RELATIONSHIP BETWEEN THE SIZE AND PERFORMANCE OF SNAP BEAN SEEDS

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NEW YORK STATE AGRICULTURAL EXPERIMENT STATION
CORNELL UNIVERSITY
GENEVA, NEW YORK

Bulletin 819

March 1968

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A publication of the
New York State Agricultural Experiment Station
Geneva, N. Y.
New York State College of Agriculture
A Statutory College of the State University of New York
at Cornell University

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Abstract

Various lots of snap bean seeds most of which represented varieties subject to transverse cracking of the cotyledon were separated into different size grades and then subjected to laboratory germination tests and planted in field trials.

In lots showing an appreciable amount of transverse cracking of the cotyledons, small seeds generally produced more seedlings with intact cotyledons and a higher total per cent germination in the laboratory tests than the large seeds.

In field plantings where seeds of the different sizes were planted in separate rows and where the same *number* of seeds was planted in each row, rows planted from large seeds generally outyielded those planted from small seeds. The same was true when planting rates were adjusted in accordance with laboratory germination tests to provide approximately the same *number of plants* in each row. When the same *weight* of seed was planted in each row, however, rows from small seeds generally outyielded those from large seeds.

When two different seed sizes were alternated in the same row, the yields obtained were generally equivalent to the average of the yields from the two seed sizes planted in separate rows.

In single harvests made on the same date for plants from small and large seeds, a higher proportion of small pods was usually obtained from small seeds than from large seeds.

Introduction

There has long been an interest in the effect of seed size upon the yield of beans. Experiments to determine that relationship were reported by the New York State Agricultural Experiment Station (1) as early as 1889.

In those experiments, a lot of Golden Wax snap bean seed was divided into large and small sizes which were planted separately in hills with the same number of seeds per hill for each size. Dry beans were harvested from these plantings and the yield from the large seeds was greater than that from the small seeds. Seeds harvested from the plants grown from both large and small seeds were kept separated and each lot was again subdivided into large and small seeds. These were planted separately as in the previous test. In this second planting, lowest yields were obtained from the small seeds which were grown from small seeds. The highest yields came from the large seeds grown from large seeds.

Cummings (3), in Vermont in 1910–12, using Golden Wax snap bean seeds obtained results quite similar to those reported by the Geneva Station.

In plantings made from sprouted seed of different sizes, Wester (5) discovered that large lima bean seeds from a lot of the Fordhook 242 variety produced larger plants and greater yields than small seeds

from the same lot. Plants from small seeds adjacent to other plants from medium or large seeds had lower yields than plants from small seeds adjacent to other plants from small seeds.

Wester and Magruder (6) found that seed size had no effect on germination percentages of Baby Fordhook bush lima bean seed matured under dry conditions and free from weather spots. The size of seedlings produced from large and small seeds and measured as green weight of the above ground portion 11 or 12 days after planting was directly proportional to the size (diameter and weight) of the seed.

Hardenburg (4) reported no significant difference in total yield from Red Kidney and Robust Pea field bean plants grown from large seeds compared to plants from small seeds.

Thus, conclusions drawn from previous research concerning the relationship between the size of bean seeds and yields from them are contradictory. Also, in all experiments cited, yields were taken from the same number of plants from large seeds as from small seeds.

The question is raised, then, as to whether more plants per foot of row from small seeds might provide a yield equal to or better than that from fewer plants from large seeds. Snap bean seeds are normally sold by the pound and a pound of small seeds may contain many more seeds than a pound of large seeds. Consequently, it would be economically feasible to adjust planting rates so that more seeds per foot of row would be planted using lots containing predominantly small seeds.

Besides the question of economics, some of the more recently developed varieties of snap beans are susceptible to transverse cracking of the cotyledons. Earlier varieties were not seriously troubled with this seed weakness. If transverse cotyledon cracking, like various types of mechanical injury, should prove more prevalent among large seeds than small ones, it might affect the relative planting value of seeds of different sizes.

Because there are these factors about which previous research did not appear to provide adequate information, it seemed desirable to conduct further research on the relationship between the size and the planting value of snap bean seeds.

A major objective of the research was to obtain information which would be of value to snap bean growers in choosing among lots of seed of the same variety but varying in seed size, and in adjusting planting rates in accordance with seed size. It was also our hope that the information obtained might suggest to plant breeders the most desirable size for snap bean seeds and might help seed suppliers decide whether size grading of snap bean seeds would be justified.

An effort is being made by means of this bulletin to record all of the significant information assembled from the several experiments that

were conducted so that it will be available not only to those who might find practical applications for it but also to those who might be considering a similar type of research.

General Procedure

Experiments to determine the relationship between the size and the performance of snap bean seeds were conducted over a 3-year period from 1961 through 1963. Different experiments with somewhat different objectives were conducted in each of the 3 years. In all of the experiments, however, the comparisons made involved seeds of different sizes within the same seed lot. Thus, the seeds were as nearly as possible identical except for size.

Seeds of different sizes were obtained by hand grading using test screens with elongated perforations that made separations on the basis of the width of the seed. In most experiments, three sizes (large, medium, and small) were used. However, seeds were graded into five different sizes for one experiment.

Although the sizes of seeds in the small, medium, and large categories varied somewhat, in general, the large seeds averaged about $^{15}/_{64}$ inch in width, the medium seeds about $^{13}/_{64}$ inch, and the small seeds between $^{10}/_{64}$ and $^{12}/_{64}$ inches.

Data on the comparative weights of seeds in different size categories are presented in Table 1. Some of the large seeds weighed nearly twice as much as some of the small ones.

Most of the experiments conducted included several varieties of beans and, in some cases, several lots from a given variety. Varieties used were mostly those which are susceptible to transverse cracking of the cotyledons. A few, such as Kinghorn Wax and Earliwax, were varieties not very susceptible and a few of the lots from susceptible varieties were hand shelled and did not have any appreciable amount of cotyledon injury.

The majority of the seed lots used were commercial lots produced in Idaho or California and processed according to usual practices. All of the seeds used in field trials were treated before planting with a combination fungicide-insecticide as protection against soil fungi and seed corn maggot.

Samples of the seeds used were subjected to standard laboratory germination tests after they had been graded into the different size categories. Then they were planted in the field trials in accordance with procedures described below for individual experiments.

Data obtained were subjected to "t" tests where paired comparisons were involved or to other statistical analyses with the results indicated in the data summary tables.

Table 1.—Comparative Weight of Seed in Different Size Grades.

Lot No.	Variety	Average weight, grams per 100 seeds			
		Large	Medium	Small	Non-graded
		1961			
1	Tenderwhite	31.0	23.5	17.5	—
2	Tenderwhite	31.8	25.0	16.5	—
3	Tenderwhite	31.8	25.5	16.8	—
4	Slenderwhite	30.3	24.8	17.5	—
5	Slenderwhite	29.8	24.0	17.5	—
6	Processor	35.8	28.5	20.0	—
7	Tenderwhite	32.5	25.3	17.0	—
8	Tenderwhite	31.5	24.0	16.3	—
9	Tenderwhite	31.8	25.5	16.8	—
10	Kinghorn Wax	35.0	29.3	21.5	—
Average, 1961		**32.1**	**25.5**	**17.7**	—
		1962			
1	Tenderwhite	35.1	26.1	18.1	22.9
2	Tenderwhite	38.2	30.5	20.6	30.2
3	Tenderwhite	36.9	28.6	24.0	25.6
4	Tenderwhite	38.4	28.6	19.1	30.0
5	Slenderwhite	37.5	29.6	21.6	31.5
6	Corneli 14	42.9	30.6	23.2	37.2
Average, 1962		**38.2**	**29.0**	**21.1**	**29.6**
		1963			
1	Earliwax	37.3	30.3	23.5	—
2	White-seeded Tendergreen	37.5	33.3	26.0	—
3	Slenderwhite	37.0	29.0	20.8	—
4	Tenderwhite	35.0	29.3	21.8	—
5	Tenderwhite	34.5	27.5	20.5	—
6	Tenderwhite	34.8	28.3	21.5	—
7	Corneli 14	51.5	41.3	32.3	—
8	Tenderwhite	33.3	27.3	21.0	—
Average, 1963		**37.6**	**30.8**	**23.4**	—

Relationship between Seed Size and Transverse Cracking of Cotyledons in Laboratory Germination Tests

Laboratory germination percentages were used in some cases to adjust planting rates to obtain desired plant populations and to observe differences in transverse cracking of cotyledon tissue. Consequently, seeds from 24 different lots were subjected to standard laboratory germination tests during the 3-year experiment. The tests

were conducted at 25°C (77°F) in rolls of germination paper in "slant roll" seed germinators. There were 4 replicates of 100 seeds each for each seed size from each of the 24 lots.

When the tests were completed in 7 or 8 days, the seedlings obtained were classified and counted. Dead or badly cracked seeds that produced no seedlings were classified as being non-germinable along with seeds which produced seedlings with abnormal roots, hypocotyls, and plumules. Such a classification is in accordance with the *Rules for Testing Seeds* prescribed by the Association of Official Seed Analysts (2).

Seedlings with otherwise normal tissues were divided into three categories in respect to transverse cracking of their cotyledons. All seedlings which had not lost any cotyledon tissue as a result of transverse cracks were placed in one category. Seedlings of the type illustrated in Figure 1 which had lost cotyledon tissue were subdivided into two additional categories. Those with half or more of the original cotyledon tissue remaining attached to the seedling were placed in one category and those with less than half in the other.

Under the *AOSA Rules for Testing Seeds* the total of the number of seedlings with intact cotyledons and those with half or more of the

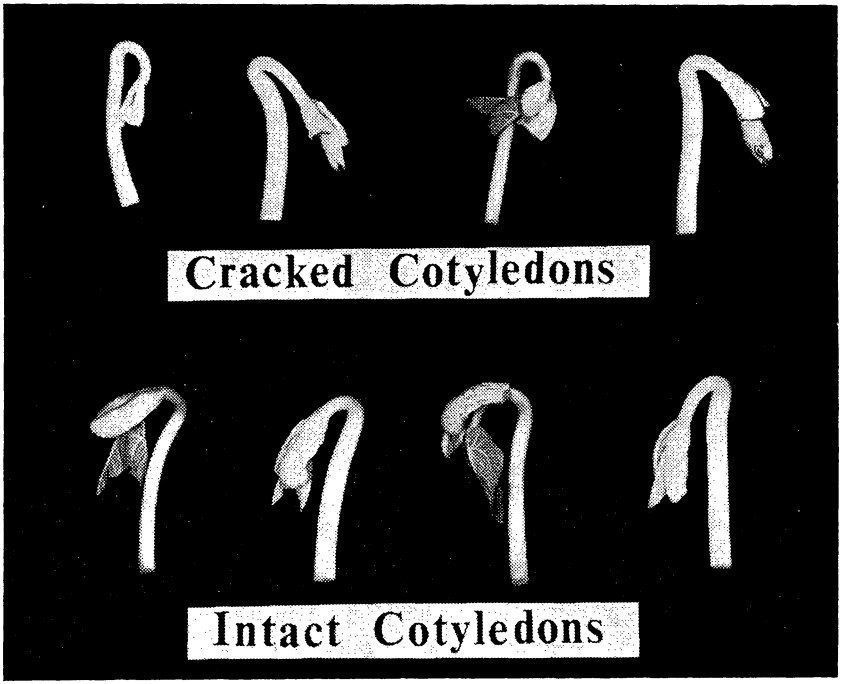

Figure 1. Comparison of snap bean seedlings which have lost cotyledon tissue as a result of transverse cracking and seedlings with intact cotyledons.

original cotyledon tissue remaining attached to the seedling constitutes the standard per cent germination. It was this total that was used for adjusting planting rates. The relationship between seed size and cotyledon cracking, however, can best be observed by comparing the number of seedlings in the first category (those with complete cotyledons) with the total number of seedlings in the other two categories (those with broken cotyledons). This comparison is provided in Table 2.

In general, the large seeds produced fewer seedlings with complete cotyledons than the small seeds. That, however, was not the case for one lot of Kinghorn Wax seed included in the 1961 tests and one lot of Corneli 14 included in the 1963 tests.

The average performance of the non-graded seeds tested in 1962 was similar to that of the medium-sized seeds. However, for lot 1, which was predominantly small seeded, performance of the non-graded seeds was similar to that of the small seeds. Also, the non-graded seeds in lot 6, which contained mostly large seeds, performed about the same as the large seeds.

Differences between lots of the same variety were quite pronounced in some cases. The lot of Corneli 14 seed included in the 1962 tests showed considerably more cotyledon cracking among the large seeds than among the small ones. The lot included in the 1963 tests, on the other hand, showed no difference from one size to another, probably because it had not been subjected to conditions which would cause cracking.

Relationship between Seed Size and Field Performance in Trials in Which Only One Size of Seed Was Planted in a Row

Same Number of *Seeds Planted in Each Row*

Two experiments were conducted in 1961 and one in 1962 in which different sizes of seed were planted in separate rows with the same number of seeds per row regardless of size or per cent germination. The first 1961 experiment involved three lots of seed with very high germination percentages (over 90 per cent) and very little transverse cracking of the cotyledons. The second 1961 experiment and the 1962 experiment involved the lots of seed indicated in Table 1 with the cotyledon breakage listed in Table 2.

One of the seed lots used in the first 1961 experiment was a selected commercial lot of Slendergreen. The other two lots were from special stocks of white seeded and colored seeded Tendercrop which had been hand threshed and therefore were free of mechanical injury.

The seeds from these three lots were separated by means of slotted hand sieves into five different size grades. The largest size grade included all seeds which did not go through $^{14}/_{64}$ inch slots. The next

Table 2.—Relationship between Seed Size and Transverse Cracking of Cotyledons in Laboratory Germination Tests.

Lot No.	Variety	Percentage of seeds producing seedlings with complete cotyledons				Percentage of seeds producing seedlings with broken cotyledons			
		Large	Medium	Small	Non-graded	Large	Medium	Small	Non-graded
				1961					
1	Tenderwhite	45	59	72	—	30	21	11	—
2	Tenderwhite	49	63	76	—	33	23	8	—
3	Tenderwhite	55	64	65	—	27	23	16	—
4	Slenderwhite	64	68	78	—	10	11	8	—
5	Slenderwhite	56	50	68	—	22	18	13	—
6	Processor	47	56	67	—	12	9	7	—
7	Tenderwhite	46	59	73	—	36	25	10	—
8	Tenderwhite	39	54	81	—	38	26	9	—
9	Tenderwhite	36	49	67	—	44	32	15	—
10	Kinghorn Wax	79	78	79	—	7	10	8	—
Average, 1961		**52**	**60**	**73**	—	**27**	**20**	**11**	—
				1962					
1	Tenderwhite	34	37	50	48	35	38	31	30
2	Tenderwhite	34	45	60	40	33	34	17	38
3	Tenderwhite	39	60	72	59	35	20	13	23
4	Tenderwhite	62	62	69	62	17	15	8	14
5	Slenderwhite	48	53	66	52	17	18	15	15
6	Corneli 14	57	70	80	58	20	10	5	14
Average, 1962		**46**	**55**	**66**	**53***	**26**	**22**	**15**	**23***
				1963					
1	Earliwax	72	76	81	—	14	11	9	—
2	White-seeded Tendergreen	62	72	73	—	16	10	9	—
3	Slenderwhite	19	45	70	—	44	31	13	—
4	Tenderwhite	58	55	69	—	18	21	14	—
5	Tenderwhite	42	60	78	—	36	25	12	—
6	Tenderwhite	40	54	75	—	28	24	14	—
7	Corneli 14	95	95	95	—	1	1	1	—
8	Tenderwhite	40	60	76	—	36	22	16	—
Average, 1963		**54**	**65**	**77**	—	**24**	**18**	**11**	—
Average, all three years		**51***	**60**	**72**	—	**25**	**20**	**12**	—

*The 3-year average differences between large and medium seeds, large and small seeds, and medium and small seeds were statistically significant at the 1% level both for the number of seedlings with complete cotyledons and the number of seedlings with broken cotyledons.

In 1962, the differences between large seeds and non-graded seeds and small seeds and non-graded in the percentage of seeds producing seedlings with complete cotyledons were significant at the 1% level. The difference between medium seeds and non-graded seeds was not significant. The difference between small seeds and non-graded seeds in the percentage of seeds producing seedlings with broken cotyledons was significant at the 5% level. The differences between medium seeds and non-graded seeds and between large seeds and non-graded seeds were not significant.

grade included those which went through the $^{14}/_{64}$ inch slots but not through $^{13}/_{64}$ inch slots. The third largest grade included seeds which went through the $^{13}/_{64}$ inch slots but not through $^{12}/_{64}$ inch slots and the fourth size grade included those which went through $^{12}/_{64}$ inch slots but not $^{11}/_{64}$ inch ones. The smallest size grade included the seeds which went through the $^{11}/_{64}$ inch slots but not $^{10}/_{64}$ inch slots.

The average weight per 100 seeds and the distribution of the seeds among the different grades are supplied for the three lots of seed in Table 3. The smallest seeds averaged 6 per cent by weight and 9 per cent by number of the total quantity of seed and weighed 18 grams per 100 seeds. The largest seeds averaged 23 per cent by weight and 17 per cent by number and weighed 36 grams per 100 seeds. The middle size, $^{12}/_{64} - ^{13}/_{64}$ inch in diameter, had the highest percentage of seeds both by weight and by number.

Table 3.—Size Grades, Weights, and Distribution among Size Grades for Seeds Used in the First Experiment in 1961.

Variety	Seed diameter 64ths. inch	Average weight grams per 100 seeds	Distribution of seeds among size grades	
			Per cent by weight	Per cent by number
Slendergreen	14+	38	35	27
	13–14	31	24	22
	12–13	26	25	28
	11–12	21	12	17
	10–11	18	4	6
White-seeded Tendercrop.	14+	34	22	16
	13–14	29	26	22
	12–13	25	30	30
	11–12	20	14	18
	10–11	17	8	14
Colored-seeded Tendercrop	14+	36	11	8
	13–14	31	26	22
	12–13	26	39	40
	11–12	22	17	20
	10–11	18	7	10
Average, all varieties	14+	36	23	17
	13–14	30	25	23
	12–13	26	32	33
	11–12	21	14	18
	10–11	18	6	9

Seeds from each size of each variety were planted in three different field trials on three different planting dates, June 5, June 12, and June 19. In each planting, 100 seeds from each size grade of each variety were planted in a row 10 feet long with the rows spaced 36 inches apart. There were four replicates for each seed size of each variety in randomized blocks.

Following seedling emergence, daily counts were made of the number of emerged seedlings. The relative rate of emergence observed in the three plantings is summarized in Table 4. The smallest seeds had the highest rate of emergence for all three varieties. Nine days after planting, there were emerged seedlings for 41 per cent of the smallest seeds and only 21 per cent of the largest seeds. Final stands, however, were essentially the same for all seed sizes.

Although the seedlings that emerged from large seeds were larger than those emerging from small seeds, this difference in plant size decreased with time. At harvest, there was no apparent size difference.

Table 4.—Emergence of Seedlings from Seeds of Different Sizes in First 1961 Experiment.

Variety	Seed diameter 64ths. inch	Number of emerged seedlings per 100 seeds on number of days after planting indicated						
		7	8	9	10	11	12	Final stand
Slendergreen	14+	0	1	5	30	62	72	86
	13–14	0	2	8	36	64	74	91
	12–13	0	1	13	45	71	78	89
	11–12	0	7	18	50	70	76	89
	10–11	1	7	20	53	75	82	90
White-seeded Tendercrop	14+	2	16	31	71	85	87	91
	13–14	5	15	41	70	86	88	92
	12–13	7	20	49	78	87	89	92
	11–12	9	22	53	77	86	88	91
	10–11	11	23	48	76	84	86	91
Colored-seeded Tendercrop	14+	1	9	28	77	91	94	98
	13–14	3	15	43	83	94	95	98
	12–13	6	19	49	83	93	94	97
	11–12	5	16	51	85	94	96	97
	10–11	5	23	55	82	89	92	96
Average, all varieties	14+	1	9	21	59	79	84	92
	13–14	2	11	31	65	81	86	93
	12–13	4	14	37	69	84	87	94
	11–12	5	15	41	71	84	87	93
	10–11	5	18	41	70	83	87	93

When pods reached processing maturity, they were hand harvested in a single picking to simulate mechanical harvester conditions. Total yields were determined and then the pods were graded into commercial sizes used by the canning and freezing industry. Percentages of pods in each grade were calculated. Additionally, immature seeds were extracted from samples of pods in the sieve size 5 grade and the fresh weight percentage of seeds in these pods was determined.

There was no significant interaction between planting dates and seed size in total yield of pods, distribution of pod sizes, or per cent seed in sieve size 5 pods. Therefore, the results for all three plantings were averaged and are presented in Table 5.

The average yield of pods per row from the largest seeds was 8.5 pounds. The average yield from the smallest seeds was 7.2 pounds.

Table 5.—Average Yield, Relative Pod Size, and Per Cent Seed in Size 5 Pods for Snap Beans Grown from Seeds of Different Sizes in First 1961 Experiment.

Variety	Seed diameter 64ths. inch	Pounds of pods per row	Per cent no. 1–3 pods	Per cent no. 4 pods	Per cent seed in no. 5 pods
Slendergreen	14+	8.7	32	29	11.1
	13–14	8.3	32	29	10.5
	12–13	8.3	34	29	10.9
	11–12	7.7	35	29	10.4
	10–11	7.6	38	29	9.9
White-seeded Tendercrop	14+	8.2	45	33	5.3
	13–14	7.9	49	32	4.9
	12–13	7.8	46	33	5.1
	11–12	7.4	53	32	5.1
	10–11	6.7	58	28	4.5
Colored-seeded Tendercrop	14+	8.6	42	34	6.8
	13–14	8.3	42	33	6.4
	12–13	7.9	42	33	6.4
	11–12	7.5	52	29	6.1
	10–11	7.1	55	28	5.6
Average, all varieties	14+	8.5	40	32	7.7
	13–14	8.2	41	32	7.3
	12–13	8.0	41	32	7.5
	11–12	7.6	47	30	7.2
	10–11	7.2	50	28	6.7
LSD for averages of all varieties	5% level	0.2	2	2	0.4
	1% level	0.3	3	2	0.5

These yields are comparable to 12,300 and 10,400 pounds per acre respectively.

The average percentage of small pods (sieve size 3 and smaller) was 40 for the largest seeds and 50 for the smallest, and the average percentage of seed in sieve size 5 pods was 7.7 for the largest seeds and 6.7 for the smallest.

It is apparent that plants from the largest seeds outyielded those from the smallest seeds but produced a higher proportion of large pods and a higher percentage of seed in sieve size 5 pods. If harvesting of the pods on the plants from the smallest seeds had been delayed until they reached the same size and maturity as those on the plants from the largest seeds, the differences in yield would not have been so great. Also, the 1961 growing season was favorable for snap bean production and that apparently provided the conditions needed for the higher yield potential of plants from large seeds to express itself consistently in all three plantings.

As indicated above, the seeds used in the second experiment conducted in 1961 involved the 10 commercial lots of seed listed for 1961 in Tables 1 and 2. The germination of some of these lots was relatively low and several of them had a high proportion of seeds with broken cotyledons. In these respects, they were quite different from the three seed lots used in the first experiment.

Large, medium, and small seeds were separated from each of the 10 seed lots by means of slotted hand screens. The large category included seeds which passed through $^{15}/_{64}$ inch slots but would not pass through $^{14}/_{64}$ inch slots. The medium seeds passed through $^{13.5}/_{64}$ inch slots but not through $^{12.5}/_{64}$ inch slots, and the small seeds passed through $^{11}/_{64}$ inch slots. Small, medium, and large seeds from each lot were planted with a V-belt seeder in rows 16 feet long and 3 feet apart. Each seed size for each lot was planted in 4 replicates with 100 seeds in each replicate. The different seed size rows were randomized within lots, but the lots were planted in numerical order. No attempt was made to compare lots or varieties. Comparisons were made only for seed sizes within lots.

Beginning 6 days after planting, daily counts were made of the number of normal seedlings which had emerged from each row. Seedlings with broken cotyledons were included in these counts if half or more of the original cotyledon tissue remained attached to the seedling. Seedlings with less than half of the original cotyledon tissue remaining attached were left in the stand but were not included in the counts as normal seedlings.

A summary of the counts made on the 7th and 14th days is provided in Table 6. The differences among seed sizes in respect to final stands of normal seedlings on the 14th day were relatively small. Greater differences in favor of the small seeds were observed on the 7th day

Table 6.—Emergence of Seedlings from Seeds of Different Sizes in Second 1961 Experiment.

Lot No.	Variety	Average number of emerged normal seedlings per row in rows planted with seeds of the size indicated					
		7th day after planting			14th day after planting		
		Large	Medium	Small	Large	Medium	Small
1.....	Tenderwhite	13	14	28	68	64	70
2.....	Tenderwhite	16	15	14	71	70	72
3.....	Tenderwhite	7	18	14	73	72	74
4.....	Slenderwhite	10	16	28	74	77	83
5.....	Slenderwhite	14	14	28	73	76	83
6.....	Processor	0	3	15	63	68	77
7.....	Tenderwhite	7	15	20	72	70	69
8.....	Tenderwhite	6	10	24	62	73	77
9.....	Tenderwhite	11	12	19	68	72	74
10.....	Kinghorn Wax	16	29	36	78	84	82
Average.....		**10***	**15**	**23**	**70****	**72**	**76**

*In the 7-day count average differences in the number of seedling were statistically significant at the 1% level for the large and medium, large and small, and medium and small seed comparisons.

**In the 14-day count, average differences were statistically significant at the 1% level for the large and small, and medium and small seed comparisons. The average difference between large and medium seeds was not significant.

indicating again a tendency on the part of the small seeds to germinate more rapidly than the large ones.

Although the average field germination percentage for the small seeds was higher than that for the large seeds, the difference was not so great as had been anticipated based on results of the laboratory tests. The average germination percentages for small, medium, and large seeds in the laboratory tests were 70, 75, and 82 respectively. The corresponding field germination percentages were 70, 72, and 76. Obviously, better field emergence was obtained from germinable large seeds than from germinable small seeds.

The pods, upon reaching suitable maturity for processing, were harvested in the same manner as in the first experiment. They were also size graded in the same fashion.

The average yields for the different seed sizes are summarized in Table 7 along with a summary of the proportions of pods which were size grade 4 or smaller. For 7 of the 10 lots of seed, higher yields were obtained from the large seeds than from the small ones. Of the three lots of small seeds that produced greater yields than large seeds, two lots showed a considerable yield advantage. These two lots also produced significantly higher plant populations from small seeds than

Table 7.—Average Yields and Relative Pod Size of Snap Beans Grown from Seeds of Different Sizes in Second 1961 Experiment.

Lot No.	Variety	Average yield of pods (pounds per row) for rows grown from seed of the size indicated			Average percentage of size 4 and smaller pods from rows grown from seed of the size indicated		
		Large	Medium	Small	Large	Medium	Small
1	Tenderwhite	6.8	6.6	7.0	51	48	44
2	Tenderwhite	7.6	6.6	5.8	42	39	47
3	Tenderwhite	7.4	8.1	6.6	39	36	41
4	Slenderwhite	10.1	9.7	9.1	54	56	62
5	Slenderwhite	10.5	9.5	9.6	55	57	59
6	Processor	6.2	6.6	7.1	50	43	42
7	Tenderwhite	7.7	7.2	6.5	42	42	43
8	Tenderwhite	7.9	8.1	8.5	41	35	39
9	Tenderwhite	8.0	7.7	7.1	38	36	37
10	Kinghorn Wax	8.6	8.7	8.3	31	30	36
Average		**8.1***	**7.9**	**7.5**	**44****	**42**	**45**

*Average yields were not significantly different for any of the seed size comparisons.

**The difference in percentage of sieve size 4 or smaller pods was significant at the 5% level for the medium and small seed comparison. Differences for the other comparisons were not significant.

from the large ones. For these two lots, it appears that the higher production potential of plants from large seeds may have been offset by the increased number of plants obtained from the small seeds.

Pod size information is summarized in Table 7 in terms of the percentage of pods that were size 4 or smaller. The pods from the large seeds and small seeds were not significantly different in relative size but the plants from the medium sized seeds produced a significantly lower percentage of size 4 and smaller pods than those from small seeds.

There were six different lots of seed included in the 1962 experiment, and a portion of each lot was graded into large, medium, and small categories in the same manner as in 1961. Another non-graded portion of each lot was also used in the 1962 experiment. The seeds were planted with a V-belt seeder in rows 16 feet long and 3 feet apart with 4 replicates for each seed size from each lot and with 200 seeds in each row. The rows for the different seed sizes were randomized within lots, but lots were planted in numerical order.

After emergence was complete, counts were made of the number of normal seedlings in each row. Seedlings with cracked cotyledons were considered normal if half or more of the original cotyledon tissue remained attached to the seedling.

A summary of the counts is provided in Table 8. Field conditions were not as satisfactory for germination in 1962 as in 1961. Conse-

quently, seedling emergence was not as good. Under these conditions, the large seeds produced as many seedlings as the small ones even though the average laboratory germination of the large seeds was only 63 per cent as compared to 77 per cent for the small seeds.

When the pods had reached the proper processing stage, they were harvested and graded in accordance with the procedures described above. However, fresh weight percentages of seed were determined for sieve size 4 pods instead of sieve size 5 pods.

The yield results summarized in Table 8 indicate that the rows planted from large, medium, or non-graded seeds outyielded those planted from small seeds. The data in Table 9 indicate that there were no significant differences in the proportions of small pods (sieve size 4 and smaller) or in the percentages of seed in sieve size 4 pods for any of the seed size comparisons.

Same Weight *of Seeds Planted in Each Row*

In 1962 and 1963, experiments were conducted to determine the relative performance of seeds of different sizes when the same *weight* rather than the same *number* of seeds was used for planting rows from each seed size.

In 1962, large, medium, small, and non-graded seeds obtained as described above were included in a trial in which 45 grams of seed were planted in each row. The six seed lots listed for 1962 in Table 1

Table 8.—Stand Counts and Yields for 1962 Field Planting in which 200 Seeds were Planted per Row.

Lot No.	Variety	Average number of normal seedlings per row for seeds of size indicated				Average yield (pounds of pods) per row for seeds of size indicated			
		Large	Medium	Small	Non-graded	Large	Medium	Small	Non-graded
1	Tenderwhite	64	55	64	65	5.6	4.4	4.0	3.6
2	Tenderwhite	86	95	82	96	6.3	6.1	4.8	6.9
3	Tenderwhite	80	94	74	89	6.8	7.0	4.9	5.8
4	Tenderwhite	120	118	90	110	8.9	7.2	5.5	7.3
5	Slenderwhite	91	116	110	114	8.0	9.5	8.1	8.7
6	Corneli 14	147	153	150	157	7.4	7.3	6.4	7.2
Average		**98***	**105**	**95**	**101**	**7.2****	**6.9**	**5.6**	**6.6**

*Differences in the average number of normal seedlings were not significant for any of the seed size comparisons.

**Average differences for the medium vs. small and non-graded vs. small comparisons were significant at the 1% level. The difference for the large vs. small comparison was significant at the 5% level. Differences for the other seed size comparisons were not significant.

Table 9.—Relative Pod Size and Per Cent Seed in Sieve Size 4 Pods for 1962 Field Planting in which 200 Seeds Were Planted per Row.

Lot No.	Variety	Per cent of size 4 and smaller pods for seed size indicated				Per cent of seed in size 4 pods for seed size indicated			
		Large	Medium	Small	Non-graded	Large	Medium	Small	Non-graded
1	Tenderwhite	66	62	73	70	1.6	1.7	1.7	1.6
2	Tenderwhite	74	74	75	73	1.5	1.4	1.5	1.5
3	Tenderwhite	69	68	68	70	1.5	1.4	1.5	1.5
4	Tenderwhite	71	75	73	73	1.4	1.5	1.4	1.5
5	Slenderwhite	92	90	95	92	3.1	3.4	2.9	3.1
6	Corneli 14	86	88	89	87	2.5	2.5	2.4	2.5
Average		**76***	**76**	**79**	**78**	**1.9****	**2.0**	**1.9**	**1.9**

*Average differences for the various seed size comparisons were not significant.
**Average differences for the various seed size comparisons were not significant.

were used for this experiment and seeds from each seed size of each seed lot were planted in a trial with four replicates for each seed size.

The average number of seedlings obtained from each seed size and the average yield for each size are summarized in Table 10. There were, of course, many more seeds per 45 grams of small seeds than for the same weight of large seeds. Consequently, the rows planted from large seeds produced only about 60 per cent as many plants as those planted from small seeds. Rows planted from medium, small, and non-graded seeds outyielded those planted from large seeds.

The proportions of small pods (size 4 and smaller) and percentages of seed in sieve size 4 pods for this 1962 experiment are summarized in Table 11. There were no significant differences among seed sizes in either the proportion of small pods produced or the percentage of seed in sieve size 4 pods.

In an experiment conducted in 1963, the same weight of seed per row was used for large, medium, and small seeds within each of the eight seed lots listed for 1963 in Table 1. However, the weight of seed used varied from one lot to another.

In that experiment, portions of each of the eight seed lots were pregraded on slotted hand screens to determine their size distribution. After that, the proper screens were selected to divide each lot by size into three portions roughly equal in weight. These portions were designated as large, medium, and small.

In establishing the weight of seed per row to be used for each seed lot, the average weight per seed and the per cent germination of the medium sized seeds were used to calculate the number of grams of seed needed to provide approximately 8 plants per foot of row (128 plants

Table 10.—Stand Counts and Yields for the 1962 Field Planting in which 45 grams of Seed Were Planted per Row.

Lot No.	Variety	Average number of normal seedlings per row for seeds of size indicated				Average yield (pounds of pods) per row for seeds of size indicated			
		Large	Medium	Small	Non-graded	Large	Medium	Small	Non-graded
1	Tenderwhite	38	52	66	56	4.0	4.9	5.0	4.9
2	Tenderwhite	46	63	80	58	5.3	5.7	5.7	5.9
3	Tenderwhite	56	76	76	81	5.6	6.5	5.9	6.3
4	Tenderwhite	75	98	113	77	6.9	7.8	8.0	7.0
5	Slenderwhite	57	81	108	70	8.8	9.5	10.8	9.9
6	Corneli 14	74	113	143	90	7.8	9.0	9.3	7.7
Average		**58***	**81**	**98**	**73**	**6.4****	**7.2**	**7.4**	**6.9**

*The difference between medium and non-graded seeds in average number of normal seedlings produced was significant at the 5% level. The differences for all other comparisons were significant at the 1% level.

**Average differences in yield were significant at the 1% level for the large vs. medium and large vs. small comparisons. The difference between the average yields from large and non-graded seeds was significant at the 5% level. The differences for other seed size comparisons were not significant.

Table 11.—Relative Pod Size and Per Cent Seed in Sieve Size 4 Pods for the 1962 Field Planting in which 45 grams of Seed Were Planted per Row.

Lot No.	Variety	Per cent of size 4 and smaller pods for seed size indicated				Per cent of seed in size 4 pods for seed size indicated			
		Large	Medium	Small	Non-graded	Large	Medium	Small	Non-graded
1	Tenderwhite	63	64	62	64	2.2	1.9	1.7	1.7
2	Tenderwhite	68	63	70	63	1.6	1.5	1.6	1.6
3	Tenderwhite	64	66	70	70	1.6	1.8	1.4	1.5
4	Tenderwhite	72	72	72	68	1.5	1.5	1.4	1.6
5	Slenderwhite	78	85	85	82	3.6	3.3	3.5	3.7
6	Corneli 14	74	78	80	73	3.0	2.9	2.8	2.8
Average		**70***	**71**	**73**	**70**	**2.2****	**2.1**	**2.1**	**2.1**

*None of the differences in average pod size was statistically significant.

**None of the differences in average per cent seed in size 4 pods was statistically significant.

per row 16 feet long). The planting rate thus calculated was used not only for the medium sized seeds but for the large and small seeds as well.

The seeds were planted in the manner previously described and counts of emerged seedlings were made when emergence was complete. The emergence data in Table 12 indicate the stands of plants obtained. As would be expected, the rows planted from small seeds produced more plants than those planted from large seeds. In fact, on the average, they produced nearly twice as many plants.

The yield data summarized in Table 12 show a higher average yield for the small seeds than for the large ones but the difference is not statistically significant as it was in the 1962 trial. There are probably

Table 12.—Stand Counts and Yield for the 1963 Field Planting in which the Same Weight of Seed was Used for All Seed Sizes.

Lot No.	Variety	Average number of normal seedlings per row for seeds of size indicated			Average yield (pounds of pods) per row for seeds of size indicated		
		Large	Medium	Small	Large	Medium	Small
1	Earliwax	100	125	165	13.0	13.0	13.5
2	White-seeded Tendergreen	95	117	146	11.5	11.6	11.6
3	Slenderwhite	69	137	203	8.9	11.6	12.0
4	Tenderwhite	91	128	170	9.6	10.6	9.3
5	Tenderwhite	88	125	188	9.9	10.4	10.4
6	Tenderwhite	86	132	196	8.9	11.5	11.3
7	Corneli 14	117	142	169	10.8	10.0	9.8
8	Tenderwhite	82	116	171	9.6	10.0	10.8
Average		**91***	**128**	**176**	**10.3****	**11.1**	**11.1**

*Average differences in number of seedlings were significant for all comparisons at the 1% level.

**None of the differences in average yield was statistically significant.

two reasons for that. Firstly, the method of grading for size in 1963 did not provide as wide a divergence between large and small seeds as that used in 1962. Secondly, the plant populations obtained in 1963 were higher than those in 1962. Therefore, there probably was not as great an advantage to the additional plants obtained from the small seeds. Nevertheless, the general seed size-yield relationships in 1963 were consistent with those observed in 1962.

The pod size data summarized in Table 13 show a significantly higher proportion of small pods for the small seeds than for the medium or large seeds. The average differences in per cent seed in sieve size 4 pods (also summarized in Table 13) were not statistically significant.

Table 13.—Relative Pod Size and Per Cent Seed in Sieve Size 4 Pods for the 1963 Field Planting in which the Same Weight of Seed Was Used for All Seed Sizes.

Lot No.	Variety	Per cent of size 4 and smaller pods for seed size indicated			Per cent of seed in size 4 pods for seed size indicated		
		Large	Medium	Small	Large	Medium	Small
1	Earliwax	69	68	73	6.0	7.0	6.8
2	White-seeded Tendergreen	39	46	46	4.2	4.6	4.6
3	Slenderwhite	82	83	84	3.8	4.2	3.5
4	Tenderwhite	61	64	74	1.6	1.4	1.6
5	Tenderwhite	57	60	70	1.8	1.8	1.7
6	Tenderwhite	61	55	70	1.6	1.6	1.6
7	Corneli 14	75	79	83	2.8	2.7	2.7
8	Tenderwhite	61	63	69	1.6	1.6	1.7
Average		**63***	**65**	**71**	**2.9****	**3.1**	**3.0**

*Average differences for large vs. small seeds and medium vs. small seeds were significant at the 1% level. The average difference for large vs. medium seeds was not significant.

**None of the average differences in per cent seed in size 4 pods was significant.

Planting Rate Adjusted to Provide Approximately the Same Number of Plants in Each Row

The more progressive growers of snap beans adjust planting rates to obtain a definite number of productive plants per foot of row—usually about 8 plants per foot. Therefore, an experiment was conducted in 1963 to determine the relative performance of different sizes of seed when they were planted at rates calculated from seed size and per cent germination to provide about 8 plants per foot for all seed sizes.

The different sizes of seed for this experiment were obtained from the same lots and in the same manner as described for the 1963 experiment in which the same weight of seed was used for all seed sizes within a lot. All other operations except the planting rate were handled in the same manner as described for that experiment.

The plant stands and yields obtained are summarized in Table 14. The average number of plants per foot obtained in the 16-foot rows that were planted was 7.7 for the large seeds, 7.9 for the medium seeds, and 7.8 for the small seeds. The average yield of pods from the small seeds was significantly lower than that for the medium and large seeds.

Relative pod sizes obtained from different sizes of seed and per cent seed in sieve size 4 pods are summarized in Table 15. The small seeds

Table 14.—Stand Counts and Yields for 1963 Field Planting in which Planting Rates Were Adjusted to Provide Approximately the Same Number of Plants per Row for All Seed Sizes.

Lot No.	Variety	Average number of normal seedlings per row for seeds of size indicated			Average yield (pounds of pods) per row for seeds of size indicated		
		Large	Medium	Small	Large	Medium	Small
1	Earliwax	123	126	116	11.2	10.9	9.7
2	White-seeded Tendergreen	123	120	114	8.3	8.0	7.1
3	Slenderwhite	134	139	140	10.5	11.1	10.5
4	Tenderwhite	112	121	110	8.4	8.4	7.2
5	Tenderwhite	119	138	132	9.1	8.8	8.2
6	Tenderwhite	118	114	125	9.7	8.9	8.7
7	Corneli 14	139	134	141	8.4	8.9	8.6
8	Tenderwhite	113	117	120	9.1	9.4	8.1
Average		**123***	**126**	**125**	**9.3****	**9.3**	**8.5**

*None of the average differences among seed sizes was statistically significant.

**The average difference between the yield from the small seeds and that from the medium and large seeds was statistically significant at the 1% level.

Table 15.—Relative Pod Size and Per Cent Seed in Sieve Size 4 Pods for the 1963 Field Planting in which Planting Rates Were Adjusted to Provide Approximately the Same Number of Plants per Row for All Seed Sizes.

Lot No.	Variety	Per cent of size 4 and smaller pods for seed size indicated			Per cent of seed in size 4 pods for seed size indicated		
		Large	Medium	Small	Large	Medium	Small
1	Earliwax	61	62	63	6.5	6.3	6.6
2	White-seeded Tendergreen	52	47	55	3.7	3.8	3.5
3	Slenderwhite	74	72	73	4.2	4.9	4.4
4	Tenderwhite	62	67	69	1.8	1.8	1.9
5	Tenderwhite	55	60	62	2.2	2.0	2.0
6	Tenderwhite	54	61	60	1.7	1.8	1.9
7	Corneli 14	71	70	75	3.7	3.8	3.9
8	Tenderwhite	56	55	67	2.0	2.0	2.1
Average		**61***	**62**	**66**	**3.2****	**3.3**	**3.3**

*The average difference between large and small seeds in pod size was significant at the 1% level and that between medium and small seeds was significant at the 5% level. The average difference between large and medium seeds was not significant.

**The average differences among seed sizes in per cent of seed in size 4 pods were not statistically significant.

produced a significantly higher percentage of small pods than the large seeds. No significant differences were observed among seed sizes in the per cent of seed in size 4 pods.

Relationship between Seed Size and Field Performance in Trials in Which Two Sizes of Seed Were Alternated in the Same Row

In 1962 and 1963, in addition to the experiments conducted in which seeds of different sizes were planted in separate rows, field plantings were made with seeds of two different sizes alternated in the same row.

A lot of Tendercrop seed and one of Slendergreen was used in 1962 and one lot each of Tendercrop, Valentine, and Kinghorn Wax was used in 1963. All of these lots had relatively high germination percentages and were relatively free of transverse cracking of the cotyledons.

Seeds from each lot were separated into size grades by 64ths of an inch in diameter from $^{10}/_{64}$ to $^{15}/_{64}$ and larger in 1962 and from $^{9}/_{64}$ to $^{18}/_{64}$ and larger in 1963. Certain of these size grades for each lot were selected as large, medium, and small seeds. The distribution of seeds among the different sizes and the size grades selected for the large, medium, and small seeds are indicated in Tables 16 and 17.

After large, medium, and small sizes of seed had been selected, they were planted in rows 10 feet long and 36 inches apart with 100 seeds per row to provide the following seed sizes within rows:

A. 100 large seeds
B. 50 large seeds alternated with 50 medium seeds
C. 50 large seeds alternated with 50 small seeds
D. 100 medium seeds
E. 50 medium seeds alternated with 50 small seeds
F. 100 small seeds

Table 16.—Size Distribution of Snap Bean Seeds Used in 1962 Trials and Size Grades Selected for Large, Medium, and Small Seeds.

Seed diameter 64ths. inch	Percentage by weight of seeds in size grade indicated:	
	Tendercrop	Slendergreen
15+	L* 17	L 16
14–15	47	28
13–14	M 24	M 24
12–13	10	21
11–12	S 2	S 9
10–11	Less than 1	2

*Grades labeled L, M, and S were the ones used for large, medium, and small seeds respectively.

Table 17.—Size Distribution of Snap Bean Seeds Used in 1963 Trials and Size Grades Selected for Large, Medium, and Small Seeds.

Seed diameter 64ths. inch	Percentage by weight of seeds in size grade indicated:		
	Tendercrop	Valentine	Kinghorn Wax
18+	–	–	1
17–18	–	Less than 1	2
16–17	Less than 1	2	L 12
15–16	2	L 14	24
14–15	L* 20	46	M 34
13–14	28	M 25	16
12–13	M 29	11	S 8
11–12	14	S 2	2
10–11	S 6	Less than 1	1
9–10	Less than 1	–	Less than 1

*Grades labeled L, M, and S were the ones used for large, medium, and small seeds respectively.

In 1962, four replicates from three seed sizes were planted on each of three different planting dates (May 8, June 7, and June 21). In 1963, three replicates were planted on July 9. The stands of plants obtained are indicated by the data summarized in Tables 18 and 19. Although there was a tendency for the large seeds to produce fewer plants per 100 seeds, the differences among seed sizes were not very great. The combined average was 79 for large seeds and 83 for medium and small seeds.

Table 18.—Average Stands of Plants Obtained in Three Plantings in 1962.

Size of seeds for which seedling count was made	Size of seeds alternated with those for which count was made	Average number of plants produced per 100 seeds		
		Tendercrop	Slendergreen	Average
Large	Large	84	92	89
Large	Medium	90	93	92
Large	Small	88	95	92
Medium	Large	89	92	90
Medium	Medium	91	93	92
Medium	Small	92	94	93
Small	Large	91	94	92
Small	Medium	91	94	92
Small	Small	91	93	92

Table 19.—Average Stands of Plants Obtained in One Planting in 1963.

Size of seeds for which seedling count was made	Size of seeds alternated with those for which count was made	Average number of plants produced per 100 seeds			
		Tender-crop	Valentine	Kinghorn Wax	Average
Large	Large	66	82	70	73
Large	Medium	64	72	70	69
Large	Small	72	80	68	73
Medium	Large	70	72	70	71
Medium	Medium	80	82	80	81
Medium	Small	76	82	74	77
Small	Large	74	84	74	77
Small	Medium	78	78	78	78
Small	Small	78	76	78	78

The growing season in 1962 was rather dry and lack of water limited yields so that the plants from the different sizes of seed were not able to reach their full potential. In 1963, the trials were irrigated as often as necessary to provide good growth.

When the pods in the 1962 and 1963 trials were at the proper stage, they were harvested and graded in the manner previously described and the total yields of pods obtained are summarized for the different sizes of seeds in Tables 20 and 21.

Significantly higher yields were obtained in both years from large seeds alternated with small seeds than from large seeds alternated with other large seeds. Also, significantly higher yields were obtained each year from medium seeds alternated with small seeds than from medium seeds alternated with large seeds.

The yields from the small seeds were not significantly affected by the size of the seeds with which they were alternated. Yields from small seeds alternated with large seeds were essentially the same as those from small seeds alternated with other small seeds and the yields from small seeds alternated with medium seeds were only slightly lower and not significantly different from these.

There were no significant differences in average yields of pods between planting 100 seeds of only one size or 50 seeds from each of two different sizes alternately spaced in 10 feet of row. The combined average yield of pods for all varieties and all plantings in 1962 and 1963 was 4.2 pounds per 100 large seeds, 4.4 pounds per 100 medium seeds, and 4.1 pounds per 100 small seeds in 10 feet of row. Alternating 50 large and 50 medium seeds in 10 feet of row provided a yield of 4.4 pounds whereas alternating 50 large and 50 small seeds provided

Table 20.—Average Yields from Seeds of Different Sizes Obtained from Three Plantings in 1962.

Size of seeds for which yield was determined	Size of seeds alternated with those for which yield was determined	Pounds of pods per 100 seeds planted		
		Tendercrop	Slendergreen	Average
Large	Large	3.8	3.7	3.7
Large	Medium	4.0	3.8	3.9
Large	Small	4.2	4.2	4.2
Medium	Large	3.4	3.1	3.3
Medium	Medium	3.8	3.8	3.8
Medium	Small	4.4	4.3	4.4
Small	Large	3.8	3.1	3.5
Small	Medium	3.2	3.3	3.3
Small	Small	3.8	3.4	3.6
LSD at 5% level				0.4
LSD at 1% level				0.5

Table 21.—Average Yields from Seeds of Different Sizes Obtained from One Planting in 1963.

Size of seeds for which yield was determined	Size of seeds alternated with those for which yield was determined	Pounds of pods per 100 seeds planted			
		Tender-crop	Valentine	Kinghorn Wax	Average
Large	Large	4.0	5.3	4.4	4.6
Large	Medium	4.7	4.9	4.9	4.8
Large	Small	7.1	6.5	5.1	6.3
Medium	Large	4.1	3.4	3.7	3.8
Medium	Medium	5.7	4.8	3.8	4.8
Medium	Small	6.1	4.9	6.3	5.8
Small	Large	5.2	4.4	4.5	4.7
Small	Medium	4.2	4.2	4.7	4.3
Small	Small	4.3	4.5	4.5	4.7
LSD at 5% level					1.0
LSD at 1% level					1.4

a yield of 4.8 pounds, and alternating 50 medium and 50 small seeds provided a yield of 4.2 lbs.

The proportions of small pods obtained from seeds of different sizes in the 1962 and 1963 plantings are summarized in Tables 22 and 23.

Table 22.—Percentages of Small Pods from Seeds of Different Sizes in Three Plantings in 1962.

Size of seeds for which pod size was determined	Size of seeds alternated with those for which pod size was determined	Percentage of sieve size 4 and smaller pods		
		Tendercrop	Slendergreen	Average
Large	Large	55	50	53
Large	Medium	50	60	55
Large	Small	52	48	50
Medium	Large	55	54	54
Medium	Medium	55	50	52
Medium	Small	54	48	51
Small	Large	51	52	52
Small	Medium	56	50	52
Small	Small	53	48	51

Table 23.—Percentages of Small Pods from Seeds of Different Sizes in One Planting in 1963.

Size of seeds for which pod size was determined	Size of seeds alternated with those for which pod size was determined	Percentage of sieve size 4 and smaller pods			
		Tender-crop	Valentine	Kinghorn Wax	Average
Large	Large	69	87	37	66
Large	Medium	70	90	59	73
Large	Small	62	88	34	63
Medium	Large	67	94	59	73
Medium	Medium	61	86	55	68
Medium	Small	57	82	27	53
Small	Large	53	92	46	63
Small	Medium	64	92	36	63
Small	Small	69	89	47	68

The proportion of sieve size 4 and smaller pods was essentially the same for all seed sizes. The combined average for the large and medium seeds was 57 per cent and that for the small seeds was 56 per cent.

Discussion

It is apparent that there is no simple answer to the question of whether large or small snap bean seeds have the greater planting value. That answer is dependent upon the seed lot involved and the planting rate used.

If a lot of seed exhibits a considerable amount of cotyledon breakage resulting from transverse cracking, the small seeds within the lot are likely to germinate better and produce a higher proportion of seedlings with intact cotyledons than the large ones. If cotyledon breakage is not a problem, large seeds within a lot may germinate as well as the small ones.

Plant populations may affect the relative performance of plants from small and large seeds. With a wide spacing of plants and limited competition, the apparently higher yield potential of plants from large seeds can probably be realized to a greater extent than where plants are spaced close together and there is greater competition for nutrients, water, and light. On the other hand, the apparently lower yield potential of plants from small seeds can be offset by increasing plant density.

A number of relationships between seed size and yield was observed for population densities in the range used for the experiments described in this bulletin. These densities varied from about 4 to about 11 plants per foot in rows 36 inches apart.

At such plant population densities, when the planting rate used was one that provided the same number of seeds or the same number of plants per foot of row for both large and small seeds, yields from the large seeds tended to exceed those from the small seeds. When a given weight of small seeds was compared with the same weight of large seeds, on the other hand, yields from the small seeds were as good as or better than those from the large seeds.

This experience suggests that equivalent yields from small and large seeds could be obtained by adjusting plant population densities in accordance with seed size. For rows 36 inches apart, a stand of 10 plants per foot from lots consisting predominantly of small seeds (more than 1,650 seeds per pound) should produce as high a yield as 7 plants per foot from lots composed mostly of large seeds (fewer than 1,250 seeds per pound). For lots containing between 1,250 and 1,450 seeds per pound, probably a population density of 8 plants per foot would provide a yield equivalent to that obtained from 7 plants per foot from lots containing fewer than 1,250 seeds per pound. A similar yield should be obtained from 9 plants per foot from lots containing from 1,450 to 1,650 seeds per pound.

The information obtained in this research is directly applicable only to different sizes of seed within the same seed lot. If the different sizes of seed used had come from different seed lots, factors other than seed size could have affected performance. Whether the principles evolved can justifiably be applied to situations where the small and large seeds come from different seed lots or different varieties, of course, is questionable. However, it is the best information available at present, and it will be difficult to obtain better information because of the problem of comparing different sizes of seed from different

lots or varieties without confounding seed size with variations in the physiological and genetic condition of the seed.

For this reason, the question of whether a small seeded variety would be preferable to a large seeded one or vice versa remains unanswered. Possibly, though, plant breeders will find information in the data presented that will help them in the search for improved seed quality.

The fact that rows planted from seed of one size did not outyield those planted with two sizes of seed alternated in the row, suggests that grading snap bean seeds for size probably would not result in a yield advantage. However, there might be other factors such as improved plantability which would justify size grading.

Summary and Conclusions

Over a period of 3 years, various lots of snap beans seeds representing a number of different varieties most of which are susceptible to transverse cracking of the cotyledons were divided by slotted hand screens into different sizes in accordance with the diameter of the seed.

Seeds of the different sizes were tested for germination in standard laboratory tests and were planted at various rates in field trials where yields were measured and comparative pod size was determined by grading the harvested pods. Relative maturity was also estimated by determining the percentage of seed in sieve size 4 or sieve size 5 pods.

In the laboratory germination tests of the seed lots in which there was a considerable amount of transverse cracking of the cotyledons, the large seeds had lower germination percentages and produced fewer seedlings with complete cotyledons and more seedlings with broken cotyledons than the small seeds.

In field trials where the same *number* of seeds of a single size was planted in each row, rows with large seeds usually outyielded those with small seeds. However, for a few seed lots where the number of plants in the rows planted from large seeds was greatly reduced by transverse cracking of the seed cotyledons, rows planted from small seeds outyielded those planted from large seeds.

In field trials where the same *weight* or seeds of a single size was planted in each row, rows planted from small seeds naturally contained more plants than those planted from large seeds and also generally provided higher yields.

In the one experiment in which planting rates were adjusted to provide approximately the *same number of plants* in each row, rows planted from large seeds outyielded those planted from small seeds.

When seeds of two different sizes were alternated in the same row, plants from large seeds yielded more when they were alternated with plants from small seeds than when they were alternated with plants from other large seeds. Plants from medium seeds yielded more when

they were alternated with plants from small seeds than when they were alternated with plants from large seeds. Plants from small seeds did not differ significantly in yield whether they were alternated with plants from large seeds or with plants from other small seeds.

There were no significant differences in yield between rows planted with 100 seeds of the same size and rows planted with 50 seeds each of two sizes alternated in the row.

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