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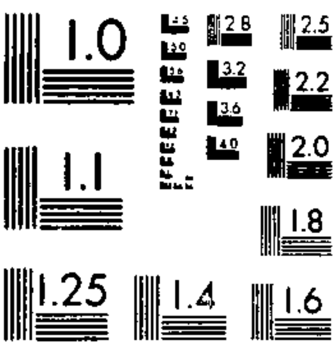

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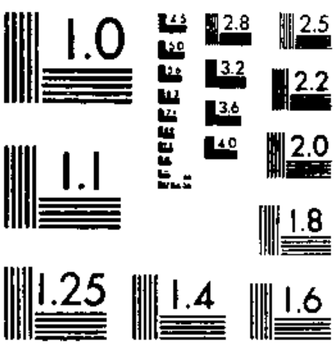

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Inheritance of Morphologic Characters in *AVENA*

Agricultural Research Service
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CONTENTS

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Inheritance of Morphologic Characters in *AVENA*

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Knowledge of the inheritance of the morphologic characters in oats is necessary for conducting an intelligent oat improvement program. When a certain plant character has been shown by inheritance studies to be unstable genetically, a breeder is forewarned; whereas, if the character is known to be stable or to be inherited in a definite percentage ratio, a breeder can proceed with considerable assurance as to the expected results.

This bulletin presents data on the inheritance of the morphologic characters of the oat plant obtained from more than 40 oat crosses. In addition, the genetic results from studies of the inheritance of most of the aberrant types found in oats are presented. Observations on nearly 150,000 plants were made, and as many as five notes were recorded for tens of thousands of these plants. All the crosses on which data appear in this publication were made by the writer, and the technique employed throughout was that described by him (*1*).[1]

A complete review of previous literature on inheritance of morphologic characters in oats is not presented here. Seven summaries of the literature are available—those by Coffman and Mac Key (*3*), Hayes and Immer (*15*), Jensen (*19*), Martin and Leonard (*20*), Nishiyama (*22*), Poehlman (*23*), and Stanton (*27*).

In the work reported here, oats of the wild species *Avena sterilis* and *Avena fatua* and 27 different cultivated varieties of the species *Avena sativa* or *Avena byzantina* were used as parents. Morphologic descriptions of these varieties and species are given by Stanton (*26*, *27*). In addition, fatuoid forms from the varieties Burt, Fulghum, and Ruakura, and an unusual steriloid-fatuoid form from Sixty-Day were used as parents. These were described by Stanton, Coffman, and Wiebe (*28*). The multiflorous form from Burt was described by Coffman and Quisenberry (*6*) and the striped variant from Burt by Coffman, Parker, and Quisenberry (*5*). Descriptions and pictures of most of the oats named appear in these publications. Some of these oats had never before been used in genetic studies.

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[1] Italic numbers in parentheses refer to Literature Cited, p. 100.

The cultivated varieties used as parents in this study were:

Albion
Appler
Aurora
Black Mesdag
Black Rival
Calcutta
Cole
Cornellian
Garton Gray
Golden Rain
Green Russian
Iogold
Kherson
Kherson (Etheridge)
Liberty Hulless
Markton
Monarch
Navarro
Nortex
North Finnish
Rainbow
Red Rustproof
Richland
Sparrowbill
Swedish Select
White Bonanza
Wisconsin Wonder

LEMMA COLOR

The most obvious character in oats, and thus the one most frequently studied genetically, is lemma color (fig. 1). Consequently, many reports on the inheritance of lemma color appear as incidental to studies of inheritance of other characters, such as resistance to some disease organism.

Although the literature includes numerous reports on the inheritance of various kernel colors, no single, systematic study of the inheritance of all the colors has been presented to date. This bulletin presents data on the inheritance of lemma color in over 40 different crosses. In some cases, the data confirm the results presented by others in earlier papers. Data from other crosses, however, offer some new or unusual results that have not been reported previously.

In this series of crosses, oats of each color were crossed with oats of the same color, as well as with oats of every other color. Many crosses were studied in both the F_2 and F_3 generations. Some were studied in only the F_2 or the F_3. The combinations studied included:

Black × Black
Black × Red
Black × Gray
Black × Yellow
Black × White
Gray × Gray
Gray × Red
Gray × Yellow
Gray × White
Red × Red
Red × Yellow
Red × White
Yellow × Yellow
Yellow × White
White × White

Crosses from each combination will be discussed separately.

In the study of inheritance of lemma color, the varieties chosen as parents were, in general, useful, economic oats. Some data resulted from the study of species crosses and other data from the use as parents of aberrant types in oats. Most of the oats studied, and all crosses in which the inheritance of lemma color was studied, were grown at the Aberdeen Branch Experiment Station, Aberdeen, Idaho. At Aberdeen, weather rarely interferes with the normal development of lemma color, since the season is dry and water is supplied by irrigation. Hence, the true lemma color develops under conditions seldom obtained elsewhere. This may explain why some of the results reported here differ from those reported by other writers.

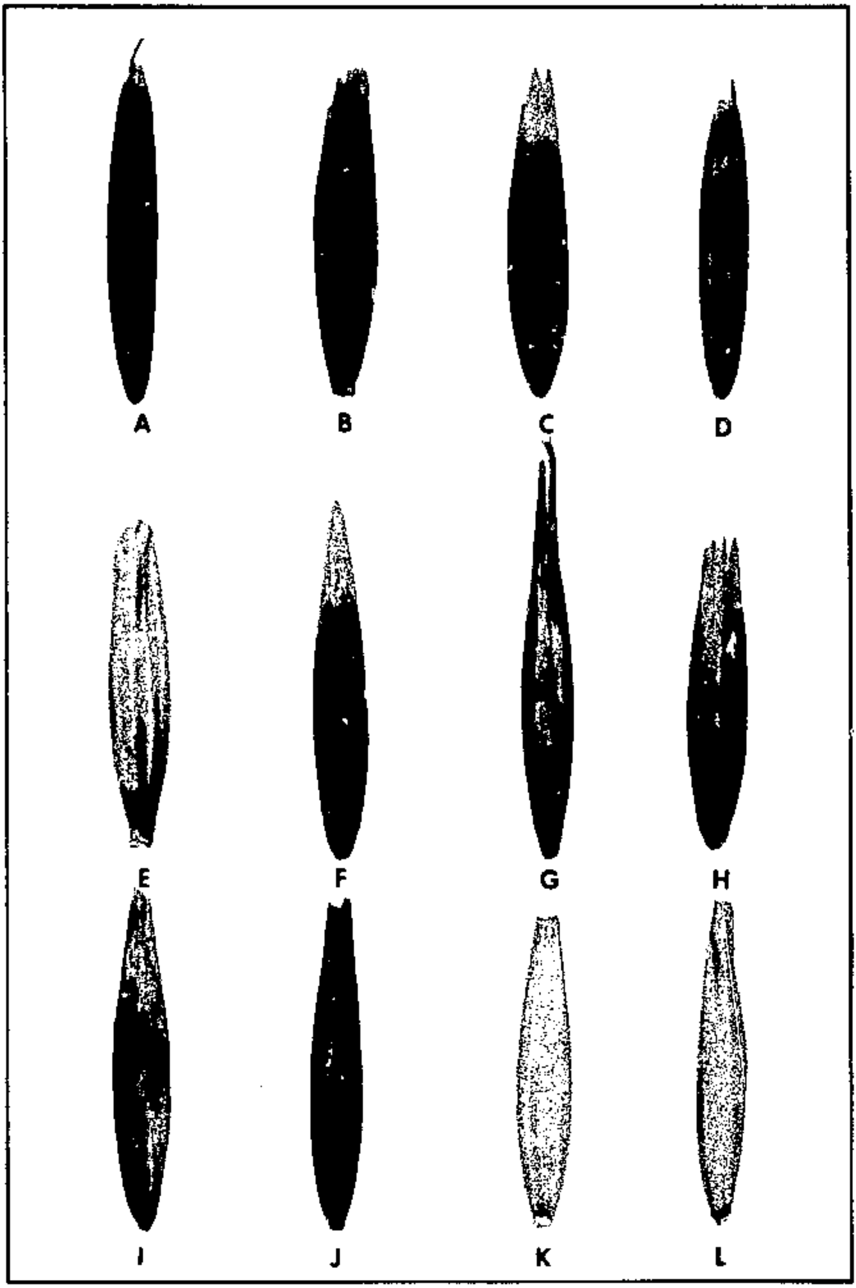

FIGURE 1. Lemma color in *Avena:* Black—*A, B, C;* gray—*D;* grayish red—*E, G;* red—*F, H;* yellow—*I, J;* white—*K, L.*

Black

Black × Black Crosses

Three black × black crosses were studied: Monarch × Black Rival; Black Mesdag × Monarch; and North Finnish × Black Mesdag.

Black Mesdag crossed with Monarch or North Finnish showed no segregation for color. Black Rival crossed with Monarch gave only black in F_3; the F_2 was not studied. Hence, all four varieties appear to have in common a particular gene for black kernel color. Otherwise, segregation for other colors would have been evident.

Monarch crossed with Black Rival gave only black segregates in 30 F_3 lines, although hybridity was evident since segregation for panicle shape occurred. Black Rival is a side oat, whereas Monarch has the open or spreading type of panicle.

Black Mesdag crossed with Monarch gave all black plants in the F_2 and F_3 generations, although the progenies segregated for the awned condition. Black Mesdag is almost always awned, whereas Monarch is seldom awned.

North Finnish crossed with Black Mesdag gave only black plants in the F_2 and F_3, but segregation for the awned condition resulted. Black Mesdag is awned, whereas North Finnish is awnless.

Black × Red Crosses

In many crosses studied, red appeared to be recessive to both black and gray. In other crosses, red appeared dominant over gray. This might indicate the existence of different factors for either gray or red. Black × red crosses studied included the following:

Black Mesdag × Red Rustproof
Fulghum fatuoid × Black Mesdag
Burt fatuoid × Black Mesdag
Burt fatuoid × Monarch
Ruakura fatuoid × Black Mesdag
Fulghum dwarf fatuoid × Black Mesdag

Inheritance of color was not classified critically in the F_2 generation of the first two crosses. Segregation in each case indicated a 3 black:1 nonblack single-factor ratio. Some gray segregates appeared in both crosses. Black was dominant to red. In the Black Mesdag × Red Rustproof cross, the segregation was a good approach to the expected ratio of 12 black:3 gray:1 red.

In the three crosses Burt fatuoid × Black Mesdag, Burt fatuoid × Monarch, and Ruakura fatuoid × Black Mesdag, all studied only in F_2, segregation indicated a two-factor ratio.

A different result was indicated in the cross between a red dwarf-type Fulghum fatuoid and Black Mesdag. The F_2 segregation suggested a three-factor ratio of 48 black:15 gray:1 red. This cross was not studied in the F_3 generation, but F_2 results were definite.

Black was dominant to red in all crosses. Monarch and Black Mesdag have an additional factor for gray that is not present in the red oats with which they were crossed. Possibly the Fulghum fatuoid also had a gray factor differing from the gray factor in Black Mesdag, and thus a three-factor segregation resulted. It is not unusual to observe grayish-red seeds in Fulghum oats. This Fulghum fatuoid was apparently of this type.

BLACK MESDAG × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O–C[1]
F_2:				
Black	837	3	843.75	−6.75
Nonblack	288	1	281.25	+6.75
F_3:				
All black	20			
Black and gray	22	12	59.25	+2.75
Black and red	6			
Black, gray, and red	14			
All gray	5	3	14.81	−0.81
Gray and red	9			
All red	3	1	4.94	−1.94

[1] O = observed; C = calculated. These abbreviations are used throughout this bulletin.

The 14 black, gray, and red lines in the F_3 segregated as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Black	314	12	314.25	−0.25
Gray	79	3	78.56	+0.44
Red	26	1	26.19	−0.19

FULGHUM FATUOID (RED) × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	169	3	172.5	−3.5
Nonblack	61	1	57.5	+3.5

BURT FATUOID (RED) × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	271	12	282.00	−11.00
Red	78	3	70.50	+ 7.50
Gray	27	1	23.50	+ 3.50

BURT FATUOID (RED) × MONARCH

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	256	9	53.13	+ 2.87
Red	150	6	168.75	−18.75
Gray	44	1	28.12	+15.88

RUAKURA FATUOID (RED) × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	291	3	303	−12.0
Nonblack	113	1	101	+12.0
	or			
Black	291	12	303.00	−12.00
Red	86	3	75.75	+10.25
Gray	27	1	25.25	+ 1.75

FULGHUM FATUOID (RED-DWARF) × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	231	48	222.00	+9.00
Gray	61	15	69.38	−8.38
Red	4	1	4.63	−0.63

Black × Gray Crosses

Two black × gray crosses of Cornellian × Black Mesdag and a third, Black Mesdag × Sixty-Day steriloid-fatuoid aberrant, were studied in both the F_2 and the F_3 generations. All crosses indicated a single-factor ratio of 3 black:1 gray. In the F_2 generation of one of the Cornellian crosses, a 12 black:3 gray:1 yellow ratio was indicated; but the F_3 and F_4 generations proved that the supposed yellow segregates were actually only dilute or bleached gray. Thus, the two gray varieties used appear to have the same factor for yellow that is present in Black Mesdag; otherwise, segregation for yellows would have been observed.

Three F_2 populations from the same cross were studied in each of 3 different years. As expected, segregation was the same in all, and the data were summarized.

CORNELLIAN × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	1,359	3	1,330.5	+22.5
Gray	423	1	445.5	−22.5
F_3:				
Black	27	} 3	48	+ 3.0
Heterozygous	24			
Gray	13	1	16	− 3.0

The 24 heterozygous F_3 populations segregated as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Black	483	3	495.75	−12.75
Gray	178	1	165.25	+12.75

BLACK MESDAG × SIXTY-DAY STERILOID-FATUOID

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	1,532	3	1,534.5	−2.5
Gray	514	1	511.5	+2.5
F_3:				
Black	6	} 3	10.5	+1.5
Heterozygous black and gray	6			
Gray	2	1	3.5	−1.5

The 6 heterozygous F_3 populations segregated as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Black	96	3	97.5	−1.5
Gray	34	1	32.5	+1.5

Black × Yellow Crosses

The black × yellow crosses studied were: Aurora × Black Mesdag (2 crosses); Markton × Black Mesdag; Black Rival × Richland; and Richland × Black Rival.

Black Mesdag was crossed with two different yellow oats and gave two types of segregation. Crossed with Aurora, a yellow selection presumably from Red Rustproof, the segregation in F_2 indicated that Aurora has an intensifying factor for red in addition to the yellow. The segregation in F_2 appeared to be 48 black:12 gray:3 yellow:1 white. The white segregate on further testing proved to be a dilute gray. Nearly half of the gray F_3 segregates clearly showed an intensification or a "bronze" coloring in lines segregating for gray and yellow.

The presence of the intensifying factor was indicated in 22 of 44 F_3 lines segregating for black and gray, in 3 of 9 lines classed as all gray, in 8 of 17 lines classed as heterozygous gray-yellow, and in 1 of 2 lines classed as all yellow. The segregation in this cross appeared to be 12 black:3 gray:1 red.

In the cross Markton × Black Mesdag, a 12 black:3 gray:1 yellow segregation was observed in F_2 and F_3. A similar segregation was observed in two crosses in F_2 and F_3 of Black Rival × Richland.

The results of the crosses might indicate that Aurora has the yellow factor plus an intensifying factor that, when present in the absence of black, may produce a reddish color.

In the black segregates, the bronze was masked by the darker color.

AURORA × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Black	145	48	129.74	+15.26
Gray	24	12	32.44	− 8.44
Yellow	3	3	8.11	− 5.11
White [1]	1	1	2.70	− 1.70

[1] One individual classed as a questionable white in F_2 proved to be a dilute gray when tested in F_3 and F_4.

AURORA × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O-C
F_3:				
All black	28	12	75.00	−3.00
Heterozygous black	44			
All gray	9	3	18.75	+7.25
Heterozygous gray	17			
All yellow	2	1	6.25	−4.25

Segregation of heterozygous F_3 lines that produced blacks, grays, and yellows was as follows:

Class and progeny	Observed	Ratio	Calculated	O-C
F_3:				
Black	572	12	566.25	+ 5.75
Gray	[1] 149	3	141.56	+ 7.44
Yellow	34	1	47.19	−13.19

[1] 64 were bronze; all of these were added to gray.

Segregation of 18 F_3 lines that produced only grays and yellows was as follows:

Class and progeny	Observed	Ratio	Calculated	O-C
F_3:				
Gray	496	3	453	+43.0
Yellow	108	1	151	−43.0

In this segregation, 165 were bronze and were not added to either group. Had they been added to gray, the following segregation would have resulted:

Class and progeny	Observed	Ratio	Calculated	O-C
F_3:				
Gray	661	13	624.81	+36.19
Yellow	108	3	144.19	−36.19

Hence, it is evident that the presence of bronze tends to intensify the yellow color and results in genetic yellows being classed as grays.

A summary of the F_3 data of this cross indicates the following:

Class and progeny	Normal	Containing bronze segregates
F_3:		
Black	50	22
Gray	15	11
Yellow	1	1
Total	66	34

Segregation of normal and bronze individuals in segregating black lines was normal 859; bronze 140. In segregating gray lines, it was normal 226; bronze 261.

In the cross Markton × Black Mesdag, a comparatively good fit to the 12 black : 3 gray : 1 yellow segregation was evident.

MARKTON × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	156	12	147.00	+9.00
Gray	31	3	36.75	–5.75
Yellow	9	1	12.25	–3.25
F_3:				
All black	11	12	40.50	–8.50
Heterozygous black	21			
All gray	8	3	10.13	+7.87
Heterozygous gray	10			
All yellow	4	1	3.38	+0.62

There appeared to be no difference between the F_2 populations derived from three unrelated F_1 plants of the Black Rival and Richland combination. Data from the first two crosses were combined in F_2, and no attempt was made to separate gray from other nonblack segregates. A 3 black : 1 nonblack segregation was observed.

BLACK RIVAL × RICHLAND

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	695	3	708.75	–13.75
Nonblack	250	1	236.25	+13.75

In the third cross, a closer inspection of the progenies was made, and an indication of a 12 black : 3 gray : 1 yellow ratio was found in F_2 and F_3.

RICHLAND × BLACK RIVAL

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	159	12	162.0	–3.0
Gray	42	3	40.5	+1.5
Yellow	15	1	13.5	+1.5
F_3:				
All black	11	12	37.50	–3.50
Heterozygous black	23			
All gray	3	3	9.38	+1.62
Heterozygous gray	8			
All yellow	5	1	3.13	+1.87

Segregation of 11 F_3 black-gray-yellow populations was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Black	188	12	187.50	+0.50
Gray	44	3	46.88	−2.88
Yellow	18	1	15.63	+2.37

Segregation of 8 F_3 gray-yellow populations was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Gray	146	3	141.75	+4.25
Yellow	43	1	47.25	−4.25

Black × White Crosses

Black Mesdag was crossed with Swedish Select and a white selection from Kherson. Both crosses showed F_2 and F_3 segregations of 48 black:12 gray:3 yellow:1 white. Hence, it is assumed that factors for black, gray, and yellow were contributed by Black Mesdag and factors for white by the white parents of these crosses.

Black Mesdag × Swedish Select

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	189	48	182.26	+6.74
Gray	41	12	45.56	−4.56
Yellow	10	3	11.39	−1.39
White	3	1	3.80	−0.80
F_3:				
All black	19	48	81.00	−9.00
Heterozygous black	53			
All gray	11	12	20.25	+8.75
Heterozygous gray	18			
All yellow	2	3	5.06	−2.06
Heterozygous yellow	1			
All white	4	1	1.69	+2.31

Segregation of 7 F_3 black-gray-yellow-white populations was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Black	262	48	256.51	+5.49
Gray	58	12	64.13	−6.13
Yellow	15	3	16.03	−1.03
White	7	1	5.34	+1.66

Segregation of 4 F_3 gray-yellow-white populations was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Gray	168	12	150.75	+17.25
Yellow	24	3	37.69	−13.69
White	9	1	12.56	− 3.56

Segregation of 1 F_3 yellow-white population was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Yellow	33	3	33.75	−0.75
White	12	1	11.25	+0.75

Kherson × Black Mesdag

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	741	48	734.26	+ 6.74
Gray	158	12	183.56	−25.56
Yellow	66	3	45.89	+20.11
White	14	1	15.30	− 1.30
F_2:				
Black	418	48	405.02	+12.98
Gray	87	12	101.26	−14.26
Yellow	26	3	25.31	+ 0.69
White	9	1	8.44	+ 0.56

Populations of this cross were studied in F_2 in two different years. The summary data for these 2 years were as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Black	1,159	48	1,139.23	+19.77
Gray	245	12	284.81	−39.81
Yellow	92	3	71.20	+20.80
White	23	1	23.73	− 0.73

The number of yellows appears too high, but, as noted in other crosses, dilute grays classed as yellows proved on further testing to be grays.

GRAY

Gray × Gray Crosses

Five crosses in which a gray oat was crossed with gray were studied in F_2. One of these was also studied in F_3. A gray *A. fatua* crossed with the Sixty-Day aberrant (also gray) gave a ratio of 63 gray : 1 yellow in F_2. Two other *A. fatua* × Sixty-Day aberrant crosses gave a 15 gray : 1 yellow segregation in F_2. Hence, *A. fatua* lines differ in their genetic color factors, as well as in their physiologic factors. Black and gray *A. fatuas* are numerous. The yellow *A. fatua* is rare.

A different type of color inheritance was not expected in the Cornellian × Garton Gray crosses, however. In two crosses, a 63 gray : 1 yellow segregation was found; and F_3 results seemed to verify the F_2 interpretation. This would indicate a three-factor difference. If Cornellian has a gray factor and a yellow factor, then Garton Gray must have a second factor for gray or a three-factor segregation could not have resulted. Garton Gray apparently lacks the yellow factor of Cornellian. Thus, we apparently have grays of three different types: (1) Those with the factors GGYY as in Cornellian; (2) those with the possible factor G_1G_1YY as in Garton Gray, which do not produce yellows when crossed with white; and (3) those with two factors for gray (G_2G_2), like the *A. fatua* used.

A. fatua × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	373	63	369.12	+3.88
Yellow	2	1	5.86	−3.86

A. fatua × Sixty-Day aberrant

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	338	15	330.94	+7.06
Yellow	15	1	22.06	−7.06

Sixty-Day aberrant × *A. fatua*

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	241	15	244.69	−3.69
Yellow	20	1	16.31	+3.69

Cornellian × Garton Gray (1st cross)

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	1,310	63	1,323.95	−13.95
Yellow	35	1	21.02	+13.98
F_3:				
All gray	34	63	60.05	− 1.05
Heterozygous gray	25			
All yellow	2	1	0.95	+ 1.05

Cornellian × Garton Gray (2d cross)

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	258	63	260.86	−2.86
Yellow	7	1	4.14	+2.86
F_3:				
All gray	53	63	137.81	−0.81
Heterozygous gray	84			
All yellow	3	1	2.19	+0.81

Gray × Red Crosses

Two gray × red crosses were studied in F_2 and F_3. In the Garton Gray × Nortex cross, the blending or gradation of the colors in F_2 made classification into groups almost impossible, but there appeared to be an approach to a 15 gray : 1 red segregation. Carried to the F_3, the segregation approached a 13 gray : 3 red, with no yellows. Garton Gray is believed either to have no yellow factor or to have a factor inhibiting yellow.

The second cross of red × gray, *A. sterilis* (red) × Sixty-Day aberrant, gave a 3 red : 1 gray segregation in F_2; but the F_3 generation was difficult to study because of the dormancy in *A. sterilis* and some of its derivatives when sown in the field. Observations indicated that the lemma color in the *A. sterilis* used may differ genetically from that of Red Rustproof (Nortex). Also, *A. sterilis* must carry the same yellow factor as the Sixty-Day aberrant, since no yellow segregates appeared.

GARTON GRAY × NORTEX

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	138	15	141.56	−3.56
Red	13	1	9.44	+3.56
F_3:				
All gray	23	} 13	53.63	+0.37
Heterozygous gray	31			
Red	12	3	12.38	−0.38

The 31 heterozygous gray F_3 populations segregated as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Gray	510	13	487.5	+22.5
Red	90	3	112.5	−22.5

A. sterilis × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Red	85	3	84	+1.0
Gray	27	1	28	−1.0
F_3:				
All red	9	} 3	18.75	−1.75
Heterozygous red	8			
All gray	8	1	6.25	+1.75

The 8 heterozygous F_3 populations segregated as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Red	87	3	91.5	−4.5
Gray	35	1	30.5	+4.5

Gray × Yellow Crosses

Three gray × yellow crosses were studied in the F_2 but only two in the F_3. Cornellian was the gray parent of the crosses. Cornellian gave a simple 3 gray: 1 yellow segregation when crossed with Aurora, and indications of a 13 gray: 3 yellow ratio in the F_2 and F_3 when crossed with either Markton or Sparrowbill. Further analysis of the Markton cross, however, indicated a 3 gray: 1 yellow segregation. Sparrowbill, a pale yellow oat, gave a 13: 3 ratio in F_2 when crossed with Cornellian. The F_3 was not studied.

Aurora might have been expected to contribute an intensifying factor to produce reds, but this was not true. Approximately one-eighth of the grays were darker than Cornellian. The condition was not studied in F_3.

CORNELLIAN × AURORA

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	718	3	720.75	–2.75
Yellow	243	1	240.25	+2.75
F_3:				
All gray	13	3	36.75	–0.75
Heterozygous gray	23			
All yellow	13	1	12.25	+0.75

CORNELLIAN × MARKTON

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	708	13	721.5	–13.5
Yellow	180	3	166.5	+13.5
F_3:				
All gray	21	13	45.5	– 1.5
Heterozygous gray	23			
All yellow	12	3	10.5	+ 1.5

An entirely different result was obtained when segregation among the 23 heterozygous F_3 gray-yellow lines of the cross Cornellian × Markton was studied. Segregation was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Gray	393	3	389.25	+3.75
Yellow	126	1	129.75	–3.75

Thus, both crosses (Cornellian × Aurora and Cornellian × Markton) may be considered as having given a 3 gray: 1 yellow ratio.

CORNELLIAN × SPARROWBILL

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	416	13	430.63	−14.63
Ivory	114	3	99.38	+14.62
F_2:	*or*			
Gray	416	3	397.5	+18.5
Ivory	114	1	132.5	−18.5

Gray × White Crosses

Lemma color was studied in two crosses between gray and white oats. Cornellian × Swedish Select gave a 12 gray:3 yellow:1 white ratio in the F_2 generation.

The Swedish Select × Garton Gray cross produced no yellows, and the segregation was 3 gray:1 white. This would indicate that Garton Gray either does not carry the yellow factor found in Cornellian or carries an inhibitor for yellow color. Such inhibitors for yellow color have been found in oats (Jensen, *19*).

CORNELLIAN × SWEDISH SELECT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Gray	1,639	12	1,699.50	−60.50
Yellow	497	3	424.88	+72.12
White	130	1	141.63	−11.63
F_3:				
All gray	18			
Heterozygous gray	23	12	37.50	+ 3.50
All yellow	2			
Heterozygous yellow	4	3	9.38	− 3.38
All white	3	1	3.13	− 0.13

Segregation of 11 F_3 gray-yellow-white populations was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Gray	157	12	164.25	−7.25
Yellow	47	3	41.06	+5.94
White	15	1	13.69	+1.31

SWEDISH SELECT × GARTON GRAY

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Gray	128	3	135	−7.0
White	52	1	45	+7.0
F_3:				
All gray	13	3	33	±0.0
Heterozygous gray	20			
All white	11	1	11	±0.0

The heterozygous F_3 lines segregated as follows:

Class and progeny	Observed	Ratio	Calculated	O-C
F_3:				
Gray	640	3	638.25	+1.75
White	211	1	212.75	−1.75

RED

Red × Red Crosses

Red Rustproof, Nortex, Calcutta, and Fulghum are all red oats. Red Rustproof crossed with Calcutta produced almost exclusively red progenies. Red Rustproof crossed with Fulghum fatuoid (red) produced only red progenies in the F_2 and F_3 generations. This would indicate that these three oats have the same factors for red.

RED RUSTPROOF × CALCUTTA

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Red	991	255	989.12	+1.88
Gray	2	1	3.88	−1.88

In the F_3 generation 50 lines were grown, 49 of which were homozygously red. No stand was obtained in the other line, and it was discarded. Hence, the two individuals classed as gray in F_2 were probably somewhat weathered or red stained.

In the F_3 generation of a Fulghum fatuoid × Red Rustproof cross, all 25 F_3 lines grown were homozygously red. The F_2 was not studied.

Red × Yellow Crosses

Three crosses involving red and yellow parents were studied: Aurora × Nortex; Red Rustproof × Navarro; and Iogold × Red Rustproof. The first cross was studied in F_2 and F_3, the second in F_2 only, and the third in F_2 and in a few F_3 generation lines. In the Aurora × Nortex cross, a segregation of 12 red:3 reddish gray:1 yellow was indicated; and the F_3 supported the F_2 results. The grays were somewhat reddish tinged, possibly because of the intensifying factor in Aurora; but the segregation was not affected.

The cross Red Rustproof × Navarro indicated that in F_2 Navarro may also have this intensifying factor, since the segregation followed the 12 red:3 reddish gray:1 yellow pattern. Both Aurora and Navarro seem to have Red Rustproof's yellow factor, which would be logical because both are apparent derivatives of Red Rustproof.

The Iogold × Red Rustproof cross gave a 15 red:1 yellow segregation without any grayish reds in F_2. This indicated a two-factor difference. Apparently Iogold, sometimes called "ivory," lacks the intensifying factor found in Aurora and Navarro; and no reddish-gray progenies appeared. The F_3 was not studied.

AURORA × NORTEX

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Red	122	12	114.75	+7.25
Gray	22	3	28.69	−6.69
Yellow	9	1	9.56	−0.56
F_3:				
All red	44	12	48	+7.0
Heterozygous red	11			
All gray	2	3	12	−6.0
Heterozygous gray	4			
All yellow	3	1	4	−1.0

Six of the heterozygous red F_3 lines segregated into red, gray, and yellow, as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Red	165	12	192	−27.0
Gray	61	3	48	+13.0
Yellow	30	1	16	+14.0

An F_4 generation of the lighter colored F_3 segregates was grown. These segregates appeared to be almost white in F_3 but were dilute gray in F_4.

RED RUSTPROOF × NAVARRO

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Red	800	12	813.75	−13.75
Reddish gray	220	3	203.44	+16.56
Yellow	65	1	67.81	− 2.81

IOGOLD × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Red	182	15	180.94	+1.06
Ivory	11	1	12.06	−1.06

Red × White Crosses

Four crosses between red and white varieties were studied: Cole (White Kherson) × Red Rustproof; Appler × Swedish Select; Calcutta × Kherson (Etheridge), a white Kherson; and Swedish Select × Fulghum fatuoid. A segregation of 48 red: 12 gray: 3 yellow: 1 white was indicated in all three crosses. Hence, the genetic factors determining color in Red Rustproof apparently are RRGGYY. Another cross between Swedish Select and a Fulghum fatuoid (red) gave no grays in the F_2 generation. Apparently, two factors for red and one for yellow were carried by the fatuoid. The segregation, therefore, was a close approach to 60 red: 3 yellow: 1 white in 445 F_2 plants. The F_3 was not studied. The indication of a second factor for red in this fatuoid is of interest.

In the F_2 Cole × Red Rustproof cross, excessive weathering of the plants occurred. This made an accurate identification of many red and yellow segregates impossible. If the yellow and red are grouped in one class, "dark," a reasonably close fit to a 15: 1 ratio results.

COLE × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Red	485	12	580.50	− 95.50
Yellow	249	3	145.13	+103.87
White	40	1	48.38	− 8.38
	or			
Dark	734	15	725.63	+ 8.37
White	40	1	48.38	− 8.38

The inheritance of floret color in this cross was so complicated that F_3 progenies were studied in each of three different years. F_3 summary data for the 3 years were as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
All red	49	48	153.74	+8.26
Heterozygous red	113			
All gray	13	12	38.44	−4.44
Heterozygous gray	21			
All yellow	4	3	9.61	−3.61
Heterozygous yellow	2			
All white	3	1	3.20	−0.20

APPLER × SWEDISH SELECT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:[1]				
Red	177	48	175.49	+1.51
Gray	37	12	43.87	−6.87
Yellow	16	3	10.97	+5.03
White	4	1	3.66	+0.34
F_3:				
Red	13	48	44.25	−3.25
Heterozygous red	28			
Gray	6	12	11.06	+1.94
Heterozygous gray	7			
Yellow	3	3	2.77	+1.23
Heterozygous yellow	1			
White	1	1	0.92	+0.08

[1] 15 of all the plants observed were grasslike, and lemma color in 7 of these could not be identified.

CALCUTTA × KHERSON (ETHERIDGE)

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Red	339	60	343.12	−4.12
Ivory	19	3	17.15	+1.85
White	8	1	5.72	+2.28
F_3:				
Red	2	48	26.25	−5.25
Heterozygous red	19			
Gray	3	12	6.56	+2.44
Heterozygous gray	6			
Yellow	3	3	1.64	+3.36
Heterozygous yellow	2			
White	0	1	0.55	−0.55

The genetic study of the crosses of red × white was difficult because of weathering. This made accurate classification almost impossible many times. Cole is a white selection from Kherson.

Kherson (Etheridge) is also white. Apparently from the cross of red × red, both Red Rustproof and Calcutta have the same genetic complex for color. Consequently, the genetic constitution of the parents of the two crosses would supposedly be equal. The accuracy of this supposition is indicated when the data from the three crosses are summarized in one table, as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Red	64	48	224.26	−0.26
Heterozygous red	160			
Gray	22	12	56.06	−0.06
Heterozygous gray	34			
Yellow	10	3	14.02	+0.98
Heterozygous yellow	5			
White	4	1	4.67	−0.67

The fourth cross was studied only in the F_2. Segregation was as follows:

SWEDISH SELECT × FULGHUM FATUOID

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Red	427	60	417.18	+9.82
Yellow	13	3	20.86	−7.86
White	5	1	6.95	−1.95

The results in F_2 of this cross do not correspond with those for the previous three crosses.

YELLOW

Yellow × Yellow Crosses

One cross in which both parents were yellow, Navarro × Markton, was studied in both the F_2 and F_3 generations. All progenies were yellow, but a few were lighter yellow than the others. The Markton yellow differed from the yellow factor in Cornellian because a 13:3 ratio was observed rather than a 3:1. Since the yellow factor in Navarro appears to be the same as that in Red Rustproof, Markton must carry a second factor for yellow. Navarro crossed with Red Rustproof gave evidence of an intensifying factor in F_2. Thus, it would seem that in Navarro the genetic factors for color are yellow, plus an intensifying factor; and those in Markton are a different yellow, plus possibly a second intensifying factor, or one that apparently differs from that in Navarro. In the Navarro × Markton cross, the presence of either intensifying yellow gives a reddish cast to the lemma. The genetics of this cross is complicated, as indicated by the numerous aberrant types, which will be discussed later.

Among the 966 progenies of this cross that headed, 285 were described as bronze, or more nearly red than yellow. The closest approach to an analysis of the interaction of factors responsible for this would be a 27:9:9:9:3:3:3:1 ratio in which 19 segregates show the bronze color and 45 segregates do not. The total numbers expected would be about 679:287; whereas actual numbers were 681:285. The slight deviations seem to justify this interpretation. Extremely intensified bronze oats are easily classed as reds, as shown by the results obtained.

NAVARRO × MARKTON

Class and progeny	Observed [1]	Ratio	Calculated	O–C
F_2:				
Reddish	954	63	950.90	+3.10
Yellow	12	1	15.09	–3.09

[1] Nine grasslike never headed.

In F_3, 53 lines were grown (primarily to study dwarfism). Progenies in all rows were almost exclusively reddish to red in color.

Lemma color has been observed in numerous other yellow × yellow combinations. In the cross Aurora × Markton, studied in connection with the inheritance of smut resistance in oats (Coffman and others, *9*), and in the cross Markton × Rainbow from which Marion resulted (Coffman and others, *4*), studied in connection with both rust and smut resistance in oats, segregates indicating that Markton has an intensifying factor appeared. In the Aurora × Markton cross, some of the progenies might easily have been classed as red in lemma color. In the Markton × Rainbow cross, a small number of somewhat lighter colored, reddish-yellow segregates were observed. Consequently, it is evident that Navarro, Aurora, and Markton all have, in addition to the factor conditioning yellow lemmas, a modifying factor or factors that intensify the color. This factor is responsible for progenies that closely approach red in color.

Indications of such an intensifying factor were not found in a Richland × Green Russian cross (Coffman and others, *9*). All progenies appeared yellow, like the parents. Thus, it is evident that not all oats classed as yellow have the same genetic factors for lemma color.

Yellow × White Crosses

Two crosses involving yellow and white oats were studied: Kherson (yellow) × Kherson (white); and Aurora × Wisconsin Wonder. In the first cross, more than 2,100 F_2 plants segregated in a ratio of 3 yellow:1 white, as expected. Part of the plants were observed before a prolonged rain, and the rest were observed after the rain. The lemmas of many of the oats examined after the rain had become stained. Because of this, many that would normally have been classed as yellowish white were erroneously classed as yellow. Data for each of the observations are as follows:

KHERSON (YELLOW) × KHERSON (WHITE)

Class and progeny	Observed	Ratio	Calculated	O–C
F_2 (before rain):				
Yellow	202	3	548.25	+7.75
Yellow white	354			
White	175	1	182.75	−7.75
F_2 (after rain):				
Yellow	558	3	1,164.75	+36.25
Yellow white	643			
White	352	1	388.25	−36.25

In the Aurora × Wisconsin Wonder cross, the intensifying factor of Aurora was evident. The ratio of dark to light or white individuals in this cross was a good fit to a 3:1 ratio.

AURORA × WISCONSIN WONDER

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Dark	133	3	136.5	−3.5
Light	49	1	45.5	+3.5

WHITE

White × White Crosses

Only one cross between white × white oats was studied: Albion × Wisconsin Wonder. Of the 326 F_2 plants in this cross, all were white except 4, which showed a slight grayish tinge. Of 208 additional F_2 plants studied, 5 had a grayish tinge. This approached a ratio of 63 white:1 gray tinged. The calculated ratio was 525.67:8.34, compared with the observed 525:9.

The few gray-tinged individuals were thought to be the result of natural crossing. Hence, an F_3 population of 31 white and 3 gray-tinged F_2 plants was grown. The 31 white F_2 plants all bred true for white in the F_3, and the 3 gray-tinged F_2 plants segregated as follows:

ALBION × WISCONSIN WONDER

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Gray-tinged	77	3	81	−4.0
White	31	1	27	+4.0

These data indicated that the gray-tinged individuals were the result of field hybrids and that, in the absence of contaminating pollen, the white parents to the cross Albion × Wisconsin Wonder produced only true-breeding white progenies, as expected.

SUMMARY

Lemma color, the most obvious character in the oat kernel, was studied extensively. Five colors are recognized—black, gray, red, yellow, and white. In these crosses, black × black gave no segregation; black × red gave five different types of segregation—(1) 12 black:3 red:1 gray; (2) 12 black:3 gray:1 red; (3) 3 black:1 nonblack; (4) 48 black:15 gray:1 red; and (5) 9 black:6 red:1 gray. In all five types of segregation, Black Mesdag was the black parent used; thus, a genetic difference in the other parents to the crosses was indicated. Monarch, the black parent to one of the crosses, gave a segregation ratio of 9 black:6 red:1 gray.

Two black × gray crosses gave similar results—3 black:1 gray. Only one type of segregation apparently resulted from crossing black with yellow oats—12 black:3 gray:1 yellow. When black was crossed with white, a segregation of 48 black:12 gray:3 yellow:1 white was found. Black Mesdag was the black oat used in both crosses studied.

In crosses of gray × gray, two types of segregation were observed: 63 gray:1 yellow; and 15 gray:1 yellow. This indicates that all gray oats do not have the same genetic constitution. When gray oats were crossed with red oats, a 13 gray:3 red segregation was observed in one cross and a 3 gray:1 red in the other cross. Two segregation ratios were observed in progenies of crosses of gray × yellow. These were 13 gray:3 yellow; and 3 gray:1 yellow. However, after studying the segregation in F_3 of the Cornellian × Markton cross, the 3:1 ratio appeared to be the most probable. When gray was crossed with white, a ratio of 12 gray:3 yellow:1 white was observed in one cross and 3 gray:1 white in the other cross.

Red crossed with red gave only red progenies; whereas red crossed with yellow gave a segregation of 12 red:3 gray:1 yellow in two crosses. In a third cross, a ratio of 15 red:1 yellow (ivory) was indicated. Red crossed with white studied in four crosses gave ratios of 48 red:12 gray:3 yellow:1 white in three crosses and a ratio of 60 red:3 yellow:1 white in the fourth cross.

Yellow crossed with yellow usually gives only yellow segregates in F_2 and later generations. This was observed earlier by the writer (Coffman and others, *4*) in two yellow × yellow crosses—Markton × Rainbow, and Richland × Green Russian. However, the Navarro × Markton cross resulted in a segregation of 63 red:1 yellow. Both parents are considered by this writer as yellowish derivatives of red oats. In crossing, the red color is accentuated. Probably because each parent includes an intensifying color factor they complemented each other when they were crossed. Thus, a wide gradation of color in the progenies resulted, ranging from those almost as distinctly red as Red Rustproof to dilute reds. Only a few true yellow individuals were observed. Many plant aberrants, such as grass tufts, were also observed in progenies of this cross.

Yellow crossed with white gave a segregation of 3 yellow:1 white in two crosses. This is the usual segregation reported.

Only one white × white cross was studied: Albion × Wisconsin Wonder. At first, an apparent ratio of 63 white:1 gray appeared. On careful examination in F_3, however, it was observed that some apparent natural crossing had occurred that resulted in a slightly gray tinge in some individuals. These grays segregated into grays and whites, and those classed as white in F_2 bred true in F_3.

AWNS

Next to lemma color, the most obvious kernel character in oats is probably the awn on the dorsal surface of the lemma. Awns may be of three general types: (1) Twisted geniculate; (2) subgeniculate; and (3) straight. Some oat florets are awnless.

Wild oats of the *A. fatua* and *A. sterilis macrocarpa* species and the fatuoid and steriloid aberrants of cultivated species are characterized by the twisted geniculate awn on all florets. Such awns are sometimes found on the florets of cultivated oats, but usually on the lower florets only. The twisting of light and dark awn tissue occurs at the base or from the point of attachment to the lemma to a point about one-third the length of the awn, where a knee or bend often occurs almost at a right angle. Beyond this knee the awn is tapering, nontwisted, and colorless.

The subgeniculate awn is frequently found on the lower floret of some of the cultivated varieties classed either as *A. sativa* or *A. byzantina*. It sometimes serves to identify heterozygotes in wild × cultivated crosses. It may have one or several twists of darker and lighter tissue at the base, and it may be somewhat dark colored for a short distance above the twists. The awn bends slightly without a distinct knee, and the upper part of the awn is usually straight and light colored.

The straight awn is rarely dark, although some individuals may have darker tissue than others along their sides. The straight awn does not twist at the base or bend to form a knee. It may be present on all or nearly all florets in the panicle, as in some Red Rustproof type oats, or on only a few florets. It is sometimes only a coarse, hairlike appendage on a few kernels in the panicle.

There are so-called awnless oat varieties, but a genetically awnless oat is rare or almost nonexistent. The fully awned, twisted geniculate condition is almost constant in breeding behavior. Next to it in constancy of breeding is the straight awn. The twisted awn on the lower floret, found in some cultivated oats, is less constant; and the subgeniculate awn is the most variable awn type. The subgeniculate awn is a fair index to heterozygosity and usually produces progenies having different awn types in following generations.

The theory that the presence of twisted awns on all florets is the basis for a genetic study of the inheritance of awns in oats is a new approach. Certainly the fully awned condition × awnlessness produces all the other awn conditions found in oats. Most earlier

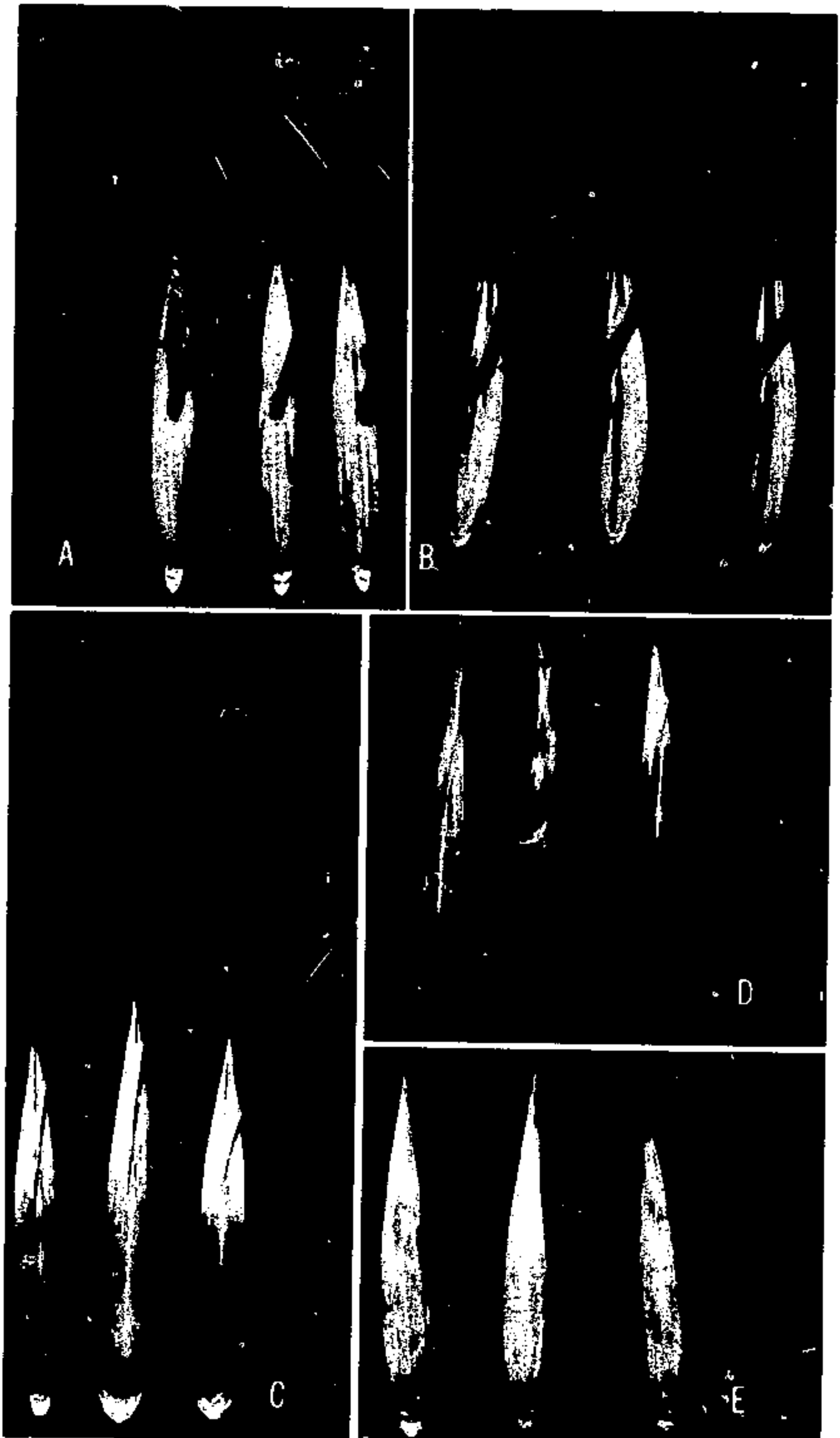

FIGURE 2.—Awn types in *Avena*: *A*, Twisted geniculate; *B*, subgeniculate; *C*, straight long; *D*, straight short; *E*, awns absent.

studies on the inheritance of awns in oats have been the results of crossing the different cultivated oat types. Different investigators using phenotypically similar oats as parents have obtained different results. This is not unusual if the theory is accepted that genes for all awn types found in cultivated oats are present in their wild progenitors and that, although two cultivated oats may appear similar phenotypically, they may differ genetically. If this concept is accepted, the diversity of results reported to date can be understood.

In these studies, an oat of each awn type was crossed with one of the same type and with one of each of the other awn types. The results obtained were often difficult to explain. Factors such as moisture, light, soil fertility, and temperature appear to influence the presence and type of awns in oats, and these factors cannot be controlled in large-scale field studies.

This writer agrees fully with Fraser (*13*) that awn development is inclined to be unstable and is affected by climatic conditions. Hence, it is difficult to study genetically, and interpretations of results usually deal in generalities.

In the study of the inheritance of awns, the following combinations were included:

Twisted (all florets) × Twisted (all florets)
Twisted (all florets) × Twisted (lower floret)
Twisted (all florets) × Straight
Twisted (all florets) × Absent
Twisted (lower floret) × Twisted (lower floret)
Twisted (lower floret) × Straight
Twisted (lower floret) × Absent
Straight × Straight
Straight × Absent
Absent × Absent

Twisted (all florets) × Twisted (all florets)

Three crosses were studied: One of *A. fatua* with the Sixty-Day aberrant; one of *A. sterilis* with this aberrant; and one with a fatuoid from Fulghum with this aberrant. All progenies in all the crosses either bore awns on all florets, or had no apparent segregation for awns. The condition of twisted awns on all florets seems to be the most constant condition genetically.

Twisted (all florets) × Twisted (lower floret)

Two crosses in which one parent had twisted awns on the lower floret only, and the other parent had twisted awns on all florets were studied in F_2 only.

BLACK MESDAG × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Twisted geniculate on all florets	520	63	2,012.06	+1.94
Twisted geniculate on lower floret only	1,140			
Subgeniculate	308			
Straight	46			
Absent	30	1	31.94	−1.94

SWEDISH SELECT × FULGHUM FATUOID

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Twisted geniculate	365	63	439.03	+0.97
Subgeniculate	43			
Straight	32			
Absent	6	1	6.97	−0.97

In these two crosses, progenies having each of the awn types and progenies having no awns were found. In both crosses, the ratio of all awns present to awns absent approached a 63:1 ratio. A summary of the two crosses reveals a segregation of 632 all florets awned: 1,734 twisted geniculate or subgeniculate awns on lower floret only: 78 straight awns on lower floret only: 36 awns absent. This was the expected segregation, since the fully awned condition is considered the progenitor type.

Twisted (all florets) × Straight

Only one cross between an oat having twisted awns on all florets and an oat having straight awns was studied. Segregation was studied only in F_3. The results were as follows:

RED RUSTPROOF × FULGHUM FATUOID

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Twisted geniculate on all florets	13	1	11.5	+1.5
All other types	33	3	34.5	−1.5

Twisted (all florets) × Absent

Only one cross in which an awnless oat was crossed with oats having twisted geniculate awns on both or all florets was studied. Only the F_2 was studied, but a three-factor difference was indicated.

BURT FATUOID × MONARCH

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Twisted geniculate on all florets	309	48	315.00	−6.00
Subgeniculate (lower)	44	15	98.44	+9.56
Straight (lower)	64			
Absent	3	1	6.56	−3.56

Twisted (lower floret) × Twisted (lower floret)

Only one cross between oats having twisted awns on the lower florets was made: Black Mesdag × Swedish Select. This was studied only in F_2, and all 244 progenies had twisted awns on the lower floret.

Twisted (lower floret) × Straight

In the cross Black Mesdag × Red Rustproof, awns were studied only in F_2. The twisted type appeared to be recessive, and a single-factor difference between the two types existed.

BLACK MESDAG × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Twisted geniculate	296	1	281.25	+14.75
Subgeniculate	103	3	843.75	−14.75
Straight	726			

Twisted (lower floret) × Absent

Six crosses were studied in which one parent was apparently awnless, and the other had a twisted geniculate awn on the lower floret. Monarch, Cornellian, North Finnish, and Albion have been classed as awnless. Swedish Select, Black Mesdag, and White Bonanza have a twisted geniculate awn on the lower floret. One Kherson strain that was used was awnless, and the other Kherson strain had twisted geniculate awns. The segregation among the progenies of the crosses studied was as follows:

CORNELLIAN × SWEDISH SELECT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Awns present	1,063	7	991.38	+71.62
Awns absent	1,203	9	1,274.63	−71.63
F_3:				
All awned	10	} 13	40.63	+ 1.37
Heterozygous for awns	32			
Awns absent	8	3	9.38	− 1.38

BLACK MESDAG × MONARCH

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Awns present	75	1	74.75	+0.25
Awns absent	224	3	224.25	−0.25
F_3:				
All awned	14	} 15	46.88	−3.88
Heterozygous for awns	29			
Awns absent	7	1	3.12	+3.88

CORNELLIAN × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Present	122	7	127.31	−5.31
Absent	169	9	163.69	+5.31
F_3:				
All awned	17	} 15	60	±0.0
Heterozygous for awns	43			
Awns absent	4	1	4	±0.0

In the cross North Finnish × Black Mesdag, a condition somewhat the reverse of that found in F_2 of Cornellian × Black Mesdag was observed. However, in F_3, 45 of the 48 lines had more awned than awnless progenies. A few awns were present in the North Finnish parent, which shows that it is not really an awnless oat. When the three primarily awnless lines are grouped together and the 45 that are fully or predominantly awned are grouped together, we have in F_3 a close approach to a 15:1 ratio of mostly awned to mostly awnless in this cross, also.

NORTH FINNISH × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Present	772	9	812.25	−40.25
Absent	672	7	631.75	+40.25
F_3:				
Twisted geniculate	16	15	45	±0.0
Heterozygous for awns	29			
Mostly awnless	3	1	3	±0.0

Segregation in the Black Mesdag × Kherson cross cannot be fitted to any known segregation pattern. However, individuals with awns absent appeared most numerous. Awns were not studied in F_3 of this cross.

BLACK MESDAG × KHERSON

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Twisted geniculate	146	7	664.56	−118.56
Subgeniculate	262			
Straight	138			
Absent	973	9	854.44	+118.56

The cross White Bonanza × Albion, studied only in the F_2 generation, gave different results than were obtained from any of the other crosses. It appeared that a three-factor difference existed, since the twisted awn character was dominant over all other conditions and a single plant out of 326 F_2 plants was classed as awnless.

WHITE BONANZA × ALBION

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Twisted geniculate	267	63	320.91	+4.09
Subgeniculate	55			
Straight	3			
Absent	1	1	5.09	−4.09

In the four crosses of Black Mesdag (twisted on lower floret) × awnless oats, segregation in all indicated a two-factor difference, although segregation ratios differed.

In Cornellian (absent) × Swedish Select (twisted on lower floret), a 7 present: 9 absent ratio was indicated in F_2. In F_3, a ratio of 13 present: 3 awnless was indicated. In the F_2 of the cross White Bonanza (awned) × Albion (awnless), a 63 awned: 1 awnless segregation was indicated. Albion at times has a few awns.

Straight × Straight

Only one cross was studied in which both parents bore straight awns. No awnless individuals were found in F_2, but 15 plants had twisted or subgeniculate awns, as follows:

RED RUSTPROOF × CALCUTTA

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Straight	978	63	977.48	+0.52
Subgeniculate	1	} 1	15.52	−0.52
Twisted geniculate	14			

In this cross, a ratio of 63 straight : 1 with awns of other types resulted. This apparently indicated that not all straight-awned oats are genetically the same.

Straight × Absent

Four crosses were studied for this character: Red Rustproof × Navarro; Calcutta × Kherson; Red Rustproof × Cole; and Kherson × Kherson. Navarro, Kherson, and Cole were previously considered to be awnless.

RED RUSTPROOF × NAVARRO

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Absent	37	3	50.86	−13.86
Straight	969	57	966.32	+ 2.68
Subgeniculate	54	3	50.86	+ 3.14
Twisted geniculate	25	1	16.95	+ 8.05

CALCUTTA × KHERSON (ETHERIDGE)

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Twisted geniculate	6			
Subgeniculate	20	} 9	205.88	+17.12
Straight	197			
Awnless	143	7	160.13	−17.13

The segregation in two F_2 and one F_3 populations of Red Rust-proof × Cole was as follows:

RED RUSTPROOF × COLE

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Twisted geniculate	7			
Subgeniculate	23	11	531.44	+19.56
Straight	521			
Absent	222	5	241.56	–19.56
F_3:				
Straight	15	15	45.94	+ 0.06
Heterozygous	31			
Absent	3	1	3.06	– 0.06

In the cross Kherson (straight awns) with Kherson (awnless), 2,284 F_2 plants were observed. An apparent three-factor difference was indicated. Segregation was as follows:

KHERSON × KHERSON

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Twisted geniculate	707			
Heterozygous	1,150	63	2,248.31	–6.31
Straight	385			
Awnless	42	1	35.69	+6.31

In these four crosses, all types of awns except the twisted geniculate on all florets were observed among the resulting progenies. In one cross, the ratio in F_2 was 3 awnless: 61 awns present. In another cross, the ratio in F_2 was 1 awnless: 63 awns present. In the two other crosses, a two-factor difference was indicated. In the F_2 of all the crosses, more awned than awnless oats appeared. In all crosses, individuals with twisted awns on the lower floret appeared. Only one cross was grown in the F_3, and in that cross a ratio of approximately 15 awned: 1 awnless was indicated.

Absent × Absent

Three oats, Cornellian, Aurora, and Sparrowbill, previously considered to be awnless, were used in crossing in this study of absent × absent awns.

Inheritance in the cross Cornellian × Aurora was studied in both F_2 and F_3 generations. No F_3 line bred true for the awned condition. Data obtained were as follows:

CORNELLIAN × AURORA

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Awns present	71	1	60.06	+10.94
Awns absent	890	15	900.90	−10.90
F_3:				
Heterozygous	46	15	45.94	+ .06
Awns absent	3	1	3.06	− .06

The cross Cornellian × Sparrowbill was studied in F_2 only and data obtained were as follows:

CORNELLIAN × SPARROWBILL

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Awns present	164	15	165	−1.0
Awns absent	12	1	11	+1.0

Hence, although Cornellian, Aurora, and Sparrowbill are supposedly awnless oats, crosses between them give indications that all have factors for awns that produce more awned than awnless individuals in the crosses.

One cross between two supposedly awnless oats, grown in the F_2, segregated in a ratio of 1 oat with awns present:15 with awns absent. In the F_3, however, the reverse was found, or 15 with some awns present:1 with awns absent. In a second cross between two supposedly awnless oats, the ratio was 15 with awns present:1 with awns absent.

These data indicate that awnless oats are rare and that some supposedly awnless oats possibly carry genes for awns in the heterozygous condition.

SHAPE OF BASE

Oat species and varieties differ as to shape of the base of the primary floret. The wild oat species *A. sterilis* separates from its peduncle, leaving a very prominent, long scar and cavity in the base of the lower floret. The angle of this separation in *A. sterilis* differs somewhat from that in *A. fatua* in that it is more oblique and the scar and cavity are longer. Both species have very large cavities surrounded by an expanded periphery ring with more or less long, bristlelike hairs. The length of the hairs in *A. fatua* is more variable than it is in *A. sterilis*. In fatuoids (false wild oats), the cavity is usually similar in size and shape to that in *A. fatua*. Fatuoids also differ in length of basal hairs.

The Sixty-Day steriloid-fatuoid has a basal scar similar to that in *A. fatua*, except that it is often somewhat longer.

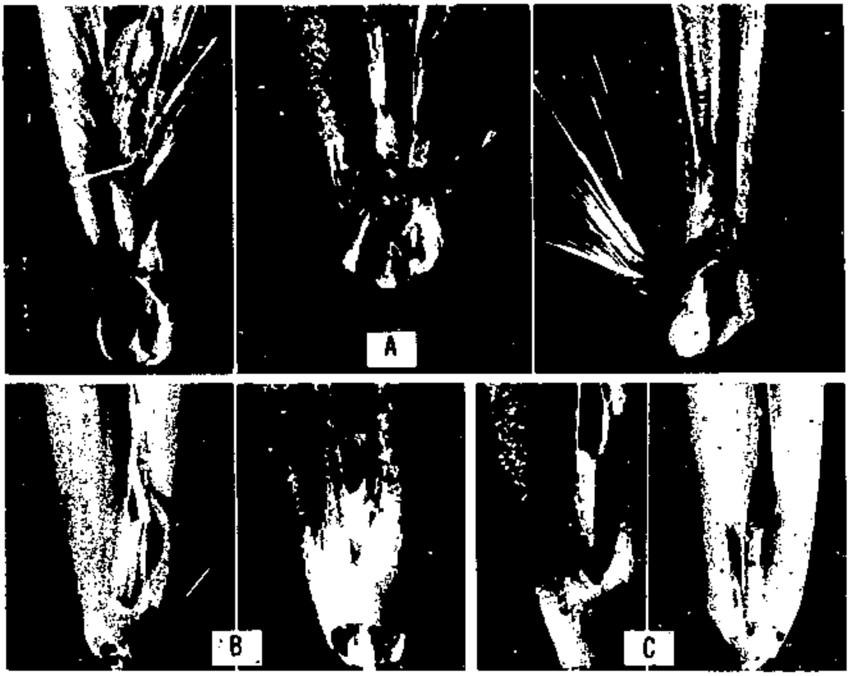

FIGURE 5.—Shape of base in *Avena*: *A*, Prominent basal scar—left to right, *A. fatua*, *A. byzantina* var. Red Rustproof, and *A. sterilis*; *B*, basal scar obscure—left, *A. sativa* var. Kherson, and right, *A. byzantina* var. Burt; *C*, basal scar absent—left, *A. byzantina* var. Burt, and right, *A. sativa* var. Victory.

The shape of the base differs among cultivated varieties. Red Rustproof has a pronounced cavity; Black Mesdag has a small or obscure cavity; and some varieties such as Kherson and Cole have no cavity at all, although occasional kernels do have an obscure type of cavity. In hybrid progenies, the shapes of bases grade into one another and make exact classification difficult and sometimes impossible.

The inheritance of shape of base was studied in the following combinations:

Prominent × Prominent	Prominent × Absent
Prominent × Obscure	Obscure × Absent

Prominent × Prominent

Two crosses of oats having prominent basal scars were studied for this character. Red Rustproof × Calcutta was studied in F_2 and F_3. Results in the F_2 generation were as follows:

RED RUSTPROOF × CALCUTTA

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	987	63	977.48	+9.52
Obscure	6	1	15.52	−9.52

In the F_2 segregation, individuals with obscure type basal scars appeared. In F_3, all 49 lines grown bred true for prominent basal scars. Not all *A. byzantina* oats with prominent basal scars are genetically alike even though they appear to be alike phenotypically. A few segregates with less prominent or more obscure type basal scars sometimes appear in crossed progenies. This is of interest in connection with the origin or appearance of cultivated or *sativa*-like individuals in *A. byzantina* oats.

In the Fulghum fatuoid × Sixty-Day aberrant cross, both parents have prominent basal scars, although the scars differ in shape. Segregation in F_2 of this cross was as follows:

FULGHUM FATUOID × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	82	63	82.69	−0.69
Obscure	2	1	1.31	+0.69

Individuals with the obscure type of scar also appeared in this cross. This fact might be indicative of the mode of derivation of cultivated types from different wild types.

Prominent × Obscure

Four crosses between oats with prominent and oats with obscure basal types were studied. In this group, the prominent basal cavity type in the sterilоid-fatuoid aberrant from Sixty-Day was crossed with Black Mesdag, which has the obscure type of scar. Segregation in this cross was as follows:

SIXTY-DAY ABERRANT × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	531	1	511.5	+19.5
Intermediate	1,152	3	1,534.5	−19.5
Obscure	363			
F_3:				
Prominent	2	1	3.5	− 1.5
Intermediate and obscure	12	3	10.5	+ 1.5

Segregation in 8 F_3 lines of this cross was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Prominent	43	1	43.25	−0.25
Intermediate and obscure	130	3	129.75	+0.25

In F_2 there were too few progenies with obscure and intermediate scars and too many with the prominent type of basal scar for a good fit to a 1:2:1 ratio, but the deviation from the expected 3:1 ratio in a population in excess of 2,000 individuals is not large. In the small F_3 grown, a segregation of 3:1 resulted.

In the Burt fatuoid × Black Mesdag cross, as in the Sixty-Day aberrant × Black Mesdag cross, a single-factor difference seemed the most logical explanation of the results obtained.

Burt fatuoid × Black Mesdag

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	94	1	94	±0.0
Obscure	282	3	282	±0.0

If the data from the two crosses Sixty-Day aberrant × Black Mesdag and Burt fatuoid × Black Mesdag are added together, the results are as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	625	1	605.5	+19.5
Obscure	1,797	3	1,816.5	−19.5

The prominent base type Red Rustproof was crossed with the obscure base type Black Mesdag. This cross was the most difficult to analyze, since there was a complete gradation of types from one parent to the other. The F_2 segregation of this cross was as follows:

Red Rustproof × Black Mesdag

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	394	1	281.25	+112.75
Intermediate	698	3	843.75	−112.75
Obscure	33			

In this cross, it was practically impossible to differentiate obscure type individuals from some intermediate types; hence it would seem logical to consider the progenies as comprising two groups. For a single-factor difference, there are far too many prominent type individuals. For a two-factor analysis, the reverse is true, as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	394	6	421.88	−27.88
Intermediate	698	9	632.81	+65.19
Obscure	33	1	70.31	−37.31

In the F_2 of the cross Red Rustproof × Navarro, segregation was as follows:

Red Rustproof × Navarro

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	334	1	271.25	+62.75
Obscure	751	3	813.75	−62.75

Usually the obscure type basal scar is dominant over the prominent scar in a 3 obscure and intermediate:1 prominent, but the data obtained do not indicate this to be true in this cross.

In three of these four crosses, a poor fit to any usual genetic interpretation was obtained. Too many prominent scars and too few scars of other types were found for a monogenic interpretation.

The summary data on the Red Rustproof × Black Mesdag and the Red Rustproof × Navarro crosses are as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	728	5	690.62	+37.38
Intermediate and obscure	1,482	11	1,519.38	−37.38

If prominent base type is recessive and obscure base type may be phenotypically alike but genotypically different, we can assume two factors for inheritance of base type in crosses of prominent × obscure. Consequently, in some crosses a segregation into a 3:1 ratio will result; whereas in others, segregation into different ratios will result. In a two-factor interpretation, 5 genotypes could produce the recessive (prominent) type bases; and 11 could produce the dominant (obscure and absent) type bases. In such a case, a ratio of 5 phenotypically recessive type (prominent):11 dominant type (obscure and absent) would be found.

Prominent × Absent

Three crosses between oat varieties having prominent basal scars and those having no basal scars were studied. Calcutta (prominent) × Kherson (Etheridge) (absent) was studied in F_2, and results obtained approached the expected monogenic ratio.

CALCUTTA × KHERSON (ETHERIDGE)

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	112	1	91.5	+20.5
Obscure	169	2	183.0	−14.0
Absent	85	1	91.5	− 6.5

In the cross Cole × Red Rustproof, a close fit to a 3:1 ratio was observed. Results in F_2 and F_3 were as follows:

COLE × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	255	1	284.75	−29.75
Obscure	486	3	854.25	+29.75
Absent	398			
F_3:				
Prominent	13	1	12.25	+ 0.75
Heterozygous	31	3	36.75	− 0.75
Absent	5			

The Burt fatuoid × Monarch was studied in F_2, and results obtained are similar to those frequently reported wherein the intermediate and obscure types are added.

BURT FATUOID × MONARCH

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	113	1	105	+8.0
Intermediate	241	3	315	−8.0
Absent	66			

If the data from the F_2 populations of these three crosses are added together, the summary is as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Prominent	480	1	481.25	−1.25
Obscure and intermediate	896	3	1,443.75	+1.25
Absent	549			

Thus it would appear that, in crosses of oats having prominent scars with oats having no scars, the prominent scar is conditioned by a single-factor difference. The same result was indicated when oats having the prominent type scar were crossed with oats having the obscure type scar.

Obscure × Absent

Two crosses of oats with obscure type scars and oats with scars absent could not be analyzed by any ordinary segregation ratio, although in both crosses, Cornellian × Black Mesdag and Black Mesdag × Kherson, a two-factor interpretation was the closest to any indicated. In the cross Cornellian (absent) × Black Mesdag (obscure), segregation in F_2 was as follows:

CORNELLIAN × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Obscure	799	13	814.94	−15.94
Absent	204	3	188.06	+15.94

In the cross Black Mesdag (obscure) × Kherson (absent), segregation also indicated that two factors were involved. However, the result differed from the cross in which Black Mesdag was crossed with Cornellian.

BLACK MESDAG × KHERSON

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Obscure	212	7	236.25	−24.25
Absent	328	9	303.75	+24.25

Apparently, the obscure type of basal scar was dominant in the Cornellian cross; whereas in the Kherson cross the reverse was true. As a result, data on the inheritance of the basal scar in obscure × absent crosses cannot be considered conclusive.

The fact that different types of segregations were observed in these two crosses might further indicate the difference in the genetic constitution of phenotypically similar types of bases found in Cornellian × Kherson.

SUMMARY

In oats, basal scar or shape of base may be classed as prominent, obscure, or absent. Some investigators have referred to the latter as "pointed."

In two crosses between two oats having a prominent basal scar, a ratio of 63 prominent: 1 obscure scar was indicated. In four crosses of oats having a prominent basal scar with oats having an obscure scar, the ratio was 1 prominent: 3 obscure in two crosses.

In the other two crosses, the fit to either a 3:1 or 15:1 was very poor. However, if the progenies of these two crosses are combined, the fit to a 5 prominent:11 obscure is indicated. The F_3 was not examined for this character.

In three crosses of oats having a prominent scar with oats having no scar, the ratio in all approached 1 prominent:3 obscure or absent; and if the segregates of the three crosses are added together, an extremely close fit to a 3 prominent and intermediate:1 absent is obtained.

Two crosses were studied in which oats having the obscure type of basal scar were crossed with oats having no scar. In both crosses, a two-factor but different segregation was indicated; but, since the F_3 was not grown, the results were inconclusive.

MODE OF FLORET SEPARATION

Oat breeders formerly assumed that floret separation in *A. sativa* took place by abscission, just as in *A. fatua*. Coffman (*2*) pointed out that this assumption was incorrect and that floret separation in *A. sativa* actually occurred by fracture. Furthermore, except for floret separation in *A. fatua* and the *fatua*-like fatuoid aberrants in which separation results by abscission (with one exception), floret separation in all hexaploid oats is actually by fracture. Musil (*21*) supported this observation by Coffman.

The exception noted above is the Sixty-Day aberrant. This oat does not separate entirely by abscission; there is often some attached tissue between the secondary floret and its supporting rachilla segment, which, in separation, frequently breaks away a portion of the periphery or wall around the basal cavity of the secondary floret. Also, in some cases the entire rachilla segment may remain attached to the upper or secondary floret.

The area in which the fracture of the supporting rachilla segment takes place differs decidedly. In *A. sterilis* and among cultivated varieties of *A. byzantina*, fracture is almost exclusively in the basal portion of the supporting rachilla segment; whereas in *A. sativa*, it is at the top or the distal portion of the segment.

In the present study, modes of floret separation observed were as follows:

Fracture (basal) × Fracture (distal)
Fracture (basal) × Semiabscission
Fracture (basal) × Abscission
Fracture (distal) × Semiabscission
Fracture (distal) × Abscission
Abscission × Semiabscission

One other mode of floret separation was studied: *A. fatua* (abscission) × *A. nuda*. In *A. nuda*, floret separation is much less clearly seen than it is in covered oats because the groats separate readily from their glumes in threshing, instead of the florets separating from one another.

Only one oat in which spikelet separation was by semiabscission was included. This was the unusual Sixty-Day steriloid-fatuoid aberrant, which may separate in any one of three different ways:

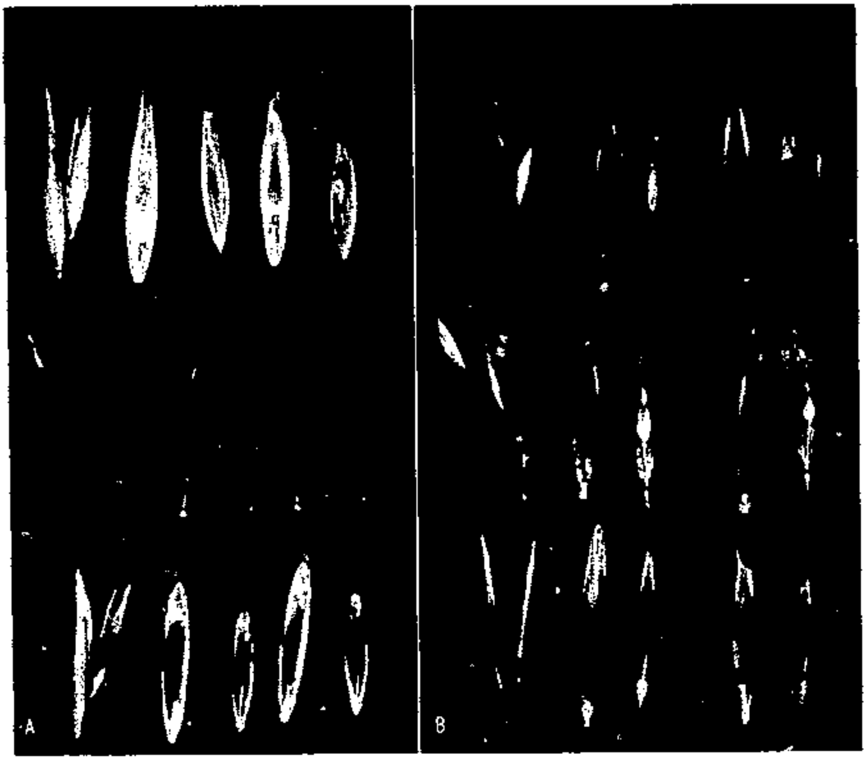

FIGURE 4.—Floret separation in cultivated varieties of *Avena*: Left, *A. sativa* (fracture distal); right, *A. byzantina* (usually fracture basal).

(1) By abscission, (2) by fracture (distal), and (3) by fracture (basal). All three ways of floret separation have been found in a single panicle of this aberrant oat. This unusual oat was discovered by the writer in Akron, Colo., in 1922. In 1961, the writer discovered a second oat of this type at Aberdeen, Idaho (see p. 73).

Fracture (basal) × Fracture (distal)

As indicated previously, fracture (basal) is represented in cultivated oats by *A. byzantina* varieties; whereas fracture (distal) is found in *A. sativa* varieties. This combination was studied in four crosses.

BLACK MESDAG × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Fracture (basal)	714	15	1,054.69	−24.69
Intermediate	316			
Fracture (distal)	95	1	70.31	+24.69

CALCUTTA × KHERSON

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Fracture (basal) and intermediate	233	9	205.88	+27.12
Fracture (distal)	133	7	160.13	–27.13

COLE × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Fracture (basal) and intermediate	637	13	628.06	+8.94
Fracture (distal)	136	3	144.94	–8.94
F_3:				
Fracture (basal) only	5 }	12	36.75	–5.75
Fracture (basal) and heterozygous	26 }			
Heterozygous only	8 }	3	9.19	+7.81
Intermediate only	9 }			
Fracture (distal) only	1	1	3.06	–2.06
	or			
F_3:				
Fracture (basal)	5 }	13	39.81	–0.81
Heterozygous	34 }			
Fracture (distal) and intermediate	10	3	9.19	+0.81

CALCUTTA × KHERSON (ETHERIDGE)

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Fracture (basal)	233	10	288.75	+ 4.25
Fracture (distal)	133	6	137.25	– 4.25
	or			
Fracture (basal)	233	37	211.59	+21.41
Fracture (distal)	133	27	154.41	–21.41

The 10:6 ratio indicated cannot be explained by any usual segregation, and no usual ratio apparently applies in this case. However, the results indicate that more than one factor is involved.

In all four crosses studied, the approach to a two-factor difference was indicated, although the approach to the expected was less close in some than in others.

Fracture (basal) × Semiabscission

Only one cross of this combination was studied. Results were as follows:

A. sterilis × Sixty-Day aberrant

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Fracture (basal)	78	3	84	−6.0
Semiabscission	34	1	28	+6.0

The number of plants observed was small, but an apparent 3:1 ratio was indicated.

Fracture (basal) × Abscission

Only one cross, Fulghum fatuoid × Red Rustproof, was studied. Results were as follows:

Fulghum fatuoid × Red Rustproof

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Abscission	46	1	54.5	−8.5
Intermediate and fracture (basal)	172	3	163.5	+8.5
F_3:				
Abscission	13	1	11.5	+1.5
Intermediate and fracture (basal)	33	3	34.5	−1.5

A very close fit to the usual ratio of 1 fatuoid (abscission) type: 3 *A. byzantina* fracture (basal) and intermediate types resulted. This was true in both the F_2 and the F_3 generations.

Fracture (distal) × Semiabscission

In the cross Sixty-Day aberrant × Black Mesdag, the approach to a two-factor difference in F_2 was very close.

Sixty-Day aberrant × Black Mesdag

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Fracture (basal)	893	7	895.13	−2.13
Intermediate and cultivated	1,153	9	1,150.88	+2.12

Floret separation in Black Mesdag is by fracture (distal); whereas, in the Sixty-Day aberrant, floret separation is by semiabscission. A very large F_2 and a very small F_3 population of this cross were studied. In an F_2 population of 2,046 plants, segregation indicated an almost perfect fit to a 7 Sixty-Day aberrant (semiabscission): 9 intermediate and cultivated (fracture distal).

Fracture (distal) × Abscission

Five crosses of this combination were studied in F_2. In four, a reasonably close fit to a 3 fracture (distal): 1 abscission was found. In the fifth cross, a closer approach to a two-factor segregation was indicated.

BURT FATUOID × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Abscission	94	1	94	±0.0
Intermediate	167	3	282	±0.0
Fracture (distal)	115			

FULGHUM FATUOID × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Abscission	56	1	57.5	−1.5
Intermediate	119	2	115.0	+4.0
Fracture (distal)	55	1	57.5	−2.5

FULGHUM FATUOID × SWEDISH SELECT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Abscission	112	1	111.5	+0.5
Intermediate and fracture (distal)	334	3	334.5	−0.5

BURT FATUOID × MONARCH

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Abscission	108	1	105.0	+3.0
Intermediate	193	3	315.0	−3.0
Fracture (distal)	119			

Although many reports have indicated that oats having the fatuoid (abscission) type of floret separation differ in floret separation from cultivated oats by a single factor, more than a single-factor difference was indicated in the following cross:

RUAKURA FATUOID × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Abscission	70	1	101.0	−31.0
Intermediate	155	3	303.0	+31.0
Fracture (distal)	179			
	or			
Abscission	70	3	75.75	− 5.75
Intermediate	155	13	328.25	+ 5.75
Fracture (distal)	179			

The fit for the usual 3:1 ratio was so poor that another ratio was suggested.

Abscission × Semiabscission

Four crosses between the Sixty-Day aberrant (semiabscission) and either *A. fatua* or a fatuoid (abscission) were studied. Segregation among the progenies of these crosses indicated that, in this combination, floret separation may differ decidedly as to mode of inheritance.

Segregation in F_2 was as follows:

A. fatua × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Semiabscission	256	3	264.75	−8.75
Abscission	97	1	88.25	+8.75

The approach to a 3 semiabscission:1 abscission was indicated in the above cross. However, the number separating by abscission was relatively high.

Two additional crosses between *A. fatua* and the Sixty-Day aberrant were studied. Because segregation in these two crosses was similar, the data were combined in calculating segregation ratios as follows:

A. fatua × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Semiabscission	555	48	571.50	−16.50
Abscission	192	15	178.59	+13.41
Fracture (basal)	15	1	11.91	+ 3.09

Results from these two crosses differed greatly from those of the first *A. fatua* × Sixty-Day aberrant cross discussed. Among the progenies of these two crosses, a small number of apparently synthetic *A. sterilis* (fracture basal) types resulted, and the segregation indicated was 48 intermediate or semiabscission : 15 that separated like true *A. fatua* (abscission) : 1 in which the upper and lower kernels separated only as in *A. sterilis*. The segregation in these crosses indicated the presence of three factors.

In a cross between a fatuoid from Fulghum (abscission) and the Sixty-Day aberrant (semiabscission), only a small F_2 population was available for study. In this cross, the fatuoid type was dominant. Segregation was as follows:

FULGHUM FATUOID × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Abscission	78	15	78.75	−0.75
All other types	6	1	5.25	+0.75

This presumed cross gave unusual results. The female parent was red for lemma color, and no segregation for that character was observed among the supposed F_2 individuals. Consequently, one may suspect that those individuals not separating by abscission were the result of natural crosses in the supposed F_1 plant and that the closeness of the suggested ratio in the assumed F_2 population was coincidental.

A. fatua (abscission) × *A. nuda* Type of Floret Separation

Few crosses have been made using the *A. nuda* variety Liberty Hulless. In *A. nuda*, floret separation is obscured by the elongated rachilla segments. In the one cross studied, only 2 plants among the 74 were of the *A. fatua* type. This indicated the possibility of a three-factor difference, although the numbers involved for analysis of a three-factor segregation were small. The approach to the expected was reasonably close.

The F_2 population was small, but segregation was as follows:

A. fatua × *A. nuda* var. LIBERTY HULLESS

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Abscission	2	1	1.16	+0.84
Fracture (basal or distal)	12	9	10.41	+1.59
A. nuda and *A. nuda* intermediate	60	54	62.44	−2.44

SUMMARY

In hexaploid oats, floret separation may be (1) by abscission, (2) by semiabscission, (3) by fracture (distal), or (4) by fracture (basal). Representatives of these four types are (1) *A. fatua* and the fatuoids, (2) the Sixty-Day aberrant, (3) *A. sativa* varieties, and (4) *A. sterilis* and *A. byzantina* varieties, respectively.

Still another type of floret separation is found in *A. nuda*, but it is complicated by the elongated connecting rachilla segments, especially of the upper florets.

A two-factor ratio appears most logical for explaining floret separation in crosses of fracture (basal) × fracture (distal); although, in the cross Calcutta × Kherson, the segregation did not approach any usual two-factor ratio. In the *A. sterilis* × Sixty-Day aberrant cross, a ratio of 3 fracture (basal):1 semiabscission was indicated. In the cross Fulghum fatuoid (abscission) × Red Rustproof (fracture basal), a ratio of 3 fracture:1 abscission was indicated. In four combinations of *A. sativa* (fracture distal) by *A. fatua* or fatuoids (abscission), a ratio of 3:1 was indicated. In a fifth cross involving this combination, a rather close fit to a 13 fracture (distal):3 abscission was indicated.

The abscission × semiabscission combination was studied in four crosses. In one, a segregation ratio of 3 semiabscission:1 abscission was indicated. In two crosses in which segregation results were combined, a segregation of 48 semiabscission:15 abscission:1 fracture (basal) resulted. This segregation indicated the presence of multiple factors. The last group appeared to be synthetic *A. sterilis* oats. Their appearance supports the theory of the origin of species among hexaploid *Avena*. In the fourth cross, the abscission type of floret separation appeared dominant in a 15:1 ratio. The population was small, and the F_3 was not grown.

One cross of an *A. fatua* oat (abscission) × Liberty Hulless (*nuda* type) was studied. Floret separation in crosses of *A. nuda* × covered oats is difficult to study genetically. The rather complicated ratio of 54 (*nuda*):9 intermediate (fracture basal or distal):1 abscission was observed in F_2. The F_3 was not studied.

BASAL HAIRS (PUBESCENCE)

The mode of inheritance of basal hairs in oats is difficult to determine, especially in crosses in which the parents differ in length of hairs. In these studies, about 10 kernels per plant were examined by use of an X14 pocket lens.

The following four combinations of basal hairs were studied:

- Numerous Long × Numerous Long
- Numerous Long × Short
- Numerous Long × Absent
- Numerous Short × Absent

In addition to the above, study was also made of the inheritance of numerous long hairs on base and sides × numerous long hairs on base only.

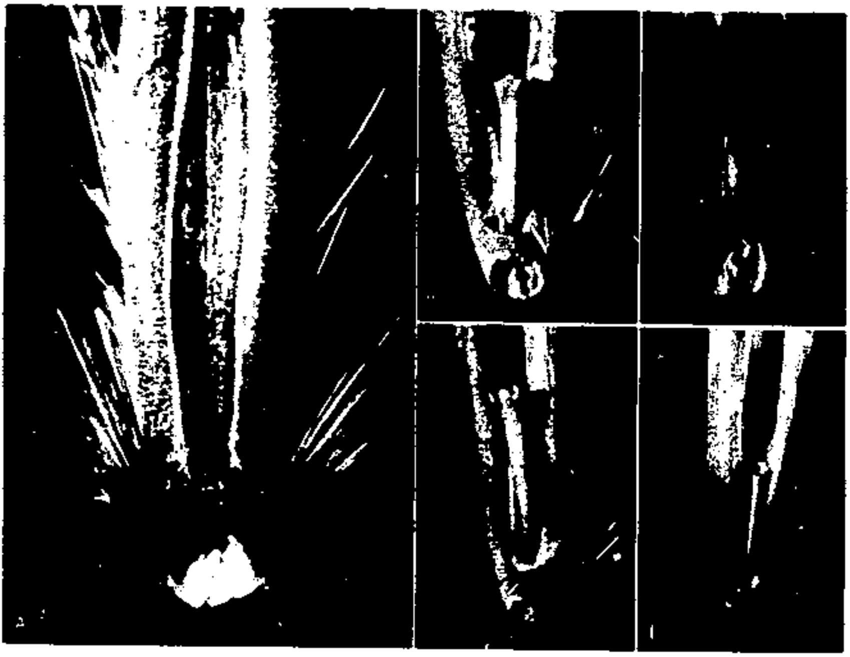

FIGURE 5.—Basal hairs (pubescence) in *Avena*: *A*, Numerous long; *B*, few long; *C*, numerous short (midlength); *D*, few short (midlength); *E*, absent.

Numerous Long × Numerous Long

Three crosses were studied in which both parents had numerous long basal hairs. These were *A. sterilis* × Sixty-Day aberrant (steriloid-fatuoid), Sixty-Day aberrant × *A. fatua*, and Calcutta × Red Rustproof.

In the F_2 of the first two crosses, all segregates had numerous long hairs on the base.

In the third cross, although both parents were similar and had numerous long hairs, segregation resulted in F_2; and all types were observed. An approach to a ratio of 1 long: 3 other types, including individuals lacking basal hairs, was observed.

CALCUTTA × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Numerous long	166	1	285	+5.0
Few long	124			
Numerous short	219	3	855	−5.0
Few short	205			
Absent	336			

These data indicate that the parents differ as to the genes for basal hairs they carry and also that oats having long hairs can produce progenies of every other type.

Numerous Long × Short

Both parents in the cross Black Mesdag × Red Rustproof have basal hairs; but Red Rustproof has both more and longer hairs. Black Mesdag has short hairs. Segregation was as follows:

BLACK MESDAG × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Numerous long	333	3	843.75	−2.75
Few long	508			
Numerous short	41	1	281.25	+2.75
Few short	119			
Absent	124			

When all segregates having long basal hairs are added together, a very close approach to the ratio 3 long hairs: 1 of all other types, including the absence of hairs, is found.

Study of the F_2 of the cross Black Mesdag × Sixty-Day aberrant gave a different result.

BLACK MESDAG × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Numerous long	384	1	511.5	−94.5
Few long	33			
Numerous short	1,090	3	1,534.5	+94.5
Few short	205			
Absent	334			
	or			
Numerous long	384	3	383.63	+ 0.37
All other types	1,662	13	1,662.38	− 0.38

In this cross, all types of hairs were observed, and an extremely close approach to a ratio of 3 numerous long: 13 of all other types was observed. This apparently indicates the presence of a two-factor difference. This cross was not studied in F_3.

Numerous Long × Absent

Four crosses were studied in which oats with numerous long basal hairs were crossed with oats in which hairs were absent. The F_3 was studied in only one of these crosses.

COLE × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Numerous long	90	1	193.5	−9.5
Few long	94			
Numerous short	148	3	580.5	+9.5
Few short	182			
Absent	260			
F_3:				
Numerous long	13	1	12.25	+0.75
Heterozygous	34	3	36.75	−0.75
Few	2			
Absent	0			

Calcutta, like Red Rustproof, has numerous long hairs; whereas in Kherson (Etheridge) hairs appear to be absent. In the F_2 of this cross, the long-hair type appeared recessive and a 1 long: 3 of all other types was indicated. This character was not studied in F_3 in this cross.

CALCUTTA × KHERSON (ETHERIDGE)

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Numerous long	76	1	91.5	+14.5
Few long	30			
Numerous short	71	3	274.5	−14.5
Few short	113			
Absent	76			

In a third cross studied, Burt fatuoid × Monarch, a ratio of 3 absent or few hairs: 1 numerous long was observed in F_2 as follows:

BURT FATUOID × MONARCH

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Numerous long	124	1	105	+19
Few long	254	3	315	−19
Absent	42			

In all three of the above crosses, numerous long hairs appeared to be recessive in a ratio of 1 numerous long: 3 of all other types.

In the cross Red Rustproof (numerous long hairs) × Navarro (few or no basal hairs), the F_2 segregation indicated a somewhat different ratio of 9 numerous and few: 7 absent.

Basal hairs were not studied in F_3 of this cross. In F_2, however, segregation was as follows:

RED RUSTPROOF × NAVARRO

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Numerous long	348	9	610.31	+24.69
Few long	287			
Absent	450	7	474.69	−24.69

When the F_2 data of all four crosses are summarized into two classes, numerous long: all other types, the result is as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Numerous long	638	1	661.25	−23.25
All other types	2,007	3	1,983.75	+23.25

The departure from a 1:3 ratio is not great, considering that the deviation from the expected was only 23 plants out of 2,645.

Numerous Short × Absent

In the cross Black Mesdag × Cornellian, segregation in F_2 was as follows:

BLACK MESDAG × CORNELLIAN

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Numerous long	88	13	814.94	+6.06
Few long	49			
Numerous short	374			
Few short	310			
Absent	182	3	188.06	−6.06

In this cross, as in crosses involving one parent having long basal hairs, all types were observed.

Numerous Long on Base and Sides × Numerous Long on Base Only

Two crosses were studied in which both parents had long hairs on the base of all kernels. In both crosses, one parent also had long hairs on the sides. One parent to both crosses was the Sixty-Day aberrant. In the first cross, the other parent was the extremely hairy *A. sterilis*; and in the second cross it was a less hairy *A. fatua*. All segregates of both crosses produced F_2 progenies having long hairs on the base of all florets. Segregation for hairs on the back in the *A. sterilis* cross was as follows:

A. sterilis × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Extremely hairy	34	1	28.25	+5.75
Absent or few hairs	79	3	84.75	−5.75

Although *A. sterilis* had profuse hairs on the back of all florets, a ratio of 1 (extremely hairy) : 3 few or no hairs was obtained.

In the second cross a different segregation resulted, as follows:

SIXTY-DAY ABERRANT × *A. fatua*

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Extremely hairy	3	1	4.11	−1.11
Absent or few hairs	260	63	258.89	+1.11

Only 3 of 263 progenies in this cross had numerous hairs on the sides of the lemma. This fact would indicate that the character for producing hairs on the back and side in the *A. fatua* used differed decidedly from that in the *A. sterilis* used.

SUMMARY

It is difficult to generalize about the inheritance pattern of pubescence in oats. In some cases, it appears that lack of hair is dominant over presence of hair. In other cases, the reverse appears to be true.

A definite observation was that the wild *A. sterilis*, which has numerous long hairs on the base and back of the lemma, may transmit that character to its progeny more often than does *A. fatua*. Also, cultivated oats having long hairs on the base may or may not be identical genetically, since all types of basal hairs, including the absence of hairs, resulted from the Calcutta (numerous long) × Red Rustproof (numerous long) cross.

When parents with numerous long hairs were crossed with parents with short hairs, progenies having all the types of hair resulted. However, decidedly different segregation ratios were found in different crosses. This would seem to be further proof that not all oats having long hairs are genetically the same, since long hairs appeared to be dominant in one cross and recessive in another.

Four crosses were studied in which either Red Rustproof or the similar variety Calcutta was used as the parent possessing numerous long basal hairs. One of these, Cole × Red Rustproof, was studied in the F_2 and F_3 generations. Results from this cross indicated that the type with numerous long basal hairs is more constant than any other type. Also, the length of the hairs seemed to be more constant than the number. The total absence of hairs, like the absence of awns, appears to be an inconsistent character affected by environmental factors. Most varieties of oats have at least one basal hair on a few kernels. When parents with many hairs are crossed with parents in which hairs are supposedly absent, few of the absent type are recovered among the progenies.

In the cross Cole × Red Rustproof, a comparatively good fit both in F_2 and F_3 to a ratio of 1 individual with long hairs: 3 with short hairs or the apparent absence of hairs was observed. In the F_3, those with long hairs tended to breed true, whereas other types often proved heterozygous.

In one cross of numerous short × absent hairs, all types of hairs appeared but in a ratio of 13 hairy: 3 absent. This indicates the complicated nature of the inheritance of basal hairs in oats. Oats that appear phenotypically alike may be genotypically different.

Both *A. sterilis* and *A. fatua* were crossed with the Sixty-Day aberrant. The data on the inheritance of hairs on the back of the lemma showed that *A. sterilis* produced all types in the F_2 progenies, whereas the less hairy *A. fatua* produced few F_2 segregates with hairs on the back. Thus, it is evident that *A. sterilis* crossed with other oats produces progenies that contain nearly all the morphologic types found among hexaploid oats. But crosses involving *A. fatua* may result in a more restricted segregation. This is further evidence supporting Coffman's theory on the origin of cultivated oats (*2*).

RACHILLA HAIRS

The inheritance of rachilla hairs was studied in four crosses. Black Mesdag, characterized by the presence of numerous short hairs on the rachilla segment, was one common parent in the four crosses involving Cornellian, Red Rustproof, Swedish Select, and Kherson. Progenies of both the F_2 and F_3 generations of three of the crosses were studied. Study of the identification of rachilla hairs was made by use of an X14 lens.

It would appear that, genetically, Black Mesdag has two factors conditioning hairs on the rachilla; whereas Cornellian, Kherson, Swedish Select, and Red Rustproof lack both factors.

Cornellian × Black Mesdag

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Present	940	15	940.31	−0.31
Absent	63	1	62.69	+0.31
F_2:				
Present	272	15	272.81	−0.81
Absent	19	1	18.19	+0.81
F_3:				
All present	30	15	60	±0.0
Heterozygous present	30			
All absent	4	1	4	±0.0

FIGURE 6. Pubescence of rachilla segment in *Avena*: *A*, Numerous; *B*, absent.

BLACK MESDAG × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Present	1,065	15	1,054.69	+10.31
Absent	60	1	70.31	−10.31

BLACK MESDAG × SWEDISH SELECT

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Present	225	15	228.75	−3.75
Absent	19	1	15.25	+3.75
F_3:				
All present	15	15	30.94	−0.94
Heterozygous present	15			
All absent	3	1	2.06	+0.94

BLACK MESDAG × KHERSON

Class and progeny	Observed	Ratio	Calculated	O–C
F_2 First year:				
Present	654	9	550.69	+103.31
Absent	325	7	428.31	−103.31
F_2 Second year:				
Present	488	15	506.25	−18.25
Absent	52	1	33.75	+18.25
	or			
Summary:				
Present	1,142	3	1,139.25	+2.75
Absent	377	1	379.75	−2.75
F_3:				
All present	24	15	61.88	−2.88
Heterozygous	35			
All absent	7	1	4.13	+2.87

SUMMARY

In the crosses Cornellian × Black Mesdag, Black Mesdag × Red Rustproof, and Black Mesdag × Swedish Select, segregations in F_2 indicated that Black Mesdag carries two factors conditioning the presence of hairs on the rachilla segment. At first it was believed inheritance in the Kherson cross was different and that a single-factor difference was indicated. However, the summary of 2 years' study of F_2 plants and the inheritance in 66 F_3 generation lines indicate that inheritance of pubescence on the rachilla is conditioned by two factors in all four crosses. Summary data on all four crosses indicate a very good fit to a 15:1 ratio.

PANICLE SHAPE

The inheritance of side and open or spreading panicles in oats was studied in the progenies of 12 crosses. These were as follows:

Black Rival × Richland (6 crosses)
Monarch × Black Rival (1 cross)
Cornellian × Garton Gray (3 crosses)
Cornellian × Sparrowbill (2 crosses)

The parents with side panicles were Black Rival, Garton Gray, and Sparrowbill. Segregation among the progenies of these crosses indicated that the open or spreading-type panicle was dominant in F_1 in all cases and that segregation in later generations may involve one, two, or three factors.

In open × side oat crosses, the resulting progenies tend to grade into one another to such an extent that accurate classification of the intermediate types is difficult, if not impossible. In these studies, a tendency to classify some segregates as intermediate rather than side oats prevailed. As a result, there is a consistent shortage of individuals classed as side oats in the data presented.

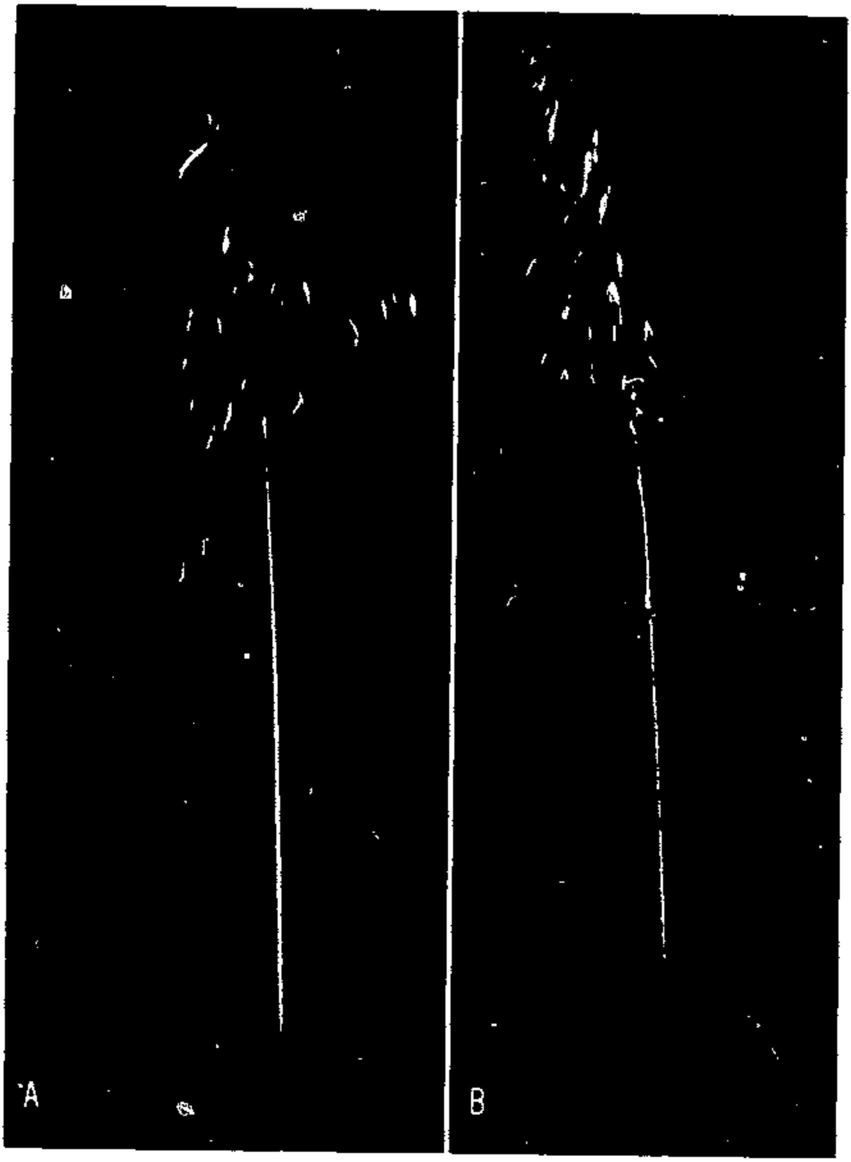

FIGURE 7.—Panicle shape in *Avena*: *A*, Spreading or equilateral; *B*, side or unilateral.

Segregation in the different F_2 populations of six F_1 plants from crosses between Black Rival and Richland was studied. Results from one cross were as follows:

BLACK RIVAL × RICHLAND

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Open	338	3	344.25	−6.25
Side	121	1	114.75	+6.25

These data indicate a reasonably close fit to a 3:1 ratio in F_2. The F_3 was not grown.

Segregation of the F_2 progenies of three of the six F_1 plants and the summary were as follows:

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Open	129	3	120.75	+ 8.25
Side	32	1	40.25	− 8.25
Open	212	3	196.5	+15.5
Side	50	1	65.5	−15.5
Open	51	3	47.25	+ 3.75
Side	12	1	15.75	− 3.75
	or			
Summary:				
Open	392	13	394.88	− 2.88
Side	94	3	91.13	+ 2.87

In each F_2 population from a single F_1 plant, the number of individuals with side panicles was low for a 3:1 ratio. Summarized on the basis of a two-factor, 13:3 basis, the fit was much better. No F_3 populations of the four previous crosses were grown. It is difficult to classify the side panicle in Black Rival because it is not always sufficiently pronounced to distinguish the side from the intermediate.

The summary of the F_2 of the two additional crosses between the same parents gave similar results. F_3 results were different, as indicated.

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Open	90	3	92.25	−2.25
Side	33	1	30.75	+2.25
Open	70	3	69.75	+0.25
Side	23	1	23.25	−0.25
Summary:	or			
Open	160	3	162	−2.0
Side	56	1	54	+2.0
F_3:				
All open	19	15	46.88	−1.88
Heterozygous	26			
All side	5	1	3.13	+1.87

The summary for the cross indicated a very good fit in the F_2 for a single-factor difference. Taken alone, the F_3 data would indicate a segregation that made a two-factor analysis appear logical. It was not noticed until after seeding, however, that the F_3 lines sown included seed from proportionately fewer F_2 plants described as having side panicles than would be expected in a random sample. Data from the 26 segregating F_3 lines indicated, however, that the original single-factor interpretation had been correct for this cross. Segregation in 26 F_3 lines was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
All open	467	3	462.75	+4.25
Side	150	1	154.25	−4.25

A summary of all F_2 populations, plus data from segregating F_3 lines, gave results as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
Open	1,357	3	1,333.5	+23.5
Side	421	1	444.5	−23.5

Hence, it is assumed that Black Rival and Richland differ by a single factor for side and open panicle.

Panicle shape was not studied in the F_2 of the cross Monarch × Black Rival but was studied in the F_3. Segregation in this cross indicated that two factors were involved, but a summation of segregation among the heterozygous F_3 lines differed somewhat from the previous cross.

MONARCH × BLACK RIVAL

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
All open	22	12	22.50	−0.50
Heterozygous	7	3	5.63	+1.37
All side	1	1	1.88	−0.88

The seven heterozygous F_3 lines segregated as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Open	493	9	511.31	−18.31
Intermediate	357	6	340.88	+16.12
Side	59	1	56.81	+ 2.19

Grouping the open and intermediate together gives a very good fit to a 15:1 ratio. Hence, a two-factor interpretation appears logical. It is of interest that 2 of the 30 F_3 populations included some individuals with false nodes. The ratio of false nodes present: false nodes absent was not determined.

Inheritance of panicle shape was studied in three crosses of Cornellian × Garton Gray. Progenies of one cross were studied only in F_2, and results were as follows:

CORNELLIAN × GARTON GRAY

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Open	281	15	274.69	+6.31
Side	12	1	18.31	−6.31

A comparatively good fit to a two-factor ratio was indicated.

Progenies of a second cross were studied in both the F_2 and F_3 generations.

Class and progeny	Observed	Ratio	Calculated	O–C
F_2 First year:				
Open	262	15	259.69	+2.31
Side	15	1	17.31	−2.31
F_2 Second year:				
Open	186	15	184.69	+1.31
Side	11	1	12.31	−1.31
Summary:	*or*			
Open	444	15	440.63	+3.37
Side	26	1	29.38	−3.38
F_3:				
All open	33	15	57.19	−4.19
Heterozygous	20			
All side	8	1	3.81	+4.19

The 20 heterozygous F_3 lines segregated as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Open	352	3	358.5	−6.5
Side	126	1	119.5	+6.5

A third cross was also grown in both F_2 and F_3. Populations of F_2 were grown in each of 2 years, and observations were as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2 First year:				
Open	288	63	292.36	−4.36
Side	9	1	4.64	+4.36
F_2 Second year:				
Open	291	63	290.39	+0.61
Side	4	1	4.61	−0.61
Summary:	*or*			
Open	579	63	582.75	−3.75
Side	13	1	9.25	+3.75

An F_3 population was grown from each of 140 F_2 plants. Data obtained were as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
All open	87	63	137.81	−0.81
Heterozygous	50			
All side	3	1	2.19	+0.81

Summation of segregation in heterozygous F_3 rows is as follows:

Class and progeny	Observed	Ratio	Calculated	O-C
F_3:				
Open	1,335	54	1,333.13	+1.87
Side	245	10	246.88	−1.88

These results indicated that, in this particular cross, Cornellian differs from Garton Gray by having three factors that condition panicle shape. Segregation in F_3 rows might indicate a 27:9:9:9:3:3:3:1 ratio, in which 27:9:9:9 were open and 3:3:3:1 were side or inclined to look like side panicles. In the study of the F_2 of this cross, some panicles classed as side did not all breed true. A few were actually heterozygous.

As a result, it would seem that different crosses between the same varieties can give different results in breeding. It would appear that an oat may have some strains that have three factors for panicle shape and others that have only two. This may explain in part the frequent observation of open panicle variations in some side-panicle oat varieties. Phenotypically, the variety may appear homozygous; whereas, for panicle shape, it is of genetically different types and, through some natural crossing within the variety itself, segregation results.

The progenies of two F_1 plants from the two crosses of Cornellian × Sparrowbill were studied in F_2. These, when summarized, segregated in a three-factor ratio. The cross was not studied in F_3.

CORNELLIAN × SPARROWBILL

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Open	606	63	604.97	+1.03
Side	10	1	11.03	−1.03

SUMMARY

A summary of the inheritance of panicle shape in the crosses studied indicates that three factors may be involved in some cases and two or only one in others. Thus, the side-oat varieties Black Rival, Garton Gray, and Sparrowbill differed from the varieties with which they were crossed by one, two, or three factors. Indications are that Garton Gray is of two genotypes as to panicle shape.

ABERRANT TYPES

The frequency with which aberrant forms occur in oat crosses is of unusual interest. This frequency of occurrence would not be expected by the apparent chromosomal compatibility of the hexaploid oats (Nishiyama, *22*). In the populations of more than 40 combinations, most of the previously reported aberrants were observed, plus a few additional aberrants. Aberrants appear most frequently in crosses between oats of the *A. byzantina* species (Red Rustproof type) and those of the so-called *A. sativa* species. At least one aberrant usually occurs from such crosses, although it may not appear in the F_2 generation. In genetic studies of oats, the following aberrancies in spikelet and plant characters have been observed:

- Spikelet aberrancies:
  - Fatuoids
    - Usual types
    - Unusual types
  - Occurrence of "Bridging" *A. sterilis-A. fatua* aberrants
  - Dorsal pubescent aberrants
  - Black aberrants
  - Aberrant awns
  - Sterility
  - Multiflorous types
- Plant aberrancies:
  - Dwarfism
  - Crook-neck aberrants
  - Striped aberrants
  - Albinism
  - "Frustrated"
- Additional aberrancies observed in 1961 and 1962

SPIKELET ABERRANCIES

Fatuoids

The occurrence of fatuoids in cultivated oats is not unusual and has probably been reported more often than any other aberrancy. Fatuoids are usually observed much more frequently in the F_3 than in the F_2 populations. In these studies, no homozygous-type fatuoids were observed in F_2; but at least one fatuoid, intermediate form, was observed among the F_2 progenies of eight crosses, as follows:

Fatuoids in F_2 Hybrid Populations

Cross	*Total population*	*Fatuoids*
Black Mesdag × Cornellian	1,782	1
Calcutta × Kherson	366	1
Cole × Red Rustproof	774	1
Cornellian × Aurora	961	6
Cornellian × Sparrowbill	530	1
Cornellian × Swedish Select	2,266	1
Markton × Navarro	966	2
Richland × Black Rival	206	1
	7,851	14

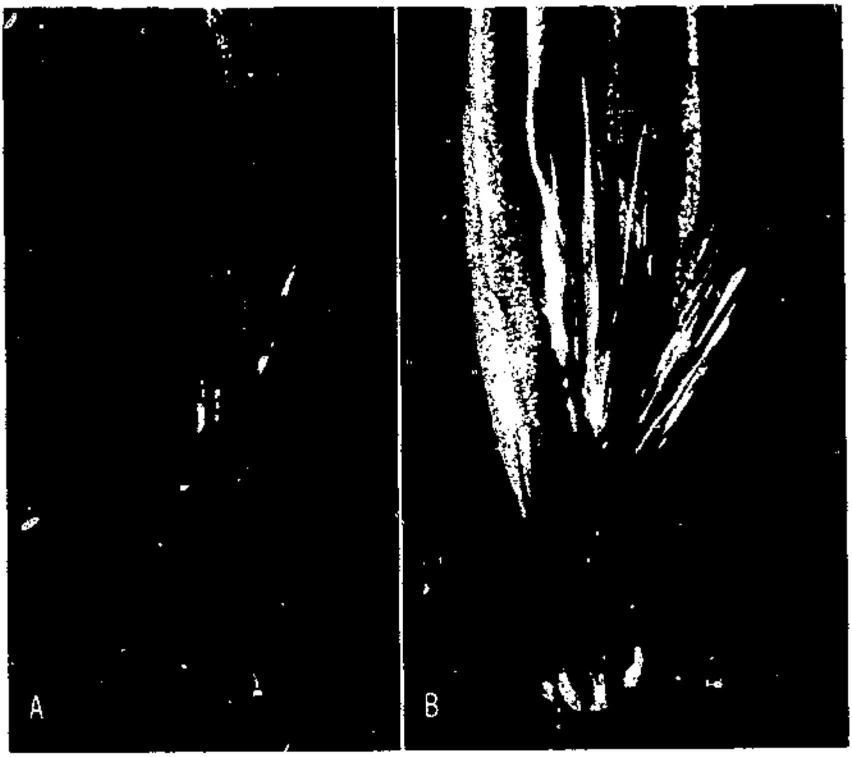

FIGURE 8.—Fatuoid aberrancy in *Avena*: *A*, *A. sativa*; *B*, *A. byzantina*.

In 7 of the 8 crosses, the occurrence of the intermediate fatuoid form was at a frequency of 8:6,890 F_2 plants, or about 1:861. No aberrant of the homozygous fatuoid type was observed. This is the expected, since the mutation is usually to the heterozygous condition. The mutation to the homozygous condition is rare.

Fatuoids appeared much more frequently in the Cornellian × Aurora cross than in the other 7 crosses, or 6 fatuoids:955 heterozygous and cultivated individuals. The percentage of fatuoids occurring in this cross was 0.624. In the other 7 crosses, only 8 of 6,890 individuals, or 0.116 percent, were fatuoids.

The percentage of fatuoids in progenies of the Cornellian × Aurora cross was some 3.8 times higher than that reported by Coffman and Taylor (*10*, *11*) in Fulghum oats (224 in 119,246 individuals, or 0.187 percent). Fatuoids occurred only 61.5 percent as often in the other 7 crosses as they did in Fulghum. This suggested that the number of fatuoids resulting from the Cornellian × Aurora cross was unusual. Later results showed this was true.

Numerous reports on the inheritance of fatuoid aberrants in oats have been received. Usually fatuoid × cultivated oats produce F_2 populations segregating into approximately 3 cultivated and heterozygous:1 fatuoid plant. This segregation was observed in numerous crosses studied, but several unusual segregations were also observed. In this report, results from those crosses giving the usual and those the unusual segregation ratios will be presented separately.

Fatuoid Crosses Giving Usual Segregation

Numerous crosses were studied that gave the usual, or 3 heterozygous and cultivated:1 fatuoid segregation. This segregation was observed in both *A. sativa* and *A. byzantina* × fatuoid crosses.

Fatuoid forms × *A. sativa*.—Segregations in F_2 of crosses of the usual fatuoid forms with the *A. sativa* varieties Black Mesdag, Swedish Select, and Monarch were studied. The usual ratio of 1 fatuoid:3 intermediate and cultivated was found, as follows:

BURT FATUOID × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Wild	94	1	94	±0.0
Intermediate and cultivated	282	3	282	±0.0

In two crosses of a Fulghum fatuoid with Black Mesdag and with Swedish Select, and in one cross of a Burt fatuoid with Monarch, similar results were obtained.

FULGHUM FATUOID × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Wild	56	1	57.5	−1.5
Intermediate	119	2	115.0	+4.0
Cultivated	55	1	57.5	−2.5

FULGHUM FATUOID × SWEDISH SELECT

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Wild	112	1	111.5	+0.5
Intermediate and cultivated	334	3	334.5	−0.5

BURT FATUOID × MONARCH

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Wild	108	1	105	+3.0
Intermediate and cultivated	312	3	315	−3.0

Fatuoid forms × *A. byzantina*.—A cross between the Fulghum fatuoid and the *A. byzantina* variety Red Rustproof gave results in F_2 as follows:

FULGHUM FATUOID × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Fatuoid	13	1	11.5	+1.5
Intermediate and cultivated	33	3	34.5	−1.5

Numbers were small, but a normal 1 fatuoid : 3 of other types was indicated.

In crosses of fatuoids with either *A. sativa* or *A. byzantina* varieties, the usual ratio of 1 fatuoid : 3 heterozygous and cultivated was observed.

Fatuoid × Cultivated Crosses Giving Unusual Segregation

In three crosses of fatuoids with cultivated oats, the results differed from the expected 3 heterozygous and cultivated : 1 fatuoid.

The Ruakura fatuoid × Black Mesdag cross, studied in F_2, produced so few fatuoids and so many other types that a two-factor difference was indicated.

RUAKURA FATUOID × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Fatuoid	70	1	101	−31
Intermediate	155	3	303	+31
Cultivated	179			

This segregation is a very poor fit to a 3 : 1 interpretation and suggests a 13 : 3 segregation, as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Fatuoid	70	3	75.75	−5.75
Intermediate	155	13	328.25	+5.75
Cultivated	179			

In the Cornellian × Aurora cross, both parents are considered awnless. Of the 961 F_2 progeny plants studied in this cross, 6 were of a type having twisted awns on the lower florets. This indicated that these six might be intermediate fatuoids, although they were not studied in the F_3.

In F_3, 49 progenies of this cross were grown. The number of lines containing fatuoids was unusually high. Seven of the 49 lines were observed to be in part fatuoids. The segregation of all normal lines to those containing fatuoids was as follows:

CORNELLIAN × AURORA

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Cultivated and heterozygous	42	13	39.81	+2.19
Part fatuoid	7	3	9.19	−2.19

The segregation among the seven fatuoid-producing lines was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Cultivated and intermediate	119	13	122.69	−3.69
Fatuoid	32	3	28.31	+3.69

Results showed that two factors were involved in the production of fatuoids in Cornellian × Aurora, as was indicated in the Ruakura fatuoid × Black Mesdag cross.

Fatuoids involving sterility.—Literature on fatuoids is extensive and somewhat controversial, as indicated by Jensen (*19*). It is not unusual to observe some sterility in fatuoid-derived populations. This apparently results from chromosomal disturbances attending the mutational processes in which the appearance of the fatuoid form is only one of the results. Nishiyama (*22*) and Huskins (*16*, *17*, *18*) have discussed this phenomenon. In the study of the inheritance of fatuoids, sterility was involved in three cases.

A dwarf-type fatuoid found in Fulghum crossed with Black Mesdag resulted in much sterility among the progenies. The fatuoid parent was late maturing, partly sterile, and dwarfish. Because it was too abnormal to be grown in the field, the study was conducted in the greenhouse. The inheritance of fatuoid complex, fertility, maturity type, awns, and lemma color was studied. Dwarfism was not studied in the greenhouse.

Two F_1 plants had been grown. Since segregation among the resulting F_2 progenies indicated that no difference existed between them, data on the two populations were summarized.

Examination of the F_2 progenies revealed much sterility. All of the 38 homozygous-type fatuoid individuals and 4 of the heterozygous, or 42 of the 296 F_2 plants, contained numerous sterile florets. The fatuoid plants were inclined to be sterile and were late maturing. Awn type and lemma color did not appear to be associated with the factor inducing sterility.

Segregation in F_2 for the fatuoid was obviously not monogenic but was closer to a 13 heterozygous and cultivated : 3 fatuoid types, However, there were too few homozygous fatuoids, sterile types, and late-maturing individuals.

Close examination of the fatuoids revealed much sterility in both the male and the female floral parts. Consequently, it was assumed that the completely recessive individuals in a 13:3 gene segregation ratio had failed to produce plants; and a ratio of 13 intermediate and cultivated:2 partly sterile fatuoid forms had resulted. The data were assembled on this basis, as follows:

DWARF FULGHUM FATUOID × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O–C
F_2 plant type:				
Fatuoid	38	2	39.47	−1.47
Intermediate	144	13	256.53	+1.47
Cultivated	114			
F_2 fertility:				
Fertile	254	13	256.53	−2.53
Partly sterile	42	2	39.47	+2.53
F_2 heading date:				
Early	256	13	256.53	−0.53
Late	40	2	39.47	+0.53

The inheritance of lemma color and awns, two characters evidently not associated with sterility, was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2 lemma color:				
Black	231	48	222.00	+9.00
Gray	61	15	69.38	−8.38
Red	4	1	4.63	−0.63
F_2 awns:				
Fully awned	54	3	55.5	−1.5
Heterozygous and awnless	242	13	240.5	+1.5

It appeared that the homozygous fatuoid condition was closely linked with sterility, late maturity, and awns, as follows:

Character	Cultivated	Intermediate	Fatuoid
Fertility:			
Fertile	113	141	—
Partly fertile	—	1	6
Sterile	1	2	32
Maturity:			
Early	113	128	15
Late	1	16	23
Awns:			
Fully awned	2	14	38
Lower awn only	61	123	—
Awns absent	51	7	—
Total	114	144	38

Only one small F_1 plant of the cross Fulghum fatuoid × Red Rustproof was obtained. It was of special interest, since many of the lemmas bore straight awns rather than the usual twisted geniculate or subgeniculate awns. Only 46 F_2 plants resulted, and they segregated as follows:

FULGHUM FATUOID × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Fatuoid	13	1	11.5	+1.5
Intermediate and cultivated	33	3	34.5	−1.5

This was not an unusual ratio in spite of the unusual awned condition on many of the F_1 florets.

Segregation as to maturity was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Early maturing	34	3	34.5	−0.5
Late maturing	12	1	11.5	+0.5

F_3 progenies of 25 lines were grown, and close to the normal ratio resulted, as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Fatuoid	4	1	6.25	−2.25
Heterozygous	15	3 (Heterozygous and Cultivated)	18.75	+2.25
Cultivated	6			

In general, the deviation from the expected in F_3 was not unusual when so few lines are considered. However, the fact that five of nine lines presumed to be homozygous fatuoids in F_2 had not bred true in F_3 was certainly unusual. Segregation in the 15 heterozygous lines was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Fatuoid	115	7	129.06	−14.06
Heterozygous and cultivated	180	9	165.94	+14.06

The usual 1:3 ratio was not indicated, and the results obtained were a poor fit even to a 7:9 ratio. Because 5 of the lines resulting from individuals classed as homozygous fatuoids in F_2 did not breed true, the ratio was 69 fatuoids:6 other types. If these 5 lines are eliminated, a summary of the segregation in the 10 other heterozygous lines is as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Fatuoid	46	1	54.5	−8.5
Heterozygous and cultivated	172	3	163.5	+8.5

Even after the five lines were eliminated, excess fatuoids were found. Examining the florets of the individual F_3 plants revealed much sterility in both the homozygous and the heterozygous fatuoids. This, together with the fact that several of the nonfatuoids in populations from the supposedly homozygous fatuoid F_2 were black or gray, indicated that unusual crossing had taken place—a clear indication of pollen (male) sterility.

Unusual sterile fatuoid from Golden Rain.—A rather undersized, intermediate-type fatuoid found in a Golden Rain increase plot at Bozeman, Mont., aroused special interest because it was so much shorter than other plants in the plot. This aberrant plant produced 105 viable seeds. These seeds were sown at Aberdeen, Idaho, and progenies were grown and studied. The F_2 population included fewer true homozygous fatuoid plants than the usually expected 3 cultivated and intermediate:1 homozygous fatuoid. Segregation was 101 cultivated and intermediate:4 fatuoids. Only one of these fatuoids bred true, and it produced only three progenies. The other 3 fatuoids produced 11 progenies, of which 3 individuals were of the heterozygous type and 8 were fatuoids. This homozygous-type fatuoid exhibited much sterility, although sterility was not observed in the heterozygous type.

Since this was not the usual segregation type of fatuoid, further study was made. A high degree of male sterility was found in the homozygous-type fatuoid segregates. This sterility was indicated by underdeveloped anthers or an absence of anthers. Close study revealed that this male-sterile condition had evidently resulted frequently in natural crossing of the fatuoid with adjacent normal plants. Hence, an irregular breeding pattern resulted under field conditions. Sizable populations of the 105 plants were grown, and data obtained were as follows:

Segregation in progenies of Golden Rain fatuoid

Class	Observed	Ratio	Calculated	O–C
Cultivated only	30			
Cultivated, intermediate, and fatuoid	68			
Cultivated and intermediate	3	63	103.36	+ 0.64
Intermediate only	1			
Intermediate and fatuoid	2			
Fatuoid only	1	1	1.64	− 0.64
	or			
Cultivated	30	12	19.69	+10.31
Heterozygous cultivated	72	48	78.75	− 6.75
Heterozygous fatuoid	2	3	4.92	− 2.92
Fatuoid	1	1	1.64	− 0.64

The relative fertility of the 105 progeny lines of this fatuoid was as follows:

Class	Progeny lines that set—				
	0–25 percent of seed	26–50 percent of seed	51–75 percent of seed	76–100 percent of seed	Total lines
	Number	*Number*	*Number*	*Number*	*Number*
Cultivated	0	2	6	25	33
Intermediate	2	25	34	7	68
Fatuoid	4	0	0	0	4

Studies were also made of the awned condition in the 11 progeny lines that segregated into the 3 types: Fully awned, single-awned, and awnless individuals. Summary data on awns in these 11 lines were as follows:

Class	Observed	Ratio	Calculated	O–C
Cultivated (awnless)	76	27	84.38	−8.38
Intermediate (1 awned)	119	36	112.50	+6.50
Fatuoid (2 awned)	5	1	3.13	+1.87

In summary, the occurrence of mutant fatuoid aberrants among the progenies of oat crosses is not unusual. Mutation is usually to the heterozygous form. Mutations to the homozygous form have been reported, but they are rare.

Fatuoids may occur in either *A. sativa* or *A. byzantina* oats or in crosses between varieties of either type or both types. Usually such fatuoids indicate in F_2 a monogenic 3:1 ratio. However, exceptions have been found. Three crosses were studied in which ratios of 13 heterozygous and cultivated:3 homozygous fatuoids occurred.

In addition, three fatuoids were studied in which sterility resulting in apparent natural crossing caused unexpected results. In one cross a 13:3 ratio was indicated; but it appeared that the complete recessive failed to produce viable seed, and a 13:2 ratio appeared plausible. In a second cross, sterility and attending natural crossing took place, which at first obscured the actual results. Study of still another fatuoid aberrant indicated that three factors were involved; much sterility resulted in natural crossing, which made genetic analysis difficult.

Occurrence of "Bridging" *A. sterilis-A. fatua* aberrants

The occurrence of aberrant forms of various types among cereal crop plants is somewhat common and is often reported in the literature. These forms frequently arouse speculation as to the origin of our cultivated oat species.

For a century it was generally accepted in this country that our common or white oat *A. sativa* was derived from the wild oat *A. fatua*. Coffman (*2*) in 1946 presented a theory suggesting that *A. sterilis* rather than *A. fatua* was the real progenitor. Since then, Griffiths and Johnston (*14*) reported the occurrence of *A. fatua* segregates derived from *A. sterilis* through use of irradiation. Their findings substantiate this theory of origin.

The *A. sterilis-A. fatua* aberrant reported here is further evidence in support of the *A. sterilis* theory.

In 1922, a panicle at first considered a false wild oat was found in a bundle of what was called Sixty-Day oats that was placed on exhibit by the grower at a county fair in eastern Colorado. The varietal name for these oats seemed logical to this writer, and finding a false wild oat in Sixty-Day oats was not considered unusual, although it indicated a lack of care on the part of the exhibitor who displayed the oat sheaf.

Later, on close examination, it was observed that this aberrant was not an ordinary false wild or fatuoid. The kernels were light gray rather than yellow, the color of the parent variety. Also, the mode of attachment of the florets differed from that of the ordinary fatuoid or false wild oat. The aberrant also differed decidedly in that its seeds had not dropped off immediately on maturing, which is a characteristic of fatuoids in general. There was a tendency for the spikelets to remain attached to their pedicles and for the florets to remain together in threshing. The latter characteristic is recognized as especially typical of derivatives of *A. sterilis*.

Progenies of 20 plants were produced the following year from seeds of this original panicle. In all observable characters the resulting plants appeared similar to the parent, and no segregation

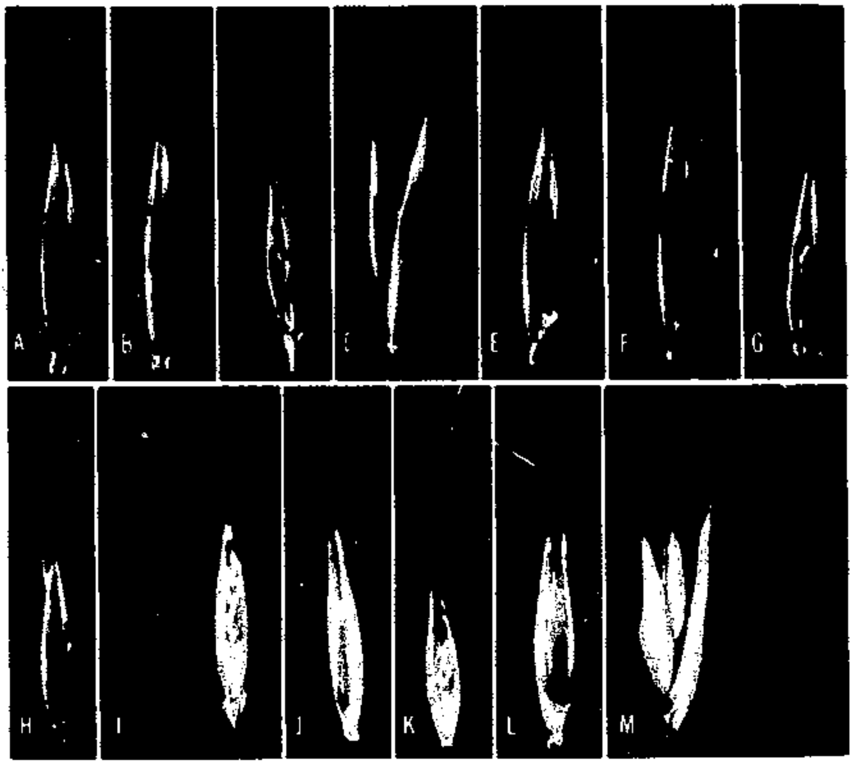

FIGURE 9.—Bridging *A. sterilis*-*A. fatua* in *Avena*: Sixty-Day aberrant (*A. sterilis* type: *A, B, C, D*; *A. fatua* type: *E, F, G, H*); Eaton aberrant (*A. sterilis* type: *I, J*; *A. fatua* type: *K, L*; complete spikelet: *M*).

was evident. The second year, 100 seeds representative of each of these 20 plants were sown. Germination was not good; however, all but 1 of the resulting 78 plants were similar to the original in panicle characteristics. In the one plant that differed, the peculiar characters of the parent were less pronounced. The progenies of this one plant were grown to further investigate this apparent difference. However, they proved it to have been a somatic variation, since all progenies were typical of the original aberrant panicle. Consequently, the aberrant found in the Sixty-Day oats appeared to have been true breeding. In general morphologic characters, it was somewhat of an intermediate type between the true *A. sterilis* and the true *A. fatua*.

In 1961, a second bridging *A. sterilis*-*A. fatua* type individual was discovered by this writer. This aberrant was observed at Aberdeen, Idaho, in a head row of the Eaton variety. Eaton resulted from the cross Iogold × Bond. Iogold is a selected strain of Kherson, and Kherson has long been considered synonymous with Sixty-Day. Hence, the two aberrancies discovered both trace directly or indirectly to the same variety Sixty-Day. Thirty-nine

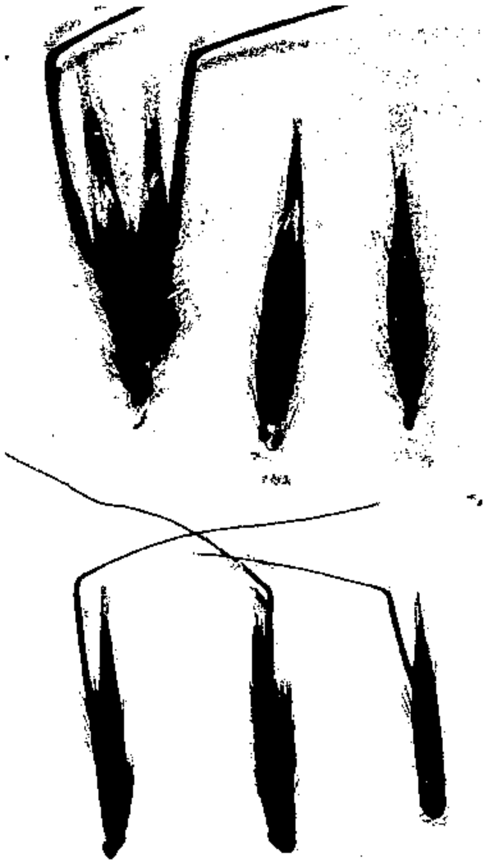

FIGURE 10.—Wild complex in *Avena*: Upper, *A. sterilis*; lower, *A. fatua*.

years elapsed between the discoveries of these two aberrants. So far as is known, these are the only aberrancies of this type found in North America.

To date, no crosses have been made using this second aberrant as a parent, but spikelet characters other than lemma and palea color appear almost identical with those in the first aberrant. The Sixty-Day aberrant was gray in color; the Eaton aberrant was yellow. Sizable progenies of this second aberrant were grown in the greenhouse at Beltsville, Md., in 1961–62; and a second generation was grown in the field at Aberdeen, Idaho, in 1962. Two populations have been grown, and this second *A. sterilis*-*A. fatua* type aberrant has also been constant in breeding behavior. The discovery of these two steriloid-fatuoid aberrants in one *A. sativa* source is further evidence of the close genetic relationship of all hexaploid oat species and further supports the theory that all hexaploid oats trace to a single source, *A. sterilis*, as previously stated (Coffman, *2*).

The aberrant found in Sixty-Day was crossed with oats belonging to nearly all the hexaploid species. In crosses with the wild *A. fatua* and *A. sterilis*, only the F_2 population was studied. Wild oats are more or less dormant, as indicated by Coffman and Stanton (*7*, *8*) and Toole and Coffman (*29*). This character makes a study of wild × cultivated difficult. Because of dormancy, prompt germination of the seeds may be extremely limited; the seeds may sometimes remain in the soil and germinate and grow several years later. This fouls soil for experimental purposes, and few experiment stations will tolerate this condition. Thus, studies of large F_3 populations are not often made.

Three crosses were made between the Sixty-Day aberrant and *A. fatua*. The segregation in F_2 populations of these three crosses was apparently similar, and summary data indicated the usual segregation ratio, as follows:

SIXTY-DAY ABERRANT × *A. fatua*

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
A. fatua	244	1	247.75	−3.75
All others	747	3	743.25	+3.75

However, a small number of the segregates in two of these three crosses (8 out of 638 F_2) appeared to be *A. sterilis* in type. None was found in the other cross. If the data for the two crosses are summarized and a special class is formed for these *A. sterilis* individuals, segregation is as follows:

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
A. fatua	147	15	149.53	−2.53
Intermediate types	483	48	478.50	+4.50
A. sterilis	8	1	9.97	−1.97

The *A. sterilis* type that resulted from these crosses indicated that three factors were involved and that *A. sterilis* had been produced synthetically through recombination of *A. fatua* with the Sixty-Day aberrant. This is of interest with regard to the origin of oats.

A. sterilis ludoviciana was crossed with the Sixty-Day aberrant. The F_2 plants indicated a dominance of the *A. sterilis* over the aberrant. The segregation in F_2 was as follows:

A. sterilis × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
A. sterilis	78	3	84.0	−6.0
Sixty-Day aberrant	34	1	28.0	+6.0

An attempt was made to study the inheritance of this cross in F_3, but the F_3 populations proved unsatisfactory because some progenies of *A. sterilis* inherited dormancy. In general, the F_3 data confirmed the F_2 interpretation. Segregation occurred among most of the F_2 *A. sterilis* type progeny lines.

The Sixty-Day aberrant was also crossed with the *A. sativa* variety Black Mesdag. A very large F_2 population and a very small F_3 were grown. The results indicated a 3 cultivated and intermediate: 1 wild type, as follows:

SIXTY-DAY ABERRANT × BLACK MESDAG

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Sixty-Day aberrant	523	1	511.5	+11.5
Intermediate	1,031	2	1,023.0	+ 8.0
Cultivated	492	1	511.5	−19.5
F_3:				
Sixty-Day aberrant	2	1	3.5	− 1.5
Heterozygous	8	2	7.0	+ 1.0
Cultivated	4	1	3.5	+ 0.5

Among 2,046 F_2 segregates studied in this cross, 1 synthetic *A. sterilis* and 4 *A. fatua* types appeared. Although a small F_3 population was grown, seeds of these particular segregates were not included.

In summary, an unusual bridging type *A. sterilis-A. fatua* aberrant was found in Sixty-Day. Progeny populations were grown for three generations, and the aberrant type bred true. When crossed with the wild *A. sterilis*, this aberrant was recessive. The segregation ratio indicated was a very close fit to a 3 *A. sterilis*: 1 Sixty-Day aberrant. On the other hand, in crosses of this aberrant with *A. fatua*, the aberrant was dominant in all three crosses studied. In one cross, the ratio was 3 aberrant: 1 *A. fatua*. In the other two crosses, the ratio was 15 *A. fatua*: 48 aberrant: 1 *A. sterilis*. Thus, this aberrant would appear to be intermediate between these two wild species. Supporting this idea was the occurrence of a small number of synthetic *A. sterilis* type segregates among the progenies of these last two *A. fatua* × Sixty-Day aberrant crosses.

In the cross Sixty-Day aberrant × *A. sativa* variety Black Mesdag, a ratio of 3 aberrant and intermediate: 1 *A. sativa* was observed. It is significant that, among 2,046 F_2 plants produced in this cross, both synthetic *A. fatua* and *A. sterilis* segregates appeared. The occurrence of these two forms is further evidence supporting the theory of the origin of cultivated oats. The ratio was 2,041 *A. sativa* and heterozygous: 4 synthetic *A. fatua*: 1 synthetic *A. sterilis*. In 1961 a second *A. sterilis-A. fatua* aberrant was found. This occurred in the variety Eaton, an indirect progeny of Sixty-Day. These two *A. sterilis-A. fatua* aberrants are the only ones of this type reported to date in North America.

Dorsal Pubescent Aberrants

Sometimes among progenies of crosses between parents with no pubescence on the sides and backs of the lemmas, extremely hairy aberrant individuals were found. None of the varieties or strains used as parents in the five crosses studied had dorsal pubescence. Yet, aberrant pubescent individuals appeared among the progenies of these five crosses. The progenies differed in number of aberrants—sometimes there were many and sometimes few.

In the cross Black Mesdag × Red Rustproof, many aberrants were produced. The segregation in F_2 was as follows:

BLACK MESDAG × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Hairs present on sides and back	45	1	70.31	−25.31
No hairs present on sides and back	1,080	15	1,054.69	+25.31
	or			
Normal	1,080	246	1,081.05	− 1.05
Pubescent	45	10	43.95	+ 1.05

In the cross Calcutta × Red Rustproof, 1 of 993 F_2 plants was very hairy on the sides and back. Pubescence was not studied in the F_3 generation of this cross.

In the cross between *A. fatua* and the Sixty-Day aberrant, neither of which bore hairs on the sides or back, 3 of the 263 F_2 plants were very hairy. Segregation was as follows:

A. fatua × SIXTY-DAY ABERRANT

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Normal	260	63	258.89	+1.11
Pubescent	3	1	4.11	−1.11

In the cross Calcutta × Kherson, only 1 of 366 F_2 plants produced exceedingly hairy kernels. In 33 F_3 populations grown, no plants were unusually pubescent. The very hairy F_2 selection was not grown in F_3.

No exceptionally hairy plants were observed among the 774 F_2 progeny plants of the cross Cole × Red Rustproof. However, 3 of the 49 F_3 lines grown contained individuals with profuse hairs on the sides and back of the lemma. Segregation among these F_3 lines was as follows:

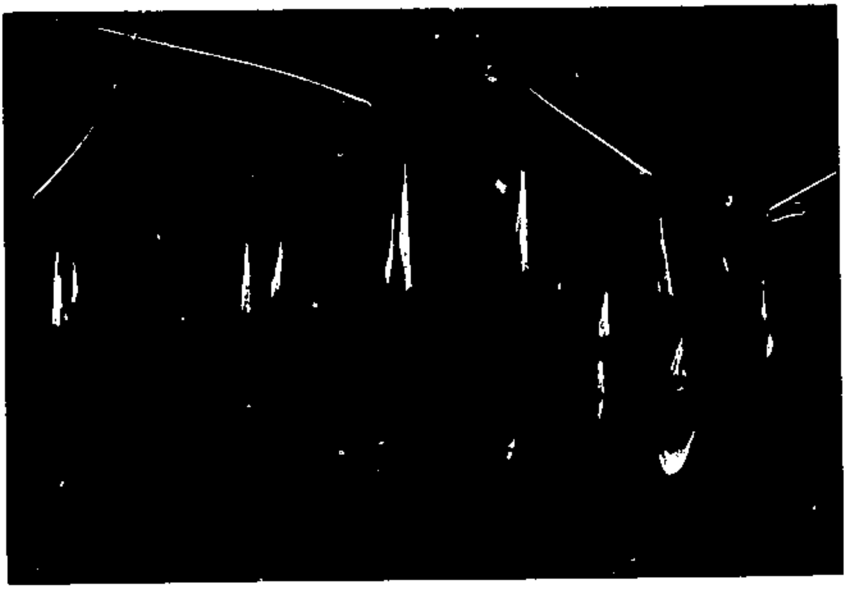

FIGURE 11.—Dorsal pubescence in *Avena*: *A. sterilis*.

COLE × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Normal	46	15	45.94	+0.06
Heterozygously pubescent	3	1	3.06	−0.06

Segregation for unusual hairs in the three heterozygous F_3 lines was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Normal	63	15	63.75	−0.75
Pubescent	5	1	4.25	+0.75

In summary, segregation for the hairy condition in the Black Mesdag × Red Rustproof cross differed from that in the other four crosses. The ratio of normal to hairy individuals was 1,080 : 45. The ratios for the combined F_2 figures for the other four crosses were much lower.

The appearance of these very hairy individuals suggests a lack of complete genetic compatibility between the parents of the crosses. Four of these crosses involved *A. sativa* and *A. byzantina* oats as parents.

Black Aberrants

It has been recognized for over 50 years that black-kerneled individuals appear occasionally in populations of some, if not most, oats of the *A. byzantina* species (Roberts and Freeman, *24;* Coffman, Parker, and Quisenberry, *5*). These have been termed mutations, reversions, or recombinations.

Crosses between varieties of *A. byzantina* or varieties of suspected *A. byzantina* origin and nonblack oats were made, and black or dark-gray individuals were observed as follows:

Cross	*Total F_2 plants*	*Dark-gray or black plants*
Red Rustproof × Calcutta	991	2
Iogold × Red Rustproof	196	3
Aurora × Nortex	153	6
Red Rustproof × Navarro	1,075	6
Swedish Select × Fulghum fatuoid	445	1
Appler × Swedish Select	234	2
Cole × Red Rustproof	774	0
Calcutta × Kherson	366	4
Navarro × Markton	966	0
A. fatua × Sixty-Day aberrant	263	2
A. fatua × Sixty-Day aberrant	353	1
A. fatua × Sixty-Day aberrant	367	2

In Red Rustproof × Calcutta, 1 F_3 line produced 24 red individuals and 1 black individual. In the F_3, the black F_2 progenies of Iogold × Red Rustproof all proved homozygously black. In the F_3 line from one of the four black F_2 individuals in the cross Calcutta × Kherson, segregation was 10 black:1 red:1 gray.

An unusually large number of black individuals were observed among progenies of the cross Appler (red) × Swedish Select (white). Among 3 F_3 progeny lines, 37 were classed as gray, 2 of which were noted as dark or almost black. In the F_3 generation taken as a whole, however, the number of blacks was most unusual. Among the F_3 progeny lines from 59 F_2 plants, 18 contained 1 or more blacks. This was more than one in four of the lines grown. The ratio of lines with and without aberrants was as follows:

APPLER × SWEDISH SELECT

Class and progeny	Observed	Ratio	Calculated	O-C
F_3:				
Normal	41	3	44.25	−3.25
Including black aberrants	18	1	14.75	+3.25

One F_3 line included 6 blacks out of 50 plants. The other 17 lines included only 30 out of 909 plants. In addition to these blacks, 24 F_3 rows also contained aberrant dwarf, grasslike plants; and 7 rows contained both black and grasslike aberrants.

A Garton Gray × Nortex cross, which was not studied in F_2, segregated 1 black:17 gray:6 red in one F_3 line. This is an unusual segregation ratio. Usually, in heterozygous populations, blacks are more numerous than are lighter colored individuals.

In summary, in crosses between varieties of known or suspected *A. byzantina* derivation, three of four produced no blacks; whereas in crosses of *A. byzantina*, including the Sixty-Day aberrant, by *A. sativa* or *A. fatua* oats, the ratio was 7 black-producing: 1 non-black-producing. Apparently in the *A. byzantina* × *A. byzantina* crosses, greater compatibility is indicated. In *A. byzantina* by *A. sativa* or *A. fatua* crosses, less compatibility exists and hence more aberrants appear.

Natural crossing cannot be ruled out entirely as causing some of these aberrant black oats, but the appearance of this peculiar type of aberrant tends to discredit that explanation in many cases, since occasional black-kerneled aberrants are found in populations that have not been grown near black oats for many generations.

Aberrant Awns

Both Calcutta and Red Rustproof are typical straight-awned *A. byzantina* type oats. Among 49 F_3 populations of the cross Calcutta × Red Rustproof, all but 5 progeny lines were homozygous for the straight type of awn. If the 49 F_3 populations are considered as a whole, the segregation of normal to lines producing abnormal awns is as follows:

CALCUTTA × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_3:				
Straight awns	44	15	45.94	−1.94
Heterozygous for awns	5	1	3.06	+1.94

In four of these five lines, a few twisted geniculate awns appeared; and in one, two subgeniculate awned individuals were observed. The segregation within these five lines was as follows:

Class and progeny	Observed	Ratio	Calculated	O-C
F_3:				
Straight awns	118	15	118.13	−0.13
Twisted or subgeniculate awns	8	1	7.88	+0.12

The approach to a two-factor expectancy in the aberrant-producing F_3 lines seems to be more than coincidental. The Calcutta × Red Rustproof cross produced several additional aberrant types, and these aberrants probably resulted from a difference in the genetic constitution of the two oats.

Sterility

The occurrence of sterility is not unusual in oat crosses, especially when an *A. byzantina* oat is crossed with an *A. sativa* oat. Sterility was observed and studied in several crosses.

In the cross Cole × Red Rustproof, 7 of the 775 F_2 plants were sterile.

Ten of 155 F_3 lines grown were partly to almost fully sterile, but none appeared completely sterile. The segregation of normal or fertile lines to lines containing some partly sterile plants was as follows:

Cole × Red Rustproof

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Normal	145	15	145.31	−0.31
Partly sterile	10	1	9.69	+0.31

In the F_2 of a Red Rustproof × Calcutta cross, 2 more or less sterile individuals were observed among the 993 progenies. Fifty lines were grown in F_3. Seeds of one of the two partly sterile F_2 plants, when sown in F_3, produced no plants. The other 49 lines produced all normal plants.

Although some sterile plants were observed among the F_2 population of 1,125 individuals of the Black Mesdag × Red Rustproof cross, the number was not recorded. In the F_3 generation, however, 14 of 79 lines grown contained partly sterile plants. The segregation was as follows:

Black Mesdag × Red Rustproof

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Normal	65	13	64.19	+0.81
Partly sterile	14	3	14.81	−0.81

Segregation in 7 of the 14 F_3 lines was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Normal	100	13	95.06	+4.94
Partly sterile	17	3	21.94	−4.94

In both crosses studied, a two-factor segregation of normal to partly sterile plants was indicated. The ratios were 15 normal : 1 partly sterile for the Cole × Red Rustproof cross; and 13 normal : 3 partly sterile for the Black Mesdag × Red Rustproof cross.

Multiflorous Types

Hulless, or at least multiflorous, aberrant individuals in crosses involving an *A. byzantina* oat are not unusual. Their appearance has been reported by Coffman and Quisenberry (*6*).

Aberrants of this type occurred in several crosses during these studies, and their frequency of occurrence was recorded.

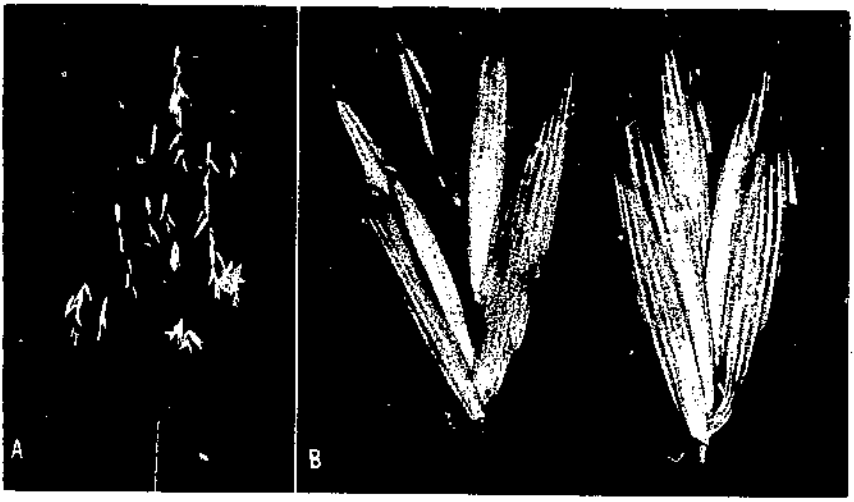

FIGURE 12.—Multiflorous type in *Avena*: *A*, Panicle of multiflorous oat *A. nuda*; *B*, spikelets of multiflorous oats: Left—spikelet of multiflorous aberrant in variety Burt; right—spikelet of multiflorous oat *A. nuda*.

In a population of 774 F_2 plants of the cross Red Rustproof × Cole, 1 plant was of the hulless type. In the F_3 generation, 49 populations were grown. The hulless plant bred true, and one additional line segregated for this character. Segregation in the F_3 was as follows:

RED RUSTPROOF × COLE

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Normal	47	63	48.23	−0.23
Heterozygous hulless	1			
All hulless	1	1	0.77	+0.23

In a population of 366 F_2 plants of the cross Calcutta × Kherson, 5 were of the hulless type, or about 1 plant in 64. Of the 33 F_3 lines of this cross studied, none was hulless.

CALCUTTA × KHERSON

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Normal	361	63	360.28	+0.72
Hulless	5	1	5.72	−0.72

In a cross of Fulghum fatuoid × Black Mesdag, studied only in F_2, 1 individual among 231 was hulless.

Among the 291 F_2 populations of a cross of Cornellian × Black Mesdag, 1 plant having the unusually long rachilla characteristic of *A. nuda*, or the hulless condition, was noted. This condition was not studied in the F_3 of this cross. Thus, the multiflorous or suspected hulless types appeared in four crosses. In three of the four, an *A. byzantina* derivative was one of the parents. The appearance of these aberrants was presumably the result of the lack of complete genetic compatability between the parents. Thus, genetic recombination resulted. The literature indicates that aberrants frequently are found among the progenies of *A. sativa* × *A. byzantina* crosses.

PLANT ABERRANCIES

Dwarfism

The observation of dwarfs among progenies of tall × tall oat parents is not new, but few studies of the frequency of their occurrence have been published. Also few reports, as far as is known, have been made on the occurrence of mere grass tufts.

The occurrence of dwarfism was studied in four crosses. In the cross Black Mesdag × Red Rustproof, 5 of 1,125 F_2 plants were grasslike dwarfs. None of these plants produced seeds. The segregation in F_2 was as follows:

BLACK MESDAG × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_2:				
Normal	1,120	255	1,120.61	−0.61
Dwarf	5	1	4.39	+0.61

From the F_2 data only, it appears that four factors might be involved. A close fit to a 255 normal : 1 dwarf was found.

Among the 124 F_3 lines of this cross grown, 91 contained only normal or tall plants, 7 were homozygously short or dwarfed, and 26 segregated into tall and short plants in apparently different ratios. Segregation among F_3 lines was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
All tall	91	12	93.00	−2.00
Heterozygous tall and short	26	3	23.25	+2.75
All short	7	1	7.75	−0.75

Segregation among the 26 F_3 heterozygous lines could be separated into groups as follows:

Class	Observed	Ratio	Calculated	O–C
Group 1:[1]				
Tall	288	15	285.0	+3.0
Short	16	1	19.0	−3.0
Group 2:[1]				
Tall	179	13	173.88	+5.12
Short	35	3	40.13	−5.13
Group 3:[2]				
Tall	115	3	120.75	−5.75
Short	46	1	40.25	+5.75

[1] 10 lines.
[2] 6 lines.

These data indicate that a two-factor analysis is the best explanation for the occurrence of dwarfs in this cross.

In the F_2 of the Appler × Swedish Select cross, 234 plants were produced, 219 of which were of normal height and 15 grasslike. Of these 15 grasslike plants, only a few produced any seeds. This precluded further testing of these dwarfs.

APPLER × SWEDISH SELECT

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Normal	219	15	219.38	−0.38
Grasslike	15	1	14.63	+0.37

In the F_3 generation, 62 lines were grown. Segregation was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Normal tall	36	63 (Normal tall + Heterozygous)	61.03	−0.03
Heterozygous	25			
All grasslike	1	1	0.97	+0.03

FIGURE 13.—Aberrant plant height in *Avena*: *A*, *E*, Parents; *B*, grass tuft; *C*, dwarf; *D*, short.

Two types of segregating F_3 lines appeared among the 25 heterozygous lines as follows:

Class	Observed	Ratio	Calculated	O–C
Group 1:[1]				
Tall	712	15	709.69	+ 2.31
Short	45	1	47.31	− 2.31
Group 2:[2]				
Tall	395	3	379.50	+15.50
Short	111	1	126.50	−15.50

[1] 13 lines.
[2] 12 lines.

Segregation in this cross differed somewhat from that in the Black Mesdag × Red Rustproof, but a two-factor condition was still indicated.

Among the 774 plants produced in the F_2 population of a Cole × Red Rustproof cross, none was exceptionally short or unusually grasslike.

Two of the 108 populations grown in F_3 contained dwarfed individuals. This fitted more nearly the ratio of 63:1 than 15:1, although the fit was poor for either. Of these 2 lines 1 produced only 19 plants, 10 of which were grasslike and 9 normal. The other line produced 8 normal plants and 3 dwarfs. Actual numbers are too few to be given much consideration, but more than a single-factor difference apparently existed.

Segregation of the two F_3 lines was as follows:

COLE × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Normal	17	9	16.88	+0.12
Dwarf	13	7	13.13	−0.13

Among 975 F_2 progenies of a Navarro × Markton cross, 56 were short and 9 were grasslike and never headed. The ratio in F_2 was as follows:

NAVARRO × MARKTON

Class and progeny	Observed	Ratio	Calculated	O–C
F_2:				
Normal	910	60	914.06	− 4.06
Short	56	3	45.70	+10.30
Grasslike	9	1	15.23	− 6.23

Seeds from 54 of the short plants that headed were planted, and an F_3 generation was produced. One of the 54 tested was evidently a chance variation, since it produced only tall plants in the next generation. One produced only very short plants to mere grass tufts that never headed, and 44 produced short but otherwise fairly normal plants. Eight lines produced plants ranging from dwarfs to grass tufts not over 3 inches in height that never headed. The segregation of the 53 F_3 populations was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
F_3:				
Short	44	54	44.72	−0.72
Heterozygous	8	9	7.45	+0.55
Grasslike	1	1	0.83	+0.17

The data indicate that at least three factors are involved in the inheritance of these aberrant types and that the grass tuft is a recessive lethal that fails to get beyond the rosette stage.

Although the average heights of Navarro and Markton were 40 and 49 inches, respectively, the 44 short individuals ranged from 28 to 32 inches in height. The taller individuals in the 8 heterozygous lines often were still shorter, ranging from 15 to 20 inches in height down to 3- to 4-inch grass tufts.

In summary, dwarf or short plants were observed among the progenies of four normal × normal height crosses. Study of the progeny populations reveals that dwarfs may be of three types: (1) Short or semidwarf, (2) dwarfs that head but produce few seed, and (3) mere grass tufts that never head.

Data indicated that dwarfs are recessive and that dwarf-producing lines segregated into normal and dwarf by approximate ratios of 63:1, 60:3:1, 54:9:1, 15:1, 13:3, 9:7, and 3:1.

Crook-Neck Aberrants

A crook-neck condition similar to that in certain sorghums, in which the head recurves or "goose necks" as it emerges from the sheath, was observed in advanced generation progeny rows from the cross Lee × Victoria. Frequently at maturity, the peduncle of the panicle is bent almost into a U-shape, with the head pointing downward. In the cross Black Mesdag × Red Rustproof, this crook-neck condition was observed in 2 of 20 F_4 progeny rows from a single F_3 population. Segregation of normal and crook-neck plants in these two progeny lines was as follows:

BLACK MESDAG × RED RUSTPROOF

Class and progeny	Observed	Ratio	Calculated	O-C
F_4:				
Normal	53	15	51.56	+1.44
Crook-neck	2	1	3.44	−1.44

The condition is heritable and may appear comparatively late in small numbers in some hybrid populations. Apparently, it is a recessive character.

Striped Aberrants

One weak, undersized, striped aberrant plant was observed in a progeny line of a Burt oat (Kansas 5020). It was one of the shortest plants and was among the last 8 to head in a population of 108 plants.

On maturity, 18 seeds were harvested; and these were sown in a greenhouse bed the next season. Only 13 of the 18 seeds germinated. Eight of the 13 plants showed the striping of the mother plant, and all were undersized. Only two of the eight plants headed, and only one actually produced any seeds. Of the 114 seeds from this one plant that headed, 111 germinated and produced plants. Of the 111 plants, 68 were normally green and 43 were chlorotic, or suspected of having the striping character. This was a rough approach to a 9 green:7 aberrant ratio. Some plants with striped leaves were nearly 50-percent green and 50-percent white or yellowish white. With a few exceptions, plants once noted as having the striped condition had it on later examination. The condition did not expand or disappear but existed proportionately throughout the life of the plant.

All the 111 plants matured and produced seeds. The normal-appearing plants matured first and yielded the most seeds. The

FIGURE 14.—Crook-neck aberrant in *Avena*: *A*, Crook-neck panicle; *B*, normal panicle.

striped plants matured in proportion to the extent of striping shown—the more area involved, the later the maturity and the fewer seed set.

The following season, progenies of all 111 plants were produced, but unfavorable field conditions caused them to develop so poorly that a second seeding was made the next year. The germination of the seed was watched closely. The amount of striping apparently had no effect on germination of the resulting progeny.

The data from the two seedings were added together for genetic analysis. The results indicated a comparatively good fit to a three-factor hypothesis, or a genetic interpretation of $GGG_1G_1G_2G_2$ for the normal and $ggg_1g_1g_2g_2$ for the completely recessive. The recessive is apparently lethal in the seedling stage.

Based on the second generation plant descriptions, the progenies bred as follows:

29 normals produced only normals.

39 normals produced progenies varying from a few with a trace of striping to all different types.

5 noted as probably having a trace of striping produced only normal green progenies.

38 noted as having definite stripes in varying amounts produced striped progenies. Three of these produced no normals at all, and one produced only white or near-white progeny.

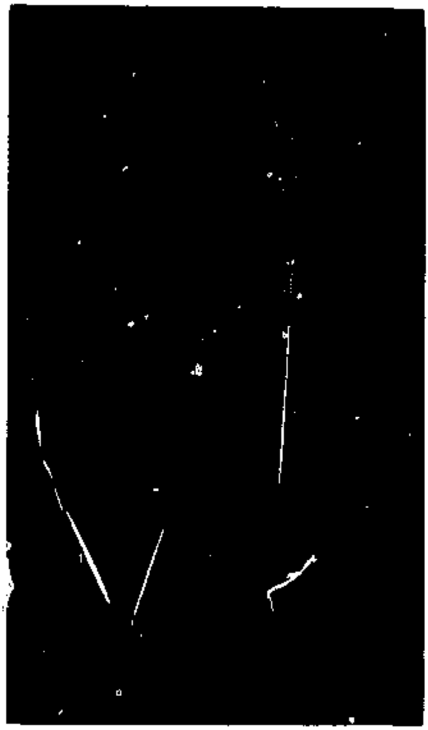

FIGURE 15.—Chlorotic striping aberrancy in *Avena*.

A two-factor analysis was not possible, but a three-factor analysis seems justified. Segregation was as follows:

Class	Observed	Ratio	Calculated	O-C
"F_3":				
All normal	34	48	83.25	+0.75
Normal with few with trace	18			
Mostly normal but many striped, including white	32			
Mostly striped but few normal	24	12	20.81	+3.19
No normals—varying types of stripes	2	3	5.20	−3.20
All apparently white	1	1	1.73	−0.73

Albinism

At Aberdeen, Idaho, in 1927, a "checkerboard" space-planted hybrid vigor experiment was conducted (Coffman and Wiebe, *12*). Seeds were sown 1 foot apart in each direction. Since the rows were of equal length, a space filler of a pure lot of Richland oats was planted to fill out spaces in rows when insufficient seeds of a single cross or parental line were available. After ripening, all

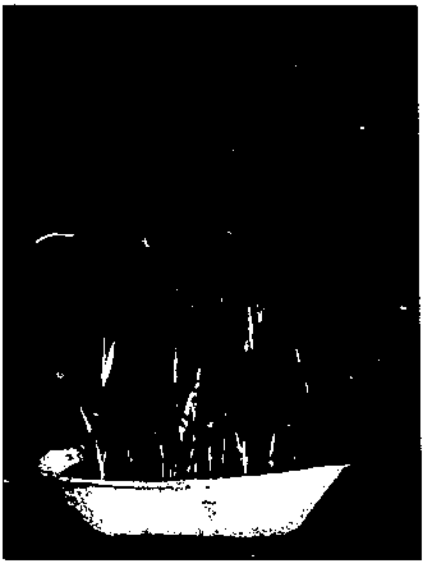

FIGURE 16. Segregating population, including albino (white) aberrants, in *Arena*.

plants were harvested. At that time it was believed some of these space-filler plants would prove valuable as reselections, since Richland had not been reselected in 20 years. A pure lot of Richland originating from single plants would thus be available as the progenies of each space filler.

Seeds of 69 space-filler Richland plants were sown 1 rod row per plant the following season. Among the 18,110 plants in 46 of the 69 rows, 232 were black aberrants and 149 were yellow aberrants. The hybridity of these individuals was later determined by planting 16 seeds of each in the greenhouse.

Among these 381 aberrant plants, the progenies of 5 proved of unusual interest, since they not only were hybrids, as indicated by morphologic characters, but also included one or two chlorotic aberrants or albino seedlings. The 5 original progenies from which the albinos came had included 67 aberrants out of 1,654 plants, as follows:

Aberrant plant number	*Total plants*	*Aberrants*	
		Black	*Yellow*
1	482	2	1
2	317	22	2
3	329	1	18
4	248	9	10
5	278	2	—
Total	1,654	36	31

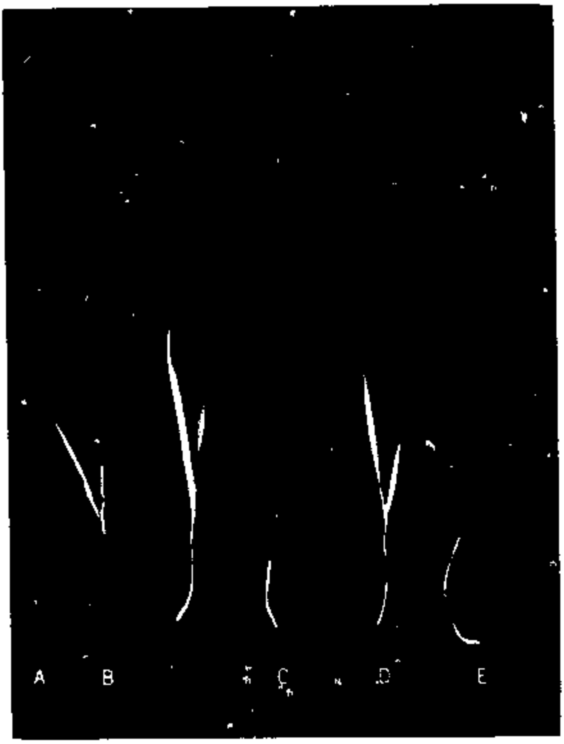

FIGURE 37. Normal and chlorotic aberrants in *Avena*: *C*, Normal; *B*, *D*, albino; *A*, *E*, light green seedlings.

As stated, small numbers of seeds of each supposedly natural cross were sown. A few progeny plants of each resulted, and segregation of green and albino seedlings in these five albino-producing lines was as follows:

Aberrant plant number	*Total plants*	*Aberrants*	
		Green	*Albino*
1	13	12	1
2	12	10	2
3	14	13	1
4	11	9	2
5	14	13	1
Total	64	57	7

Because the albino seedlings died, further testing was impossible. To save greenhouse space, many seeds had been sown in each pot, and the resulting green plants were small. Seeds of only 48 of the 57 green plants were available for growing the next generation. The 48 populations segregated as follows:

Aberrant plant number	Total progeny lines grown	Segregation of lines		Segregation of plants among heterozygous lines	
		Green	Heterozygous	Green	Albino
	Number	*Number*	*Number*	*Number*	*Number*
1	11	1	10	166	30
2	6	2	4	124	23
3	10	6	4	55	12
4	9	8	1	10	3
5	12	7	5	68	9
Total	48	24	24	423	77

Large families of all available seeds were sown in still another test, and in the following generation 23,206 seedlings were produced. Summarizing the data on the basis of the five original albino-producing lines, results were as follows:

Aberrant plant number	Total	Homozygous green	Segregating
	Number	*Number*	*Number*
1	13	2	11
2	14	7	7
3	12	6	6
4	11	6	5
5	14	6	8
Total	64	27	37

In summary, segregation of green and albino plants in the several progeny lines differed widely. Ratios of 63:1, 27:37, 15:1, 9:7, and 3:1 were found. This indicated that the albino is conditioned by three factors. With the exception of one line in a later generation, practically no striped individuals were observed in any population. The plants were either green or albino, and the albino died in the seedling stage. The striped individuals observed in the single progeny line probably resulted from a crossover.

The plants maturing in the second greenhouse-grown generation differed in kernel color, and the color was recorded. Progenies from three of the five lines bred true, producing either all black- or all yellow-kerneled plants. In the other two, segregation resulted, and some grays were also noted. Of the 44 progeny populations tracing to one or the other of these 2 albino-producing lines, 17 were all black, 7 were all yellow, and 20 segregated for lemma color. Among these 20 segregating populations, 13 produced blacks and yellows; 1 produced 47 black, 10 gray, and 4 yellow; 1 produced 4 gray and 10 yellow; and the other 5 produced black and gray segregates but no yellow. The numbers were small, but indications were that all the albino-producing plants might well have resulted originally from a single black-yellow combination.

The data indicated no association between kernel color and albinism. In each of the 20 segregating lines, some progenies were albino and some were green. The 17 homozygous black populations, as well as the 7 homozygous yellow, produced albinos.

Segregation for kernel color among these 44 progeny populations was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
"F_4":				
All black	17	13	35.75	+1.25
Heterozygous	20			
Yellow	7	3	8.25	−1.25

"Frustrated"

In 1961, at Aberdeen, Idaho, a peculiar bridging-type steriloid-fatuoid aberrant was observed in the Eaton variety. A similar aberrant had been observed 39 years earlier in Sixty-Day. These aberrants are described in this bulletin (pp. 73–74).

In the row of Eaton in which the above-mentioned aberrant occurred, six plants appeared to be of the intermediate type. Seeds of these were planted in the greenhouse in 1961–62, and 32 plants resulted. However, no progenies were of the aberrant type mentioned. Five of the 32 were of the usual fatuoid type.

In addition to the five fatuoids, four plants were distorted, one each in two progeny populations and two in a third. The two occurring singly in the two populations had somewhat distorted, short, bunchy or compact sorghum-type panicles. The panicles of the other aberrants were unusual in that they bent over or "goose-necked" after emerging from the boot. Goose-necked aberrants sometimes occur in oats, as reported earlier (p. 87).

These aberrants, however, were different. After first bending to one side, the panicles later reversed the direction of growth and eventually were in an upright position. A hairpin bend remained in the peduncle area throughout later growth and maturity. Such an indecisive and irregular growth type had not previously been observed, and this type of aberrancy was named "frustrated."

To test the breeding behavior of these oats, all seeds of all 32 plants were sown in progeny rows at Aberdeen, Idaho, in 1962. Some distorted aberrants had been anticipated, but not a large number.

Practically all aberrant types previously observed in oats occurred among this small progeny population of fewer than 700 plants. In the second generation, no individuals of the steriloid-fatuoid type were observed; but many fatuoids, both normal types and others similar to those produced in the greenhouse, were observed. Numerous types of distorted individuals were produced. One aberrant was a very tall plant resembling *A. sterilis ludovi-*

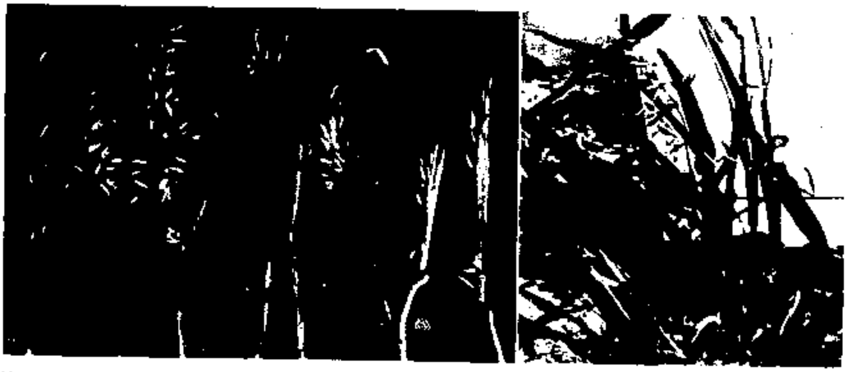

FIGURE 18.—Distorted or "frustrated" aberrants in *Avena* var. Eaton: *A*, Distorted panicles; *B*, distorted plants.

FIGURE 19.—Aberrant and normal panicles and culms in *Avena* var. Eaton: *A*, Aberrant panicle and culms; *B*, normal panicle and culms.

ciana. Individuals with very stout culms and short, stiff-branched panicles were observed. Several dwarf plants, one of which failed to head, and individuals with chlorotic striping were observed. Some plants appeared to have a high percentage of sterile florets. The only known similar distortion in any cereal crop in the last 40 years was that reported by Scholz and Lehmann (*25*) in 1961. These scientists irradiated barley and obtained numerous types of aberrancies, some of which appeared to be similar to those described here.

Both normal and distorted types of fatuoid and cultivated plants were present at Aberdeen, and it was obvious the two aberrancies

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were inherited independently. Segregation for fatuoid types in the 32 progenies grown was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
"F_3":				
Cultivated	9	13	26.0	+1.0
Intermediate	18			
Fatuoid	5	3	6.0	–1.0

Although, on the basis of the "F_3" lines, a close fit to a 13:3 ratio was indicated, segregation among the heterozygous lines was less close.

Class	Observed	Ratio	Calculated	O–C
Heterozygous lines:				
Cultivated	122	13	316.06	–10.06
Intermediate	184			
Fatuoid	83	3	72.94	+10.06

Study was also made of the inheritance of the frustrated type. Segregation was as follows:

Class and progeny	Observed	Ratio	Calculated	O–C
"F_3":				
All normal	14	13	26.0	±0.0
Heterozygous	12			
All frustrated	6	3	6.0	±0.0

The 12 heterozygous lines segregated as follows:

Class	Observed	Ratio	Calculated	O–C
Heterozygous lines:				
Normal	261	13	247.0	+14.0
Frustrated	43	3	57.0	–14.0

Segregation among the lines for the frustrated type gave a perfect fit to a 13:3 ratio. Segregation among the 12 heterozygous lines was not so close but still indicated 13 normal:3 frustrated. Without doubt, the distortion is heritable.

The observation of so many different aberrants in such a small progeny population, derived from a single head row of Eaton, is most unusual. Just what potent force affected this series of malformed aberrancies is a matter for speculation.

ADDITIONAL ABERRANCIES OBSERVED IN 1961 AND 1962

A number of additional aberrants have been observed by the writer. To date their inheritance has received little study. Among progenies of cross X57BL, supposedly Black Mesdag × Abd. 101 (derived tetraploid), the following four aberrants have appeared to date:

1. *A. sativa orientalis*-like types (side oats) with long glumes. Several of these did not segregate in the second generation test. Two of six produced a few very small-kerneled segregates.
2. *A. strigosa*-like type. One original, weak, dwarfish, undersized plant was observed in a greenhouse pot, progeny of which did not segregate in the second generation test. The plants were midtall.
3. *A. sterilis ludoviciana*-like type. It has large, pubescent kernels. Such a high degree of dormancy exists that few seeds have germinated in 60-day tests.
4. Aberrants with dorsal pubescence. These have not been tested to date.

Additional aberrants observed include:

1. *A. nuda*-type with small undersized glumes and panicles and fully awned florets. This aberrant did not segregate in the second generation. It was derived in F_2 from a cross in which strain 5041–2837 from the supposed cross X57BL (Black Mesdag × Abd. 101) was crossed with a strain from the cross C.I. 7199 × C.I. 7498. (C.I. 7498 is a strain from X57BL.)
2. Male-sterile aberrant. In addition to the above *A. nuda*-type oat, numerous short, slender strawed male-sterile type plants appeared in one progeny population of the above cross.
3. *A. sterilis ludoviciana*-like type. This very tall aberrant was derived from a progeny line of cross X6019. It has small, very pubescent kernels. Such a high degree of dormancy exists that few seeds have germinated in 60-day tests. The parents of cross X6019 were "Bingham" (C.I. 7571) crossed with strain 5042 from the supposed cross X57BL (Black Mesdag × Abd. 101).
4. An exceptionally tall fatuoid. (Usually fatuoids are no taller and are sometimes much shorter than normal plants.) This unusually tall aberrant was derived from cross X60AU. The parents of the cross are "Bingham" (C.I. 7575) crossed with strain 5041 of the supposed cross X57BL (Black Mesdag × Abd. 101).

All these aberrants are of sufficient interest to warrant study.

FIGURE 20.—*A. sterilis ludoviciana*-like aberrants in *Avena*: *A*, Panicle from X57BL cross; *B*, *D*, Eaton panicle and plant; *C*, panicle from another X57BL cross.

FIGURE 21.—Aberrant panicle types in *Avena*: *A*, Multiflorous *A. nuda* type; *B*, unilateral *A. sativa orientalis* type; *C*, *A. strigosa* type.

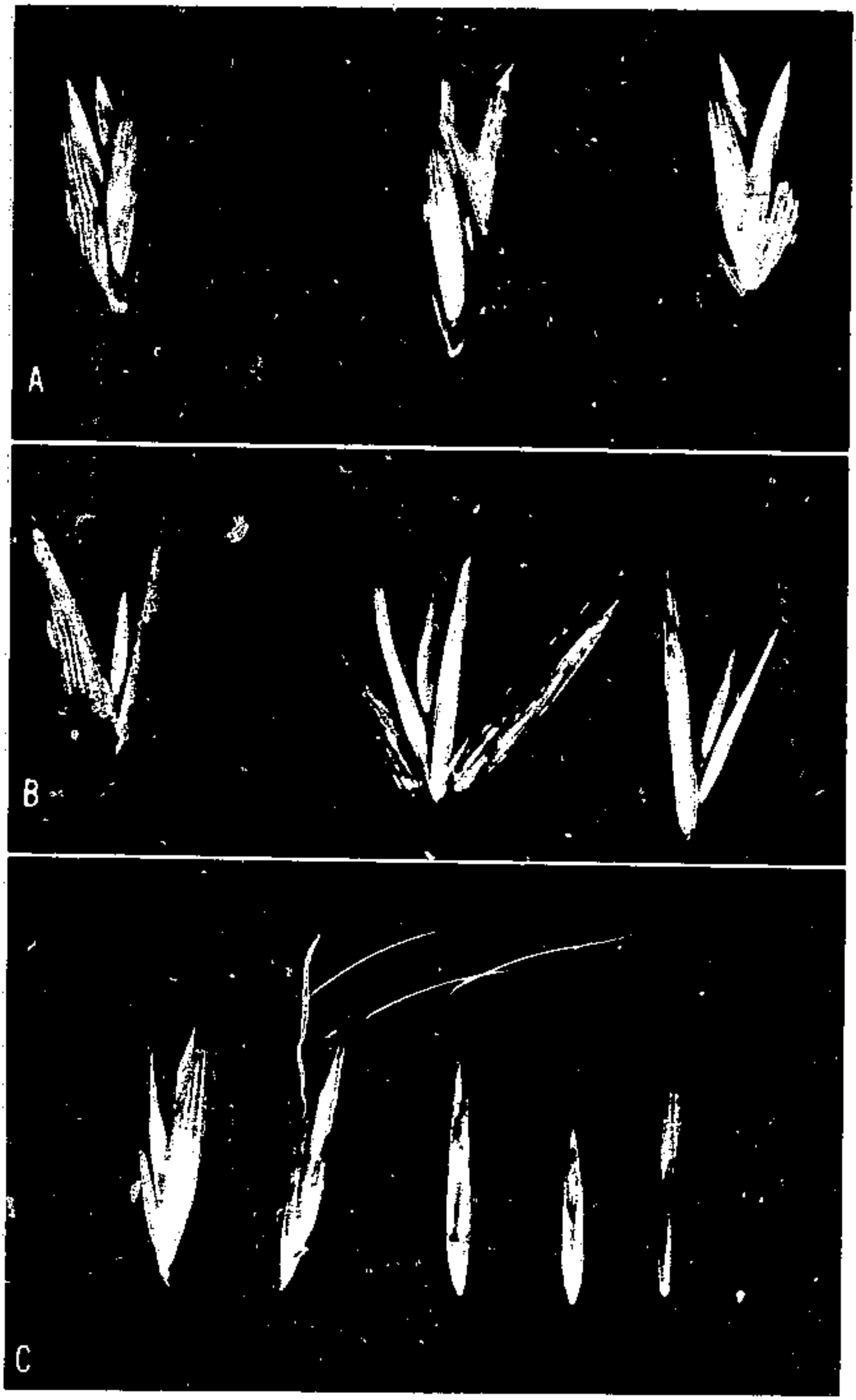

FIGURE 22.—Spikelets of aberrants in *Avena*: *A*, Multiflorous-type aberrant; *B*, unilateral-type aberrant; *C*, *A. strigosa* type aberrant.

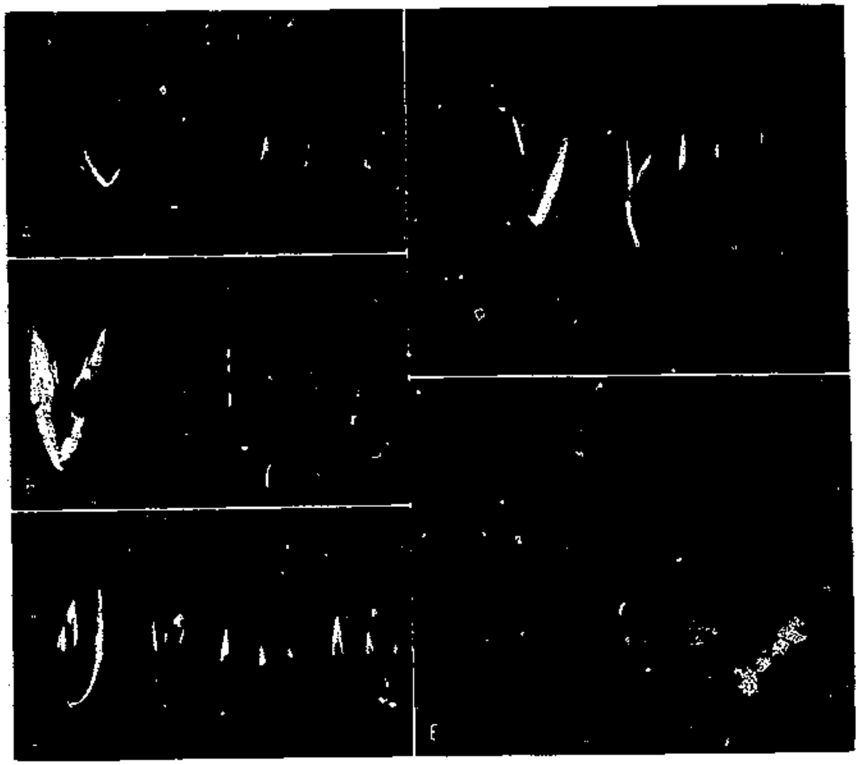

FIGURE 23.—*A*, *B*, *C*, Aberrant spikelets and florets of *A. sterilis ludoviciana* type; *D*, true *A. sterilis ludoviciana* spikelets and florets; *E*, tall-strawed fatuoid aberrant.

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