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THE CROSSBREEDING OF POULTRY

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SUMMARY

The data obtained in this study seem to support fairly consistently the view that crossbreeding stimulates the vigor of the resulting offspring. Crossbreeding tends to improve hatchability of eggs, viability of chicks, rate of growth, and, finally, egg production. In many instances the stimulation is not great, but the cumulative gains from consideration of all these characteristics are of economic significance. There is considerable variability in results from crossbreeding, but similar variation is found among strains of the same pure breed. In some instances there is a tendency to combine in the crossbreds the more desirable characteristics of the two breeds utilized.

Not all crossbreds are superior to purebreds, but in general their sturdiness ranks them above purebreds used in this study. It is evident that there is a reflection in their offspring of the qualities of the purebreds used in the production of crossbreds. Crossbreds appeal most to those poultrymen who have no breeding program of their own but depend upon the hatcheryman for the replenishment of stock. Crossbreds are also extensively used by broiler producers who find the high viability and uniform growth a valuable asset.

Even though it is admitted that there is stimulation of vigor of crossbreds, other considerations may make their production uneconomical under certain situations. Local market prejudices, although frequently having no basis in quality characteristics, must be given consideration. Such instances are found in plumage color and egg shell color preferences. If these considerations outweigh gains from increased vigor then crossbreeding should not be practiced.

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THE CROSSBREEDING OF POULTRY[1]

By D. C. WARREN

HYBRID VIGOR

The exceptional sturdiness of certain types of crossbreds resulting from the mating of breeds and varieties of domestic animals has long been a matter of common knowledge among practical breeders. This sturdiness has been referred to as hybrid vigor and is not limited to the animal kingdom, since some of the most extreme examples of stimulation are found in the hybridization of plants. Because of the labor involved in hand pollination, however, the exceptional vigor of the first generation of crossed plants has little practical application. In hybrid corn the same general principles are concerned; however, the technique of its production is not merely one of crossing varieties but involves the crossing of inbred strains of the same variety.

Use has been made of crossbreds in sheep, swine, and cattle breeding. Such crossbreds have the reputation of being exceptionally thrifty and rapid growing, making desirable meat-type animals. Numerous studies have been made of crossbred hogs and the results are in general agreement by indicating that in most respects the crossbreds are superior to the purebreds from which they originated. In most instances the superiority of the crossbreds is not extreme, but results are fairly consistent.

Probably the most familiar hybrid is the mule, resulting from the crossing of the horse and the ass. This is a cross of two more widely divergent forms than most of the crosses in poultry later to be reported. As is frequently the case in wide crosses, the mule is a sterile hybrid. The mule exhibits the exceptional sturdiness and combines many of the desirable qualities of the two types crossed.

Another characteristic of hybrid vigor which should be emphasized is its limitation to the first generation, thus making it inadvisable to breed from crossbreds. The crossbred is characterized by exceptional sturdiness and relatively uniform appearance while the offspring of crossbreds frequently show wide variability in size, conformation, and color and often do not have the vigor equal to that of the parental stocks. The desirable qualities of crossbreds sometimes lead the producer to make the error of using them as breeders. In hogs it has been proposed that the crossbreds may be used as breeders to be mated to a third breed or to one of the parent stocks. Because of the wide divergence of types and the variability in resulting plumage color, this procedure for the production of poultry crossbreds is very questionable. If crossbreds are to be used, the small cost of replacement of stock will probably make it advisable to repeat the original cross.

1. Contribution No. 144, Department of Poultry Husbandry.

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UTILIZATION OF CROSSBREDS

It may appear inconsistent to the average poultry breeder to suggest the practice of crossbreeding after years of proclaiming the gospel of pure breeding. The use of the pure or standard-bred fowl was urged because it has been improved by skilled breeders and made a more productive and uniform market animal, and when comparing the purebred and the mongrel all these advantages exist. The crossbred fowl, except for color in some crosses, is as uniform as most standard breeds and in vigor and productiveness it may be superior to the breeds used in its origin. From work in plant breeding it may be inferred that the best results are to be expected from crossing of breeds and varieties of fowl that have survived a period of breeding toward a definite standard. The utilization of the crossbred is not necessarily a reversion to the old system of promiscuous breeding, but the adoption of a system which is of value only when well-bred standard fowl are available. The poultryman, noted for his exact standards, has built up breeds and varieties that provide favorable material for crossbreeding. If the use of crossbreds becomes widespread it should not mean the reversion to mongrelization of the fowl, but should place a premium upon well-bred pure breeds.

Since crossbreds cannot be used as breeders they have no place in the program of the poultryman who depends upon the sale of breeding stock for a portion of his income. There are, however, many poultrymen who confine their operations to market eggs and poultry. Many of this group depend upon the hatcheryman for their supply of chickens. To this type of an organization the crossbred fowl lends itself most favorably. It is a relatively simple matter for the hatcheryman to arrange his flocks for the production of crossbreds. The possibility of identifying the sexes at hatching, which is discussed later in this publication, has been a factor in stimulating the use of crossbred poultry.

To date the crossbred chicken seems to have its greatest popularity among the farmers in the Middle West and broiler producers in the East. It would appear from data reported later in this study that the most popular cross with the poultrymen of the Middle West is that of the White Leghorn with some good producing heavier breed.

In the extensive broiler producing industry of the eastern states crossbreds are becoming increasingly popular. Poffenberger and others (1936) report that 41 percent of the broiler producers in Maryland were using crossbreds. The most popular crossbred broilers are from the mating of Barred Plymouth Rock males with Rhode Island Red or New Hampshire females.

APPEARANCE OF OFFSPRING OF MORE COMMON CROSSES

It is frequently of interest to know the plumage color of crossbreds resulting from various combinations. In Table 1 is listed the color of crossbreds from matings of the more common breeds and varieties of chickens. In the case of the matings involving White

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TABLE 1. *Color of adult offspring from crosses of the more common breeds and varieties of chickens.*

FEMALE PARENT	Male parent						
	White Leghorn	White Plymouth Rock	White Wyandotte	Black Varieties	Rhode Island Red	Buff Varieties	Barred Plymouth Rock
White Leghorn. . .		White, some black flecks			White with some black flecks, may show buffish or reddish on surface		White, some black flecks
White Plymouth Rock.	White, some black flecks		White	Females black, males barred or black	Females black or reddish buff; males black, barred or Columbian pattern		Barred
White Wyandotte.	White, some black flecks	White		Mostly black	Females reddish buff, males Columbian pattern		Barred
Black Varieties. . . .		Barred, but some black	Mostly black		Mostly black, showing red		Barred
Rhode Island Red. .	White with some black flecks and some red or buff on surface	Barred, black, or Columbian pattern	Usually Columbian pattern, some blacks	Mostly black, showing buff or red		Reddish buff	Barred
Buff Varieties.					Reddish buff		Barred
Barred Plymouth Rock.	White, some black flecks	Barred; some females black	Females black, males barred				

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Wyandottes and White Plymouth Rocks the color may vary some, depending upon the strain. In some instances the color may be barred, black or even white, depending upon the patterns masked under the white, or on whether the strain carries dominant instead of the usual recessive white. In crossbreds where the color has been listed as mostly black, some red, buffish or whitish feathers may show in the wingbows of the males and the breasts of the females. Unless indicated otherwise in the table the two sexes will be the same color. Where either parent has white skin, the crossbreds will also have white skin.

POPULARITY OF VARIOUS CROSSES

The writer was earlier of the opinion that much of the popularity of poultry crossbreds might be due to the fact that their sex could be identified at hatching. If this view be correct then the introduction and wide use of the Japanese method of sex identification should have restricted the production of crossbreds. This does not appear to have occurred.

In order to gain information regarding the interest in poultry crossbreds a questionnaire was sent out to 100 hatchery men known to have sold crossbred chicks in the past few years. Replies were received during January, 1941. Most of the names of those on the list living outside of Kansas were obtained from advertisements in poultry journals. Fifty-four responded, of which 24 were located in Kansas and 30 in the states of Alabama, Illinois, Indiana, Iowa, Michigan, Missouri, New Hampshire, Ohio and Oklahoma.

The answers to the inquiries listed in Table 2 and 3 do not always total 54 since some answers were omitted by those responding. In order to learn the opinion of hatcherymen regarding trends in popularity of crossbreds, the question was asked—During the last two years is there an increasing or decreasing interest in crossbreds? Of those replying to the question, two reported decreasing, one no change, and 44 reported increasing interest in crossbreds. Since only those having previously offered crossbred chicks for sale were included it is possible that the response does not represent an accurate cross section of the opinions of poultrymen. However, the response was preponderantly favorable to crossbreds. It was believed that the hatcherymen's opinion would reflect the interest of the chick buying public. Only two of the 54 hatcherymen responding stated that they had sold but no longer were carrying crossbred chicks. It is also of interest that about half of the hatcherymen replying stated that they were either doing no sexing or used the Japanese method of sexing crossbreds. This would seem to indicate that the ability to sex crossbreds by sex-linked characters is not a factor in encouraging their use. The most widely popular cross, Australorp male-White Leghorn female, is not one in which sex can be identified at hatching by sex-linked traits.

In Table 2 are summarized the replies regarding hatcherymen's rating of the popularity of various crosses. They were asked to

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name the three most popular crosses in order of their rank. The cross of the Australorp male by the White Leghorn female greatly outranked all others in popularity, 31 placing it first while all other crosses combined were given this rating by only 18.

A number of factors probably enter into the ratings which hatcherymen have given the different crosses. One is whether the crossbreds are produced for general farm use or for broilers. The abundance of breeds or varieties in a region will affect their availability for crossbreeding. The possibility of identification of sex at hatching also has some influence in the choice of breeds for crossing. The data in Table 2 are segregated for those received from Kansas hatcherymen and from those outside the state. The extensive use of White Plymouth Rocks by Kansas hatcherymen probably reflects the popularity of this variety in the state. It is also seen that outside the state there is a greater use of those crosses suited for broiler production, while in Kansas most of the crossbreds are produced for general farm flocks. The White Leghorn-White Plymouth Rock cross is popular when made in either direction. When the White Leghorn male is used sex identification at hatching is possible. The reciprocal cross in which sex cannot be identified at hatching is highly popular with Kansas hatcherymen since better fertility is reported when using a male of the larger breed. The Black Minorca-White Leghorn cross which is popular in all states included, is the only one listed in Table 2 which produces a pure white egg. The Dark Cornish crosses were listed for production of broilers.

The hatcherymen reporting were asked to list all the crosses from which they were offering chicks for sale and to cite any objections coming to their attention, regarding any of them. In Table 3 are listed the more popular crosses together with any unfavorable comments on them. The number of times each cross was listed gives some indication of their popularity among chick buyers. In noting the number of unfavorable comments one should take into consideration the frequency of use of the cross, since no unfavorable comments would be received unless the cross was being used. The comments are of value primarily in indicating some of the major short-comings, of the crosses listed. Again the Australorp-White Leghorn cross greatly exceeded all others in frequency of listing. Reciprocal matings between White Plymouth Rocks and White Leghorns, and between Barred Plymouth Rocks and Rhode Island Reds were also widely used. Other crosses given a high rating in Table 2 rank well toward the top of the list in Table 3.

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TABLE 2. *Popularity rank* of various crosses of various breeds and varieties of chickens as rated by 52 hatcherymen selling crossbred chicks.*

BREEDS CROSSED (Male parent listed first).	How crosses were ranked by Kansas hatcherymen.			How crosses were ranked by out-of-state hatcherymen.			Total.		
	First.	Second.	Third.	First.	Second.	Third.	First.	Second.	Third.
Australorp × W. Leghorn	22	1		9			31	1	
W. Leghorn × W. P. Rock	1	2	2	2	3	1	3	5	3
Blk. Minorca × W. Leghorn		3		3	3	1	3	6	1
R. I. Red × B. P. Rock				3	5		3	5	
B. P. Rock × R. I. Red				2	2	3	2	2	3
New Hampshire × B. P. Rock			1	3			3		1
W. P. Rock × W. Leghorn		11			1			12	
Dark Cornish × R. I. Red		1	1		1	4		2	5
R. I. Red × W. Wyandotte			3			2			5
B. P. Rock × New Hampshire				1	1		1	1	
R. I. Red × W. Leghorn	1		1				1		1
Dark Cornish × W. Leghorn					3	1		3	1
New Hampshire × W. Leghorn		2	2					2	2
W. Leghorn × B. P. Rock						3			3
W. Leghorn × R. I. Red			3						3

* Crosses not being ranked by at least two reporting hatcherymen were omitted. Two of those reporting are not included here since they were no longer selling crossbreds.

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TABLE 3. *Types of crosses of chickens listed by hatcherymen in the order of frequency of their use, together with unfavorable comments regarding them.*

BREEDS CROSSED (Male parent listed first.)	Number times listed.	Unfavorable comments on—									
		Size.	Plumage color.	Leg color.	Egg-shell color.	Skin color.	Brood-iness.	Fer-tility.	Growth.	Feath-ering.	General traits.
Australorp × W. Leghorn	35	.....	.....	2	1	1	5	2	.....	.....	.....
R. I. Red × B. P. Rock	18	.....	7	.....	.....	.....	1	.....	.....	.....	.....
W. P. Rock × W. Leghorn	18	1	.....	.....	1	.....	.....	.....	1	.....	.....
W. Leghorn × W. P. Rock	15	2	.....	.....	.....	.....	1	3	.....	.....	.....
Blk. Minorca × W. Leghorn	14	1	1	.....	.....	.....	1	.....	.....	.....	.....
B. P. Rock × R. I. Red	10	.....	1	.....	.....	.....	.....	.....	.....	2	.....
R. I. Red × W. Wyandotte	10	.....	3	.....	.....	.....	.....	.....	.....	.....	.....
New Hampshire × B. P. Rock	8	.....	2	.....	.....	.....	.....	.....	.....	.....	.....
Dark Cornish × R. I. Red	7	.....	.....	.....	.....	.....	.....	1	.....	2	.....
W. Leghorn × R. I. Red	7	1	1	.....	.....	.....	.....	2	.....	.....	.....
R. I. Red × W. Leghorn	6	.....	2	.....	.....	.....	.....	.....	.....	.....	.....
W. Minorca × W. Leghorn	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	2
Dark Cornish × W. Leghorn	5	.....	.....	.....	.....	.....	.....	1	.....	.....	1
W. Leghorn × New Hampshire	4	.....	1	.....	.....	.....	.....	.....	.....	.....	.....
W. Leghorn × B. P. Rock	3	.....	.....	.....	.....	.....	.....	1	.....	.....	.....

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EARLIER WORK

Although crossbred poultry is extensively used both in this country and England critical experiments comparing them with related purebreds are few in number. Cushman (1893) made crosses of a number of breeds of chickens but did not compare them with purebreds kept under similar conditions. For meat birds he recommended crosses between Indian Games and Light Brahmas. One of the early investigations comparing first generation crossbreds with purebreds was reported by Pearl and Curtis (1910). The major object of the experiment was not to test the effects of crossbreeding as such but they did record the fact that crosses between Barred Plymouth Rocks and Dark Cornish were superior in some respects and inferior in others when compared with the parent stocks. Warren (1930) reporting primarily on crosses of White Leghorns to Jersey Black Giants, Rhode Island Reds and Barred Plymouth Rocks, found evidence from most measures of vigor for superiority of the crossbreds when compared with the pure breeds involved. Byerly, Knox and Jull (1934) made comparisons of the hatchability of crossbreds and purebreds and found considerable variability depending upon the hatchability of the purebreds used. They concluded that where the hatching power of the eggs of the purebreds was low crossbreeding would improve it but where it was already good, crossbreeding might lower hatchability as often as increase it. Hoffman-Bang and Holm (1933) compared the egg production of crossbreds between Barred Plymouth Rocks and Brown Leghorns. The two breeds were very similar in egg production, laying 191 and 181 the first year and 110 and 133 the second year, respectively. Reciprocal crosses between them produced 226 and 220 the first year, and 153 and 142 eggs the second year.

One of the most comprehensive studies was conducted by Knox (1939). First he compared crossbreds of various types by purchasing eggs from crossbred matings by poultrymen in different sections of the country. This instead of being a measure of crossbreeding as such was a comparison of available crossbreds with purebreds the source of which he does not state. From the practical point of view of the buyer of crossbreds the results would probably be the same. From this test the results were not very favorable to crossbreds and in egg production the crossbreds were definitely inferior to the purebreds.

Knox made a more critical test of the effects of crossbreeding using Rhode Island Reds, Light Sussex and White Wyandottes and hybrids from mating Rhode Island Red males to females of the other two breeds. The crossbred females showed egg production intermediate between the parent stocks while the 10-weeks weight was similar in both purebreds and crossbreds.

Bice and Tower (1939) made a careful study of the effects of crossbreeding using the Japanese Shamo Game, a popular meat bird in Hawaii. This local breed was crossed with Rhode Island Reds,

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Barred Plymouth Rocks and White Leghorns. The four pure breeds were compared with crossbreds resulting from matings of the Shamo Game males to females of each of the other three mentioned breeds. There was definite improvement in hatchability of all crossbreds over the purebreds except in the case of the Rhode Island Reds. The crossbreds in each group had a lower chick mortality rate than the purebreds of the corresponding group. The crossbreds grew more rapidly than any purebred except the Shamo Game and ate less through the first eight weeks than did any of the purebreds.

The foregoing results differ rather widely regarding the merits of crossbreeding poultry. Perhaps a similar variability of results would have been obtained had a like number of pure breeds been compared, or even different strains of the same breed. These results emphasize the need for having as nearly identical parent stock as possible for producing the crossbreds and purebreds being compared. Otherwise the results may be a measure of the qualities of different samples of purebreds rather than the effects of crossbreeding.

PLAN AND OBJECTIVE OF THE EXPERIMENT

OBJECTIVE

The purpose of these studies was to compare critically crossbreds with the pure breeds from which they were derived. It was also intended to make a survey of the qualities of some of the commoner types of crossbreds.

STOCK USED

The number of breeds and varieties of chickens used in crosses was 12. They were Single Comb White Leghorn, Single Comb Rhode Island Red, Barred and White Plymouth Rock, White Wyandotte, New Hampshire, Australorp, Black and White Minorca, Ancona, Light Brahma, and Jersey Black Giant.

The qualities of the pure breeds utilized in the more extensive tests were well known. However, in the case of the less common pure breeds used in the exploratory tests little was known regarding the stocks except that they were from what were considered good farm flocks of the breed. All stock used was pullorum tested. The types of crosses made are indicated in the tables which follow.

The results here reported cover the period 1926 to 1940 and 14,566 purebred and crossbred chicks were hatched for the study.

MANAGEMENT OF STOCK

Although the study covered a considerable period of years, no attempt has been made to compare results of different years. The general management was similar from year to year but many uncontrolled variables entered into the results of successive seasons. For any one year the stocks being compared were treated as nearly identically as possible. Chicks were hatched over an eight-weeks period and in each hatch were representatives of the matings being compared. All the crossbreds and purebreds from each hatch were

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kept in a group while brooding so that they encountered the same environmental conditions. Chicks were usually hatched in March and April. The early season hatching probably handicapped the Leghorn type birds while the late season handicapped the larger later-maturing birds. When mature, representatives from each type of mating were placed in the same laying house so as to have their environment the same during the laying period. Various disease outbreaks occurred during the period of the experiment and loss from fowl paralysis was excessive, but since birds being compared were all subject to the same conditions they afforded opportunity to check upon the relative disease resistance of crossbreds.

MATING METHODS

In the more critical experiments the males were rotated in a manner to make the crossbreds as closely related to the purebreds as possible. As many males as possible were used in the crosses in order to avoid the vitiation of results by the individuality of the few birds of this sex used. Since several females were ordinarily used on the maternal side, it was less of a problem to obtain a representative sample of the breed being tested.

MEASUREMENT OF QUALITIES

The qualities compared in testing the effects of crossbreeding were hatchability, chick mortality, growth rate, maturity age, adult weight, egg weight, egg record, and adult mortality. The methods of evaluating each will be given in more detail under their respective headings.

EXPERIMENTAL RESULTS

RECIPROCAL CROSSES

In a number of the tests it was possible to produce for comparison during the same year, stock of the two pure breeds and crossbreds resulting from reciprocal matings between them. This constitutes one of the most critical tests of the effects of crossbreeding as such. It is especially true where a system of rotation of males was followed making the crossbreds and purebreds half brothers and sisters. This gives better assurance that the differences observed are the results of crossbreeding rather than due to individual variation in genetic makeup of birds used as parent stock.

In Table 4 are given the results of reciprocal matings for five different years involving Australorps, White Leghorns, Rhode Island Reds, Barred Plymouth Rocks and New Hampshires. Two different strains of White Leghorns and of Rhode Island Reds, differing widely in qualities, were utilized in the comparisons. In each case the offspring of reciprocal matings were compared with those of the two pure breeds. The method of mating was varied from year to year depending upon the characteristics of the breeds involved. The inheritance of these characteristics made it possible to identify chicks with their sire when the same group of females was mated with males of the different breeds. In all except the Rhode Island

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TABLE 4. *Comparison of reciprocal crosses between various pure breeds to the purebreds themselves.*

	Percent chick mortality	Mean 8-week weight*	Mean age at maturity	Mean egg weight	Mean egg production	Mean adult weight	Percent adult mortality
1928							
White Leghorn (Strain A)	6.0	547	170	51.5	212	1,763	31.5
Rhode Island Red (Strain F)	7.0	627	242	54.4	172	2,602	25.5
White Leghorn male by Rhode Island Red female	3.1	647	175	54.6	214	2,160	42.9
Rhode Island Red male by White Leghorn female	0.1	611	206	54.5	201	2,065	18.3
1936							
White Leghorn (Strain B)	2.9	488	202	55.4	200	1,831	73.6
Rhode Island Red (Strain G)	14.7	509	230	56.4	210	2,594	71.2
White Leghorn male by Rhode Island Red female	2.9	493	215	55.8	230	2,291	43.1
Rhode Island Red male by White Leghorn female	3.1	525	217	58.2	202	2,215	48.8
1934							
White Leghorn (Strain C)	4.9	474	180	53.4	194	1,763	53.8
Australorp	26.9	558	260	56.6	152	2,525	66.7
White Leghorn male by Australorp female	2.9	457	197	53.9	232	1,942	57.6
Australorp male by White Leghorn female	4.8	613	188	57.7	187	2,195	44.1
1937							
White Leghorn	10.1	491	205	54.6	170	1,642	73.6
New Hampshire	10.7	701	264	60.6	124	2,471	38.2
White Leghorn male by New Hampshire female	4.3	596	208	58.0	173	2,054	50.0
New Hampshire male by White Leghorn female	5.8	633	221	59.3	168	2,098	36.4
1939							
Barred Plymouth Rock	5.8	532	232	55.6	154	2,513	66.7
Rhode Island Red (Strain G)	8.7	553	218	54.1	177	2,545	52.3
Barred Plymouth Rock male by Rhode Island Red female	5.9	569	216	53.9	188	2,586	50.0
Rhode Island Red male by Bar. Plymouth Rock female	2.0	621	208	57.9	199	2,881	33.8

* All weights are in grams.

Red-Barred Plymouth Rock mating, the tests were of the White Leghorn mated to some larger breed. Comparisons of hatchability are not included here since in tests where the males were rotated, measures of this characteristic were not available.

In the 1928 test two pens each of White Leghorn and Rhode Island Red pullets were used. Two males of each breed were rotated weekly in the pens. It was possible to identify the chicks with their sire by means of color and rate of feathering. This procedure made the crossbreds and purebreds half brothers and sisters.

The 1934 matings were not the result of rotating males. They were flock matings, including several males on the paternal side, making the sample fairly representative and lessening the effects of the individuality of the birds used as parents.

The Rhode Island Red-White Leghorn crosses of 1936 were the result of mating two Rhode Island Red males to corresponding groups of White Leghorns. The White Leghorns came from a large flock mating. The Rhode Island Reds and the crossbreds from the

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White Leghorn male-Rhode Island Red female mating resulted from rotating White Leghorn and Rhode Island Red males on the same flock of Rhode Island Red females.

The 1937 White Leghorn-New Hampshire crosses were made in the same manner as were those in 1936 except that New Hampshire male-White Leghorn female mating was a flock mating using several males and females. Here in order to avoid any problem of inbreeding in the White Leghorns they were obtained by crossing two different strains of this breed.

Matings of Barred Plymouth Rocks and Rhode Island Reds in 1939 were all flock matings in order to increase the number of individuals used as parents, but the males involved were rotated in so far as it was possible and identify the chick with its sire. One flock of Rhode Island Red pullets and two flocks of Barred Plymouth Rock pullets were used on the maternal side. The same Rhode Island Reds produced both pure Rhode Island Red and crossbred chicks, while one Barred Plymouth Rock flock produced pure Barred Plymouth Rocks and the other crossbreds. Two flocks of the Plymouth Rocks were necessary since the purebred and crossbred chicks could not be distinguished in the cross where Barred Plymouth Rocks were used on the maternal side. One group of Rhode Island Red males was alternated between the pens of Rhode Island Reds and the crossbred-producing Barred Plymouth Rocks. Two groups of Barred Plymouth Rock males were alternated between the pens of Rhode Island Reds and the Barred Plymouth Rocks. The manner of making the foregoing crosses made the purebreds and crossbreds as closely related as possible.

The different years' results are listed in Table 4 as units giving the two parent breeds and the crossbreds resulting from the reciprocal matings. Comparisons can only be made within a given year's results in checking upon the effects of crossbreeding. It will be noted the pure breeds used exhibit a wide range of the qualities measured.

In the first section of Table 4 are the comparisons of White Leghorns (strain A) and Rhode Island Reds (strain F) with crossbreds from their reciprocal matings. Although there was little opportunity for improvement of the chick mortality (to three weeks of age) in the purebreds, the chick mortality in the crossbreds was less. The eight-weeks weight (mean of male and female mean weights) of the crossbreds was similar to that of Rhode Island Reds, the more rapid growing parent, one showing a slightly lower and the other a slightly higher rate.

The comparisons of age at sexual maturity (age of female at first egg) shows evidence of the action of sex-linked factors. The parent stocks differed markedly in this characteristic. The cross involving the Rhode Island Red male showed intermediate female maturity age while its reciprocal gave female offspring maturing at an age almost identical with that of the White Leghorns. In adult weight

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(1 year old) the crossbreds were intermediate in size as is usually true in crossing breeds differing much in weight.

The egg weight of the White Leghorns was considerably less than that of the Rhode Island Reds, while the crossbreds had egg size similar to the Rhode Island Reds. This White Leghorn strain produced very well, laying an average of 212 eggs while the Rhode Island Reds were definitely inferior to them. The crossbreds had a mean egg production similar to the White Leghorns, the cross involving the Leghorn male being the better. The adult mortality showed no improvement as a result of crossbreeding.

Except for adult mortality there is a tendency throughout the tests in this cross for the crossbreds to possess a combination of the more desirable traits found in the two breeds involved. They have the Rhode Island Red growth rate, intermediate size, Leghorn maturity, Rhode Island Red egg weight and Leghorn egg production.

In the second section of Table 4 are recorded the results of crossing another good but unrelated strain of White Leghorns to a strain of Rhode Island Reds which was a much better egg producer than that used in the first test. The chick mortality was somewhat high in the Rhode Island Reds but the crossbreds, even from the same Rhode Island Red dams, had better viability. It is to be expected that the general constitutional vigor of the dam, whether genetic or otherwise, affects the early period viability of the chick.

The crossbreds of one type grew slightly more rapidly and those of the reciprocal mating grew slower than the more rapidly growing parent, the Rhode Island Red. In maturity age the Leghorns were rather late for that breed while the Rhode Island Reds were considerably earlier maturing than those in the first test, thus reducing the difference between the two breeds crossed. The maturity age of the crossbreds was intermediate. In adult body weight the crossbreds were intermediate, approaching more nearly that of the Rhode Island Reds. The egg size of the Leghorns and Rhode Island Reds was similar, as was that of the crossbreds. The egg production of the two pure breeds was also similar and about on an equality with that of the cross involving the Rhode Island Red male. The egg production of the reciprocal cross, however, was outstandingly good as it was in the same type of mating of the previous test. The adult mortality in the two pure breeds was excessive, being due largely to fowl paralysis. Although some improvement is seen in the crossbreds over the purebreds, it cannot be said that crossbreeding solved the problem. The results are less striking than in the first test, but it can again be said that the crossbreds tended to combine the good qualities of the two breeds crossed.

The next cross produced the widely popular Austra-Whites, resulting from the mating of the Australorp male with the White Leghorn female. The crossbreds showed low chick mortality although the pure Australorps had excessive mortality in the early post hatching period. The reciprocal crosses showed wide divergence in eight-

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weeks weight, probably the result of the individuality of the parent stock utilized since rotation of the male parents was not possible.

In maturity age the females of each cross were virtually as early as were the Leghorns while the Australorps were exceptionally late. The Leghorns used here were considerably earlier than those in the preceding test. The adult weight was again intermediate being more like the Leghorn. Egg size of the crossbreds was intermediate in one cross and superior in the other. In egg production both the purebreds were rather low, especially in the case of the Australorps. In the cross where the Australorp was used as the male, egg production was similar to the Leghorn (the superior one of the parental breeds) while the crossbreds of the reciprocal mating were markedly superior in number of eggs produced. In this test the number of Australorps surviving the first year of production was small, as was true of the crossbreds for the Leghorn male, so the mean production records may not be the true measure of the relative merits of these groups. Attention may be called to the fact that again in this test crossbred offspring of the Leghorn male outlaid those of the reciprocal cross. The adult mortality data in this test fail to show much improvement of viability resulting from crossbreeding.

The White Leghorn-New Hampshire test shows the results of crossing strains of these two breeds which were somewhat inferior in maturity age and egg production. Each of the parent strains exhibited higher than average chick mortality but crossbreeding seemed to reduce it materially. The crossbreds again showed the influence of sex-linked factors on age at sexual maturity. The crossbreds from the Leghorn sire matured at the same age as did the pure Leghorns while those of the reciprocal mating were intermediate in maturity. The two breeds differed widely in eight-weeks weight and the crossbreds were again intermediate in growth rate, as was true of adult body size. The effect of crossbreeding on egg production is somewhat different from that found in most of the other tests. Neither parent breed showed satisfactory egg laying tendencies with the New Hampshires doing very poorly. The crossbreds from reciprocal matings were similar in egg production and were virtually on an equality with the White Leghorns, the better producing of the two parental stocks. An annual egg production of about 170 eggs in the crossbreds, however, cannot be considered satisfactory. The egg size of the crossbreds was intermediate, approaching more nearly that of the larger-egg parent. The adult mortality in the White Leghorns was excessive and was considerably higher than that recorded in the New Hampshires. One group of crossbreds showed mortality similar to the New Hampshires and the other was intermediate between the two parental stocks. The general results of this test cannot be said to be so favorable to crossbreds as the previous tests. Chick mortality was definitely improved, but most other traits, excepting egg production of the crossbreds, were intermediate between the White Leghorn and New Hampshire.

The last comparison was that of the Barred Plymouth Rock-

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Rhode Island Red crossbred which is widely used. Each of the strains used was better than average for the breed. The chick mortality was not excessive in either pure breed and the crossbreds showed a mortality rate as low or less than that of the better purebreds. The crossbreds had a slightly better growth rate than either pure breed. The age at sexual maturity was similar in the two parental stocks and the crossbreds from both crosses showed a slight improvement over both the parental stocks.

The egg size was similar in the two purebred and crossbred lots. The body size of the Barred Plymouth Rock and Rhode Island Red strains was virtually identical while each type of crossbred averaged somewhat larger than either parental stock.

Another test which did not include reciprocal mating between two breeds is given in Table 5. It is discussed here because the matings

TABLE 5. *Results of mating the same group of Rhode Island Red females with Rhode Island Red, Barred Plymouth Rock, and White Leghorn males.*

	Percent chick mortality	Mean 8-week weight*	Mean age at maturity	Mean egg weight	Mean egg production	Mean adult weight	Percent adult mortality
Rhode Island Red.....	10.7	538	230	56.5	193	2,536	28.5
Barred Rock male by Rhode Island Red female..	6.6	549	205	55.3	202	2,458	47.2
White Leghorn male by Rhode Island Red female..	4.9	557	189	56.9	231	2,035	53.1

* All weights are in grams.

were so arranged to make it a critical test of the effects of crossbreeding. Throughout the breeding season, a group of six males each of the Rhode Island Red, of the Barred Plymouth Rock and of the White Leghorn breeds were rotated weekly on the same flock of Rhode Island Red pullets. This system of mating produced pure Rhode Island Reds, Barred Rock-Rhode Island Red crossbreds, and White Leghorn-Rhode Island Red crossbreds which were all half brothers and half sisters. The offspring of the different sires could be separated by down color and in some single hatches chicks of the three colors would be produced by one dam. The Barred Plymouth Rock males were from the strain measured in Table 4.

The chick mortality of the two groups of crossbreds was an improvement over that of the Rhode Island Reds. The eight-weeks weight of the two types of crossbreds showed a better growth rate than the Rhode Island Reds. There was a definite shortening of the period to maturity in the crossbreds, especially in those resulting from the Leghorn sire. In adult size the crossbreds were each less than the purebreds, since the other two pure breeds involved were smaller than the Rhode Island Reds. Egg size was identical with the purebred in the Leghorn cross and slightly less in the Rock cross.

The egg production of the two types of crossbreds was improved

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over the Rhode Island Reds. The cross of the White Leghorn male on Rhode Island Red females was excellent, confirming the earlier reported favorable results for crossing the White Leghorn male on females of good producing heavy breeds. The Leghorns here used were of the same stock as those giving poor results on the New Hampshires.

The adult mortality of the two groups of crossbreds was considerably higher than that of the Rhode Island Reds.

THREE-WAY CROSSES

Because of the resulting variability in color, size and type as well as probable loss of vigor, poultrymen are advised to avoid using first generation crossbreds as breeders. Winters and others (1935) have recommended such a procedure in swine breeding. It was thought that the mating of first generation crossbreds to a third breed might give a greater stimulus to the vigor of the resulting offspring than would the single cross. The results of such a system of crossbreeding in poultry are given in Table 6.

TABLE 6. *A three-way cross compared with White Leghorns. Crossbred males of the mating of Rhode Island Red male with Barred Plymouth Rock females, mated with White Leghorn females.*

	Percent chick mortality	Mean 8-week weight*	Mean age at maturity	Mean egg weight	Mean egg production	Mean adult weight	Percent adult mortality
White Leghorns	5.1	449	182	54.0	211	.....	61.6
Three-way crossbreds	5.0	490	189	50.1	215	2,095	73.8

* All weights are in grams.

A Rhode Island Red male was mated with Barred Plymouth Rock females and four sons of this cross were mated with White Leghorn pullets. Pullets of the same White Leghorn stock were mated to four males from another White Leghorn strain to produce purebred stock for comparison with the three-way crossbreds. The two Leghorn strains were crossed to avoid any possible reduction of vigor of the purebreds from inbreeding. Such strain crosses will be seen later in this publication to improve the vigor of the purebreds.

In Table 6 is given the comparison of the three-way crossbreds with the purebred White Leghorns. Chick mortality was low in both purebreds and crossbreds. At 8 weeks of age the crossbreds outweighed the White Leghorns as was usually true of such two breed crosses. The maturity age was virtually identical in the crossbreds and purebreds. Through error the purebred White Leghorns were not weighed at maturity and a comparison was not possible. However, it is to be expected from other tests that such crossbreds would be larger than White Leghorns. The egg size of the crossbreds was definitely inferior to the Leghorns. The egg production of the crossbreds and purebreds was nearly identical, each being good.

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Adult mortality was excessive in both crossbreds and purebreds, being higher in the former.

Although the three-way hybrids measure up fairly satisfactorily in most respects, they are no better than are most first generation crosses. Knox (1939) reported on two types of three-way crosses between Rhode Island Reds, White Wyandottes, and Light Sussex and found that in egg production the crossbreds were very similar to those resulting from first generation crosses between two of the breeds. The problems of obtaining uniformity of color, size and type would be great in most three-way crosses. Probably the most promising procedure would be of the type followed here, that is, mating two breeds of a similar size and mating the crossbred to White Leghorns. One of the major arguments in favor of the three-way cross in swine is the possibility of taking advantage of the superior vigor of the crossbred females in using them as mothers. Unfortunately, the test with the chicken was made utilizing the crossbred male and it might have yielded better results had the reverse cross been made. However, problems already mentioned make this method of poultry breeding of doubtful value.

EFFECT OF STRAIN CHARACTERISTICS ON CROSSBREDS

From the foregoing data it seems probable that the qualities of the pure breeds utilized in crossbreeding influence those of the resulting crossbreds. For the purpose of more accurately testing this, the data given in Table 7 were obtained. In the test three strains

TABLE 7. *Results of crossing three strains of White Leghorns with the same strain of Barred Plymouth Rocks.*

	Percent chick mortality	Mean 8-week weight*	Mean age at maturity	Mean egg weight	Mean egg production	Mean adult weight	Percent adult mortality	Percent hatch
1930								
White Leghorn Strain W	6.4	382	180	50.0	221	1,548	53.2	61
White Leghorn Strain E	20.9	326	198	53.2	182	1,575	26.7	84
White Leghorn Strain K	4.4	345	191	50.4	180	1,492	46.2	71
Leghorn Strain W crossbreds	2.6	421	156	52.2	221	2,229	18.5	80
Leghorn Strain E crossbreds	5.6	384	167	52.2	227	2,306	25.4	86
Leghorn Strain K crossbreds	5.0	411	162	54.2	219	2,318	25.7	80

* All weights are in grams.

of White Leghorns were used. As far as the records could be followed there had been no interbreeding of the strains. To make the test critical eight Barred Plymouth Rock males headed pens in which the females were equally divided among the three strains of White Leghorns. This made it possible to compare half brother and sister hybrids from the three White Leghorn strains. At midseason the females were redistributed and mated with males of their

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own strain. The seasonal factor made the hybrids and purebreds not so strictly comparable as in the other tests but the primary purpose here was to compare crossbreds from the three White Leghorn strains, all of which were produced in the same season. The purebred White Leghorns produced at the end of the season made it possible to compare the qualities of the three strains of purebreds, in offspring from the females which also produced the crossbreds.

The data given in Table 7 offered an opportunity to compare the crossbreds from the three different strains of White Leghorns and to determine to what extent the crossbreds reflect the relative qualities of the parent stock.

The chicks of strain E Leghorns were outstandingly poor in viability and its crossbred offspring showed slightly higher mortality than any other crossbreds. However, the chick mortality was low in all three groups of crossbreds. With respect to weight at 8 weeks, the crossbreds arrange themselves exactly in the same order as did the parent stocks from which they came and each group of crossbreds excelled its respective parent strain. The crossbreds rank in age at sexual maturity in the same order as their respective purebred parental stocks.

The adult weight did not differ greatly among the three Leghorn strains and the crossbred weights did not seem to bear any relationship to that of the Leghorn strain from which they came. Egg weight of the pure Leghorn strains seemed not to be reflected in their crossbreds. The best hatching pure strain of Leghorns gave the best hatching crossbreds, but the difference among the crossbreds did not vary in a corresponding degree nor in the same direction as did the purebreds. In most of the characteristics there was a striking improvement of the crossbreds over their respective purebreds. Although some traits in the parent stock seemed to be reflected in their respective crossbreds, the improvement sometimes was of about the same degree regardless of the expression of the character in the parent stock. The data as a whole in Table 7 seem to indicate a tendency for the qualities of the parent strains to be reflected in their crossbred offspring.

CROSSING STRAINS OF THE SAME BREEDS

Theoretically the crossing of strains of the same breed should have a stimulating effect in the same manner, although perhaps not of the same degree as is found in crossing different breeds or varieties. To determine the results of crossing strains of the same breed, the three strains of White Leghorns used in the test previously discussed, were here utilized and designated as E, K, and W. Strain W was mated with strains E and K in reciprocal matings during two breeding seasons.

The results of the strain crossings are given in Table 8. Chick mortality was low except in strain E and this was materially reduced in the cross-strain chicks. Rate of growth to eight weeks differed somewhat in the strains being crossed and the cross-strain

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chicks tended to show an intermediate rate. In respect to age at sexual maturity strains W and K were virtually identical, both being rather early. Strain E was late maturing for the Leghorn breed. In each cross the chicks from reciprocal matings were on equality and early maturing. The lateness of strain E seemed to have no influence on its cross-strain offspring.

TABLE 8. *Results of crossing various strains of the same breed (White Leghorns)*

	Percent chick mortality	Mean 8-week weight*	Mean age at maturity	Mean egg weight	Mean egg production	Mean adult weight	Percent adult mortality	Percent hatch
1929								
Strain W.....	2.4	468	168	52.2	207	1,577	65.4	72
Strain K.....	5.6	425	166	52.8	201	1,455	19.3	75
Strain W male by Strain K female..	3.5	470	160	53.9	223	1,466	34.8	84
Strain K male by Strain W female..	2.7	435	163	51.5	230	1,497	27.8	75
1931								
Strain W.....	3.0	530	175	51.2	193	1,753	50.0	61
Strain E.....	16.4	426	203	53.9	165	1,676	40.6	71
Strain W male by Strain E female..	8.0	501	175	53.4	214	1,726	33.3	72
Strain E male by Strain W female..	4.5	512	175	54.1	204	1,850	22.7	59

* All weights are in grams.

The three Leghorn strains did not differ greatly in adult weight and only in the mating of E male by W female did the cross-strain females differ greatly from the mean weight. They were larger than those of any other group. The data on egg weight did not show much difference between the two parent stocks used in 1929 and one cross had considerably larger eggs than either parent while the other was slightly smaller than either. The 1931 matings included strains differing considerably in egg weight and the reciprocal crosses had egg size equal to or larger than the larger parent.

In egg production, strain E was definitely inferior to the other two which themselves were better than average. Crossings of the similarly producing strains W and K gave cross-strain pullets, which from each type of cross, laid considerably better than either parental strain. Where the poorer producing strain E was involved the cross-strain pullets did not lay so well as did those from the other strain cross but the egg production was better than either of the involved pure strains. In the case of hatchability there was some evidence of improvement in the crosses of strains W and K but in the other strain cross this characteristic seemed to be little influenced.

The various comparisons presented in Table 8 indicate that some stimulation is obtained by crossing of strains of the same breed, similar to that observed in crossing of different breeds and varieties. However, the stimulation seems to be somewhat less than in most breed crosses.

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COMPARISON OF CHARACTERISTICS OF CROSSBREDS AND PUREBREDS

Under the following subdivisions are compared the various characteristics of vigor of crossbreds and purebreds. Each characteristic is considered separately including data for all years reported and makes possible a general view of the effects of crossbreeding on the particular characteristic. The data are segregated on a yearly basis as well as by type of cross because the conditions under which the chicks were raised were considered comparable for the same year only. In each type of cross, chicks from one or both of the parent stocks were usually available for comparison with the crossbreds of that year. In a few of the survey crosses comparable purebreds were not produced during the same year. The samples of a pure breed produced during the successive years were frequently from different strains of the breed and thus not comparable. Comparisons should be made only of data in the same column of the table. The results on the same type of mating in successive years indicate the variability to be expected as a result of strain differences and environmental influences from year to year. In Tables 9 to 19 the first mentioned parent is the male, thus White Leghorn by Rhode Island Red indicates that the sire is the White Leghorn and the dam a Rhode Island Red.

CHICK MORTALITY

Chick mortality as here used includes the mortality occurring during the first three weeks after hatching. Accidental mortality excluded the chick from consideration. It is during this period that most of the inherently weak chicks succumb. This estimate of vigor probably measures to a degree not only the genetic makeup of the chick but also the ability of the mother to place in the egg constituents for the production of a normal chick.

The data given in Table 9 are the percentages of mortality and the numbers of chicks hatched (italics). It will be noted that the totals of chicks in the mating range from 62 to 572.

From a study of Table 9 it is seen that there is a general tendency for crossbreds to show less mortality than comparable purebreds. In some instances the chick mortality in the purebreds was low enough that there was little opportunity of improvement in the crossbreds. In 1928 this was the case but even so the crossbreds were somewhat more viable. In 1929 there was higher mortality in the purebreds and a definite improvement in the crossbreds. In 1930 three different strains of White Leghorns were mated to the same strain of Barred Plymouth Rocks. The comparable crossbreds are listed in the same order as their parent stock of purebreds. There was little room for improvement in the first two listed strains but in the last the mortality was reduced from 21 to 6 percent. In 1934 the reciprocal matings of White Leghorns and Australorps offer the best opportunity for comparison. The Leghorn chick mortality was low and the Australorp was high. The hybrids showed slight

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TABLE 9. *Percentage chick mortality to three-weeks age.*
(Italicized figures show the number of chicks from each mating)

TYPE OF CROSS	Year of test								
	1928	1929	1930	1934	1935	1936	1937	1938	1939
White Leghorn	*182*	*101*	*171*	*143*	*230*	*345*	*356*		
	6.0	9.9	6.0	4.9	2.6	2.9	10.1		
White Leghorn			*92*						
			4.0						
White Leghorn			*139*						
			21.0						
Rhode Island Red	*256*	*87*				*477*		*540*	*508*
	7.0	8.7				14.7		10.7	8.7
Barred Plymouth Rock		*117*							*172*
		19.7							5.8
New Hampshire							*272*		
							10.7		
Australorp				*145*					
				26.9					
W. Leghorn × R. I. Red	*162*	*75*				*208*		*514*	
	3.1	4.0				2.9		4.9	
R. I. Red × W. Leghorn	*176*	*32*				*98*			
	0.1	6.3				3.1			
B. P. Rock × R. I. Red		*103*			*147*			*572*	*441*
		5.8			8.2			6.6	5.9
R. I. Red × B. P. Rock		*107*			*135*				*201*
		4.7			5.9				2.0
New Hampshire × W. Leghorn							*342*		
							5.8		
W. Leghorn × New Hampshire							*210*		
							4.3		
Australorp × W. Leghorn				*186*					
				4.8					
W. Leghorn × Australorp				*104*					
				2.9					
Black Minorca × W. Leghorn					*310*				
					2.6				
W. Leghorn × Black Minorca					*62*				
					12.9				
Ancona × W. Leghorn				*175*					
				2.9					
Light Brahma × R. I. Red				*136*					
				8.1					
Light Brahma × W. Leghorn				*169*					
				2.4					
W. P. Rock × R. I. Red				*154*					
				8.4					
Australorp × B. P. Rock					*82*				
					13.4				
Black Minorca × R. I. Red					*110*				
					19.0				
W. Wyandotte × W. Leghorn						*155*			
						4.5			
W. Wyandotte × R. I. Red						*95*			
						4.2			
B. P. Rock × W. Leghorn		*114*	*310*						
		4.4	3.0						
B. P. Rock × W. Leghorn			*423*						
			5.0						
B. P. Rock × W. Leghorn			*319*						
			6.0						
W. Leghorn × B. P. Rock		*70*							
		5.7							

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improvement over the Leghorns and considerable reduction in mortality when compared with the Australorp parent stock. Some of the other exploratory crosses made the same year had no comparable purebreds but in all cases the mortality was low.

In 1935 the White Leghorns used showed exceptionally low chick mortality. The mortality of the Black Minorcas crossed with the Leghorns is not available. One cross showed mortality similar to the Leghorns and the other showed considerably higher mortality. Some of the other exploratory matings made this year had offspring giving rather high mortality, in fact the highest recorded in any crossbreds. The results in the years 1936 to 1939 all show marked reduction of chick mortality resulting from crossbreeding.

Other workers have also published data to show that crossbreeding reduces chick mortality. Waters (1937) quotes Hoyman's data where reciprocal matings between White Wyandottes and Rhode Island Reds were compared with the two pure breeds. The mortality percentages were Rhode Island Reds 15.1, White Wyandottes 15.9, Rhode Island Red male by White Wyandotte female 5.2, and White Wyandotte male by Rhode Island Red female 9.9.

Bice and Tower (1939) in various types of crosses of the Japanese Shamo breed with Barred Plymouth Rocks, Rhode Island Reds and White Leghorns found the respective crossbreds to show less mortality than either of the two pure breeds used in their production.

Horlacher, Smith and Wiley (1941) present data on 11 different crosses compared to seven different purebreds. In all but three cases the crossbreds had a mortality rate less than 10 percent; whereas only two lots of purebreds showed less than 10 percent mortality.

In summarizing it can be said that in a large percentage of the comparisons where either parent showed a high percentage of mortality, the crossbreds were considerably more viable than the purebreds, indicating that in general crossbreeding does reduce chick mortality.

ADULT MORTALITY

Adult mortality was calculated for the first laying year and included the 12-month period from September 1. Accidental deaths were excluded. Unfortunately it was not possible to determine the diseases causing mortality. It was known that the fowl paralysis complex was probably the major cause of mortality. A succession of very hot summers occurred during the period of the tests and was the cause of considerable summer mortality. All birds were vaccinated for chicken pox.

It will be noted from Table 10 that the pullet mortality was excessive in many of the groups. In none of the purebreds utilized had there been any selection for reduction of adult mortality. In view of the fact that the purpose of the study was to determine the effects of crossbreeding on economic qualities of the fowl no attempt was made to obtain purebreds with low adult mortality.

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TABLE 10. *Percentage adult mortality.*
(Italicized figures show number of pullets from each mating)

TYPE OF CROSS	Year of test							
	1928	1930	1934	1935	1936	1937	1938	1939
White Leghorn	*54*	*62*	*39*	*60*	*87*	*87*		
	31.5	53.2	53.8	61.7	73.6	73.6		
White Leghorn		*26*						
		46.2						
White Leghorn		*45*						
		26.7						
Rhode Island Red	*55*				*66*		*137*	*132*
	25.5				71.2		28.5	52.3
Barred Plymouth Rock								*51*
								66.7
New Hampshire						*76*		
						38.2		
Australorp			*24*					
			66.7					
W. Leghorn × R. I. Red	*56*				*72*		*145*	
	42.9				43.1		53.1	
R. I. Red × W. Leghorn	*60*				*43*			
	18.3				48.8			
B. P. Rock × R. I. Red				*36*			*142*	*140*
				86.1			47.2	50.0
R. I. Red × B. P. Rock				*33*				*71*
				48.5				33.8
New Hampshire × W. Leghorn						*129*		
						36.4		
W. Leghorn × New Hampshire						*74*		
						50.0		
Australorp × W. Leghorn			*59*					
			44.1					
W. Leghorn × Australorp			*33*					
			57.6					
Black Minorca × W. Leghorn				*115*				
				42.6				
W. Leghorn × Black Minorca				*15*				
				66.7				
Ancona × White Leghorn			*62*					
			40.3					
Light Brahma × R. I. Red			*41*					
			41.5					
Light Brahma × W. Leghorn			*56*					
			26.8					
W. P. Rock × R. I. Red			*45*					
			57.8					
Australorp × B. P. Rock				*21*				
				85.7				
Black Minorca × R. I. Red				*21*				
				66.7				
W. Wyandotte × W. Leghorn					*61*			
					51.6			
W. Wyandotte × R. I. Red					*27*			
					63.0			
B. P. Rock × W. Leghorn		*65*						
		18.5						
B. P. Rock × W. Leghorn		*70*						
		25.7						
B. P. Rock × W. Leghorn		*67*						
		25.4						

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From the results shown in Table 10 it is evident that there was no very striking reduction in pullet mortality as the result of crossbreeding. In some of the more critical matings the percentage loss is less in the crossbreds than in the respective purebreds but even so the loss during the pullet year in most of the crossbred matings was excessive. It would appear then that the major causes of pullet loss (probably because of the paralysis complex of diseases) were of a nature that increased vigor as evidenced in other characteristics, was no protection to the bird.

A comparison of the data in Tables 9 and 10 shows that there is no correlation between chick and adult mortality further indicating that the loss in the adult stage is probably no measure of inherent vigor.

TABLE 11. *Growth of females (grams).*
(Italicized figures show number of females from each mating)

YEAR	Mating	1 day	4 wks.	8 wks.	12 wks.	16 wks.
1928	W. Leghorn	*93*	*90*	*90*	*86*	*83*
		33	181	506	849	1,110
	R. I. Red	*130*	*122*	*119*	*112*	*114*
		35	186	581	1,007	1,383
	W. Leghorn male × R. I. Red female	*88*	*86*	*86*	*86*	*84*
		35	205	599	1,009	1,298
	R. I. Red male × W. Leghorn female	*83*	*83*	*81*	*80*	*79*
		34	185	553	948	1,196
1936	W. Leghorn	*159*	*161*	*142*	*130*	*121*
		37	192	452	753	973
	R. I. Red	*236*	*192*	*155*	*141*	*129*
		40	208	498	863	1,176
	W. Leghorn male × R. I. Red female	*106*	*101*	*106*	*82*	*77*
		39	203	480	824	1,117
	R. I. Red male × W. Leghorn female	*55*	*53*	*52*	*46*	*50*
		42	230	499	843	1,112
1934	W. Leghorn	*67*	*63*	*60*	*52*	*45*
		35	195	445	698	913
	Australorp	*69*	*46*	*41*	*39*	*36*
		36	185	535	947	1,211
	W. Leghorn male × Australorp female	*33*	*32*	*32*	*30*	*28*
		34	178	444	690	915
	Australorp male × W. Leghorn female	*87*	*84*	*80*	*81*	*78*
		35	220	576	931	1,199
1937	W. Leghorn	*155*	*121*	*117*	*103*	*97*
		39	171	464	776	913
	New Hampshire	*124*	*108*	*104*	*93*	*92*
		41	219	649	1,112	1,405
	W. Leghorn male × N. Hamp. female	*107*	*93*	*81*	*70*	*61*
		40	231	562	904	1,137
	N. Hamp. male × W. Leghorn female	*175*	*167*	*157*	*145*	*139*
		38	238	589	959	1,195
1939	Barred Plymouth Rock	*77*	.....	*62*	.....	.....
		43	.....	513	.....	.....
	Rhode Island Red	*240*	.....	*195*	.....	.....
		39	.....	530	.....	.....
	B. P. Rock male × R. I. Red female	*216*	.....	*169*	.....	.....
		39	.....	536	.....	.....
	R. I. Red male × B. P. Rock female	*94*	.....	*86*	.....	.....
		41	.....	596	.....	.....

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GROWTH RATE

In all of the comparisons growth was recorded by individual weights taken in grams at 1 day, 4, 8, 12 and 16 weeks of age. All males were sold at the 8 weeks age so that growth data on them were not recorded after that age. All weights were taken in the morning, feed having been withheld since the evening before.

In Table 11 are found data on growth of females at four-week intervals to 16 weeks of age. Data on males are not included since they were carried only to 8 weeks. The data given are limited to those crosses where results from reciprocal mating were available. The mean weights given are based upon a large enough number of females to be dependable. The average number was approximately 80 with a range from 28 to 240.

The weight at 1 day reflects largely variations in egg size of the maternal parent. At 4 weeks the crossbreds were usually larger than either parental stock. It is to be noted that all of the crosses but one are of the White Leghorn to some larger breed. As will be shown later crossbreds between two breeds differing considerably in body size, are usually intermediate in size. This intermediacy in adult size is reflected in later stages of growth and such crossbreds are intermediate between the two parent stocks. Thus at 8 weeks and beyond the crossbreds are usually smaller than the heavy breed parent when the Leghorn is mated to a larger breed. In the one cross between two heavy breeds, Barred Plymouth Rocks and Rhode Island Reds, the crossbreds were larger than either purebred at the 8-week age.

In Table 12 are given growth data on a large number of crosses. The weight's given are the means of the male and female weights at the 8-week age. Comparisons should be made only of chicks grown during the same year since external conditions vary too greatly from year to year.

The growth data here recorded, and a much larger amount not included, indicate that up to the 6-week age crossbreds are usually of more rapid growth than the purebreds from which they come. Where the smaller Mediterraneans are crossed to larger breeds, the crossbreds are usually intermediate in size after the eight-week age. The crossing of two larger breeds usually produces crossbreds which outgrow the parent stocks at all ages.

Horlacher, Smith and Wiley (1941) present some excellent data on growth rate of crossbreds, including several heavy breed crosses. Their results are somewhat variable but where two heavy breeds were mated the crossbreds usually grew more rapidly than did the parent stock. The cross of Rhode Island Red female by White Wyandotte male was most consistent in giving crossbreds with superior growth rate.

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TABLE 12. *Eight-weeks chick weight (average of male and female averages in grams).*
(Italicized figures show the number of chicks from each mating)

TYPE OF CROSS	Year of test								
	1928	1929	1930	1934	1935	1936	1937	1938	1939
White Leghorn	*180*	.....	*155*	*123*	*85*	*312*	*254*	.....	.....
	547	.....	382	474	357	488	491	.....	.....
White Leghorn	.....	*99*	*116*	.....	.....	.....	.....	.....	.....
	.....	426	326	.....	.....	.....	.....	.....	.....
White Leghorn	.....	*54*	*82*	.....	.....	.....	.....	.....	.....
	.....	444	345	.....	.....	.....	.....	.....	.....
Rhode Island Red	*255*	*74*	.....	.....	.....	*323*	.....	*453*	*398*
	627	465	.....	.....	.....	508	.....	538	553
Barred Plymouth Rock	.....	*91*	.....	.....	.....	.....	.....	.....	*136*
	.....	383	.....	.....	.....	.....	.....	.....	532
New Hampshire	.....	.....	.....	.....	.....	.....	*214*	.....	.....
	.....	.....	.....	.....	.....	.....	701	.....	.....
Australorp	.....	.....	.....	*94*	.....	.....	.....	.....	.....
	.....	.....	.....	557	.....	.....	.....	.....	.....
W. Leghorn × R. I. Red	*161*	*72*	.....	.....	.....	*192*	.....	*475*	.....
	647	486	.....	.....	.....	493	.....	557	.....
R. I. Red × W. Leghorn	*176*	*30*	.....	.....	.....	*93*	.....	.....	.....
	611	526	.....	.....	.....	525	.....	.....	.....
B. P. Rock × R. I. Red	.....	*97*	.....	.....	*106*	.....	.....	*512*	*350*
	.....	489	.....	.....	382	.....	.....	549	569
R. I. Red × B. P. Rock	.....	*102*	.....	.....	*112*	.....	.....	.....	*182*
	.....	539	.....	.....	434	.....	.....	.....	621
N. Hampshire × W. Leghorn	.....	.....	.....	.....	.....	.....	*292*	.....	.....
	.....	.....	.....	.....	.....	.....	633	.....	.....
W. Leghorn × N. Hampshire	.....	.....	.....	.....	.....	.....	*169*	.....	.....
	.....	.....	.....	.....	.....	.....	596	.....	.....
Australorp × W. Leghorn	.....	.....	.....	*164*	.....	.....	.....	.....	.....
	.....	.....	.....	613	.....	.....	.....	.....	.....
W. Leghorn × Australorp	.....	.....	.....	*77*	.....	.....	.....	.....	.....
	.....	.....	.....	457	.....	.....	.....	.....	.....
Blk. Minorca × W. Leghorn	.....	*69*	.....	.....	*270*	.....	.....	.....	.....
	.....	497	.....	.....	439	.....	.....	.....	.....
W. Leghorn × Blk. Minorca	.....	.....	.....	.....	*44*	.....	.....	.....	.....
	.....	.....	.....	.....	377	.....	.....	.....	.....
Ancona × W. Leghorn	.....	.....	.....	*160*	.....	.....	.....	.....	.....
	.....	.....	.....	469	.....	.....	.....	.....	.....
Lt. Brahma × R. I. Red	.....	.....	.....	*116*	.....	.....	.....	.....	.....
	.....	.....	.....	547	.....	.....	.....	.....	.....
Lt. Brahma × W. Leghorn	.....	.....	.....	*144*	.....	.....	.....	.....	.....
	.....	.....	.....	517	.....	.....	.....	.....	.....
W. P. Rock × R. I. Red	.....	.....	.....	*127*	.....	.....	.....	.....	.....
	.....	.....	.....	549	.....	.....	.....	.....	.....
Australorp × B. P. Rock	.....	.....	.....	.....	*63*	.....	.....	.....	.....
	.....	.....	.....	.....	432	.....	.....	.....	.....
Blk. Minorca × R. I. Red	.....	.....	.....	.....	*74*	.....	.....	.....	.....
	.....	.....	.....	.....	436	.....	.....	.....	.....
W. Wyandotte × W. Leghorn	.....	.....	.....	.....	.....	*142*	.....	.....	.....
	.....	.....	.....	.....	.....	466	.....	.....	.....
W. Wyandotte × R. I. Red	.....	.....	.....	.....	.....	*86*	.....	.....	.....
	.....	.....	.....	.....	.....	502	.....	.....	.....
B. P. Rock × W. Leghorn	.....	*107*	*281*	.....	.....	.....	.....	.....	.....
	.....	459	421	.....	.....	.....	.....	.....	.....
B. P. Rock × W. Leghorn	.....	.....	*295*	.....	.....	.....	.....	.....	.....
	.....	.....	384	.....	.....	.....	.....	.....	.....
B. P. Rock × W. Leghorn	.....	.....	*363*	.....	.....	.....	.....	.....	.....
	.....	.....	411	.....	.....	.....	.....	.....	.....
W. Leghorn × B. P. Rock	.....	*66*	.....	.....	.....	.....	.....	.....	.....
	.....	420	.....	.....	.....	.....	.....	.....	.....
Blk. Giant × W. Leghorn	.....	*68*	.....	.....	.....	.....	.....	.....	.....
	.....	436	.....	.....	.....	.....	.....	.....	.....
Dark Cornish × W. Leghorn	.....	*48*	.....	.....	.....	.....	.....	.....	.....
	.....	461	.....	.....	.....	.....	.....	.....	.....
Dark Cornish × R. I. Red	.....	*15*	.....	.....	.....	.....	.....	.....	.....
	.....	418	.....	.....	.....	.....	.....	.....	.....
Dark Cornish	.....	*25*	.....	.....	.....	.....	.....	.....	.....
	.....	401	.....	.....	.....	.....	.....	.....	.....

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HATCHABILITY

Most of the data obtained in this study were not from matings satisfactorily arranged for measuring hatchability. Frequently males of different breeds were rotated on the same group of females and under such circumstances hatchability could not be measured. Hatchability as used here applies to fertile eggs only. Table 13 includes data on percentage hatch and the number of fertile eggs set (italics) in various matings.

TABLE 13. *Percentage hatchability.*
(Italicized figures show number of fertile eggs from each mating)

	Year of test			
	1930	1934	1935	1936
White Leghorn	*289*			*511*
	61			81
White Leghorn	*167*		*653*	
	84		83	
White Leghorn	*132*	*199*		
	71	73		
Australorp		*199*		
		72		
R. I. Red × W. Leghorn				*113*
				90
B. P. Rock × R. I. Red			*188*	
			78	
R. I. Red × B. P. Rock			*156*	
			87	
Australorp × W. Leghorn		*231*		
		81		
W. Leghorn × Australorp		*114*		
		90		
Blk. Minorca × W. Leghorn			*338*	
			93	
W. Leghorn × Blk. Minorca			*102*	
			61	
W. Wyandotte × W. Leghorn				*202*
				86
Ancona × W. Leghorn		*209*		
		86		
Lt. Brahma × R. I. Red		*181*		
		82		
Lt. Brahma × W. Leghorn		*252*		
		79		
W. P. Rock × R. I. Red		*221*		
		70		
Australorp × B. P. Rock		*91*		
		90		
Blk. Minorca × R. I. Red		*155*		
		71		
B. P. Rock × W. Leghorn	*406*			
	80			
B. P. Rock × W. Leghorn	*387*			
	86			
B. P. Rock × W. Leghorn	*584*			
	80			

The matings in 1930 of females from three different strains of White Leghorns with Barred Plymouth Rock males of the same strain gave evidence of the stimulating effect of crossbreeding on hatchability. The groups of White Leghorn females when mated to males of their own breed gave hatchability percentages of 61, 84 and

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71. When these same groups of females were mated in the same season to Barred Plymouth Rock males, the hatchability of their eggs was 80, 86 and 80 percent, respectively. The number of eggs used in each test that year ranged from 132 to 584.

In 1934 data were available on Australorps, White Leghorns and their reciprocal matings. The Australorps had a hatchability percentage of 73, the White Leghorns 72, while the Australorp male mated to White Leghorn females gave a percentage of 81 and the reciprocal cross, 90. Hatchability results are also reported on some miscellaneous crosses during this year. In all cases the number of eggs incubated was above 113.

In 1935 White Leghorns were compared with reciprocal matings to Black Minorcas. Hatchability results for the pure Black Minorcas were not available. The White Leghorns had a hatchability percent of 83 while the reciprocal crosses gave 61 and 93 percentages. The better results were obtained when the White Leghorn females were used with the Black Minorca males. The number of eggs incubated ranged from 102 to 653. For the same year a few exploratory crosses were made and reported upon in Table 13.

White Leghorns were compared with crosses of White Leghorns with Rhode Island Reds and White Wyandottes in 1936. The hatchability percentages were 81, 90 and 86 respectively, while the numbers of eggs incubated were 511, 113 and 202.

In all of the tests, except, one, the crossbred chicks hatched better than did the comparable purebreds.

Similar results have been reported by other workers. Byerly, Knox and Jull (1934) compared 11 purebred matings with 35 crossbred matings with hatchability of 69 percent for the purebreds and 76 percent for the crossbreds. Funk (1934) compared Barred Plymouth Rocks with crossbreds from matings of Rhode Island Red males to the same females and found that the purebred matings gave a hatchability of 57 percent while the crossbred matings gave 74 percent. The same type of comparison was made by Funk of White Leghorns and White Plymouth Rock males mated to White Leghorn females. For the purebreds 71 percent hatched and those of the crossbred mating, 80 percent.

The foregoing data seem fairly convincing that crossbreeding does stimulate hatchability. It is true, however, if one of the pure breeds involved has exceptionally high hatchability there will be little room for improvement when using it in crossbred matings. Hatcherymen are of the opinion that using the smaller Mediterranean males with larger breed females tends to increase infertility.

EGG PRODUCTION

The data on egg production include only the records of females completing their first year of laying. The first laying year was the 365-day period following the first pullet egg. Records of less than 50 eggs were eliminated upon the belief that such birds were abnormal and that the egg record was not an accurate measure of the

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pullet's laying potentialities. The high pullet mortality reduced the number of egg records available in the various groups and in some instances made the number so small that the mean of the group was not listed in Table 14.

It will be noted that a wide range of production is represented in the parent stocks involved. Variation is found not only among breeds but also among strains of the same breed. In the 1928 mating the two breeds differed widely in egg production and the resulting crossbreds had records similar to that of the higher producing

TABLE 14. *Annual egg production.*
(Italicized figures show number of pullets from each mating completing year)

TYPE OF CROSS	Year of test							
	1928	1930	1934	1935	1936	1937	1938	1939
White Leghorn	*37* 212	*28* 221	*15* 194	*24* 202	*26* 200	*26* 170		
White Leghorn		*16* 180						
White Leghorn		*31* 182						
Rhode Island Red	*33* 172				*20* 210		*98* 193	*61* 178
Barred Plymouth Rock								*15* 154
New Hampshire						*45* 124		
W. Leghorn × R. I. Red	*38* 214				*39* 230		*74* 231	
R. I. Red × W. Leghorn	*45* 201				*42* 202			
B. P. Rock × R. I. Red							*77* 202	*69* 188
R. I. Red × B. P. Rock				*15* 163				*46* 199
New Hampshire × W. Leghorn						*78* 168		
W. Leghorn × New Hampshire						*35* 173		
Australorp × W. Leghorn			*34* 137					
W. Leghorn × Australorp			*16* 232					
Blk. Minorca × W. Leghorn				*67* 202				
Ancona × W. Leghorn			*34* 169					
Lt. Brahma × R. I. Red			*18* 145					
Lt. Brahma × W. Leghorn			*38* 230					
W. P. Rock × R. I. Red			*18* 158					
W. Wyandotte × W. Leghorn					*49* 214			
B. P. Rock × W. Leghorn		*54* 221						
B. P. Rock × W. Leghorn		*53* 219						
B. P. Rock × W. Leghorn		*50* 227						

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Leghorns. One strain of White Leghorns used in 1930 was outstanding for egg production but it is of interest to note that the crossbreds coming from the lower producing Leghorn strains were as good or better egg producers than those from the high producing strain. In 1934 the egg records were not especially good. In this year the only control purebreds were White Leghorns and some of the crosses did not involve this breed. The White Leghorn-Light Brahma crossbreds laid best and the Light Brahma-Rhode Island Reds and White Plymouth Rock-Rhode Island Reds were exceptionally poor. The latter two were the poorest producing crossbreds recorded in all the tests. Little is known of the egg producing tendencies of the parent stock involved but the results demonstrate that not all crossbreds are superior egg producers.

The few data in 1935 provide little critical information but do show that the cross of a strain of Black Minorcas known to be mediocre for egg production, when crossed to White Leghorns, produced crossbreds which laid similarly to the Leghorns. The matings in 1936 show the crossbreds from the White Leghorn male by the Rhode Island Red female to be outstanding egg producers. In fact, this particular cross showed superior egg production in three years it was made. The purebred White Leghorns and Rhode Island Reds used that year each gave high egg production and the cross involving the Rhode Island Red male produced similarly.

The 1937 results showed that crossbreeding may not materially increase egg production even when the involved purebreds have low egg production. The crossbreds had egg records similar to those of the better of the two pure breeds but a mean production of 173 eggs is rather low. In 1938 the crossbreds were definitely superior to the pure breed used as a control. The 1939 crosses of two heavy breeds show the egg production of the crossbreds from reciprocal matings each to be superior to either parent breed.

A summary of all results shows that in most of the tests the egg production of the crossbreds was equal to or better than that of the better producing purebred parent. In some instances the stimulation of egg production for crossbreeding was striking. However, not all crossbreds were superior egg producers.

BROODINESS

The incidence of broodiness is an important factor in a bird's annual egg record. In some breeds and varieties broodiness largely has been eliminated by breeding. It is of interest to consider the incidence of broodiness among poultry crossbreds, especially where broody and nonbroody breeds are being mated. In Table 15 are recorded the incidence and degree of broodiness among crossbreds in which adequate information is available in the parent stocks. The information recorded is the percentage of birds showing broodiness, average number of times birds exhibited broody tendencies, and the average number of days lost per bird as a result of broodi-

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ness. The last two mentioned averages apply only to broody birds. Pullets dying before July 1 were not included in the summary.

The three measures of broodiness are in close agreement. In all except one of the matings where the breeds involved differed greatly in tendency toward broodiness, the daughters from reciprocal matings differed in broodiness in the direction of the stock from which their sires came. These results suggest the existence of sex-linked factors for broodiness. This had previously been suggested by Roberts and Card (1933). In general the results show that cross-

TABLE 15. *Incidence of broodiness in various crosses.*

	Number birds	Percent broody	Av. No. times broody per bird	Av. days lost per bird in broodiness	Annual egg production
White Leghorn	37	5.4	1.0	16.0	212
Rhode Island Red	33	48.5	2.1	39.2	172
W. Leghorn × R. I. Red	37	40.5	2.0	30.9	214
R. I. Red × W. Leghorn	45	86.7	2.6	37.6	201
White Leghorn	16	0.0	0.0	0.0	194
Australorp	8	12.5	2.0	42.0	152
Australorp × W. Leghorn	38	81.6	2.5	48.4	187
W. Leghorn × Australorp	18	27.8	1.4	22.6	232
White Leghorn	26	0.0	0.0	0.0	200
Rhode Island Red	24	8.3	1.5	24.0	210
W. Leghorn × R. I. Red	38	18.4	1.3	27.0	230
R. I. Red × W. Leghorn	23	26.1	2.2	38.5	202
W. Wyandotte × W. Leghorn	27	59.3	2.4	50.1	214
White Leghorn	25	0.0	0.0	0.0	170
New Hampshire	41	53.7	2.2	41.2	124
W. Leghorn × N. Hampshire	39	41.0	2.4	42.4	173
N. Hampshire × W. Leghorn	80	42.5	2.3	41.6	168
Rhode Island Red	102	24.5	1.7	31.7	193
W. Leghorn × R. I. Red	69	11.6	2.4	40.8	231
B. P. Rock × R. I. Red	82	28.1	2.3	39.7	202
Rhode Island Red	63	27.0	2.0	37.3	178
Barred Plymouth Rock	18	61.1	3.4	62.6	154
R. I. Red × B. P. Rock	45	28.9	2.2	38.3	199
B. P. Rock × R. I. Red	73	56.2	3.0	50.3	188

breds from matings of stocks differing greatly in broodiness tended to be more like the one with the higher incidence of broodiness. In some instances the crossbreds exhibited a greater degree of broodiness than did either parent stock. It should be noted, however, that in spite of high incidence of broodiness many of the crosses showed superior egg production.

MATURITY AGE

Age at which birds reach sexual maturity differs widely among breeds and varieties of poultry. In general the Mediterranean breeds mature considerably earlier than do most other types. In this study age at sexual maturity has been measured by the age at which females laid their first egg and the data were thus available only from the female offspring of crosses studied. There is no very accurate method of identifying the age of sexual maturity in males.

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Numerous management factors influence the age at first egg in females but since stock being compared was kept under as nearly identical conditions as possible, these conditions were believed not to affect the conclusions.

The data given in Table 16 are for age at sexual maturity (age at first egg in females). Data are reported only where records were available on 15 or more females since results from fewer birds were

TABLE 16. *Female maturity age (days).*
(Italicized figures show number of pullets from each mating)

TYPE OF CROSS	Year of test							
	1928	1930	1934	1935	1936	1937	1938	1939
White Leghorn	*38* 169	*62* 180	*29* 180	*53* 209	*71* 202	*67* 205		
White Leghorn		*26* 191						
White Leghorn		*45* 198						
Rhode Island Red	*33* 242				*51* 230		*128* 229	*115* 218
Barred Plymouth Rock								*44* 232
New Hampshire						*53* 263		
Australorp			*18* 260					
W. Leghorn × R. I. Red	*38* 175				*66* 215		*132* 189	
R. I. Red × W. Leghorn	*46* 206				*38* 217			
B. P. Rock × R. I. Red				*21* 220			*140* 205	*65* 203
R. I. Red × B. P. Rock				*26* 242				*124* 216
New Hampshire × W. Leghorn						*110* 221		
W. Leghorn × New Hampshire						*53* 203		
Australorp × W. Leghorn			*57* 183					
W. Leghorn × Australorp			*26* 197					
Black Minorca × W. Leghorn				*106* 212				
Ancona × W. Leghorn			*59* 176					
Light Brahma × R. I. Red			*86* 237					
Light Brahma × W. Leghorn			*53* 200					
W. P. Rock × R. I. Red			*85* 201					
Black Minorca × R. I. Red				*18* 224				
W. Wyandotte × W. Leghorn					*57* 216			
W. Wyandotte × R. I. Red					*22* 245			
B. P. Rock × W. Leghorn		*67* 156						
B. P. Rock × W. Leghorn		*70* 162						
B. P. Rock × W. Leghorn		*69* 167						

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believed to have little significance. Pullets dying before starting to lay were not included.

As was pointed out earlier in this publication, evidence has been obtained (Hays 1924, Warren 1934) supporting the view that difference between some breeds in maturity age is due to sex-linked factors. This evidence was obtained from reciprocal matings in which earlier maturity in female offspring resulted where the sire was from the earlier of the two breeds crossed. It is known that only some of the genetic factors determining age at sexual maturity are sex-linked and that breeds will probably differ as to the presence of this factor in their genetic makeup.

The matings in 1928 clearly show the evidence of sex-linked differences in the strains of Rhode Island Reds and White Leghorns used. Crossbreds from the Leghorn sire were of virtually the same maturity age as were the pure Leghorns, while the females from the reciprocal mating were intermediate between the two breeds with respect to age at sexual maturity. Reciprocal matings were not made in 1930 but since the crossbred offspring of Barred Plymouth Rock males were even earlier than the White Leghorns it seems probable that no sex-linked differences existed between the two breeds and it would appear that the Barred Plymouth Rock strain may have had maturity age similar to that of the Leghorns.

The 1934 matings show a striking difference in age at sexual maturity between the White Leghorns and Australorps used. The offspring of both crossbred matings matured much like White Leghorns and there was little difference between reciprocal matings. This would indicate the absence of sex-linked factors being responsible for difference between the two breeds.

In 1936 a relatively late maturing strain of White Leghorns was mated to a relatively early maturing strain of Rhode Island Reds. The crossbreds from reciprocal matings were very similar and intermediate between the two breeds in age at sexual maturity. The difference between the strains of these two breeds was probably not due to sex-linked factors.

The Leghorns and New Hampshires used in 1937 differed considerably with respect to age at sexual maturity and the results for reciprocal matings would indicate that the difference is partially due to sex-linked factors since the offspring of the Leghorn sire matured earlier than those from the reciprocal mating. The only other year's results where reciprocal matings were used was 1939 and the data from each were so similar that sex-linked factors could hardly be said to be involved.

The results of the various matings differ somewhat but where early and late maturing strains were crossed the more frequent result was maturity similar to the earlier breed or intermediate maturity. In 12 out of 15 crosses of the Leghorn by later maturing breeds, the crossbreds were virtually as early maturing as the Leghorn breed. The crossing of two larger breeds gave crossbreds which were only slightly earlier maturing than the purebreds. There were

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a number of matings between breeds differing in age at sexual maturity in which the differences could not be attributed to sex-linked factors.

EGG WEIGHT

The measure of egg weight used in the comparisons here was the mean weight of ten eggs taken when the pullets were approximately one year old. This was at about the maximum egg size for the pullet year since soon after this high summer temperatures began to de-

TABLE 17. *Egg weight (grams).*
(Italicized figures show number of pullets whose eggs were weighed)

TYPE OF CROSS	Year of test							
	1928	1930	1934	1935	1936	1937	1938	1939
White Leghorn	*43* 51.5	*53* 50.0	*15* 53.4	*49* 56.1	*80* 55.4	*35* 54.6		
White Leghorn		*23* 50.0						
White Leghorn		*38* 53.0						
Rhode Island Red	*43* 54.4				*81* 56.4		*104* 56.5	*61* 54.1
Barred Plymouth Rock								*19* 55.6
New Hampshire						*50* 60.6		
Australorp			*15* 56.6					
W. Leghorn × R. I. Red	*50* 54.6				*44* 55.8		*88* 56.9	
R. I. Red × W. Leghorn	*52* 54.5				*23* 58.2			
B. P. Rock × R. I. Red							*95* 55.3	*74* 53.9
R. I. Red × B. P. Rock				*22* 53.1				*47* 57.9
New Hampshire × W. Leghorn						*88* 59.3		
W. Leghorn × New Hampshire						*35* 58.0		
Australorp × W. Leghorn			*42* 57.7					
W. Leghorn × Australorp			*20* 53.9					
Black Minorca × W. Leghorn				*89* 58.3				
Ancona × W. Leghorn			*39* 54.4					
Light Brahma × R. I. Red			*31* 55.4					
Light Brahma × W. Leghorn			*46* 58.2					
W. P. Rock × R. I. Red			*24* 54.0					
W. Wyandotte × W. Leghorn					*38* 54.5			
W. Wyandotte × R. I. Red					*15* 54.1			
B. P. Rock × W. Leghorn		*68* 52.0						
B. P. Rock × W. Leghorn		*60* 54.0						
B. P. Rock × W. Leghorn		*68* 52.0						

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press egg size. Double-yolked and yolkless eggs were not included. As was true of other measurements, only when data were available on 15 or more birds were the results tabulated. The data on crossbred egg size for all matings are given in Table 17.

The more frequent result, was for the crossbred to be more like the larger than the smaller of the two parent breeds in egg weight. In the data where reciprocal matings were made (Table 4) five out of 10 of the crossbred groups exceeded either parent stock. Of the remainder one was like the larger parent, two were intermediate between the parent stocks, and two were like the smaller parent. The results favor the view that in most instances large egg size tends to act as a dominant to smaller egg size.

EGG COLOR

It has generally been observed that where the two breeds being crossed differ in egg color, the crossbreds produce eggs which are intermediate in color. In the 1928 Rhode Island Red-White Leghorn cross the eggs produced by the crossbred females were classified according to nine arbitrary grades ranging from chalk white to the darkest eggs produced by the Rhode Island Red mothers. A female's color grade was determined by selecting a representative egg from among five produced during the period of December to February. The Rhode Island Red mothers had a range of color from six to nine, while the White Leghorns all produced eggs of grade 1.

Table 18 presents the data from the reciprocal cross between the Rhode Island Reds and White Leghorns. The distribution of color is similar in the two matings with the daughters of the White Leghorn male producing slightly lighter colored eggs. The daughters of the White Leghorn male had a mean color grade of 3.5 and those of the Rhode Island Red male 4.1. It is seen that a majority of the eggs were intermediate in color and this fact makes crossbreds from a white and a brown egg breed unpopular in regions where the market is discriminating for shell color.

TABLE 18. *Egg color in the White Leghorn-Rhode Island Red crossbreds.*

	Grades of egg color							
	1	2	3	4	5	6	7	8
White Leghorn × R. I. Red.....	9	4	14	9	7	5	1	1
Rhode Island Red × W. Leghorn....	3	2	15	9	9	9	1	1

ADULT FEMALE WEIGHT

Adult weight was taken when the birds were approximately one year old and these data are recorded in Table 19. Only female weights were recorded since few males were kept to this age. For accuracy, the weight was given in grams and 454 grams equal one

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pound. Where the two breeds crossed differed widely in size such as the Leghorns and the Rhode Island Reds, the crossbreds were approximately intermediate in weight between the two breeds.

TABLE 19. *Adult female body weight (grams).*
(Italicized figures show number of pullets weighed)

TYPE OF CROSS	Year of test							
	1928	1930	1934	1935	1936	1937	1938	1939
White Leghorn	*38*	*39*	*16*	*45*	*32*	*55*		
	1,763	1,549	1,763	1,750	1,831	1,642		
White Leghorn		*36*						
		1,575						
White Leghorn		*18*						
		1,492						
Rhode Island Red	*45*				*32*		*117*	*75*
	2,602				2,594		2,536	2,545
Barred Plymouth Rock								*30*
								2,513
New Hampshire						*63*		
						2,471		
Australorp			*16*					
			2,525					
W. Leghorn × R. I. Red	*50*				*46*		*96*	
	2,160				2,291		2,035	
R. I. Red × W. Leghorn	*52*				*26*			
	2,065				2,215			
B. P. Rock × R. I. Red							*105*	*91*
							2,458	2,586
R. I. Red × B. P. Rock				*22*				*52*
				2,395				2,831
New Hampshire × W. Leghorn						*105*		
						2,098		
W. Leghorn × New Hampshire						*48*		
						2,054		
Australorp × W. Leghorn			*43*					
			2,195					
W. Leghorn × Australorp			*19*					
			1,942					
Black Minorca × W. Leghorn				*85*				
				1,888				
Ancona × W. Leghorn			*41*					
			1,574					
Light Brahma × R. I. Red			*27*					
			2,572					
Light Brahma × W. Leghorn			*44*					
			2,423					
W. P. Rock × R. I. Red			*24*					
			2,200					
W. Wyandotte × W. Leghorn					*33*			
					2,052			
W. Wyandotte × R. I. Red					*15*			
					2,371			
B. P. Rock × W. Leghorn		*55*						
		2,229						
B. P. Rock × W. Leghorn		*54*						
		2,306						
B. P. Rock × W. Leghorn		*57*						
		2,318						

Only in 1939 do we have a critical test involving two heavier breeds in which the weights of both purebred parental stocks are known. In earlier years where the larger breeds were crossed the data on the parent stocks were not adequate. The Rhode Island Reds and Barred Plymouth Rocks utilized in 1939 were similar in

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weight. In reciprocal crosses between them the crossbreds were larger than either purebred. In 1938 the weight of the Rhode Island Red parent only was known but its crossbred offspring from matings with Barred Plymouth Rocks were somewhat smaller than were the Rhode Island Reds. The results taken as a whole show little evidence of important sex-linked factors being involved in determining the body size differences.

EFFICIENCY OF FEED UTILIZATION

Maw (1933) compared White Wyandottes, Rhode Island Reds, White Plymouth Rocks, Barred Plymouth Rocks and White Leghorns with crossbreds resulting from the mating of each of the heavier breeds with White Leghorns. Efficiency of feed utilization was measured by grams gained per 100 grams of feed consumed during the first 10-weeks period and during the 12- to 24-weeks periods. At the 10-weeks age the White Wyandottes and Rhode Island Reds considerably outranked the crossbreds and the White Leghorns were at the bottom of the listing on the basis of efficiency of feed utilization. At the later stage the Barred Plymouth Rocks and Rhode Island Reds were among the most efficient food utilizers with the White Leghorn-White Wyandotte crossbreds performing similarly. As far as these studies go little can be said in favor of crossbreds as efficient food utilizers.

Bice and Tower (1939) compared White Leghorns, Rhode Island Reds, Barred Plymouth Rocks and Japanese Shamo Games with crossbreds from matings of each of the other breeds with the Shamo Games. They measured efficiency of feed utilization in cost per pound gain. To eight weeks of age the three types of crossbreds each made cheaper gains than did any of the four purebreds.

Fattening trials made at the broiler, fryer and roaster stage each showed the crossbreds to be efficient utilizers of feed. Pure Shamo Games were not included in these fattening tests but at the first two ages the crossbreds all ranked above any of the three pure breeds. The Rhode Island Red and Barred Plymouth Rock crossbreds ranked first and second in the broiler and fryer tests and first and third in the roaster fattening test.

Hess, Byerly and Jull (1941) reported on the efficiency of feed utilization of Barred Plymouth Rocks, New Hampshires and reciprocal crosses between the two. Their conclusion is "in general crossbreds are more efficient than purebreds in the utilization of feed."

Based upon the amount of feed required to produce a pound of gain Horlacher, Smith and Wiley (1941) also found crossbreds to be relatively efficient utilizers of feed. The results were upon the first twelve weeks growth. They found in four comparisons that the crossbreds were noticeably superior to the purebreds in feed utilization. In six other tests they were slightly superior and in only one out of eleven comparisons were they found to be inferior. Their crosses involved Rhode Island Reds, White Wyandottes, Barred Plymouth Rocks, White Plymouth Rocks, White Leghorns and a

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few other breeds. Crosses which gave the most efficient feed utilizers were the White Wyandotte male by the Rhode Island Red female and the White Plymouth Rock male by the Barred Plymouth Rock female.

The results of the various workers taken as a whole seem to indicate the crossbreds are relatively efficient feed utilizers. The work of Maw includes most of the evidence to the contrary. His data are entirely upon White Leghorn crosses and it is known that growth after eight weeks is somewhat slower due to the intermediate maturity size of such crossbreds. His birds were carried to 12 and 24 weeks of age.

DRESSING PERCENTAGE

A certain amount of study has been given to the dressing percentages of crossbreds as compared with purebreds. Maw (1933) computed the dressing percentages of crossbreds resulting from mating White Leghorns to White Wyandottes, Barred Plymouth Rocks, White Plymouth Rocks and Rhode Island Reds and compared them to the respective parental stocks. He also included a cross of Cornish by Barred Plymouth Rocks. Maw recorded the percentage waste of both live and dressed weight, percentage bone and percentage edible flesh on carcass when dressed at the 10-weeks age. He found the Leghorn-Rhode Island Red, Leghorn-White Plymouth Rock and Leghorn-White Wyandotte crosses outranking all of the purebreds. At the roaster age (26 weeks) the results were not the same as at the earlier age. The purebreds tended to rank equal to or better than the crossbreds in most of the characteristics considered.

Bice and Tower (1939) compared Rhode Island Reds, Barred Plymouth Rocks and White Leghorns with crossbreds from each of them with the native Japanese Shamo Game at the broiler, fryer and roaster stages. The comparison was based on dressing loss. At the broiler stage White Leghorns and Rhode Island Reds were superior to the crossbreds but at later stages the Shamo Game-Barred Plymouth Rock crossbreds showed a lower percentage loss than any purebred, with the Rhode Island Red crossbred ranking a close second.

These results are too meager to be very conclusive but it would seem that the Leghorn-heavy breed crosses are satisfactory as broilers but less so when carried to more advanced stages of maturity.

SUMMATION OF ALL CHARACTERISTICS

In attempting to evaluate the merits or demerits of crossbreeding one should consider as a whole its effects on the qualities measured. This is somewhat difficult to do but in Table 20 an effort has been made to do so. In this table such characteristics as chick mortality, growth to eight weeks, maturity age, egg weight, egg production and adult mortality have been considered. The crossbreds have been ranked as to how they measure up with respect to a particular characteristic in comparison to the parent stocks involved. The

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TABLE 20. *Ranking of various crossbreds in relation to parent stock.*

(Rank 1 indicates crossbreds superior to either parent stock; rank 2, equal to better parent; rank 3, like poorer parent. This table is of value for indicating the effects of crossbreeding rather than the relative merits of the various crosses shown.)

	W. Leghorn by R. I. Red	W. Leghorn by R. I. Red	W. Leghorn by Australorp	W. Leghorn by N. Hampshire	R. I. Red by B. P. Rock
Chick mortality (%).....	1	2	1.5	1	1.5
8-wks. weight (gr.).....	2	2	2.5	2.5	1
Maturity age (days).....	2.5	2.5	2	2.5	1
Egg weight (gr.).....	2	2	2.5	2.5	2.5
Egg production (No.)....	2	2	1.5	2	1
Adult mortality (%).....	2.5	1	1.5	2	1.5

rating is an estimation based upon the average of reciprocal matings. The five tabulated breed crossings include all those upon which it appeared that critical data were available. In each, data were obtained in the same year for both parent stocks and reciprocal matings between them.

The rankings were, (1) indicating that the crossbreds were superior to both parent stocks, (2) crossbreds equal to the better of the two parent stocks, and (3) crossbreds like the poorer of the two parent stocks. The decimal fractions indicate intermediate positions between the indicated rankings. Thus, for the first listed White Leghorn by Rhode Island Red cross, the crossbreds were superior to either parent stock in chick mortality; like the better of the two parent stocks in eight weeks weight, egg weight, and egg production; and intermediate between the two parent stocks in maturity age and adult mortality. Considering the results as a whole and including all types of matings it is seen that in the 30 ratings, 6 were better than either parent; 5 had a rating of 1.5 which meant that one cross was superior to either and the reciprocal like the better parent; 10 were like the better parent; and 9 were like the poorer parent. Thus in 21 out of 30 comparisons the crossbreds were equal to or better than the superior of the two parent stocks. Strains, breeds and varieties differ quite widely in the expression of the characteristics here used as a measure of vigor. In these results there is a tendency for the crossbreds to have a combination of the desired characteristics found in the two stocks being crossed or to have brought together in it the superior qualities of the parent stocks. In nine of the comparisons the crossbreds were only intermediate between the parents, that is, better than the poorer but poorer than the better. In a very few tests the crossbreds had qualities like the poorer parent but the averaging of reciprocal matings in Table 20 tended to obscure them. In some instances the recorded improvement is small, but if by crossbreeding eggs can be made to hatch slightly better, the chicks to grow better and live better, and finally the matured females to lay even slightly better, the cumulative results are of considerable economic significance.

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