



Inheritance of awnedness, kernel color, glume pubescence, and reaction to two physiologic races of *Tilletia* in spring wheat  
by Samuel C Litzenberger

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Montana State University  
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**Abstract:**

This investigation is primarily an inheritance study of awnedness, kernel color, and glume pubescence in spring wheat. In a cross of Reliance-Reward x Comet-(Hussar-Hard federation) the inheritance of awnedness, kernel color, and glume pubescence was studied on 100 F<sub>3</sub> hybrid progeny as well as their reaction to two races, T-8 and L-7, of *Tilletia*. Only awnedness one investigated in 100 F<sub>3</sub> lines of a second cross, Comet-(Hussar-Hard federation) x Ceres-(Hope-florence).

Two major factors were found to govern the awn development between the awnless and awned varieties, since these were the two types represented in each cross, intermediate dominance prevailed with the factors for the awnless condition being more potent than the awned, four true-breeding types were obtained in the F<sub>3</sub>, namely two intermediates, weakly awn-letted and strongly awn-letted, and the other two like the parents, awnless and awned. A few epically awned and half awned true-breeding lines were observed in the F<sub>4</sub> of the first cross, a 1:2:2:4:1:1:2:2:1 gene-typic ratio was observed in both crosses, however, different phenotypic ratios were obtained. A 1:8:1:3:2:1 ratio of awnless, epically awn-letted, weakly awn-letted, strongly awn-letted, half awned, and awned, respectively, was obtained in the Comet-(Hussar-Hard federation) x Ceres-(Hope-Florence) cross and a 1:4:5:3:2:1 phenotypic ratio was found in the other cross. A single factor difference was obtained for kernel color and glume pubescence in the cross Reliance-Reward (dark-red seeded with pubescent glumes) x Comet-(Hussar-Hard federation) (light-red seeded with glabrous glumes). The glabrous condition was found to be recessive to the pubescent.

The seed of the F<sub>3</sub> hybrids and parents in the first cross studied were inoculated with a mixture of races M and L-7 of *Tilletia*. The parents differed in their reaction to the individual races, each being resistant to one race and susceptible to the other. Nine lines were obtained which were more resistant than the resistant parent, demonstrating it is possible to combine the resistance of each parent into a single variety of wheat.

All characters studied were found independently assorted except seed color and per cent bunt infection. A weak linkage apparently exists between dark-red-seeded plants and susceptibility to bunt and light-red-seeded plants and resistance to bunt.

INHERITANCE OF AWNEDNESS, KERNEL COLOR, GLUME PUBESCENCE, AND  
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Samuel C. Litszenberger

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ABSTRACT

This investigation is primarily an inheritance study of awnedness, kernel color, and glume pubescence in spring wheat. In a cross of Reliance-Reward x Comet-(Hussar-Hard Federation) the inheritance of awnedness, kernel color, and glume pubescence was studied on 100 F<sub>3</sub> hybrid progeny as well as their reaction to two races, T-8 and L-7, of Tilletia. Only awnedness was investigated in 100 F<sub>3</sub> lines of a second cross, Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence).

Two major factors were found to govern the awn development between the awless and awned varieties, since these were the two types represented in each cross, intermediate dominance prevailed with the factors for the awless condition being more potent than the awned. Four true-breeding types were obtained in the F<sub>3</sub>, namely: two intermediates, weakly awnletted and strongly awnletted, and the other two like the parents, awless and awned. A few apically awned and half awned true-breeding lines were observed in the F<sub>1</sub> of the first cross. A 1:2:2:4:1:1:2:2:1 genotypic ratio was observed in both crosses, however, different phenotypic ratios were obtained. A 1:8:1:3:2:1 ratio of awless, apically awnletted, weakly awnletted, strongly awnletted, half awned, and awned, respectively, was obtained in the Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence) cross and a 1:4:5:3:2:1 phenotypic ratio was found in the other cross.

A single factor difference was obtained for kernel color and glume pubescence in the cross Reliance-Reward (dark-red seeded with pubescent glumes) x Comet-(Hussar-Hard Federation) (light-red seeded with glabrous glumes). The glabrous condition was found to be recessive to the pubescent.

The seed of the F<sub>3</sub> hybrids and parents in the first cross studied were inoculated with a composite of races T-8 and L-7 of Tilletia. The parents differed in their reaction to the individual races, each being resistant to one race and susceptible to the other. Nine lines were obtained which were more resistant than the resistant parent, demonstrating it is possible to combine the resistance of each parent into a single variety of wheat.

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Samuel C. Litszenberger

INTRODUCTION

The role played by genetics in establishing the underlying principles of inheritance cannot be over-emphasized. Exact information on the mode of inheritance of various characters has aided in setting up more efficient breeding programs. Many of the characters of the wheat plant have been studied and much has been accomplished, but little is known about the mode of inheritance of many characters which should be combined into the perfect variety as conceived by the plant breeder. Many problems remain to be solved; genetics can and will play an important role in their solution.

Gregor Mendel furnished us with the plan for inheritance, dealing with unit characters, dominance, segregation and recombination. It was not until 1900 when De Vries, Correns, and von Tschernak independently and simultaneously rediscovered Mendel's classic findings published in 1866 that wide interest developed in the science of genetics. While unit characters have not proved to be as simple in wheat as was first thought, and dominance is incomplete in most cases, the single character is still the foundation for studying wheat inheritance, and dominance the primary basis for genetic interpretations.

The presence and importance of disease resistance in wheat is well

known. In recent years marked progress has been made in breeding wheat for resistance to disease. Many fungus diseases contain numerous physiologic races. Bunt or stinking smut of wheat, caused by Tilletia tritici (Bjerk.) Wint. and T. levis (Kuehn), is one of the most destructive of this type. A variety may be resistant to some physiologic races but may be very susceptible to others. The genetic foundation for resistance to bunt has been proved beyond a doubt, and its mode of inheritance has been shown in some cases. Since these conditions prevail, it is the hope of the plant breeder through recombinations to combine in a single variety the near-immune reaction to all races of bunt as well as to other diseases.

The importance of genetics in a crop improvement program has been clearly defined by Salmon and Laude (1932) who state that "the random crossing of varieties to induce variation or in the hope of securing favorable chance combinations is too uncertain a method on which to base a crop-improvement program". Thus, in order to proceed most efficiently in a breeding program, it is important to know the mode of inheritance for most of the important characters of the parental material.

The investigations reported in this paper consist of inheritance studies in two spring wheat crosses. In one cross, Reliance-Reward x Comet-(Hussar-Hard Federation), studies were made on awnlessness, kernel color, glume pubescence, and resistance to bunt; in the other cross, Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence), only the inheritance of awnlessness was studied.

LITERATURE REVIEW

Awnedness

Wheat varieties generally have been separated into two major groups on the basis of awnedness character, namely: awned and awnless. It is now recognized that all wheats cannot be classified into these two simple groups and that various intermediate types exist. The failure to recognize these intermediate types probably accounts for much of the disagreement between the results of the early workers who studied the inheritance of this character.

The first genetic study on awnedness in wheat hybrids was reported in 1905 by Biffen, who concluded that the beardless condition is a dominant, the bearded, a recessive character. He made many crosses between bearded and so-called beardless wheats. The  $F_1$  was always "beardless", and the  $F_2$  segregated into 3:1 of "awnless" to awned. He obtained very close fits to a 3:1 monohybrid ratio. Plants occurred with short terminal awns up to half an inch in length; these were put into the awnless class. Some of these were also found in the parents. Without exception the awned types bred true, while the "beardless" types either bred true or segregated into bearded and "beardless" types.

Other early workers obtained similar results in the first generation and in the second generation also, when the "awnless" and awned plants occurred in a simple Mendelian ratio of 3:1. Saunders (1907) first questioned the idea that the first generation between an awnless and an awned wheat always is awnless and maintained that the awns in the  $F_1$  varies with the wheats

used. Percival (1921) later reported that  $F_2$  segregation in numerous crosses approached a 1:2:1 ratio when intermediates occurred, and when the semi-bearded forms of Triticum vulgare were crossed with typically bearded forms, the  $F_1$  plants have heads easily distinguished from those of the beardless parent. The  $F_2$  generation from these "semi-bearded"  $F_1$  hybrids consisted of "beardless", semi-bearded and bearded plants in the ratio of 1:2:1. Many workers have verified these results. Hayes and Aasodt (1923) found a one-factor difference in a cross between awned and semi-awned varieties. The  $F_1$  was strongly awnletted and segregated as a monohybrid. With a reciprocal cross Clark and Quisenberry (1929) verified these results. Gaines and Singleton (1926), Stewart and Woodward (1931), Stewart and Dalley (1932), Quisenberry and Clark (1933), Ausemus (1934), and Tingey and Tolman (1934) all reported single-factor differences when awned and semi-awned parents were crossed.

In most cases monohybrid ratios have been obtained when these semi-awned wheats have been crossed with the true awnless types. Workers who found single-factor differences when awnless wheats were crossed with awnletted types are: Stewart and Tingey (1928), Stewart (1932), Quisenberry and Clark (1933) and Ausemus (1934).

Several workers have reported minor factors playing a part in the type of awn produced. Clark and Hooker (1926) in making a Hard Federation x Marquis cross found an unusual number of plants with extremely short beaks which were not exactly like the awnless parent, and were not like the next higher class. When these were put in the awnless class they obtained a 3:1 ratio, but when put with the awnletted class a 15 to 1 ratio of awnletted

to completely awnless were obtained. The results of the reciprocal cross were the same. They concluded that two factors (1 major and 1 minor) governed the awn development in this cross.

Two minor factors were needed to explain the results obtained by Clark, Florell, and Hooker (1928) when Bobs and Hard Federation were crossed. Both parents are classed as awnless wheats. The Bobs variety possesses no beaks whatsoever, whereas Hard Federation has short beaks of 1 to several mm. in length at the tips. An approximate 13:3 ratio in the  $F_2$  was obtained.

Apparently the awnless wheats referred to in most of the early genetic studies were weakly or strongly awnletted. Howard and Howard (1912, 1915) in India were the first to report results of crosses between true awnless wheats and awned varieties and they reported a two-factor difference. They grouped the awned and tip-awned classes together as awned and compared them to the awnless types which gave a 15:1 ratio. They thus concluded that the double recessives were awnless. The  $F_1$  was nearly awnless.

Various workers have obtained a two-major factor difference for awnedness when awnless and awned types were crossed. In a Kota x Hard Federation cross Clark (1924) found a two-major factor difference, but since no completely awnless or awned types were obtained which bred true he assumed that minor modifying factors were present. Clark, Florell, and Hooker (1928) reported a two-factor difference in one cross of a bearded with a beardless wheat but a three-factor (2 major and 1 minor) difference in another. The only effect of the minor factor in the presence of one of

the major factors is to reduce the amount of awnedness as from the stronger to the weaker limits of a class. From this study they have concluded that as many as four factors may be involved in awnedness inheritance in some wheat crosses. Other workers who found two-factor differences when awnless wheats were crossed with awned types are: Stewart and Hayward (1929), Stewart and Judd (1931), Clark, Quisenberry, and Powers (1933), Ausemus (1934), and Tingey and Tolman (1934). All found the  $F_1$  awnless and the  $F_3$  progenies were classified into nine genotypic groups.

Evidently there are two genetically different types of semi-awnless wheats, since Love and Craig (1926) found when Sonora (semi-awnless) was crossed with certain other semi-awnless types, the  $F_1$  was nearly awnless while the  $F_2$  and later generations awned and partly awned types appeared. The results showed a 15:1 ratio which indicated this variety although semi-awnless carried a factor for the awned condition. Stewart (1932) crossed two true breeding awnless types which he obtained as segregates from a Sevier x Federation cross and obtained all types again. Four true breeding types were recovered: one completely awnless, one awned, and two intermediates. Quisenberry and Clark (1933) obtained similar results from a cross between two awnless wheats, Sonora x Quality. A complete range of segregation from awned to awnless was obtained in the  $F_2$  with four types breeding true. It was assumed that Sonora contains the genetic factors  $aAEB$  and Quality contains factors  $AAbb$ , whereas the awnless segregates were  $AABB$  and the awned ones were  $aabb$ .

Multiple allelomorphs for half-awned and fully-awned plants arising by complex mutation from the awnless plants has been used as a basis for

interpreting the awnedness in wheats by Nilsson-Ehle (1920). He reported that he obtained by mutation true breeding forms of awless, half-awned, and awned wheats. Awless forms were partly dominant to half-awned and to awned, and half-awned forms to awned.

The basis for inheritance of awnedness has been found to be simple in some crosses and very complex in others. A difference of only a single-factor pair was found in some crosses but as many as four factors (2 major and 2 minor) have been found necessary to explain results obtained in combination of crosses involving Hard Federation, Kota, and Bobs. Incomplete dominance for awlessness has been demonstrated, the  $F_1$  more nearly approaching the awless parent than the awned type. Awless, awned, and two intermediate types which may be recognized are the four true breeding types most often found, although true breeding apically awletted or half-awned types have been obtained in some crosses.

#### Kernel Color

Kernel color was early recognized as an important character in wheat varieties and consequently was among the first used for a study of Mendelian inheritance in wheat. Most varieties of wheat were observed to have either red or white kernels, although some Abyssinian durum wheats and emmers are purple.

In the early work by Biffen (1905), red was found dominant to white in the  $F_1$  and segregated in a simple 3:1 ratio in the  $F_2$ . Nilsson-Ehle (1911) was the first to report crosses which in the  $F_3$  gave 3:1, 15:1, and 63:1 ratios of red-kernelled and white-kernelled plants, indicating the presence

of 1, 2 and 3 genetic factors. Howard and Howard (1912), Gaines (1917), Love and Craig (1918), Clark (1924), Stewart (1928), Stewart and Tingey (1928), Stewart and Woodward (1931), Stewart and Dalley (1932), Clark, Quisenberry, and Powers (1933), Tingey and Tolman (1934), and Schlehner (1935) have obtained similar ratios depending on the varieties used when studying the progeny in red x white seeded wheats. Thus, from  $F_3$  studies, the presence of 1, 2, or 3 independent genetic factors for kernel color has been proved in different varieties. Nilsson-Ehle's theory was that, taken together, the three red color factors behave cumulatively, following the law of a trihybrid, and increase the intensity of the seed color.

Some varieties of wheat have been reported to possess strains having different numbers of factors for grain color. Harrington (1922) reported Kitchener contains two independently inherited factors for red color, and that some of the strains of Red Bobe and Hard Red Calcutta contain two independently inherited factors for grain color while others contain only a single factor. Clark and Hooker (1926) found that in Marquis x Hard Federation crosses two factors were most frequently present, but that in some crosses only a single-factor difference was obtained. The fact that two different ratios were obtained indicates either that Marquis does not always have two dominant factors for kernel color or that the white Hard Federation parents differed in their genotype.

The usual result of crossing two white-grained wheats is the production of white-grained descendants in the  $F_1$  and all subsequent generations. However, Percival (1921) has reported that Vilmorin obtained some red-grained plants in the  $F_2$  when two white wheats, Triticum polonicum and T. turgidum,

were crossed. Percival further states that Pitech recorded the appearance of a few yellow or reddish-grained plants in the sixth generation from a Squarehead x Challenge cross. Both varieties are white seeded. Gaines (1917) reported that in two cases when white-grained individuals were crossed some red-kernelled plants occurred. So far as known these results have never been repeated by other workers, nor have similar results been obtained by crossing two white-kernelled varieties within the same species. The results, if authentic, would indicate dominant genetic factors for white kernels and recessive complimentary factors for red.

Percival (1921) suggested that when red-grained varieties are crossed the progeny is generally red in all generations. However, he cites Techermak as having obtained in some instances white-grained individuals among the descendants of hybrids between different red-grained varieties. Percival also reports Nilsson-Ehle as having recorded the occurrence of white-grained plants in  $F_2$  of the hybrid "Bore" wheat x "Extra Squarehead", both red-grained parents.

Hayes and Robertson (1924) noted the frequency of the occurrence of the white-kernelled plants in the  $F_2$  studies of Minturki x Marquis and Kenred x Marquis crosses where the parents were both red-kernelled. From the data obtained, they concluded that the red color in Marquis is the result of two independently inherited factors, either one of which leads to the production of seed color and that Minturki and Kenred have a single factor for red different from either of those in Marquis. The crosses approximated the ratio of 63 red-kernelled plants to 1 white-kernelled plant. Kenred and Minturki have the following genetic constitution  $rrr'r' R'R'$

while Marquis has  $RHE'R' r''r''$  for its constitution.

#### Glume Pubescence

Pubescent and glabrous glumes usually constitute an allelomorphous pair of characters. Biffen (1905) was first to report felted or velvety chaff dominant over glabrous chaff in a single 3:1 ratio. In all the hybrids studied the progeny segregated into a 3:1 ratio. Incomplete dominance was shown in a few cases since the  $F_1$  was intermediate in pubescence, but the  $F_2$  segregation was normal as complete dominance of 3:1 pubescent and glabrous glumes. Percival (1921) also reported these same conditions and results. According to this author Ruenker obtained both glabrous and velvet-chaffed plants in the  $F_2$  generation in the ratio 3 velvet: 1 glabrous, in the hybrid between a pubescent and beardless Triticum vulgare and a pubescent and bearded T. compactum (Igel). Percival reported similar results from a hybrid between two pubescent-chaffed wheats, T. dicoccum x T. sphaerococcum. None other than a 3 pubescent: 1 glabrous ratio has been found in crosses between varieties of common wheats.

#### Bunt Reaction

Bunt or stinking smut of wheat, Tilletia tritici (R.Jerk) Wint. or Tilletia levis (Kuehn), has been and continues to be a destructive disease of wheat in the United States and in other countries where wheat is produced. In those wheat producing areas the presence of many physiologic races of bunt or the appearance of new races increases the difficulty for the wheat breeder of obtaining commercial varieties resistant to bunt. Reed (1924), Rodenhiser and Stakman (1927), Gaines (1928), Bressman (1931),

Holton and Heald (1936), Rodenhiser and Holton (1937), and others have studied and reviewed the physiologic specialization work with bunt. The mode of inheritance of resistance to physiologic races of bunt has been explained on one, two, three, and multiple factor differences. Schlemmer (1938) has reviewed the literature on the nature of segregation rather exhaustively and has grouped the authors according to the number of factors involved in the cross with which they worked.

The pioneer work in breeding wheat for resistance to bunt was done in Australia by Farrer and in the United States by Gaines of Washington. Farrer in 1901 reported his first attempts to bring about bunt resistance in wheat by hybridization. Having observed that 10 Australian varieties carried infections varying from 12 to 95.5 per cent, he thought a similar degree of variation might occur in the hybrid generation of his crosses. His plan was to subject  $F_2$  and  $F_3$  populations to a heavy attack and select the bunt-free plants. He made no attempts to observe the segregation into resistant and susceptible strains in order to establish Mendelian ratios. The varieties, Florence and Genoa, which are highly resistant, were produced. Gaines (1920) began his investigations, including the genetics of resistance in 1915, and in 1923 he described his extensive results. He grouped varieties into four classes--susceptible, intermediate, resistant, and immune. When resistant varieties were crossed with susceptible ones, susceptibility was dominant, with only about 2 per cent of the progeny as resistant as the resistant parent. When susceptible varieties were crossed with immune ones (Martin and Hussar) there seemed to be a preponderance of resistant plants. More than half of the hybrids in the

third generation produced less than 5 per cent of bunted heads, whereas about 20 per cent were bunt-free. Altogether he studied more than 25 separate crosses and explained the results obtained in each on a multiple-factor basis. The influence of any single factor was not well defined. When all factors are present, as in immune varieties, resistance is apparently dominant, but a lesser number gives the recessive effect. Briggs (1926), however, found that the Martin variety had one dominant factor for near immunity and that Hussar had two. In an excellent series of papers, Briggs (1930, 1930a, 1931, 1932, 1932a, 1933, 1934, and 1936) has shown the inheritance of bunt reaction in different crosses to be quite simple, due to one or two factor differences. He worked principally with single physiologic races of bunt. He (1934) has determined the genetic constitution of 10 bunt resistant varieties of wheat and lists them as follows:

<u>Variety</u>	<u>Genetic Constitution</u>
Martin	MMhhtt
White Odessa	MMhhtt
Banner Berkeley	MMhhtt
Odessa	MMhhtt
Shorman	MMhhtt
Hussar	MMHhTt
Hussar-Hd. Fed. x Little Club Sel. 1418	mmHhTt
Hussar-Hd. Fed. x Little Club Sel. 1403	mmHhTt
Turkey C.I. 1558	mmhhTT
Turkey C.I. 3055	mmhhTT
Cro	mmhhTT

These varieties contain the Martin (MM), Hussar (HH), or Turkey (TT) factors for resistance. The first five listed depend on the Martin factor for resistance. Hussar contains both the Martin and Hussar factors. Briggs (1936) concluded Turkey C.I. 2578 contained the Turkey factor for resistance. Bressman (1933) found Albit contains one main factor for resistance to certain physiologic races of bunt and he suggested that this factor is the same as that carried by its male parent White Odeessa.

The near-immune reaction to some races of bunt possessed by Hussar has been transferred to hard red spring wheat in a Komar x Hussar cross by Smith (1932). According to Clark (1936) Florell and Bayles have developed another nearly immune hard red spring wheat (N.No. 1018, C.I. 11442) from a cross of Hussar, a hard red winter wheat and Hard Federation, a white spring wheat. Both of these strains have been crossed with susceptible varieties, and the  $F_1$  plants were found by Clark (1936) to be bunt-free, proving dominance of near immunity. According to Clark (1936) in the  $F_2$  studies made by Clark and Rodenhiser these crosses showed a single-factor difference. This is sharply in contrast to the inheritance from such varieties as Hope, Marquis, Redit, Cro, Turkey and Florence crossed upon susceptible varieties in which the  $F_1$  plants are susceptible.

The strong resistance of Hope wheat to bunt was studied by Clark, Quisenberry, and Powers (1933) in crosses involving the weaker resistance of Marquis and different degrees of susceptibility in Ceres and Hard Federation. The resistance of these three crosses was studied following inoculation with a collection of bunt (Tilletia levis) from Montana. The results indicated that several factors were involved but that the stronger

the resistance in the parents the less complicated is the inheritance.

#### MATERIALS AND METHODS

The parents of the cross in which genetic studies on awnedness, kernel color, glume pubescence, and reaction to two physiologic races of Tilletia were Nursery Number 1388, a selection from Reliance x Reward and Nursery Number 1315, a selection from Comet x Hussar-Hard Federation. The Reliance x Reward parent is completely awned (awn type 5), has dark red kernels, pubescent glumes, is highly resistant to race T-8 of T. tritici, but is susceptible to race L-7 of T. levis. The other parent, Comet x Hussar-Hard Federation, is awnless (awn type 1), has light red kernels, glabrous glumes, resistant to L-7 but is susceptible to race T-8.

In addition to the studies made on the cross described above, an  $F_3$  progeny of another cross, Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence), was classified for awn type only. One parent, Comet x Hussar-Hard Federation, N. N. 1383, is awnless (awn type 1). However, a few beaks, one to several millimeters in length, appear on a few of the plants. The Ceres x (Hope-Florence), Selection Number 60.4.19, is an awned variety (awn type 5).

The parent wheat varieties (Reliance x Reward and Comet x Hussar-Hard Federation) and  $F_3$  hybrid progenies were grown at the Montana Agricultural Experiment Station, Bozeman, Montana in 1937. The original cross was made by J. A. Clark, Division of Cereal Crops and Diseases, Washington, D. C., and advanced to the  $F_3$  by him as part of the wheat improvement program in the selection of a bunt resistant variety with desirable agronomic

characters for Montana conditions. The  $F_2$  was grown by him under bunt-free conditions in 1936.

Four hundred and twenty seeds of each of the parents and 70 seeds each of 100 plants taken at random from the spaced  $F_2$  population were inoculated with a composite of races L-7 and T-8, Tilletia levis and T. tritici respectively, by shaking an excess quantity of spores and the seed wheat in a small paper envelope. The  $F_3$  hybrid and parent plants were grown on summer fallow land spaced 3 inches apart in rod rows 12 inches apart. Nine rows of progeny were followed by one row of parent, the parents occurring alternately.

Shortly before ripe (stiff-dough stage) the individual plants in each row were pulled and classified in the field into the five groups; 0, 25, 50, 75, and 100 per cent bunt, based on the per cent of infected heads on each plant.

The percentage of smut in a row was calculated according to the following illustration: Row 50 of Reliance x Reward had 25 smut-free plants, twelve 25 per cent smutted plants, six 50 per cent smutted plants, three 75 per cent smutted plants, and one 100 per cent smutted plant.

$$\frac{(25 \times 0) + (12 \times 25) + (6 \times 50) + (3 \times 75) + (1 \times 100)}{47 \text{ (total number of plants)}} = 19.7 \text{ per cent bunt}$$

This method not only gives the per cent of bunt in the whole family but maintains the individual plant as a unit.

The main spike from each plant in an  $F_3$  family was harvested, placed in envelopes, and brought to the laboratory for smuttedness classi-

fication. The hybrid plants of this cross were classified into six classes. Class 1, awless, included those types with no development of awlets as well as those types like Hard Federation and Comet x Hussar-Hard Federation, N. No. 1383, which sometimes may have awlets up to 2 mm. long at the tip of the spike. Class 2, apically awletted, has awlets from 2 to 15 mm. long at the apex of the spike, but rarely occurring in the central or basal portion of the spike. Class 3-, weakly awletted, has awlets from 3 to about 20 mm. long, the shorter occurring at the base of the spike and the length increasing toward the apex. Class 3+, strongly awletted, has awlets from 3 to 40 mm. long, the shorter occurring at the base of the spike and the length increasing toward the apex where they exceed the length of the awlets on Marquis (a typical 3-) by 10 to 20 mm. In addition, the lower awlets in class 3+ are characteristically incurved. Class 4, half awned, has short awns varying throughout the spike from 18 to 50 mm. long, but only about half the length of normal awns and frequently incurved or recurved, much more than the strongly awletted class. In class 5, awned, the awns vary from 30 to 100 mm. in length. Questionable awn types were grown in individual head rows in 1938, one-half the seed of each head was planted at Moccasin and the other half at Rozeman. Both plantings were used to correct the  $F_3$  classification.

The same spikes used for the  $F_3$  awnedness study were classified for character of glumes.

The individual heads were then threshed and the grain placed in separate envelopes. The three classes for color used in grouping the seed were: (1) dark red, like the Reliance x Reward parent, (2) medium red,

and (3) light red, like the Comet x Hussar-Hard Federation parent.

For a more detailed study of the inheritance of awnedness in the Reliance-Reward x Comet-(Hussar-Hard Federation) cross various crosses involving the parents or progeny were made in the greenhouse at Bozeman, Montana during the winter of 1937. The  $F_1$  and  $F_2$  of these crosses were grown at Bozeman in the greenhouse during 1938 and early 1939. Awnedness notes were taken on both the  $F_1$  and  $F_2$  plants. The following crosses were made:

Parent (1 awn type) x Parent (5 awn type)  
Progeny (1 awn type) x Progeny (5 awn type)  
Progeny (3- awn type) x Parent (5 awn type)  
Progeny (3+ awn type) x Parent (5 awn type)  
Progeny (3+ awn type) x Progeny (3- awn type)

One hundred  $F_3$  plant rows from the Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence) cross were grown at Bozeman, Montana in 1938 under the same conditions as the 100 strains from the other cross. When ripe the plants in each  $F_3$  family were pulled and tied in a bundle. These were taken to the laboratory and classified into the 6 awn classes, an average being taken of all heads on a plant to determine the class into which it was put. The awn classes used were the same as in the other cross.

#### EXPERIMENTAL RESULTS

##### Segregation of Characters

The characters studied in the Reliance-Reward x Comet-(Hussar-Hard Federation) cross were awnedness, kernel color, and glume pubescence. The

breeding behavior of all three characters for the lines studied are recorded in Table I. A pedigree diagram of this cross is given in Figure 1. In the Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence) only awnedness has been studied and the breeding behavior in respect to this character of the 100  $F_3$  lines is given in Table II. The results of the studies in the  $F_3$  generation follow in the order listed above.

#### Awnedness

The  $F_1$  and the larger number of  $F_2$  plants of Reliance-Reward x Comet-(Hussar-Hard Federation) were weakly awnletted (Class 3-) which approach more closely the awnless than the awned parent.

A total of 100  $F_2$  plants was selected at random for growing in the  $F_3$  generation. The classification of these plants is shown in Table III. The material proved to be rather variable, as there were 38 apparently separate segregating groups, however, several of these groups may not differ inherently from the others. The modal classes are indicated by underlined numbers and the various types are arranged in the order of length of awns, and totals are drawn between groups not regarded as inherently different. Variation within the groups may be due either to minor genetic factors, to environment, or to the single head classification method used. Figure 26 shows photographs of the 6 awn classes which were obtained in this cross and used for classification.

Among the  $F_3$  lines there was a wide range of overlapping of awnedness classes. Allowing for a wide range of overlapping of classes, the material was separated into nine groups (Tables III, IV, and V) as

Table I The classification of plants for awnness, per cent bunt, kernel color, and glume pubescence in  $F_2$  lines and parent rows in the cross Reliance-Reward (N.N. 1388) x Comet-(Nussar-Hard Federation) (N.N. 1315) grown at Bozeman, Montana in 1937

1937 row No.	Parent or cross	No. of plants having awn type					No. of plants having per cent bunt					Ave.	No. of plants having kernel color			No. plants having glumes		
		1	2	3	4	5	0	25	50	75	100		Dark red	Med. red	Light red	Glab- rous	Pubes- cent	
1	N.N. 1388 (Parent)					23	12	5	2	3	1	23.9						23
2	Cross 351162 A-1-1				12	12	5	23	4	1		5.4	8	16	5			29
3	do -3	27	6					29	4	2	1	7.6		19	13		10	23
4	do -7	1	4	8	5	3		16	7			7.6	11	8			3	18
5	do -9	2	9	2	8			14	8			9.1	10	8			5	16
6	do -11	7	13	5	3			19	8	2		10.3	16	10			7	21
7	do -12	9	7	5	9			22	8	1		8.1	8	15	6			30
8	do -13	2		3	10	5	9	16	11	1		11.6	6	10	7		5	21
9	do -15	3	7	10	7	4	4	30	6		1	6.1		7	27		1	34
10	N.N. 1315 (Parent)	27						24	3			2.8					27	
11	Cross 351162 A-1-17					14	13	19	9			8.0	7	13	7		9	18
12	do -18					13	18	31	1			0.8		12	18		6	25
13	do -20	4	8	5	1	8		16	7	2	2	15.7	11	6	8		8	18
14	do -21			2	6	8	16	23	6	3		9.4		5	27		6	26
15	do -22	10	8	4	9			23	7			5.8	4	14	12		8	23
16	do -23	2	13	10	6	3	2	25	9	2		9.0		1	35		36	
17	do -24	6	11	5	7			23	11	2		10.4	6	14	9		2	27
18	do -25	16	7					6	7	3	3	35.7	14	8				23
19	do -26		2	13	1	2		10	7	2		14.5	3	12	3			18
20	N.N. 1388 (Parent)						33	22	8	2	1	11.4						33
21	Cross 351162 A-1-27	4	11	13	3	2		21	8	4	1	16.4	20	11				33
22	do -28	1	2	14	8			16	4	7	2	20.7		4	20		7	18

Table I (continued)

1937 row No.	Parent or cross	No. of plants having awn type					No. of plants having per cent bunt					No. of plants having kernel color			No. plants having glumes			
		1	2	3-	3+	4	5	0	25	50	75	100	Ave.	Dark red	Med. red	Light red	Glab- rous	Pubes- cent
23	Cross 351162 A-1-29	15	10	14				23	13	2			11.2	6	20	12		39
24	do -30	5	7	9				17	4				4.8	4	10	7	13	8
25	do A-2-1	6	5	14		7		26	7				5.3	22	10		11	21
26	do -2	3	11	10	1	7		20	11	1			10.2		9	22	8	24
27	do -3						30	22	8				6.7	6	16	8	30	
28	do -4	5	13	7		6		25	6				4.8	7	14	10	10	21
29	do -5	1	4	13	4	3	5	21	6	2			8.6	6	16	6	6	24
30	N.N. 1315 (Parent)	19						17	2				2.6				19	1
31	Cross 351162A-2-6	1	9	5	9	2	6	26	6				4.7		26	6	9	23
32	do -7	3	7	12	8	4	2	19	19	1			13.5	22	11		11	25
33	do -8							21	12	7	2		11.9	11	9			21
34	do -11							27	18	8	1		9.3	16	12		8	19
35	do -12				24			15	9	1	1		13.5	11	13		7	17
36	do -13			5	15		7	25	5				4.2	18	9		27	
37	do A-3-1			28				17	9	1	1		12.5	6	15	7	7	21
38	do -2			7	12		10	12	12	2			15.4	18	7		29	1
39	do -3	2	6	10	1	1	1	18	4				4.5	5	10	6	21	
40	N.N. 1388 (Parent)							27	12	18	2		17.2					27
41	Cross 351162 A-3-4				4	16	10	21	8	2			9.7	6	21		30	
42	do -5	15	14	2		1	1	29	4		1		5.1		21	10	10	23
43	do -6	2	4	9	7	3	1	15	11	2			13.4	5	18	3	4	22
44	do -7		2	11	11		6	26	4				3.3		11	19	11	19
45	do -8	2	6	16	6	4	1	15	15	5			17.9	16	22		22	13
46	do -9	14	7	8				11	13	1	2	2	25.0	4	15	8	10	19
47	do -11	3	3	17	4	2	1	26	4				3.3	4	15	11	13	17

Table I (continued)

1937 row No.	Parent or cross	No. of plants having awn type					No. of plants having per cent bunt					Ave.	No. of plants having kernel color			No. plants having glumes			
		1	2	3-	3+	4	5	0	25	50	75		100	Dark red	Med. red	Light red	Glab- rous	Fubes- cent	
48	Cross 351162 A-3-12		9	21		7	26	9	3				9.9		5	30		37	
49	do -14		34				15	10	7	1	3		27.1	4	18	8		34	
50	N.N. 1315 (Parent)	40					32	8					5.0					40	
51	Cross 351162 A-3-15	8	13	14			28	6	2				6.9	8	20	7		35	
52	do -16	7	6	14	6	4	3	24	9	10			16.9	7	20	10		17	23
53	do -17	4	5	32			20	16	2	1	1		16.9	7	23	10		41	
54	do -18	1	4	10	10	5	11	23	17	2			12.5	14	26			12	29
55	do -19		4	20			18	27	9	6			12.5	13	22	6		15	27
56	do -20	2	10	22			11	37	6	1		1	6.7		17	28		45	
57	do -21	11	9	14	1	7	32	11	2				8.3	8	23	10		10	32
58	do -22	1		50			24	15	10	3			21.2	30	20			8	43
59	do -23						27	26	1				0.9		7	20		9	18
60	N.N. 1315 (Parent)						52	30	18	4			12.5	43	9				52
61	Cross 351162 A-3-24	13	18	9	1		40	1	1				1.8	26	15			41	
62	do -25				24	15	2	38	4				2.4		20	21		9	32
63	do -26	7	8	39		1	1	35	15	7			12.7		15	38		12	44
64	do -27	1			2	13	36	42	8				4.0	17	29	8			51
65	do -28	2	4	13	10	7	6	25	15	1			10.4	26	15			42	
66	do -29	7	19	6	4	1	33	4					2.7	8	24	4			37
67	do -30	11	24	16			27	19	6				14.9	10	22	16		17	34
68	do -31						47	42	2				1.1	8	23	9		11	34
69	do A-4-1	6	17	18			23	15	2	1			13.4	5	23	13			41
70	N.N. 1315 (Parent)	44					35	9					5.1		14	30		44	
71	Cross 351162 A-4-2	1	6	13			13	25	6	3			8.8	5	17	9			33
72	do -3	2	8	15	4	6	3	29	8	2			7.7		16	21		12	26

Table I (continued)

1937 row No.	Parent or cross	No. of plants having awn type								No. of plants having per cent bunt					No. of plants having kernel color			No. plants having glumes	
		1	2	3-	4	5	0	25	50	75	100	Ave.	Dark red	Med. red	Light red	Glab- rous	Pubes- cent		
73	Cross 351162 A-4-4	2	3	21	5	10	6	39	8	2				6.1	10	21	16	13	34
74	do	-5		11	19		11	25	10	4				11.5		14	27	6	35
75	do	-6		8	30		17	51	4					1.8		15	40	55	
76	do	-7	3	4	17	4	4	3	25	9	3			10.1	25	9		35	
77	do	-9	10	15	9	2	9	36	6					3.6	3	23	9	17	28
78	do	-10			1	3	36	36	4	3				5.8	10	20	10	2	38
79	do	-11		3	13	8	5	6	30	4	1			4.3	9	16	10	1	34
80	N.N. 1388 (Parent)							47	25	12	6	3	1	19.7	45	2			47
81	Cross 351162 A-4-12		4	9	13	2	6	26	10					6.9	10	16	7	34	
82	do	-13			5	20		5	26	3				2.6		17	13		30
83	do	-14	6	19	22			42	7					3.6	37	11		15	33
84	do	-15	1	5	12	10	8	13	33	14	2			9.2	11	23	15	8	41
85	do	-16	17	15	6			14	12	5	4	3		30.3	32	4		7	31
86	do	-17					47	40	9	1				5.5		13	32	47	
87	do	-18	4	12	21	2	8	1	28	15	1	1		11.1		14	34	13	35
88	do	-19	4	18	19			13	11	10	2	4		33.1	25	11		18	23
89	do	-20	31	8				27	11	1				8.3	10	21	8	10	29
90	N.N. 1315 (Parent)							32	6					3.9		11	27	38	
91	Cross 351162 A-4-21	2	11	17	1	8	1	33	7					4.4		10	29	40	
92	do	-22			34			16	16	1	1			15.4	6	18	9	34	
93	do	-23	6	39				28	12	5				12.2		20	25	45	
94	do	-24				13	20	25	8	2	1			11.1	18	14		7	26
95	do	-25			45			19	20	4	1			17.6	7	24	12	45	
96	do	-26	3	4	9	4	5	6	10	12	5	1		22.3	18	8			31
97	do	-27			3	21	26	23	13	7	5			21.9	11	25	13	9	41

Table I (continued)

1937 row No.	Parent or cross	No. of plants having awn type					No. of plants having per cent bunt					Ave.	No. of plants having kernel color			No. plants having glumes			
		1	2	3-	3+	4	5	0	25	50	75		100	Dark red	Med. red	Light red	Glab- rous	Pubes- cent	
98	Cross 351162 A-5-1				5	9	11	20	2		1		5.4	9	16		25		
99	do -2				7	20	15	37	3			1	4.3	18	24		16	26	
100	N.N. 1388 (Parent)						49	33	10	5		1	12.2					49	
101	Cross 351162 A-5-3	9	8	6	5	4		22	3	3	3	2	19.7		11	19		32	
102	do -4			9	21			9	21	17	1		12.2	8	19	12		39	
103	do -10	6	9	18				27	4				3.2	10	23			33	
104	do -13			7	20			10	29	10			6.4	5	19	13		37	
105	do -14				10	16	7	24	8	1	1		9.6	9	16	8		13	20
106	do -15			1		2	34	22	12	1			10.0	9	21	8		11	26
107	do -17	4	18	5	3	3		25	8	1			7.4		17	16			33
108	do -18	7	13	17				15	17	1	2		17.9	22	15				38
109	do -19				46			29	15	1	1		9.2	28	18			12	34
110	N.N. 1315 (Parent)	39						32	7				4.5					39	
111	Cross 351162 A-5-21	18	26					34	10				5.7	9	28	7		44	
112	do -22	11	18	15				38	6				3.4	8	23	13		8	36

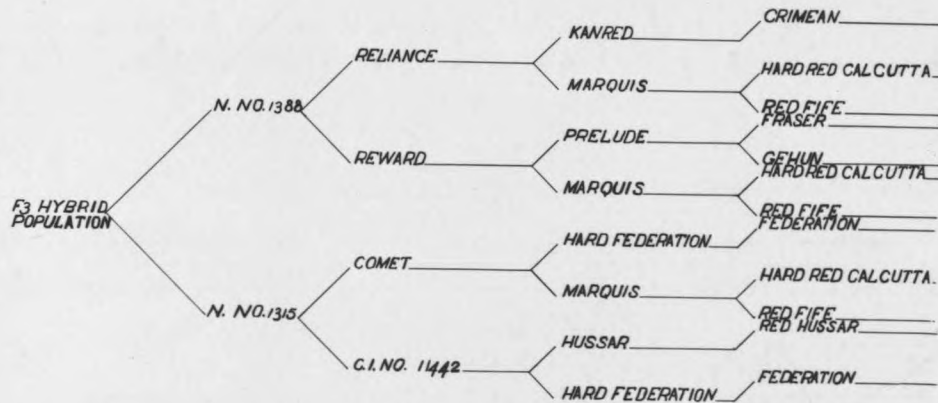


Figure 1 Pedigree diagram of the 100 F<sub>3</sub> lines of Reliance-Reward x Comet-(Hussar-Hard Federation)

Table II The classification of plants for awnedness in F<sub>3</sub> lines and parent rows in the cross Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence) grown at Bozeman, Montana in 1938

1938 row No.	Parent or cross	No. of plants having awn type					
		1	2	3	4	5	
113	Cross 361239 A-1-4	5	23	8	11	11	4
114	do -5				15	28	15
115	do -6				52		
116	do -10	3	24	4	19		5
117	do -11	17	27		13	1	
118	do -14				50	5	
119	do -16				1		67
120	Comet x Hussar-Hard Federation	34	22				
121	Cross 361239 A-1-17						58
122	do -21				14	26	16
123	do -22	1	26	4	10	5	3
124	do -26			61			
125	do -28			17	34		11
126	do -29	15	30		15		
127	do -32						63
128	do -33	1	22	8	14	7	4
129	do -34	4	34		18		
130	Ceres x Hope-Florence						64
131	Cross 361239 A-1-35	12	28		16		
132	do -36			14	22		17
133	do -39	41	8				
134	do -42	4	29	4	8	9	5
135	do -7				18	30	14
136	do -9			16	32		16
137	do -38	2	22	10	12	5	7
138	do -12	6	26	28			
139	do -37		4	19	31		7
140	Comet x Hussar-Hard Federation	42	22				
141	Cross 361239 A-1-13	2	21	6	13	6	5
142	do A-2-1	11	32	13			
143	do -3				16	23	11
144	do -4			58		1	
145	do -5	58	2				
146	do -6	16	30	14			
147	do -8	45	7				
148	do -10			13	35		14
149	do -11	5	28	2	13	10	1
150	Ceres x Hope-Florence						62
151	Cross 361239 A-2-12	16	31		15		

Table II (continued)

1938 row No.	Parent or cross	No. of plants having awn type				
		1	2	3	4	5
152	Cross 361239 A-2-17			15	29	13
153	do -19				57	2
154	do -21	21	22		13	
155	do -23	4	26	6	8	6
156	do -24	2	24	7	15	6
157	do -26	18	29	16		
158	do -27	2	22	8	15	10
159	do -28	4	26	4	11	5
160	Comet x Husser-Hard Federation	50	7			
161	Cross 361239 A-2-29	13	29		20	1
162	do -31	10	34	16		
163	do -34			43		
164	do -38				9	29
165	do -39			58		
166	do -40			60		
167	do -44	52	8	2		
168	do -13	1	28	5	14	5
169	do -30	4	31	1	12	6
170	Ceres x Hope-Florence					3
171	Cross 361239 A-2-41	9	32	19		65
172	do A-3-3					18
173	do -5					51
174	do -6	7	31	2	14	3
175	do -9		20	6	14	9
176	do -13	21	25	11		
177	do -14			14	22	13
178	do -15	16	24		12	
179	do -17	17	24	15		
180	Comet x Husser-Hard Federation	50	7			
181	Cross 361239 A-3-18			12	31	16
182	do -21			12	30	15
183	do -23				50	1
184	do -24	1	29	4	12	4
185	do -27	2	20	6	14	7
186	do -30	3	28	5	15	4
187	do -32				11	29
188	do -33	2	26	3	12	10
189	do -34				58	
190	Ceres x Hope-Florence					62
191	Cross 361239 A-3-35	18	33		14	
192	do -36	11	30		14	1
193	do -37				55	1

Table II (continued)

1938 row No.	Parent or cross	No. of plants having awn type					
		1	2	3-	3+	4	5
194	Cross 361239 A-3-38				16	29	19
195	do -39	4	25	5	13	8	5
196	do -40	10	31	4	8	5	1
197	do -41			53			
198	do -42				53	1	2
199	do -46				8	26	17
200	Comet x Hussar-Hard Federation	50	12				
201	Cross 361239 A-3-48			59			
202	do -52			18	31		18
203	do -54			12	28		16
204	do -56	3	22	7	15	5	2
205	do -58	52					
206	do -59			53			
207	do -60	2	26	8	13	5	3
208	do -61	6	22	4	12	10	6
209	do -62	3	34	6	15	5	2
210	Ceres x Hope-Florence						55
211	Cross 361239 A-3-20			13	28		12
212	do -16	4	26	9	12	5	1
213	do -28				10	27	12
214	do -49			19	31		11
215	do A-4-2	2	32	6	10	5	5
216	do -5	15	29	17			
217	do -9				57		
218	do -1	3	24	5	8	4	1
219	do -10				13	31	15
220	Comet x Hussar-Hard Federation	41	15				
221	Cross 361239 A-4-13	10	30	13			
222	do -8	53	2				
223	do -3	9	29	5	10	9	3
224	Ceres x Hope-Florence						64

Table III Number of F<sub>3</sub> plants in each awnedness class in the nine F<sub>2</sub> breeding groups of Reliance-Reward x Comet- (Russar-Hard Federation)

F <sub>2</sub> breeding groups	Number of F <sub>3</sub> plants in awnedness class No.						Total
	1	2	3	4	5	6	
I	98	86					184
II	149	215	258	1	2	4	629
III	83	117	89	48	43		380
IV	64	183	332	161	119	97	956
V			108				108
VI				167	13		180
VII		10	184	448		248	890
VIII		1	2	74	159	202	438
IX			1		2	231	234
Total	394	612	974	899	338	782	3,999

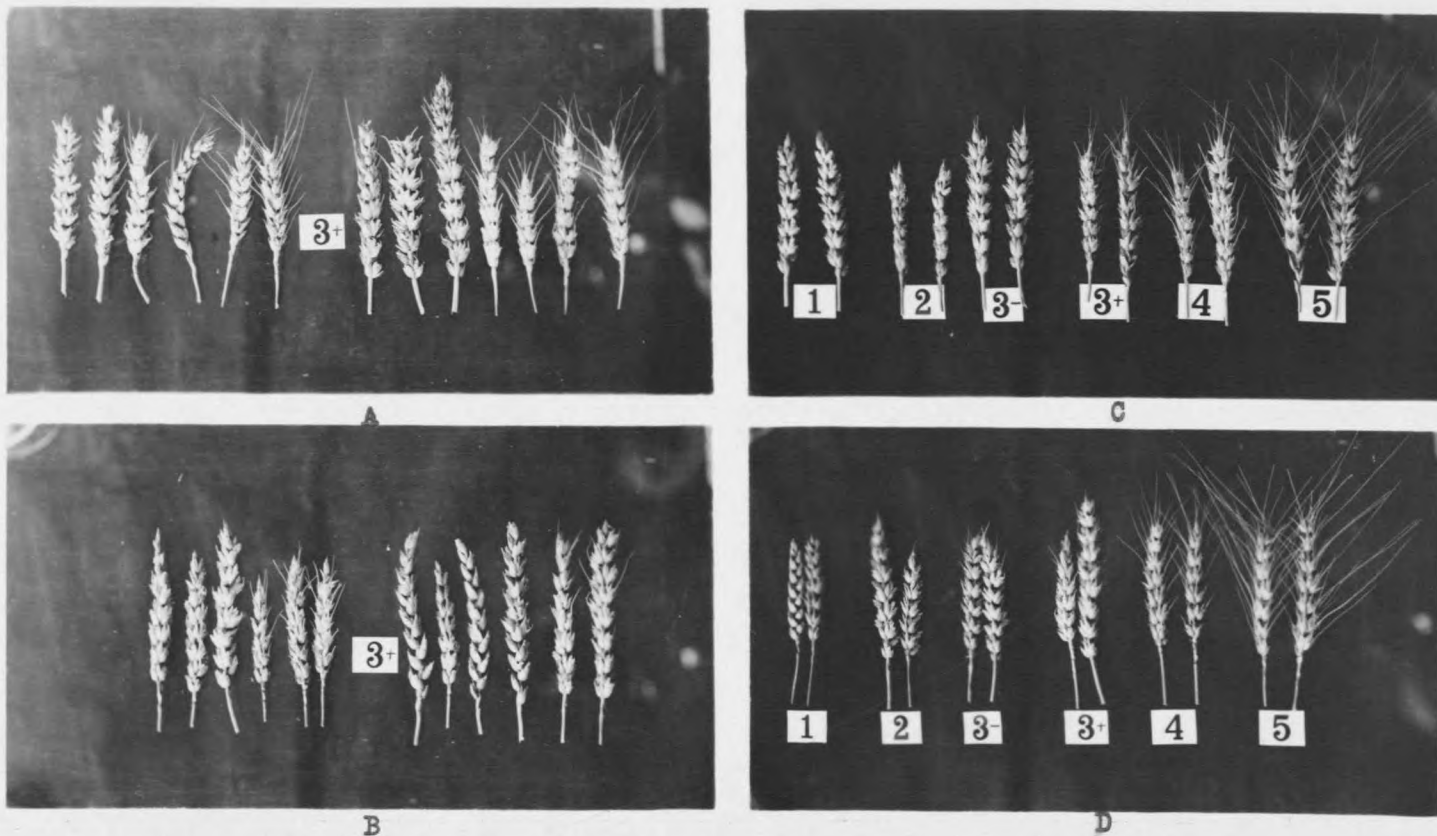


Figure 2. Awn types found in progeny of Reliance-Reward x Comet-(Hussar-Hard Federation) and Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence): A and B, variations in awnedness from each of two plants classed as 3+ awn types from the two crosses, respectively; C and D, representative spikes from the two crosses, respectively, 1, awnless; 2, apically awnletted; 3-, weakly awnletted; 3+, strongly awnletted; 4, half awned; and 5, awned.

Table IV Breeding behavior in the F<sub>3</sub> generation for the six awnness classes in the cross Reliance-Reward x Comet-(Husar-Hard Federation) grown at Bozeman, Montana in 1937

F <sub>2</sub> classes and their breeding behavior in the F <sub>3</sub> generation *	F <sub>2</sub> lines		Number of F <sub>3</sub> plants by awnness classes						Percentages of F <sub>2</sub> plants Calculated on		
	Number	Per cent of total	1	2	3-	3+	4	5	Total	Observ- ed	2-factor basis
			Number of F <sub>3</sub> plants by awnness classes								
<b>1, awnless</b>											
<u>True breeding for 1</u>											
1 and 2	3	3	74	21					95		
1 and 2	2	2	24	65					89		
<b>Total</b>	<b>5</b>	<b>5</b>	<b>98</b>	<b>86</b>					<b>184</b>	<b>5</b>	<b>6.25</b>
<b>2, apically awnletted</b>											
<u>segregating for 1, 2, and 3-</u>											
1, 2 and 3-	3	3	46	32	28				106		
1, 2, 3-, 4, and 5	1	1	15	14	2		1	1	33		
1, 2, and 3-	2	2	22	42	31				95		
1, 2, 3-, and 3+	1	1	13	18	9	1			41		
1, 2, and 3-	6	6	33	69	110				212		
1, 2, 3-, 4, and 5	1	1	7	8	39		1	1	56		
1, 2, 3-, and 5	2	2	13	32	39			2	86		
<b>Subtotal</b>	<b>16</b>	<b>16</b>	<b>149</b>	<b>215</b>	<b>258</b>	<b>1</b>	<b>2</b>	<b>4</b>	<b>629</b>	<b>16</b>	<b>12.50</b>

Table IV (continued)

F <sub>2</sub> classes and their breeding behavior in the F <sub>3</sub> generation *	F <sub>2</sub> lines		Number of F <sub>3</sub> plants by awnedness classes							Percentages of F <sub>2</sub> plants Calculated on Observ- 2-factor ed basis	
	Number	Per cent of total	1	2	3-	3+	4	5	Total	ed	basis
segregating for 1, 2, and 3+											
1, 2, 3-, and 3+	2	2	19	15	9	18			61		
1, 2, 3-, 3+, and 4	1	1	9	8	6	5	4		32		
1, 2, 3-, and 3+	3	3	15	33	12	18			78		
1, 2, 3-, and 4	1	1	5	13	7	0	6		31		
1, 2, 3-, 3+, and 4	2	2	14	23	14	3	17		71		
1, 2, 3-, and 4	1	1	6	5	14	0	7		32		
1, 2, 3-, 3+, and 4	2	2	15	20	27	4	9		75		
Subtotal	12	12	83	117	89	48	43		380	12	12.50
Total	28	28								28	25.00
3-, weakly awnletted											
segregating for 1, 2, 3-, 3+, 4 & 5											
1, 2, 3-, 3+, 4, and 5	2	2	3	22	15	15	5	8	68		
1, 2, 3-, 3+, and 4	3	3	14	48	21	8	11		102		
1, 2, 3-, 3+, 4, and 5	15	15	41	89	214	73	73	44	534		
1, 2, 3-, and 3+	1	1	1	2	14	8			25		
1, 2, 3-, 3+, and 4	1	1	1	4	8	5	3		21		
2, 3-, 3+, and 4	1	1		2	13	1	2		18		
2, 3-, 3+, 4, and 5	1	1		3	13	8	5	6	35		
1, 3-, 3+, 4, and 5	1	1	2		3	10	5	9	29		
2, 3-, 3+, 4, and 5	1	1		4	9	13	2	6	34		
1, 2, 3-, 3+, 4, and 5	2	2	2	9	22	20	13	24	90		
Subtotal	28	28	64	183	332	161	119	97	956	28	25.00

Table IV (continued)

F <sub>2</sub> classes and their breeding behavior in the F <sub>3</sub> generation *	F <sub>2</sub> lines		Number of F <sub>3</sub> plants by awnedness classes					Percentages of F <sub>2</sub> plants Calculated on			
	Number	Per cent of total	1	2	3-	3+	4	5	Total	Observed	2-factor basis
True breeding 3-											
3-	3	3			108				108		
Subtotal	3	3			108				108	3	6.25
Total	31	31								31	31.25
3+, strongly awnletted											
True breeding for 3+											
3+	4	4				153			153		
3+, 4	1	1				14	13		27		
Subtotal	5	5				167	13		180	5	6.25
segregating for 3-, 3+, and 5											
3-, 3+, and 5	9	9			65	178		94	337		
2, 3-, 3+, and 5	3	3		5	27	46		30	108		
Subtotal	12	12		5	92	224		124	445	12	12.50
Total	17	17								17	18.75

Table IV (continued)

F <sub>2</sub> classes and their breeding behavior in the F <sub>3</sub> generation *	F <sub>2</sub> lines		Number of F <sub>3</sub> plants by awnness classes						Percentages of F <sub>2</sub> plants Calculated on Observ- 2-factor ed basis		
	Number	Per cent of total	1	2	3-	3+	4	5	Total	ed	2-factor basis
4, half awned segregating for 3, 4, and 5											
3+, 4, and 5	4	4				33	64	37	134		
3+, 4, and 5	1	1				24	15	2	41		
3+, 4, and <u>5</u>	3	3				9	33	73	115		
2, 3+, 4, and <u>5</u>	1	1	1			2	13	36	52		
3-, 3+, 4, and <u>5</u>	1	1			2	6	8	16	32		
4, and <u>5</u>	2	2					26	38	64		
Total	12	12	1	2	7 <sup>4</sup>	159	202	438	12	12.50	
5, fully awned True breeding for 5											
5	5	5						197	197		
3-, 4, and <u>5</u>	1	1			1		2	3 <sup>4</sup>	37		
Total	6	6			1		2	231	234	6	6.25
Grand total observed			39 <sup>4</sup>	612	97 <sup>4</sup>	899	338	782	3,999	100	100
Expected if F <sub>2</sub> plants were bulked and selfed			9	12	13	15	6	9			
			) Number calculated		562.5	812.5	375.0	4,000			
					750.0	937.5	562.5				

\* Underlined numbers indicate modal class.

Table V Calculation of Goodness of Fit to a 1:2:2:4:1:1:2:2:1 ratio (A) and a 1:4:5:3:2:1 ratio (B) on a two-factor difference for awnness from a Reliance-Reward x Comet-(Huscar-Hard Federation) spring wheat cross grown at Bozeman, Montana in 1937

$F_2$ classes based on breeding behavior of the $F_3$ and some of the questionable $F_4$ 's	Ratio		o	c	(o-c)	(o-c) <sup>2</sup>	$\frac{(o-c)^2}{c}$
	A	B					
1, breeding true	1	1	5	6.25	1.25	1.5625	.2500
2, segregating for 1,2, and 3-; ratio 1:2:1	2		16	12.50	3.50	12.2500	.9800
2, segregating for 1,2, and 3+; ratio 1:2:1	2		12	12.50	0.50	.2500	.0200
Total		4	28	25.00	3.00	9.0000	.3600
3-, segregating for 1,2,3-,3+,4, and 5; ratio 1:4:5:3:2:1	4		28	25.00	3.00	9.0000	.3600
3-, breeding true	1		3	6.25	3.25	10.5625	1.6900
Total		5	31	31.25	0.25	.0625	.0020
3+, breeding true	1		5	6.25	1.25	1.5625	.2500
3+, segregating for 3-,3+, and 5; ratio 1:2:1	2		12	12.50	0.50	.2500	.0200
Total		3	17	18.75	1.75	3.0625	.1633
4, segregating for 3+,4, and 5; ratio 1:2:1	2	2	12	12.50	0.50	.2500	.0200
5, breeding true	1	1	7	6.25	0.75	.5625	.0900
Grand total	16	16	100	100.00			

Df 5  $\chi^2$  of .8853 P = between 0.90 - 1.00  
Df 7  $\chi^2$  of 3.6800 P = between 0.90 and 0.80

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follows:

- I strains of awn class 1 or 2 that have a mode of class 1 or class 2 plants and breed true or within the limits of class 1 and 2;
- II strains of class 2 that have a mode of class 1, class 2, or class 3- plants and segregate for classes 1, 2, and 3-;
- III strains of class 2 that have a mode of class 1, class 2, and class 3- plants and segregate for classes 1, 2, 3-, 3+ and 4, or at least 4 of them;
- IV strains of class 3- that segregate for classes 1, 2, 3-, 3+, 4 and 5, or at least five of them;
- V strains of class 3- that breed true;
- VI strains of class 3+ or have a mode of class 3+ and do not breed beyond the limits of class 3+ and 4;
- VII strains of class 3+ that segregate for classes 3-, 3+ and 5, or have a mode of class 3+ plants with only a few class 2 plants;
- VIII strains of class 4 that segregate for classes 3+, 4 and 5 and have a mode of class 3+, class 4, or class 5 plants with only a few class 2 and class 3- plants; and
- IX strains of class 5 that breed true or within the limits of classes 4 and 5.

Table III shows the number of plants in each awnness class in each of the 9 groups.

In group I there were 86 plants in 16<sup>4</sup> that were classified as of class 2. In group IV, which should segregate as in the F<sub>2</sub> generation, there were more class 3- than class 2 plants. In all the other groups there was considerable overlapping but the range in these groups was more or less definite. Probably the greatest variation within a group was in III; however, the segregation usually was never beyond class 4. The plants which were placed in class 4 closely resembled the 3+ types.

The results of these studies indicate the presence of two major factors for awn development. It is assumed that the awned Reliance x Reward parent is aabb, and the awless Comet x Hussar-Hard Federation parent is AABb. On this basis the phenotypic class, general breeding behavior, and genotypic groups may be indicated as follows:

Phenotypic class, breeding behavior, and genotypic groups	Groups
Class 1, awless 1 AABb - Breeding true	I
Class 2, apically awnletted 2 AABb - Segregating for class 1, 2, and 3- 2 AaBb - Segregating for class 1, 2, and 3+ 4	II III
Class 3-, weakly awnletted 4 AaBb - Segregating as in F <sub>2</sub> for classes 1, 2, 3-, 3+. 4 and 5 1 Aabb - Breeding true 5	IV V
Class 3+, strongly awnletted 1 AABb - Breeding true 2 Aabb - Segregating for 3-, 3+ and 5 3	VI VII
Class 4, half awned 2 aaBb - Segregating for 3+, 4, and 5	VIII
Class 5, fully awned 1 aabb - Breeding true	IX

On this genetic interpretation the goodness of fit for both the 6 phenotypic classes and 9 genotypic groups, which is based on the calculated numbers for two major genetic factors, is shown in Table V. The expected 1:4:5:3:2:1 phenotypic ratio for the six awnedness classes was very closely approached in the observed data. The *F* value for goodness

of fit between the observed and calculated data is between 0.95 and 0.90. The P value between 0.90 and 0.80 for the 1:2:2<sup>4</sup>:1:1:2:2:1 genotypic ratio indicates that a worse fit, due to chance alone might be expected 80 to 90 times in a hundred trials. It would seem, therefore, that two major genetic factors satisfactorily explains the inheritance of awnedness in this cross. Although it is recognized that some of the variability observed may be caused by minor factors, it has been impossible to prove the interaction of an additional genetic factor or factors because of the effect of uncontrolled variation caused by environment.

Tremendous variations in type of awns on different heads were found within plants of various genotypes from this cross. In Figure 2A is shown the variation in types observed in plants which indicates a range of awn expression from about 3+ to 5. Similar variations were found in less awned types. Frequently heads from a single plant were found having awns of more than one class. The presence of these variations may account for some of the segregating types which were not inherently different from each other.

To further the investigation of awnedness in the Reliance-Reward x Comet-(Hussar-Hard Federation) cross various crosses were made. These were made to determine whether the awn-group classification as made was correct. The following crosses, giving the  $F_1$  phenotypic awn expression and the  $F_2$  breeding behavior for those combinations with the modal classes underlined, were made as follows:

Cross	F <sub>1</sub> pheno- type	F <sub>2</sub> breeding behavior for awnness classes					
		1	2	3-	3+	4	5
Parent 1 awn type x Parent 5 awn type	3-	+	+	±	+	+	+
Progeny 1 awn type x Progeny 5 awn type	3-	+	+	±	+	+	+
Progeny 3- awn type x Parent 5 awn type	3+			+	±		+
Progeny 3+ awn type x Parent 5 awn type	3+ - 4			+	±		+
Progeny 3+ awn type x Progeny 3- awn type	3-			+	+		

Photographs of the various F<sub>1</sub>'s obtained in these crosses are given in Figures 3A, B, C, D, and E. Figure 3A shows a number of heads which are representative of the F<sub>1</sub>'s obtained in the parent 1 awn type x parent 5 awn type; 3B, the F<sub>1</sub> of the progeny 1 awn type x progeny 2 awn type; 3C, the F<sub>1</sub> of the progeny 3- awn type x progeny 3+ awn type; 3D, the F<sub>1</sub> of the progeny 3- awn type x parent 5 awn type; and, 4E, the F<sub>1</sub> of the progeny 3+ awn type x parent 5 awn type. The four types listed, namely: awn types, 1, 3-, 3+, and 5, were the only types used in crossing since these were the true-breeding types observed in the F<sub>3</sub>. A few true-breeding apically awn-letted (awn type 2) and half awned (awn type 4) were observed in the F<sub>4</sub>, but no crosses were made using these as parents.

Although comparatively small populations were grown in each case, an indication of the segregation of each group was obtained. These segregations were of prime importance, since this would indicate how the various phenotypes would segregate in later generations.

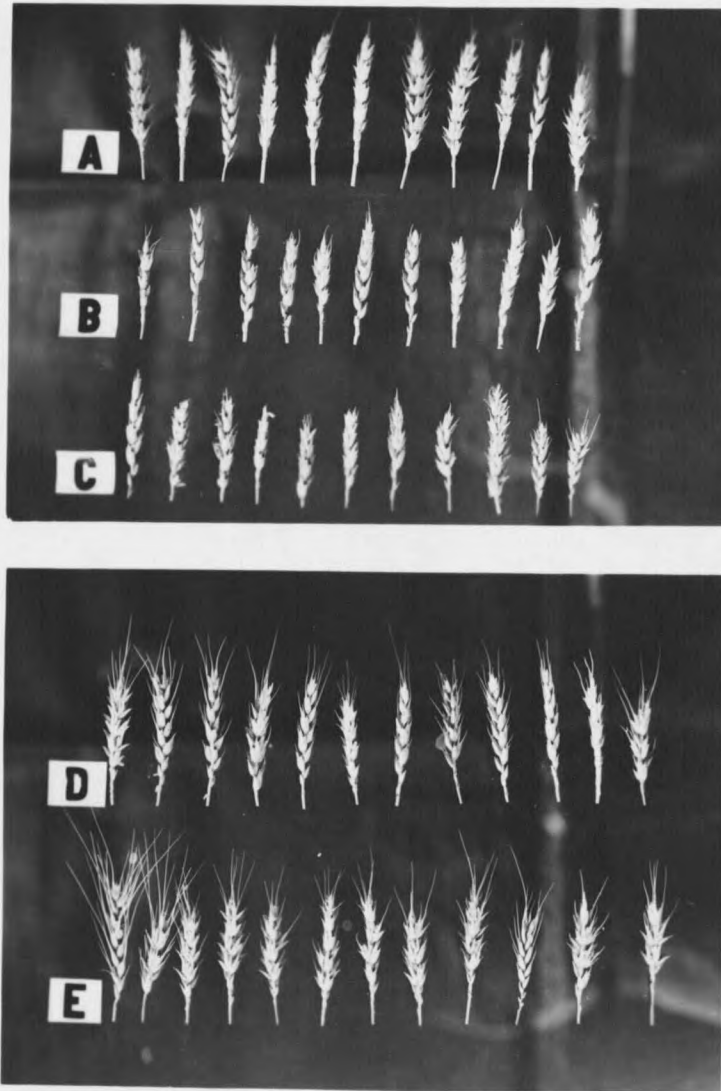


Figure 3 F<sub>1</sub> awn types in Reliance-Reward x Comet- (Hussar-Hard Federation): A, parent 1 awn type x parent 5 awn type; B, progeny 1 awn type x progeny 5 awn type; C, progeny 3- awn type x progeny 3+ awn type; D, progeny 3- x parent 5 awn type; and E, progeny 3+ x parent 5 awn type

In the Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence) cross only the inheritance of awnness was studied. The experimental design and plan of study was the same as that for the previous cross. In this cross one of the parents was fully awned, and the other parent had a few individuals present which possessed apical beaks of about 2 mm. in length. The data obtained on the various  $F_3$  lines are presented in Table II. A photograph of a representative specimen of each of the six awned classes from this cross is given in Figure 2D.

This material proved to be quite variable, but not as much as the Reliance-Reward x Comet-(Hussar-Hard Federation) which showed 38 different types of segregation. This cross showed only 21 different segregating types with 9 outstanding major breeding groups predominating, which are listed in Tables VI and VII. The modal classes in each case are indicated by underlined numbers in Table VII. They are arranged in the order of length of awns, and totals are drawn after groups not regarded as inherently different. Several of these types apparently do not differ inherently from the others. Variation within the groups may be due either to the effect of a minor genetic factor or to environment. It seems reasonable to assume that a minor factor may cause some of this variability since some of the awnless parent plants had awnlets at the tip of the spikes and one of the awnless segregates had no awn types beyond the limits of awn type 1.

Allowing for overlapping of the classes, the material was separated into nine groups (Tables VI and VII) as follows:

Table VI Number of  $F_3$  plants in each awnness class in the nine  $F_3$  breeding groups of the 100 lines of Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence)

$F_3$ breeding groups	Number of $F_3$ plants in awnness class No.						Total
	1	2	3	4	5	6	
I	301	27	2				330
II	133	291	162				586
III	143	288		150	3		584
IV	101	777	162	372	189	104	1,705
V			445		1		446
VI				433	10	2	445
VII		4	194	384		179	761
VIII				130	278	153	561
IX				1		351	352
Total	678	1,387	965	1,470	483	789	5,772

Table VII Breeding behavior in the  $F_3$  generation for the six awnedness classes in the cross Comet-(Russet-Hard Federation) x Ceres-(Hope-Florence) grown at Bozeman, Montana in 1938

$F_2$ classes and their breeding behavior in the $F_3$ generation *	$F_2$ lines		Number of $F_3$ plants by awnedness classes						Percentages of $F_2$ plants Calculated on		
	Number	Per cent of total	1	2	3-	3+	4	5	Total	Observ- ed	2-factor basis
<b>1, awnless</b>											
<u>True breeding for 1</u>											
$\frac{1}{1}$	1	1	52						52		
$\frac{1}{1}$ and 2	4	4	197	19					216		
$\frac{1}{1}$ , 2, and 3-	1	1	52	8	2				62		
<b>Total</b>	<b>6</b>	<b>6</b>	<b>301</b>	<b>27</b>	<b>2</b>				<b>330</b>	<b>6.00</b>	<b>6.25</b>
<b>2, apically awnletted</b>											
<u>segregating for 1, 2, and 3-</u>											
1, 2, and 3-	9	9	124	259	143				526		
1, 2, 3-, and 4	1	1	9	32	19		2		62		
<b>Subtotal</b>	<b>10</b>	<b>10</b>	<b>133</b>	<b>291</b>	<b>162</b>		<b>2</b>		<b>585</b>	<b>10.00</b>	<b>12.50</b>
<u>segregating for 1, 2, and 3+</u>											
1, 2, and 3+	7	7	102	202		103			407		
1, 2, 3+ and 4	3	3	41	86		47	3		177		
<b>Subtotal</b>	<b>10</b>	<b>10</b>	<b>143</b>	<b>288</b>		<b>150</b>	<b>3</b>		<b>584</b>	<b>10.00</b>	<b>12.50</b>

Table VII (continued)

F <sub>2</sub> classes and their breeding behavior in the F <sub>3</sub> generation *	F <sub>2</sub> lines		Number of F <sub>3</sub> plants by awnness classes							Percentages of F <sub>2</sub> plants Calculated on Observ- 2-factor ed basis	
	Number	Per cent of total	1	2	3-	3+	4	5	Total	ed	basis
segregating for 1, 2, 3-, 3+, 4 & 5											
1, 2, 3-, 3+, 4, and 5	27	27	97	705	147	325	175	96	1,545		
1, 2, 3-, 3+, and 5	1	1	3	24	4	19		5	55		
1, 2, 3-, 3+, and 4	1	1	1	28	5	14	5		53		
2, 3-, 3+, 4, and 5	1	1		20	6	14	9	3	52		
Subtotal	30	30	101	777	162	372	189	104	1,705	30.00	25.00
Total	50	50								50.00	50.00
<u>3- weakly awnletted</u>											
3-	7	7			387				387		
3-, and 4	1	1			58		1		59		
Total	8	8			445		1		446	8.00	6.25
<u>3+, strongly awnletted</u>											
True breeding for 3+											
3+	3	3				167			167		
3+, and 4	4	4				213	9		222		
3+, 4, and 5	1	1				53	1	2	56		
Subtotal	8	8				433	10	2	445	8.00	6.25

Table VII (continued)

F <sub>2</sub> classes and their breeding behavior in the F <sub>3</sub> generation *	F <sub>2</sub> lines		Number of F <sub>3</sub> plants by awnedness classes							Percentages of F <sub>2</sub> plants Calculated on Observ- 2-factor ed basis	
	Number	Per cent of total	1	2	3-	3+	4	5	Total	ed	basis
segregating for 3-, 3+, and 5											
3-, 3+, and 5	12	12		175	353		172	700			
2, 3-, 3+, and 5	1	1	4	19	31		7	61			
Subtotal	13	13	4	194	384		179	761	13.00	12.50	
Total	21	21							21.00	18.75	
4, half awned segregating for 3+, 4, and 5											
3+, 4, and 5	10	10			130	278	153	561			
Total	10	10			130	278	153	561	10.00	12.50	
5, fully awned True breeding for 5											
5	5	5					284	284			
3+ and 5	1	1			1		67	68			
Total	6	6			1		351	352	6.00	6.25	
Grand total observed	100	100	678	965	483			5,772	100.00	100.00	
Expected if F <sub>2</sub> plants were)				1,387	1,470		789				
bulk and selfed ) Ratio			9	16	9	15	6	9			
) Number calculated		511.8		511.8	541.2		5,772.8				
			1,443.2	1,353.0	511.8						

\* Underlined numbers indicate modal class

- I strains of class 1, 2, or 3- that have a mode of class 1 plants and breed true or within the limits of classes 1 and 2 with only a few class 3- plants;
- II strains of class 2 that have a mode of class 2 and segregate for classes 1, 2, and 3-;
- III strains of class 2 awn type that have a mode of class 2 and segregate for classes 1, 2, and 3+;
- IV strains of class 2 awn type that have a mode of class 2 and segregate for classes 1, 2, 3-, 3+, 4, and 5, or at least five of them;
- V strains of class 3- that breed true;
- VI strains of class 3+ that breed true, or have a mode of class 3+ plants with only a few of class 4 and class 5 plants;
- VII strains of class 3+ that segregate for classes 3-, 3+, and 5 with a mode of class 3+ plants;
- VIII strains of class 4 that have a mode of class 4 plants and segregate for classes 3+, 4, and 5; and
- IX strains of class 5 that breed true.

The number of plants in each awnness class in each of the nine breeding groups is shown in Table VI.

In Group I 27 plants in 330 were classified into class 2 and two into class 3-. One line of 52 plants was observed which showed no overlapping into the class 2 type. In no other group with a possible exception of Group VI (true breeding 3+) was there very much overlapping of classes. There seems to be an overlapping of the 3+ type into type 4. This might be expected since some plants had heads with types varying from 3+ to 5. This is clearly shown in Figure 2B.

In Table VII is given the breeding behavior by groups based upon the six awned classes of the 100 F<sub>3</sub> lines. The F<sub>2</sub> genotypes were determined

by the breeding behavior of the  $F_3$ .

The results of these studies indicate that two major factors are present which influence the development of awns. It is assumed that the awnless Comet x Hussar-Hard Federation parent is AAbb, and the awned Ceres x Hope-Florence parent is aabb. On this basis the general breeding behavior and genotypic groups may be assumed to be the same as in the previous cross studied.

The goodness of fit, based on the calculated numbers for two genetic factors on both 9 genotypic and 6 phenotypic classes, is shown in Table VIII. The agreement is good throughout. The P value for the expected genotypic ratio 1:2:2:4:1:1:2:2:1 compared with the observed was between 0.70 and 0.80. The P value for the calculated phenotypic ratio 1:8:1:3:2:1 compared to the observed data was much higher, being between 0.80 and 0.90. In either case the P value is high and a worse fit, due to chance alone, might be expected to occur on an average of 80 times in 100 trials. It would seem, therefore, that two genetic factors satisfactorily explain the inheritance of awnedness in this cross. In this cross as in the former minor factors may have played a role in awn development, but because of the effects of uncontrolled variation caused by environment it was impossible to prove the presence of such factors.

In a few lines there were plants which were widely different in awn type from what might have been expected in that inheritance group. These few widely divergent types may have been due to cross fertilization in the previous generation as it is known that some cross fertilization does occur in wheat.  $F_3$  plants resulting from cross-fertilization could and would be

Table VIII Calculation of Goodness of Fit to a 1:2:2:4:1:1:2:2:1 ratio (A) and a 1:8:1:3:2:1 ratio (B) on a two-factor difference for awnness from a Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence) spring wheat cross grown at Bozeman, Montana in 1938

F <sub>2</sub> classes based on breeding behavior of the F <sub>3</sub> generation	Ratio		Observed	Calculated on 2-factor difference			$\frac{(o-e)^2}{e}$
	A	B		o-e	(o-e) <sup>2</sup>	c	
1, breeding true	1	1	6	6.25	.25	.0625	0.01
2, segregating for 1, 2, and 3-; ratio 1:2:1	2		10	12.50	2.50	6.2500	.50
2, segregating for 1, 2, and 3+; ratio 1:2:1	2		10	12.50	2.50	6.2500	.50
2, segregating for 1, 2, 3-, 3+, 4, and 5; ratio 1:8:1:3:2:1	4		30	25.00	5.00	25.0000	1.00
Total		8	50	50.00	0.00	0.0000	0.00
3-, breeding true	1	1	8	6.25	1.75	3.0625	.49
3+, breeding true	1		8	6.25	1.75	3.0625	.49
3+, segregating for 3-, 3+, and 5; ratio 1:2:1	2		13	12.50	.50	.2500	.02
Total		3	21	18.75	2.25	5.0625	.27
4, segregating for 3+, 4, and 5; ratio 1:2:1	2	2	10	12.50	2.50	6.2500	.50
5, breeding true	1	1	5	6.25	1.25	1.5625	.25
Grand total	16	16	100	100.00			

Df 7  $\chi^2$  for Ratio A = 3.76

Df 5  $\chi^2$  for Ratio B = 1.52

P = very high for ratio designated

P = very high for ratio designated

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most conspicuous in Groups I, III, VI, VII, and IX, and it is in these groups that the deviations are seen. A few deviations may be due to mixtures, but some deviations (Groups I and VI) occur too frequently to be classed as mixtures or the result of cross-fertilization. This range is probably caused by a minor modifying factor and its action can be noticed only in these groups.

#### Kernel Color

Since the parents in the Reliance-Reward x Comet-(Hussar-Hard Federation) cross differed in intensity of redness of seed color, the seed of the individual heads from the plants in the 100  $F_3$  lines were classified for seed color into the classes: dark, intermediate, and light red. The seed of the Reliance x Reward parent was much darker red than the other parent. In the  $F_3$  lines three breeding types appeared among the progeny, namely: (1) lines in which only light and intermediate red-seeded plants were found, and (2) lines in which there were found dark, intermediate, and light red-seeded plants. Since the light red-seeded parent had both light and intermediate types and the dark red parent had some intermediate types, it was thought justifiable to class an  $F_3$  line as breeding like the light parent, if it possessed only light- and medium-redkerneled plants, and like the dark red parent, if only dark and intermediate types were found.

The original data on classification for kernel color is given in Table I. The breeding behavior of twenty-eight  $F_3$  lines was like the light red parent for kernel color; twenty-six bred like the dark red parent,

while the remainder, or 46 lines, segregated for all three types. Totaling the plants for the 46 segregating lines there were obtained 357 dark red: 846 intermediate red: 415 light red as compared to an expected of 405.5 dark red: 809 intermediate red: 404.5 light red.

Calculating Chi-square for goodness of fit for kernel color on a single-factor difference, 1:2:1 ratio, on the 100 F<sub>3</sub> lines shows the observed number to be very close to the expected which is given in Table IX. The P value for goodness of fit between the observed and calculated data is between 0.70 and 0.50.

Table IX Calculation of Goodness of Fit on a one-factor difference for kernel color in the F<sub>3</sub> generation of Reliance-Reward x Comet-(Hussar-Hard Federation) grown at Bozeman, Montana in 1937

Class	Observed	Calculated on 1:2:1 ratio	o-c	(o-c) <sup>2</sup>	$\frac{(o-c)^2}{c}$
Seg. for 1:2:1 of dark: int: light	46	50	-4	16	.32
True breeding for light color	28	25	+3	9	.36
True breeding for dark color	26	25	+1	1	.04
Total	100	100			

Df 2  $\chi^2$  of 0.72 P = between 0.70 and 0.50

### Glume Pubescence

Since the parents differed in glume pubescence, the 100  $F_3$  lines of Reliance-Reward x Comet-(Hussar-Hard Federation) provided excellent material for a study of the inheritance of this character. The data on the breeding behavior of each line are given in Table I. Three breeding groups appeared in the progeny, namely: (1) true breeding for glabrous glumes, (2) true breeding pubescent types, and (3) those segregating for glabrous and pubescent glumes.

In a few of the  $F_3$  lines abnormal ratios appeared. For instance, in some families 1 or 2 plants were pubescent and the remainder glabrous. Warwick's (1932) Tables of Probabilities were used as a basis for classifying these lines into either the segregating or true-breeding group.

The data obtained show a close fit to a 1:2:1 ratio which may be explained by a single genetic factor difference with the pubescent condition dominant to glabrous. Twenty-four  $F_3$  lines bred true for pubescent glumes; twenty-one bred true for glabrous glumes; while fifty-five segregated for pubescent and glabrous glumes in a 3:1 ratio. In the fifty-five segregating lines there were obtained 1319 pubescent and 442 glabrous plants as compared to the expected number of 1320.75 pubescent and 440.25 glabrous types.

It was thought advisable to test the observed number of breeding types with the calculated number. The calculated P value for goodness of fit is shown in Table X. The P value was determined to be between 0.50 and 0.70 which is a close fit to a 1:2:1 ratio. The discrepancies between the observed and calculated ratios can be assumed to be due to

chance and not to some other genetic cause.

Table X Calculation of Goodness of Fit for inheritance of glume pubescence on a single-factor difference in 100 F<sub>3</sub> lines of Reliance-Reward x Conet-(Hussar-Hard Federation) grown at Bozeman, Montana in 1937

Breeding behavior for glume pubescence	Observed	Calculated	o-c	(o-c) <sup>2</sup>	$\frac{(o-c)^2}{c}$
Segregation for pubescent and glabrous glumes; ratio 3:1	55	50	5	25	.50
True breeding for pubescent glumes	24	25	1	1	.04
True breeding for glabrous glumes	21	25	4	16	.64
Total	100	100			

Df 2  $\chi^2$  of 1.18 P = between 0.70 and 0.50

#### Bunt Reaction

Although this experiment was designed to be an inheritance study, the results obtained can not be interpreted in that light. Instead of determining the reaction of the 100 F<sub>3</sub> lines to each of the two physiologic races of bunt, as is necessary in a genetic study, a composite of the inoculum was used. Various workers have concluded that it is essential to work with single physiologic races rather than with a composite of several to study the inheritance of resistance to bunt. The reaction of several races composited is much different than when races are acting on the host individually. This probably accounts for the complexity of the

inheritance of reaction to bunt in early investigations. More recent work has shown the inheritance of resistance to bunt to be less complex than was indicated by some of the early investigations.

Percentages of infection by bunt for the parents and 100  $F_3$  lines of the Reliance-Reward x Comet-(Hussar-Hard Federation) cross are given in Table I. The range of the Reliance x Reward parent for bunt infection was from 12.2 per cent to 23.9 per cent with an average of 16.2 per cent. The other parent Comet x Hussar-Hard Federation showed more resistance and a much narrower range of susceptibility, the range being from 2.6 to 5.1 per cent infection with an average of 4.0 per cent. The range of the  $F_3$  progeny extended beyond the limits of either the resistant or susceptible parent. Six of the  $F_3$  lines averaged lower infection than the lower limit of the resistant parent. The most resistant  $F_3$  progeny line averaged 0.8 per cent bunt, while the most susceptible line showed 35.7 per cent bunt. Five lines were more susceptible to the composite than the susceptible parent. Forty-two lines averaged bunt infection between the lower limit of the more susceptible parent and upper limit of the more resistant parent.

The standard deviation for percentage of bunt for each of the parents was calculated by the formula  $\sqrt{\frac{\sum d^2}{N-1}}$ . From this the probable error was obtained by multiplying the standard deviation by 0.6745. By the use of this method the P.E. of Reliance x Reward was calculated to be  $\pm 3.4$  giving a class range of 12.8 per cent to 19.6 per cent. The P.E. of Comet x Hussar-Hard Federation was calculated to be  $\pm 0.7$ , giving a class range of 3.3 per cent to 4.7 per cent. From these calculations the classes were determined, i.e., those  $F_3$  lines which would

fall within the smut percentages of 12.8 per cent and 19.6 per cent might be expected to breed the same as the Reliance x Reward parent, and those falling within the range of 3.3 per cent and 4.7 per cent might be expected to react like the more resistant parent. Consequently, the lines giving percentages of bunt below 3.3 per cent were classed as being more resistant than the resistant parent. Those lines falling between the upper limit (4.7 per cent) of the group breeding like the resistant parent and below the lower limit (12.8 per cent) of those breeding like the susceptible parent are classed as intermediates and comprise the class 4.8 per cent to 12.7 per cent bunt infection. Since 19.6 per cent is the upper limit of the class for those breeding like the susceptible parent all the lines which are showing bunt percentages of 19.7 and above are classed as being more susceptible than the susceptible parent. Thus the 5 bunt classes were as follows:

0 - 3.2 per cent	Class Midpoint at 1.6 per cent
3.3 - 4.7 per cent	Class Midpoint at 4.0 per cent
4.8 - 12.7 per cent	Class Midpoint at 8.75 per cent
12.8 - 19.6 per cent	Class Midpoint at 16.2 per cent
19.7 - 35.7 per cent	Class Midpoint at 27.7 per cent

Using these bunt classes, the parent reaction in percentage of bunted plants, the number of rows of each parent, and the segregation in the Reliance-Reward x Comet-(Hussar-Hard Federation) cross as shown by the average of the  $F_3$  hybrid strains, are shown in Table XI, and graphically in Figure 4.

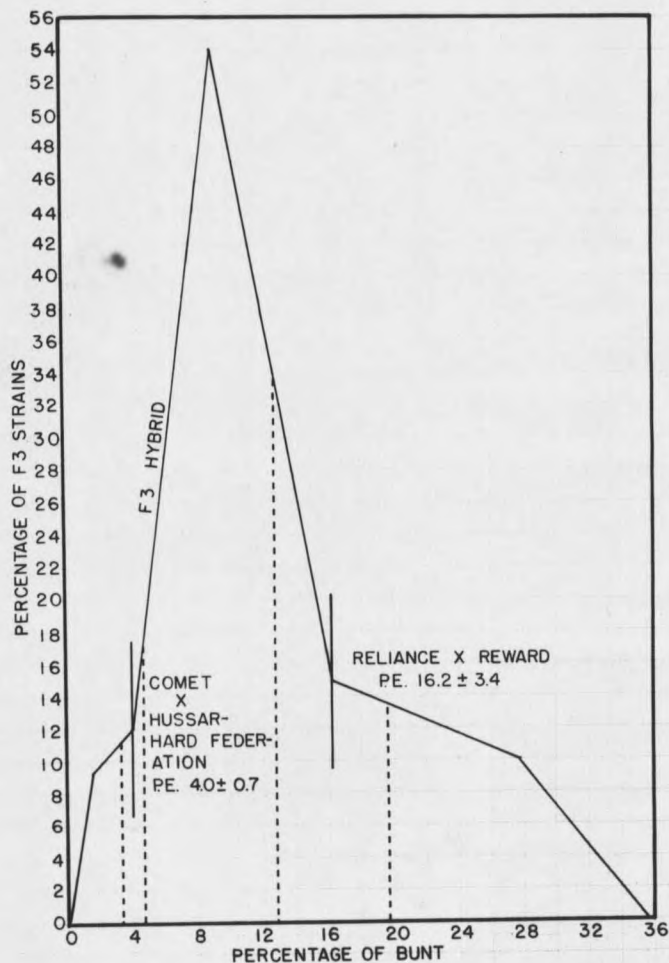


Figure 4 Frequency distribution of the average percentage of bunted plants when inoculated with a composite of races of T-8 and L-7 of *Tilletia* in parents and progeny of Reliance-Reward x Comet-(Hussar-Hard Federation)

Table XI Percentages of bunted wheat plants in rows of Reliance x Reward and Comet x Hussar-Hard Federation parents and  $F_3$  hybrid strains of the cross grown at Bozeman, Montana in 1937

Classes in per cent bunt	<u><math>F_3</math> hybrid</u>		<u>Reliance x Reward</u>		<u>Comet x Hussar- Hard Federation</u>	
	Number	Per cent	Number	Per cent	Number	Per cent
0-3.2	9	9			2	33.3
3.3-4.7	12	12			2	33.3
4.8-12.7	54	54	3	50.0	2	33.3
12.8-19.6	15	15	1	16.6		
19.7-35.7	10	10	2	33.3		
Total	100	100	6	99.9	6	99.9

The hybrids segregated beyond the limits of the parents. Twelve of the 100 strains had a bunt reaction similar to that of the Comet x Hussar-Hard Federation parent. At the other end of the curve there were 15 strains within the limits of the Reliance x Reward parent. Considering the five classes for bunt which were formed on the basis of the breeding behavior of the parents toward the composite inoculum of the two races the number of families in each class would be as follows:

- 9 more resistant than the resistant parent
- 12 like the resistant parent
- 54 intermediate between the two parents
- 15 like the susceptible parent
- 10 more susceptible than susceptible parent

### Linkage Studies

Linkage studies have been made in certain phases of genetics, and many linkage groups have been determined in numerous crop plants. Comparatively few cases of linkage have been reported in wheat crosses. A few investigators studying linkage have been cited by Hayes and Garber (1934). Some of them mentioned are Biffen, Engledow, Gaines and Carstens. It is always of value and of interest to the plant breeder to know whether a character is linked with another, in that good agronomic qualities may be linked with other good or poor characters. Consequently, certain good agronomic qualities may be transferred with ease or difficulty depending on the strength of the linkage of the other factors.

In this study the data on the three characters, awnedness, kernel color and glume pubescence, are compared with the data on smut resistance in order to determine whether or not there is linkage between the factors controlling these various characters. Contingency tables were prepared to compare the various characters to determine whether or not the factors determining the characters are linked. Chi-square and P values obtained in each comparison of characters are as follows:

Characters	Chi-square value	Degrees of freedom	P value	Conclusions
Awnedness vs. glume pubescence	13.847	16	0.50-0.70	Indep. Ass'td
Awnedness vs. kernel color	10.976	16	0.80-0.90	do
Awnedness vs. per cent bunt	34.090	32	0.346	do
Glume pubescence vs. kernel color	1.272	4	0.80-0.90	do
Glume pubescence vs. per cent bunt	5.829	8	0.50-0.70	do
Kernel color vs. per cent bunt	16.617	8	0.05-0.02	Poss. Linkage

Calculation of independence by Fisher's (1936) method was employed to obtain the Chi-square value when comparing the observed with the calculated number. The P value was obtained after the Chi-square value and degrees of freedom were determined. In Fisher's (1936)  $\chi^2$  Table, "n" has not been calculated beyond 30. Since the degrees of freedom between awnedness and per cent bunt was 32, Fisher's method of obtaining a good approximation of P was employed. He assumed that  $(2\chi^2 - 2\sqrt{2n-1})$  is normally distributed about zero with unit deviation. If the resulting quantity obtained is greater than two, the value of  $\chi^2$  is not in accordance with the expected. In this comparison  $\chi^2$  equals 34.09; substituting in the formula  $(2\sqrt{2\chi^2} - \sqrt{2n-1})$  we have  $(\sqrt{68.618} - \sqrt{64-1})$  or 0.346 for the value of P which is within the expectation for independence.

Very little, if any, relationship exists between awnedness and glume pubescence, awnedness and kernel color, awnedness and bunt per cent, glume pubescence and bunt, and glume pubescence and kernel color, since the obtained results came within expectation for independent assortment. However, some relationship exists between per cent bunt and kernel color, since the progenies are more or less confined to certain bunt classes depending on the color of the kernel.

A comparison of smut resistance and seed color in the 100  $F_3$  progenies is shown in Table XII. In this table it may be observed that the greater number of resistant plants tend to have light red seed and the more susceptible ones to have darker kernels. The nature of this distribution indicates a possible linkage between smut resistance and seed color.

resistance to smut being linked with light color and susceptibility with dark color. The P value was calculated to be between 0.05 and 0.02 which is regarded as not being independent assortment, but indicates at least a weak linkage. In interpreting results it is safe to assume that if the value of P for any distribution is higher than 0.05 there is no evidence of significant correlation between the characters being considered.

Table XII A comparison of smut reaction to composite of T-8 and L-7 smut races with seed color in 100 F<sub>3</sub> lines of Reliance-Reward x Comet-(Hussar-Hard Federation)

Bunt classes	True breeding dark red	Segregating dark, intermediate, and light red kernels	True breeding light red	Total
0 - 3.2 per cent	1	2	6	9
3.3 - 4.7 per cent	2	6	4	12
4.8 - 12.7 per cent	12	26	16	54
12.8 - 19.7 per cent	6	9	0	15
19.7 - 35.7 per cent	5	3	2	10
Total	26	46	28	100

#### DISCUSSION AND CONCLUSIONS

Two crosses Reliance-Reward x Comet-(Hussar-Hard Federation) and Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence) were studied for the inheritance of smedness. Distinct breeding groups were obtained in the 100 F<sub>3</sub> lines studied. In the Reliance-Reward x Comet-(Hussar-Hard Federation) cross rather wide deviations from the expected were obtained.

A number of lines were observed with plants differing from the majority of plants in that line. Comparatively few lines of this type were observed in the second cross studied.

The method of using a single head from a plant to establish the awn type for that plant may account for much of the variation which was observed in the Reliance-Reward x Comet-(Hussar-Hard Federation) cross. Wide variations were found to appear within a single plant. Variations on single plants were found to range from strongly awletted type to completely awned spikes. On plants possessing fewer awns the range was from completely awnless to weakly awletted types. Thus, considerable deviations may appear depending upon the single head selected for classification. Field observations indicate the later culms to have longer awns. The first spikes which appear ordinarily have such shorter awns than do the later heads. Why these later culms possess spikes with longer awns than the earlier spikes has not been determined. Further research on this phase needs to be conducted.

Minor modifying factors may have played an important part in causing these variations within some lines. Apparently the only effect of the minor factors in the presence of the major factors is to reduce the amount of awnedness, as from the strong to the weaker limits of a class. It has been impossible to demonstrate the interaction of an additional genetic factor because of the effect of uncontrolled variation caused by environment. The potency of the minor factor in the Reliance-Reward x Comet-(Hussar-Hard Federation) was apparent, while in the Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence) the effect of minor factors

was less pronounced. Evidence points toward a minor factor being present in the latter cross, since a true breeding completely awnless line was obtained in the  $F_3$ , even though the Comet x Hussar-Hard Federation was not of this type. Parent plants were occasionally found which possessed awnlets up to several millimeters in length and consequently were placed in the apically awnletted class.

Cross fertilization is known to occur in wheat. It has been shown by the work of Leighty and Taylor (1928) that as high as  $3\frac{1}{4}$  per cent may be expected in certain wheats and environments. A few of these widely divergent types may have been due to cross fertilization in the previous generation. In certain groups natural crossing can not be observed but in certain breeding types it is obvious.

Evidently four true breeding awn types can be isolated. These types are apparently due to two major genetic factors (AA and BB) which contribute differently toward the expression of the awns. The final awn expression is dependent upon which factor is or factors are present. It has been shown that there is an imperfect dominance of awnlessness. The awned type is the phenotypic expression of the double recessive of these two factors while the double dominant is the awnless expression. Factor AA when in combination with a double recessive of the other factor for awnedness produces a true breeding weakly awnletted type while the opposite condition, a strain of wheat having the BB factor with the double recessive of the other factor, will produce a strongly awnletted spike. True breeding apically awnletted and half-awned strains of wheat have been known to occur. Some of these true breeding types were observed in the

$F_1$  in the Reliance-Reward x Comet-(Hussar-Hard Federation) cross which again indicates the presence of a minor factor in this cross.

Since the original cross has been made and the  $F_1$  produced, it can be seen in Figure 3A that in the Reliance-Reward x Comet-(Hussar-Hard Federation) cross the  $F_1$  was weakly awletted rather than apically awletted as was apparently found in the other cross studied. All other workers when studying awless x awed crosses have found the  $F_1$  to be apically awletted. Since the  $F_1$  was apically awletted a different phenotypic ratio of 1:4:5:3:2:1 of awless, apically awletted, weakly awletted, strongly awletted, half awed to awed, was obtained. However, in the second cross a phenotypic ratio of 1:8:1:3:2:1 was obtained for the six classes, respectively.

The results on the various crosses involving the parents and progeny of the Reliance-Reward x Comet-(Hussar-Hard Federation) cross confirm the awn-group classification with the exception of the crosses involving the true-breeding segregate belonging to the awn group 3+. Since the 3- and 3+ types were thought to represent different intermediate types, each genetically one-factor removed from either parent, the Reliance x Reward lacking both dominant factors and Comet x Hussar-Hard Federation possessing both dominant factors, it was thought by crossing these two intermediate types the factors would be re-assembled and restore the original parents. In this cross the grand parental types were not restored, but only intermediate progenies were obtained. Also when the 3+ true-breeding segregate was backcrossed with the Reliance x Reward parent (awn type 5), the  $F_1$  was neither a 3+ nor a 4 awn type but approached more nearly the 3+ awn type; a 4 awn type was expected.

From these results it appears that the 3+ progeny plant used in crossing did not possess the factorial composition aabb as was expected if the 3- segregates may be indicated by the factorial formula AAbb. Since this 3+ awn type x 5 awn type cross segregated very similar to the 3- awn type x 5 awn type, and the grand parental types were not restored from the 3- x 3+ awn types plants, it is believed that the difference in awn expression between these intermediates used in this cross is due to a single minor factor or factors. Although the modal classes were of the 3+ type in both of the backcrosses involving the 3- and 3+ to the 5 awn type parent, there was a greater number of plants of the 5 awn type in the 3+ cross than is normally expected in a 1:2:1 ratio.

Since the parents in the Reliance-Reward x (Russar-Hard Federation) differed in intensity of redness of seed color, it was possible to study the inheritance of this character in the 100 F<sub>3</sub> lines. The seed of the Reliance x Reward parent was much darker than those of the other parent. Three breeding groups appeared among the progeny, namely: (1) lines breeding like the dark red parent, (2) lines breeding like the light red parent, and (3) lines segregating for light, intermediate, and dark-red-kerneled plants in a 1:2:1 ratio. Of the one hundred lines, twenty-six bred like the dark parent, twenty-eight bred true for light-red-kerneled plants, and the remaining, or forty-six, lines segregated for kernel color. Of the segregating lines there were 357 dark red: 846 intermediate red: 415 light-red-kerneled plants obtained as compared to the expected of 404.5 dark red: 809 intermediate red: 404.5 light-red-kerneled plants.

The data obtained on the  $F_3$  lines indicate a one-factor difference for intensity of red color between Reliance x Reward and Comet x Hussar-Hard Federation. From these data along with the verification of seed color of the  $F_1$  plant it has been concluded that there is imperfect dominance of redness. Both parents possess factors for red kernel color, the light colored parent possessing at least one factor and the dark-red-kerneled parent possessing at least two. From the results obtained in this study it can be concluded that factorial differences in intensity of color can be observed. This work furnishes further proof or evidence for the explanation of kernel color by Nilsson-Ehle's theory.

The results on glume pubescence substantiate the facts known regarding the inheritance of pubescent and glabrous glumes. These two characters constitute an allelomorphic pair of characters, the pubescent condition being dominant over the glabrous glume and in the  $F_2$  segregate into a 3:1 ratio. This  $F_2$  breeding behavior was established by the  $F_3$  studies. The  $F_3$  data reveal the presence of about equal true breeding and segregating strains. On the basis of a single-factor difference for glume pubescence, 25 are expected to breed true for glume pubescence, 50 to segregate 3:1, and 25 to breed true for glabrous glumes. On this calculated basis the  $P$  value was determined to be between 0.50 and 0.70 which indicates a good fit to the one-factor 1:2:1 ratio.

Data are presented for 100  $F_3$  progenies of Reliance-Reward x Comet-(Hussar-Hard Federation) that have demonstrated various degrees of susceptibility to bunt when inoculated with a composite of physiologic races T-6 and L-7.

Since this experiment was not set up as an inheritance study, the results obtained can not be interpreted in that light. A composite of the two races was used instead of determining the reaction of each race individually to the progeny. It has been shown that the use of composites of a number of races of Tilletia tritici and T. levis is not a reliable method of determining the absolute bunt resistance of varieties. Various factors enter which probably accounts for the complexity of the inheritance of bunt by early investigators. More recent work has shown the inheritance of bunt to be quite simple, probably due to the use of single races for the inoculum rather than a composite.

The range of bunt infection to the composite of the two races for the Reliance x Reward parent was from 12.2 per cent to 23.9 per cent with an average of 16.2 per cent, although it was highly resistant to T-5 and susceptible to race L-7 when tested individually. The other parent showed more resistance to the composite and a much narrower range of susceptibility, the range being from 2.6 to 5.1 per cent infection with an average of 4.0 per cent. This parent, Comet x Hussar-Hard Federation, is resistant to L-7 but susceptible to T-5. The range of the F<sub>3</sub> progeny extended beyond the limits of either the resistant or susceptible parents. Nine of the progeny averaged lower infection than the lower limit of the resistant parent, the most resistant hybrid line averaging 0.5 per cent bunt. There were ten lines more susceptible than the susceptible parent. Fifty-four of the hybrid strains produced an intermediate reaction to the composite bunt, while 12 bred like the resistant parent and 15 bred like the susceptible parent.

It has been demonstrated by various workers that resistance or susceptibility to smut of wheats can be transferred to other varieties. Good agronomic qualities and smut resistance can be combined into a single variety by means of hybridization. In this cross both parents reacted differently to the two races of smut, each variety being resistant to different races. Since lines were obtained in the  $F_3$  which segregated beyond the limits of the resistant parent, it was concluded these strains possessed the factors for resistance to the two races of smut. Nine of these lines averaged less bunt infection than the resistant parent. A number of head selections were made from these resistant lines and grown in the  $F_4$  to determine whether the resistant lines were true breeding or whether they were escapes. These lines demonstrated their immunity by being bunt-free. Thus the near-immune reaction of each parent to the two races individually has been transferred and combined into a single line which was the primary object of making the cross.

In order to determine whether a relationship exists between the various morphological characters and resistance to stinking smut, a series of contingency tables was prepared showing a comparison of the reaction to smut infection and morphological characters. A measure of the relationship between the distribution of the various characters and bunt reaction taken two at a time was obtained by calculating  $\chi^2$  and determining the value of  $P$  from Fisher's (1936) tables. Table XII gives the probabilities obtained in each case. In interpreting the results it was considered safe to assume that if the value of  $P$  for any given distribution is higher than 0.05, there is no evidence of significant correlation between the characters being con-

sidered; however, if the value obtained is below this point, relationship between the characters compared is exhibited.

Only one P value in Table XII is below 0.05. This is between kernel color and smut susceptibility. The remaining comparisons showed no significant correlations, since the lowest P value was above 0.3. Results obtained between awnedness and bunt compare favorably with Ansemas (1934) who found awnedness and bunt independently assorted. Kernel color and awnedness were independently assorted both in these experiments and those conducted by Clark and Hooker (1926).

A comparison of data by Schlehuber (1935) indicated a possible weak linkage between smut resistance and seed color in an Albit x Minhardi cross. Albit, white seeded, is the resistant parent and yet, of the 20 pure red-seeded  $F_3$  progenies, 10 were found to be smut free. No susceptible pure white progenies were discovered, and only four pure whites were obtained. He concluded this number made it impossible to draw any satisfactory conclusions concerning this particular group. The nature of the distribution of the four breeding groups for color in relation to the three smut groups indicated a possible linkage between smut resistance and seed color. The results of Schlehuber are of interest in view of the fact that the results obtained in this study verify his supposition that the dark colored lines or varieties are more susceptible to stinking smut than are the light colored varieties. Apparently a relationship exists between these two characters from the standpoint of inheritance rather than a matter of chance.

SUMMARY

1. Genetic studies on the inheritance of awnedness, kernel color, and glume pubescence, and reaction to two physiologic races of Tilletia are reported on the 100  $F_3$  lines of Reliance-Reward x Comet-(Hussar-Hard Federation).

2. Awnedness was studied and reported on 100  $F_3$  hybrid lines of a second spring wheat cross, Comet-(Hussar-Hard Federation) x Ceres-(Hope-Florence).

3. In both crosses the inheritance of awnedness was studied by grouping the material into the six following classes: (1) awnless, (2) apically awnletted, (3) weakly awnletted, (4) strongly awnletted, (5) half awned, and (6) awned.

4. The expression of awnedness was shown to be rather variable in the Reliance-Reward x Comet-(Hussar-Hard Federation) cross, but by grouping different segregating types a good fit was shown for six phenotypic classes and for nine genotypic groups. Two major factors are clearly shown, with a 1:4:5:3:2:1 phenotypic ratio of awnless, apically awnletted, weakly awnletted, strongly awnletted, half awned, respectively, and a genotypic ratio of 1:2:2:4:1:1:2:2:1 based upon the segregating groups. The  $F_3$  awnedness classification was based upon a single head from each plant.

5. Various crosses were made involving the parents and progeny of the cross Reliance-Reward x Comet-(Hussar-Hard Federation). The  $F_1$  and  $F_2$  results from these crosses indicated the awn-group classification as made was correct.

6. In the second spring wheat cross the expression of awnedness

was based upon an entire plant and was found not as variable as the first cross. By grouping the nine segregating types a good fit was shown for the six phenotypic classes and for the nine genotypic groups. Two major factors are clearly shown, with a 1:5:1:3:2:1 phenotypic ratio for the six awnedness classes and a genotypic ratio of 1:2:2:4:1:1:2:2:1 for the segregating groups.

7. Variation occurs within heads on the same plant relative to awnedness expression. It is considered advisable to use the whole plant for classification rather than a single head to determine the expression of awns upon a plant.

8. A single major factor difference for kernel color was obtained between the Reliance-Reward x Comet-(Hussar-Hard Federation) cross. Both are red wheats, the Reliance-Reward being somewhat darker than the other parent. The  $F_3$  progenies segregated into 26 pure light-red seeded, 26 dark-red seeded, and 46 segregating 1:2:1 dark, intermediate to light red.

9. Pubescent and glabrous characters are expressions of an allelomorphous pair of factors. Pubescent glumes are dominant to glabrous, and in the  $F_3$  generation the deviations in numbers were not significantly different from the simple 1:2:1 ratio in any of the 100  $F_3$  families studied. Twenty-four lines bred true for pubescent glumes; twenty-one bred true for glabrous glumes; and fifty-five segregated for glume pubescence in a 3:1 ratio for pubescent to glabrous.

10. The  $F_3$  genetic studies of awns, kernel color and glume pubescence indicate the genetic constitution of the parent material to be as follows:

Parents	awns	Kernel color	Glume pubescence
Reliance-Reward, N.W. 1388	aabb	-R R R'R'	PbPb
Comet x Hussar-Hard Federation, N.W. 1315	AABB	-R R r'r'	pbpb
Comet x Hussar-Hard Federation, N.W. 1383	AABB		
Ceres x Hope-Florence Sel. 60.4.19	aabb		

11. The probable error for per cent of bunt for each of the parents was calculated, and from these calculations the five different bunt classes were determined, namely: 0-3.2 per cent, 3.3-4.7 per cent, 4.8-12.7 per cent, 12.8-19.6 per cent, and 19.7-35.7 per cent. The 3.3-4.7 per cent class was determined to be like the Comet x Hussar-Hard Federation parent and the 12.8-19.6 per cent class was like the Reliance x Reward parent.

12. Since this experiment was not designed as a genetic study, it was impossible to determine the number of factors responsible for resistance to bunt in this cross.

13. The segregation of the hybrids was beyond the limits of either the resistance or susceptibility of the parents, showing that the resistance to both races T-5 and L-7 has been combined into a single strain of wheat.

14. There was no evidence in the studies made of any relation between awnedness and glume pubescence, awnedness and kernel color, awnedness and bunt per cent, glume pubescence and bunt, and glume pubescence and kernel color, since the results obtained came within expectation for

independent assortment.

15. A comparison of data on bunt reaction and seed color indicates a possible weak linkage between reaction to the composite of races of T-5 and L-7 and seed color. The P value for independence was calculated to be between 0.05 and 0.02 which is regarded as not being independent assortment.

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