THE INHERITANCE OF DROUGHT TOLERANCE IN SUNFLOWER.

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ABSTRACT

This study was conducted to determine the genetic basis of the inheritance of drought tolerance in sunflower (*Helianthus annuus* L.). Thirty-one sunflower inbreds have been treated in preliminary screening tests both for heat tolerance and tolerance to high osmotic potential. Five inbred lines from the high osmotic potential method and seven inbred lines from the heat stress treatment and their respective diallel crossed constituted the test material. The inheritance of drought tolerance in sunflower, based on tolerance to high osmotic pressure follows a pattern of partial dominance and over-dominance. On the other hand, tolerance to heat basically follows a pattern of non-allelic gene interaction superimposed on a system of partial dominance.

INTRODUCTION

Crop plants rarely attain their full genetic potential for yield because of the limitations imposed by the environment, especially unfavorable temperatures and lack of water. In a rough breakdown of specific stress features that characterize soils worldwide, Dudal (1976) reported that 28% of plant crops were affected by drought stress. An additional 24% were affected by shallowness of soil, a condition that causes initial soil water deficits to develop during short periods in which there is no precipitation. One important way to develop an optimum production system in which there are constraints from plant water deficits is to design through breeding and selection plants that are best suited to the environment. The objectives of this study were to 1) investigate the inheritance of heat tolerance in sunflower (*Helianthus annuus* L.), 2) study the inheritance of drought tolerance by germinating sunflower seeds in a high osmotic solution, and 3) to compare the two methods to determine heat and drought tolerance and investigate the practical application of each.

MATERIALS AND METHODS

This study to determine inheritance of drought tolerance was based on a 7 x 7 diallel cross of sunflower for the heat tolerance investigation and a 5 x 5 diallel cross of sunflower for the investigation of germination ability in a solution of high osmotic pressure. Prior to the diallel cross, inbreds were screened to determine the tolerance status of each. Thirty-one different sunflower genotypes representing a cross section of available germplasm (Table 1) were grown in a mannitol 35D Mannitol, CH_2OH $(CHOH)_4$ CH_2OH solution to begin selecting drought tolerant genotypes. Also, all 31 genotypes were heat stressed as seedlings at the four leaf stage and were exposed to a temperature of 51.6°C (125°F) for six hours in a heat chamber. All genotypes utilized were released inbred lines or experimental germplasm in advanced generations of selfing. Data for diallel cross analysis was obtained from two drought measurement techniques. The first method was germination in solutions of high osmotic potential as a measure of drought tolerance. Mannitol was used to induce the high osmotic potential treatment. Forty seeds of each sunflower genotype were placed on two layers of Schleicher and Schnell (SxS) No. 595 analytic paper in 15 x 100 mm plastic petridishes. Dishes were arranged in a germinator in a completely randomized design with four replications (four dishes of 10 seeds per genotype). Seeds were germinated for 6 days at 20°C (68°F) temperature. Following this period, the number of seeds germinated per dish was recorded. A seed was considered germinated only when both the radicle and cotyledon had obviously emerged. Genotypes with acceptable germination were ranked as high and low tolerant, and were transplanted in the field to be used as parental lines for diallel crosses. The second method exposed sunflower seedlings at the four leaf stage to a temperature of 51.6°C (125°F) for six hours in a heat chamber. Thirty-one sunflower genotypes were grown in 10 cm diameter peat pots. After germination the pots were thinned to 5 seedlings uniform in growth. After seedlings reached the four leaf stage they were transferred to a heat chamber with the inside temperature of 51.6°C (125°F). After six hours exposure to this temperature the plants were removed and survival counts were recorded after 48 hours. Genotypes with more than two plants surviving per pot were transplanted into larger plastic pots which were placed in stainless steel trays holding water and ½ strength Hogland nutrient solution. Seven genotypes ranked as low and high heat tolerant were used as parents in a 7 x 7 diallel cross as well as self pollinated genotypes. All results were analyzed statistically by analysis of variance. Diallel analysis followed the procedure of Hayman (1954).

RESULTS

Preliminary screening of germination in a solution of high osmotic potential indicated that genotypes CM306 and CM400 had the lowest percentage of germination and genotypes CH-73-101, RHA-265 and RHA-273 had the highest degree of survival. These five parents were utilized for the diallel cross analysis. Vr,Wr regression graphs were calculated from the logarithus of percent germination according to the procedure of Hayman (1954). Figures 1 and 2 present the Vr,Wr graph for both replications. The regression coefficients are $b = 0.67 \pm 0.14$ and $b = 0.69 \pm 0.20$ for replications 1 and 2 respectively. Analysis of variance with a very high F value for lines or arrays indicates that interallelic interaction may be present in crosses between one or more parents. Removal of line CM 306 creating a 4 x 4 diallel drastically changed the value of F for lines as well as the regression coefficient in both replications. The slope of the actual regression line of $b = 0.77 \pm 0.36$ and and $b = 1.21 \pm 0.31$ corresponding to replications 1 and 2 is shown in Figures 3 and 4. Preliminary screening of exposing seedlings to high temperatures indicated that genotypes HA-113 and HA-124 had the lowest degree of tolerance and genotypoes CH-73-101, CM306, CM400, RHA-265, and RHA-273 had the highest degree of tolerance. Figures 5 and 6 present the Vr,Wr graph for both replications. The regression coefficients are $b1 = 0.04 \pm 0.08$ and $b2 = 0.19 \pm 0.12$ for replications 1 and 2 respectively. Due to a conflict of statistics resulting from the analysis of data the possibility that interallelic interaction or perhaps non-allelic gene action was present. By removing line RHA-273 slight improvement occurred in the slope of the graphs shown in Figures 7 and 8. Regression coefficients changed to $b_1 = 0.11 \pm 0.09$ and $b_2 = 0.22 \pm 0.17$.

DISCUSSION

An examination of the diallel graph for tolerance to high osmotic potential shows that the inheritance of drought tolerance among these genotypes follows a pattern of partial dominance although the Y intercepts for both graphs confirm the presence of some over-dominance. Genotypes RHA-265 and RHA-273 are the most dominant parents. The correlation coefficients of −0.92 and −0.94 for replications 1 and 2, respectively, shows that in this experiment survival of three of the four genotypes was enhanced by the dominance effect of genes. Statistics related to tolerance to heat shows the possibility that interallelic interaction or perhaps non-allelic gene action exists among the genotypes. The scatter of the points representing the parental arrays along the line of

regression indicates that genotypes HA-113 and RHA-265 possess dominant genetic effects for drought tolerance and genotype CH-73-101 possesses the most recessive effect of all parents. Comparing the two screening methods in this experiment it was quite clear that there was not much similarity between the reaction of plants to either high osmotic potential or heat treatment. First of all, different genotypes reacted differently to heat stress treatment than to the mannitol solution treatment. Furthermore, even those parents which had similar responses in the mannitol treatments had different gene action in the experiment for heat resistance. Only genotypes which were similar in genetic action and showed similar responses to both treatments are genotypes CM400 and RHA-265.

LITERATURE CITED

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Table 1. Genotypes screened in two different experiments to determine drought tolerance of sunflower.

No.	Genotype No.	Pedigree	Type
1	3009	HA-113	B-line oilseed inbred
2	3011	HA-124	B-line oilseed inbred
3	3055	SP-3-1-2	B-line oilseed inbred
4	3129	CH-73-101	B-line oilseed inbred
5	3243	HA-79	B-line oilseed inbred
6	5001	HA-60	B-line oilseed inbred
7	5003	HA-64	B-line oilseed inbred
8	5007	HA-99	B-line oilseed inbred
9	5017	HA-234	B-line oilseed inbred
10	5019	HA-277	B-line oilseed inbred
11	5021	HA-289	B-line oilseed inbred
12	780398	RHA-274	R-line oilseed inbred
13	5027	HA-300	B-line oilseed inbred
14	5031	HA-302	B-line oilseed inbred
15	5033	HA-303	B-line oilseed inbred
16	5035	CM-306	B-line oilseed inbred
17	5045	CM-400	B-line oilseed inbred
18	5051	RMIB-1-1-3	B-line oilseed inbred
19	5067	VS-14-2-1-3	B-line oilseed inbred
20	5083	P 308-12-3-1-2	B-line oilseed inbred
21	5127	CH 66-61-2-1-1	B-line oilseed inbred
22	5149	CH 74-31-1-1	B-line oilseed inbred
23	5151	8960-1-51-1-1	B-line oilseed inbred
24	5501	RHA-265	R-line oilseed inbred
25	5504	RHA-266-3-3-33	R-line oilseed inbred
26	5505	RHA-271-11-1-1-7-12	R-line oilseed inbred
27	5507	RHA-273-66-2-2-1	R-line oilseed inbred
28	5593	RHA-296	R-line oilseed inbred
29	Sundak		o.p.* nonoil
30	W. Sun.**	Helianthus annuus	
31	W. Sun.	Helianthus annuus	Insect Resistant

* o.p. = open-pollinated variety
** W. Sun. = Wild Sunflower

See Figures on following 2 pages.

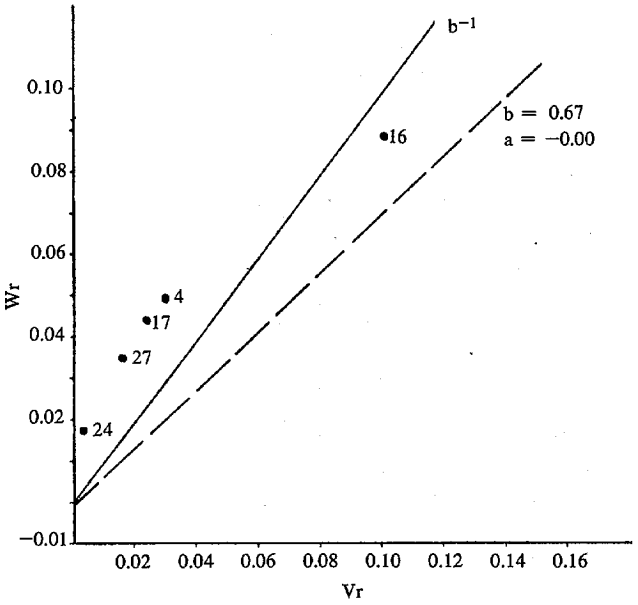

Figure 1. Vr, Wr regression for germination % after exposure to 15 atmospheres osmotic potential for six days, replication 1.

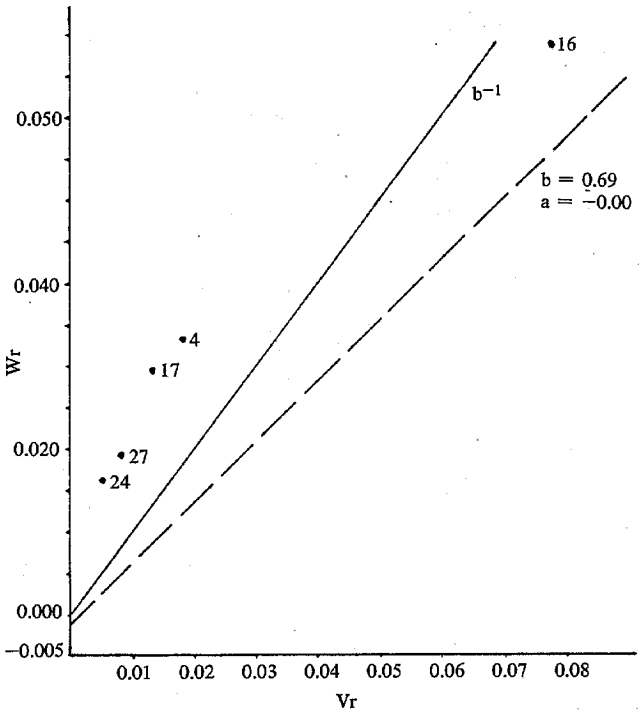

Figure 2. Vr, Wr regression for germination % after exposure to 15 atmospheres osmotic potential for six days, replication 2.

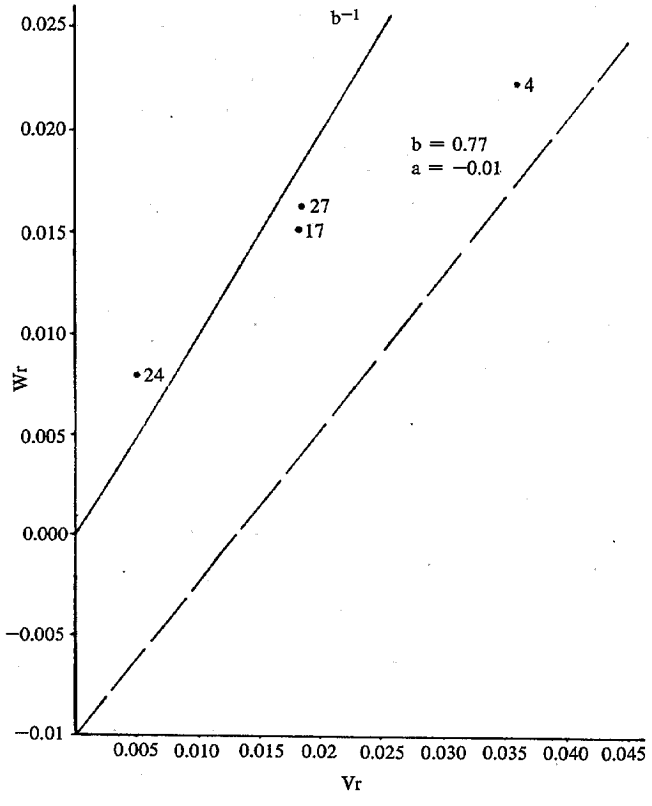

Figure 3. Vr, Wr regression for germination % after exposure to 15 atmospheres osmotic potential for six days, replication 1.

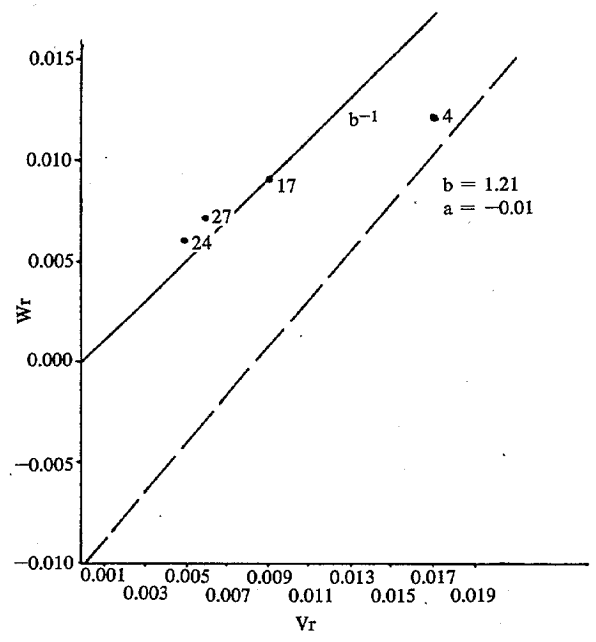

Figure 4. Vr, Wr regression for germination % after exposure to 15 atmospheres osmotic potential for six days, replication.

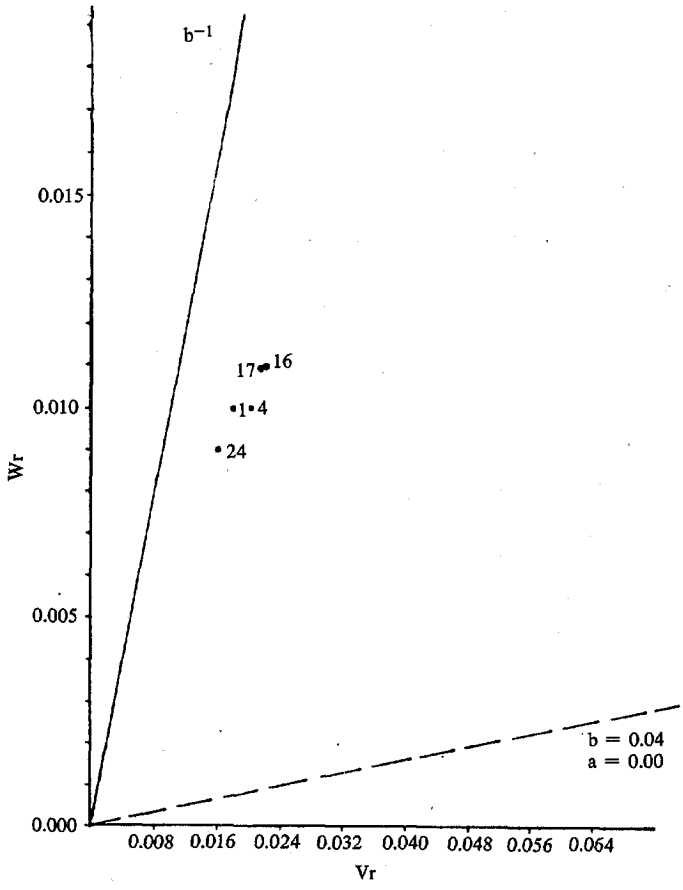

Figure 5. Vr, Wr regression for survival % after exposure to 52°C for six hours, replication 1.

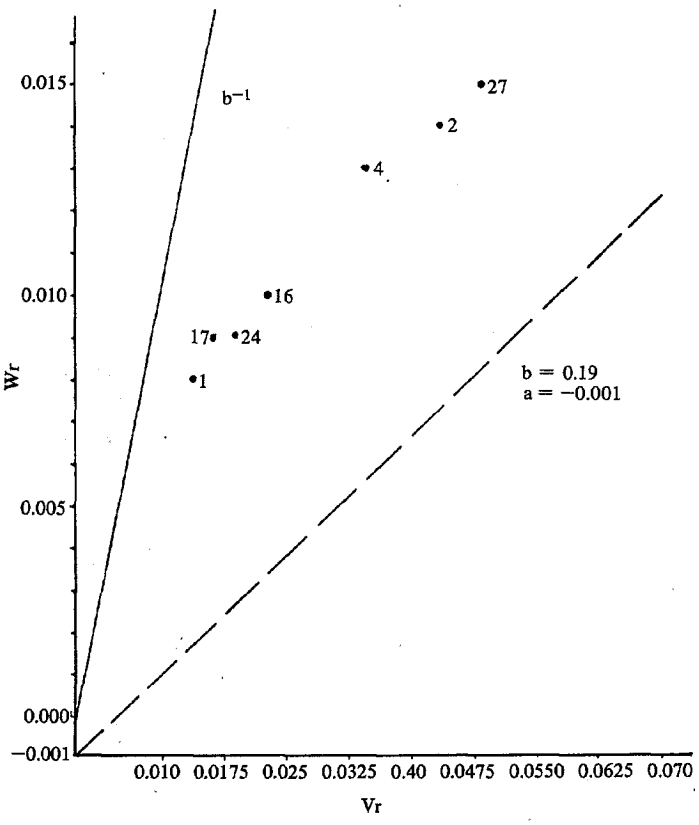

Figure 6. Vr, Wr regression % after exposure to 52°C for six hours, replication 2.

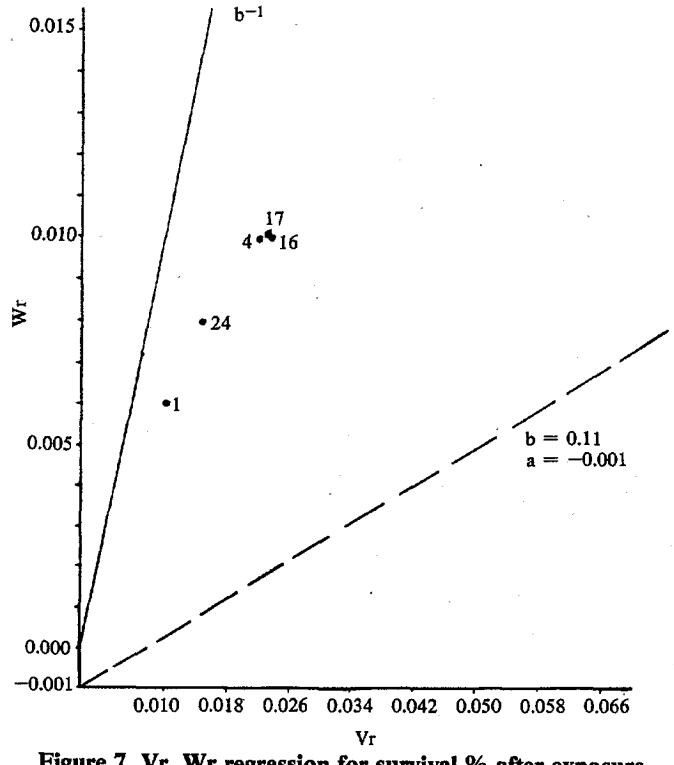

Figure 7. Vr, Wr regression for survival % after exposure to a 52°C for six hours, replication 1.

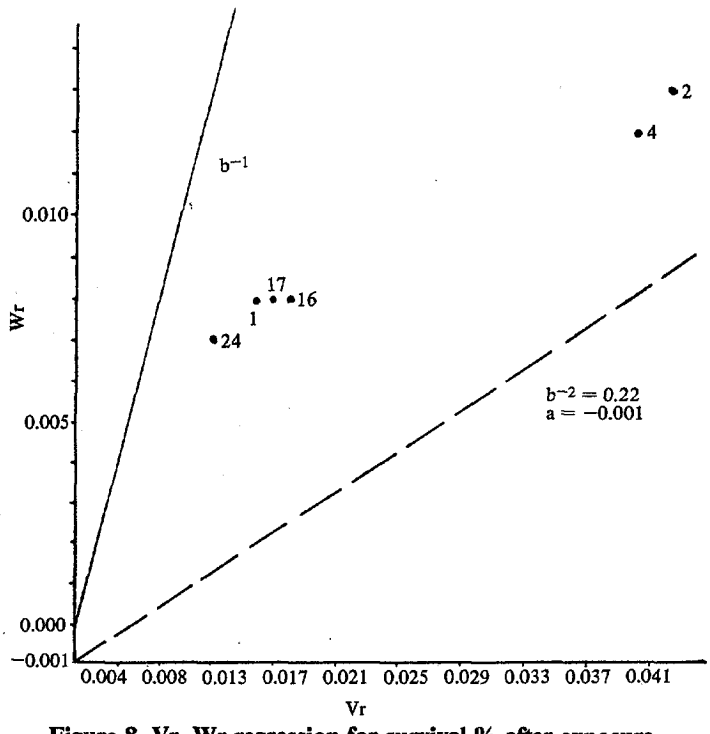

Figure 8. Vr, Wr regression for survival % after exposure to 52°C for six hours, replication 2.