

COMPATIBILITY, AUTOGAMY AND ENVIRONMENTAL EFFECTS ON SEEDSET IN SELECTED SUNFLOWER HYBRIDS AND THEIR INBRED PARENTS

D. L. GEORGE*, S. E. SHEIN** and P. F. KNOWLES***.

INTRODUCTION

The percent seedset in sunflower (*Helianthus annuus L.*) is of concern in commercial fields. When open-pollinated cultivars are grown, it is important to have insect pollinators in the field because most of the plants are self-incompatible (Free and Simpson, 1964). With hybrid varieties that are considered to be more self-compatible, insect pollinators may be much less important for seed production (Fick and Rehder, 1977); however, there are few data that describe the situation in quantitative terms.

As defined by Frankel and Galun (1977), self-compatibility "describes the phenomenon of an inability of plants having functional gametes to set seeds when either self-pollinated or crossed with some of their genetic relatives". Many investigators (Habura, 1957; Luciano, 1965; Robinson, 1978; and Vranceanu et al. 1978) have estimated self-compatibility as seedset under isolation bags. This procedure fails to ensure the potential self-pollination in some genotypes that can be achieved by manipulating selfed flowers and can result in erroneous estimations. By definition, this additional seedset due to self-pollination should be included in self-compatibility estimations.

Environmental influences on self-compatibility in sunflower have been investigated by Vranceanu et al. (1978) who reported the nega-

* Graduate Assistant, Dept. of Agronomy and Range Science, Univ. of California, Davis, CA. 95616.

** Director, Sunflower Research, Northrup King Co. Woodland, CA. 95695.

*** Professor of Agronomy, Univ. of California, Davis, CA. 95616.

tive influence of high temperature (35/24°C) and short light/dark sequences (6/18 H): Production of selfed seed was influenced greatly by temperature (Pinthus, 1959; Fernandez-Martinez and Knowles, 1978).

The objective of this study was to differentiate between autogamous pollination and self-compatibility among selected hybrids and their inbred parents. The effects of location and planting dates on these characters were also investigated.

MATERIALS AND METHODS

Five hybrids and their inbred parents (Northrup, King and Company proprietary lines) were used. Codes referred to in Figure 1 are used throughout this paper. Genotypes A through D are maintainer (B) lines, E through G are pollinator (R) lines, whereas AG through DG are single cross hybrids between cytoplasmic male-sterile (A) lines and R lines. AG is a USDA 894 type.

Four trials were sown at Woodland, California on a Yolo clay loam soil on April 21, May 11, June 1 and June 18, 1979. A split plot design with three replications was used. Main plots were genotypes with subplots being bagging treatments which included self-pollination, manual self-pollination (heads were rubbed through the bag each morning by hand), sib pollination (pollen transfer by leaf among plants within a plot performed every alternate day) and open-pollination (unbagged). An additional treatment, bulk pollination, was included in the May 11 planting to determine the effect that the Delnet plastic perforated bags had on seedset. This involved collecting a bulk of diverse pollen from the nursery and using a brush to transfer it to bagged heads every alternate day.

Bagging treatments were applied to single rows 6.1 m. long and 76 cm apart. Main plots had single rows as borders. Plots were thinned to a uniform spacing of 45,000 plants/ha. Cultural practices including surface irrigation were applied to each planting as needed during the growing season.

The percentage seedset for each plot was determined from the mean of 10 heads by counting filled and unfilled achenes in two sectorial transects (each approximately 22-1/2°) taken at random across each head.

Autogamous self-pollination and self-compatibility percentages were determined as follows:

$$\text{autogamous pollination} = \frac{\% \text{ seedset under autogamous pollination}}{\% \text{ seedset under open-pollination}} \times 100 \%$$

$$\text{self-compatibility \%} = \frac{\% \text{ seedset under manual self-pollination}}{\% \text{ seedset under open-pollination}} \times 100 \%$$

The difference between self-compatibility and autogamous pollination percentages in some genotypes is that due to pollination and is referred to as the pollination effect.

At Kauai, Hawaii, a similar trial was planted on November 16, 1978, which included only the five hybrids.

RESULTS AND DISCUSSION

Preliminary results only are presented here (results for the third planting date were not available when the paper was prepared).

Percent seedset following autogamous pollination is not necessarily a good indicator of self-compatibility (Table 1); for example, mean values for B and D differ by 29% for autogamous pollination but are not significantly different for self-compatibility. For inbreds B, F and G, there is not a significant pollination effect. For the other genotypes, the self-compatibility percentages are high compared with autogamous pollination percentages; for example, the self-compatibility of DG was 78% and the autogamous pollination was 26% (in Figure 1 the dashed line represents autogamous pollination equal to self-compatibility).

Poor agreement between the yields of small-plot varietal trials and commercial plantings have been observed in some hybrids (Shein, unpubl.). In variety tests where pollinators are present, seedset can be high in less self-compatible genotypes due to pollen transfer from unrelated genotypes. On the other hand, in commercial plantings where foreign pollen is less available and pollinators may not be present, seedset will be reduced in genotypes with a high pollination effect regardless of the level of self-compatibility. Because insect pollinators are scarce in many commercial situations, cultivars that are both highly self-compatible and highly self-pollinating are essential.

For the first and fourth planting dates at Woodland, mean values for the manual self-pollination and sib-pollination treatments were not significantly different (62% and 61% respectively). This would be

Table 1

Open-pollination (OP), self-compatibility (SC) and autogamous pollination (AP) percentages for 5 hybrids and their parents for 3 planting dates at Woodland, California, 1979

Genotype	Planting date											
	April 21			May 11			June 18			Mean 3 dates		
	OP	SC	AP	OP	SC	AP	OP	SC	AP	OP	SC	AP
	%	%	%	%	%	%	%	%	%	%	%	%
A	85	90	67	68	77	43	77	79	30	77	82	47
B	74	96	86	74	78	77	68	87	66	72	87	76
C	71	66	23	65	63	18	69	59	17	68	63	19
D	64	89	43	58	84	51	60	80	48	61	84	47
E	70	93	74	67	91	79	66	95	78	68	93	77
F	72	83	78	64	93	88	65	91	86	67	89	84
G	55	97	85	50	92	89	49	98	88	51	96	87
AG	90	95	70	83	85	55	83	97	80	85	93	68
BE	82	93	65	82	94	75	80	93	62	81	93	67
CG	88	81	20	82	68	15	79	61	9	83	70	15
DF	86	68	29	79	65	20	80	65	27	82	66	26
DG	83	84	25	85	77	27	77	72	26	82	78	26
Mean	77	86	55	71	81	53	71	81	51	73	83	53
LSD (5%)											12	12

expected as the pollen of genetically homogeneous genotypes (highly inbred parents and their hybrids) should be constant in their incompatibility reaction within and between heads.

For three planting dates at Woodland, California, the self-compatibility of two genotypes, AG and BE, remained high (Figure 2). They were high also when grown in Hawaii. Three genotypes, DG, CG, and DF, showed a decline in self-compatibility from the first to the last planting date at Woodland and a pronounced decline in Hawaii. The environmental factors causing reduced self-compatibility have not been positively identified, but it is suspected that increasing temperatures with later dates of seeding at Woodland and short days in Hawaii may have been involved.

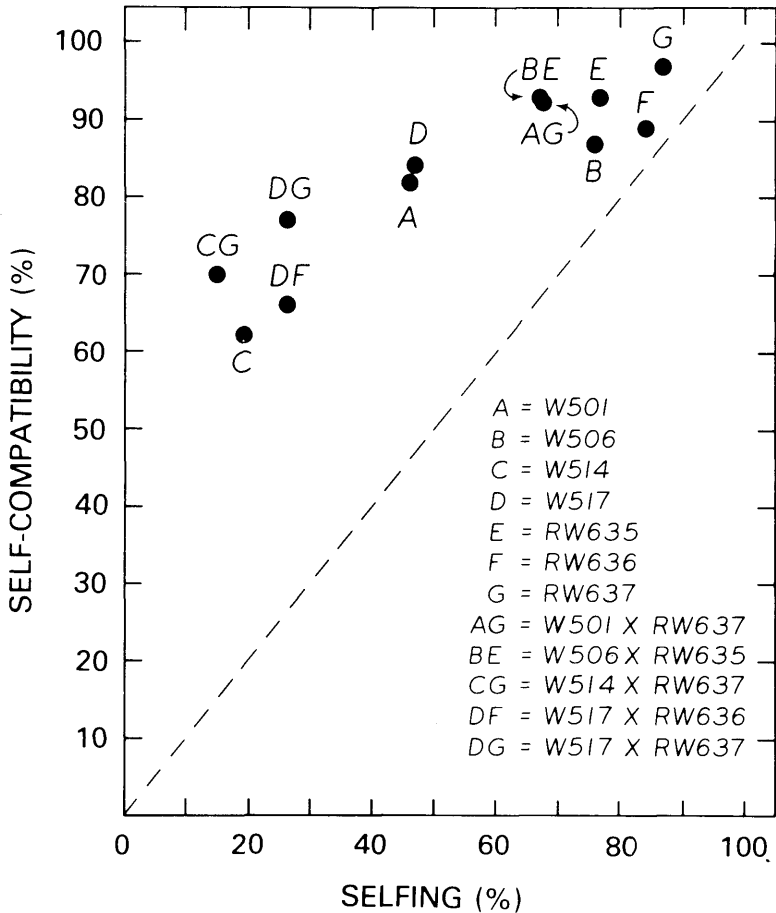


Fig. 1.— Selfing % vs. Self-compatibility for 5 hybrids and their parents for 3 planting dates.

The effects of bagging were not adequately measured in this study. Obviously the effects were small, because self-compatible genotypes when selfed and manipulated had seedsets above 90% of that under open-pollination (Table 1, Fig. 1).

In the future this study will look for anatomical and morphological differences in flowers that may be responsible for differences in seedset. It will attempt to find where the block to seedset occurs in some genotypes.

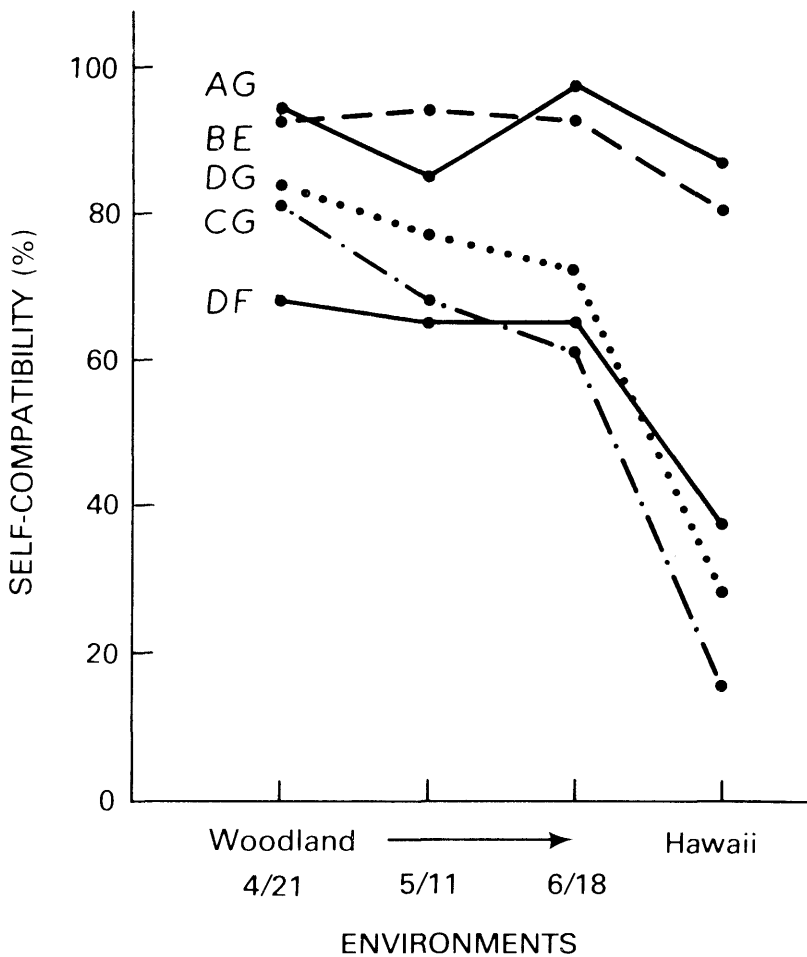


Fig. 2.— Self-compatibility % of 5 hybrids across 4 environments.

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EVALUATION OF HELIANTHUS SPP. FOR RESISTANCE TO RHIZOPUS HEAD ROT

S.M. YANG; J.B. MORRIS, and T.E. THOMPSON*

INTRODUCTION

Rhizopus head rot is one of the most important diseases of cultivated sunflower in Texas, especially when heads are predisposed to infection by mechanical injury (1, 3). The pathogens of *Rhizopus* head rot in Texas are *R. arrhizus* Fischer (2), *R. oryzae* Went and Prinsen-Geerligs (1), and *R. stolonifer* (Ehrenb ex Fr.) Vuill (2). *Rhizopus arrhizus* is more prevalent and virulent than *R. stolonifer* in Texas (2). Inoculation tests in the field and greenhouse showed that *R. oryzae* is as virulent as *R. arrhizus*. (Yang and Thomas, unpublished data).

Resistance of wild species of *Helianthus* to *Rhizopus* spp. is unknown. Yang et al. (2) reported that some of the plants of an *H. annuus* × *H. petiolaris* population, following inoculation with a spore suspension of *R. arrhizus* and *R. stolonifer* through a scalpel injury, showed the head rot restricted to the inoculation site.

This paper reports on the reevaluation of the resistance of these hybrids and the reactions of other sunflower hybrids and wild species to *R. arrhizus* and *R. oryzae* in the field.

MATERIALS AND METHODS

Sunflower hybrid varieties 894, 896, 27 interspecific hybrids selected from *H. annuus* × *H. petiolaris* populations, sunflower

*Research Plant Pathologist and Agricultural Technician, respectively, USDA, Science and Education Administration, Agricultural Research, Conservation and Production Laboratory, Bushland, Texas 79012; and Research Geneticist, USDA, W.R. Poage Pecan Field Station, Brownwood, Texas 76801.

hybrids from A. Luciano, Argentine, and wild species of *Helianthus* were planted in the experimental plots and nurseries at Bushland, Texas.

Inocula included *R. arrhizus* and *R. oryzae*. *Rhizopus arrhizus* was isolated from diseased sunflower heads in Texas, and *R. oryzae* was supplied by J.M. Klisiewicz, USDA-SEA-AR, Davis, California. The inocula were prepared 4 to 10 days earlier, from *Rhizopus* cultures, which had been transferred to wheat-grain medium. The wheat-grain medium was prepared by leaving 20 g of wheat grains in 300 ml of tap water in a 500-ml flask overnight. The grain was then washed twice in tap water, decanted; 60 ml of tap water were added, and the medium was autoclaved for 2 hr at 121 C on 2 consecutive days.

Inoculations were made at full-bloom stage by the insertion-inoculation technique. The insertion inoculation technique which Yang and Thomas found to be an effective technique for screening greenhouse-grown sunflower for resistance to *Rhizopus* spp. (unpublished data), was used. The mycelial mat on wheat grains was inserted into the receptacle with forceps. Flowers of some wild species were too small for insertion inoculation. The receptacle of such flowers was injured first by the forceps and the inoculum (mycelial mat with wheat grains) was then fastened with a strip of adhesive tape to the site of injury on the receptacle. The sunflower heads were covered with plastic bags to maintain a high level of moisture. Sunflower hybrids 894 and 896 inoculated with the same pathogens were used as susceptible controls. Heads of each hybrid and species injured by sterile forceps only served as uninfected controls. Each treatment was replicated at least 5 times.

Disease ratings were taken 7 to 14 days after inoculation unless otherwise stated. A numerical system of 0 to 5 was used to rate the severity of rot on the head: 0, no rot; 1, rot near the inoculation injury area; 2, rot exceeding the site of inoculation but covering less than 1/4 the area of the receptacle; 3, rot exceeding 1/4 but covering less than 1/2 of the receptacle; 4, rot exceeding 1/2 but covering less than 3/4 of the receptacle; and 5, rot encircling the peduncle or greater than 3/4 the area of the receptacle. The rot index was calculated as follows:

$$\text{Rot Index} = \frac{\sum (\text{Rot rating class} \times \text{N}^\circ \text{ of heads in that class})}{\text{Total N}^\circ \text{ of heads}}$$

RESULTS AND DISCUSSION

All of the inoculated heads of sunflower plants of the 27 interspecific hybrids selected from the *H. annuus* × *H. petiolaris* population in 1978 were severely decayed (Rot index 5) by both *Rhizopus* species when inoculated by the insertion-inoculation technique. Conversely, only limited rot occurred on heads when inoculation was made by the scalpel-injury inoculation technique (2). Rot developed in 18 hr and spread to the entire head in 3 days, and some of the heads dropped to the ground within 7 days after inoculation. Their resistance in 1978 apparently was an escape from infection due to the use of an ineffective inoculation technique.

Twenty sunflower hybrids from Argentina and the five *Verticillium* resistant varieties from J.A. Hoes, Morden, Canada, were also susceptible to both *Rhizopus* species. Severe rot (Rot index, 4 and 5) occurred on all of the inoculated heads in 3 days after inoculation and some of the rotten heads were on the ground within 7 days.

The reactions of inoculated sunflower hybrids 894 and 896 and 32 wild species and subspecies and of inoculated *Viguiera porteri* to *R. arrhizus* and *R. oryzae* separately in the field are shown in Table 1. Fourteen days after inoculation, *H. divaricatus*, *H. hirsutus*, *H. × lactiflorus*, and *H. resinosus* showed rot on less than 1/4 of the receptacle of the inoculated heads. The rest of the tested wild species and subspecies were moderately (Rot index 3), to severely (Rot index 4 and 5), attacked by the two *Rhizopus* species. The responses of these four wild species of sunflower to artificial inoculation in the field suggest the possibility of control of *Rhizopus* head rot by breeding for resistance.

All of the inoculated susceptible controls (hybrids 894 and 896) were severely infected, but all of those serving as uninoculated controls remained uninfected during the test. Several heads were selected for reisolation of *Rhizopus* spp. Both *Rhizopus* species were reisolated from the inoculated heads as appropriate. No *Rhizopus* species were isolated from the uninoculated heads which served as control 14 days after inoculation.

ABSTRACT

The resistance of sunflower to *Rhizopus arrhizus* and *R. oryzae* was studied. All of the cultivated hybrids tested were susceptible to *Rhizopus* head rot. Four of the 32 wild species and subspecies tested

were resistant when inoculated separately with *R. arrhizus* and *R. oryzae*. The remaining taxa tested showed moderate to severe rot following inoculation. The resistant response of some wild species to the two most destructive *Rhizopus* pathogens of sunflower suggests the value of further screening of sunflower for resistance to *Rhizopus* head rot.

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Table 1

Reaction of *Helianthus* spp. and hybrids to *Rhizopus arrhizus*
and *R. oryzae*.

Entry	<i>R. arrhizus</i>	<i>R. oryzae</i>	No. <i>Rhizopus</i>
Hybrid 894	5 ^a	5	0
Hybrid 896	5	5	0
<i>H. annuus</i>	4	5	0
<i>H. debilis</i> ssp. <i>debilis</i>	5	5	0
<i>H. praecox</i> ssp. <i>runyonii</i>	3	5	0
<i>H. pumilus</i>	5	5	0
<i>H. arizonensis</i>	3.6	4	0
<i>H. laciniatus</i>	4.6.	5	0
<i>H. ciliaris</i>	4.4	3.8	0
<i>H. mollis</i>	5	5	0
<i>H. occidentalis</i> ssp. <i>occidentalis</i>	4	4	0
<i>H. occidentalis</i> ssp. <i>plantagineus</i>	5	5	0
<i>H. divaricatus</i>	2	2	0
<i>H. hirsutus</i>	2	2	0
<i>H. decapetalus</i>	5	5	0
<i>H. strumosus</i>	4	4.4	0
<i>H. tuberosus</i>	3.6	5	0
<i>H. × laetiflorus</i>	2.2	2.6	0
<i>H. grosseserratus</i>	4.4	4.0	0
<i>H. nuttallii</i>	5	5	0
<i>H. maximiliani</i>	4.4	4.8	0
<i>H. salicifolius</i>	4	5	0
<i>H. californicus</i>	5	5	0
<i>H. resinosus</i>	2.6	1.4	0
<i>H. schweinitzii</i>	5	5	0
<i>H. microcephalus</i>	4	4.2	0
<i>H. glaucophyllus</i>	5	5	0
<i>H. laevigatus</i>	5	5	0
<i>H. smithii</i>	5	5	0
<i>H. angustifolius</i>	5	5	0
<i>H. simulans</i>	3.5	3.4	0
<i>H. silphioides</i>	5	5	0
<i>H. atrorubens</i>	3.6	4.4	0
<i>Viguiera porteri</i>	5	5	0
<i>H. × multiflorus</i>	5	5	0

^a Average rot index calculated from 5 heads. 0 = no rot; 1 = resistant; 2 = moderately resistant; 3 = moderately susceptible; 4 and 5 = highly susceptible.