THE LARGE SEED FACTOR

IN

CROP PRODUCTION

A THESIS

BY

Lowrie Baird Nevin

Presented in partial fulfillment
of the requirements for the degree
of
Bachelor of Science

University of California
College of Agriculture
Division of Agronomy
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THE LARGE SEED FACTOR IN CROP PRODUCTION.

Introduction

The question of larger yields is a very vital one with the farmer of to-day. In many cases more than is realized by the farmers themselves do the profits depend upon the last refinements in efficient production. Therefore any factor that gives larger returns for practically the same effort merits attention. Such a factor is the influence of large heavy seed in crop production.

In opening his discussion of experiments with wheat in which some of the advantages of large plump seed were demonstrated, Dr. N. A. Cobb (1) remarks that any effort to prove the lower value of small seed will be regarded by many as an effort to kill a dead horse; but as long as there exist among us advocates of small seed, and the bulk of wheat growers use poor seed, it will be necessary to harp on the superior value of large seed.

It is the intent of this paper to deal principally with the large seed factor as applying to cereals, especially wheat; but from time to time reference is made to experiments with other plants to show that the principle applies not alone to the cereals.

There has been no attempt to make an exhaustive survey of the field, either as regards the literature or as a discussion of the subject.

The one definite objective of the experimental part of the task has been to secure some experimental ground as a basis for the assumption that the extra development of the plants from large seed is due to the additional supply of endosperm available to the germinating plantlet.

There is no lack of literature showing that this is the explanation favored by many but it has not been the good fortune of the writer to find any experiments in support of the theory, logical as it certainly seems.

The subject has been taken up from the standpoint of the influence of large seed upon the yield, of large seed upon germination, of the specific gravity or weight upon the yield, and the relation of the size and weight of the kernel to composition. There has been included also a short discussion of some of the available mechanical aids to the selection of large, heavy seed.

The Influence of Large Seed upon the Yield.

Sanborn(2), at the Utah Experiment Station, reports experiments to ascertain the effect of using seed separated for size. He used five grades: large, medium, small, ordinary, and shrivelled. His results are given as follows:-

Kind of seed.	pounds per acre yields: 1890	1891	1892	1893	Average 4 years bu. per A.
Large	88.5	72.5	111.0	63.0	18.72
Medium		70.0	87.0	67.0	16.60
Small	94.0	105.0	64.0	74.0	18.72
Ordinary	84.0	95.0	87.0	29.5	16.42
Shrivelled		43.0	78.0	31.0	11.25

His conclusion that very little if any advantage is to be gained by separating seed wheat and planting the large kernels is of questionable value on account of the irregularity of the results.

Latta, at the Indiana Experiment Station, (3) conducted experiments in which wheat was cleaned of chaffy seed and impurities and separated into light and heavy kernels by

Table, at the fall experiment ... experiments in which wheat was cleaned of dockage and impurities and separated into light and heavy kernels by means of a fanning mill. The experiments were continued for three years, each year taking seed not grown from seed so selected. The results showed an average gain for large seed of two and one half bushels per acre.

Georgeson, at the Kansas Experiment Station, has done considerable work on the subject and we find the results of his work in several of the publications of that station. In Bulletin No. 13 the following results are presented:

Grade of seed	Yield of grain per A.
Light	21.6 bu.
Common	24.0 "
Heavy	30.0 "

These tests, he says, prove "only what is already well known".

He later seeded plats with seed of different weights per bushel and one of seed from selected heads. The grades were as follows:

Light seed	56 lbs. per bu.
Common seed 62.5	62.5 " " "
Heavy seed	63 " " "
The seed from selected heads.	

Each year seed was selected from wheat not grown from selected seed. The average results from three years trials were as follows:

Grade of seed	Bu. of grain per acre.
Light	25.19
Common	26.57
Heavy	27.07
Select (Average for two years)	25.82

In Bulletin No. 54 of the same station the average for six years shows as follows:

Light	28.48
Medium	29.85
Heavy	30.76

The results of eight years' experiments recorded in Bulletin No. 54 of the same station are similar.

Of oats he says in Bulletin 63, " light inferior seed is certain to produce less than seed of a fair quality, but between a fair quality of seed oats and heavy sifted seed there is not much difference."....."the average for seven years is, however, in favor of heavy seed."

In 1892-3 Desprez at the Experiment Station of Capello (4) experimented with seed of different sizes and from different locations in the spike, with results as follow:

1892	Kilograms From large	From small	Dif. favor lge.
Var. No. 1.	5,726	4,799	927
Early ears, middle			
Late " "	6,172	4,235	1,937
Var. No. 2.			
Early ears, middle	5,231	3,123	2,108
Late " "	4,680	2,456	2,224
Var. No. 3.			
Early ears, middle	5,879	3,543	2,336
1893			
Var. No. 1.			
Early ears, middle	5,835	5,796	66
" " extremity	5,492	4,425	1,067
Late " middle	5,869	4,347	1,522
" " extremity	5,291	4,491	800
Var. No. 2.			
Early ears, middle	5,142	5,035	107
" " extremity	5,587	5,242	345
Late " middle	6,330	4,543	1,787
" " extremity	4,897	4,393	504
Var. No. 3.			
Early ears, middle	6,365	6,161	204

The seed was sown in drills eight inches apart and eight inches in the rows. They were sown with large-seed drills alternating with small-seed drills. The author draws no conclusions.

Two years later (5) he reports experiments with large kernels selected from a crop grown from large seed for three years and with small seed grown from small seed for several years. Five varieties of wheat were used. The average re-

sults for three years were a difference of from 1,067 to 1,828 kilograms of grain per hectare in favor of the large seed. But the difference was in general greater the first year than later. The use of large seed gave a crop with kernels larger than those grown from small seed.

Middleton (6) reporting experiments with wheat, oats, and beans, says the large seed yielded almost twice as much as small seed, in the case of wheat; the difference was less marked with oats and with beans there was scarcely any.

Bolley (7), of north Dakotah, after experiments lasting for four years in which plump kernels of large size and plump kernels of small size were selected for seed, concludes from the results that "perfect grains of large size and greatest weight produce better plants than perfect grains of small size and light weight, even when the grains come from the same head".

After presenting data of fourteen years' experiments with large, medium and small seeds of oats, barley, field peas, spring and winter wheat, mangels, sugar beets, swedes, fall turnips, field carrots, rape, and potatoes C. A. Zavitz(9) of the Ontario Agricultural College concludes that "it seems very evident that large seeds will give a greater yield than will an equal number of small seeds, in the case of at least twelve different classes of farm crops."

In a report of the same college (8) he (8) submits the following table:

sults [illegible] differences of from 1.061 to
1.82 [illegible] in favor of the large
seed. [illegible] was in general greater the first
year than after. [illegible] of large seed gave a crop [illegible]
kernels [illegible] grown from small seed.

[illegible] reporting experiments with wheat, oats,
and barley, [illegible] large seed yielded almost [illegible]
as small seed, in the case of wheat; the difference was less
marked with oats and field beans [illegible].

[illegible] (7), [illegible] after experiments lasting
for four years in which [illegible] of large size [illegible]
kernels [illegible] size were selected for seed, [illegible]
the results that [illegible] of large size [illegible]
weight [illegible] plants [illegible]
size [illegible], even when the grains came [illegible]
same [illegible].

[illegible] of fourteen years' experiments
[illegible], medium and small seeds of oats, barley, [illegible]
peas, spring and winter wheat, [illegible] roots, mangels,
fall turnips, [illegible], rape, [illegible]
of the Ontario Agricultural College [illegible] that [illegible]
been very evident that large seeds will [illegible] greater
yield than will an equal number of small seeds, [illegible]
at least twelve different classes of farm crops."

In a report of the same college (8) [illegible] the follow-
ing table:

Class	Years test	selection	bu. wt.	Average yield per A. tons straw	bus. grain
Spring wheat	8	L.plump	59.1	1.4	21.7
		S. "	58.3	1.3	18.0
		Shrunken	56.9	1.2	16.7
Winter wheat	6	L. plump	59.4	2.6	46.9
		S. "	59.2	2.2	40.4
		Shrunken	59.1	2.1	39.1
		Split	54.2	.6	9.3
Oats	7	L.plump	33.2	1.9	62.0
		Medium	32.2	1.8	54.1
		Small	31.8	1.8	46.6
Barley	6	L.plump	49.5	1.5	53.8
		S. "	48.8	1.5	50.4
		Shrunken	49.1	1.4	46.0
		Broken	48.6	1.3	43.2
Peas	6	Large	56.3	1.3	28.1
		Small	56.3	1.1	23.0
"	9	Sound	58.1	1.4	29.2
		Split	59.7	.6	10.2

P. P. Dehérain (10) reports a slightly better yield of wheat from large seed and he and Dupont (11) are cited as reporting yields from large and small kernels of a number of varieties of wheat to have been in all cases in favor of the large kernels, but a large difference in yield was obtained only when there was a marked difference in the weight of the kernels.

Soule and Vanatter (12) of the Tennessee Experiment Station conducted experiments for three years in which large and small wheat kernels were separated by means of sieves, after the first year each grade being selected from wheat grown from a similar grade. A check plot of unselected seed was planted.

"The average difference in yield at the end of three years between large grains (689 per ounce), and small grains

Class	No. of tests	Selection	Wt.	Average yield per A.	
				[illegible]	[illegible]
Spring wheat	3	Plump	89.1	1.4	81.7
		"	[illegible]	1.7	[illegible]
		Shrunken	66.[illegible]	1.[illegible]	11.7
Winter wheat	6	Plump	89.[illegible]	2.0	40.9
		"	[illegible]	2.[illegible]	[illegible]
		Shrunken	[illegible]	2.1	[illegible]
		Split	[illegible]	.6	[illegible]
Oats	7	Plump	[illegible]	1.[illegible]	[illegible]
		Medium	22.2	1.2	54.1
		Small	[illegible]	1.[illegible]	[illegible]
Barley	6	Plump	[illegible]	1.1	[illegible]
		"	[illegible]	1.5	50.[illegible]
		Shrunken	[illegible]	1.4	[illegible]
		Broken	[illegible]	1.3	[illegible]
Peas	6	Large	[illegible]	1.[illegible]	[illegible]
		Small	[illegible]	1.1	[illegible]
"	3	Round	[illegible]	1.4	[illegible]
		Split	[illegible]	.6	[illegible]

... Dehérain [illegible] reported a slightly better yield of wheat from large [illegible] and Lugeon (11) are cited as reporting yields from large and small kernels of a number of varieties of wheat to have been in all cases in favor of the large kernels, but a large difference in yield was obtained only when there was a marked difference in the weight of the kernels.

Soule and Vanatter (12) of the Tennessee Experiment Station conducted experiments for three years in which large and small wheat kernels were separated by means of sieves, after the first year each grade being selected from wheat grown from a similar grade. A check plot of unselected seed was planted.

"The average difference in yield at the end of three years between large grains (610 per ounce), and small grain.

(882 per ounce) with Mediterranean wheat, was 2.06 bushels in favor of large grains as compared with the commercial sample, and 5.18 bushels in favor of large grains over small grains. The difference in yield between the large grains and the commercial sample chiefly occurred the first year; but it is possible, though hardly probable, that the difference was partly due to variation in the soil. The experiment has been carried out in different parts of the field for the last two years, and the difference in the yield is now only 0.32 in favor of the large grains."

Cobb (13) gives a summary of the comparisons of the results of some very carefully conducted experiments to determine the relative advantages of large seed and small seed of wheat. He used sieves with rectangular openings of measured width which give a fairly accurate grading on the basis of diameter of kernel. Three grades are cited in the summary: very large, large, and medium which were respectively 3.25, 3.00 and 2.50 millimeters in diameter.

If the comparison is made on the basis of yield of grain and straw, the following is a general statement of the results:

The very large or 3.25 grade excelled in 66.7% of the trials.
" " " 3.00 " " " 89.7% " " "
" medium " 2.50 " " " 93.1% " " "

This statement fails to tell the whole story for the reason that the excess of yield in the majority cases is greater than in the minority cases. Thus--

Grade	When excelling did so by per cent	When excelled was only by --%
Very large or 3.25	14.7	8.5
Large or 3.00	30.4	12.3
Medium or 2.50	44.5	3.5

In these statements the basis of the percentage calculations is the weight of the lower of the two constants.

If instead of taking the sum of the weights of grain and straw as the criterion of yield, we take the weight of the grain alone, we arrive at the following:--

The very large	or 3.25 grade	excelled	in	58.3 %	of the	trials.
" large	" 3.00	"	"	93.1 "	" "	"
" medium	" 2.50	"	"	86.2 "	" "	"

As before, we find, however, that the victories of the large seed are more decisive than those of the small seed, and this must be taken into account in estimating the superiority of the larger grades. We find that:--

Grade	Excelling by	Excelled by
3.25	12.9 %	6.6 %
3.00	26.5 %	7.0 %
2.50	40.5 %	3.3 %

If instead of taking the sum of the weights of grain and straw as the criterion of yield we take the yield of the straw alone, we arrive at the following:--

The very large	or 3.25 grade	excelled	in	66.7 %	of the	trials.
" large	" 3.00	"	"	89.7 %	" "	"
" medium	" 2.50	"	"	93.1 %	" "	"

But again we find that the victories of the large grades are much more decisive than those of the small grades, and this must not be forgotten in estimating the superiority of the larger grades. Examination of the table proves that:--

Grade	% excelling by when excelling.	% excelled by when excelled.
3.25	19.2	10.8
3.00	29.6	19.4
2.50	40.7	4.5

The above trials include some twenty-nine varieties of wheat. Also, the comparisons have been made on the basis of equal numbers of seed and not between equal bulks or equal weights.

Grenfell (14) selected plump and shrivelled kernels from the same bulk of grain. They were sown with the plump [illegible] of the weights of grain [illegible] yield, we take the weight of the grain [illegible], we arrive at the following:--

The very large [illegible] grade excelled in [illegible] of the trials.
" large [illegible]
" medium [illegible]

[illegible], we find, however, that the victories of the [illegible] were more decisive than those of the small seed, [illegible] into account in estimating the superiority [illegible]. We find that:-

[illegible]	excelling by	excelled by
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

In [illegible] taking the weight of [illegible] grain [illegible] the criterion of yield [illegible] the yield of the [illegible], we arrive at the following:--

The very [illegible] grade excelled in [illegible] of the trials.
" large [illegible]
" medium [illegible]

[illegible] we find that the victories of the [illegible] were [illegible] than those of the small grades. [illegible] estimating the superiority of the [illegible] calculation of the table proves that:--

Grade	% excelling by when excelling.	% excelled by when excelled.
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible] trials include [illegible] twenty-nine varieties of wheat. [illegible], the comparisons have been made on the basis of equal numbers of seed and not between equal bulks or equal weights.

[illegible] (14) selected plump and shrivelled kernels from the same bulk of grain. They were sown with the plump and shrivelled kernels in alternate rows. The germination appeared much the same but the plants in the rows sowed from plump grain soon began to gain on the others and kept ahead for the remainder of the season. The tillering was better in the plump grain. The average of the plants that grew was 92.7 % for the plump and 88.5% for the shrivelled: the plump produced and average of 180 heads from each row which originally was planted with 150 seeds, giving a tillering power of 1.32. The tillering power of the shrivelled seed was 1.23 and the yield per acre in bushels was 9.8 for the plump and 7.5 for the shrivelled.

Von Liebenberg (15) working with red clover found that the smaller the seed the less favorable the result.

P. de Caluwe (16) working with oats to ascertain the effect of different sizes of seed reports that very large, large, ordinary, small and very small grains of oats were sown; all at the rate of 111 pounds per acre. The yields of grain were slightly in favor of the small and ordinary seed. The result was attributed to the greater number of grains sown per plat with the smaller classes of seed. The author considers it advisable to employ a greater weight of large than of small seed.

In a test of whole and cut tubers of potatoes the same author (17) says that the largest yield, after deduction of the seed potatoes planted, was afforded by the large whole tubers, and the next largest yield by the medium sized whole potatoes.

The yield of large and small seed of wheat is reported by Desprez (18) as being the greatest from large seed except in two cases where there was a larger yield of straw for the

small seed.

By growing selected lots of large and small radish seed, Mr. B. T. Galloway(19) found that the large seeds germinated more quickly and with more certainty and produced marketable crops sooner and more uniformly than the small seeds. The latter, however, gave proportionally larger plants. He submits the suggestion that the radish has been cultivated for the root and selection has been made continually with the development of the root in view without attention to the seed and says that if more nutrition is utilized in root development with plants of equal vigor, less would probably remain for seed development, resulting naturally in small seed.

The reasoning in this case, however, does not appeal to the writer of this thesis as it would seem that the very fact of a large uvuolus being present would result in better seed if the conception of its function as a storage organ for the production of seed is correct. Rather the answer must be looked for in some natural tendency if it should always prove to be the case that large seed gives small root development. It is not at all uncommon to find that some undesirable quality is emphasized just as rapidly as the desired one when selection is practiced in animal breeding, and selection for root alone might result in small seed merely according to the chances in selection.

In experiments with wheat, barley, oats and sugar beets Lubanski (20) reports that the results show the influence on yield and to some extent on quality of crop was in favor of large seed.

According to the Ontario Agricultural College experiments (21) with wheat, oats and barley during a five to eight

year period show that the average yield of grain and straw and the weights per measured bushel were in favor of large plump seed as against either medium size or small seed.

With oats the Aberdeen and North of Scotland Agricultural College (22) found that when equal bulks of small and large seed were planted the "results were slightly in favor of the small seed". The two lots of seed were selected from the same field.

The West of Scotland Agricultural College (23) reports a series of experiments with oats in which the oats were divided into (a) singles, or kernels that bear rudiments that might have developed into bosom oats, (b) and firsts, or oats in which the rudiments did so develop. The small seeds are made up of seconds or bosom oats broken from the firsts. The firsts produced heavier yields of straw and grain than either the seconds or the singles. The seconds produced more straw and less grain per acre than the singles. The differences reported range from twenty-three to thirty-six per cent in terms of the weights yeilded by the singles.

The Vermont Station (24) reports the influence of size of seed in golden wax beans as follows:--

Season 1910 (green weights)

Size seed	No. used	Wt. Seed grams	No. plants	Wt. green pods	Av. wt. pods per plant grams.
Large	500	312	426	5,894	13.8
Medium	500	252	429	4,762	11.1
Small	500	169	370	3,629	9.8

Air dry weights

Size seed	Dry wt. pods.	Total No. pods	No. empty pods	No pods w. 1 or more beans	No. of beans	Wt. beans grams
Large	1,899	2,545	1,580	965	2,503	964
Medium	1,389	2.032	1,390	642	1,578	624
Small	709	1,211	694	517	1,445	567

The same station shows the following results with sweet pumpkins:--

Size seed	No. vines	No. fruits	total wt. lbs	No. ripe fruits	pounds ripe fruit	No. fruits unripe	Wt. unripe fruit
Large	76	213	1,084	133	696	80	388
Small	76	256	1,247	68	386	188	361

This shows that the plants from large seed (76 vines) yielded sixty-five more ripe fruits and three hundred and ten more pounds of edible product.

From the same station we have an interesting tabulation of results with sweet peas.

Size seed	No. sown	Wt. seed grams	Total No. plants	Total No. blossoms	Average No. blossoms per plant.
			Duke of Westminster		
Large	50	4.98	45	11,831	263
Medium	50	3.70	40	10,069	252
Small	50	2.74	40	8,240	206
			Earliest of All		
Large	50	6.25	40	3,496	87
Medium	50	4.11	33	2,932	89
Small	50	2.51	16	567	35
			Her Majesty		
Large	50	4.50	34	12,244	360
Medium	50	3.19	35	10,585	321
Small	50	2.45	18	3,702	206
			Coccinia		
Large	50	5.13	40	16,226	407
Medium	50	3.07	40	13,578	339
Small	50	4.22	46	14,673	319
			Agnes Eckford		
Large	30	3.13	25	1,701	68
Medium	30	2.51	24	2,199	89
Small	30	1.87	25	2,145	82
			Apple Blossom		
Large	50	5.40	39	11,678	315
Medium	50	3.78	29	10,443	266
Small	50	2.65	38	9,592	273

They conclude that large seed is heavier, germinates better, seems more likely to produce strong plants, and more important, yields a larger number of blossoms. Also

their results with Hubbard squash indicate that while the seeds do not vary as widely as those of some other plants, large seed gave more pounds and more numbers of edible squash.

Lettuce responded very uniformly, the larger seed giving heavier heads and more salable ones.

Effect of Large Seed on Germination.

Kerpelley (25) found that the growth of plants from large and fully developed wheat kernels was more uniform and vigorous and produced the largest number of seeds capable of germinating.

A.J.J. Vandevelde (26) reports on the germination of 1800 each of large, average and small seeds of peas, oats, rye, wheat and barley. He states that the time required for germination is longer for the large seed but only slightly so. Total germinations were greater with small in every case except barley.

Cobb (27) Gives as an average of experiments with twenty eight varieties of wheat these figures. Out of two hundred seeds each, large seed showed 12.5 failures, medium seed 18.6 and small seed 34.1 failures. This gives almost three times as many failures in small as in large.

Eisenmenger (28) found in experiments with spruce and Scotch and Austrian pine that large seeds germinated quicker and reached the period of maximum germination earlier than small seeds.

In certain experiments by R. Slegrell (29) the author points out the fact that with one exception the period required for germination increased with the specific gravity.

A comparison of germination by the heavier and lighter kernels in the same head is given by the Kansas State Agri-

cultural College: (30)

Grade	No. kernels tested	No. kernels germinated	per cent germination
Heavier than the average	4,707	4,684	98.74
Lighter	2,972	2,877	96.80
Total	7.679	7,561	97.99

Separation into five sizes by sieves showed;--There is a slight but not constant difference between the germination of kernels separated by sieves. (2) The largest kernels do not always germinate the best. (3) The smallest kernels usually but not always germinate the poorest.

Separation according to density by means of a wind blast gave the following results:

Grade	Average % germination
1	99.19
2	98.00
3	95.16
4	87.63
5	71.70
6	53.95

The Effect of the Specific Gravity

Upon the Yield.

Pammel and Stewart at the Iowa Experiment Station (31) report that of thirty-seven samples examined the average specific gravity of the seed of wheat was 1.469, the amount varying between 1.503 and 1.407. Their method was to first weigh the seed in air and again while immersed in Kerosene oil. That this does not represent the range of the specific gravities of the wheat kernel is readily seen from the succeeding reference.

"Seed wheat of four varieties was separated by Church (32) by means of solutions of calcium chloride having specific gravities of 1.247, 1.293, and 1.31. The seed was first

treated with a solution of mercuric chloride to remove the adherent air. Each lot of seed was planted separately. From the results the following conclusions are drawn:--

1. The seed wheat of the greatest density produced the densest seed.

2. The seed wheat of the greatest density yielded the largest amount of dressed grain.

3. The seed of medium density generally gave the largest number of ears, but the ears were poorer than those from the densest seed.

4. Seed of medium density generally produced the largest number of fruiting plants.

5. The seed wheat that sank in water, but floated in a solution having the density 1.247, was of very low value, yielding on an average only 34.4 pounds of dressed grain for every 100 yielded by the densest seed."

Working with soy beans Hicks and Dabney (33) found that the plants and roots were heavier from heavy seed and the same was true with Alaska peas with the additional advantage of earliness. Earliness also developed with radish and Kafir corn from heavy seed. Also, with barley, oats, and rye the weights of the seedlings were closely proportional to the weights of the seed.

Von Liebenberg (34) says that the results of the experiments with Hanna barley grown in five different places "corroberate those of other experiments and it can be safely stated that with a heavy weight per bushel go a greater weight per kernel, a smaller percent of husk, and a richer content of extract, and finally a greater yield."

The North Dakotah Station, (35) from a four years'

[illegible] air. [illegible]
[illegible] --

1. [illegible] seed [illegible] of the greatest density produced the [illegible]

2. [illegible] the greatest density yielded the [illegible] of [illegible] grain.

3. [illegible] number [illegible], but the same [illegible] of the [illegible] densest seed.

4. Seed of medium density [illegible] produced the largest number of fruiting heads.

5. [illegible] that sank in [illegible], but floated [illegible] solution having the density 1.0 [illegible] of very low density [illegible] only [illegible] of [illegible] the densest seed."

[illegible] and Stanley [illegible] plants, sand [illegible] with the additional advantage [illegible] weights of the [illegible] were [illegible] weights of the seed.

[illegible] (24) says that the results [illegible] barley grown in [illegible] other experiments, and it can be [illegible] that with a heavy weight per bushel, a greater [illegible] per kernel, a smaller percent of husk, and a [illegible] content of extract, and finally a greater yield.

The [illegible] Station, (25) from a four years' test, concludes that perfect grains of large size and high weight produce better plants than those of smaller size and weight even though the grains come from the same spike.

The Purdue University Experiment Station submits a summary of results taken from a number of stations thus: (36)

Stations	Yields in bu. per acre		
	heavy seed :	light seed :	Diff. favor heavy
Minnesota	29.4	24.8	4.6
Nebraska	27.9	22.8	5.1
Kansas	27.1	25.2	1.9
Ontario	38.6	33.7	4.9
Averages	30.7	26.6	4.1
	Large seed :	Small seed :	Diff. fav. Lge
Indiana	30.5	27.9	2.6
Ohio	16.3	16.3	---
Ontario	46.9	40.4	6.5
Tennessee	28.6	23.4	5.2
Averages	30.6	27.0	3.6

The figures from experiments by Burnett at the Iowa (37) Station tend to show that with oats the heavy seed and the light seed were about equal pound for pound but not seed for seed, nor measure for measure. All plots were sown at the rate of three bushels per acre.

The Minnesota Station (38) state that a plump heavy kernel of grain will produce a stronger plant and nourish it better than will a shrunken, light kernel. They quote from the Nebraska station the following table:

Kind of seed	Yield per acre in bushels		
	1900	1901	2 yr. av.
Heavy	29.5	29.3	29.4
Light	23.0	26.7	24.8
Gain in favor of heavy seed			4.6

A similar experiment in their own station gave an increase of 9½ bushels per acre in favor of the heavy seed and heavy wheat gave a yield of 36 per cent greater than that of light wheat.

Lyon (39) cites Wollny as objecting to experiments by a number of experimenters with various cereals in which almost without exception kernels of high specific gravity produced the best yields, because no distinction was made between absolute weight and specific gravity in the kernels. He claims that the value of the seeds lies in the kernels of absolute heavy weight rather than in kernels of high specific gravity, concluding that the specific gravity of the seed exerts no influence on the yield. Lyon goes on to say that in the light of the experiments that have been conducted it would seem that there is a difference between seed of low specific gravity and high specific gravity in favor of the dense seed, but there is little difference between seed of high and medium specific gravity.

Relation of Size and Weight of Kernel to Composition.

It is not the purpose of this thesis to enter far into this phase of the large seed factor. Therefore only brief reference will be made.

Lyon (40) concludes that in general it may be said that as between wheat kernels of the same variety grown in the same season and upon the same soil, the specific gravity is inversely proportional to the nitrogen content. This conclusion is given after citing several experimenters who present varying results. He suggests that as the ash, which varies so considerably with the soil on which the wheat is grown, has such a high specific gravity compared to that of the other constituents this would prevent the establishment of a constant relation. He further suggests that the number and size of vacuoles would affect the specific gravity.

Comparing oats Hienrich (41) considered that he had found very little difference in feeding value between oats of heavy and light weight. In general the lighter grains had more fibre and less carbohydrates.

Johannsen (42) found great variation in the nitrogen content of fully developed ripe barley grains from different heads of the same variety of barley grown under like conditions. No definite law relative to this variation was found but in general the nitrogen content increased with the weight of the kernels. By careful selection, for four years, a strain of barley was found which yielded heavy grains low in nitrogem. A later and fuller table may be found in the Experiment Station Record, Vol XII page 236.

Snyder (43) submits results to show that light-weight kernels contain a somewhat larger percent of nitrogen, phosphoric acid and potash than the heavy seed but the total amount of these is much less.

Sperling (44) was unable to correlate weight in barley seed with protein content.

Shaw (45) working with California white wheats, concludes that the normal kernels usually carry a larger per cent of nitrogen than smaller kernels of the same type.

It is important to have a good start because three fourths of the total mineral matter is taken from the soil in the first fifty days (46) .

The Minnesota Station presents a table of the composition of the ash of heavy and light weight wheat kernels. Under the head of total ash in the wheat is given the number of pounds of ash in every hundred pounds of wheat. The figures given for the potash, lime, etc. are the per cents of those

substances found by the analysis of each ash. This wheat was all grown from one lot of seed in different parts of Minnesota. (47)

Note that the heavy seed has more potash and phosphoric acid.

Composition of the Ash of Heavy and Light Weight Wheat.

No.	Bu. wt	Total ash	Potash.	Soda	Lime	Magnesia	Iron	Phosphates	Silica	Sulphates	Chlorides	Carbon dioxide
1	65	2.00	30.44	.50	3.12	12.10	.41	50.83	.76	.11	.13	1.30
2	65	1.91	32.46	.67	2.55	12.39	.27	50.76	.37	.06	.11	----
3	64	2.02	31.85	.86	3.16	12.54	.38	50.95	.09	---	.04	.11
4	63	2.07	30.45	.06	3.00	12.10	.34	50.95	.24	.10	.10	1.64
5	63	1.94	31.29	.09	3.89	12.54	.29	50.60	.26	.07	.10	----
6	62	2.04	31.16	.62	3.16	12.62	.34	48.86	.35	.06	.11	1.96
7	61	1.92	30.02	.74	3.06	13.17	.62	48.04	.39	.09	.09	2.12
8	60	2.10	30.16	.26	3.02	12.86	.44	48.10	.27	.71	.07	2.86
9	59	2.08	29.01	.89	3.91	13.48	1.16	45.18	1.12	.16	.14	2.99
10	58	2.16	28.86	1.45	3.86	14.90	1.33	44.17	1.35	.10	.13	----
11	57	2.05	28.41	.79	4.81	15.30	.81	43.52	1.67	.11	.47	3.04
12	55	2.09	28.77	.88	4.52	14.48	.86	43.07	1.92	.12	.42	3.02

In Minnesota Snyder (48) has divided small kernels of wheat into two classes; those small because shrunken, and those well filled though small. As between small, shrunken kernels and those large and well filled he finds that the former contain the higher per cent of nitrogen. But between small well filled and large well filled kernels the latter contain the higher per cent of nitrogen.

A balancing of the foregoing results and opinions seems to leave little room for the contention that there is no advantage in large seed. Conceding this, we come to the question as to the reason for the superiority of large heavy seed.

Endeavoring to answer this several writers make certain statements as if the reasons given were established but none submit experimental proof. The reason given is that it is on account of the larger supply of nutrients for the young plant.

This is advanced by Shaw when he says (49) that the main reason for the difference is physiological, and lies in the greater reserve supply in the larger seed. It has been shown, he goes on to say, that heavier seeds possess more of the important plant foods (phosphoric acid, nitrogen and potash (50)). Continuing, he says that there is abundant material immediately available to the plantlet and the young plant is soon in a position to take a vigorous hold upon the soil.

Blanchard, (51) gives the same reason and goes on to say that this is a fact well understood by all who are endeavoring to improve their crops by careful and practical selection of seed.

In connection with the subject of effect of inheritance in the case of wheat a cut, herewith reproduced, in Seed Wheat by Cobb (52) shows the variation in the size of kernels in the same spike.

Lyon (53) quotes Rünker who gave the weights of individual grains of a spike which was presented as being an average head; the figures show kernels varying from 36 to 71 milligrams. This cut from Cobb's work bears out the observation of others that the heaviest grains in a spike are found in the lower middle part.

A suggestion comes from the

Seed Wheat. 5

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Fig. 11.—An ear of Defiance wheat, with the grains arranged as extracted from one side of the ear.

Kentucky Experiment Station (54) that this may be accounted for by the fact that the florets at the center of the spike are pollinated first.

Since it is so that there is such a variation in weight between kernels of the same spike there are a number of men who consider that it is not to be expected that all large seed should suppass smaller seed because the small seed may possess the same inheritance as the large. It would seem, then, that on account of this fact the smaller seed in a selection for size and weight would contain a larger proportion of the immature and poorly developed seed the first time than it would the second after the weaker plants resulting from such poor seed would have been eliminated. The second and succeeding seasons selections was practiced from wheat grown from seed so selected the small size would contain a larger proportion of seeds which are naturally small and this is pointed out by Lyon (55) with the observation that several of the experiments cited exactly fulfil these conditions.

Mechanical Aids to Selection of Seed.

It is obvious that some of the finer methods of determining the weights of seed are utterly impractical for use on the farm. Thus far there seems to be but one method of selecting for weight which is at all practical for the average man and at the same time is generally understodd. This is the air blast applied in some form.

There are various devices making use of centrifugal force or of the ability of seed to bounce from taught wires but at the present time the most help would seem to lie

in some type of fanning mill.

It is the opinion of the writer of this thesis that no separation of seed wheat or barley is adequate that does not select for size as well as weight.

Herewith are presented a few references to literature on the subject. It will be noticed here also that there is a certain amount of difference of opinion as to the value of such selection but it may be possible that other factors have affected the results of some of the dissenters or that their machines have not been mechanically what they should have been.

Montgomery (56) found that the use of a fanning mill for separating heavy and light seed wheat did not result in improvement in either the yield or the quality of the grain. He concludes that, as every wheat plant contains both heavy and light seed, the fanning mill will give about the same kind of wheat, so far as inheritance is concerned, in the light as in the heavy.

The Ohio Station (57) pronounce against the fanning mill but their test cannot be very well guarded as they refer to hand-sorted tests which are giving results in favor of large seed.

Experiments in Missouri indicate that, while the difference is not great, the large seed gives the best yields. The fact is also pointed out that more seed by weight should be used when large seed is planted. In these tests the seed was put first through a fanning mill and then through a grader, separations being made into three grades. (59)

Burlison (60) found in a test of fanned and unfanned seed wheat of three varieties that the fanned showed an advantage over the unfanned of 1.43 bushels per acre in yield.

Kansas Bulletin 33 gives the resuls of two years' trials with fanned and unfanned seed as follows:-- (61)

	Yield per acre Bu. grain	Tons straw
Heavy seed	31.90	1.92
Light seed	30.03	1.62
Common seed	31.13	1.73

The seed was graded with a clipper fanning mill. The "common" was wheat as it came from the thresher but cleaned of trash. It weighed 62¼ pounds per bushel. The heavy seed weighed 64½ pounds, and the light weighed 60 7/8 pounds per bushel.

The statement of Montgomery above should be taken in the light of the statement of page 22 of the same bulletin that the first two years the lightest seed produced least, the ordinary was next, and heavy seed yielded the best. Since then the results have varied from year to year and the average for the eight years does not show a marked advantage for either.

Fanning Mills.

Since a bushel of wheat contains somewhere in the neighborhood of a million kernels, it is obvious that hand selection of seed wheat is impractical except for careful experimental purposes.

For commercial production of small grains it is necessary to have some means of selection which is of rather high efficiency and, according to the results noted in the preceding pages, there should be good returns from its use. The type of machine commonly employed for such a purpose is generally called a fanning mill.

The functions of a fanning mill (62) are; (1) to clean the grain; (2) to grade the grain; and (3) to separate different kinds of grain.

The modern mill uses several physical differences for the separation of grain; among them being difference in weight, difference in size, and difference in shape. Also the roughness of the hull, and to some extent the location of the heavy part of the seed, may be used. But in this connection we are concerned chiefly with the difference in size and density.

Selection for different sizes may be made by the use of sieves or riddles with different sizes of openings. Since denser seed offers less surface to the air, an air current may be utilized to select seed for weight.

The first of the machines used for cleaning and grading grain made use of the air blast only and hence the term fanning mill has come to be applied to all machines of this type; although the best of them combine the principles of sieves and air blast.

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There are two general types of fanning mills. In the first the air is directed upon the grain as it passes over the sieves; and in the second the air blast is independent of the sieves and riddles.

The first of these is the older type. It has a rather larger capacity for the amount of sieve surface provided and when properly handled will do good work. A diagram of a mill of this sort is shown in figure 2. The latter type, however, has the greater refinement and is capable of more careful selections. Diagrams of machines of this type are presented in Figs. 3 and 4.

From a Minnesota Bulletin we get a diagram that is quite helpful to the understanding of some of the arrangements of a mill of this sort. See Fig. 5. (63)

Figure 6. (64) shows an arrangement where selection is being made on the basis of density alone. This would also blow out a great deal of the trash and dust.

Other machines are designed to make selection merely on the basis of size. Herewith are presented three cuts to illustrate one means of sorting for size which should be capable of considerable refinement. In any mill of this kind the efficiency of selection decreases with the increase in amount of grain put through per hour. These are taken from Cobb's work (65) and are presented to show first (Fig. 7) the simple principle on which they work and are kept clean. Here note the brush for keeping the meshes cleared of grains which are just large enough to wedge slightly without going through. It seems to the writer that considerable efficiency must be lost by some of the commercial machines in this manner.

Fig. 8 shows a more elaborate mill which makes selection of several sizes and blows out dust and chaff.

The apparatus shown in Fig. 9. is interesting on account of the adjustability of the meshes but the danger of bending the wires out of shape would seem to lessen its probable durability.

A criticism applying to the three last machines is that they make use only of size in selecting seed and do not select on the basis of weight as well. If Wollny (39) is right in saying that the advantage of large seed lies in absolute weight rather than in density, the very way to secure this absolute high weight is by combining selection for size with selection for density.

PART II.

E X P E R I M E N T A L

If there be much truth in the assumption that the advantage of large seed over small is due to the extra start given to the very young plantlet by the additional endosperm, it would seem that removing the extra endosperm should counteract to some extent if not nullify this effect.

Acting upon this assumption, experiments were undertaken to determine the effect of so removing the balance of the endosperm at the time when the plant becomes able to support itself. The plan was to allow the seed to germinate and, as soon as the young plant became able to draw its nourishment from the soil and air, remove the balance of the endosperm.

Three sets of plantings were made, the second of which was lost on account of the fact that wet weather kept the seeds submerged until they failed to germinate at all. The plantings will be described more at length later.

The seed for these plantings was prepared with considerable care. Separations were made first by size. In order to do this the seed was put through a series of three sieves which are shown in Fig. 1. Sieve No.1 will pass a grain of $3\frac{1}{4}$ millimeters in diameter, No. 2 will pass grains of $2\frac{1}{2}$ millimeters and No. 3 passes all $2\frac{1}{4}$ millimeters or less.

In this manner seed was separated into two classes, all not falling in these two, being rejected from the experiment. The first class, which will hereafter be designated as large, consists of kernels that are retained by the $3\frac{1}{4}$ millimeter sieve. The seed retained by the $2\frac{1}{2}$ millimeter sieve was rejected and the kernels passed by it but retained by the $2\frac{1}{4}$

sieve were used for the second class, which will be referred to hereafter as small seed.

These two classes of seed were each separated further into heavy and light kernels by means of solutions of sodium nitrate. Seed that sank in a solution of specific gravity 1.35 but floated in a solution of 1.40 was used for the heavy, and those kernels which floated in a solution of specific gravity 1.26 but sank in one of 1.20 were classed as the light. In this manner there were four grades of seed obtained: large heavy, large light, small heavy, and small light.

The first plantings were made in the Agronomy green house at Berkeley and ordinary nursery flats were used. Soil was prepared by taking surface soil, a clay adobe, from the field south of Agriculture Hall and mixing it with about equal parts of sand. The seed was planted at a depth of about two inches in three of the six flats used and at a depth of one inch in the others. Each was planted with all of the classes of seed arranged according to the following diagram in order to secure results as nearly comparable as possible.

```
aabcdad        a-= large heavy
babcdbc        b = large light
cabcdcb        c = small heavy
dabcdda        d = small light
aabcdad
babcdbc
cabcdcb
dabcdda
```

The endosperms were removed two weeks later but by that time it was found that practically all of it had been used up by the plants so there could be no results expected.

But the effect of large and small and heavy and light seed as such was noted in the following data taken from the experiment:

sieve [illegible] second class, which [illegible]

to [illegible]

These two classes of seed were each [illegible] by further very heavy and light separated by means of [illegible]

Such [illegible] condition [illegible]

in a condition [illegible]

which [illegible]

[illegible]

were [illegible]

small [illegible]

[illegible]

at [illegible]

period [illegible]

of [illegible]

seed. [illegible]

these [illegible]

other [illegible]

[illegible]

[illegible]

[illegible] time [illegible] found that [illegible]

by [illegible]

The [illegible] of large and small seed [illegible]

seed, as such was [illegible] in the following data taken from the experiment:

	Large Heavy	Large light	Small heavy	Small light
Per cent germination	77	62.5	64.5	33 1/3
Average height	24.9 cm.	22.4 cm.	16.2 cm.	13.0 cm.

The second set of plantings, which was made on the thirtieth and thirty-first of December of the same year, was the most comprehensive undertaken. Fifty seeds each of the four classes were planted at distances of four inches in each direction. They were planted ten seeds in a row and five rows of each. Around the whole were two rows planted in like manner and at the same intervals to serve for guard rows. None of this seed sprouted. The seed of this lot were placed in pockets of sand in a manner similar to that described for the following set.

The third set of plantings was made February twentieth and twenty-first at the University Farm, Davis, Cal. having had to wait on late rains until the soil was in proper condition. Owing to the slow method of placing the seed, which is described later, all could not be planted the first day and rain the next compelled a delay of about a week before the last could be planted. Fortunately this amounted to only the guard ro on either end of the experiment, or rows 0 and 14. The seed was planted according to the following plan. Twelve seed were planted in a row at intervals of four inches and the rows were planted four inches apart. The rows constituted by the first and last plants of all the rows are considered guard rows, leaving ten plants in each row to be considered in the experiment.

The class of seed used in each row is shown by the following;

Class of seed	rows planted
Small light	1,2,3,
" heavy	4,5,6,
Large light	7,8,9,10,
" heavy	11,12,13.

To facilitate the later work each seed was planted in a small body of loamy sand collected from the bed of the creek where it had been washed down by recent rains. A dibble was used to make a small hole about two inches deep and one and one half inches across the top. A moderate amount of sand was introduced and the hole opened again with the dibble to a depth of about one and one quarter inches. Each seed was placed in its hole by means of a pair of forceps so that it lay with the suture down, embryo uppermost and pointing in the same direction as all the others, the long diameter of the seed being about horizontal. This placed all the seed in the same relative position so it was possible later to find the endosperm with a minimum disturbance of the soil about the plant. The effectivness of this precaution was apparent, for in the large majority of cases the surface of the soil where the plant emerged was not broken while removing the endosperm.

The unabsorbed portion of the endosperms in rows 1,3,4, 6,7,9,11,& 13 was removed early in the afternoon of the first of March. In the case of the small light seed, the endosperm was nearly all liquified in some cases but it was not all used up in any. Noticeably more was left in the small heavy. Between the light and heavy large seed there was less apparent difference in the amount of endosperm remaining but between the small and large size the difference was very marked. While it was nearly used up in the small seed, apparently half of the endosperm in many cases and in some about two thirds remained in the large.

Owing to force of circumstances the endosperms were not removed for a little more than twenty-four hours after it was planned to do so, but at the time they were removed the plants were but two and one half inches in height.

It was about two weeks before any difference could be noted in the appearance of the rows thus treated and those not treated. Then for a time there seemed to be a checking of the growth in the rows treated but this difference has disappeared or is so slight that at the present time it is not possible to tell which rows have been deprived of part of their endosperm and which rows have not. See Figs. 10 and 11.

On the twenty-second of March the heights of the plants measured by the longest leaf were as follows:

Heights of plants in millimeters.

Plants : rows:	1:	2:	3:	4:	5:	6:	7:	8:	9:	10:	11:	12:	13:
1	152		162	170		178	218		184	216		246	248
2	142	191	148	199	222	171		197	236		218	226	158
3	175	169	161	141	208	182	163	208	218	215		240	170
4	70	150	128	176	193	199	154	222		215	232	222	188
5		176	200	90	186	199	204	223	201	219	216	211	236
6	110	174	136	128	196	152	232	198	188	230	236	160	221
7	150	226	153	226	119	199	210	228	187	276	220	248	213
8	140			201	173	209	228	220	236	239	226	221	210
9	175	200	196		200	193	233	210	244	211	176	226	238
10	130	197	196	210	118	201	161	220	233		234	217	245
Averages	138	185	164	171	179	188	200	214	214	228	220	222	213

While the longest leaf may not be a very reliable criterion of the development of the plant, the averages represent fairly well the superficial appearance of the experiments at the time. It took a careful scrutiny to make sure which rows had had the endosperm removed and which had not, if no reference was made to the record. But on the other hand there was no difficulty in deciding which rows were planted with large seed and which from small.

Fig. 10 shows the appearance of the plat on the fourteenth of April, and on the twenty-seventh a plant was taken from each row, which was as nearly as possible a representative plant for the row. Herewith, Fig. 11, is shown the comparison of the development of the plants. There seems to be no definite corre-

lation between the removal of the endosperm and the comparative development at this time.

The numbers run from right to left in order that they may correspond with the location of the rows in Fig. 10. It was necessary to take the picture of the plat from this side on account of more advantageous light conditions.

C O N C L U S I O N S.

Though perhaps it is futile to attempt conclusions at this stage of the experiments, or in the light of the various difficulties in the way of making a completely satisfactory trial, it seems to the writer that there is considerable doubt cast upon the theory of the extra food supply. If this factor were at all the most important one it would seem that the removal of one half or two-thirds of the material would certainly cause a profound difference in the development at least of plants from the same class of seed. Moreover, the difference between the effect on the small seed and on the large should be less upon the small seed proportionally since less endosperm in proportion was removed from it than from the large. The facts as developed from an examination of the figures in regard to the heights show that the reverse is the case and that the effect on the small amounted to 9,2% while the effect on the large was but 4.2%.

It is certain that all the factors concerned in what we are pleased to refer to as vitality and vigor, etc., are really but little understood. Therefore since there is something which we refer to as vigor, or response to environment, or indicate by various other terms, is it not possible that it

may be present in varying degrees in the germ itself?

Grant, for the sake of argument, that it is an inherent quality of the soluble proteins in the embryo. We must consider the embryo not as a gamete or as a pair of them but as a zygote. The combination of the hereditary equipment has already been made and determined. Even though the pollination is by the same plant there is a chance for a certain amount of variability on account of the maturation process. Then is it not entirely possible that a certain degree of the capability of the plant is already determined in this "plant packed and ready for shipment". There may be some correlation between the extent of the development of the seed and the capability of making a large plant under proper circumstances after planting. A young animal loses its power of response to proper food quite early in life, as is common knowledge to stock men. It is entirely concievable to the author that some measure of loss of power to develop may be due to the same conditions, whatever they are, that cause the development of a smaller endosperm.

It becomes necessary to discover some other factor than hereditary equipment on account of the variation of the weight of kernels in the same spike, if their equipment be considered the same, and this certainly is not shown to be extra food supply by the experiments here recorded.

R E F E R E N C E S.

1. Seed Wheat by N.A.Cobb. N.S.Wales. Misc. pub. No. 625 p.2.
2. B.P.I. Bul. #78 p. 30 from Utah Ex. Stn. Rpt 1893, p. 168.
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60. Bul. 128, So. Dak. Expt. Stn.
61. Bul 33, Kan. Expt. Stn. p. 14.
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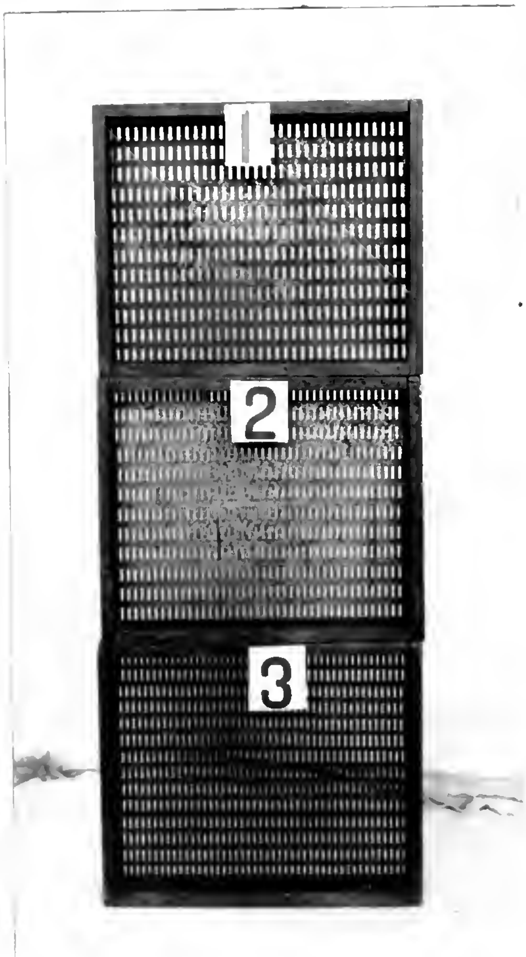

Fig. 1.
Original.

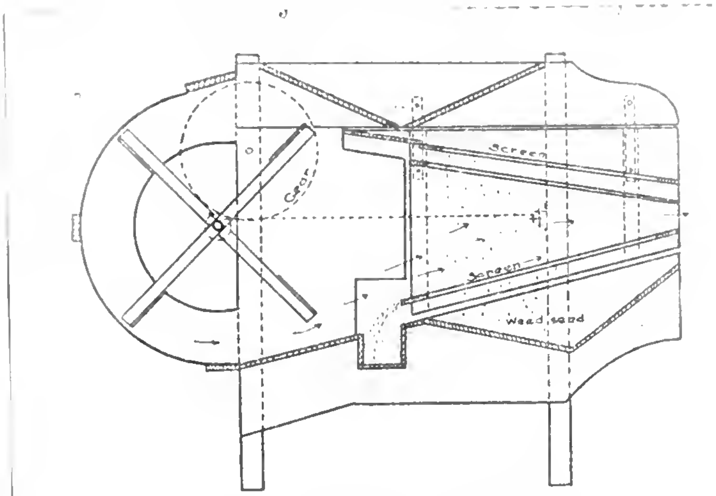

Fig. 180. A section of a fanning mill in which the blast is directed below and through the sieves.

Fig 2.

From Agricultural Engineering, Davidson.

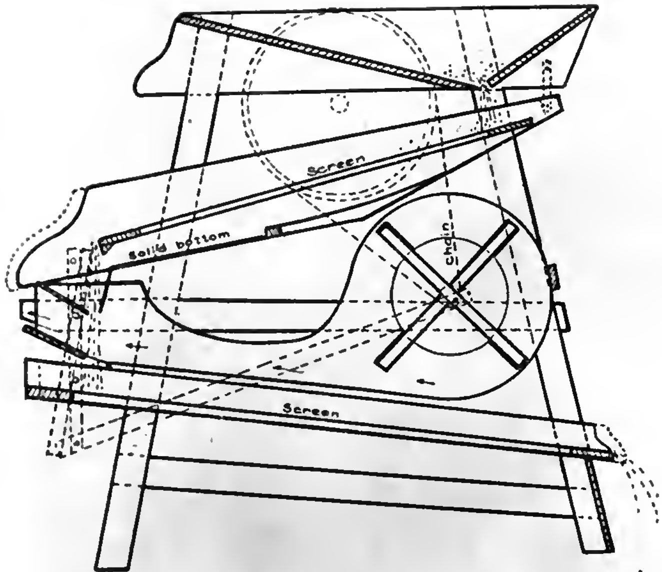

Fig. 178. A section of a fanning mill in which the blast does not strike the grain until after it has passed through the sieves.

Fig. 3.

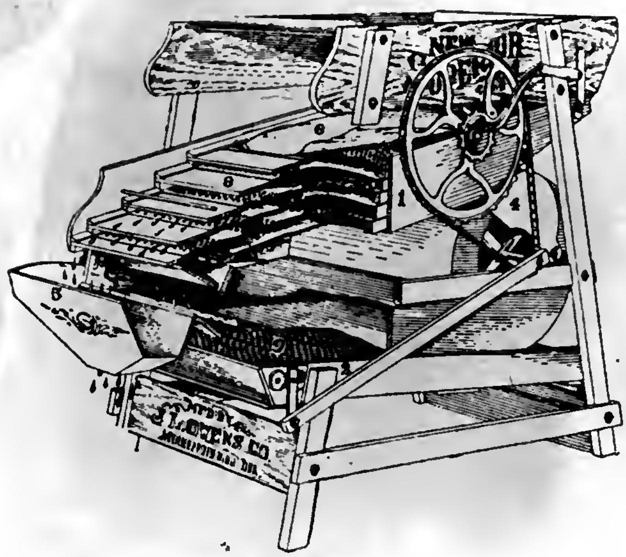

Fig. 179. Another view of the type of machine shown in Fig. 178.

Fig. 4. Both above from Agricultural Engineering, Davidson.

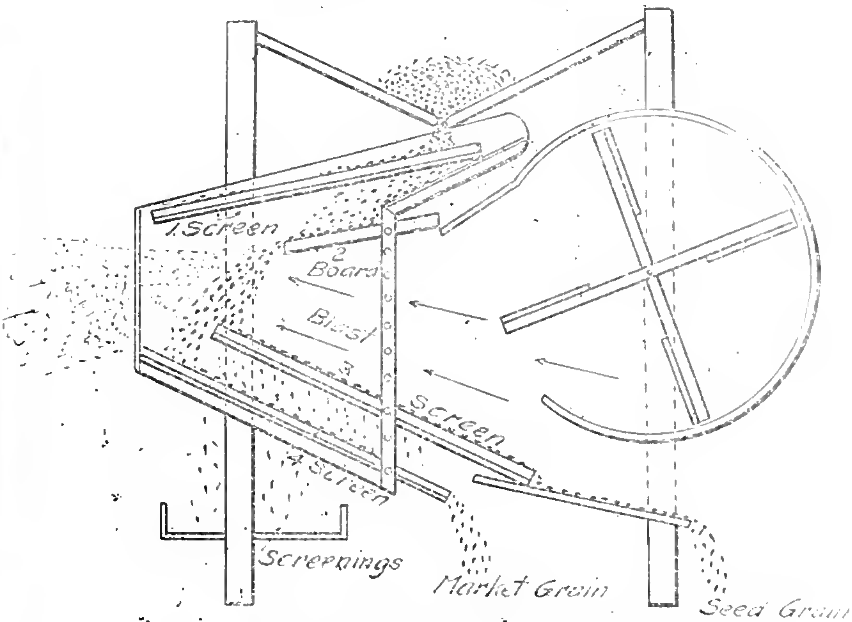

Fig. 2. "Side-Shake" Mill for Separating Seed Grain

Screen No. 1 should be just coarse enough to let the grain through. It is used simply to run off sticks and straw. Board No. 2 carries the grain backward in the mill, so as to let it drop through the blast at once. The light kernels are blown past the end of screen No. 3, the heavier kernels fall on screen No. 3. Board No. 2 may be moved forward or backward to throw a large or small per cent of grain on screen No. 3, as desired. Screen No. 3 should be coarse enough to let the small kernels through onto screen No. 4.

It is adjustable as to slant and may be moved forward or backward to regulate the amount of grain it will catch. Screen No. 4 is fine enough to carry nearly all of the grain over into market grain. Any side shake mill may be fixed up in this way. Separation by weight can easily be made with the end shake mills, but the large kernels can be separated from the small ones in any proportion desired, simply by using coarse or fine screens in the lower part of mill.

Fig. 5. (63)

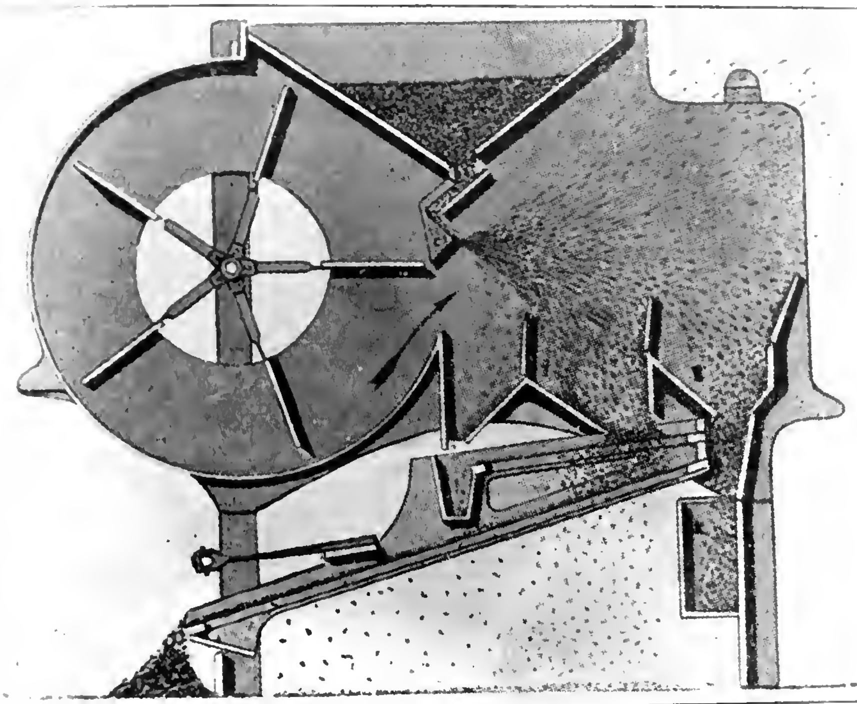

Fig. 3. Sorting Grain According to Weight.

Fig. 6. (64)

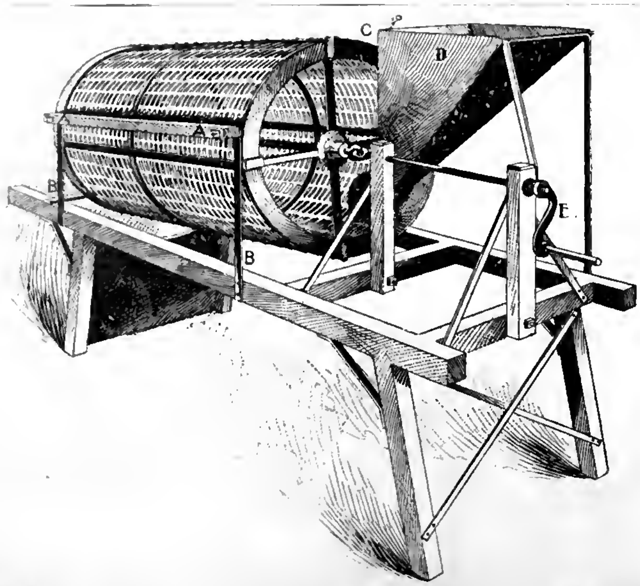

Fig. 35.—An Australian form of seed-wheat screen, or grader, suitable for use by farmers. The screen is a cylinder of perforated sheet metal, actuated by the crank, E. A brush, A A, is held against the screen by the springs, B B. The feed from the hopper, D, is regulated by the handle, C. The seed-wheat is caught at the further end of the screen, while the tailings fall on to the floor beneath. The capacity of the machine ranges up to 50 bushels per hour, but of course the quality of the work is not so good at 50 bushels per hour as at 20 bushels per hour: the slower the grading is done, the better it is done. The brush, A A, is an important factor in machines of this class. When, as in this case, only one size of mesh is supplied with the machine, a variety of grading can still be done by working the samples through several times. In this manner three quite distinct grades may be prepared with this machine, at the expense, however, of extra labour. For Australian wheat the mesh should not be less than 2·75 millimetres.

Fig. 7. (65)

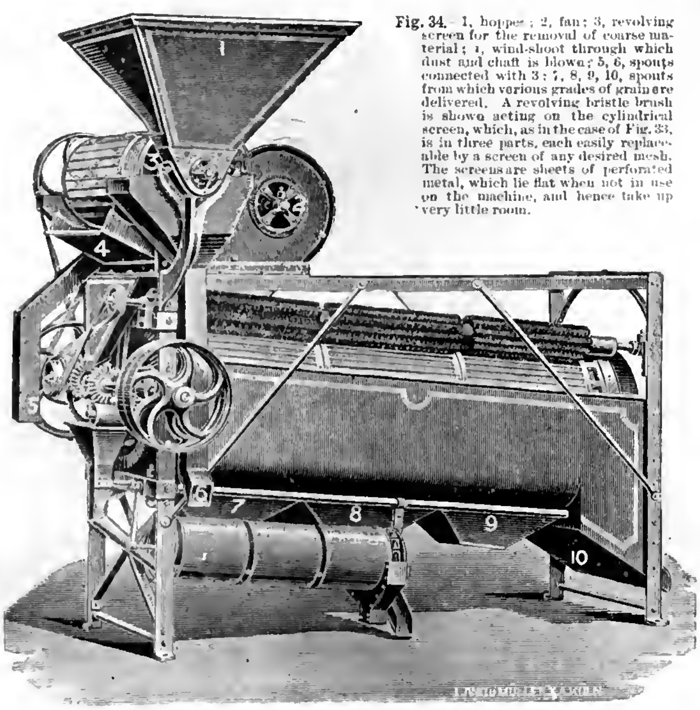

Fig. 34.—1, hopper; 2, fan; 3, revolving screen for the removal of course material; 4, wind-shoot through which dust and chaff is blown; 5, 6, spouts connected with 3; 7, 8, 9, 10, spouts from which various grades of grain are delivered. A revolving bristle brush is shown acting on the cylindrical screen, which, as in the case of Fig. 33, is in three parts, each easily replaceable by a screen of any desired mesh. The screens are sheets of perforated metal, which lie flat when not in use on the machine, and hence take up very little room.

Fig. 8. (65)

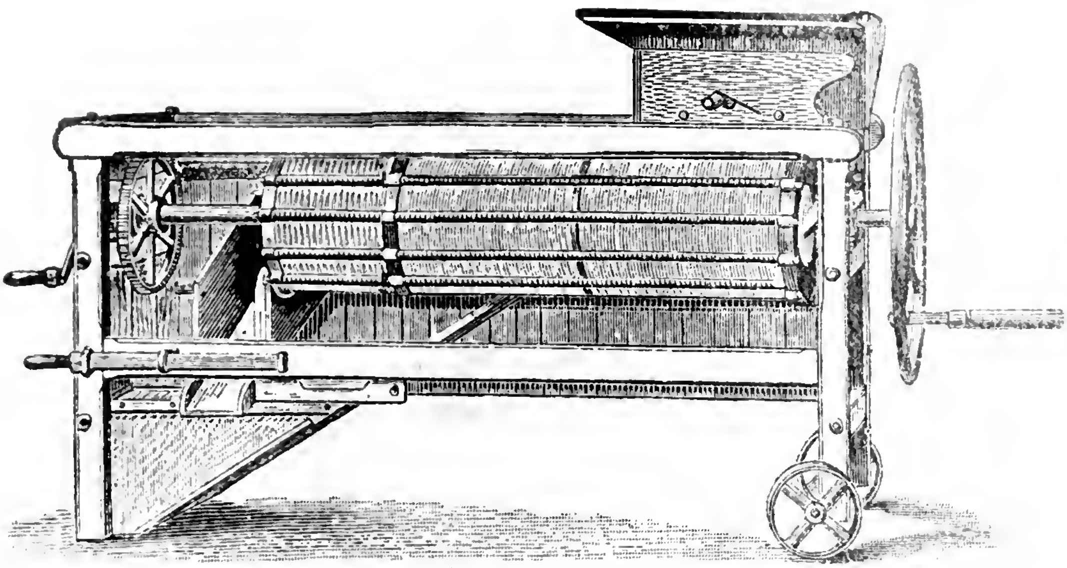

Fig. 36.—An English grader in which the meshes are made of wire in such a way as to be *adjustable in width*, without removal. The machine gives four grades of grain and does very good work. At the back near the top is the brush for keeping the meshes clear. This machine may be had with or without a fan.

Fig. 9. (65)

Fig. 10. Photograph by the author.

Fig. 11. Photograph by the author.