Hybridization of Wheat

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HYBRIDIZATION of WHEAT.

INTRODUCTION.

The purpose of this paper is to set forth the purpose of wheat hybridization. To do this properly it is necessary to know the history of hybridization of plants. Also to know some of the workers in this field and the hybrids produced by them. In the work at the Experiment Stations the various experimenters have discovered many interesting facts which it is necessary to know and understand. To thoroughly comprehend the work it is also necessary to do the actual processes of the work and to carry the hybrid through several generations and eventually to the goal for which purpose the cross was made to attain.

This paper is divided into three major parts and a bibliography. Part or section number one comprises from page 1 to 13 inclusive.

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HYBRIDIZATION.

(a) Brief history of the art and discovery of sexuality in plants. (Hays & Garber) (15b).

There is a close relation in plants between the mode of reproduction and the methods of breeding. A knowledge of sexuality was therefore, almost a necessity before it was possible to develop the art of breeding. The sex process was observed by the Egyptians and Assyrians three or four centuries, B.C., but it was not thoroughly understood. They did however know of fruit-bearing and sterile trees of the date palm.

The first records of artificial pollination was as early as 700 years B.C. The Assyrians referred to the date palm as the male and female trees. The early Greeks passed this up without interpretation and Theophrastus advanced the idea that this phenomenon did not exist with other plants.

The first to suggest the possibility of sexuality, which ultimately led to its discovery, was Sir Thomas Millington. He suggested the possibility of the stamens serving as the male organ of the plant. Grew (1676), accepted this postulate and added to it his own supposition, that when the anther opened the "globules in the thecae act as vegetable sperm which fall upon the seed-case or womb and touches it with prolific virtue." This was merely a supposition but a good guess at that. Grew however failed to test its validity.

Camerarius (1694) tested out the possibility of sexuality in plants by using isolated plants of the mulberry and emasculating the flowers of the castor-bean and also by removing the stigma from Indian corn. In the Ostawald's Klassiker page 25 is found the following statement attributed to him. "In the vegetable kingdom there is accomplished no reproduction by seeds, that most perfect gift of nature, and the usual means of perpetuating the species, unless
the previously appearing apices of the flower have already prepared the plant therefore. It appears reasonable to attribute to these anthers a noble name and the office of male sexual organs."

Thomas Fairchild 1719, Bradley 1717, Miller 1731, Logan 1739, and Gleditsch 1750, all followed up the work of Camerarius but it was not till Koeler's of Carlsruhe 1761, saw the actual union of the male and female substance, that the work was carried on to further investigation. Koeler in his crosses saw what he believed the "oil" of the pollen grain to mix with the stigmatic fluid of the female; these then to penetrate the ovule.

With the advancement of science and the microscope which aided further in the efforts of the workers, Amici, 1823, first observed the pollen tubes and followed them to the micropyle of the ovule by 1830. Schleiden soon afterwards made several studies of the pollen tubes and since his observations showed that the pollen tube entered the embryo sac he concluded that the embryo developed from this tube and that the embryo sac was the hatching place. This theory was corrected by Amici, 1846, by his proving that the embryo of the orchid arises from an egg which develops in the embryo sac before the pollen tube reaches it.

Koeler's proof of the sexuality of plants was not generally accepted and not until early in the nineteenth century when in answer to the question of the Physical Section of the Royal Prussian Academy, "Does hybrid fertilization occur in the plant kingdom?", Weigmann practiced crossing on several garden plants. His results was that he got several crosses showing variations in families of similar type. He advocated that this was due to too close planting of like kind and insect crossing. Sprengel, 1793, in his study of insect pollination concluded that nature intended flowers should not be pollinated by their own pollen.
In 1835 The Dutch Academy of Science at Haarlem offered a prize for a paper on the place of hybridization in producing new varieties of economic and ornamental plants. Gartner's paper in 1849, won this prize. His paper was on his own work of crossing which from nearly 700 species resulted in about 250 hybrids. This work was so carefully done and checked that it proved the fact of plant sex beyond further doubt.

The fact of sex in plants was now established but the first to see and describe fertilization was Schmitz in 1879. Later in 1884 Strasburger in his research observed the male nuclei to exit bodily from the end of the pollen tube in the plant on which he was working but found only one of these nuclei fused with that of the egg. This led to further research to determine the reason or use of multiple nuclei.

Gartner explained the appearance of the first hybrid generation as due to an inner force operating according to law. This with other forms of research as to color changes, led to a greater desire for explanation of these phenomenon.

(b) Investigations into the physical basis of Heredity. (14b).

Hybridization cannot take place without the manifestation of the parent characters, but how? This question brought out two different classes of workers with directly opposite postulates.

Charles Darwin's "Gemmule Hypothesis" was advanced to explain heredity. Also his work on evolution which he backed up with many examples, seemed plausible. This theory was founded on the following facts:

1. Variability - no two things are exactly alike.

2. A Struggle for Existence - if all the progeny of some of the lower forms grew to maturity and each in turn produced as many progeny, the world would soon be overrun with a single form. There is competition also between different species and genera.
3. Natural Selection - the forms survive which possess characters better adapted to a given environment and therefore gave those particular forms advantage in the struggle for existence.

4. Heredity - variation produces the material for natural selection to work upon and heredity tends to perpetuate the variations.

Darwin's "Gemmule" theory was, that each cell secretes into the blood or cell sap certain gemmules which tend to reproduce the part as perfected by the condition. This allowed the transmission of acquired characters.

Weissman (1834-1914) advanced the theory opposing the 'gemmule' hypothesis, namely the "Germ Plasm" theory, which was outlined to show that the inheritance of acquired characters was an impossibility.

Gregor Mendel by his observations and work on peas, discovered a fundamental law on which plant breeding is founded for definite success. This law was published 1866 but was unnoticed until 1900 when its being reaffirmed brought it to notice.

A summary of Mendel's law from a plant breeders standpoint would be:

1. Plants breed true for certain characters when all factors necessary for the development of the characters are in a homozygous condition. There are relative conditions of stability of factors. Changes in factors of "mutations" are far too infrequent to furnish a basis for a system of breeding.

2. There is independent segregation of certain factors.

3. Partial coupling of certain determiners sometimes is found. The degree of linkage in transmission is quite constant.

4. Perfect coupling of certain factors occurs, i.e., constant association of characters in inheritance.

Mendel's work was reaffirmed separately and independently (1900) by DeVries, Correns and Tschermak. This brought the original law to light and opened the gateway to advancement and to modern plant breeding.
WHEAT HYBRIDIZATION.

A Survey of the Work by Investigators at other Stations.

Much of the early work was done by the "selection" method. This method is practiced at the present time and is a great aid in establishing a type or strain after hybridization creates a new form.

(a). Early Workers and Hybrids Produced. (Carleton) (6)

C.G. Pringle of Charlotte, Vermont, was the pioneer in the production of wheat hybrids of commercial value in this country. Among his best hybrids of commercial value in this country are Defiance, from Club x Pacific Coast, distributed in 1878; Champlain a cross of Black Sea x Golden Drop, distributed in 1878; Other good varieties were his No. 4, No. 5, No. 6 and Pringle Best.

A.E. Blount while at the Colorado Agriculture Experiment Station produced several valuable hybrids. While these are not well known in this country they are very valuable in Australia. In New Mexico where field tests of all his hybrids were made, Ruby and Feldspar have mostly been grown. Those extensively grown in Australia are, Improved Fife, Blount No.16, Gypsum, Hornblend, Quartz and Amethyst.

S.M. Schindel of Hagerstown, Md. 1886 produced one of the most popular hybrids of the eastern U.S., namely Fulcaster from a cross of Fultz x Lancaster.

A.N. Jones of LeRoy, New York has attempted several breeding problems and produced numerous varieties which are widely used. Jones, like Farrer and Garton, often resorted to the use of composite crossing to reach his aim in producing a suitable character in a hybrid. Among his hybrids are Early Red Clawson from Clawson X Golden Cross the last being a hybrid of Mediterranean x Clawson. Winter Fife from Fultz x Mediterranean x Russian Velvet. Diamond Grit from Jones Winter Fife x Early Genesee Giant.
Canada.

William Saunders of Ottawa produced some valuable hybrids for Canada and northern United States. Some of these hybrids are, Early Riga, Percy, Progress, Stanley and Preston. Stanley and Preston are from crosses of Fife x Lagoda.

A.P. Saunders at Agassiz (British Columbia) Experiment Farm in 1892 is credited with making the cross of Calcutta Hard Red x Fife which produced the hybrid from which C.E. Saunders in 1904, selected what is now known as Marquis wheat. Marquis is a high yielding, early maturing variety with stiff straw, rust avoiding, and of high gluten content. "If the spring wheat known as Marquis (Saunders) was the only one of economic importance which had been produced by artificial crossing, the practice would be justified." (14b).

Sweden.

Svalof Station, Sweden has contributed a popular wheat hybrid in Extra Squarehead II, a high-yielding winter hybrid from a cross of Old Extra Squarehead x Grenadier II. It combines Winter hardiness and rust resistance with stiff straw and high yield of the Grenadier II. A selection from Extra Squarehead II named Extra Squarehead III has outyielded the original hybrid.

Australia.

William Farrer (9a) of Lambrigg, Queanbeyan, New South Wales, "the Burbank of Australia", the most noted in the Australian field, like Jones resorts to composite crossing to gain variations from which to select and cross to gain his aim. He used Blount's hybrids frequently for his crosses. Federation, the results of his efforts to reproduce a wheat ideal for the Australian method of harvesting with the 'stripper', is from a composite cross. Federation from Yandilla x Purple Straw, Yandilla is a hybrid of a Fife-Indian cross. Federation is a high yielder, grows erect, medium height, good quality, does not shatter when harvested by stripper and is of good quality. Other hybrids are Bunyip, Firbank, Florence, Cedar, et al.
(b) Research Workers and Results Secured.

Hays (17a), gives the following as his method of artificial crossing: "All the upper part of the spike is cut away; also a few of the spiklets at the base of the spike. The middle smaller flower of each spiklet is pulled out, thus leaving the strongest pair of flowers on each of six or more spiklets, or in all 12 to 20 flowers on each spike or head. The anthers are then removed from these flowers and transferred inside the glumes of the other plant from which the stamens have been removed. All flowers which are so ripe that the anthers have opened are discarded and removed. The spike or head of wheat which has been treated or 'handled' is then wrapped with a piece of paper about the size of toilet paper, this is tied with a piece of string above and below the head. As a rule, only 6% to 10% of the flowers thus pollenized produce kernels."

While the above method dates back to 1894 the percent of flowers that produce kernels is so small as to be discouraging when compared with present results. Stewart at the Utah Station gets a set from 40% to 80% from artificial crossing, depending on the time of day the work is done. The highest percentage comes from work done before 11:00 A.M., and the lowest from that done from noon till sunset. Stewart's methods are similar except instead of using paper for protection he uses a leaf of the plant. He wraps the leaf about the head much after the fashion of a spiral bandage. He reports that it is ample protection and that it dries and falls off after the head begins to fill, and is not affected by wind or rain.

Carruthers (7) 1893, found, "in wheat the stamens ripen their pollen and the stigmas become receptive at nearly the same time and both being in the same flower the tendency is to close fertilization." In the field when different varieties were grown in rows with close proximity and no natural crosses were noticed. In order to secure a cross that will propagate itself it must be made within
the same species, as hybrids resulting from crosses of species or genera are seldom fertile the second year. The nearer the affinities of the two parents the more certain will be the successful fertilization.

Hays (17d) 1893, gives, in order to cross valuable grains artificially several varieties were planted with only one plant in a hill. One half of each kind planted 12 days later than the other half to insure abundant supply of pollen. This was found unnecessary as spikes of wheat plants given plenty of room do not ripen simultaneously but at intervals.

Buffum (5) 1910, reports his work on the possible origin in which he crossed a mutation winter wheat and a mutation winter emmer and from the combination in the second generation obtained well defined specimens of a number of species, including Triticum monococcum, T. dicoccum, T. spelta, and T. polonicum, as well as various forms of wheat that would be classed as T. sativum.

Buffum believes that his experiments along this line shows that all the wheats have developed from not more than two forms and possibly from a single form of Triticum.

Love and Craig (24) 1919, crossed T. vulgare (Early Red Chief) on T. durum (Marouani) secured from 113 individuals in the F2 generation two plants similar in all respects to the typical wild wheat of Palestine. "While this occurrence of a wild segregate in the cross does not prove that the wild wheat is the prototype of wheat, it rather raises the question whether it really is a prototype or a contemporary form."

Saunders (33a) 1894, from experiments started in 1888 with the idea of combining good qualities and early ripening with vigorous growth and productiveness gives a cross of Red Fife and Lagoda that produced a hybrid having an average gain in earliness of 5 to 6 days also the hybrid was more vigorous and productive. In 1888 crossing.
Lagoda and White Fife, a beardless sport was secured. This after selection of only beardless types for six years, shows a fixed type, the Stanley.

Spillman (35) 1919, after long and wide experiments has discovered what he terms the law of recombination of hybrids. "In the second generation of a hybrid there tends to occur every possible combination of the original parent characters and every possible hybrid between these combinations." He states that reports from growers of hybrids put out by the Washington Station are to the effect that the hybrids produce considerably in excess of those of standard varieties.

Garton (13) 1900, claims to have crossed Triticum spelta with an easy shelling variety of wheat and to have secured a variety with tough heads and tenacious chaff which retained the grain under all atmospheric conditions, even when dead ripe. It is of desirable quality and the ripe grain was easily secured by threshing or usual mechanical means.

Saunders (33d) 1902, reports that in his crosses of Hard Red Calcutta, Ghun and Lagoda against Red Fife and White Fife to combine the earliness of the Indian varieties with the vigor and productiveness as well as high quality of the Fife wheats. He got varieties that ripen three or four days earlier than the Fife varieties, and have the full vigor and productiveness. The hybrid Preston from Red Fife and Lagoda, for over six years has led in productiveness, yielding an increase of 1 bushel and 28 pounds over the parent Red Fife.

Saunders (33e) 1903 states that crosses of Red Fife with early-ripening sorts from Russia and India, have given hybrids that were from 4 to 10 days earlier and satisfactory in other respects.

Pitsch (30) 1903, crossed Essex and Rouge Invertable, a Bordeaulx wheat, and produced a hybrid known as Bordeaux Bastard, which
outyielded the parent and other standard sorts. It was also reported that he noticed the Bordeaux Bastard strain that showed the Squarehead type ear, was more winter resistant than the parent and other common types.

Nilsson-Ehle (28a) 1909, in breeding wheat having brown heads against white heads, found that in the monohybrid segregations transmissible gradations of the brown color. In crosses between deep brown and white heads the color of heterozygotes was always plainly brown even if reduced, and the monohybrid segregation was in the proportion of 3 brown headed individuals to 1 of the white headed.

Withycombe (40) 1911-12, reports cross between Little Club and Fortyfold varieties produced a selection which gave a gluten test of 53% as against the general average of 30%. Another desirable type was secured by crossing the Durum and Club Varieties.

Rimpau (31) 1912, found in studying field crosses and artificial crosses for over thirty five years, that in close planted breeding plats in a possible 1,000 cases only 12 natural crosses were found. He also concludes that "out of a heterogeneous cross one can with difficulty produce offspring with constant characters; that parents whose origin is not known to be of pure line breeding should never be used; that all crosses with individual breeding under the Mendelian law should be followed up; and that intermediate forms should not be bred as they contain the variations the longest."

Kezer and Boyack (22) 1918, show that for practical purposes the Mendelian law of inheritance is an exceedingly useful tool in practical plant breeding. They state that if pure chance controls the recombination of factors in the combining gametes, then, in a large number of cases, the difference between observed and theoretical results should be divided about equally between values less than and greater than, the probable error of the binomial frequency
distribution of those differences."

Boss (3) 1919, in his selections from crosses of Turkey on Odessa, produced two hybrids, Minturki and Minhardi, which have the high yield and quality of Turkey and the winter resistance to the Odessa. Minhardi is even more winter resistant than the parent stock.

Hayes and Garber (15a) 1919 gives his methods of selection of a hybrid and reasons for crossing as follows. "Cross because of some particular characters." Selection: "F1 no selection if all are of same genotype, but discard all noncrosses. F2 are grown in large plats. Selections from these plats are made and each plant is sown in a separate plat for the F3. This routine is continued until many homozygous forms are obtained. These homozygous forms are planted rod in/rows and handled thereafter the same as regular selections."

Snyder (34) 1917, gives the following advice which sounds good. "A wheat that has high bread-making quality is the main object. Get all the protein or gluten you can in the wheat providing the gluten is of such character as to impart the maximum bread-making quality. Too many breeders work for a high gluten content but do not consider the desirability of the gluten so obtained. A high gluten content with rather poor bread-making value is a poor combination. Use of a test mill is good but the results are very misleading and the advice of a good miller should always be sought."

Biffin (2c) 1907, crossed immune and susceptible varieties for rust and found that the hybrids were susceptible. Selfing the hybrids brought a ratio of 1 immune: 3 susceptible. Where susceptibility varied in the parents the hybrid resembled the more susceptible. The relative immune bred true in this respect. (Page 4 of Sect. #2).
Evans (10) 1911 gives the findings from his work in South Africa. "Rust (P. graminis) from hybrids attack immune as well as the susceptible parent, and was more virulent than rust from the parent itself. Pathogenic properties of the rust was distinctly increased by a sojourn on the hybrid plant and produced more severe infection than rust from the susceptible parent." (Page 4 of Section #2)

Stalman, Parker and Piemeisel (36) 1918, shows work that is contrary to the results of Evans although of earlier date. They claim that rust characters do not change with biological changes but are considered rather heredity characters which cannot be changed by fluctuation of variable characters or changes in the host. (Page 4 of Section #2)

Biffen (2b) 1905, from his fields of work and observation of the segregations of plant crosses in accordance with Mendel's law gives the following characters classed according to their pure dominance and recessiveness.

Dominant.  
Beardless heads. 
Velvety glumes 
Keeled glumes. 
Loose heads. 
Red Chaff. 
Red grain. 
Thick and hollow stem. 
Rough leaf surface. 
Bristle stem. 
Large sclerenchyma girders and angular stem outline. 
Hard, translucent endosperm. 
Susceptibility to yellow rust.

Recessive.  
Bearded heads. 
Smooth glumes. 
Round glumes. 
Compact heads. 
White chaff. 
White grain. 
Thin and solid stem. 
Smooth leaf surface. 
Smooth stem. 
Small sclerenchyma girders and almost circular stem outline. 
Soft, opaque endosperm. 
Immunity to yellow rust.

Irregular dominance was observed in the crosses in velvety and glabrous glumes and gray and red or white glumes.

In other cases the pairs of characters showing no dominance and in which the cross was intermediate between the parents were, loose and compact heads; large and small glumes; long and short grain; and early and late maturing. (Pages 1-2 & 3 of Section #2)
Backhouse (1) 1918, crossed T. polonicum (average glume length, 29 mm, faintly pubescent) on T. durum -Kubanka (average length of glume, 12 mm, glabrous). Results, in the F1 generation the glumes were intermediate in length being 18-19 mm long and distinctly pubescent. The F2 generation showed some glumes to be glabrous and some intermediate or slightly pubescent. The ratio of pubescence in this case against glabrousness was 3:1, the shorter glumes being glabrous or smooth. The conclusions drawn were, "there is no relation between length of glume and degree of felting. Long glumes inhibit the dominant character (pubescence). Color in glumes is independent of pubescence. The short glumes carries the factor for color." (Pages 3 & 5 of Section #2).

Kajanus (21) 1918, reports results from crosses between two types of spring wheat, showing, 1. awnless dominant over awned heads, 2. Red colored leaf auricles dominant over white leaf auricles. (pages 1 & 3 of Section #2)
Mendelian Characteristics of Dominance over Recessiveness

Reported by Investigators working by Hybridization.

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<th>Bibliography No.</th>
<th>Characters Reported</th>
<th>Determinations</th>
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<tbody>
<tr>
<td>(24) Love and Craig, 1919</td>
<td>Wild Form</td>
<td>1. Crossed T. vulgare on T. durum and secured 2 individuals similar to the wild wheat of Palestine.</td>
</tr>
<tr>
<td>(5) Buffum, 1910</td>
<td>Possible Origin</td>
<td>1. Cross of Mutant winter wheat on mutant winter emmer, gave F2, T. monococcum, T. dicoccum, T. spelta, T. polonicum, and varieties of T. sativum. 2. That above cross shows possibility of origin of wheat from not more than two forms and possibly from a single form of Triticum.</td>
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<tr>
<td>(20b) Howards, 1915</td>
<td>Awn</td>
<td>1. There is a short factor and a long factor for beards in some crosses so that beardless and bearded ratios are not all regular.</td>
</tr>
<tr>
<td>(22) Keyser, 1906</td>
<td>Awn</td>
<td>1. Obtained ratios, 1 bearded : 2 intermediate: to 1 beardless, showing the Mendelian characters.</td>
</tr>
<tr>
<td>(23) Kezer and Boyack, 1918</td>
<td>Awn</td>
<td>1. Awnless heads dominant over awned heads.</td>
</tr>
<tr>
<td>(29) Olson, Schaefer, Mccall and Hill, 1920</td>
<td>Awn</td>
<td>1. Awns recessive except when Turkey or Red Russian is used as one parent, then there are ( \frac{1}{2} ) the number of awned segregates.</td>
</tr>
<tr>
<td>(21) Kajanus, 1912</td>
<td>Awn &amp; Head</td>
<td>1. Awnless dominant over awned heads. 2. Loose heads dominant over square heads. 3. True compact heads dominant over loose.</td>
</tr>
<tr>
<td>(12) Gains, 1917</td>
<td>Awn &amp; head</td>
<td>1. Beardless head dominant over bearded. 2. Club head dominant over long head.</td>
</tr>
<tr>
<td>(2b) Biffen, 1905</td>
<td>Awn &amp; Head</td>
<td>1. Beardless head dominant over bearded. 2. Loose heads dominant over compact.</td>
</tr>
</tbody>
</table>
Awn & Color. 1. There are two factors for beards which separate in crossing.
2. Color of an awn is inheritable.

Awn, Head & Flowers. 1. Awnless heads dominant over awned.
2. Irregular dominance in long and short heads, and in open and compact heads and in few and many flowers.

Chaff. 1. Brown chaff dominant over white chaff.
2. Velvety chaff dominant over smooth.
4. Red glumes dominant over white, 3:1.
5. Irregular dominance in velvety and glabrous chaff, gray, red and white glumes; large and small glumes.

2. Brown chaff dominant over whiteish-yellow chaff, in F1, but not in a clean separation in F2.
5. 39 hairy brown; 18 hairy white; 13 smooth brown; 5 smooth white.

Glumes. 1. Polish wheat F2, 1 long; 2 intermediate; 1 short.

Glume & Pubescence. 1. Felt on glumes made up of two different lengths which are inheritable independently.
(1) Backhouse. 1918. Glume & Pubescence. 1. No correlation between length of glume and degree of felting.
2. Glume color is independent of pubescence.
3. Short glumes carry color factor.


2. Hard translucent endosperm dominant over soft opaque endosperm.
3. Irregular dominance in long and short kernels.


(20a) Howards. 1912. Kernel. 1. Consistent of grain is inheritable.


2. Bristled stem over smooth stem.
3. Large sclerenchyma girders and irregular stem outline dominant over small sclerenchyma girders and almost circular outline.

(4) Bryan. Maturity. 1. Late maturity dominant over early maturity.

(33e) Saunders. 1903. Earliness. 1. Secured additional earliness from cross of early Russian & Indian with Red Fife. An increase of from 4 to 10 days.

(33d) Saunders. 1902. Earliness, Vigor, Productiveness, Quality. 1. Combined earliness of Indian with vigor and productiveness of Fife with also high qualities of Fife present.
<table>
<thead>
<tr>
<th>Variety</th>
<th>Year</th>
<th>Trait(s)</th>
<th>Result(s)</th>
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<tr>
<td>Vigor added</td>
<td></td>
<td></td>
<td>1. More vigor and productiveness was secured by a cross of Red Fife and</td>
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<tr>
<td>Saunders, 1894</td>
<td></td>
<td></td>
<td>Lagoda.</td>
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<tr>
<td>Yield</td>
<td></td>
<td></td>
<td>1. Increased yield by hybridization.</td>
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<tr>
<td>Spillman</td>
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<tr>
<td>Yield</td>
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<tr>
<td>Nilsson-Ehle,</td>
<td>1917</td>
<td></td>
<td>1. 9 tests showed hybrid No. 0880 to out-yield one parent 6% and the</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>other 9%.</td>
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<tr>
<td>Yield, Earliness</td>
<td></td>
<td></td>
<td>1. Combined earliness with productiveness.</td>
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<tr>
<td>Saunders, 1902</td>
<td></td>
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<tr>
<td>Yield, Quality</td>
<td>Freeman, Bryan &amp; Pressley, 1919</td>
<td></td>
<td>1. Combined earliness of Sonora with hard grain of Turkey.</td>
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<td>Winter Hardy</td>
<td></td>
<td></td>
<td>2. Increased yield.</td>
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<td>(3) Boss, 1918.</td>
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<td>1. Combined winter hardiness of Odessa with high yield and quality of</td>
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<td></td>
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<td></td>
<td>Turkey.</td>
</tr>
<tr>
<td>Yield &amp; Winter</td>
<td>Pitsch, 1903</td>
<td></td>
<td>1. Secured hybrid with high yield with a strain that was winter hardy,</td>
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<tr>
<td>Winter resistance.</td>
<td></td>
<td></td>
<td>more so than parent.</td>
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<td>Disease</td>
<td>Evans, 1911</td>
<td></td>
<td>1. Hybrid tends to vitalize pathogenic properties of rust.</td>
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<td></td>
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<td>2. Immune parent was susceptible to rust grown one season on hybrid.</td>
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<td>3. Rust from hybrid produced more severe infection than rust from</td>
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<td></td>
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<td></td>
<td>susceptible parent.</td>
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<tr>
<td>Disease</td>
<td>Stakman, Parker &amp; Piemeisel, 1918</td>
<td></td>
<td>1. Rust characters do not change with biological change of the host.</td>
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<td></td>
<td></td>
<td></td>
<td>2. Rust characters are hereditable only.</td>
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<tr>
<td>Disease</td>
<td>Biffen, 1903</td>
<td></td>
<td>1. Combined rust resistance and earliness increased yield but decreased</td>
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<td></td>
<td></td>
<td></td>
<td>gluten content.</td>
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<tr>
<td>Disease</td>
<td>Biffen, 1905</td>
<td></td>
<td>1. Susceptibility to yellow rust dominant over immunity.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2. Irregular dominance in early and late maturity.</td>
</tr>
<tr>
<td>Disease</td>
<td>Biffen, 1912</td>
<td></td>
<td>1. Immunity to rust in F2 persisted through F8.</td>
</tr>
</tbody>
</table>

2. No correlation between head type and rust resistance.

Biffen. 1907. Disease. 1. F1 hybrid susceptible showing susceptibility dominant over immunity.
2. F2 hybrid ratio, 3 susceptible: 1 immune.

Farrer. 1898. Disease & 1. Improved the quality and secured rust resistance by hybridization.

Hays, Parker, & Kurtzweil. 1920. Disease. 1. F1 of different crosses varied in susceptibility to rust. F2 and F3 individuals included susceptibility on some of all types; and immunity on some of all types.


Howards. 1912. Shattering. 1. Shattering characters are heritable.
Standing. 2. Standing ability is inheritable.

Withycombe. 1911-12. Added Gluten. 1. Hybridization gave added gluten of 53% against average of 30%.

Engledow. 1920. Inhibition. 1. Degree of red coloring in kernel directly inhibits or retards quick germination.

Nilsson-Ehle. 1909. Inhibition. 1. Degree of red coloring in kernel directly inhibits or retards quick germination.

Engledow. 1920. Inhibition. 1. Some short glumated plants develop long hairs; while long glumes inhibit them.

Backhouse. 1918. Inhibition. 1. Long glumes inhibit dominant character pubescence.
2. Long glumes inhibit color in glumes.
Dicklow wheat, a high yielding variety grown under irrigation, while a very popular variety in the Great Basin has but fair to poor milling quality. Professor George Stewart, of the Utah Agricultural Experiment Station decided to try to combine the high-yielding character of the Dicklow with another wheat of the same species that had good milling qualities.

After careful consideration a decision was reached to cross the Dicklow onto the Australian variety of wheat, the Federation. Federation like Dicklow is a soft wheat; a good yielder but shorter straw and more slender heads. It also differs in that it has bronze colored chaff and does not shatter when ripe. Shattering is one of the disadvantages of Dicklow. Federation embodies the one character most sought after in Dicklow, that is, good milling quality.

Stewart using pure lines of Dicklow as the male parent and a pure line of Federation as the female parent, crossed the two in the spring of 1920. This cross was made on the hybridization plats East of the Windbreak on the College Hill Farm. The soil on these plats is very heterogeneous being laid down by the Logan River in a delta formation in the bed of the prehistoric Lake Bonneville.

The F1 generation was planted in short rows according to the number of seeds in each plant that set seed. At time of harvest these were harvested by pulling the entire plant thus keeping each plant a distinct unit. The plants were tagged and numbered for distinction at time of threshing and planting the forthcoming year. These F1 plants were a distinct cross being of bronze color and long club-shaped heads.

F2 plants were sown each plant in a separate row or section of a row. The rows were 18" apart and the plants in the row approximately 3" apart.
During the first term of summer school 1922 the F2 generation was turned over to my care for field observations and working out of the segregations. At first an attempt to draw a correlation between the length of straw and the dead type was made but this failed. The failure was caused by the heterogeneous condition of the soil which did not permit of equal growth of all plants. This heterogeneous condition of the soil caused the plants to mature very unevenly and also caused considerable second growth. The condition varied according to the soil variation being least noticeable where the soil was more loamy and worse where the gravel pockets were located. About the only field work possible under the conditions was to keep the rows free from weeds and see that the proper irrigation was taken care of. A determination was made to find the number of dwarf plants in relation to the total number of mature plants. (See Table #1). The dwarf plants were of a bunchy nature very similar to orchard grass. The plants were almost entirely foliage with no straw to speak of. The straw exceptions that did appear and bear heads were sterile and set no grain.

Table #1. Comparison of Mature Plants to Dwarfed Plants.

<table>
<thead>
<tr>
<th>Row. Sec</th>
<th>No. Plants Mature</th>
<th>No. Plants Dwarfed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. - 2.</td>
<td>111</td>
<td>21.</td>
</tr>
<tr>
<td>2. - 2.</td>
<td>24</td>
<td>6.</td>
</tr>
<tr>
<td>2. - 3.</td>
<td>50</td>
<td>7.</td>
</tr>
<tr>
<td>10. - 1.</td>
<td>278</td>
<td>62.</td>
</tr>
<tr>
<td>10. - 2.</td>
<td>317</td>
<td>82.</td>
</tr>
<tr>
<td>12. - 2.</td>
<td>752</td>
<td>163.</td>
</tr>
<tr>
<td>13. - 1.</td>
<td>347</td>
<td>108.</td>
</tr>
<tr>
<td>Total...</td>
<td>1926</td>
<td>...</td>
</tr>
</tbody>
</table>

Approximate Ratio. 4:1.

No correlation is intended by this table, but only a condition shown. Using only this one generation it is not possible to state any condition of the above nature as meaning any definite thing.
At time of harvest each row or section of row was harvested separately. The method of harvesting was to pull each individual plant and remove the dirt from the roots by striking them against a rock or the edge of the shoe sole. Plants thus cleaned were placed in bunches and later tied in bundles. Each bundle being marked with a tag showing row number and section.

The bundles were removed from the field and stored in the Agronomy Seed Testing Laboratory of the Plant Industry Building. After harvest was completed the bundles comprising a row or section of a row representing a plant unit of the Fl generation, were opened and placed together. They were then sorted out according to the segregation types. Each plant was first divided into two classes according to head types, (See Table #2), namely long clubbed heads and slender heads.

Table #2 Division of plants according to head types.

```
<table>
<thead>
<tr>
<th>Row</th>
<th>Sec</th>
<th>Clubbed Heads</th>
<th>Slender Heads</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. - 2.</td>
<td></td>
<td>87</td>
<td>24</td>
</tr>
<tr>
<td>2. - 2.</td>
<td></td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>2. - 3.</td>
<td></td>
<td>36</td>
<td>14</td>
</tr>
<tr>
<td>9. - 2.</td>
<td></td>
<td>40</td>
<td>7</td>
</tr>
<tr>
<td>10. - 1.</td>
<td></td>
<td>231</td>
<td>47</td>
</tr>
<tr>
<td>10. - 2.</td>
<td></td>
<td>262</td>
<td>55</td>
</tr>
<tr>
<td>12. - 1.</td>
<td></td>
<td>624</td>
<td>128</td>
</tr>
<tr>
<td>13. - 1.</td>
<td></td>
<td>283</td>
<td>64</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1583</td>
<td>343</td>
</tr>
</tbody>
</table>
```

Approximate Ratio. 4:1 rather than 5:1.

It appears from this segregation ratio that there possibly is a number of characters involved which go to make up head type. Federation is a distinct slender head type. Dicklow has pure lines which are likewise distinct slender head types. It has also pure lines having long club shaped head types commonly known as Dicklow Club. It would seem that there is a possibility of the Dicklow carrying a factor for club shape which combined with a similar character occurring in the Federation would produce a club shape.
Having separated each row into two types as to head shape or slender, the next or final segregation for external character was that of chaff color. The heads were divided into four separate divisions according to intensity of color or lack of color. The four colors for each head type were, Dark Bronze (D.B.); Medium Bronze (M.B.); Light Bronze (L.B.); and White (W). Each row was subjected to the same division and the results tabulated (See Table #3.). This was to find if there was a relation between color types that could be accounted for according to the Mendelian law of color inheritance.

Table #3. To find correlation in color type in accordance to Mendel's law of color inheritance.

<table>
<thead>
<tr>
<th>CLUBBED HEADS</th>
<th>SLENDER HEADS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row. Sec.</td>
<td>D.B.</td>
</tr>
<tr>
<td>1. - 2.</td>
<td>55</td>
</tr>
<tr>
<td>2. - 2.</td>
<td>13</td>
</tr>
<tr>
<td>2. - 3.</td>
<td>24</td>
</tr>
<tr>
<td>9. - 2.</td>
<td>25</td>
</tr>
<tr>
<td>10. - 1.</td>
<td>161</td>
</tr>
<tr>
<td>10. - 2.</td>
<td>192</td>
</tr>
<tr>
<td>12. - -</td>
<td>395</td>
</tr>
<tr>
<td>13. - 1.</td>
<td>198</td>
</tr>
<tr>
<td>Total</td>
<td>1063</td>
</tr>
</tbody>
</table>

Approximate Ratio. 9:3:3:1

Heterogeneity of the soil caused very uneven ripening and at the time of harvest not all plants were thoroughly ripened, therefore, the true color could not be determined with certainty. This would possibly account for the variation in the possible ratio, and the increased number of dark bronze color. A small amount of this if fully mature would possibly have showed color when true would have placed it in the other groups. Under the circumstances they could not be placed in other than the Dark Bronze group.
The object for which the cross was made was to combine the high yield of the Dicklow with the good milling-quality and yield of Federation. These are both soft spring wheats. There is a varying degree of softness in the class of soft wheat, likewise there is a slight difference in the texture of these two wheats. Federation being slightly harder than Dicklow. It seems this slight difference makes up the difference in milling quality. Using this as a possible fact the segregations were separated into two classes according to the texture of the kernel. The means used for determining the difference in texture was to shell a head from each plant and test the kernels, by chewing, to find in which class to place them. Five kernels from each head being so tested to make certain the selection. Using this method of selection showed that the harder kernels contained the most gluten. It was therefore decided to place them under the head of Federation which had the better milling quality. The results were tabulated (See Table #4) in a form to give comparison between the Clubbed heads and the Slender heads. Also between the different variations in color. The grade showing highest gluten content of Federation quality was termed (M.H.) meaning, medium hard, which is in a sense a misnomer for a soft wheat. The grade showing the Dicklow quality being more starchy, was termed (S) meaning soft. The reason for this distinction and terminology was because the (M.H.) grade was slightly harder than the (S) grade. There were only three or four plants in the entire 560 (M.H.) grade that were distinctly hard and flinty. This was possibly due to their immaturity.

In the work in testing the milling quality of this hybrid the uneven ripening condition offers a severe handicap. Some were fully mature while others were not completely ripe and hence were not filled properly or contained shrunken kernels which did not show distinctly the true texture as wished.
Tabulation of the amount of Federation quality wheat (M.H.) in comparison to the Dicklow quality wheat (S), and comparing the Clubbed heads with the same quality in the Slender heads.

Table #4. \( \text{FEDERATION} \times \text{DICKLOW} \), \( \text{F}_2 \).

<table>
<thead>
<tr>
<th>Row, Sec.</th>
<th>D.B.</th>
<th>M.B.</th>
<th>L.B.</th>
<th>W.</th>
<th>MH.</th>
<th>S.</th>
<th>MH.</th>
<th>S.</th>
<th>MH.</th>
<th>S.</th>
<th>MH.</th>
<th>S.</th>
<th>MH.</th>
<th>S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. - 2.</td>
<td>17</td>
<td>38</td>
<td>7</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. - 2.</td>
<td>4</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. - 3.</td>
<td>8</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. - 2.</td>
<td>9</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. - 1.</td>
<td>27</td>
<td>134</td>
<td>7</td>
<td>25</td>
<td>8</td>
<td>28</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. - 2.</td>
<td>59</td>
<td>133</td>
<td>10</td>
<td>25</td>
<td>5</td>
<td>25</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. - .</td>
<td>130</td>
<td>265</td>
<td>40</td>
<td>66</td>
<td>28</td>
<td>66</td>
<td>16</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. - 1.</td>
<td>63</td>
<td>135</td>
<td>9</td>
<td>31</td>
<td>5</td>
<td>30</td>
<td>28</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MH.</td>
<td>317</td>
<td>81</td>
<td>54</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>746</td>
<td>166</td>
<td>167</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head Type Totals</td>
<td>M.H.</td>
<td>S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MH.</td>
<td>474</td>
<td>1109</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.</td>
<td>86</td>
<td>257</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Total</td>
<td>Medium Hard (M.H.)</td>
<td>Soft (S)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MH.</td>
<td>560</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.</td>
<td></td>
<td>1366</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Approximate Ratio. \[ \text{MH}:\text{S} = 3:1 \]

From the evidence shown it seems that this cross follows the Mendelian laws in various ways.

1. It complies with the findings of Gaines (12) 1917, that club heads are dominant over long heads. (Page 1 of Section #2)
2. Color of chaff in F1 and F2 generations as found by Nilsson-Ehle (28a) 1909, brown chaff dominant over whitish-yellow chaff in F1. Tschermak (39b) 1915 brown chaff dominant over whitish-yellow chaff in F1, but not in a clean separation in F2. (Page 2 of Section #2). This last is shown by the gradual gradation of the brown color into the white.
All segregations of this cross shattered. This bore out the findings of the Howards (20a) 1912, shattering characters are heritable. No difference in the degree of shattering was shown by any certain color, showing that color and shelling properties are not correlated.

Whether or not the head shape and the M.H. grade of grain will breed true and not segregate remains to be shown by growing of the selected plants for a few more generations. The final task on this research work was to select the most promising plants from each row and each segregation. Special care was used in this to secure a plant that might be classed as an Elite plant. In this plants were chosen which carried three main factors, 1. Good stooling properties, 2. Strong upright straw, 3. Long strong head types. The present condition of these plants selected might be due to good soil and moisture relations, or what is hoped for, inherent quality which makes them superior plants. This hope will be verified or shattered by the growing of future generations in a more homogenous soil. The milling quality will also be found fixed or absent by growing the grain on a better soil, for the soil east of the windbreak is too spotted to give an accurate estimate of the true quality of the kernel. This work tends to show that the hybrid produced by this cross bids fair to equal the Dicklow parent in yield and also gives a possibility that the goal sought by the cross will also be reached ultimately.
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