

PEA ENATION MOSAIC VIRUS: VARIATION IN RESISTANCE CONFERRED BY En

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Resistance to pea enation mosaic was reported by Schroeder and Barton (2) to be conferred by a single dominant gene, En. They noted that when resistant pea plants were inoculated with any of several pea enation mosaic virus (PEMV) isolates, the plants usually became infected, with only minor effects on growth. Hagedorn and Hampton (1) demonstrated that commercial breeding lines putatively containing En varied in degrees of PEMV-susceptibility, as indicated by symptom severity. Even the most resistant lines, when inoculated in greenhouse tests, either developed mild symptoms or, if affected by the virus more severely, progressively recovered from symptoms. Follow-up field tests confirmed that lines able to recover from PEM symptoms in the greenhouse also manifested field resistance, corroborating the presence of the En allele.

The data of Hagedorn and Hampton have been retabulated in descending order of susceptibility (disease indices), from greenhouse tests (Table 1). To these data we have added a column to indicate presumptive presence of the En allele, as deduced from greenhouse recovery data and information provided by the breeder of the cultivar. The 45 entries in Table 1 comprise a continuous range of PEMV responses including intermediate types which, based on PFM-recovery, contain either En or en alleles (see Line Nos. 15-25). These data suggest that modifier genes and perhaps cytoplasmic factors, working either independently of or interactively with gene En, affect the type and severity of PEM symptoms. Thus, among these intermediate lines, some with en showed a lower disease index than some lines carrying En.

We sought to elucidate the nature of this modification by crossing 'Perfected Freezer 60' (En En) reciprocally with three susceptible (en en) and three other resistant cultivars. F2 progenies from these crosses were rub-inoculated in two successive "greenhouse tests, using mechanically transmissible Wisconsin isolate (C3) of PEMV used by Hagedorn and Hampton (1). These progenies were also field tested Corvallis under a severe natural incidence of PEMV. Disease indices were calculated from individual-plant symptom scores, where visible symptoms, 1 = slight chlorotic flecking, 2 = moderate PEM symptoms, 3 = severe PEM symptoms, and 4 = PEMV-induced plant necrosis. To obtain a refined estimate of disease severity, we removed the plants from containers at peak development of PEM symptoms and made side-by-side visual comparison. This procedure, however, was done at the expense of greenhouse PEM-recovery data.

Symptom scores of greenhouse-grown progenies from PEMV-resistant x susceptible parents were combined into resistant (scores 0 and 1) and susceptible (scores 2-4) classes for computation of segregation ratios. Most χ^2 values for 3:1 ratios were within a 0.05 level of probability, clearly indicating conformity with and affirming single-dominant-gene inheritance for PEMV resistance (Table 2). There were a few non-conforming ratios. For example, control plants of 'Banff' and 'Canner PL' tended to escape PEMV-infection during greenhouse inoculation, particularly in Test #1, but were extremely susceptible in field tests

(Table 3). The cultivar 'Aurora' and the progeny of P.F.60 x Canner PL, in Test #2, contained more than expected PEMV-susceptible plants. Perhaps some of these plants were in the process of recovery when they were sacrificed. Segregation ratios varied somewhat between progenies of reciprocal crosses, with a suggestion of maternally mediated PEMV-resistance by P.F. 60 in crosses with 'Melody' (en en), Aurora (En Ea), and 'Tempter' (En En).

PEMV-resistance classes of naturally infected progenies (Table 3) were derived by combining symptom scores 0-2 as resistant, and 3-4 as susceptible. X^2 values for 3:1 ratios were within the 0.05 level of probability for five of the six progenies from PEMV-resistant x susceptible parents. Likewise, parental controls responded predictably to natural PEMV infection. Maternal mediation of PEMV-resistance by P.F. 60 was again suggested in progenies from crosses with Banff, Aurora, and Tempter, particularly apparent in the distribution of plants per symptom score.

Our results verify the work of Schroeder and Barton (2), but failed to demonstrate germplasm-related modification of En. We expected Aurora and Tempter to contribute germplasm that skewed progenies from P.F. 60 toward greater PEMV susceptibility. Instead, these parents were quite resistant to PEMV in our studies. Although it is tempting to attribute PEMV-resistance enhancement to P.F. 60 cytoplasm, we recognize that new approaches are likely to be required to further elucidate this phenomenon.

1. Hagedorn, D. J. and R. O. Hampton. 1975. Plant Dis. Reprtr. 59:89 5-899.
2. Schroeder, W. T. and D. W. Barton. 1958. Phytopathology 48:628-653.

Table 1.

Ranking of pea lines and cultivars by greenhouse indices for enation mosaic symptom expression, 1973 .

No.	Line	Source	Greenhouse index	Greenhouse recovery	Field index	En gene-present
1	72-1554	1	94	none	77	no*
2	Exp. 331-485	2	91	none	62	no
3	Exp. 326	2	86	none	80	no
4	9776	3	85	-		no#
5	Banff	4	85	-		no
6	72-626	1	85	few-none	63	no*
7	Melody	5	85	none	84	no*
8	72-665	1	82	none	46	no*
9	72-673	1	82	none		no*
10	Can. 49	4	80	none		no
11	Tonka	2	78	none	69	no
12	Dark Skin Perf.	-	76	none	83	no*
13	9778	3	74	-		no#
14	9868	3	74	-		no#
15	Can. 69141	5	73	excellent		yes*
16	Anoka	2	71	none	37	no
17	Exp. 306	2	69	none		no
18	71-2687	6	61	excellent-fair		yes*
19	Aurora	5	61	good		yes*
20	9867	3	59	-		?#
21	9869	3	58	-		?#
22	Tempter	5	53	good		yes*
23	72-3711	6	47	good, fair		yes*
24	Puget	8	47	none, fair		no*
25	72-689	1	46			
26	70C-56	6	39	good	11	yes*
27	Perf. Fr. 60	-	38	excellent	6	yes
28	71-GP106	6	36	good		yes*
29	Freezer 52	4	35	good, excellent		yes
30	226 C	7	35	good		yes
31	328 F	7	34	good		yes
32	70C-36	6	31	good	6	yes*
33	Trident	8	31	excellent, fair		yes*
34	Fr. 6650	5	31	excellent	5	yes
35	310 F	7	30	good	2	yes
36	Can. 695	5	29	excellent	3	yes
37	H286-1-1	8	28	excellent	1	yes*
38	329	7	27	excellent		yes
39	H294-5-1-1.	8	24	excellent	0	yes*
40	H302-2	8	24	excellent		yes*
41	203 C	7	24	good	7	yes
42	Fr. 50	4	24	excellent	5	yes
43	Can. 50	4	22	excellent		yes
44	H312-2-3	8	21	excellent	2	yes*
45	305 C	7	21	good	10	yes

1- From the data of D. J. Hagedorn and R. O. Hampton (Plant Disease Reporter 59, No. 11, 8M5-399. 1975.)

2- Sources: (1) Anonymous, (2) Northrup King, (3) Canner Seed, (4) Pureline, (5) Rogers, (6) Crites-Moscow, (7) Western Valley, (8) Gallatin Valley

3- Concluded from test results, with emphasis on greenhouse recovery tendency.

* indicates the breeder confirms conclusion. # indicates that one parent was enation mosaic resistant but progenies were not selected for resistance.

Table ft Ratios of resistant:susceptible plants and disease indices, sreenhouse tests, 1978.

Cross		Test #1						Test #2					
Female	Male	R (0-1)	S (2-4)	χ^2 (3:1)	χ^2 recip. ¹	Index	χ^2 recip. ²	R (0-1)	S (2-4)	χ^2 (3:1)	χ^2 recip.	Index	χ^2 recip.
P.F. 60	Melody	62	10	4.2*	0.8	15.6	2.5	55	10	2.7	3.6	15.9	10.7*
Melody	P.F. 60	65	17	0.5		17.5		50	22	0.9		33.7	
P.F. 60	Banff	65	15	1.4	0.1	22.3	13.2*	53	20	0.1	1.7	22.7	4.7
Banff	P.F. 60	58	16	0.3		15.2		59	12	2.1		14.8	
P.F. 60	Can. 50	54	21	0.2	3.5	27.9	9.2	39	34	17.0*	8.8*	37.3	28.2*
Can. 50	P.F. 60	66	11	4.2*		38.0		52	14	0.3		20.0	
P.F. 60	Aurora	74	2		0.6	5.2	1.7	62	2		42.7*	8.9	46.4*
Aurora	P.F. 60	71	5			7.4		28	38			39.8	
P.F. 60	Tempter	68	0		6.1*	0.4	8.3*	69	0		35.3*	0.4	106.8*
Tempter	P.F. 60	64	8			8.7		45	33			42.6	
P.F. 60	H312-2-3	79	0		2.2	0.0	37.1*						
H312-2-3	P.F. 60	53	3			13.6							
Parents													
Melody		5	64			85.3		1	48			67.7	
Banff		19	41			64.3		12	56			56.7	
Can. 50		23	46			61.3		1	58			84.2	
Aurora		73	1			9.2		44	29			35.0	
Tempter		74	0			0.4		72	0			0.8	
H312-2-3		57	0			0.4		61	0			3.1	
P.F. 60		87	0			9.6		72	0			7.1	

*Significant at 5% level.

¹Ratios of R:S for reciprocals compared by contingency table test.

²Complete distribution of reciprocals in disease classes 0-4 compared by contingency table test.

Table 3. Ratios of resistant:susceptible plants, and disease indices, field test, 1978.

Class		Major classification				No plants in score classes					χ^2 for recip. ²	Disease index
Female	Male	R (0-2)	S (3-4)	χ^2 (3:1)	χ^2 (recip.) ¹	0	1	2	3	4		
P.F. 60	Melody	45	16	0.01	0.002	14	15	16	3	13	2.5	44.9
Melody	P.F. 60	48	16	0.00		13	22	13	5	11		41.8
P.F. 60	Banff	93	28	0.1	3.9*	45	35	13	11	17	19.4*	35.5
Banff	P.F. 60	45	27	5.4*		7	30	8	8	20		50.7
P.F. 60	Can. 50	41	11	0.2	0.1	9	25	7	3	8	4.6	38.5
Can. 50	P.F. 60	41	8	1.5		5	30	6	0	8		37.5
P.F. 60	Aurora	50	0		1.7	4	37	9	0	0	11.4*	27.7
Aurora	P.F. 60	59	4			8	28	23	5	1		34.5
P.F. 60	Tempter	56	0			16	39	1	0	0	3.6	18.3
Tempter	P.F. 60	51	0			9	38	4	0	0		22.5
P.F. 60	H312-2-3	51	1			2	48	1	1	0		25.5
Parents												
Melody		0	55			0	0	0	0	55		100.0
Banff		0	34			0	0	0	4	30		97.1
Canner 50		0	55			0	0	0	0	55		100.0
Aurora		45	5			0	30	15	5	2		17.1
Tempter		52	1			0	35	17	1	0		34.0
H312-2-3		49	1			12	36	1	1	0		20.5
P.F. 60		51	0			8	37	6	0	0		24.0

"Significant at the 5% level.

¹Ratios of R:S for reciprocals compared by contingency table test.

²Score distribution for reciprocals compared by contingency table test.