THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given Arthur Noble Wilcox final oral examination for the degree of

Master of Science

We recommend that the degree of

Master of Science

be conferred upon the candidate.

H.K. Hayes Chairman

E. M. Freeman

R. B. Harvey.

Fred Griffee

Date May 27, 1922

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THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Arthur Noble Wilcox for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

H. K. Hayes
Chairman

E. M. Freeman

R B Harvey.

Date May 27, 1922

10-20 5M

THE EFFECTS IN CORN OF CERTAIN LETHAL FACTORS WHEN IN THE HETEROZYGOUS CONDITION.

A thesis presented to the Faculty of the
Graduate School of the University of
Minnesota in partial fulfillment
of the requirements for the
Degree of Master of
Science

By

Arthur N. Wilcox.

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INTRODUCTION

The inheritance of plant characters is understood probably more extensively in corn than in any other plant. A large number of characters have been described and their mode of inheritance determined. Many of these are called "abnormal" characters, because of their departure from the apparently normal condition in corn. Most such abnormal characters are Mendelian recessives to the normal type. They usually diminish, to a greater or less degree, the ability of the plant to perform its normal functions. Examples of such characters are <u>dwarfness</u>, <u>golden</u>, and <u>Japonica</u>. Some abnormal characters are actually lethal. In one such type, which includes <u>white</u> and <u>yellow</u> seedlings, the production of chlorophyll is prevented in the seedlings, so that as soon as the food supply in the seed is exhausted, they die. In another type the seed is rendered incapable of germination.

If such characters were dominant, at least the most degenerative would quickly perish. Being recessive, they are carried from generation to generation in apparently normal plants, heterozygous for the factors involved, and only appear when chance combines them into the homozygous condition.

The occurrence of such abnormalities when a commercial variety of corn is subjected to a system of self-pollination indicates that the factors, or genes, for the abnormal characters are very common. The ordinary occurrence of these characters in fields of corn necessarily causes some loss. If the factors involved have a deleterious effect also when they occur in the heterozygous condition, the resulting losses

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must be very much greater, because of their much more frequent occurrence in the heterozygous condition.

It is the purpose of this thesis to determine whether the factors which, in the homozygous condition, produce unfavorable characters, may also, when in the heterozygous condition, have any detectable éffect on such important and easily measured characters as weight of the individual seed, height of plant, and lodging of plant.

For this study the most unfavorable factors, the lethal factors, were chosen, because it seems reasonable to expect that if there is any effect in the heterozygous condition it is likely to be greatest in the case of those factors which are most injurious when in the homozygous condition.

SUMMARY OF PREVIOUS WORK WITH LETHAL FACTORS

Seedling Chlorophyll Factors.

The occurrence of albinism in corn and other plants has long been observed. The occurrence of corn seedlings lacking chlorophyll was first mentioned in the literature by East and Hayes (1911). Investigations on the inheritance of this character were reported by Emerson (1912), by Miles (1915) and by Lindstrom (1918, 1920, and 1921), who has worked out the interrelations of the various factors responsible for the occurrence of white, virescent-white, and yellow seedlings. These three types are very distinct, especially when they are grown under uniform conditions in the greenhouse.

The white seedlings are entirely lacking in green pigment and are apparently devoid of chloroplasts. In some cases the leaves become faintly tinged with yellow, due, probably, to aging of the tissues. Because of their lack of chlorophyll, these seedlings die without growing higher than several inches.

The virescent-white seedlings may appear pure white at first but soon become yellowish green, the color appearing first in the tips of the leaves. Under favorable conditions these plants sometimes grow to maturity and bear seed.

The yellow seedlings have from the first a clear lemon yellow color. The pigment closely resembles xanthophyll. These seedlings also die at an early stage. Virescent-yellow seedlings, which may become green, also occur.

The three types, white, virescent-white, and yellow, are each inherited as simple recessives to normal green. Their inheritance is governed by three factor pairs: Ww, Vv, and Ll. The various types of seedlings possess the following factors:

Green	LVW and lVW
Virescent white	LvW
White	LVw and Lvw
Virescent yellow	lvW
Yellow	lVw and lvw

Thus W and V are necessary for the development of green. The factor v confines the green pigment to the virescent condition. The factor w inhibits all development of green, either virescent or normal. The factor l, in presence of w results in the appearance of yellow.

Kernel Lethal Factors.

Jones (1920) described a new character, "defective seed", which he designated by the recessive factor de. This factor completely stops the development of both embryo and endosperm or greatly reduces it shortly after fertilization. This results in aborted seeds with either entirely empty pericarp or badly shrivelled seeds. The factor is completely lethal in some cases and partly so in others.

Observations made by Professor Hayes at Minnesota indicates that the inheritance of lethal kernels is much more complex than the simple single-factor hypothesis suggested by Jones. It has been the practise at Minnesota to separate the lethal kernels into two groups. The "pericarp lethals" constitute one group, in which the seeds are flattened almost to a chaffy thinness, and contain no visible embryo or endosperm. The other group, called "endosperm lethals" includes a range from those kernels which resemble closely the pericarp lethals,

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but contain a visible trace of endosperm, to those in which the endosperm is apparently fully developed, but which have a rather shrunken embryo and a dull, lifeless color.

METHOD OF PROCEDURE

The first step in the present experiment consisted in weighing a number of seeds of corn taken from ears which were known to be producing lethals. The seeds were planted in the field and the important plant characters were recorded. The genetic constitution of the seeds with regard to the lethal factors was determined. Calculations were then made to find whether lethal factors, such as white and yellow seedlings or pericarp or endosperm lethals, have any effect, when in the heterozygous condition, on other characters, such as weight of seed, height of plant, and degree of lodging.

Seeds were taken in the spring of 1921 from eleven ears of corn, five of which came from first-year-selfed strains of Minnesota 13, Minnesota 23, and King Phillip, and six from the F_2 generation of several crosses. These ears were selected because they were known to contain lethal factors; seven ears contained white factors, one contained yellow, two contained pericarp and endosperm lethals, and one contained the non-lethal japonica-striping factor. This ear was later dropped from consideration.

Seeds were removed from these ears and individually weighed to an accuracy of five milligrams. To facilitate weighing the large number of seeds, 1320 in all, a jolly balance was constructed. A piece of fine steel wire about two feet long was coiled into a spiral and one end was attached to a standard. On the lower end of the spring thus formed a small paper pan was suspended, and just above it a paper indicator was attached. A mirror was attached to the standard behind the spring, to insure level reading of the indicator, and a paper was fastened to the front of the mirror. On this paper a vertical scale was drawn, after its divisions had been determined by using known weights in the pan. In the course of weighing the scale was checked, or calibrated, after the weighing of each ten seeds, by placing known weights in the pan.

These seeds were then planted in order in 44 rows, 30 seeds in each row, the seeds one foot apart in the row. After the seedlings had emerged, notes were taken on their color. It is obvious that the seeds homozygous for white and yellow factors could at this time be recognized by the white and yellow color of their seedlings. The green seedlings, however, came from two kinds of seeds, homozygous and heterozygous for the factors involved. These greens could not, of course, be distinguished in the seedling stage, but had to be tested further by growing their self-fertilized seed in the greenhouse the following winter.

About four hundred of the plants were self-pollinated. Notes were then taken on these plants on height of plant in inches, on degree lodging, on number of suckers per plant, and on presence or absence of smut. Degree lodging was recorded by means of the numbers 1 to 5, representing five equal divisions of an angle of ninety degrees, the most upright of which was indicated by 1.

The self-fertilized seed of ears from strains which produced white and yellow seedlings in the field test were planted in the greenhouse, to determine whether they were homozygous for the green factors. Twenty seeds from each ear were planted in coarse sand in pots, ten seeds in a six-inch pot. The seeds were planted according to a uniform pattern to make the spacing as equal as possible. Notes were later taken on the color of the seedlings. The presence of any white or yellow seedlings from an ear indicated that the seed from which that ear came, that is, the original kernel weighed in the spring of 1921, had been heterozygous for the factor involved. The absence of any white seedlings from an ear, indicated, on the other hand, that the original seed had been homozygous green.

Normal seeds from first year self-pollinated ears of Minnesota 13 bearing pericarp and endosperm lethals were similarly weighed and planted. A number of the plants were self-pollinated. Observations were made on these plants similar to those made on white- and yellow-bearing strains. Since the presence of the lethal condition in the seeds of these self-pollinated plants could be recognized by examination, testing in the greenhouse was unnecessary. The ears were shelled and the numbers of normal seeds and of those containing pericarp and endosperm lethals were recorded. Because of the lack of knowledge concerning the mode of inheritance of these lethals, the numbers of kernels containing the two lethals were thrown together and the percentage of lethal kernels on each ear was calculated.

As a result of this experimental work the following records were secured: (1) in seedling-lethal strains, the genetic constitution of the original seeds, whether homozygous or heterozygous green, or homozygous white or yellow; (2) in kernel-lethal strains, the percentage of lethal kernels on the ears; (this was determined by self-fertilizing ears and counting the lethals) (3) the height of the self-pollinated plants; (4) the degree lodging of the same plants; (5) the number of suckers per plant; and (6) the presence or absence of smut. Because of the very small numbers of plants affected with smut, those records (6 above) were dropped from further consideration.

In order to determine the effect, if any, of the lethal factors considered, a biometrical analysis was made of the relation existing between the genetic constitution of the original seeds and their weight, the height of the plants which they produced, and the degree of lodging of those plants.

Because the original seed containing factors for white came from seven different ears of various histories, it was necessary, before combining the data of the seven strains, to place the data on a comparable basis. In the case of seed weight this was accomplished by calculating the mean weight in grams of all seeds from the same ear. With this mean taken as 100 the seed weight index of each seed of known genotype was placed on a percentage basis. It is to be noted here that the mean seed weight for each ear was calculated from the weights of the all seeds coming from that ear rather than from the weights of only the seeds of known genotype, because the larger number available by that method reduced the probable error of the mean.

Height of plants in inches was converted into a similar index, save that the heights of only the self-pollinated plants entered into the calculation of the means.

Records in the two strains bearing kernel lethals were also placed on an index basis.

Correlation tables and frequency tables were then prepared to show whether the presence in the original seed of lethal factors, particularly in the heterozygous condition, had any effect on the other characters studied.

EXPERIMENTAL RESULTS

The Effects of Seedling Lethal Factors.

The original data are given in the appendix in Tables I to IV. The biometrical analysis of the data is presented in this section in the form of correlation and frequency tables.

In order to determine whether white-seedling lethal factors have any effect on the weight of seeds carrying them, the writer placed the seeds in three classes numbered 1, 2, and 3, and respectively representing seeds homozygous for white, heterozygous for green, and homozygous for green. The coefficient of correlation between the genotypic condition and the seed weight index was calculated. (Table VII)

TABLE VII.

Correlation Between Seed Weight Index and Genotypic Condition in Strains Producing White Seedlings.

Seed Weight Index	Genotypic Condition			N
	Homozygous white 1	Heterozygous green 2	Homozygous green 3	
65		1		1
70		1		1
75	1			1
80	1			1
85	2	1	1	4
90	16	9	5	30
95	24	22	6	52
100	30	24	23	77
105	29	23	9	61
110	10	6	11	27
115	15	8	7	30
120	4	2		6
125	3	2		5
130		3		3
N	135	102	62	299

$$r = + .023 \pm .040$$

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It was found to be + .023 ± .040. No correlation exists. Consequently the white-seedling lethal factors present in the seeds had no detectable effect on their weights.

In the Yellow-bearing type the coefficient of correlation was found to be + .420 ± .123. (Table VIII.)

TABLE VIII.

Correlation between Seed Weight Index and Genotypic Condition in Strains Bearing Yellow Seedling.

Seed Weight Index	Genotypic Condition			N
	Homozygous White 1	Heterozygous Green 2	Homozygous Green 3	
80	1			1
85				
90	2			2
95	2			2
100	5	3		8
105	4	1	1	6
110		2		2
N	14	6	1	21

$$r = +.420 \pm .123$$

Inasmuch as the coefficient is only about three and one-half times the probable error, the correlation cannot be accepted as a certainty. The small number of seeds heterozygous and homozygous for green makes it necessary to view with great caution the indication that there is a significant difference between the homozygous greens and the heterozygous greens with regard to seed weight.

The possible effect of seedling lethals on height of plant was next considered. Due to the fact that the homozygous white plants died while in the seedling stage, measurements of plant height could be made only on the homozygous and heterozygous green plants. The mean height index for homozygous green plants was found to be 99.60 and for heterozygous greens, 99.65. (Table IX.) The difference is not significant. Consequently no effect of the lethal factor on this character is demonstrated. No calculations were made on the yellow-bearing type because only seven green plants were completely tested.

TABLE IX

Frequency Distribution of Index for Height of Plants
in Strains Producing White Seedlings.

Types of Plants	Class Centers for Plant Height Index.										Totals	Means
	75	80	85	90	95	100	105	110	115	120		
Homozygous Green	1	3	1	6	13	13	15	6	3	1	62	99.60
Heterozygous "	1	2	2	12	10	32	22	14	4	1	100	99.65

The effect of white-seedling lethals on degree lodging was similarly determined. (Table X). The mean degree lodging for heterozygous green plants was found to be 1.67 ± .06, for homozygous greens, 1.55 ± .06. The difference, .12 ± .08 is not significant. Consequently no effect is demonstrated.

TABLE X

Frequency Distribution of Degree Lodging of Plants
in Strains Producing White Seedlings.

Types of Plants	Classes for Degree Lodging					Totals	Means
	1	2	3	4	5		
Homozygous Green	35	20	7			62	1.55 ± .06
Heterozygous "	53	32	11		3	99	1.67 ± .06

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There was found to be no effect of white-seedling factors when in the heterozygous condition on number of suckers per plant. (Table XI.) The mean number of suckers for heterozygous green plants was found to be .51 ± .06; for homozygous greens, .52 ± .08.

TABLE XI

Frequency Distribution of Number of Suckers per Plant in Strains Producing White Seedlings.

Types of Plants	Number of Suckers per Plant.					Totals	Means
	0	1	2	3	4		
Homozygous Green	45	8	4	4	1	62	.52 ± .08
Heterozygous "	74	8	11	7		100	.51 ± .06

The Effects of Kernel Lethals.

The possible effects of pericarp and endosperm lethal factors when in the heterozygous condition were studied somewhat differently. All of the seeds used were either heterozygous for the lethal factors involved or homozygous for their absence. The percentage of lethal kernels in the progeny ears was accepted as the best available measurement of the degree of heterozygosity of the original kernels.

The coefficient of correlation between this value and seed weight index was found to be + .166 ±.084. (Table XII.) Inasmuch as the probable error is half as large as the coefficient, the significance of the correlation must be considered very uncertain.

Between percent of lethals and index for plant height the coefficient of correlation was found to be -.030 ±.086. (Table XIII). This very definitely demonstrates that there is no effect of these lethal factors on plant height.

A similar lack of correlation ($r = -.068 \pm .086$) was found between percent of lethals and degree of lodging. (Table XIV).

TABLE XII

Correlation Between Seed Weight Index and Percentage of Lethal Kernels in Progeny Ears.

Class Centers for Seed Wt. Index	Class Centers for Percent Lethal Kernels.					N
	7.5	22.5	37.5	52.5	67.5	
80	1	1				2
85	1	1				2
90	4	2		2		8
95	2	8	2		1	13
100	2	8	3	4		17
105	4	5		1		10
110	2	1	1	1		5
115			2	1		3
125		1				1
N	16	27	8	9	1	61

$r = +.166 \pm .084$

TABLE XIII

Correlation Between Plant Height Index and Percentage of Lethal Kernels in Ears.

Class Centers for Plant Ht. Index	Class Centers for Percent Lethal Kernels					N
	7.5	22.5	37.5	52.5	67.5	
70				1		1
85		2				2
90		5	1			6
95	3	6	4		1	14
100	4	3	2	2		11
105	4	6	1	5		16
110	2	1	3	1		7
115	2		1	1		4
N	15	23	12	10	1	61

$R = -.030 \pm .086$

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TABLE XIV

Correlation Between Degree Lodging of Plants and Percentage of Lethal Kernels in Ears.

Classes For Degree Lodging	Class Centers for Percent of Lethal Kernels					N
	7.5	22.5	37.5	52.5	67.5	
1	13	20	11	9	1	54
2	2	1	1	1		5
4		2				2
N	15	23	12	10	1	61

$r. = -.068 \pm .086$

CONCLUSIONS

In the material studied there was not found to be any marked or certain effect of lethal factors, when they were in the heterozygous condition, on other important characters such as weight of individual seeds and height and uprightness of plants.

The results of this investigation do not support the suggestions of previous workers that the lethal factors have an effect when in the heterozygous condition. In a paper by Lindstrom (1918) it was said: " --- it is interesting to note a general correlation between chlorophyll factors and plant growth. In all the material in which the w factor is concerned, the plants show a tendency toward producing only a single stalk which finds great difficulty in standing up in a strong wind. It is only rarely that a sucker is produced." If, as it would seem from this statement, it was Lindstrom's belief that the w factor when in the heterozygous condition has an effect on uprightness and on the number of suckers, the present investigation shows that no such result should in general be expected.

In substance, the results on the material studied indicate a complete dominance for the factors involved, and give the assurance that the lethal factors studied, when in the heterozygous condition, have no marked deleterious effect on the seeds or on the plants in which they are transmitted. The economic losses from certain lethal factors in corn are consequently confined to losses resulting from the homozygous condition; that is, from the inability of certain seeds to germinate or to produce plants capable of maturing.

SUMMARY

1. Factors for white seedlings, both in the homozygous and heterozygous conditions, were found to have no effect on the weight of the seeds in which they were carried.
2. Factors for white seedlings when in the heterozygous condition were found to have no effect either on the height of plants or on the degree of lodging.
3. A slight correlation ($r = .420 \pm .123$) was found to exist between presence of yellow-seedling factors in the seeds and weight of the seeds.
4. In the heterozygous state there was found to be no effect of the lethal factors on the number of suckers produced.
5. A very slight and not at all certain correlation ($r = +.166 \pm .084$) was found between the weight of the original kernels and the percentage of pericarp and endosperm lethal seeds on the progeny ears.
6. Factors for pericarp and endosperm lethals, when in the heterozygous condition, were found to have no effect on the height of plants.
7. Factors for pericarp and endosperm lethals, when in the heterozygous condition, were found to have no effect on the uprightness of the plants.

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APPENDIX

TABLE I.

Frequency Distribution of Seed Weights in White-Seedling Strains (Nos. 1-7) and Yellow-Seedling Strains (No. 8)

Strains	Types	Class Centers in Grains for Weights of Individual Seeds.														Totals	Means
		.17	.19	.21	.23	.25	.27	.29	.31	.33	.35	.37	.39	.41	.43		
	Homozygous Green				3	1										4	.235
1	Heterozygous "			3	12											15	.226
	Homozygous White			5	7	1										13	.224
	Homozygous Green						1	3	2	3	5	2				16	.327
2	Heterozygous "							3	3	1	3	2	2	2		16	.345
	Homozygous White						1	4	3	1	1	2	1			13	.321
	Homozygous Green						4	8	1							13	.285
3	Heterozygous "					2	4	6	8	1						21	.292
	Homozygous White					1	2	12	7	5		1				28	.302
	Homozygous Green						1	2								3	.283
4	Heterozygous "					2	3	1	1	1						8	.280
	Homozygous White					2	5	12	6							25	.288
	Homozygous Green				1	7	4	1								13	.258
5	Heterozygous "	1			6	7		3	1							18	.249
	Homozygous White		1	2	6	5	2	3								19	.245
	Homozygous Green										2	2	4	1		9	.379
6	Heterozygous "				1					2	4	6	2			15	.353
	Homozygous White									2	4	3	1	1	1	12	.367
	Homozygous Green							1		2	1					4	.325
7	Heterozygous "							1	1	3	1	3	1			10	.344
	Homozygous White						1	1	6	6	2	6	1	1		24	.338
	Homozygous Green											1				1	.370
8	Heterozygous "										3	1	2			6	.367
	Homozygous Yellow							1	1	1	8	4				15	.347

TABLE II

Frequency Distribution of Height in Inches of Plants in White-Seedling Strains (Nos. 1-7) and Yellow-Seedling Strain (No.8)

Strains	Types	Class Centërs in Inches fo Height of Plants.												Totals	Means
		50	55	60	65	70	75	80	85	90	95	100	105		
1	Homozygous Green					1			1	1			1	4	87.5
	Heterozygous "				1			2	1	7	3			14	87.5
2	Homozygous "					1			3	4	6	2		16	90.9
	Heterozygous "								4	7	3	1	1	16	91.3
3	Homozygous "					2	4	4	2	1				13	78.5
	Heterozygous "			1	1	1	5	8	4					20	77.5
4	Homozygous "							2	1					3	81.7
	Heterozygous "					3	4	1						8	73.7
5	Homozygous "				1	3	4	2	2	1				13	76.5
	Heterozygous "					3	3	5	5	1	1			18	80.3
6	Homozygous "	1			4	4								9	65.6
	Heterozygous "		2	2	2	6	3							15	67.0
7	Homozygous "		1	2	1									4	60.0
	Heterozygous "			2	6	1								9	64.4
8	Homozygous "									1				1	90.0
	Heterozygous "						1	2		1		1	1	6	88.3

TABLE III

Frequency Distribution of Degree Lodging in White-Seedling Strains (Nos. 1-7) and Yellow-Seedling Strains (No. 8).

Strains	Types	Classes for Degree Lodging.					Totals	Means
		1	2	3	4	5		
1	Homozygous Green	2	1	1			4	1.75
	Heterozygous "	7	6	1			14	1.57
2	Homozygous "	15		1			16	1.13
	Heterozygous "	16					16	1.00
3	Homozygous "	1	8	4			13	2.23
	Heterozygous "	5	7	7			19	2.11
4	Homozygous "	1	2				3	2.33
	Heterozygous "	1	6	1			8	2.00
5	Homozygous "	11	2				13	1.15
	Heterozygous "	13	5				18	1.28
6	Homozygous "	5	4				9	1.44
	Heterozygous "	10	3				13	1.23
7	Homozygous "		3	1			4	2.25
	Heterozygous "		4	2		3	9	3.22
8	Homozygous "	1					1	1.0
	Heterozygous "	6					6	1.0

TABLE IV

Frequency Distribution of Seed Weights in Kernel Lethal Strains.

Strains	Per cent Lethals	Class Centers in Grams for Weights of Individual Seeds.							Totals	Means
		.23	.25	.27	.29	.31	.33	.35		
9	0 to 15	2	3	2	2				9	.259
	16 to 30	2	2	3	3			1	11	.272
	31 to 45			2					2	.270
	46 to 60			2					2	.270
10	0 to 15			1	1	3	1		6	.303
	16 to 30			2	5	4	1		12	.297
	31 to 45			2	5	1	2		10	.296
	46 to 60			2	3	2		1	8	.298
	61 to 75				1				1	.290

TABLE V.

Frequency Distribution of Height in Inches of Plants in Kernel-Lethal Strains.

Strains	Per Cent Lethals	Class Centers in Inches for Height of Plants										Totals	Means
		55	60	65	70	75	80	85	90	95	100		
9	0 to 15							4	1	2	2	9	91.1
	16 " 30					2	2	4	3			11	83.6
	31 " 45									1	1	2	97.5
	46 " 60										2	2	100.0
10	0 " 15						3	2	1			6	83.3
	16 " 30				1	2	3	2	3	1		12	82.9
	31 " 45					1	3	2	2	2		10	85.5
	46 " 60	1						5	1	1		8	83.1
	61 " 75						1					1	80.0

TABLE VI

Frequency Distribution of Degree Lodging of Plants in Kernel-Lethal Strains.

Strains	Per Cent Lethals	Classes for Degree Lodging 1	2	3	4	Totals	Means
9	0 to 15	7	2			9	1.22
	16 to 30	9	1		1	11	1.36
	31 to 45	1	1			2	1.50
	46 to 60	1	1			2	1.50
10	0 to 15	6				6	1.00
	16 to 30	11			1	12	1.25
	31 to 45	10				10	1.00
	46 to 60	8				8	1.00
	61 to 75	1				1	1.00

12-21-6M

PLATE I

Green and white seedlings produced by self-fertilized seeds from a plant heterozygous for the white factor. (Photographs for all plates made by T. J. Horton and colored by G. D. George).

PLATE II

Green and virescent-white seedlings produced by self-fertilized seeds from a plant heterozygous for the virescent-white factor.

PLATE III

Green and Yellow Seedlings Produced by Self-Fertilized Seeds from a Plant Heterozygous for the Yellow Factor.

PLATE IV

Various Kinds of Seeds from a Self-Fertilized Plant Heterozygous for Kernel-lethal Factors.
Top row: normal seeds
Middle row: endosperm lethals
Bottom row: pericarp lethals