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HERITABILITY AND GENETIC GAIN FOR RESISTANCE TO LEAF BLIGHT IN CARROT (*Daucus carota* L.) POPULATIONS EVALUATED AT DIFFERENT TIMES AFTER SOWING

Jairo Vidal Vieira[1], Vicente Wagner Dias Casali[2], João Camilo Milagres[3], Antonio Américo Cardoso[2] and Adair José Regazzi[4]

ABSTRACT

The genetic structure of four populations of carrots was studied for resistance to leaf blight. Populations were evaluated at 45, 70, and 90 days after sowing in order to determine the best time to study this character. The following parameters were estimated from half-sib progenies of each population: broad sense heritability (45.6 to 81.9%), expected response to selection as a percentage of the mean (7.0 to 28.1%), additive genetic variance coefficient (7.0 to 18.0%), and the ratio between the genetic and environmental coefficient of variation. In addition, there was a tendency of this character to show a greater phenotypic than genotypic variance with increased plant age. Seventy days after sowing is suggested as the best time to evaluate progenies for resistance to leaf blight in carrots.

INTRODUCTION

Leaf blight is the major disease affecting carrots in Brazil during the summer season. A survey of seven production fields in the Federal District indicated the occurrence of three pathogens - *Alternaria dauci, Cercospora carotae* and *Xanthomonas campestris pv. carotae* - causing damage to carrot leafstalks and leaf borders

[1] CNP-Hortaliças/EMBRAPA, Caixa Postal 07.0218, 70359 Brasília, DF, Brasil. Send correspondence to J.V.V.

[2] Departamento de Fitotecnia, [3]Departamento de Zootecnia, and [4]Departamento de Matemática, Universidade Federal de Viçosa, 36570 Viçosa, MG, Brasil.

(leaf blight) (Reifschneider, 1980). It was not possible to distinguish the pathogens on the basis of leaf symptoms, which demonstrates the existence of a fungal-bacteriological complex as the causative agent of this disease.

In later studies conducted by Reifschneider (1983) in the area of Brasília only one of the causative agents of the disease was found in plants with leaf blight. The area of "Vargem Bonita" presented the highest incidence of *A. dauci* (80%) and the lowest incidence of *C. carotae* (1%) in association with damage to the leaf limbus and petiole (leaf blight), whereas in other areas these percentages were inverted. In the experimental fields of the "Centro Nacional de Pesquisa de Hortaliças" (National Research Center on Vegetables, CNPH), there was no predominance of one pathogen over another (Reifschneider, 1980).

Few studies are available on breeding programs aiming at the development of carrot cultivars resistant to leaf blight. Della Vecchia and Reifschneider (1983) evaluated the level of resistance to *A. dauci* under conditions of natural infection in 96 half-sib progenies of the CNPH-CENI carrot population (cv. Brasília) grown in the Rural Nucleus of "Vargem Bonita", Brasília (DF). Narrow-sense heritability estimates based on variance and covariance components for the genetic design used showed $h^2 = 0.40$. The authors concluded that selection of half-sib progenies is effective and may result in relatively rapid genetic gain in terms of population resistance. In contrast, Vieira *et al.* (1979), in an attempt to determine the level of horizontal resistance and to quantify additive genetic variance for resistance to *A. dauci* in a commercial carrot population, cv. Kuroda, concluded that heritability of the trait was low (2.28%), indicating low additive genetic variability in the population when compared with overall phenotypic variation. These investigators also concluded that mass selection and selection between and within half-sib progenies may not be recommendable for increasing the level of horizontal resistance of this population.

According to Casali *et al.* (1984), the study of the genetic basis, as well as the determination of the genetic parameters of several carrot characters might have contributed to an advance of at least two decades in relation to other crops of greater economic importance if they had been evaluated in depth in the different groups and cultivars. This statement is justified by the fact that genetic improvement of populations, in terms of quantitative characters such as carrot leaf blight, should be based on the knowledge of certain genetic-statistical parameters that would permit a more efficient selection program for the traits involved (Ikuta, 1971).

There are no data on the appropriate time for the evaluation of leaf blight resistance. Thus, the objective of the present study was to determine the expected heritabilities and genetic gains for four carrot populations belonging to the breeding program of CNPHortaliças-EMBRAPA for the "leaf blight resistance" character, evaluated at three different times after sowing.

MATERIAL AND METHODS

Experimental material

The data utilized in the present study refer to progenies of four carrot populations belonging to the breeding program of the "Centro Nacional de Pesquisa de Hortaliças" (CNPH/EMBRAPA), Brasília, DF, are described below.

Population 1 was collected in 1976 at Viamão, Rio Grande do Sul, State Southern Brazil, where it had been cultivated for several years by local farmers. The plant has practically cylindrical light orange color roots and dark green leaves. The plant has a cycle of approximately 90 days and is resistant to leaf blight.

Population 2 was a composite formed by crossing a population from Ilha de Leonídeo, municipality of Rio Grande, Rio Grande do Sul State, as a female parent with four populations supplied by "Escola Superior de Agricultura Luiz de Queiróz" (ESALQ), Piracicaba in 1976 as male parents. The female parent was highly uniform in terms of size and cylindrical root shape, and was also resistant to leaf blight. The main characteristic of the male parents were a high level of resistance to leaf blight. In both parents, a small percentage of roots grow above bed level, with consequent greening defects. The carrot cultivar Brasília was originated from this population.

Population 3 was a hybrid of cultivars Kuroda and Nantes, generation C3, supplied by Dr. Hiroshi Ikuta, (ESALQ) in 1977. The plants had vigorous foliage, a high level of resistance to leaf blight and to heat, with almost cylindrical roots and dark-orange. Up to generation C3, the population was grown in the Mogi das Cruzes region on turf-type soil. Cultivar Kuronan was originated from this population.

Population 4 was obtained from seeds of cultivar Kuroda, which has excessively exuberant foliage, it is resistant to leaf blight and it has approximately conical roots dark-orange. The original population of this cultivar was brought from Japan by Dr. Hiroshi Ikuta in 1971 and has been constantly bred for adaptation to the requirements of the Brazilian market, especially in terms of format.

Methods

A total of 166, 134, 234 and 100 half-sib progenies of populations 1, 2, 3 and 4, respectively, were tested under field conditions in Brasília during the summer.

The trial was conducted using a randomized block design with three replications. Each plot consisted of four 2 m rows spaced 20 cm. Seeds were sown in November 1980 at a density of 0.7 g seeds/m^2 and seedlings were thinned out 20 to 25 days after sowing with a spacing of approximately 5 cm between plants in each row.

Standard fertilization and culture methods were used, except that no application was used against leaf disease in order to evaluate progeny resistance to leaf blight under field conditions. Each population was surrounded by a 2 m wide strip planted with the cultivar Nantes which was used as a natural source of inoculum because of its susceptibility to leaf blight. This strip was sown 45 days before the half-sib progenies of each population.

The level of progeny resistance was assessed by two independent evaluators who examined the plots at 45, 70 and 90 days after sowing, using the criteria suggested by Della Vecchia and Reifschneider (1983) after inverting the order of magnitude of the score scale. The evaluations of the character at the three different times are represented by the symbols E-45, E-70 and E-90. The data were analyzed using the mean value of the scores attributed by the two evaluators.

Variance components of expected mean squares were obtained for each population by the methods of Cokerham (1963) and Falconer (1964). The h^2, CV_g and b parameters were estimated according to Vencovsky (1978). The expected genetic gain was calculated according to Eberhart (no date) using 10% selection intensity and selection cycles of one year duration.

RESULTS AND DISCUSSION

Table I shows that only population 3 was evaluated for the genetic parameters at E-45. This was due to the great difficulty in scoring leaf blight at 45 days after sowing since carrots present very slow vegetative growth within this period of time, with very reduced foliage both in terms of leaf numbers and size. The h^2 values obtained at E-45, E-70 and E-90 for each population tended to be reduced with testing age. This is due to the greater participation of residual variance in relation to total phenotypic variance among progenies with increasing plant age (Table II).

The h^2 values obtained at E-90 (Table I) differed from those obtained by Della Vecchia and Reifschneider (1983) who estimated heritability of resistance to leaf blight in cv. Brasília to be 0.40 in plants harvested 85 days after sowing and grown under natural infection conditions. The higher h^2 values observed in Table I for population 2 ($h^2 = 76.4$) may be explained by the more uniform inoculum distribution in the experimental area when the susceptible cv. Nantes was used as a source of fungal spores.

It should also be emphasized that the h^2 value of 63.0% obtained for population 4, although different from the 2.3% obtained by Vieira *et al.* (1979) for a population of the same cultivar (Kuroda group), is a demonstration of the particularity of heritability estimates, since this parameter varies for each character and

population, and also according to environmental circumstances and experimental design (Falconer, 1964).

Table I - Estimates of genetic parameters for resistance to leaf blight using 166, 134, 234 and 100 half-sib progenies evaluated at 45 (E-45), 70 (E-70) and 90 (E-90) days after sowing. Brasília, 1987.

Character	Population	Genetic parameters				
		h2*	G	G /X*	CVg*	b
A-45	1	-	-	-	-	-
	2	-	-	-	-	-
	3	81.9	0.61	23.0	11.5	1.48
	4	-	-	-	-	-
A-70	1	72.8	0.48	26.0	18.0	0.94
	2	79.2	0.57	28.1	16.8	0.94
	3	52.4	0.29	8.6	7.0	0.62
	4	69.0	0.41	17.6	12.4	0.87
A-90	1	69.4	0.44	24.5	17.3	0.87
	2	76.4	0.54	24.1	16.2	0.95
	3	45.6	0.24	7.0	8.5	0.55
	4	63.0	0.40	13.8	10.2	0.75

h^2, heritability of the character considering the progeny mean; G, genetic gain using 10% selection of the best progenies; CVg, coefficient of genetic variation between plots; b, relationship between the coefficient of genetic variation and the coefficient of experimental variation (CVg/CVe); X, estimated mean of the character/population; * values reported as percentages.

Population 3 at E-45 presented the highest genetic gain in absolute terms (Table I), a fact that may be explained by the magnitude of the heritability estimate (h^2 = 81.9) and also by the greater experimental precision (CV% = 7.78, Table III).

Even though h^2 estimates were relatively high for E-70 and E-90 in population 3, the genetic gain values reported as a percentage of the mean were low (8.6 and

7.0% for E-70 and E-90, respectively). This may have been related to the low genetic variance coefficients observed for both characters. The small magnitude of the genetic variance coefficients for population 3 was probably related to the higher resistance detected in this population (Table III), suggesting that a more uniform distribution of alleles for resistance to leaf blight exists in this population. The use of other types of progenies may permit a better release of additive genetic variance, with consequent higher gains.

Table II - Estimates of variance components for resistance to leaf blight evaluated at 45 (E-45), 70 (E-70) and 90 (E-90) days after sowing, Brasília, 1987.

Character	Population	Estimate of variance components		
		VAR_f	VAR_P	VAR_e
A-45	3	0.20310	0.16332	0.07377
A-70	1	0.15076	0.10983	0.12256
A-70	2	0.18331	0.14528	0.11097
A-70	3	0.11214	0.05873	0.14838
A-70	4	0.12059	0.08390	0.10859
A-90	1	0.14069	0.09761	0.12900
A-90	2	0.17280	0.13211	0.11873
A-90	3	0.10076	0.04606	0.15196
A-90	4	0.14181	0.08891	0.15657

VAR_f, Phenotypic variance between half-sib progenies on the basis of plot means; VAR_P, genotypic variance between half-sib progenies calculated on the basis of plot; VAR_e, residual variance.

The high genetic gains (G/X) and heritabilities (h^2) obtained for E-70 and E-90 in populations 1 and 2 indicate the presence of effective additive genes (Panse, 1957), which means that selection based on phenotypic value may provide satisfactory genetic gains (Falconer, 1964; Brar and Sukhija, 1981; Della Vecchia and Reifschneider, 1983). The CV_g/CV_e ratio (Table I) has been extensively utilized in

maize breeding because, in addition to permitting additional evaluation of experimental precision, it indicates the presence of conditions highly favorable to selection when equal to, or higher than 1.0 (Vencovsky, 1978). Within this context, the best time for the selection of carrot genotypes with resistance to leaf blight is 70 days after sowing, since E-70 had the highest b, G/X and h^2 values for the populations studied.

Table III - Summary of analysis of variance of resistance to leaf blight for half-sib progenies of four carrot populations evaluated at three different times after sowing (E-45, E-70 and E-90). Brasília, 1987.

Character	Population	Progenies (adjusted)		Error		Character mean	CV (%)	K
		d.f.	MS	d.f.	MS			
E-45	3	233	0.377290*	200	0.073711	2.67	7.78	1.8583
E-70	1	165	0.451404*	327	0.122562	1.84	19.02	2.5494
E-70	2	133	0.456474*	255	0.110977	2.05	16.25	2.9173
E-70	3	234	0.311541*	416	0.148282	3.45	11.13	2.7777
E-70	4	99	0.419741*	196	0.156573	2.90	13.61	2.9595
E-90	1	165	0.421269*	329	0.129002	1.80	19.94	2.9459
E-90	2	133	0.530692*	255	0.145284	2.23	17.05	2.9173
E-90	3	234	0.279910*	416	0.151961	3.49	14.58	2.7777
E-90	4	99	0.356905*	196	0.108597	2.32	14.17	2.9595

d.f., Degrees of freedom; MS, mean squares; CV, coefficient of experimental variation; K,'coefficient of variation between half-sib progeny means; * Significant at the 5% level of probability by the F test.

RESUMO

O presente trabalho objetivou conhecer a estrutura genética de quatro populações de cenoura com relação ao caráter resistência à queima das folhas, avaliado aos 45, 70 e 90 dias após a semeadura, bem como, a melhor época para avaliação do mesmo.

As estimativas de herdabilidade, ganho genético com seleção, coeficiente de variação genética, razão entre o coeficiente de variação genética/coeficiente de variação experimental foram obtidas a partir da avaliação de progênies de meio irmãos de cada uma das populações estudadas.

O emprego dos métodos usuais de melhoramento, como seleção recorrente baseada no desempenho de progênies de meios-irmãos, seguramente proporcionará progressos substanciais no nível de resistência das populações estudadas em um espaço de tempo relativamente curto.

Verificou-se ainda que, para esse caráter, há uma tendência de maior incremento do componente de variância residual em relação ao componente de variância genotípica com o aumento da idade da planta. Este fator, aliado à dificuldade de ordem prática na avaliação por notas do caráter aos 45 dias, indica que a melhor época para avaliação da resistência à queima das folhas é 70 dias após a semeadura.

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