THE GENETIC RELATION BETWEEN TRITICUM DICOCCUM DICOCCOIDES AND A SIMILAR MORPHOLOGICAL TYPE PRODUCED SYNTHETICALLY

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The synthetic production of a form similar to the wild emmer (Triticum dicoccum dicoccoides Kcke.) has been reported by the authors of this paper. This synthetic form resulted from a cross between Early Red Chief, a variety of Triticum vulgare Vill., and one the writers received under the name Marouani, a variety of Triticum durum Desf. It is possible that the name Marouani was a misnomer, as Dr. C. R. Ball, on examining the sample, stated that it more nearly resembled the variety Peliss.

In the earlier paper it was noted that the chief difference between the true wild emmer and the synthetic form is the width of spikelets. The kernels of the synthetic type are broader than those of the true wild form as illustrated by the samples on hand. This causes the spikelets to be broader. The true wild emmer, however, is very variable and some forms are found that have very broad spikelets, even resembling the synthetic form.

One of the chief characteristics of the wild emmer is the fragility of the rachis. The articulation is such that at maturity the spikelets separate one from another very readily. The rachis segment which bears a spikelet remains attached to the base of the spikelet when the spike disarticulates, just as in ordinary emmer. Disarticulation occurs so easily that it is very difficult to obtain a head of the wild emmer intact. The synthetic form, Pl. 1, B, is very similar to this wild one, Pl. 1, A.

As the synthetic form, which was produced as a result of the cross, so nearly resembled the true wild emmer in all its visible characters, it seemed worth while to compare the two forms as to their genetic behavior. With this in mind the two have been crossed upon the same variety.

Two different kinds of crosses were made for this study. In one case a durum wheat, the Kubanka, was crossed with the two wild types, and in the other case both of them were crossed with Black Winter emmer. In the discussion of these results the synthetic type will be referred to as synthetic wild and the true wild emmer as true wild or simply as wild.

THE F₁ GENERATION

The F₁ plants resulting from the two crosses, where the true wild and synthetic wild were crossed with Kubanka, prove to be quite similar. The culms are solid or full of pith below the head. The spikes break up readily, indicating the domi-
nance of the fragile rachis. On first examination it seemed that those heads coming from the cross in which the true wild was used were more fragile, but after thorough drying there seemed to be no difference. The F₁ heads in both crosses have a flattened appearance similar to those of the wild type and the rachis is heavily pubescent, as is the case in the wild forms. The awns resemble those of the wild parents and the kernels have the red color of the wild forms. In shape the kernels are longer than those of Kubanka, but are somewhat broader than those of the wild forms.

The F₁ plants which resulted from crossing the two wild types with Black Winter emmer were alike in each case. So far as the characters mentioned above are concerned, these F₁ plants were similar to those from the Kubanka crosses with the exception that the glumes of the hybrids with Black Winter emmer were black or grayish-black. The color is slightly lighter than that of the Black Winter emmer.

THE F₂ GENERATION

When the second generation was grown there was considerable diversity of form and of degree of fragility of the rachis. Some of the characters will be discussed separately.

The first character to be considered is the fragility of the rachis. Owing to the nature of this character, it is very difficult to classify. This is especially true if the material has not dried thoroughly. Some of the rachises are brittle only toward the tip of the head while others may be fragile the entire length of the head, except for a few spikelets at the base. In the wild emmer usually two or three spikelets at the base of the head are held rather firmly.

Various tests were used in order to classify this material, such as natural shattering, readiness of breaking when the spike was shaken, or when the spikes were subjected to some stress, and so on. Finally, the classification was made by means of the above tests plus an examination of the end of the rachis segment under a lens. The rachis of the true wild emmer disarticulates in such a way that the end of the rachis segment is round and perfectly smooth. This test was then applied and all plants that showed disarticulation leaving the rachis segments with smooth round ends were classed as fragile. If the end of the rachis segment was broken or torn the plants were classed as tenacious. The results of segregation for this character in the second generation plants are given in Table I.

<table>
<thead>
<tr>
<th>Cross</th>
<th>Number of plants having—</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fragile rachis</td>
<td>Tenacious rachis</td>
<td>Deviation</td>
<td>Probable error</td>
<td>Deviation divided by probable error</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Observed</td>
<td>Calculated</td>
<td>Observed</td>
<td>Calculated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kubanka X true wild</td>
<td>134</td>
<td>133.5</td>
<td>44</td>
<td>44.5</td>
<td>0.50</td>
<td>3.90</td>
</tr>
<tr>
<td>Kubanka X synthetic wild</td>
<td>147</td>
<td>150.0</td>
<td>53</td>
<td>50.0</td>
<td>3.00</td>
<td>4.13</td>
</tr>
<tr>
<td>Black Winter emmer X true wild</td>
<td>216</td>
<td>219.38</td>
<td>18</td>
<td>14.62</td>
<td>3.98</td>
<td>2.50</td>
</tr>
<tr>
<td>Black Winter emmer X synthetic wild</td>
<td>221</td>
<td>227.8</td>
<td>22</td>
<td>15.20</td>
<td>6.80</td>
<td>2.55</td>
</tr>
</tbody>
</table>

From these results it is very evident that, so far as this character is concerned, the segregation for fragile and for tenacious rachis gives about the same ratio whether the wild or synthetic type is used as the parent. It seems evident that
Comparison of Natural and Synthetic Wild Emmer.

in the crosses with Kubanka, the segregation follows the simple 3 : 1 ratio. The deviation from the expected numbers is very small compared with the probable errors. This ratio was established further by an examination of some F3 material.

In the case of the crosses with Black Winter emmer a different condition exists. Here the segregation suggests a 15 : 1 ratio. The deviation from the expected numbers is within the limit of three times the probable error in each case. Such behavior may be expected from emmer as it has a different method of disarticulation from that of Kubanka. The emmer spike does not break up readily but when the rachis disarticulates the spikelet carries the rachis segment which bore it. This fact would lead one to expect a behavior in inheritance different from that in the case of the Kubanka wheat.

These results show very plainly that, so far as these two crosses are concerned, the true wild and the synthetic wild are very similar in their behavior with respect to the inheritance of the character of the rachis.

The different types of heads obtained from these crosses are shown in Plates 2 to 8, inclusive.

In Plate 2 are shown two heads resembling those of Black Winter emmer. Head A was obtained from crossing Black Winter emmer with the true wild, and head B from crossing it with the synthetic wild.

The heads shown in Plate 3 also are from the crosses with Black Winter emmer. Heads A and C are from the cross with the true wild and heads B and D from that with the synthetic wild. These illustrations show the great similarity between the heads from the two different crosses. Heads A and B have a tenacious rachis and heads C and D a fragile rachis. These heads all have black glumes.

The heads in Plate 4 also are from the crosses between Black Winter emmer and the two wild emmers. These heads have brown glumes and are selected to show the tenacious and the fragile rachis from the two crosses. Heads A and C are from the cross in which the wild was used as a parent and heads B and D are from the cross where the synthetic wild was used.

The heads in Plate 5 also are from the crosses between Black Winter emmer and the two wild forms. Heads A and B are from the cross with the true wild and heads C and D from the other cross. All have white glumes. They again show the close resemblance between the heads from the two crosses.

The heads from the crosses between Kubanka durum and the two types of wild emmer are shown in Plates 6, 7, and 8. Heads A and C of each plate are from the cross with the true wild and heads B and D of each plate are from the cross with the synthetic wild. The heads in Plate 6 resemble those of emmer to some extent. The heads in Plate 7 are more like those of durum, and the heads in Plate 8 are similar to those of spelt except that the articulation is more like that of emmer. In general, it is clear that heads obtained from the two types of crosses are very similar and indicate that the synthetic wild carries the same factors for head type as does the true wild.

These crosses did not show any segregation for color of kernel in the series where Black Winter emmer was used. This indicated that the constitution of the two types of wild was the same as that of Black Winter emmer. In the crosses where Kubanka was used, however, segregation did occur. (See Table II.)
TABLE II.—Segregation in $F_2$ for color of kernel in crosses between Kubanka durum and the two wild emmers

<table>
<thead>
<tr>
<th>Cross</th>
<th>Observed</th>
<th>Expected</th>
<th>Deviation</th>
<th>Probable error</th>
<th>Deviation divided by probable error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red</td>
<td>White</td>
<td>Red</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td>Kubanka X true wild</td>
<td>164</td>
<td>14</td>
<td>166.9</td>
<td>11.1</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
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<td>2.18</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.33</td>
</tr>
<tr>
<td>Kubanka X synthetic wild</td>
<td>185</td>
<td>15</td>
<td>187.5</td>
<td>12.5</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.08</td>
</tr>
</tbody>
</table>

TABLE III.—Segregation in $F_2$ for color of glumes in crosses between Black Winter emmer and the two wild emmers

<table>
<thead>
<tr>
<th>Cross</th>
<th>Observed</th>
<th>Expected</th>
<th>Black</th>
<th>Brown</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Winter emmer X true wild</td>
<td>181</td>
<td>43</td>
<td>10</td>
<td>14.6</td>
<td>16.6</td>
</tr>
<tr>
<td>Black Winter emmer X synthetic wild</td>
<td>175.2</td>
<td>45.8</td>
<td>17</td>
<td>14.6</td>
<td>16.6</td>
</tr>
</tbody>
</table>

These results indicate a 15:1 ratio and the deviations are not very large. In fact, when they are compared with their probable errors they are not significantly different from what one would expect. The red color of the true wild and the synthetic wild must, therefore, depend upon two factors.

From another cross where the true wild was used a segregation of 15 red:1 white was obtained. It is rather interesting that this synthetic wild emmer should have the same genetic constitution for color of kernel as the true wild.

The crosses between Kubanka and the wild emmers did not show any segregation for color of glumes, as both parental forms had white or yellowish-white glumes. In the case of the Black Winter emmer crosses, however, there was segregation, as would be expected, with contrasted glume colors. (See Table III.)

The results show that the segregation follows a 12:3:1 ratio. That is, the Black Winter emmer carries both the factor for black or purple glume color and the one for brown color. While the observed and expected numbers show some deviation, they are in fair agreement, considering the numbers of plants. For the cross where the true wild emmer was used $P$ equals 0.450, and for the one where the synthetic wild was used $P$ equals 0.392.

The distribution and closeness of fit show very clearly that the two types of wild emmer react in a very similar way when crossed upon the Black Winter emmer. This fact is further emphasized when the pubescence of the glume is considered. The pubescence of the glume of the Black Winter emmer is linked with the black or purple color of the glume. The cross with the true wild gives 181 black pubescent and 53 nonblack glabrous, while the cross with the synthetic wild gives 173 black pubescent and 70 nonblack glabrous. These numbers deviate somewhat from the expected 3:1 ratio, yet if the numbers of plants were larger no doubt the agreement would be closer. Regarding other characters, such as the number of spelt or emmer types occurring in the different crosses, the data show that the results are about the same no matter whether the true wild or synthetic wild was used as a parent.
So far as these studies have been conducted it is evident that the synthetic wild emmer, which occurred as a result of crossing a variety of *Triticum vulgare* and a variety of *Triticum durum*, is the same as, or certainly genetically very similar to, the true wild emmer found in Palestine. The earlier paper mentioned above shows that, so far as the visible characters are concerned, the two forms are alike, and it is a very interesting fact that genetically the same is true. These two forms are now being compared in other ways. The evidence seems to indicate that the synthetic form will repeat in every way the behavior of the true wild form.

Such evidence, however, does not yet answer the question as to whether this wild emmer, *Triticum dicoccum dicoccoides*, is the progenitor of all other types. Argument may be presented that it is the progenitor or that it is only a contemporary form. One fact has been established, namely, that through hybridization a form similar morphologically and genetically to the true wild type has been found. That this is no mere accident is supported by the fact that from still other crosses other synthetic forms of wild emmer have been obtained.

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PLATE 1

Basal portion of spike and individual spikelets of the true wild (A) and synthetic wild (B) emmers.

(520)
Comparison of Natura and Synthetic Wild Emmers
PLATE 2

Spikes of the F₁ generation, resembling those of Black Winter emmer, resulting from crossing Black Winter emmer with the true wild and synthetic wild emmers.
PLATE 3

Black-glummed spikes of the F$_2$ of the crosses between Black Winter emmer and the two wild emmers. Heads A and C from the cross between the true wild and heads B and D from the cross with the synthetic wild.
PLATE 4

Brown-glummed spikes of the $F_2$ of the crosses between Black Winter emmer and the two wild emmers. Heads A and C from the cross between the true wild and heads B and D from the cross with the synthetic wild.
PLATE 5

White-glumed spikes of the $F_2$ of the crosses between Black Winter emmer and the two wild emmers. Heads A and C from the cross between the true wild and heads B and D from the cross with the synthetic wild.
Comparison of Natural and Synthetic Wild Emmers
PLATE 6

Spikes, somewhat resembling those of emmer, from the F₂ generation of the cross between Kubanka durum and the two kinds of wild emmer. Heads A and C from the cross between the true wild and heads B and D from the cross with the synthetic wild.
PLATE 7

White-glumed spikes, resembling those of durum wheat, from the cross between Kubanka durum and the two kinds of wild emmer. Heads A and C from the cross between the true wild and heads B and D from the cross with the synthetic wild.
Comparison of Natural and Synthetic Wild Emmers
Comparison of Natural and Synthetic Wild Emmer
PLATE 8

Spelt-like spikes of the $F_2$ from the cross between Kubanka durum and the two kinds of wild emmer. Heads A and C from the cross between the true wild and heads B and D from the cross with the synthetic wild.