Inheritance Studies in Kanred X Martin and in G-149 X Ridit

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INHERITANCE STUDIES IN
KANRED \times MARTIN AND IN G-149 \times RIDIT

A

Thesis

Submitted to the Department of Agronomy

Utah State Agricultural College

In
Partial Fulfillment
of the
Requirements for the Degree of
Master of Science

By

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# INHERITANCE STUDIES IN KANRED x MARTIN AND IN G-149 x RIDIT

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INHERITANCE STUDIES IN KANRED × MARTIN AND IN G-149 × RIDIT

INTRODUCTION

The studies here reported involve two crosses, one of which was between a pure line of Kanred and a pure line of Martin from a bunt resistant selection. The other was between a pure line of G-149, a rust-resistant segregate from Sevier x Dicklow, and a pure line of Ridit. These were both economic breeding projects made in an effort to combine the good commercial qualities of Kanred and G-149 with the high bunt resistance of Martin and Ridit, respectively.

These crosses also furnished, as a by-product, some good genetic data, as in each cross one parent was fully awned and the other awnless, one had red grain and the other white grain.

REVIEW OF LITERATURE

AWNS

The awned condition in wheat is regarded by some as being dominant over the awnless condition. Biffen (1) states that "the beardless condition is a dominant, the bearded a recessive". He obtained a monohybrid ratio of 3:1.

Howard and Howard (7) in India crossed a bearded wheat and one described by them as completely awnless, a fact which is emphasized as important as most of the awnless varieties really have short tipawns. They obtained five distinct classes of segregates in the ratio of 15 variously awned types to one awnless. The results were explained on the basis of a two-factor difference.
In a cross between Kota x Hard Federation, Clark (2) found five classes of awn types which he partially explained as due to two factors. He finally concludes that "complete homozygosity for armed or awnless strains apparently is due to multiple factors".

In another paper, Clark et al (3) report a series of three crosses between Bobs, Hard Federation, and Propo. He found that incomplete dominance for awnlessness was shown as the \( \mathbf{F}_1 \) approach nearer the awnless parent. The \( \mathbf{F}_2 \) and \( \mathbf{F}_3 \) plants were separated into five awn classes which he numbered 1 to 5. By combining 1's and 2's and the 3's, 4's, and 5's and correcting \( \mathbf{F}_2 \) by the \( \mathbf{F}_3 \) breeding behavior, results for both crosses were statistically close to a two-factor or 9:7 genetic ratio. The Bobs x Propo cross was less complicated in \( \mathbf{F}_3 \) than was the Hard Federation x Propo, the former segregating into 7 breeding groups and the latter into 11. Bobs class (1) x Hard Federation class (1) gave segregation for awns 1 and 2. The genetic interpretation given is as follows:

\begin{align*}
\text{Bobs x Propo} & : 2 \text{ major-factor} & \text{ ratio } 1:8:4:2:1 \\
\text{Hard Federation x Propo} & : 2 \text{ major-factor} & 1 \text{ minor-factor} \text{ ratio } 1:35:16:2:4 \\
\text{Hard Federation x Bobs} & : 2 \text{ minor-factor} \text{ ratio } 13:3
\end{align*}

The presence of the minor factor in the presence of the major is to reduce uniformly the extent of awnlessness. His conclusions are that there are as many as four genetic factors involved in inheritance of awns in wheat.

Stewart (8), in a cross between Federation x Sevier, obtained four homozygous classes of awns with the two parental classes more numerous than the two intermediate classes. This segregation was explained by the hypothesis that there were two factors for awns located in the same chromosome and that there was a crossing over of about 35 per cent. The ratio obtained was 1:3:1:1:1:8.
In a Turkey x Bluestem cross reported by Gaines (5), the F1 plants were all alike and slightly bearded. In the F2 generation there was segregation into awnless, like the Bluestem parent, awned, like the Turkey parent, and intermediate, like the F1. This segregation was 26.7 per cent awnless, 49.2 per cent like F1, and 24.1 per cent awned. These percentages were very close to a 1:2:1 ratio and indicated a one-factor difference.

Gaines (5) reports another cross where Turkey was the awned parent and Marquis the awnless parent. In this cross the segregation of the F2 progeny, as shown by the performance of the F3, was 35 awnless, 92 heterozygous, 33 (±5) awned. The expected monohybrid ratio of the same population was 41:83:41. "The fact that the awned recessive all breed true makes the unit factor hypothesis the most plausible."

Stewart and Heywood (10), in a study of a cross between Federation and F22, a hybrid of Sevier x Dicklow, which were awnless and awned, respectively, reported four true-breeding classes and five segregating classes in the F3 progenies. A ratio of 1:2:2:4:1:2:1:2:1 was suggested and a rather close fit obtained. In this case the inheritance was explained on a two-factor difference with independent segregation.

When Marquis and Federation wheats were crossed, as reported by Stewart and Tingey (12), the breeding behavior was explained by a one-factor difference. In this case, both parents were almost entirely awnless except for short, apical beaks. The F3 progeny were in one of these groups: (1) like parents, (2) like F1, between awnless and awned varieties, and (3) segregating for groups 1 and 2.

**GRAIN COLOR**

The inheritance of kernel color in various crosses has been explained by differences of one, of two, and of three Mendelian factor pairs.
Biffen (1) found that red was dominant to white in the F1, and segregated in a 3:1 ratio in the F2. A similar ratio was found by Stewart and Price (11) in a cross of Sevier x Odessa. This is the ordinary type of kernel color inheritance which has been found in many crosses.

The 15:1 ratio has been reported by Clark (2) in the F2 of a Kota x Hard Federation cross. In the F3 the white strains bred true and the red strains bred true or segregated in a 3:1 or in a 15:1 ratio.

Stewart and Tingey (12) report a 15:1 ratio when Marquis x Federation are crossed. This gives in the F3 four groups of progenies, i.e., true-breeding for red grain, segregating 15 red grain : 1 white grain, segregating 3 red grain : 1 white grain, and true-breeding for white grain.

A 15:1 ratio was obtained by Gaines in a cross of Turkey x Bluestem. From his data he concludes that "Three identical factor hypothesis seems the most tenable".

In a Kanred x Sevier cross made by Stewart (8), a three-factor difference for grain color was found.

DESCRIPTION OF PARENTS

KANRED

The Kanred variety is a pure-line selection made at the Kansas Station from Crimean wheat. It closely resembles ordinary Turkey but differs from it visibly in having appreciably longer beaks on the glumes. Kanred is very important in the central Great Plains and has increased rapidly in the dry-farming sections of the central Rocky Mountain region. It has had the most rapid increase of any variety in the past few years. In 1918, only about 300 Kansas farmers grew this variety. By 1924 it ranked second only to
Turkey in the hard red winter class and third in total acreage in the United States, there being 4,314,962 acres grown which comprised 8.48 per cent of the total wheat production. Kanred is known to be immune to eleven of the common physiologic races of black-stem rust. It is considered more drought-resistant in the central Great Plains, and is thought to be somewhat more winter-hardy. Kanred is bearded and has glabrous, white glumes. It has a lax to mid-dense fusiform spike, and winter growth habit.

**MARTIN**

The Martin variety originated from a single plant found as a mixture in a field of Clawson in Seneca County, New York about 1875 (4). The parent used in this experiment came from a pure-line selection (C.I. No. 4463) which is highly resistant to many forms of bunt. It has the winter habit and is classed as a tall growing variety. The spike is awless, long, lax, and tapering. The glumes are white and glabrous and the kernel is white, midlong, and soft. Martin is not an important wheat commercially, though it is grown over a wide range in the United States.

**G-149**

G-149, a segregate from the cross Sevier x Dicklow made at the Utah Station, has not as yet been given a varietal name. It has the spring growth habit and moderately long, slender culms which do not stand well. The spikes are fully awned. The glumes are glabrous and white. The kernels are semi-hard, white, and midlong. The spike is lax and held in a partially nodding position. The grain is held rather firmly in the spike. It is known to be highly resistant to all forms of black-stem rust that were available at the Minnesota Station in 1924-25.
RIDIT

Ridit is of hybrid origin, resulting from a cross made at the Washington Station in 1915 between Turkey and Florence. It is a winter variety and has red grain, white glumes, and is beardless. It seems to be thoroughly winter-hardy and has a stiffer straw than Turkey. At Pullman, it compares favorably in yield with the best winter varieties and is immune to stinking smut. At the Utah Station its yield is enough lower that it cannot compete with the best commercial varieties. In milling qualities Ridit is about the same as Turkey.

Awns and grain color are the contrasted characters studied in these two crosses. The parents and these characters are shown in Table 1. The awn length is given in terms of numbered awn classes as discussed later in this paper.

Table 1. -- The parents, the awn length given in awn class numbers, and the grain color of the parents.

<table>
<thead>
<tr>
<th>Parent Variety</th>
<th>Awn Length</th>
<th>Grain Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kanred</td>
<td>Fully awned (awns 4)</td>
<td>Red</td>
</tr>
<tr>
<td>Martin</td>
<td>Short apical (awns 2)</td>
<td>White</td>
</tr>
<tr>
<td>G-149</td>
<td>Fully awned (awns 4)</td>
<td>White</td>
</tr>
<tr>
<td>Ridit</td>
<td>Awnless (awns 1)</td>
<td>Red</td>
</tr>
</tbody>
</table>

EXPERIMENTAL PROCEDURE

The crosses for these studies were made at the Utah Station in 1926. In 1927 the F1 plants were grown. They were spaced one foot apart each way to permit the production of a large number of kernels. The following year the F2 plants were grown in rod-rows one foot apart and with the plants spaced three or four inches in the rows. Kernels of each F2 plant were spaced three or four
inches apart in rows 15 feet long and one foot apart. This gave from 30 to 60 plants per row. It was these rows that furnished the F3 material for these studies.

KANRED X MARTIN

In this cross the kernels of 255 F2 plants were seeded to produce the F3 plants.

AWNS

The F1 awns were of intermediate length, but were considerably less than half the length of the awned parent. The plants of the F2 generation, as determined by the F3 breeding behavior, were classified into three awn groups and designated as true-breeding awns 2, segregating for awns 2, 3, and 4, and true-breeding for awns 4.

Awns 2 consisted of plants with apical awns like the Martin parent. Awns 3 were distinguished from awns 2 in that they extended further down the spike and were coarser and longer, but they were enough shorter than the awned parent to be easily distinguished from them. Awns 4 were fully awned and compared as far as possible with the fully awned parent.

There were 50 F2 plants in the awn 2 class, 141 plants segregating for awns 2, 3, and 4, and 64 plants in the awn 4 class.

The three awn-classes may be designated as follows:

\[
\begin{align*}
\text{Awns 4} & \quad \text{-----} \quad \text{AABB} \\
\text{Awns 3} & \quad \text{-----} \quad \text{AaBB} \\
\text{Awns 2} & \quad \text{-----} \quad \text{aaBB}
\end{align*}
\]

Table 2 shows the awn classes based on their genotypic differences, their expected ratios, and their breeding behavior on the assumption that a one-factor difference is present as this cross seems to indicate.
Table 2. -- Three awn-class genotypes, their expected ratio and breeding behavior based on a one-factor difference.

<table>
<thead>
<tr>
<th>Awn class: Proportions</th>
<th>Genotypes</th>
<th>Expected breeding behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1</td>
<td>AABB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Breeding true for awns 4</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>AaBB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Segregation for awns 2, 3, and 4</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>aaBB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Breeding true for awns 2</td>
</tr>
</tbody>
</table>

In Table 3 is shown the goodness of fit between the observed and the calculated frequencies on the basis of three awn classes. $x^2 = 4.3958$ and $P = .1142$, which is a fair fit when only three classes are concerned. The "goodness of fit" indicates that if the experiment were repeated 100 times, the data and the theory would give a worse fit in 11 cases due to chance alone. The widest divergence was found in the group homozygous for awns 2, as indicated by the size of $\frac{(O - E)^2}{E}$.

Table 3. -- "Goodness of fit" of three awn genotype classes of F3 progenies when compared with a 1:2:1 ratio which would be expected theoretically with a one-factor difference.

<table>
<thead>
<tr>
<th>Progeny Group</th>
<th>Observed Value (O)</th>
<th>Calculated Value (C)</th>
<th>O - C</th>
<th>(O - C)^2</th>
<th>$\frac{(O - C)^2}{C}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homozygous</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awns 2</td>
<td>50</td>
<td>62.75</td>
<td>12.75</td>
<td>157.0625</td>
<td>2.4856</td>
</tr>
<tr>
<td>Heterozygous</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awns 2, 3, 4</td>
<td>141</td>
<td>127.50</td>
<td>13.50</td>
<td>182.25</td>
<td>1.4293</td>
</tr>
<tr>
<td>Homozygous</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awns 4</td>
<td>64</td>
<td>65.75</td>
<td>.25</td>
<td>.0625</td>
<td>.0009</td>
</tr>
</tbody>
</table>

$P = .1142 \quad x^2 = 4.3958$

**GRAIN COLOR**

The F1 plants all produced dark red grain. In the F2 generation, the 255 F2 plants, as determined by their F3 progenies, gave 184 families true-breeding for red grain; 28 segregating 63 red grain to one white grain; 42 segregating 15 red grain : 1 white grain; 20 segregating for 3 red grain : 1
white grain; and 1 true-breeding for white grain. These groups of genotypes and the numbers obtained in each group suggest a three-factor difference for grain color with independent segregation. When the data were analyzed by the $X^2$ method to obtain the "goodness of fit" on this theory, as shown in Table 4, $X^2 = 5.9153$. On the basis of a three-factor difference, this gives a value for $P = .2066$, which means that if the experiment were repeated 100 times a worse fit would be expected 20 times due to chance alone.

Table 4. "Goodness of fit" of the five grain color genotype classes of the $F_3$ progenies when compared with a 27:8:12:6:1 ratio which would be expected theoretically when a three-identical-factor difference.

<table>
<thead>
<tr>
<th>Progeny Group</th>
<th>Observed: Value (O)</th>
<th>Calculated: Value (C)</th>
<th>$(O - C)^2$</th>
<th>$O - C$</th>
<th>$(O - C)^2/ C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>True-breeding red</td>
<td>164</td>
<td>147.4228</td>
<td>16.5772</td>
<td>274.8035</td>
<td>1.8540</td>
</tr>
<tr>
<td>Segregating 63:1</td>
<td>28</td>
<td>31.8752</td>
<td>3.9752</td>
<td>15.0171</td>
<td>.4711</td>
</tr>
<tr>
<td>Segregating 15:1</td>
<td>42</td>
<td>47.6128</td>
<td>5.6128</td>
<td>33.7886</td>
<td>.7066</td>
</tr>
<tr>
<td>Segregating 3:1</td>
<td>20</td>
<td>23.9066</td>
<td>3.0066</td>
<td>15.2599</td>
<td>.6393</td>
</tr>
<tr>
<td>True-breeding white</td>
<td>1</td>
<td>3.9344</td>
<td>2.9844</td>
<td>8.3066</td>
<td>2.2353</td>
</tr>
</tbody>
</table>

$P = .2066 \quad X^2 = 5.9153$

This is a fair fit and suggests that three identical factors for red grain color with independent segregation are probably the right explanation of inheritance of grain color in the cross between Kanred and Martin.

The true-breeding white class with 1 $F_3$ family in it, where 3.9344 is the expected, has the greatest variance from the calculated as indicated by $(O - C)^2/O$. It is probable that a larger population would have brought this nearer the expected ratio.
There were in this cross 126 F₃ progenies, which were studied to determine the genetic behavior of the F₂ plants for awns and grain color.

**AWNS**

The F₁ awns in this cross were intermediate between the two parents. They more nearly approached the awnless parent as in the Kanred x Martin cross.

In the F₂ the segregation for awns was more complex than in the Kanred x Martin cross. They were classified into nine groups. The designation of these groups were awns 4; awns 3, 4; awns 2, 3, 4; awns 1, 2, 3, 4; awns 1; awns 1, 2, 3; awns 2; awns 1, 2; and awns 1.

Awns 2, awns 3, and awns 4 are the same as in the Kanred x Martin cross. Awns 1 were apical beaks of shorter length and a closer restriction to the tip of the spike than awns 2.

There were four true-breeding groups and five groups that were segregating. The four true-breeding awn classes may be designated as follows:

- Awns 4  \( \text{---------------} \) AABB
- Awns 3  \( \text{---------------} \) AAbb
- Awns 2  \( \text{---------------} \) aaBB
- Awns 1  \( \text{---------------} \) aabb

Table 5 shows the awn genotypic groups, the ratio expected in each group, the calculated value for the groups based on 126 population, the observed value for the groups, and the expected breeding behavior based on the hypothesis of a two-factor difference segregating independently.

The numbers obtained in this cross do not correspond to the expected ratio very closely, but they are suggestive that the two-factor difference with independent segregation is probably the right hypothesis. When these
Table 5. — The 9 genotypic groups, the observed value for the group, the ratio expected, the calculated value for the group, and the expected breeding behavior based on a two-factor difference segregating independently.

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Value</th>
<th>Expected Ratios</th>
<th>Calculated Value</th>
<th>Expected Breeding Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>AABB</td>
<td>2</td>
<td>1</td>
<td>7.825</td>
<td>Breed true for awns 4</td>
</tr>
<tr>
<td>AABB</td>
<td>12</td>
<td>2</td>
<td>15.75</td>
<td>Segregate for awns 5, 4</td>
</tr>
<tr>
<td>AaBB</td>
<td>21</td>
<td>3</td>
<td>15.75</td>
<td>Segregate for awns 2, 3, 4</td>
</tr>
<tr>
<td>AaBB</td>
<td>43</td>
<td>4</td>
<td>31.50</td>
<td>Segregate for awns 1, 2, 3, 4</td>
</tr>
<tr>
<td>AAbb</td>
<td>3</td>
<td>1</td>
<td>7.875</td>
<td>Breed true for awns 3</td>
</tr>
<tr>
<td>Aabb</td>
<td>16</td>
<td>2</td>
<td>15.75</td>
<td>Segregate for awns 1, 2, 3</td>
</tr>
<tr>
<td>aABB</td>
<td>5</td>
<td>1</td>
<td>7.875</td>
<td>Breed true for awns 2</td>
</tr>
<tr>
<td>aBBb</td>
<td>12</td>
<td>2</td>
<td>15.75</td>
<td>Segregate for awns 1, 2</td>
</tr>
<tr>
<td>aabb</td>
<td>7</td>
<td>1</td>
<td>7.875</td>
<td>Breed true for awns 1</td>
</tr>
</tbody>
</table>

Data are subjected to the $X^2$ method for "goodness of fit"; the result is not significant, as the $X^2 = 21.0794$ and $P = .00656$, which indicates that if this is the correct interpretation, the experiment would have to be repeated 126 times to get as bad a fit as the one obtained.

There are two possible explanations for this lack of fit: (1) The population is rather small, and (2) wide divergences are to be expected occasionally. There was some error due to moving the plants about, which caused the awns on many of the plants to be injured.

GRAIN COLOR

The inheritance of grain color is apparently the same for the cross between 3-149 and Ridit as it was for that between Kanred and Martin. Of the 126 F3 progenies there were 85 breeding true for red grain; 9 segregating 63 red grain : 1 white grain; 21 segregating 15 red grain : 1 white grain; and 11 segregating 3 red grain : 1 white grain. There were no true-breeding white grain F2 parents. This was probably due to the small population.
The data indicate that the same genetic factors would account for this grain color inheritance as were used to explain the grain color inheritance in the cross between Kanred and Martin. This explanation was that there were three identical factors for grain color and that they segregated independently. When these data for grain color from the cross G-149 x Ridit were subjected to the \( X^2 \) method to determine the "goodness of fit", \( X^2 = 7.844 \) and \( P = .11 \). This indicates that a worse fit would be expected 11 times in 100 if the experiment were repeated. Though this is not a good fit, it indicates that the explanation for the inheritance of grain color as being due to three identical factors which segregate independently is probably the correct explanation.

**SUMMARY**

Two wheat crosses from which these studies were made were both economic wheat-breeding projects for bunt resistance.

The first study was from a cross between Kanred, a high-yielding, hard red, awned wheat, with Martin, a white, beardless, bunt-resistant strain but one having comparatively lower yielding powers for this region.

The other study was from a cross between G-149, a white, high-yielding, bearded wheat, with Ridit, a beardless, red wheat, completely resistant to bunt but not able to compete commercially with the best yielding varieties in Utah.

As a by-product of these two crosses, a genetic study was made in awn and grain color inheritance.

From the Kanred x Martin cross 255 F₂ progenies resulted. The awn inheritance was explained on a single-factor difference. There were 64 fully awned like the Kanred parent, 141 segregating for awns 2, 3, and 4, and 50 homozygous for awns 2 like the Martin parent. This is rather close
to the expected 1:2:1 ratio.

In the F\textsubscript{2} generation of the G-149 x Ridit cross there were 126 families. These were divided into nine awn groups. Four of these groups bred true and five segregated. The nine awn groups, with the number in each group, suggested a two-factor difference with independent segregation. The ratio expected was 1:2:2:4:1:2:1:2:1. The numbers obtained were 2:12:21:49:3:16:5:12:7. Some of these numbers were very close to those expected. In the same 4 group, only one-fourth of the expected number were actually obtained.

The inheritance of grain color was apparently the same in both crosses and was explained by three identical factors for grain color with independent segregation. This calls for a ratio of 37:8:12:6:1. In the Kanred x Martin cross the numbers obtained were 164:28:42:30:1. The numbers obtained in the G-149 x Ridit cross were 35:9:21:11:0.

The "goodness of fit" by the X\textsuperscript{2} method were P = .2066 and P = .1100, respectively, which are only fair fits.
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(6) __________
1925
Genetics of Marquis x Turkey wheat in respect to bunt
resistance, winter habit, and awnlessness.

(7) Howard, A
Howard, G. L. C.
1915
On the inheritance of some characters in wheat.

(8) Stewart, George
1928
Inheritance of awns in crosses involving Sevier and
160-170

(9) __________
1928
Correlated inheritance in Kanred x Sevier varieties

(10) Heywood, D. E.
1929
Correlated inheritance in a wheat cross between Fed-
eration and a hybrid of Sevier x Dicklow.

(11) Harold Price
1929
Inheritance studies in Sevier x Odessa wheat cross.

(12) Tingey, D. C.
1928
Transgressive and normal segregation in a cross of
Marquis x Federation wheats.