at the end of the procedure plants of the genotype *ef-1ef-1Ef-2Ef-2aa*. Since *Ef-2* is not replaced by *ef-2*, this genotype is not an improvement for bolting time over the original parent. The preferred cross is *ef-1ef-1Ef-2Ef-2AA* x *Ef-1Ef-1ef-2ef-2aa*, which permits the selection, at the end of backcrossing, of the genotype *ef-1ef-1ef-2ef-2aa*, the slowest-bolting genotype in this system. On the other hand, if the recurrent parent is *ef-1ef-1ef-2ef-2AA*, then, in order to maximize the speed of advance and yet have the opportunity to return to the slowest-bolting genotype, the donor parent should be *Ef-1Ef-1Ef-2Ef-2aa*. In this case, the heterozygous parent in each backcross should be *Ef-1ef-1Ef-2ef-2Aa*, which is 2 to 3 weeks earlier than *Ef-1ef-1ef-2ef-2Aa*.

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Aviary and Field Evaluations of Sweet Corn Resistance to Damage by Blackbirds

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Abstract. **Each of 11 cultivars of sweet corn (*Zea mays* L.) was presented to red-winged blackbirds (*Agelaius phoeniceus* L.) in an aviary under no-choice conditions in 1985. This evaluation was repeated in 1986 with eight cultivars, five of which had been tested in 1985. In both years, there were significant differences in damage among cultivars; the damage rankings of the cultivars tested in both years were correlated. Total husk weight and husk weight beyond the cob tip individually explained 68% to 69% of the variation in damage among cultivars. Husk characteristics were more important than kernel characteristics in determining the amount of damage a cultivar received. Six of the cultivars evaluated in a field test near a blackbird roost showed differences in damage similar to that found in the aviary. In the field test, the most- and least-resistant cultivars had 16% and 76% of the ears damaged, respectively. Resistance is a viable approach to reduce damage in situations where sweet corn is grown near concentrations of blackbirds.**

Blackbird (Icterinae) damage to maturing sweet corn is a serious economic problem in localized areas of North America (4). One promising means of reducing damage is through the use of cultivars resistant to bird attack. Previous aviary experiments revealed significant, consistent differences among cultivars in damage by starlings (*Sturnus vulgaris* L.) and two species of blackbirds under free-choice and no-choice test regimes. Husk extension length and husk weight beyond the cob tip were the best correlates (negative) with damage, indicating that the incorporation of long, heavy husks into sweet corn lines should increase resistance (4).

The first objective of this study was to explore further, with additional cultivars, the relationship between cultivar characteristics and resistance in controlled aviary and laboratory tests. Of particular interest was to determine feeding preferences by birds to kernels from the various cultivars. The second objective was to evaluate cultivars in a field test near a blackbird roost to determine if differences in damage among cultivars as established in aviary tests also are observed under field conditions with high bird numbers.

Materials and Methods

Aviary tests. Eleven cultivars of sweet corn (Table 1) were planted on 27 May 1985 in six-row × 90-m plots in Erie County, Ohio. Row spacing was 0.75 m, and plant spacing averaged 20 cm. Starting 24 July and at 2-day intervals until 13 Aug., all plants with newly silked ears in rows 2 to 5 of each plot were marked with spray paint. A different color was used each day to allow use of ears of the same silking date in the evaluations.

In early July, 150 adult male red-winged blackbirds were captured in mist nets. Birds from the population were placed, four to a cage, in twenty-four 1.5 × 1.0 × 0.5 m cages in an outdoor pavilion. The birds were adapted to feeding on ears of corn in captivity for 2 weeks before the experiment began. Each cultivar was evaluated for damage at 18 days after silking (DAS) (15 to 25 Aug.) under a no-choice test regime by placing eight ears of freshly picked corn at 0800 HR, with husk and shank intact, in each of eight random cages for 6 hr (0900 to 1500 HR). For 1 hr before and during the 6-hr test, all other food (mixed wild bird seed) was removed from the cages. Woronecki et al. (9) provided a detailed description of the methodology.

Immediately before placing each ear in a cage, the length from cob butt to minimum and maximum husk extension and the length from cob tip to maximum husk extension were mea-

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Table 1. Selected characteristics of the 14 sweet corn cultivars evaluated for resistance to bird damage in aviary and field tests, 1985–86.

			Characteristics of cultivars[z]				
Cultivar no.[y]	Cultivar name	Year	Days to 50% silking	Total husk wt (g)	Husk extension wt (g)	Husk extension (mm)[x]	Cob length (mm)
6	133 Silver Prince	1985	63	12.76	0.83	13	225
13	Trigold	1985	62	9.01	0.45	18	189
15	South. Delicious	1985	68	11.72	1.12	35	220
16	Miracle	1985	60	11.98	0.51	33	206
		1986	58	10.62	0.32	18	185
18	Crisp 'N Sweet	1985	58	14.13	1.01	45	209
		1986	58	8.76	0.54	43	184
19	Star Dust	1985	52	9.80	1.50	66	165
		1986	46	6.56	1.27	66	133
22	Gold Dust	1985	55	18.43	2.15	79	185
		1986	55	16.40	2.08	73	179
23	Jazz	1985	51	8.56	0.99	42	183
		1986	46	4.06	0.25	8	138
25	Crusader	1985	58	14.11	0.66	32	199
27	Advance	1986	57	13.07	1.04	58	189
31	How Sweet It Is	1985	60	12.52	0.89	45	204
32	Sunsweet	1985	60	11.54	1.32	54	195
34	CXP 516	1986	55	7.74	0.57	34	177
35	Incredible	1986	59	9.39	0.37	18	189

[z] See text for details of measurements: N = 32 ears/cultivar.

[y] Seed company: 6, Harris; 13, Sun; 15, 16, 18, 31, 35, Crookham; 19, 22, 32, Agway; 23, Roger Bros.; 25, Seedway; 27, 34, Musser.

[x] From cob tip to minimum point of husk extension.

sured to the nearest millimeter. Immediately after each test, the shank and cob stem were separated from each ear by sawing through the husk at the butt of the cob. The husk then was separated into two components by cutting with scissors at the tip of the cob. The husk from butt to cob tip and husk beyond cob tip were weighed after drying at 30°C for several weeks. The following measurements were made on each ear: a) maximum corn row length; b) maximum ear length from butt to cob tip; c) maximum ear circumference; and d) maximum length of damage down a corn row.

In 1986, eight cultivars (Table 1), including five evaluated in 1985, were planted on 14 June. Each cultivar was evaluated in a no-choice test as in 1985 by placing eight ears in each of four cages for 6 hr. In addition, the same no-choice test was run for each cultivar in four other cages, with the difference that the husk of each ear was cut 2 cm above the cob butt and removed. Cultivar characteristics were not measured in these "no husk" tests. Damage was evaluated by counting the number of kernels pecked on each ear. The maximum length of damage down a corn row was not measured because the birds pecked kernels at random on ears without husks instead of starting at the tip and working down uniformly, as they did when the husks were intact. Finally, on the day of each cultivar evaluation, the kernels from four additional ears were cut from the cob within 1 hr of picking and frozen for use in the laboratory test described below.

To determine if differences in damage among cultivars were significant, one-way analysis of variance (ANOVA) tests were run for each of the three groups of cultivars (1985 and 1986 with husks, 1986 without husks). Also, step-wise regression was performed to determine which cultivar characteristics were correlated best with damage. Spearman's rank correlation coefficients were used to compare the relative damage rankings of cultivars in the various tests (6).

Laboratory tests. Kernels from the eight cultivars evaluated in the 1986 aviary tests were presented to red-winged blackbirds in two-choice preference tests at the Monell Chemical Senses Center, Philadelphia, during Feb. 1987. Five adult male redwing blackbirds were housed individually in 61 × 36 × 41 cm cages in a room with a 9:15 hr light-dark cycle.

After 2 weeks adaptation to cage conditions, each bird was given 1-hr pretreatment feeding trials at 1, 4, and 7 hr following light onset. For each trial, the birds were presented with two 5-g samples of freshly thawed corn kernels in cups (7.5 cm in diameter). These samples contained kernels from the eight cultivars. Maintenance food (Purina Flight Bird Conditioner) was removed from the cages when corn kernels were present.

Over the 12 days following the second pretreatment day, the birds were given twenty-eight 1-hr, two-choice tests (three/day) among the cultivars. All possible pairings of the eight cultivars were presented once to each bird in a random order. Mean consumption by each bird of each cultivar was evaluated in a Friedman two-way ANOVA by ranks (6).

Field test. On 4 June 1986, six of the eight cultivars evaluated in the aviary and laboratory were planted at Ottawa National Wildlife Refuge, Lucas County, Ohio. The field was 2 km south of Metzger Marsh, a traditional roosting site for blackbirds adjacent to Lake Erie. The sweet corn was planted in six replicate blocks, each containing six plots measuring 12 rows (9.1 m) by 152 m. The six cultivars were randomly assigned to plots in each block. Blocks were at least 41 m apart.

Starting 24 July, 100 ears were examined in each plot at 2-day intervals to establish the date when 50% of the ears had silked. At 24 days after 50% silking in each plot, five consecutive ears were examined in each of 12 randomly established subplots to determine incidence of bird damage and to obtain a visual estimate of percent of kernels eaten on damaged ears (7). Damage assessments were from 21 Aug. to 2 Sept. Differences in damage among the six cultivars were evaluated by ANOVA.

The population size of the blackbird roost was estimated on 12 Aug. and 3 and 24 Sept. Two or three observers estimated numbers entering the roost in the evening (5).

Results

Aviary tests—ears with husks. In both 1985 and 1986, there were significant ($P < 0.01$) differences among cultivars in length of damage per ear and in percent of ears damaged. Percent of ears damaged per cultivar ranged from 31% to 78% in 1985 and from 38% to 97% in 1986 (Table 2). The rankings of the five cultivars evaluated in 1985 and in 1986 were significantly ($P < 0.05$) correlated ($r = 0.90$) for the 2 years. Cultivars 22 and 23 were the least and most damaged, respectively, in both years.

Husk weight beyond the cob tip and minimum husk extension beyond the kernels were the characteristics best correlated (negatively) with damage for individual ears in 1985 and 1986, respectively (Table 3). These characteristics individually explained 12% to 16% of the variation in damage among ears. A much higher proportion of the variation in damage among cultivars was explained when mean values for these characteristics were examined. Total husk weight and husk weight beyond the cob tip were the best correlates (negative) with mean percent of ears damaged and mean damage length per ear, respectively, for the 19 no-choice tests of the 14 cultivars in the 2 years combined (Table 3, Fig. 1). These characteristics individually explained 68% to 69% of the variation in damage among cultivars. The following step-wise regression equations gave the highest correlations with the two measures of mean damage for each cultivar (N = 19): % of ears damaged/cultivar = 148.69 − 3.05 THW − 0.24 HMAX, ($R^2 = 0.72$); and mean damage length (mm)/ear/cultivar = 73.00 − 11.88 HEW − 1.41 THW, ($R^2 = 0.80$); where THW = total husk weight (g), HMAX = maximum husk length (mm)—cob butt to husk tip, and HEW = husk extension weight (g).

Aviary test—ears with husk removed. There were significant ($P < 0.01$) differences among the eight cultivars in the number of kernels eaten per ear. The most-damaged cultivar (cultivar 16) received 2.7 times the loss of the least-damaged cultivar (cultivar 23). This range was similar to the 2.5-fold range in damage for the same eight cultivars in the no-choice test with husks not removed (Table 4). However, there was no significant ($P > 0.10$) correlation between the rankings of cultivars in the two tests ($r = -0.36$). In fact, cultivar 23, which consistently received high damage in aviary tests when the husks were not removed, had the least damage when the husks were removed.

Laboratory test. There was no significant ($P > 0.05$) difference among the eight cultivars in the mean weight of kernels eaten in the two-choice preference tests. Mean consumption (per bird per hour ± SD) ranged from 1.3 ± 0.9 g to 1.8 ± 1.2 g for cultivars 27 and 34, respectively. There was no significant ($P > 0.10$) correlation between the rankings of the eight cultivars for mean consumption in these two-choice preference tests and in the aviary tests with ($r = -0.24$) and without ($r = -0.21$) husks.

Field test. There were significant ($P < 0.01$) differences among the six cultivars in the percent of ears damaged and percent of corn eaten. Cultivar 23, with 76% of the ears damaged, had 4.8 times the damage of cultivar 22 (16%). Estimated percent of corn eaten ranged from 1% in cultivars 22 and 27 to 17% in cultivar 23. The ranking of the cultivars for percent of ears damaged was virtually identical ($P < 0.01$) with the ranking measured in the aviary in 1985 ($r = 1.00$) and in 1986 ($r = 0.94$) (Table 2).

Estimated numbers of blackbirds and starlings at the roost were 41,000, 31,800, and 41,800 on 12 Aug., 3 Sept., and 24 Sept., respectively. Species composition was about 70% red-winged blackbirds, with the remainder being starlings and brown-headed cowbirds (*Molothrus ater* L.). Daily flightlines to and from the roost went over the sweet corn plots.

Discussion

These tests further established that cultivars of sweet corn vary consistently in their susceptibility to damage by red-winged blackbirds, both in an aviary setting, where alternate food is not available, and in a field situation, where the cultivars are subjected to heavy feeding from free-ranging flocks of birds. Total husk weight and weight of husk extension were the best cor-

Table 2. Ranking of cultivars of sweet corn for percent of ears damaged by red-winged blackbirds in two no-choice aviary tests and in a field test in northern Ohio.

	Ears damaged by birds (%)					
	1985 Aviary test		1986 Aviary test		1986 Field test	
Rank	Cultivar	(N = 8 cages)[z]	Cultivar	(N = 4 cages)[z]	Cultivar	(N = 6 plots)[y]
1	22	31 a[x]	22	38 a[x]	22	16 a[x]
2	18	36 a	27	41 ab	27	21 a
3	31	42 ab	16	56 abc	18	42 b
4	6	45 abc	18	63 abc	16	50 b
5	32	52 bc	34	69 bcd	19	54 b
6	15	56 bcd	35	69 bcd	23	76 c
7	16	58 cde	19	75 cd		
8	19	59 cde	23	97 d		
9	13	64 def				
10	25	72 ef				
11	23	78 f				

[z] Eight ears of cultivar, with husk intact, per cage.
[y] Sixty ears sampled for damage per plot.
[x] Mean separation by Duncan's multiple range test ($P < 0.05$).

Table 3. Simple correlation coefficients between bird damage and a) various characteristics of individual ears of sweet corn in the 1985–86 aviary tests and b) mean values for the various characteristics of 19 (11 in 1985 and eight in 1986) cultivars of sweet corn.

	Correlation coefficients			
	Individual ears		Mean values per cultivar per ear	
	Mean damage (length/ear)			
Cultivar characteristics	1985 (N = 352)	1986 (N = 256)	Mean damage (length/ear) (N = 19)	Percent of ears damaged (N = 19)
Cob length	0.02	−0.15*	−0.13	−0.57*
Corn row length	0.00	−0.16*	−0.35	−0.65*
Ear circumference	−0.03	−0.15*	−0.15	−0.27
Max. husk length	−0.12*	−0.24**	−0.56*	−0.78*
Min. husk length	−0.18**	−0.38**	−0.67**	−0.82**
Max. husk ext. beyond cob	−0.13*	−0.10	−0.57*	−0.37
Min. husk ext. beyond cob	−0.18**	−0.25**	−0.75**	−0.47*
Max. husk ext. beyond kernels	−0.13*	−0.17**	−0.45	−0.39
Min. husk ext. beyond kernels	−0.19**	−0.40**	−0.70**	−0.53*
Total husk weight	−0.25**	−0.35**	−0.77**	−0.82**
Husk ext. weight	−0.34**	−0.38**	−0.83**	−0.56*

*,**Significant at the 5% or 1% levels, respectively.

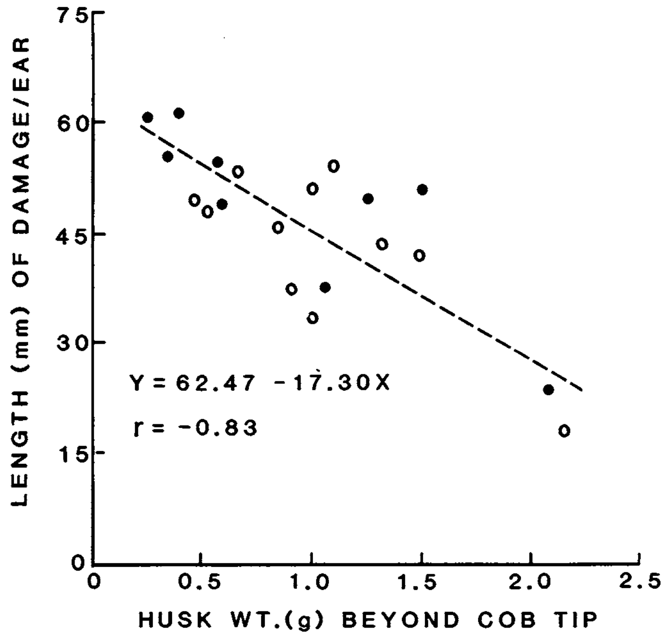

Fig. 1. Relationship of mean husk dry weight beyond the cob tip to mean length of damage per ear for 11 (1985, ○) and eight (1986, ●) cultivars of sweet corn evaluated in no-choice aviary tests, 1985 and 1986. The trend was a significant ($P < 0.01$) linear regression.

Table 4. Ranking of eight cultivars of sweet corn for bird damage in no-choice aviary tests, one in which the husks remained on the ears and the other in which the husks were removed, 1986.

	Condition of ears in test			
	With husks		Without husks	
Rank	Cultivar	Mean damage length/ear (N = 4 cages)^z	Cultivar	Number of kernels eaten/ear (N = 4 cages)^z
1	22	24 a^y	23	49 a^y
2	27	38 ab	34	59 a
3	34	49 bc	19	68 a
4	19	50 bc	35	97 b
5	16	55 bc	18	97 b
6	18	56 bc	22	101 b
7	23	60 c	27	126 c
8	35	61 c	16	130 c

^{z}Eight ears of cultivar per cage.

^{y}Mean separation by Duncan's multiple range test ($P < 0.05$).

relates (negative) with damage, explaining almost 70% of the variation in damage among cultivars. Cultivar 22, with a mean husk extension weight of ≈2 g, had about one-third to one-half the damage per ear as did cultivars with husk extension weights of <1 g (Fig. 1). Length of husk extension also was correlated negatively with damage. Minimum husk extension measurements consistently had higher negative correlations with damage than did maximum husk extension measurements (Table 3). Birds tend to search for the minimum point of husk extension to insert their bill to expose kernels (1). The farther that minimum point is from the kernels, the less likely damage will occur.

If the husks were removed and birds had unencumbered access to kernels on the cob, the birds had a perference for certain cultivars. However, these preferences were unrelated to the feeding preferences revealed for unhusked ears in the field and aviary. Moreover, if kernels alone were presented to the birds in the laboratory, no significant differences in preferences were observed. Together, these findings indicate that husk characteristics are the dominant factors influencing damage patterns among cultivars in the field, even though differences in kernel characteristics can influence feeding if husks are removed.

In conclusion, resistance, based on husk characteristics, can reduce bird damage in situations where sweet corn is grown near concentrations of blackbirds. Using the equations and correlations established in this and previous studies (3, 4), husk characteristics can be measured for samples of ears from currently available cultivars to rate them for their relative resistance to damage. In addition, sweet corn breeders should be able to develop improved resistant lines if so desired.

One final point with regard to the use of cultivar resistance in an integrated pest management program for corn. Red-winged blackbirds often feed extensively on insects, such as rootworm beetles (*Diabrotica longicornis* Say), in corn fields during the silking and early ear development stage (2, 8). If resistant cultivars can be used to minimize damage, these feeding habits of blackbirds that are beneficial may be enhanced.

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Addition of Genes for Dwarf Seed (*ds*) and Spindly Branch (*sb*) to the Linkage Map of Common Bean

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Additional index words. *Phaseolus vulgaris,* induced mutants

Abstract. **Linkage detection and estimation procedures based on deviation from expected F_2 segregation ratios in common bean (*Phaseolus vulgaris* L.) were used to localize two genes. The product ratio method of estimation was used with four-class segregations, and the maximum likelihood method was used with three-class segregations and for combining multiple sets of data. A tight linkage of 1.6 ± 1.5 map units (m.u.) was found between dwarf seed (*ds*) and dark green savoy leaf (*dgs*), two genes in linkage group VII. A third gene in linkage group VII, stipelless lanceolate leaf (*sl*), was found to be 18.7 ± 1.6 m.u. from *ds*. The distance between *dgs* and *sl* was found to be 21.2 ± 1.0 m.u., thus establishing that *ds* is located between *dgs* and *sl*. This location of *ds* supports the contention that *ds* and tenuis (*te*), a gene described by Lamprecht, are the same gene. In linkage group IX, an estimate of 4.6 ± 1.5 m.u. was obtained for the linkage between diamond leaf (*dia*) and progressive chlorosis (*prc*). Spindly branch (*sb*) was found to be 15.4 ± 0.7 m.u. from *prc* and 11.4 ± 1.1 m.u. from *dia*. Thus, *dia* is located between *sb* and *prc*. The independence of linkage groups VII and IX is demonstrated by the independence of representatives of the two groups.**

The gene linkage map of common bean is rather rudimentary. Lamprecht published a summary of all gene linkages reported in common bean prior to 1961 (6). There were 26 genes in eight linkage groups. Fewer than a dozen genes have been mapped in common bean since 1961. The lack of an inviting foundation of good-quality marker genes probably discouraged interest in mapping genes in bean. Most of the genetic markers in Lamprecht's map are expressed late, i.e., at flowering or later. Also, many of the genes are involved in complex epistatic relationships, which makes them difficult to classify in segregating populations. Furthermore, many of Lamprecht's lines have been lost. Crop species such as corn (*Zea mays* L.), tomato (*Lycopersicon esculentum* L.), barley (*Hordeum vulgare* L.), and pea (*Pisum sativum* L.) are more attractive to researchers, in part because of the availability of fairly detailed gene maps.

Nagata and Bassett (9) reported a linkage of 38 centimorgans (cM) between yellow wax (*y*), a gene in Lamprecht's linkage group VII, and dark green savoy leaf (*dgs*). Linkage intensities of 21 cM between *dgs* and stipelless lanceolate leaf (*sl*) and 12 cM between *sl* and round leaf (*rnd*) also were reported (9). The three new genes mapped to Lamprecht's linkage group VII—*dgs, sl,* and *rnd*—are induced mutants that had been described previously (8). A gene of uncertain origin (2), named dwarf seed (*ds*), also was found to be 29 cM from *rnd,* but its relationship with other genes in linkage group VII was not determined. One of the two possible orientations of *ds* relative to *rnd* would place it at about the same location as tenuis (*te*), a gene mapped by Lamprecht (6). The expression of *ds* (2) reduces pod length by ≈50% and is similar in phenotype to *te* described by Lamprecht (5). These observations lead to the hypothesis that *ds* and *te* may be the same gene. The unavailability of stocks carrying *te* precludes a direct allelism test. However, if *ds* and *te* are the same gene, then *ds* should be located a few map units (m.u.) from *dgs* and between *dgs* and *sl* (9). Such a location implies a linkage between *ds* and *sl* of a few units less than 21 cM, the linkage distance between *dgs* and *sl*.

Nagata and Bassett (9) also reported a linkage between diamond leaf (*dia*) and progressive chlorosis (*prc*), two induced mutants (8). The progressive chlorosis gene was first designated *pc* by Nagata and Bassett (8), but the symbol was changed to *prc* to avoid confusion with the use of *pc* for the persistent green pod color character (3). The linkage between *dia* and *prc* was estimated from two different sets of repulsion phase linkage data to be 1 cM in one instance and 9 cM in the other. The wide variation in estimates raises questions about the reliability of the combined estimate of 6 cM. Continuing efforts to add other genes to the linkage map of common bean have uncovered the linkage of the spindly branch (*sb*) gene to the *dia–prc* linkage group. A description of this marker and evidence supporting its map location are presented here.

The five objectives of this report are to a) test the hypothesis that *ds* and *te* are the same gene, b) to establish the map position of *ds* relative to *dgs* and *sl*, c) improve the accuracy of the estimate for linkage between *dia* and *prc*, d) determine the map location of *sb* relative to *dia* and *prc*, and e) report linkage tests

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