T1974BRE02

FERTILITY RESTORATION AND VARIABILITY FOR PLANT AND SEED CHARACTERISTICS IN WILD SUNFLOWERS

G. N. FICK, D. E. ZIMMER, J. DOMINGUEZ GIMENEZ, and D. A. REHDER
(U.S.A.)

A major objective of the sunflower research program conducted cooperatively by the Agricultural Research Service, U.S. Department of Agriculture, and North Dakota State University, Fargo, North Dakota is the development of high-yielding, disease-resistant F_1 hybrids suitable for production in the Northern Great Plains area. As part of this objective we have placed considerable emphasis on evaluating numerous sources of cultivated and wild species of *Helianthus* for traits which might prove useful in the breeding program. In this paper we report on the results of some of our investigations involving fertility restoration of male-sterile cytoplasm from both cultivated and wild sunflowers, and on the variability which exists for certain agronomic characteristics, disease resistance, and oil quantity and quality among wild sunflowers.

FERTILITY RESTORATION

Fertility restoration of the cytoplasmic male-sterility discovered by Leclercq (4) was first identified by Kinman in 1970 (3). This source of restoration has proven extremely valuable in the development of F_1 hybrids for commercial production. Approximately 20,000 hectares of F_1 hybrids produced by the cytoplasmic male-sterility and fertility restorer system are now grown in the U.S., and all of these hybrids are produced using fertility restorer lines derived from Kinamn's T66006-2 source.

Because of the potential hazards associated with using a single source of fertility restoration, we have placed considerable emphasis in our program on identifying new fertility restorers from both cultivated and wild sunflowers. Recently we reported on the discovery of two fertility restorer lines from the large-seeded confectionery variety Sundak (2). Limited data suggested that two independent complementary domi-

nant genes were required for restoration, and work since that time suggests that the gene or genes for restoration may be different from the Rf_1 gene present in the Texas source. We have made crosses with the fertility restorer lines Acc 1338 and bcl-17-2-2 from Canada and France, respectively, to determine whether these lines represent different sources of restoration. Previous reports by Enns (1) and Leclercq (5) indicated that restoration in these materials was controlled by a single dominant gene. Our results suggest that the Canadian line Acc 1338 carries the Rf_1 gene. The three F_2 populations obtained from a three-way cross of cytoplasmic male-sterile line HA 89 x Acc 1338 with the fertility restorer line R489, derived from T66006-2, segregated 37 : 0, 38 : 0, and 13 : 3 for fertile and sterile plants. These results agree with the expected ratios of 4 : 0 and 3 : 1 if the same genes are involved. In a similar cross which involved bcl-17-2-2 all of five F_2 populations segregated for fertile and sterile plants. Thus it may be that the French source of restoration carries a gene or genes different from Rf_1.

Genes for fertility restoration of male-sterile cytoplasm were found to be extremely common among collections of wild *H. annuus* and *H. petiolaris*. Among 85 crosses involving 70 different collections of *H. annuus* and 15 collections of *H. petiolaris* to cytoplasmic male-sterile line HA 89, restoration of fertility was observed in 81 crosses (table 1). All F_1 plants were fertile in 51 crosses, whereas both fertile and sterile plants were observed in 30 crosses. Seven of the crosses were selected for study of the inheritance of restoration. In backcrosses to cms HA 89, segregation of fertile and sterile plants in four of the seven crosses fit the expected 1 : 1 ratio assuming a single dominant gene for fertility restoration (table 1). In the other crosses the segregation more closely

Table 1

Fertility restoration of male-sterile cytoplasm in F_1 and BC_1 generations of crosses among wild H. annuus and H. petiolaris with cytoplasmic male-sterile line HA 89

F_1 generation	Number of crosses			
	Total	All fertile plants	Fertile and sterile	All sterile plants
	85	51	30	4
BC generation	Number of plants			
	Cross No.	Fertile	Sterile	Ratio	P
	1	43	51	1 : 1	.50—.30
	2	45	48	1 : 1	.90—.80
	3	47	49	1 : 1	.90—.80
	4	38	56	1 : 1	.10—.05
	5	68	27	3 : 1	.50—.30
	6	66	28	3 : 1	.50—.30
	7	75	14	7 : 1	.50—.30

approximated 3 : 1 or 7 : 1 ratios, indicative of two or three genes for fertility restoration, respectively. We are currently examining F_2 populations from most of these crosses which we expect will lead to further clarification of the inheritance of fertility restoration. The results of our studies to date show that genes for fertility restoration occur in most wild annual sunflowers and indicate the existence of additional Rf genes besides the Rf_1 gene originally identified by Kinman.

AGRONOMIC CHARACTERISTICS

Wild species of *Helianthus* are found in virtually all parts of the United States. In 1972 we collected over 200 populations of wild sunflowers, representing eight different species, from the North Central Region of the U.S. These populations were planted at Fargo, North Dakota in the fall of 1972 shortly before freeze up. Excellent germination and emergence of seedlings was obtained the following spring. Wide variation for agronomic traits including flowering, height, and degree of branching was observed both among and within the different species. Individual plants from a common collection were surprisingly uniform. As a group the populations of *H. petiolaris* flowered considerably earlier that those of *H. annuus*, and both *H. petiolaris* and *H. annuus* populations flowered earlier than the perennial species (table 2). The difference in peak flowering periods of *H. petiolaris* as compared to *H. annuus* is probably of significance as a barrier to gene exchange between these two species since they cross quite readily under controlled conditions. Within each species, as expected, the populations collected from the more northern areas (North and South Dakota) flowered earlier than those from the southern area (Nebraska and Kansas).

A wide range in height also was observed both among and within species (table 2). For the most part those populations which were the

Table 2

Range in flowering and height of wild sunflowers grown at Fargo, North Dakota in 1973

Species	No. of Populations	Days to 50% flowering*	Height, cm
H. annuus	148	36—48	71—330
H. petiolaris	53	15—26	81—218
H. tuberosus	1	78	137
H. rigidus	1	75	142
H. grosseserratus	2	78—80	102—122
H. maximiliani	5	75—88	107—157
H. nuttallii	1	78	152

* Days after June 1.

shortest also were those which flowered the earliest. For both height and flowering, certain of the wild populations represented significant departure from that of the cultivated types.

All of the wild populations grown were branched with multiple heads. The annual species *H. annuus* and *H. petiolaris,* in particular, showed profuse branching arising from the entire length of the main stem. The branching character was expressed in all of the F_1 plants involving 62 crosses of wild *H. annuus* and *H. petiolaris* with cultivated sunflowers.

DISEASE RESISTANCE

Reactions of wild sunflowers to rust *(Puccinia helianthi)* and downy mildew *(Plasmopara halstedii)* are shown in table 3. The reactions to rust were obtained from the field on an individual plant basis from 20 plants of each collection. The race of rust was primarily that of race 1.

Table 3

Reaction of wild sunflowers to rust and downy mildew

Species	Rust				Downy mildew			
	No. of Populations	Reaction			No of Populations	Reaction[1])		
		R	R&S	S		R	R&S	S
H. annuus	146	0	90	56	60	0	8	52
H. petiolaris	56	46	9	1	23	0	1	22
H. tuberosus	3	3	0	0	1	1	0	0
H. rigidus	3	3	0	0	2	2	0	0
H. grosseserratus	1	1	0	0	1	1	0	0
H. maximiliani	10	10	0	0	8	7	0	1
H. nuttallii	1	1	0	0	1	1	0	0

1) Plants which exhibited systemic symptoms were classed as susceptible, all others were classed as resistant.

Among the 146 populations of *H. annuus* examined, 90 showed one or more plants to be resistant. All but one of the 56 populations of *H petiolaris* were resistant or had some resistant plants. All populations of the five perennial species were resistant to rust. These data indicate that resistance to the prevalent race of rust occurring in our area is widely available in the wild species. Additional work indicates that resistance to other races of rust also is present in wild sunflowers and that certain of the perennials are host to strains of rust that are species specific (6).

Many of the wild populations also were evaluated for resistance to the Red River race of downy mildew using the greenhouse techniques described by Z i m m e r and K i n m a n (7) (table 3). Resistance to downy mildew, as evidenced by the absence of systemic infection, was most

common among the 5 perennial species. All populations except one collection of *H. maximiliani* were totally resistant. Resistance among *H. annuus* and *H. petiolaris* was less frequent with only eight of 60 and one of 23 of the populations of these two species, respectively, showing resistance to systemic infection. Additional tests are being conducted to determine whether those plants which appeared resistant in these population were "escapes" or actually carry resistant genes.

OIL QUANTITY AND QUALITY

Seed from 47 different populations of wild sunflowers, representing six different species, were evaluated for oil content and fatty acid composition using nuclear magnetic resonance and gas chromotographic techniques, respectively (table 4). Oil contents ranged from 18.2 to 31.5 percent. This compares to about 42 percent for the check variety

Table 4

Range in seed oil quantity and fatty acid composition of wild sunflowers grown at Fargo, N. D. in 1973 [1]

Species	No. of populations	Oil quantity %	Fatty acid content, %			
			Palmitic 16 : 0	Stearic 18 : 0	Oleic 18 : 1	Linoleic 18 : 2
H. annuus	23	18.2—29.4	4.8—7.5	2.4—5.7	14.5—35.6	54.6—73.2
H. petiolaris	20	23.2—30.8	4.1—6.7	2.0—3.8	19.5—31.2	59.0—72.0
H. tuberosus	1	21.5	6.1	3.0	16.2	72.4
H. rigidus	1	25.8	6.3	3.6	12.4	76.4
H. macrophyllus	1	21.1	6.0	3.4	13.7	75.6
H. grosseserratus	1	31.5	6.0	3.0	33.0	56.1

1 Data supplied by D.C. Zimmerman, Research Chemist, ARS-USDA, Fargo, N.D.

Peredovik grown at the same location. Oil contents of seed from F_1 plants involving 52 crosses of *H. annuus* and *H. petiolaris* to a cultivated inbred line HA 89 (41,4% oil) ranged from 26.5 to 35.9 percent oil. The mean oil content of the seed from the wild x cultivated crosses was 31.9 percent compared to 26.7 percent for the wild sunflowers used in the crosses. These data indicate the lack of dominant or heterotic gene action for oil content in crosses of these materials, and suggest the need for considerable backrossing to the cultivated types in order to recover lines with acceptable oil content.

Variation in fatty acid composition of the wild sunflowers was limited and similar to the variation expected for cultivated sunflowers grown in our area. Because the wild populations were grown in a common environment much of the variation that was observed probably is due to genetic effects.

REFERENCES

1. Enns, H., 1972, *Fertility restorers,* Proc. Fifth Intl. Sunflower Conf., Clermont-Ferrand.
2. Fick, G. N. and D. E. Zimmer, 1974, *Fertility restoration in confectionery sunflowers (Helianthus annuus L. variety Sundak)* Crop Sci., *14.*
3. Kinman, M. L., 1970, *New developments in the USDA and state experiment station sunflower breeding programs,* Proc. Fourth Intl. Sunflower Conf., Memphis, Tenn.
4. Leclercq, P., 1969, *Une stérilité mâle cytoplasmique chez le tournesol,* Ann. Amélior. Plantes, *19, 2,* 99—106.
5. Leclercq, P., 1971, *La stérilité mâle cytoplasmique du tournesol. 1. Premières études sur la restauration de la fertilité.,* Ann. Amélior. Plantes, *21, 1,* 45—54.
6. Zimmer, D. E. and G. N. Fick, 1974, *Diseases of sunflowers in the United States, their occurrence, biology and control,* Proc. Sixth Intl. Sunflower Conf., Bucharest, Romania.
7. Zimmer, D. E. and M. L. Kinman, 1972, *Downy mildew resistance in cultivated sunflower and its inheritance,* Crop Sci., *12,* 749—751.