INHERITANCE STUDIES OF GERM PROPORTION IN MAIZE

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Paul Leighton Pfahler

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This is to certify that the

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Inheritance Studies of Germ Size In Maize

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Major professor

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INHERITANCE STUDIES OF

GERM PROPORTION IN

MAIZE

By

Paul Leighton Pfahler

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of requirements for the degree of

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THESIS

THESIS ABSTRACT

In 1952, 46 inbred lines were degerminated to determine their proportions of germ to kernel weight. An inheritance study was conducted using two crosses Wr3 x Oh2 and Wr3 x Hy2. Wr3 was the high ratio parent for both crosses and Oh2 and Hy2 were the low ratio parents. In 1953, the parents, F_1, F_2, BC_1 and BC_2 of each cross were planted at the College Farm, East Lansing, Michigan. The plants were self-pollinated. Each population of each cross was harvested and stored separately. Degermination of the 1953 material was done using the method suggested by Watson et al (13).

1. The method of degerminating corn suggested by Watson et al (13) was relatively more rapid and complete compared to the warm water technique.

2. The evidence for or against dominance is not clear-cut from the results of this study. Most of the evidence seemed to favor partial dominance for high germ proportion.

3. The observed means did not fit those calculated on the assumption of either arithmetic or geometric gene action.

4. The number of genes governing germ size in maize was calculated to be at least 6.

5. The heritability of germ size was found to be high, an average of 75%.

6. Correlations between proportion of germ and kernel weight were not significant. Therefore, total kernel weight

could not be used as a measure of the proportion of germ. Correlation of germ weight with kernel weight were highly significant.

7. The Wr3 x Oh2 cross showed no heterosis for either germ weight or kernel weight. Using the 1953 mean for Oh2, there was heterosis for low germ proportion. Comparisons made using the 1952 mean for Oh2 showed no heterosis. Wr3 x Hy2 showed heterosis for germ and kernel weights but no heterosis for germ proportion.

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INTRODUCTION

Oil and protein constitute valuable and important components of the corn kernel. Eighty-four percent of the oil contained in the corn kernel is in the germ. Corn oil is a valuable by-product in the industrial processing of corn and is also a high energy livestock feed. Approximately twenty-two percent of the total protein in the corn kernel is found in the germ. This protein is well balanced nutritionally whereas the endosperm protein is deficient in tryptophan and lysine. From the standpoint of both the industrial processor and the feeder of livestock, a larger proportion of germ to total kernel weight might be a distinct advantage.

If hybrids with a higher oil content and a higher percentage of nutritionally balanced protein are to be developed, a more rapid and less costly method of determining the percentages of these fractions would be advantageous to the plant breeder in evaluating strains or selections. Brunson, et al (1) found that the proportion of germ and percentage of total oil had a correlation coefficient of +.86. In the same experiment, the proportion of germ and percentage of germ protein had a correlation coefficient of +.81. These high, positive correlations would indicate that if the ratio of germ weight to total kernel weight was increased, the content of oil and nutritionally balanced protein could be increased. However, the correlation of percent oil in the germ with percent protein in germ was -.71 indicating that it would be difficult to increase both components through an increase in proportion of germ.

The purposes of this study were to study the mode of inheritance and heritability of germ ratio; to determine the relationship of germ weight to kernel weight; and the relationship of germ ratio to the total kernel weight.

REVIEW OF LITERATURE

Brunson, Earle and Curtis (1) hand-dissected 57 hand-pollinated F_2 ears into endosperm, embryo and bran. Each fraction was analyzed for oil and protein. They found a high positive correlation, +.86, between oil in the kernel and the proportion of germ. A high positive correlation, +.81, was obtained between germ protein and the proportion of germ to kernel weight.

Earle, Curtis and Hubbard (5) hand-dissected 11 varieties of corn and reported a high positive correlation between oil content of the entire grain and the oil content of the germ.

It was found by Earle and Curtis (4) that oil content was genetically inherited and capable of being altered by breeding.

In 1896, research was begun at the Illinois Agricultural Experiment Station on oil and protein content of corn. The experiment was set up in two parts; in the first part, selections were made for both high and low oil content and in the second part, selections for both high and low protein.

Woodworth, Leng, and Jugenheimer (14) reported the results for 50 generations of selection. The original foundation seed lot was the Burr White variety with a mean oil percentage at the beginning of selection of 4.70%. In 1949 after fifty generations of selection, the mean oil percentage of the high oil selection was 15.36% while that of the low oil selection was 1.01%. The mean protein percentage of the Burr White variety was 10.92%. After fifty generations of selection for both the high and the low protein, the mean protein percentage of the high protein selection was 19.45% while that of the low protein selection was 4.91%. Ear to row selection had a pronounced effect on raising or lowering the oil and protein content of the original parent.

In conjunction with the Illinois Experiment, "Student" (11) determined the minimum number of genes necessary to account for the results obtained. On the basis of certain assumptions on gene action, he estimated that oil percentage in corn was conditioned by at least 20 to 40 genes and possibly involved 200 to 400 genes.

Sprague and Brimhall (9) studied the effect of environmental conditions and season on the oil content of the corn kernel. After testing nine inbreds for fifteen seasons, they concluded that genetic constitution was more important than environment in affecting the oil percentage of the kernel. Low oil percentage showed a slight degree of dominance and it was concluded that the minimum number of genes conditioning oil content was twenty to forty.

Sprague, Miller, and Brimhall (10) compared the relative effectiveness of recurrent selection with selection in selfed lines for increasing the oil content of corn. The parent material was a synthetic variety designated as Stiff Stalk. The mean oil percentage for the original population was 4.2%. In the recurrent selection series, the mean of the first cycle was 5.2% and the mean of second cycle 7.0%. The range for the original population was from 2.5 - 5.0%; for the first cycle 4.0 - 8.0%, and for the second cycle 5.5 - 9.5%. Selection within inbred lines was effective in raising the general mean from 4.97 to 5.62% after five generations of inbreeding. However, it was noted that selection was not equally effective in all families. In the selfing and selection series, some lines evidenced a decrease in mean oil percentage whereas other lines showed a considerable increase in mean oil percentages. Recurrent selection was found to be 1.3 to 3.0 times as effective as selection within selfed lines.

Frey (6) found that total protein in the corn kernel was governed by at least 20 genes, zein by a minimum of six genes and tryptophan by 15 genes. He postulated that a minimum of 20 genes conditioned the high and low lewels of both oil and protein in corn.

Frey, Brimhall and Sprague (17) reported that the amount of non-zein protein appears to be a better guide in selection for increased tryptophan content than does the amount of total protein. They suggested that corn grain with a moderate protein content having a larger tryptophan-protein ratio is to be desired rather than merely a high protein corn.

METHODS AND MATERIALS

In the winter of 1953, the proportion of germ to endosperm in the kernel was determined for 46 inbred lines of corn. Twenty-five kernels were used for each test from a bulk lot of seed of each inbred line. Separation of the germ from the kernel was accomplished by soaking fifteen minutes in water at approximately 100°F and dissecting the germ from the endosperm with a scalpel. The germ portion included that portion of the seed coat which covered the germ of the kernel. The endosperm portion included the seed coat surrounding the endosperm and the tip cap. The dissected portions were oven-dried at 100-110°C for 24 hours. The weight of the germ, endosperm and total weight of the kernel was obtained and the ratio calculated.

From crosses already on hand, two crosses were chosen for an inheritance study:

1.	Wr3	x	Oh2
	high ratio		low ratio
2.	Wr3	x	Hy2
	high ratio		low ratio

In 1953, the parents, the F_1, F_2, BC_1 and the BC_2 of each cross were planted at the College Farm, East Lansing, Michigan. Single rows of twenty-five plants of the parents and F_1's were grown. Eight rows of approximately twenty-five plants each were grown for each of the F_2, BC_1 and BC_2. The plants were self-pollinated by hand. Each ear was harvested, dried by natural air circulation and stored separately.

The process suggested by Watson et al (13) was used to dissect the germ from the endosperm. This method was faster and gave a more complete separation of germ from endosperm. A solution of 1% lactic acid and .2% sodium bisulfite (active ingredient-sulfur dioxide, SO_2) was used. Approximately three ml. of this solution was used per gram of corn to be degerminated. The corn was immersed in the solution and incubated for 24 hours at 130°F. During incubation, occasional shaking was necessary. At the end of the 24 hour period, the germ was removed by cutting the seed coat around the germ with a scalpel and lifting the germ out. The dissected portions were oven-dried at 100-110°C for 24 hours.

The number of kernels per ear required for an adequate sampling of the ear was calculated from a formula used by Henry et al (8):

$$n = \frac{\text{Error Variance}}{NK}$$

where

n = number of kernels required from each ear for a given significance level.

N = number of ears.

K = required variance of each mean.

Seven ears were selected at random from each of the three parent inbreds. Ten kernels from each ear were chosen at random, analyzed individually using the sulfur dioxide treatment, and the ratio calculated. The oven-dry weights of the germ and endosperm and the ratio for each kernel are given in Table I of the Appendix. The error variance was computed by an analysis of variance of each parent population. The number of ears was considered as one. K had two values depending on the level of significance:

K at the 5% level = (.05 x general mean of the parent population)^2

K at the 1% level = (.01 x general mean of the parent population)^2

Table I. Number of kernels from each ear needed for an adequate sample

Inbreds	Levels of Significance	
	5%	1%
Wr3	5	114
Oh2	3	57
Hy2	6	144

Two samples of five kernels from each ear were considered sufficient. Each sample was analyzed using the solution recommended by Watson et al (13) and weighed separately. The oven-dry weights of the germ and endosperm and the calculated ratio x 100 of all samples analyzed in each generation of both crosses are presented in Tables II and III of the Appendix.

The theoretical means for arithmetic and geometric gene interaction presented in Table II of the Experimental Results were calculated from these formulae:

$$\text{Theoretical Arithmetic } \bar{F}_1 = \frac{\bar{P}_1 + \bar{P}_2}{2}$$

$$\text{Theoretical Arithmetic } \bar{F}_2 = \frac{\bar{P}_1 + 2\bar{F}_1 + \bar{P}_2}{4}$$

$$\text{Theoretical Arithmetic } \overline{BC}_1 = \frac{\bar{F}_1 + \bar{P}_1}{2}$$

$$\text{Theoretical Arithmetic } \overline{BC}_2 = \frac{\bar{F}_1 + \bar{P}_2}{2}$$

$$\text{Theoretical Geometric } \bar{F}_2 = \text{Antilogarithm of } \frac{\log \bar{P}_1 + 2 \log \bar{F}_1 + \log \bar{P}_2}{4}$$

$$\text{Theoretical Geometric } \overline{BC}_1 = \text{Antilogarithm of } \frac{\log \bar{F}_1 + \log \bar{P}_1}{2}$$

$$\text{Theoretical Geometric } \overline{BC}_2 = \text{Antilogarithm of } \frac{\log \bar{F}_1 + \log \bar{P}_2}{2}$$

The extent of agreement between the observed and calculated means furnishes an indication of the nature of gene interaction in the inheritance of germ size.

Three methods were used to estimate the number of genes governing the expression of germ proportion in corn.

1. The formula suggested by Wright and used by Burton (2):

$$n = \frac{.25\,(.75 - h + h^2)\,D^2}{\sigma_{F_2}^2 - \sigma_{F_1}^2}$$

$$h = \frac{\bar{F}_1 - \bar{P}_1}{\bar{P}_2 - \bar{P}_1}$$

$$D = \bar{P}_2 - \bar{P}_1$$

$\bar{P}_1$ = the mean of the smallest parent

$\bar{P}_2$ = the mean of the largest parent

$\bar{F}_1$ = the mean of the F_1 population

$\bar{F}_2$ = the mean of the F_2 population

The above formula will furnish an estimate of the gene number governing the expression of a particular characteristic if the following assumptions apply:

(1) no linkage exists between pertinent genes,

(2) one parent supplies only plus factors and the other only minus, factors among those in which they differ,

(3) all genes are equally important, and

(4) no interaction exists between pertinent nonallelic genes.

2. The formula suggested by Castle (3):

$$n = \frac{D^2}{8\,(\sigma F_2^{\,2} - \sigma F_1^{\,2})}$$

$$D = \bar{P}_2 - \bar{P}_1$$

3. t test on the F_2 population. A t value at the 5% and 1% level of significance was calculated for the F_2 generation of each cross. If one gene was responsible for or controlled each significant or highly significant interval in the distribution, the number of intervals for each level of significance in the F_2 population would be equal to the gene number.

Two methods were used to estimate the heritability of germ size in corn.

1. $$\text{Heritability} = \frac{V_{F_2} - V_{F_1}}{V_{F_2}}$$

2. The formula suggested by Warner (12):

$$\text{Heritability} = \frac{2(V_{F_2}) - (V_{BC_1} + V_{BC_2})}{V_{F_2}}$$

V = the variance of the population which appears as a subscript

EXPERIMENTAL RESULTS

The ratio of germ in percentage to total kernel weight for the 46 inbred lines tested in 1952 are given in Table I.

Table I - Ratio in percentage of germ weight to total kernel weight of 46 inbred lines. 1952

Inbred	Ratio percentage germ to kernel weight	Inbred	Ratio percentage germ to kernel weight
H	5.9	Ia.153	7.9
ND230	6.8	R4	6.2
Wr3	8.7	M14	7.7
Oh45	5.5	Fe	7.2
WF9	8.7	Kr1921-1-1-1-2	6.6
Oh40B	8.0	Hy2	5.2
W25	6.4	W8	9.1
Oh51A	7.5	A334	9.1
W9	7.0	A374	8.2
M13	9.7	NY44-2C	6.3
W22	6.9	P8	5.4
Ill.A	6.4	187-2	8.4
Oh26	6.7	Y82 (138)	8.3
Oh51	5.2	Ill.90	5.6
W23	7.4	R54	9.7
R53	8.5	Ill. Hy.	7.4
Id D50	9.2	N6	6.8
Id D59	5.2	A342	8.7
A385	5.2	Ill.4451	8.2
A158	10.9	Ms113	8.1
Ms24A	5.7	Ms51	7.6
Ms40	8.9	Ms1341	8.8
Ms206	7.9	Oh2	5.4

The range was 5.2 to 10.9%. Wr3 was chosen as the parent with a high ratio of germ to kernel weight and Oh2 and Hy2 were chosen as parents with a low ratio.

Mode of Inheritance

The results of the mode of inheritance study will be given under three headings: (1) dominance, (2) number of genes and (3) heritability.

1. Dominance.

Frequency distributions for the Wr3 x Oh2 cross are given in Figure 1. The theoretical normal frequency curve distribution is shown in relation to the actual frequency distribution of the F_2. The actual frequency distribution of the F_2 fits a normal curve distribution as shown by the Chi Square test. The Chi Square value was calculated at 12.92 when the least value for significance at the 5% level was 16.92. The normal curve distribution of the actual F_2 population indicates that no dominance was present in the cross.

The actual mean, the predicted arithmetic and geometric means, the standard deviation and the standard error of each population of the cross are given in Table II. Assuming no dominance, the F_1 mean should be half way between the two parents. If the standard error of the actual F_1 mean is considered equal to the standard error of the predicted arithmetic mean of the F_1, a t test can be computed to determine if there is a significant difference between the two means. The standard error of the actual F_1 mean was .078. The t value was found to be 13.82 which is highly significant. Therefore, the two F_1 means could not have been obtained by

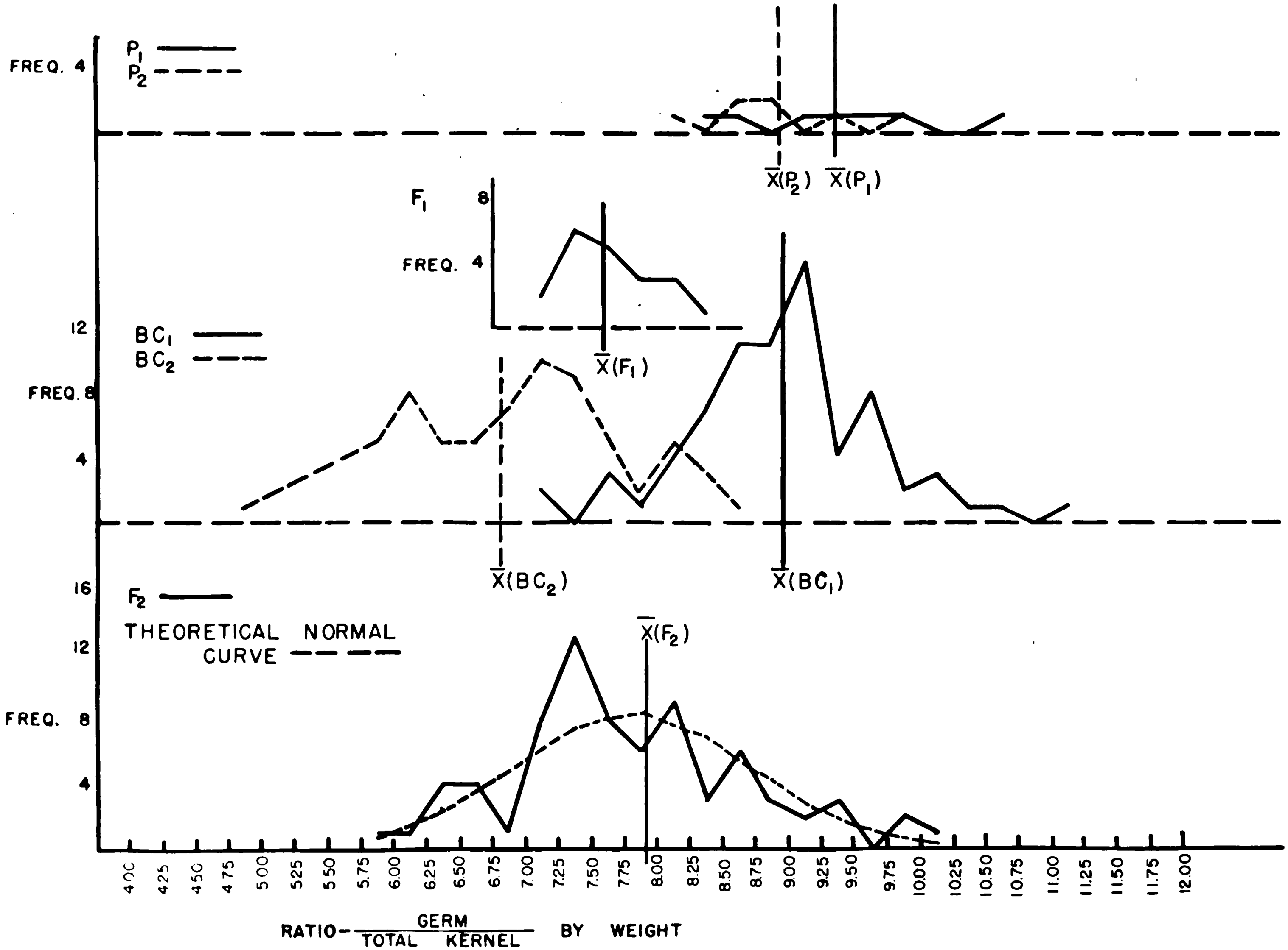
Table II - The actual and predicted means, the standard deviation and standard error of each of the two crosses

Generation	Wr3 x Oh2 cross						Wr3 x Hy2 cross					
	No.	Actual mean	Predicted mean Arith*	Predicted mean Geom.#	Standard deviation	Standard error of mean	No.	Actual mean	Predicted mean Arith.*	Predicted mean Geom.#	Standard deviation	Standard error of mean
P_1	7	9.37	-	-	.76	.295	7	9.37	-	-	.76	.295
P_2	7	8.93	-	-	.57	.216	7	5.49	-	-	.38	.144
F_1	20	7.63	9.15	-	.35	.078	19	8.29	7.43	-	.48	.110
BC_1	75	8.26	8.50	8.45	.74	.085	50	7.53	8.83	8.81	.75	.106
BC_2	75	6.81	8.28	8.25	.89	.103	75	8.59	6.89	6.75	.92	.106
F_2	75	7.81	8.39	8.35	.91	.105	76	8.44	7.86	7.71	1.17	.134

* Arithmetic

Geometric

FIGURE I - FREQUENCY DISTRIBUTION OF THE WR3 x OH2 CROSS

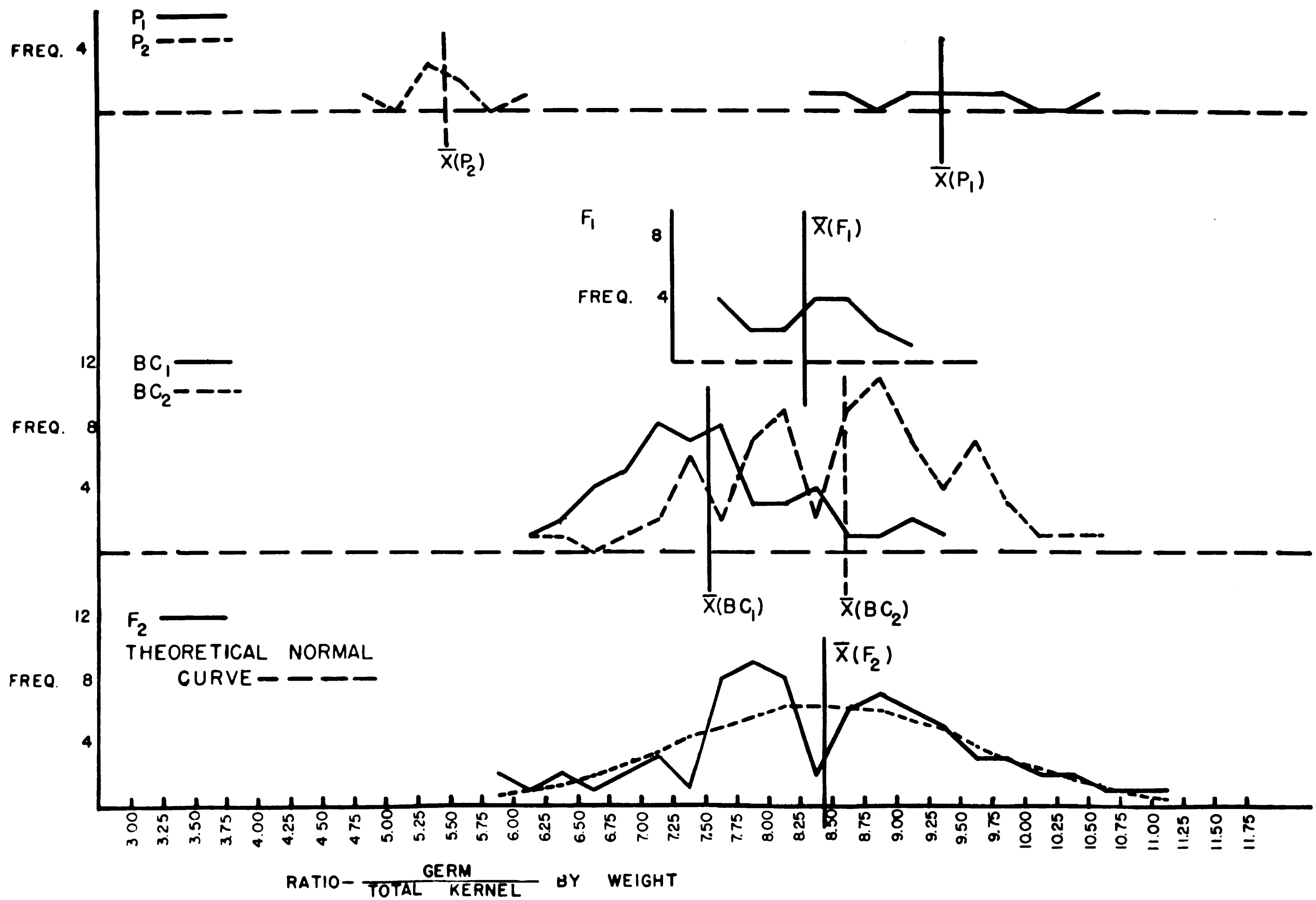


random sampling from the same parent population. No conclusion can be made concerning the degree of dominance because the means of both parents were above that of the F_1 population, actually showing heterosis for low germ ratio.

The mean of the Oh2 parent was 5.4 when analyzed in 1952. Using this mean, the predicted arithmetic mean of the F_1 population was 7.39 assuming no dominance. The actual mean was 7.63. Using the t test to determine significance between these two means (assuming the standard error of the predicted and actual means of the F_1 to be equal), a highly significant t value of 3.27 was obtained. This indicates slight partial dominance for a high ratio of germ. Frequency distributions of the two backcrosses and their means indicate partial dominance for a high ratio of germ.

Using the mean obtained in 1953 for the Oh2 parent, both the predicted arithmetic and geometric means were significantly different from the actual means as shown in Table II. Possibly, both types of gene action were operating in the inheritance of germ size. Using the mean obtained in 1952 for the Oh2 parent, the predicted arithmetic means for the F_2, BC_1 and BC_2 were 7.51, 8.50, 6.52 respectively and the geometric means for the F_2, BC_1 and BC_2 were 7.37, 8.45 and 6.42 respectively. The predicted means were significantly different from the actual means.

FIGURE 2—FREQUENCY DISTRIBUTION OF THE WR3 x HY2 CROSS



Frequency distributions for the Wr3 x Hy2 cross are given in Figure 2. The theoretical normal frequency curve distribution is shown in comparison to the actual F_2 frequency distribution. The actual frequency distribution fits a normal curve distribution as shown by the Chi Square test. The Chi Square value was 11.58 when the least value for significance at the %5 level was 16.92. The distribution of the actual F_2 population indicates no dominance was present in this cross.

The actual means, the predicted means, the standard deviations, and the standard errors of each population of this cross are given in Table II. Partial dominance for a high ratio of germ was shown by the relationship of the actual F_1 mean compared to the predicted F_1 mean. If no dominance was present, the mean of the F_1 should approximate 7.43. The actual mean obtained was 8.29. The t value was 5.55, highly significant. Partial dominance for a high ratio of germ was indicated. If partial dominance for a high ratio of germ was present, the frequency distribution of the F_2 should be skewed towards the high parent. However, there was no evidence of a skewed distribution in the F_2 as the Chi Square test indicated that the actual F_2 frequency distribution fitted a normal curve. The two backcross means in this cross were the reverse of the expected means if partial dominance was present.

The predicted arithmetic and geometric means were significantly different from the actual means in the Wr3 x Hy2 cross. It was impossible to determine which scheme of gene interaction was predominant.

2. Number of genes

Since the mean of the Oh2 parent was higher in the 1953 analysis than expected, the 1952 mean for this inbred was also used in calculations for gene number in the Wr3 x Oh2 cross. Only the 1953 results were used in the gene number calculations for the Wr3 x Hy2 cross.

Table III - Calculated gene numbers governing the expression of ratio of germ for two crosses

Formula	Wr3 x Oh2		Wr3 x Hy2
	1953 Mean	1952 Mean	
Burton (2) formula	.728	2.84	1.8
Castle (3) formula	.0345	2.79	1.7
t test			
5% level	5.8		6.4
1% level	4.4		4.9

The number of genes responsible for the expression of germ size in these two crosses ranged from .0345 to 6.4, the lowest value being the result of the unexpectedly high mean for the Oh2 parent in 1953. The mean of the Oh2 parent analyzed in 1952 was 5.4. When the 1952 mean for Oh2 was used in the calculations instead of the 1953 mean, a more plausible estimate of the gene number was obtained. A minimum of six genes were responsible for the inheritance of germ ratio.

3. Heritability

The heritability of a character gives an estimate of how much of the variation may be due to the genetic make-up of the plant. The results of the heritability studies on each cross are presented in Table IV.

Table IV - Heritabilities for germ proportion in two crosses

Formula	Cross	
	Wr3 x Oh2	Wr3 x Hy2
Burton (2) formula	.85	.83
Warner (12) formula	.38	.97

These high heritabilities indicate that germ size was largely an inherited characteristic.

Correlations

Correlation coefficients for each population in each cross were calculated to determine relationship between germ and total kernel weights and between the ratio of germ to the total kernel weight. The results are given in Table V. Two levels of P are given to show the extent of significance.

Table V - Correlations coefficients for germ weight with total kernel weight and ratio of germ with total kernel weight for the parents and the segregating populations of Wr3 x Oh2 and Wr3 x Hy2

Cross	Generation	Number	Calculated r		P For significance	
			Germ weight-total kernel weight	Ratio-total kernel	5%	1%
Wr3 x Oh2						
	P_1	70	+.6824**	-.2026	.2355	.3063
	P_2	69	+.5266**	-.5404**	.2373	.3086
	F_1	20	+.7188**	-.1216	.4438	.5614
	BC_1	75	+.8571**	+.0942	.2274	.2961
	BC_2	75	+.8038**	+.2921*	.2274	.2961
	F_2	75	+.8015**	-.1498	.2274	.2961
Wr3 x Hy2						
	P_1	70	+.6824**	-.2026	.2355	.3063
	P_2	69	+.5979**	+.0159	.2373	.3086
	F_1	19	+.7433**	-.0689	.4555	.5751
	BC_1	50	+.7469**	-.2620	.2789	.3611
	BC_2	75	+.7544**	-.2250	.2274	.2961
	F_2	76	+.7795**	+.1350	.2260	.2942

* Significant at the 5% level
** Significant at the 1% level

Correlations between germ weight and total kernel weight were highly significant showing that large kernels tended to have large germs. Correlations between proportion of germ and kernel weight were not significant except in the Oh2 parent, which showed a highly significant negative correlation, and the backcross to Oh2 which showed a significant positive correlation. In the Oh2 inbred, the smaller kernels tended to have a higher proportion of germ. Since the correlations were not significant in the other populations, there appeared to be no consistent relationship between proportion of germ and kernel weight.

The mean germ weights and the mean kernel weights for each population of both crosses are given in Table VI.

Table VI - Mean germ weights and mean kernel weights in grams for each population of two crosses

Cross	Generation	Mean germ weight	Mean kernel weight
Wr3 x Oh2			
	P_1	.0177	.1892
	P_2	.0229	.2572
	F_1	.0194	.2510
	F_2	.0184	.2366
	BC_1	.0190	.2120
	BC_2	.0175	.2565
Wr3 x Hy2			
	P_1	.0177	.1892
	P_2	.0090	.1631
	F_1	.0228	.2758
	F_2	.0198	.2336
	BC_1	.0157	.2082
	BC_2	.0195	.2264

The F_1 populations should show the maximum amount of heterosis, if present. The F_1 and other populations of the Wr3 x Oh2 cross showed no heterosis for either germ weight or kernel weight. The F_1 in the Wr3 x Hy2 cross showed heterosis for both germ weight and kernel weight. The F_2 and backcross populations of this cross showed hybrid vigor to a lesser extent. None of the ratio means of the Wr3 x Hy2 cross were lower or higher than the parent means. Thus, it appeared that heterosis affected both the germ and endosperm equally.

DISCUSSION

Since Brunson et al (1) found a high positive correlation between germ oil and proportion of germ in the kernel, use of the ratio, germ weight to kernel weight, in evaluating lines for oil content might be an effective measure for selection toward higher oil content. They also found a high positive correlation of percent protein in the germ and the proportion of germ. Thus, this ratio might also be used as an indication of the proportion of balanced protein in the kernel. Since these workers found a highly significant negative correlation of - .71 between percent protein in the germ and percent oil in the germ, it appears that selection for a larger proportion of germ would not lead to maximum increases in both oil and germ protein. Soaking the kernels in the sulfur dioxide solution provided more complete separation of germ from endosperm than soaking in warm water.

In both crosses, there was some evidence for a slight degree of partial dominance for the high ratio of germ. Due to the inconsistencies in the results, the study of these crosses and possibly other crosses should be repeated. Sprague and Brimhall (9) found low oil percentage to be slightly dominant over high oil percentage. Frey (6) found that low percentage of protein, zein, tryptophan, valine and iso-leucine was completely dominant over high percentage. Genes other than those determining oil and balanced protein contents of the germ might be exerting major effects leading to a show of partial dominance for high ratio of germ. It was impossible to determine whether the observed means conformed to either arithmetic or geometric gene interaction.

The number of genes responsible for the expression of germ size in these two crosses ranged from .0345 to 6.4. The lowest value was the result of the unexpectedly high mean of the Oh2 parent. Frey (6) postulated that at least 20 genes were responsible for inheritance of both oil and protein. Other genes, besides those conditioning oil and balanced protein content, with major effects may be involved in germ proportion inheritance.

Since the standard deviations of the parents were large in relation to the segregating populations in each cross, it appears that the parents were variable in the germ ratio characteristic. Thus, the formulae which were used to calculate gene numbers would give rough estimates of the number of genes governing the expression of germ proportion.

Heritabilities for germ size were relatively high in both crosses indicating that environmental conditions had a relatively minor effect on germ proportion which appeared to be largely an inherited characteristic. Sprague and Brimhall (9), after testing nine inbreds for fifteen seasons, concluded that the genetic constitution is more important than environment in determining the oil percentage of the kernel. Earle and Curtis (4) concluded that oil content was a varietal characteristic rather than being due to environment.

Coefficients were highly significant in all populations of each cross for the germ - total kernel weight correlations, showing that the larger kernels tended to have larger germs. If there was a high correlation between the ratio of germ and the total kernel weight, the weight of the kernel could be used as an indication of the proportion of germ. The value of using an easily measured characteristic, such as kernel weight as a guide to the proportion of germ and possibly the oil and balanced protein content of a line, would be great. The correlations between the ratio and total kernel weight were not significant. The proportion of germ seems to be largely independent of kernel weight. Brunson et al (1) also reported no relationship between proportion of germ and kernel weight.

No heterosis for germ weight or kernel weight was exhibited in the Wr3 x Oh2 cross. Heterosis for low germ proportion was shown in the Wr3 x Oh2 cross with the 1953 mean for Oh2. When the 1952 mean for Oh2 was used, there was no evidence for heterosis but partial dominance for high germ proportion was indicated. In the Wr3 x Hy2 cross, heterosis for both large germ and kernel weights was evident in all of the populations except the backcross to the Wr3 parent. There was no indication of heterosis for germ proportion in this cross.

CONCLUSIONS

In 1952, 46 inbred lines were degerminated to determine their proportions of germ to kernel weight. An inheritance study was conducted using two crosses, Wr3 x Oh2 and Wr3 x Hy2. Wr3 was the high ratio parent for both crosses and Oh2 and Hy2 were the low ratio parents. In 1953 the parents, F_1, F_2, BC_1 and BC_2 of each cross were planted at the College Farm, East Lansing, Michigan. The plants were self-pollinated by hand. Each population of each cross was harvested, stored separately and later degerminated.

1. The method of degerminating corn suggested by Watson et al (13) was relatively more rapid and complete compared to the warm water technique.

2. The evidence for or against dominance is not clear-cut from the results of this study. Most of the evidence seemed to favor partial dominance for a high proportion of germ.

3. The observed means did not fit those calculated on the assumption of either arithmetic or geometric gene action.

4. The number of genes governing germ size in maize was calculated to be at least 6.

5. The heritability of germ size was found to be high, an average of 75%.

6. Correlations between proportion of germ and kernel weight were not significant. Therefore, total kernel weight

could not be used as a measure of the proportion of germ. Correlation of germ weight with kernel weight were highly significant.

7. The Wr3 x Oh2 cross showed no heterosis for either germ weight or kernel weight. Using the 1953 mean for Oh2 there was heterosis for low germ proportion. Comparisons made using the 1952 mean for Oh2 showed no heterosis. Wr3 x Hy2 showed heterosis for germ and kernel weights but no heterosis for germ proportion.

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APPENDIX

Table I - Oven-dry weights in grams for the germ and endosperm and the ratio x 100 for each kernel from individual ears of the three parent inbred lines. 1953.

A. Parent - Wr3

	Germ Weight	Endosperm Weight	Ratio
Ear 1			
	.023	.203	10.1
	.019	.197	8.7
	.020	.184	9.8
	.023	.206	10.0
	.023	.215	9.6
	.013	.152	7.8
	.025	.206	10.8
	.022	.206	9.6
	.022	.186	10.5
	.022	.215	9.2
		Mean-	9.61
Ear 2			
	.019	.150	11.2
	.019	.146	11.5
	.015	.139	9.7
	.013	.153	7.8
	.018	.144	11.1
	.018	.141	11.3
	.019	.147	11.4
	.017	.143	10.6
	.017	.148	10.3
	.019	.149	11.3
		Mean-	10.62
Ear 3			
	.020	.180	10.0
	.019	.184	9.3
	.015	.178	7.7
	.019	.170	10.0
	.019	.187	9.2
	.020	.164	10.8
	.020	.191	9.4
	.021	.170	10.9
	.019	.161	10.5
	.019	.179	9.5
		Mean-	9.73

	Germ Weight	Endosperm Weight	Ratio
Ear 4			
	.020	.171	10.4
	.014	.131	9.6
	.014	.134	9.4
	.016	.135	10.5
	.015	.131	10.2
	.015	.139	9.7
	.016	.140	10.2
	.014	.145	8.8
	.014	.168	7.6
	.013	.141	8.4
			Mean- 9.48
Ear 5			
	.018	.210	7.8
	.019	.180	9.5
	.019	.212	8.2
	.016	.178	8.2
	.016	.201	7.3
	.015	.169	8.1
	.020	.202	9.0
	.019	.191	9.0
	.021	.182	10.3
	.019	.193	8.9
			Mean- 8.63
Ear 6			
	.019	.171	10.0
	.015	.161	8.5
	.014	.144	8.8
	.013	.161	7.4
	.013	.165	7.3
	.015	.178	7.7
	.017	.171	9.0
	.018	.182	9.0
	.015	.168	8.1
	.015	.161	8.5
			Mean- 8.43
Ear 7			
	.019	.170	10.0
	.020	.190	9.5
	.019	.160	10.6
	.016	.162	8.9
	.016	.190	7.7

Germ Weight	Endosperm Weight	Ratio
.018	.186	8.8
.019	.170	10.0
.016	.186	7.9
.019	.196	8.8
.017	.179	8.6
	Mean-	9.08

B. Parent Oh2.

Ear 1

.021	.217	8.8
.023	.238	8.8
.024	.245	8.9
.023	.245	8.5
.023	.242	8.6
.023	.211	9.8
.022	.238	8.4
.027	.248	9.8
.022	.229	8.7
.021	.234	8.2
	Mean-	8.85

Ear 2

.020	.220	9.0
.021	.245	7.9
.021	.229	8.4
.024	.259	8.4
.020	.234	7.9
.029	.295	8.9
.020	.215	8.5
.028	.261	9.6
.028	.261	9.6
	Mean-	8.64

Ear 3

.020	.190	9.5
.020	.190	9.5
.020	.182	9.9
.022	.184	10.6
.021	.199	9.5
.021	.181	10.3
.024	.189	11.2
.022	.212	9.4
.021	.181	10.3
.020	.189	9.5
	Mean-	9.97

	Germ Weight	Endosperm Weight	Ratio
Ear 4			
	.021	.220	8.7
	.025	.223	10.0
	.023	.223	9.3
	.023	.228	9.1
	.022	.242	8.3
	.022	.231	8.6
	.023	.234	8.9
	.020	.225	8.1
	.019	.245	7.1
	.023	.241	8.7
			Mean- 8.68
Ear 5			
	.021	.243	7.9
	.029	.285	9.2
	.024	.232	9.3
	.023	.224	9.3
	.026	.259	9.1
	.022	.267	7.6
	.023	.229	9.1
	.023	.242	8.6
	.024	.230	9.4
	.022	.228	8.8
			Mean- 8.83
Ear 6			
	.026	.283	8.4
	.023	.248	8.4
	.028	.289	8.8
	.023	.293	7.2
	.022	.253	8.0
	.022	.262	7.7
	.022	.248	8.1
	.022	.266	7.6
	.023	.228	9.1
	.024	.267	8.2
			Mean- 8.15
Ear 7			
	.025	.221	10.1
	.021	.239	8.0
	.027	.224	10.7
	.023	.229	9.1
	.025	.246	9.2

Germ Weight	Endosperm Weight	Ratio
.028	.248	10.1
.022	.209	9.5
.022	.204	9.7
.022	.249	8.1
.024	.243	8.9
		Mean- 9.34

C. Parent - Hy2

Ear 1

.011	.163	6.3
.012	.174	6.8
.010	.139	7.2
.009	.164	5.2
.012	.155	7.1
.010	.164	5.7
.009	.153	5.5
.009	.149	5.6
.011	.169	6.1
.010	.162	5.8
		Mean- 6.13

Ear 2

.009	.165	5.1
.009	.148	5.8
.009	.152	5.5
.010	.149	6.2
.009	.159	5.3
.010	.149	6.2
.008	.159	4.7
.009	.159	5.3
.009	.143	5.9
.009	.156	5.4
		Mean- 5.54

Ear 3

.009	.162	5.3
.006	.126	4.5
.007	.142	4.6
.010	.162	5.8
.010	.156	6.0
.010	.150	6.2
.009	.149	5.6
.009	.147	5.1
.009	.141	6.0
.008	.136	5.5
		Mean- 5.46

	Germ Weight	Endosperm Weight	Ratio
Ear 4			
	.010	.189	5.0
	.010	.182	5.2
	.009	.185	4.6
	.010	.181	5.2
	.006	.169	3.4
	.010	.182	5.2
	.010	.178	5.3
	.010	.181	5.2
	.010	.191	4.9
	.011	.175	5.9
		Mean-	4.99
Ear 5			
	.009	.151	5.6
	.008	.149	5.1
	.009	.144	5.8
	.010	.149	6.2
	.010	.155	6.0
	.007	.139	4.7
	.007	.145	4.6
	.009	.142	5.9
	.009	.149	5.6
	.008	.149	5.0
		Mean-	5.45
Ear 6			
	.008	.159	5.0
	.010	.156	6.0
	.010	.148	6.3
	.009	.141	6.0
	.009	.148	5.7
	.008	.135	5.5
	.008	.139	5.4
	.005	.119	4.0
	.005	.149	3.3
	.009	.155	5.4
		Mean-	5.26
Ear 7			
	.010	.141	6.6
	.009	.158	5.3
	.007	.135	4.9
	.008	.132	5.7
	.008	.149	5.0

Germ Weight	Endosperm Weight	Ratio
.008	.138	5.4
.008	.144	5.2
.010	.152	6.1
.010	.149	6.2
	Mean-	5.60

Table II - Oven-dry weights in grams for the germ and endosperm and the ratio x 100 for the F_1, F_2, BC_1, and BC_2 of the Wr3 x Oh2 cross. Two samples of five kernels each were taken from each ear.

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
A. F_1					
.122	1.33	8.40	.118	1.27	8.50
.090	1.16	7.20	.090	1.11	7.50
.079	.94	8.60	.079	.92	7.91
.095	1.21	7.28	.091	1.19	7.10
.104	1.17	8.16	.097	1.19	7.54
.107	1.19	8.25	.110	1.18	8.53
.111	1.17	8.67	.122	1.30	8.58
.095	1.19	7.39	.091	1.22	6.94
.105	1.33	7.32	.111	1.28	7.98
.088	1.14	7.17	.099	1.20	7.62
.092	1.18	7.23	.104	1.13	8.43
.109	1.28	7.85	.098	1.34	6.81
.101	1.23	7.59	.098	1.22	7.44
.078	.87	8.23	.074	.89	7.68
.089	1.09	7.55	.095	1.10	7.95
.104	1.20	7.97	.102	1.16	8.08
.085	1.10	7.17	.093	1.14	7.54
.091	1.09	7.71	.090	1.12	7.44
.081	.99	7.56	.082	1.06	7.18
.102	1.25	7.54	.111	1.19	8.53
B. F_2					
.074	1.05	6.58	.070	1.05	6.25
.101	1.01	9.09	.096	1.07	8.23
.091	.90	9.18	.090	.94	8.74
.129	1.30	9.03	.128	1.41	8.32
.116	1.51	7.13	.129	1.54	7.73
.090	1.02	8.11	.091	1.03	8.12
.119	1.27	8.57	.115	1.21	8.68
.089	1.20	6.90	.081	1.16	6.53
.049	.76	6.06	.047	.74	5.97
.123	1.59	7.18	.122	1.50	7.52
.095	1.02	8.52	.103	1.03	9.09
.098	1.29	7.06	.099	1.29	7.13
.110	1.05	9.48	.107	1.05	9.25
.091	.83	9.88	.091	.85	9.67
.072	.85	8.26	.072	.88	7.56

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.103	1.22	7.78	.117	1.25	8.56
.089	1.06	7.74	.079	1.03	7.12
.111	1.42	7.25	.103	1.35	7.09
.083	1.02	7.52	.070	.89	7.29
.091	1.07	7.84	.101	1.11	8.34
.098	1.34	6.81	.101	1.26	7.42
.071	1.04	6.39	.078	1.14	6.40
.089	1.21	6.85	.095	1.23	7.17
.059	.83	6.64	.059	.90	6.15
.081	.84	8.79	.081	.86	8.61
.069	.91	7.05	.070	.93	7.00
.088	1.07	7.60	.095	.98	8.84
.097	1.19	7.54	.095	1.12	7.82
.105	1.39	7.02	.103	1.42	6.76
.116	1.55	6.96	.122	1.40	8.02
.084	1.02	7.61	.085	1.00	7.83
.081	.95	7.86	.071	.92	7.16
.095	1.26	7.01	.102	1.25	7.54
.104	1.27	7.57	.099	1.24	7.39
.096	1.16	7.64	.095	1.15	7.63
.078	.85	8.40	.092	.91	9.18
.090	1.19	7.03	.088	1.15	7.11
.089	.94	8.65	.085	.97	8.06
.122	1.04	10.50	.119	1.09	9.84
.099	1.25	7.34	.111	1.26	8.10
.092	.92	9.09	.091	.88	9.37
.081	1.08	6.98	.089	1.12	7.36
.102	1.21	7.77	.088	1.17	7.00
.090	1.09	7.63	.099	1.32	6.98
.098	1.13	7.98	.094	1.10	7.87
.082	.99	7.65	.082	.97	7.79
.071	.99	6.69	.068	.97	6.55
.089	1.28	6.50	.095	1.36	6.53
.130	1.52	7.88	.129	1.37	8.61
.069	.87	7.35	.069	.92	6.98
.108	1.24	8.01	.111	1.22	8.34
.075	.95	7.32	.079	1.00	7.32
.077	.82	8.58	.071	.84	7.79
.078	.89	8.06	.078	.94	7.66
.089	.90	9.00	.088	.83	9.59
.080	.99	7.48	.075	.97	7.18
.091	1.21	6.99	.088	1.03	7.87
.089	1.04	7.88	.081	1.02	7.36
.135	1.36	9.03	.141	1.29	9.85
.081	1.03	7.29	.085	1.00	7.83

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.069	.95	6.77	.060	.87	6.45
.080	.84	8.69	.081	.84	8.79
.087	1.12	7.21	.089	1.11	7.42
.115	1.30	8.13	.104	1.28	7.51
.083	.94	8.11	.088	.94	8.56
.066	1.08	5.76	.072	1.16	5.84
.117	1.29	8.32	.104	1.27	7.57
.129	1.35	8.72	.122	1.46	7.71
.071	1.08	6.17	.071	1.04	6.39
.079	.80	8.99	.079	.79	9.09
.079	.74	9.65	.076	.68	10.05
.090	1.02	8.11	.089	1.05	7.81
.066	.77	7.89	.070	.79	8.14
.120	1.18	9.23	.110	1.18	8.53
.116	1.32	8.08	.121	1.24	8.89
C. BC_1					
.123	1.21	9.23	.122	1.22	9.09
.095	.98	8.84	.098	1.00	8.93
.118	1.07	9.93	.111	1.06	9.48
.078	.87	8.23	.083	.87	8.71
.075	.79	8.67	.066	.70	8.62
.061	.83	6.85	.060	.77	7.32
.100	1.00	9.09	.111	1.08	9.32
.102	.97	9.51	.100	.96	9.43
.099	.89	10.01	.108	.92	10.51
.099	.89	10.01	.110	.95	10.38
.116	1.17	9.02	.116	1.21	8.75
.095	1.01	8.60	.100	.95	9.52
.099	1.04	8.69	.107	1.10	8.86
.098	.88	10.02	.098	.86	10.23
.091	.96	8.66	.095	.99	8.76
.079	.80	8.99	.082	.81	9.19
.095	.97	8.92	.105	1.09	8.78
.106	1.11	8.72	.101	1.00	9.17
.082	.83	8.99	.081	.86	8.61
.091	.85	9.67	.089	.86	9.38
.129	1.02	11.23	.129	1.05	10.94
.099	1.07	8.47	.101	1.02	9.01
.089	.92	8.82	.088	.92	8.73
.113	1.02	9.97	.106	1.01	9.50
.088	.91	8.82	.085	.94	8.29

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.096	.98	8.92	.097	.96	9.18
.091	.99	8.42	.091	.93	8.91
.075	.77	8.87	.078	.77	9.20
.089	.95	8.56	.088	.96	8.40
.099	1.08	8.40	.101	1.13	8.20
.081	.92	8.09	.101	.91	9.99
.076	.82	8.48	.076	.83	8.39
.081	.81	9.09	.089	.86	9.38
.088	.85	9.38	.084	.87	8.81
.099	.94	9.53	.100	.93	9.71
.114	1.27	8.24	.118	1.29	8.38
.125	1.31	8.71	.119	1.19	9.09
.070	.75	8.54	.071	.72	8.98
.099	.94	9.53	.096	.88	9.84
.102	1.00	9.26	.099	1.00	9.01
.083	.85	8.90	.086	.84	9.29
.073	.83	8.08	.071	.79	8.25
.082	.81	9.19	.088	.86	9.28
.073	.83	8.08	.077	.83	8.49
.085	.87	8.90	.087	.88	9.00
.116	1.09	9.62	.119	1.09	9.84
.070	.79	8.14	.073	.80	8.36
.119	1.10	9.76	.121	1.10	9.91
.109	.91	10.70	.107	.89	10.73
.081	.92	8.09	.120	1.17	9.30
.102	.89	10.28	.105	.97	9.77
.107	1.13	8.65	.105	1.09	8.79
.120	1.15	9.45	.120	1.13	9.60
.088	1.02	7.94	.091	1.02	8.19
.101	1.09	8.48	.100	1.07	8.55
.093	1.07	8.00	.095	1.09	8.02
.101	1.04	8.85	.105	1.17	8.24
.102	1.11	8.41	.107	1.09	8.94
.109	1.09	9.09	.090	1.04	7.96
.109	1.02	9.65	.105	.97	9.77
.091	.88	9.37	.101	.96	9.52
.118	1.16	9.23	.114	1.08	9.55
.108	1.27	7.84	.098	1.12	8.05
.097	.96	9.18	.095	.98	8.84
.076	.74	9.31	.074	.75	8.98

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.090	.89	9.18	.081	.79	9.30
.086	.87	9.00	.089	.86	9.38
.073	.89	7.58	.072	.99	6.78
.082	1.06	7.18	.092	1.08	7.85
.111	1.04	9.64	.102	.91	10.08
.110	1.06	9.40	.119	1.15	9.38
.091	.94	8.83	.091	.94	8.83
.071	.84	7.79	.078	.94	7.66
.063	.74	7.84	.061	.74	7.62
.076	.83	8.39	.083	.91	8.36
D. BC_2					
.080	1.20	6.25	.085	1.25	6.37
.077	1.11	6.49	.069	1.16	5.61
.123	1.56	7.31	.125	1.53	7.55
.108	1.31	7.62	.109	1.36	7.42
.069	.94	6.84	.071	.94	7.02
.061	1.07	5.39	.061	1.00	5.75
.088	1.28	6.43	.076	1.19	6.00
.100	1.02	8.93	.095	1.08	8.09
.099	1.49	6.23	.101	1.36	6.91
.060	1.11	5.13	.061	1.12	5.17
.098	1.27	7.16	.090	1.31	6.43
.050	.98	4.85	.051	1.02	4.76
.059	1.09	5.13	.059	1.10	5.09
.071	1.11	6.01	.072	1.13	5.99
.092	1.29	6.66	.101	1.21	7.70
.079	1.19	6.23	.081	1.19	6.37
.101	1.30	7.21	.089	1.32	6.32
.092	1.24	6.91	.096	1.24	7.19
.062	1.03	5.68	.065	1.02	5.99
.095	1.66	5.41	.101	1.66	5.73
.081	1.25	6.09	.082	1.19	6.45
.069	1.12	5.80	.070	1.06	6.19
.109	1.34	7.52	.098	1.36	6.72
.101	1.15	8.07	.100	1.17	7.87
.082	1.23	6.25	.086	1.21	6.64
.058	1.06	5.19	.059	.99	5.62
.072	1.21	5.62	.074	1.23	5.67
.091	1.30	6.54	.097	1.33	6.80
.085	1.13	7.00	.099	1.18	7.74
.085	1.33	6.01	.091	1.32	6.45

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.079	1.24	5.99	.081	1.18	6.42
.095	1.18	7.45	.085	1.17	6.77
.120	1.38	8.00	.104	1.38	7.01
.070	1.17	5.65	.070	1.19	5.56
.119	1.44	7.63	.101	1.40	6.73
.092	1.17	7.29	.097	1.23	7.31
.109	1.35	7.47	.099	1.36	6.79
.074	1.01	6.83	.069	.94	6.84
.079	1.25	5.94	.064	.95	6.31
.063	.99	5.98	.062	1.04	5.63
.086	1.15	6.96	.088	1.14	7.17
.129	1.49	7.97	.125	1.36	8.42
.111	1.40	7.35	.108	1.33	7.51
.102	1.40	6.79	.102	1.37	6.93
.103	1.09	8.63	.100	1.15	8.00
.071	1.12	5.96	.071	1.17	5.72
.102	1.37	6.93	.094	1.38	6.38
.101	1.23	7.59	.121	1.26	8.76
.122	1.51	7.48	.130	1.51	7.93
.049	.86	5.39	.051	.93	5.20
.099	1.15	7.93	.095	1.16	7.57
.105	1.20	8.05	.100	1.13	8.13
.073	1.00	6.80	.074	1.02	6.76
.078	1.36	5.42	.076	1.36	5.29
.103	1.33	7.19	.116	1.31	8.13
.105	1.20	8.05	.101	1.14	8.14
.062	.82	7.03	.060	.87	6.45
.069	1.09	5.95	.069	1.03	6.28
.101	1.15	8.07	.091	1.08	7.77
.082	1.10	6.94	.083	1.09	7.07
.091	1.26	6.74	.089	1.25	6.65
.073	.91	7.43	.070	.92	7.07
.098	1.26	7.22	.092	1.15	7.41
.072	1.10	6.14	.072	1.04	6.47
.108	1.28	7.78	.096	1.31	6.83
.111	1.23	8.27	.110	1.23	8.21
.088	1.11	7.34	.079	1.06	6.94
.068	.98	6.48	.067	.97	6.46
.100	1.09	8.40	.108	1.21	8.19
.110	1.26	8.03	.123	1.28	8.77

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.099	1.32	6.98	.111	1.35	7.60
.092	1.14	7.47	.089	1.14	7.24
.095	1.45	6.15	.098	1.42	6.45
.063	.96	6.16	.063	.99	5.98
.075	1.05	6.67	.078	1.05	6.91

Table III - Oven-dry weights in grams for the germ and endosperm and the ratio x 100 for the F_1, F_2, BC_1 and BC_2 of the Wr3 x Hy2 cross. Two samples of five kernels each were taken from each ear.

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
A. F_1					
.101	1.18	7.78	.116	1.15	9.16
.099	1.15	7.93	.091	1.14	7.39
.119	1.33	8.21	.119	1.27	8.57
.100	1.17	7.87	.130	1.20	9.77
.141	1.54	8.39	.121	1.47	7.61
.139	1.41	8.97	.126	1.24	9.22
.101	1.16	8.01	.109	1.10	9.01
.120	1.28	8.57	.119	1.26	8.63
.111	1.28	7.98	.113	1.19	8.67
.125	1.29	8.83	.118	1.19	9.02
.117	1.23	8.68	.101	1.24	7.53
.131	1.36	8.79	.108	1.29	7.73
.104	1.35	7.15	.121	1.37	8.11
.111	1.31	7.81	.110	1.29	7.86
.129	1.38	9.16	.120	1.32	8.33
.109	1.23	8.14	.128	1.24	9.36
.101	1.29	7.26	.115	1.35	7.85
.101	1.28	7.31	.104	1.17	8.16
.108	1.17	8.45	.102	1.19	7.89
B. F_2					
.111	1.18	8.59	.104	1.20	7.97
.103	1.28	7.44	.100	1.19	7.75
.061	1.02	5.64	.063	.99	5.98
.102	1.19	7.89	.100	1.15	8.00
.074	1.09	6.35	.070	1.00	6.54
.071	.87	7.54	.080	.94	7.84
.131	1.42	8.44	.123	1.48	7.67
.101	1.14	8.13	.110	1.15	8.37
.118	1.13	9.45	.104	1.08	8.78
.115	1.28	8.24	.096	1.25	7.13
.138	1.32	9.46	.131	1.30	9.15
.119	1.09	9.84	.119	1.06	10.09
.118	1.19	9.02	.112	1.19	8.60
.120	1.11	9.75	.119	1.04	10.26
.090	1.11	7.50	.100	1.15	8.00

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.091	1.07	7.83	.098	.98	9.09
.095	1.06	8.22	.092	1.11	7.65
.122	1.12	9.82	.133	1.23	9.75
.099	.97	9.26	.095	.92	9.36
.091	1.05	7.97	.101	1.00	9.17
.140	1.29	9.79	.141	1.39	9.20
.083	.77	9.73	.076	.74	9.31
.101	1.22	7.64	.089	1.15	7.18
.091	.90	9.18	.089	.86	9.37
.105	.95	9.95	.101	.92	9.89
.111	1.22	8.34	.112	1.14	8.94
.129	1.25	9.35	.114	1.21	8.61
.081	1.19	6.37	.078	1.21	6.05
.071	.78	8.34	.067	.82	7.55
.115	1.06	9.78	.114	1.07	9.62
.052	.87	5.63	.058	.88	6.18
.099	1.10	8.25	.089	1.07	7.67
.104	1.08	8.78	.114	1.06	9.71
.062	.73	7.83	.050	.73	6.41
.109	1.13	8.80	.119	1.11	9.68
.125	1.10	10.24	.120	1.04	10.34
.110	1.27	7.97	.121	1.20	9.16
.128	1.04	10.96	.135	1.16	10.42
.101	.99	9.26	.101	1.07	8.63
.075	.89	7.77	.076	.91	7.71
.094	.97	8.83	.099	.98	9.18
.079	.99	7.39	.085	1.02	7.69
.080	1.14	6.56	.091	1.13	7.45
.066	.87	7.05	.062	.85	6.80
.075	.77	8.87	.068	.70	8.85
.121	1.19	9.23	.120	1.18	9.23
.077	.77	9.09	.069	.73	8.64
.120	1.07	10.08	.131	1.14	10.31
.098	.91	9.72	.101	.96	9.52
.161	1.27	11.25	.159	1.29	10.97
.085	1.13	7.00	.085	1.08	7.30
.086	.93	8.46	.074	.90	7.60
.089	.99	8.25	.101	.96	9.52
.079	1.18	6.27	.082	1.17	6.55
.092	1.13	7.53	.091	1.11	7.58

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.060	.73	7.59	.062	.74	7.73
.099	1.12	8.12	.099	1.17	7.80
.091	1.04	8.05	.099	1.08	8.40
.103	1.14	8.29	.094	1.14	7.62
.125	1.21	9.36	.123	1.16	9.59
.071	.84	7.79	.071	.82	7.97
.109	1.26	7.96	.109	1.23	8.14
.086	.95	8.30	.083	.86	8.80
.117	1.37	7.87	.112	1.32	7.82
.089	.95	8.57	.092	.99	8.50
.110	1.20	8.40	.105	1.27	7.64
.080	.89	8.25	.078	.92	7.82
.078	.78	9.09	.075	.74	9.20
.105	1.10	8.71	.107	1.12	8.72
.099	1.25	7.34	.109	1.12	8.87
.100	1.26	7.35	.108	1.20	8.26
.124	1.31	8.65	.119	1.22	9.11
.071	.99	6.69	.071	1.02	6.51
.091	1.28	6.64	.095	1.24	7.12
.146	1.15	11.27	.148	1.24	10.66
.115	.99	10.41	.105	.91	10.34
C. BC_1					
.091	.97	8.58	.081	1.00	7.49
.076	.89	7.87	.073	.92	7.35
.068	.92	6.88	.069	.91	7.05
.085	1.12	7.05	.085	1.01	7.76
.084	1.01	7.68	.079	.99	7.39
.093	1.14	7.54	.090	1.08	7.69
.068	.73	8.52	.069	.73	8.64
.099	1.19	7.68	.107	1.19	8.25
.080	.98	7.55	.080	.95	7.77
.064	.82	7.24	.059	.73	7.48
.098	1.14	7.92	.091	1.10	7.64
.079	.97	7.53	.076	1.02	6.93
.080	.99	7.48	.078	1.01	7.17
.089	1.11	7.42	.087	1.12	7.21
.080	.89	8.25	.073	.85	7.91

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.082	1.09	7.00	.079	1.01	7.25
.101	1.22	7.65	.099	1.14	7.99
.077	.92	7.72	.074	.91	7.52
.081	.94	7.93	.082	1.01	7.51
.068	.84	7.49	.069	.85	7.51
.082	.92	8.18	.085	.89	8.72
.072	.97	6.91	.073	1.03	6.62
.069	.81	7.85	.069	.87	7.35
.104	.91	10.26	.080	.91	8.16
.090	.88	9.28	.090	.84	9.68
.081	1.15	6.58	.080	1.18	6.35
.064	.80	7.41	.061	.81	7.00
.051	.69	6.88	.049	.71	6.45
.063	.90	6.54	.065	.93	6.53
.090	1.06	7.83	.081	1.02	7.36
.083	.92	8.27	.082	.88	8.52
.091	1.22	6.94	.073	.91	7.43
.095	1.02	8.52	.092	1.03	8.20
.071	.96	6.89	.077	1.01	7.08
.074	1.05	6.58	.074	1.01	6.83
.081	1.16	6.53	.078	1.11	6.57
.080	.86	8.51	.081	.75	9.75
.071	.91	7.24	.069	.93	6.91
.082	1.10	6.94	.079	1.06	6.94
.069	.96	6.71	.063	.96	6.16
.075	1.02	6.85	.077	1.02	7.02
.071	.94	7.02	.074	.94	7.30
.059	.73	7.48	.060	.75	7.41
.080	1.06	7.02	.079	1.03	7.12
.084	.89	8.62	.088	.90	8.91
.071	.93	7.09	.072	.94	7.11
.065	.73	8.18	.065	.73	8.18
.080	1.03	7.21	.075	1.00	6.98
.088	1.10	7.41	.088	1.15	7.11
.085	.94	8.29	.085	.92	8.46
D. BC_2					
.101	1.09	8.48	.099	1.04	8.69
.091	1.07	7.84	.084	.93	8.28
.082	.81	9.19	.086	.82	9.49
.099	1.24	7.39	.100	1.26	7.35
.100	.90	10.00	.099	.96	9.35

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.067	.87	7.15	.071	.88	7.47
.095	1.17	7.51	.099	1.26	7.28
.090	1.14	7.32	.098	1.11	8.11
.090	1.27	6.62	.098	1.24	7.32
.075	.91	7.61	.073	.85	7.91
.090	1.15	7.26	.102	1.09	8.56
.098	1.02	8.77	.097	1.06	8.38
.091	.99	8.42	.095	1.05	8.30
.104	.99	9.51	.109	.98	10.01
.079	.84	8.60	.059	.69	7.88
.112	1.25	8.22	.115	1.15	9.09
.128	1.35	8.66	.130	1.35	8.78
.100	.99	9.17	.100	1.00	9.09
.130	1.09	10.66	.071	.61	10.43
.089	1.11	7.42	.089	1.12	7.36
.099	.97	9.26	.103	.92	10.07
.090	.94	8.74	.090	.96	8.57
.105	1.05	9.09	.101	1.04	8.85
.091	.93	8.91	.090	.97	8.49
.119	1.17	9.23	.099	.98	9.18
.099	1.16	7.86	.103	1.20	7.90
.113	1.18	8.74	.110	1.10	9.09
.082	1.02	7.44	.081	1.00	7.49
.097	1.13	7.91	.096	1.15	7.70
.091	1.06	7.91	.071	.83	7.88
.091	.95	8.74	.088	.87	9.19
.072	.92	7.26	.079	.98	7.46
.085	1.17	6.77	.072	1.21	5.62
.072	.73	8.98	.075	.73	9.32
.101	1.07	8.63	.101	1.09	8.48
.110	1.18	8.53	.080	.96	7.69
.099	.99	9.09	.089	.94	8.65
.099	1.09	8.33	.098	1.12	8.05
.085	.80	9.60	.090	.84	9.68
.078	.93	7.74	.078	.91	7.89
.089	1.33	6.27	.089	1.25	6.65
.090	1.08	7.69	.091	1.08	7.77
.131	1.35	8.85	.121	1.25	8.83
.101	1.27	7.37	.094	1.24	7.05
.081	.80	9.19	.075	.85	8.11

Sample 1			Sample 2		
Germ Weight	Endosperm Weight	Ratio	Germ Weight	Endosperm Weight	Ratio
.089	1.03	7.95	.093	1.02	8.36
.112	1.18	8.67	.111	1.09	9.24
.089	.87	9.28	.088	.89	9.00
.120	1.35	8.16	.116	1.30	8.19
.090	.95	8.65	.101	1.10	8.41
.108	1.02	9.57	.100	1.05	8.70
.109	1.17	8.52	.105	1.27	7.64
.091	.82	9.99	.097	.87	10.03
.099	1.06	8.54	.100	1.01	9.01
.121	1.16	9.45	.121	1.13	9.67
.091	.93	8.91	.092	.94	8.91
.089	.79	10.13	.082	.84	8.87
.070	.82	7.87	.069	.78	8.13
.133	1.25	9.62	.123	1.23	9.09
.130	1.26	9.35	.122	1.05	10.41
.092	1.10	7.72	.101	1.10	8.41
.099	.94	9.53	.098	.88	10.02
.067	.84	7.39	.061	.82	6.92
.114	1.26	8.30	.111	1.20	8.47
.119	1.14	9.45	.119	1.18	9.16
.104	1.11	8.56	.121	1.22	9.02
.116	1.14	9.23	.109	1.18	8.45
.130	1.20	9.77	.121	1.16	9.44
.099	1.00	9.00	.101	1.02	9.00
.105	.94	10.04	.116	.97	10.68
.128	1.23	9.43	.130	1.28	9.22
.111	1.21	8.40	.116	1.33	8.02
.091	.83	9.88	.090	.86	9.47
.099	1.02	8.85	.095	.92	9.36
.075	.72	9.43	.073	.75	8.87