become an economically important crop for fructose, inulin, or fuel alcohol, as has been suggested (1,3,10,11).

Of the three pathogens studied, *P. helianthi* is likely the greatest threat to the commercial production of Jerusalem artichoke, because it may cause severe foliar blight and tuber-yield reductions when it develops early in the season (5). Before our previous study (5), there were few reports to indicate that *P. helianthi* was a serious problem on Jerusalem artichoke in the United States. In fact, when grown on a limited basis, the crop was reported to be relatively free of diseases outside the southeastern United States (3,11). However, Shoemaker (13) observed that an outbreak of *P. helianthi* reduced yields in Jerusalem artichoke research plots in 1926 near Rosslyn, Virginia, on land used for the same crop the previous year. In Europe in the 1920s, the disease was serious enough that burning of stalks and rotation of planting sites were recommended for control (13). During each of the 8 yr we had experimental plots near Athens, we observed moderate to severe outbreaks of *P. helianthi* on Jerusalem artichoke, indicating that this rust would pose a significant problem with commercial production. Furthermore, the presently grown cultivars with potentially high yields and desirable tuber characteristics, such as Mammoth French White, are highly susceptible to *P. helianthi.* Also, many of the high-yielding lines from the former U.S.S.R. are highly susceptible. Perhaps some of the PI lines identified in this study would be useful in improving resistance in these otherwise desirable cultivars.

No tests were conducted to determine tuber yield losses caused by *C. helianthi* and *E. cichoracearum,* although they are likely to be less damaging than *P. helianthi.* Powdery mildew usually develops late in the season and does not cause foliar blight. The uredial and telial stages of *C. helianthi* develop on the abaxial side of the leaf but rarely cause leaf blight, even with fairly heavy infection.

The relationship between the strain of *P. helianthi* that commonly occurs on *H. tuberosus* in the southeastern United States and the strains that occur on *H. annuus* is not clear. *P. helianthi* has not been observed on the limited acreage of commercial sunflower grown in the Athens area (5). Furthermore, in the present tests it did not occur on any of the eight commercial cultivars of sunflower growing near Jerusalem artichoke plants that were heavily infected. However, a few pustules of *P. helianthi* did develop on some of the sunflower differentials that are currently used for determination of the four North American races (6,12,15,16). In greenhouse tests we have, with some difficulty, induced pustules on Giant Gray Stripe (5) and CM 90-RR sunflower plants by inoculating them with uredospores of *P. helianthi* collected from Jerusalem artichoke plants in the field. However, T. J. Gulya (*personal communication*) was unable to induce infection on several cultivated lines of sunflower with uredospores collected directly from Jerusalem artichoke. He was also unsuccessful in producing rust on one of our most susceptible lines (PI 357299, also called Leningrad) by separate inoculations with the four North American races of *P. helianthi* from sunflower. Such confusing results might be expected, because Zimmer and Rehder (17) found that *P. helianthi* is a complex species made up of various strains with considerable, but not completely restrictive, specificity on annual and perennial *Helianthus* species. They found that only one of three strains collected from *H. tuberosus* from the north central United States was virulent on *H. annuus* 'S 37-388,' a genotype reported (12) to be susceptible to all four North American races. Additional work on the nature of the strain of *P. helianthi* on Jerusalem artichoke in the southeastern United States could help determine whether the resistant PI lines identified in this study could improve resistance to *P. helianthi* in sunflowers.

Because interspecific hybridization of *Helianthus* is possible, the transfer of resistance genes to and from *H. tuberosus* is feasible (8,9,17). However, the use of host resistance may be complicated by the cross-infectivity of *P. helianthi* on different *Helianthus* species, and by the development of new, virulent forms that may occur on these species (17).

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