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The Study of the Effect of Various Methods of Harvesting and Curing on the Color and Viability of Lima Bean Seed

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THE STUDY OF THE EFFECT OF VARIOUS METHODS OF HARVESTING AND CURING ON THE COLOR AND VIABILITY OF LIMA BEAN SEED

by

S. G. Date

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S. G. Date

INTRODUCTION

Many seedsmen have observed that lima bean seed of a variety like Early Thorogreen, which has green cotyledons, often fades in color during harvesting. This fading of color is known as bleaching. A variety which has green cotyledon and hence green seed, should retain this green color during harvest. Bleached seeds are likely to emerge slowly when planted. Also the final field stand from a planting of bleached seed is likely to be poor.

Some seedsmen require that bleached seed to classify as green must show at least 50 per cent good green color after it has been soaked overnight or an equivalent time.

Mr. George M. Fish, a seedsman, of Ben Fish and Sons Seed Company of Santa Barbara, California, wrote the following in a letter dated January 13, 1961 to Dr. Bruce M. Pollock of U. S. D. A.:

> Several reasons for excessive bleach are allowing the beans to stand in the field too long before cutting, careless windrowing, delay in harvesting past time when the plants are first dry enough, and occasionally the need for turning the windrows if a serious rain falls before the harvest. Another cause of excessive bleaching would be from irrigation and cultural practices that would split the pod seed, making it necessary to delay cutting until the second or third set of pods would be sufficiently filled.

As bleaching seems to be associated with harvesting and curing it seemed desirable to study experimentally some of the conditions encountered at harvest time to determine, if possible, which factors cause this undesirable appearance in lima bean seed.

Objectives

In order to achieve the following objectives five different experiments were conducted.

1. To determine under what conditions bleaching is most likely to occur. Factors studied included time of harvest, size of windrow or bunch, length of curing period and effect of shade, and the effect of sunlight on bleaching.

2. To determine the effect of rain—or simulated rain—at the time of harvest and curing. This particular study was made to check on Mr. Fish's statement, "In general we have found that rained-on lots will be of more uniform moisture content and will give better laboratory and field results as to germination and vigor, despite the increase in bleach."

3. To determine to what extent bleaching may be an inherited character under conditions favorable for its occurrence.

REVIEW OF LITERATURE

The problem of bleaching has apparently not been investigated to any extent in the past. References were found about the change of color from green to white, from pod formation to the maturity of the pod, but no studies have been conducted to see the effect of various methods of harvesting and curing on the seed color of the lima beans.

The results of the experiments conducted by Magruder (5) indicate that continued exposure to sunlight and weathering out of doors results in fading of green color of cotyledons to white or near white. These plants were grown in the greenhouse and the pods were exposed to sunlight after harvest. He also found that in several instances in the greenhouse, when the pods on the terminal clusters were allowed to remain for several weeks after they were dry enough to harvest, the beans in those pods almost faded to white. He concluded that dry green cotyledons seed when exposed to the sunlight after harvest fade in color.

In an experiment in Virginia to see the effect of fertilizer on the yield and quality of the lima bean, Carolus (2) concluded that the use of potassium in a mixture resulted in an increase in both the yield and the

quality. By quality he meant less bleached seed. He stated that potassium produced beans of high acre value because of its action of delayed whitening. In an experiment conducted to see the effect of pod to vine ratio on the quality of the lima bean he stated that pod to vine ratio was consistant for six days. The decrease in the ratio during the last two days of harvest show that the pods are drying at more rapid rate than that of the rest of the plant. The drying was associated with increase in percentage of white beans.

According to Thompson and Kelley (7), as the seed matures the starch content of the seed increases and the sugar content decreases. As a result the color of the seed changes from the dark green to pale green and ultimately to white, in some varieties.

Havis (3) found out that in most cases where twining occurs the pods on the terminal raceme reach maturity very early. Beans in these pods become over-mature and turn white.

According to Shoemaker (6) if the crop is harvested when most of the seeds are green then the terminal seed will be white. A few days of cloudy weather and rain will have the same effect as above. On the other hand dry conditions may make the cotyledon white before they reach the required size, this condition causes whitening over all the plant, rather than only on the raceme.

METHODS AND MATERIALS

Wasatch Bush and Early Thorogreen were the two varieties used in this study. Early Thorogreen had been divided into two lots—one green, the other bleached—by Ben Fish and Company of Santa Barbara, California. The separation had been made by running the seed through an electric eye machine. The variety Wasatch Bush was a local variety originated and developed by Dr. L. H. Pollard.

Lima beans were planted on the Utah Agricultural Experiment Station farm at Farmington on May 1, 1961. Fifteen days after planting the stand from the bleached seed of the variety Early Thorogreen was poor (Figures 1 and 2), but as the crop grew it was evident that sufficient quantities of seeds would mature in the heat of August and early September to permit conducting of all experiments.

In Experiments 2 and 3, when the seed matured, the plants were cut beneath the soil surface and windrowed. In Experiment 1 there was different harvest of seed, but later treatment was the same for all three experiments. When the pods and plants had dried sufficiently the crop was threshed. A small experimental bean thresher with two spike-toothed concaves was used. After cleaning, each lot of seed was run twice through an electric eye separator

(Gunsons Electric Sortex of England) in order to separate the green seed from the bleached. This separation was made through the courtesy of Northrup King and Company, Twin Falls, Idaho.

When the seed was returned to Logan, a visual inspection showed that the so-called bleached lots of seed actually still contained some green seeds. Hence it was decided that a further separation would have to be made. This was done as follows. A plywood board $\frac{1}{4}$ inch thick in which 100 holes $\frac{1}{2}$ inch in diameter had been bored was used. A sheet of white paper was glued to the underside. When a lamp was placed below this board the bleached seed appeared translucent, but the green seeds were definitely opaque, and let very little, if any, light through.

Out of each lot of green and bleached seed (as separated by the electric eye machine) a sample of 200 seeds was examined on the board just described. In general around 25 per cent of each bleached lot proved to be green. The number of bleached seeds in each green lot was usually quite small. Because the board had 100 holes percentages could be determined directly, and with such records the true percentage of bleached seed in each larger lot of seed could be calculated quickly.

The percentages of bleached and green seed for Experiments 2 and 3 were redetermined in this way.

Germination Tests

Germination tests were conducted in the greenhouse at Logan for Experiments 1, 2, and 3.

Seed from all the plots in these experiments was grown separately in metal flats. A lot of 100 seeds from each green separation and 100 seeds from each bleached separation was planted in a flat. This enabled an easier visual comparison to be made between the seedlings from the two types of seed.

Fine sand was used as the culture medium. Sand and the flats were sterilized each time before planting. Care was taken to plant the seed deep. Seeds were sown in moist sand. Watering was done as and when needed. The sand in the flats was kept at an optimum moisture level, i.e., it was never over-watered, neither was it allowed to become dry.

The germination counts were made of the eighth day after planting. Only those seedlings which were not rotted and were free from fungus attack were counted, while others were discarded.

The thermostat was kept at 70^{o} to 72^{o} F. throughout the growing period of the beans, but temperature might have fluctuated.

Experiment 1. To determine the effect of time of harvest

Randomized single row paired plots each 50 feet long were planted in six replications. Each plot was then

divided into two 25 foot sub-plots. As harvest time approached the early maturing pods in one sub-plot were hand picked. They were then placed in paper bags and stored until all of the beans were ready to be threshed. Hand picking was done when the pods turned brown and were dry enough for picking. The remaining half portion of the plot was left unpicked and kept as a control. Hand picking of the pods was done on August 23. The plants from these plots and those where hand picking was not done were harvested eight days later on August 31, and were piled in bunches.

In this experiment there were extremely few bleached seed in the hand picked lots of Wasatch Bush. It was, therefore, necessary to mix the replications in order to run the germination test. To be consistant in the test for Early Thorogreen, even though there were enough seeds, a portion of each replication was mixed to give one small lot of green and another of bleached seed for the germination test.

In the case of the late machine-threshed plots there was plenty of seed available in each variety, so the germination of the harvested seed from each plot could be determined separately (Figure 3).

Experiment 2. To measure the influence of shading and size of the bunch

The experiment had five replications, each 50 feet long, with three bunch sizes as main plots. Each of these

plots was then divided into 25 foot sub-plots. One half of the rows in each replications were planted with green seed of Early Thorogreen and the other half was planted with bleached of the same variety. At harvest time (August 31) plants were cut and piled into large, medium, and small bunches. Half of each plot planted with green seed of Early Thorogreen was shaded, with burlap nailed over the top of wooden frames.

Determination of the size of the bunch was somewhat approximate. For the large size of bunch only one bunch was made in a plot, for the medium size two bunches were made, and four bunches per plot were made for the small size. A wire was pushed down through each bunch into the soil in order to prevent the vines being scattered by the wind.

All the plots were threshed on September 5, and the seed was stored in cotton bags until it was processed with a 4-screen, 2-air suction separator. Later it was run through the electric eye machine in order to separate green seed from bleached. Germination tests were conducted in the greenhouse. The methods and material used in the study has been already discussed earlier in this section.

Experiment 3. To determine effect of rain at the time of harvest and threshing

Randomized split plots, each 50 feet long were planted. The experiment was conducted in six replications and there were 24 plots in all.

Green and bleached seed of the variety Early Thorogreen was planted. When the crop was ready to harvest it was cut and windrowed. Half the windrows of each variety were sprinkled (artifical precipitation) while others were not sprinkled. These unsprinkled windrows were covered with plastic when natural precipitation was anticipated; so they were never wet. Sprinkling was done three times in a period of eight days, with the help of a water tank mounted on the tractor trailer. Excessive soaking was avoided while sprinkling. The vines and pods were dry enough to thresh on October 8. The seed was kept in cotton bags, cleaned and later it was run through an electric eye seed separator.

The methods and materials for germination tests has been discussed earlier.

Experiment 4. To determine to what extent bleaching may be an inherited character

Wasatch Bush, as well as green and bleached seed of Early Thorogreen were used for this experiment. A single row 330 feet long of each variety was planted.

As the crop matured, 100 plants of approximately the same maturity were selected from each variety. These plants were pulled on September 2, and dried separately on the ground in the sun. When the pods and vines were sufficiently dry each plant was stored separately in paper bags. On September 10 the plants were threshed, and the

seed of each plant was run through the electric eye machine, after the initial cleaning.

Insufficient seed was obtained per plant to permit the germination test and at the same time we had to save seed for an inheritance study.

Experiment 5. To study the effect of sunlight on the viability of lima bean seed

For this experiment the bleached and green seed of Early Thorogreen, originally obtained from Ben Fish and Son, was planted. Both bleached and green seed was first exposed to the sun on metal screens for 1, 3, 5, and 7 days respectively (Figure 4). In addition those seeds which had been exposed 5 and 7 days respectively were sprinkled with water. After treatment, the seed of each lot was placed in paper bags and stored until it was planted in the field on August 3. There were 100 seeds of each of these 12 lots together with two unexposed lots of seeds were planted in five replications, making 70 separate plots.

Emergence and germination counts were made on August 14, 24, and 31, 1961.

The five experiments described in this section constitute the source of the data for the statistical analysis. Separate analysis was done for each experiment. The data were composed of per cent of bleached and green seed. One of the cardinal assumptions implicit in the analysis of

variance technique is that the observations should be normally distributed. The percentage data violates this assumption, because such data are multinominally distributed. So, in order to stabilize the variance, we had to make an arc-sine transformation, which makes the data normally distributed.

In the case of Experiments 4 and 5 instead of using an analysis of variance, the modified Karl Pearson minimum chi square analysis method was followed. Explanation for using this method is given in a few words below.

When the distribution of the population of interest is discreate, an analysis of variance test yields only approximate results. Hence, the proposal of modified Karl Pearson minimum chi square test was thought to be appropriate, because in this experiment the attribute involved was bleaching.

RESULTS AND DISCUSSION

The germination tests in the greenhouse of the harvested seed from Experiments 1, 2, and 3 failed to show any significant difference between green and the bleached seed. This might be the result of the temperature which was definitely higher than in the field.

Experiment 1

In the case of Experiment 1, early hand picking greatly decreased the amount of bleached seed (Table 1).

Production of the more desirable green seed was distinctly greater in early hand picked plots than those threshed later. This finding is supported by the analysis of variance (Appendix Table 1). The variety Wasatch Bush produced significantly less bleached seed in both harvests than did the variety Early Thorogreen (Table 1). There was no valid difference in the amount of bleached seed produced when the plots were threshed at the end of the season, between the remaining yield of the early hand picked plots and those where hand picking was not practiced (Table 1).

Table 1. The effect of time of harvest of lima bean seed on the production of bleached seed

		Amount of bleached seed
		Per cent
Plots early hand picked		
Plus late threshed		
Seed hand picked		
Wasatch		21.00a
Early Thorogreen		32.70b
	Average	$26.81b_1$
Seed harvested late		
Wasatch		40.90a
Early Thorogreen		50.30b
	Average	$45.60a_1$
Plot harvested late		
Wasatch		44.70a
Early Thorogreen		49.15b
	Average	$46.92a_1$

Means followed by the same letter are not significantly different from each other at the 1 per cent level. a and b should not be compared to a_1 and b_1.

Results of the germination test show that there was no marked difference in the germination of the green and bleached seed of the two varieties (Table 2).

Table 2. Effect of time of harvest on the germination of lima bean seed

Variety	Average per cent germination	
	Green	Bleached
	Per cent	Per cent
Plots early hand picked Plus late harvest Seed hand picked		
Wasatch	88.0	83.0
Early Thorogreen	51.0	51.0
Seed harvested late		
Wasatch	57.50	60.16
Early Thorogreen	43.33	43.66
Plot harvested late		
Wasatch	60.16	54.33
Early Thorogreen	45.83	47.33

Experiment 2

In the experiment to determine the effect of size of the bunch on the production of bleached seed, the data show that the amount of bleached seed produced was not associated with the size of the bunch. There seemed to be less bleaching in the medium size of bunch in both green and bleached

seed of the variety Early Thorogreen (Table 3), but an analysis of the data does not give any clear cut support to the statement. Neither was there any valid difference in the amount of bleached seed produced between the bunches cured in shade and those cured in sun (Table 3).

Results of the germination test show that there was no marked difference in the average per cent germination of the green and bleached seed of the variety Early Thorogreen obtained from this experiment (Table 4).

Analyses of variances are presented in Tables 2 and 3 of the appendix.

Experiment 3

In the experiment to study the effect of rain at the time of harvest and threshing on the production of the bleached seed it was observed that the windrows which were sprinkled produced significantly more bleached seed than those which were not sprinkled (Table 5). There was no valid difference in the amount of bleached seed produced between the green and the bleached seed of Early Thorogreen (Table 4 in the appendix).

This experiment proves that rain at the time of harvest will cause an increase in the amount of bleached seed. So a seedman should, if possible, protect his crop from rain. Rain even for a day might increase the percentage of bleached seed. Perhaps he could harvest earlier if rain is predicted in the area where seed is being grown.

Table 3. Effect of size of bunch and shading versus sun curing of lima beans on the percentage of bleached seed

Variety	Size of bunch	Amount of bleached seed cured by	
		Shade	Sun
		Per cent	Per cent
Early Thorogreen (Green)	Large	52.74	54.13
	Medium	42.71	51.90
	Small	51.94	54.63
Early Thorogreen (Bleached)	Large		51.67
	Medium		49.92
	Small		55.41
Average of all Early Thorogreen (Green lot)		49.11	53.55
Average of all sizes of bunch in sun	Large		52.90
	Medium		50.91
	Small		55.20

Note: There was no significant differences between the figures in this table. See text.

Table 4. Effect of size of bunch and shading on the germination of the lima bean seed

Variety	Size of bunch	Average per cent germination	
		Green	Bleached
	Cured in sun	Per cent	Per cent
Early Thorogreen (Green) Seed:	Large	49.0	49.60
	Medium	52.20	54.60
	Small	47.0	46.40
Early Thorogreen (Bleached) Seed:	Large	38.0	37.81
	Medium	45.20	45.60
	Small	44.60	45.00
	Cured under shade		
Early Thorogreen (Green) Seed:	Large	49.60	49.80
	Medium	49.40	48.60
	Small	49.60	52.40
Average of all bunches cured in sun:			
Green seed		49.32	50.23
Bleach seed		42.60	42.83
Average of all bunches cured under shade:			
Green seed		49.53	50.30

Table 5. Effect of sprinkling on the percentage of bleached seed in Early Thorogreen

Treatment (sprinkling)	Amount of bleached seed harvested from type of seed sown	
	Green	Bleached
	Per cent	Per cent
Sprinkled	53.33[a]	59.91[a]
Not sprinkled	45.53[b]	46.01[b]

Means by the same letter are not significantly different from each other. Different letter indicates significance at .01 level.

The germination test shows that there was no real difference in the germination of the green and bleached seed of the variety Early Thorogreen under both treatments (Table 6).

Table 6. Effect of sprinkling at the time of curing on the germination of the lima bean seed

Variety	Sprinkling and non sprinkling	Average per cent germination	
		Green	Bleached
		Per cent	Per cent
Early Thorogreen (Green) Seed:	Sprinkled	51.0	52.66
	Non sprinkled	51.0	54.83
Early Thorogreen (Bleached) Seed:	Sprinkled	48.33	58.66
	Non sprinkled	49.16	57.0

Experiment 4

In the experiment to find out if bleaching could be inherited character the following formula was proposed by Dr. N. Bohidar.

For the case where there was unequal number of seeds per plant (treatment).

$$X^2 = \frac{\frac{Eri^2}{ni} - \frac{(Eri)^2}{ni}}{(\frac{Eri}{Eni})\ (1 - \frac{Eri}{Eni})}$$

Where ri is number of green and bleached seeds associated with i th variety. n is number of seed involved in the variety.

The data show that Wasatch Bush and bleached seed of Early Thorogreen significantly produced more green seed than did the green seed of Early Thorogreen. No valid difference was observed in the variety Wasatch Bush and bleached lot of Early Thorogreen (Appendix Table 5).

Wasatch Bush and bleached seed of Early Thorogreen definitely produced less bleached seed than green seed of Early Thorogreen. There was no significant difference between Wasatch Bush (Appendix Table 5) and bleached seed of Early Thorogreen.

The data show that there was a definite difference in the amount of bleached seed produced by an individual plant (Appendix Table 6). Results of this study are tabulated in Tables 7, 8, 9, 10, 11, and 12.

The most interesting and probably the most important finding in Experiment 4 is the fact that the highest percentage (57.89) of green seed produced by the green-seeded planting of Early Thorogreen was lower than the lowest percentage (60.60) of green seed produced by the bleached seeded planting of the same variety (Tables 8 and 9).

Twenty plants of each variety which had high percentages of bleached seed and twenty plants with high percentages of green seed were selected for further study along this line.

Table 7. The twenty plants of Wasatch Bush showing the highest percentages of green seed in 1961

S. No.	Plant No.	Seed per plant		Total seed	Per cent green
		Green	Bleached		
1	48	84	17	101	83.15
2	94	48	12	60	80.0
3	92	38	9	47	80.85
4	95	70	18	88	79.54
5	15	70	18	88	79.54
6	79	35	10	45	77.77
7	62	58	17	75	77.33
8	24	57	17	74	77.02
9	94	98	30	128	76.56
10	51	58	18	76	76.31
11	75	80	26	106	75.47
12	26	72	24	96	75.00
13	80	86	29	115	74.78
14	52	117	41	158	74.05
15	89	59	21	80	73.75
16	1	65	23	88	73.86
17	47	130	48	178	73.03
18	63	35	13	48	72.91
19	45	80	30	110	72.72
20	88	61	23	47	72.61

Table 8. The twenty plants of bleached seed of Early Thorogreen showing the highest percentages of green seed in 1961

S. No.	Plant No.	Seed per plant		Total	Per cent Green
		Green	Bleached		
1	80	49	15	64	75.56
2	31	56	19	75	74.66
3	45	62	24	86	72.09
4	44	57	23	80	71.25
5	59	42	17	59	71.18
6	69	55	22	77	71.42
7	94	48	21	69	69.56
8	89	44	20	64	68.75
9	40	37	18	55	67.27
10	35	96	48	144	66.66
11	6	36	18	54	66.66
12	15	31	16	47	65.95
13	78	56	29	35	65.88
14	66	61	35	96	64.21
15	17	37	21	58	63.79
16	20	66	38	104	63.46
17	1	45	28	73	61.64
18	18	22	14	36	61.11
19	5	51	33	84	60.71
20	70	20	13	33	60.60

Table 9. The twenty plants of green seed of Early Thorogreen showing the highest percentages of green seed in 1961

S. No.	Plant No.	Seeds per plant		Total	Per cent green
		Green	Bleached		
1	43	55	40	95	57.89
2	41	30	22	52	57.69
3	63	19	15	34	55.88
4	64	12	10	22	54.54
5	26	15	13	28	53.57
6	73	73	83	156	46.79
7	48	35	40	75	46.66
8	35	26	30	56	46.42
9	15	12	14	26	46.15
10	2	49	58	107	45.79
11	3	27	32	59	45.76
12	59	21	26	47	44.68
13	53	40	50	90	44.44
14	86	15	19	34	44.11
15	39	21	27	48	43.75
16	50	54	70	124	43.54
17	69	32	44	76	42.10
18	1	25	35	60	41.66
19	93	20	28	48	41.66
20	44	35	46	81	40.20

Table 10. The twenty plants of bleached seed of Early Thorogreen showing highest percentages of bleached seed in 1961

S. No.	Plant No.	Seeds per plant		Total	Per cent bleached
		Green	Bleached		
1	7	4	57	61	93.44
2	83	7	38	45	84.44
3	93	8	37	45	82.22
4	22	6	27	33	81.81
5	12	4	14	18	77.77
6	25	8	27	35	77.14
7	52	12	36	48	75.00
8	38	15	42	57	73.68
9	19	13	33	46	71.73
10	68	12	30	42	71.42
11	76	28	70	98	71.42
12	8	16	38	54	70.37
13	82	29	58	87	69.87
14	27	18	41	59	69.49
15	32	8	18	26	69.23
16	33	20	41	61	67.21
17	4	16	35	51	68.62
18	24	18	39	57	68.42
19	51	24	52	76	68.41
20	72	14	27	41	65.85

Table 11. The twenty plants of Wasatch Bush showing the highest percentages of bleached seed in 1961

S. No.	Plant No.	Seed per plant		Total	Per cent bleached
		Green	Bleached		
1	56	2	11	13	84.61
2	54	6	26	32	81.25
3	46	8	30	38	78.94
4	73	5	16	21	76.19
5	59	5	14	19	73.61
6	57	12	28	40	70.00
7	42	14	32	46	69.56
8	31	4	9	13	69.23
9	14	36	69	105	65.71
10	43	13	23	36	63.88
11	71	6	10	16	62.50
12	78	36	57	93	61.29
13	12	38	60	98	61.22
14	40	32	48	80	60.00
15	37	15	22	37	59.45
16	16	50	72	122	59.01
17	76	32	45	77	58.44
18	66	20	28	48	58.33
19	36	16	21	37	56.76
20	93	17	20	37	54.05

Table 12. The twenty plants of green seed of Early Thorogreen showing the highest percentages of bleached seed in 1961

S. No.	Plant No.	Seed per plant		Total	Per cent bleached
		Green	Bleached		
1	32	1	16	17	94.11
2	24	2	24	26	92.30
3	63	3	23	26	88.46
4	90	9	59	68	86.76
5	20	2	10	12	83.33
6	66	5	24	29	82.75
7	57	14	37	51	82.24
8	55	5	23	28	82.14
9	56	5	22	27	82.14
10	60	9	41	50	82.00
11	38	11	47	58	81.03
12	96	11	52	63	81.00
13	19	4	16	20	80.00
14	22	5	20	25	80.00
15	38	10	39	49	79.59
16	18	7	26	33	78.78
17	71	21	71	92	77.17
18	42	6	20	26	76.92
19	58	10	32	42	76.19
20	4	8	24	32	75.00

Experiment 5

In this experiment original green and bleached seed of Early Thorogreen was exposed to sunlight to see the effect on germination. The statistical analysis proposed in this case was also a modified Karl Pearson minimum chi square method.

The following formula was proposed where there were an equal number of seeds per treatment.

$$X^2(t-1) = \frac{Eri^2 - \frac{(Eri)^2}{t}}{n\left(\frac{Eri}{T}\right) \quad (1 - \frac{Eri}{T}}$$

Where ri is the number of germinated green seed associated with the i th treatment.

t is the number of treatments

n is the total number of seed subjected to a particular treatment

T is the total of seeds involved in the whole experiment.

Germination of the exposed seed was significantly lower than non-exposed seed. Exposure even for one day definitely reduced the germination (Table 13). After three days exposure germination did not drop significantly even though it still continued to drop until the seventh day of exposure (Figure 5).

When lots of five and seven day exposure were sprinkled the germination was lowered to zero. As the average germination in this case was zero, statistical analysis was not conducted.

The farmer should avoid exposing the seed to sunlight after harvest because germination may be reduced a considerable extent.

Statistical results of this study are tabulated in Table 7 of the appendix.

Table 13. Effect of exposure to sunlight on the germination of the lima bean seed

Exposure in days	Average per cent Germination	
	Green	Bleached
Not exposed	60.0	27.0
1 day exposed	8.8	11.0
3 days exposed	0.8	3.4
5 days exposed	0.2	1.2
7 days exposed	0.6	0.6
Sprinkling		
5 days exposed and sprinkled	0.2	0.5
7 days exposed and sprinkled	0.0	0.0

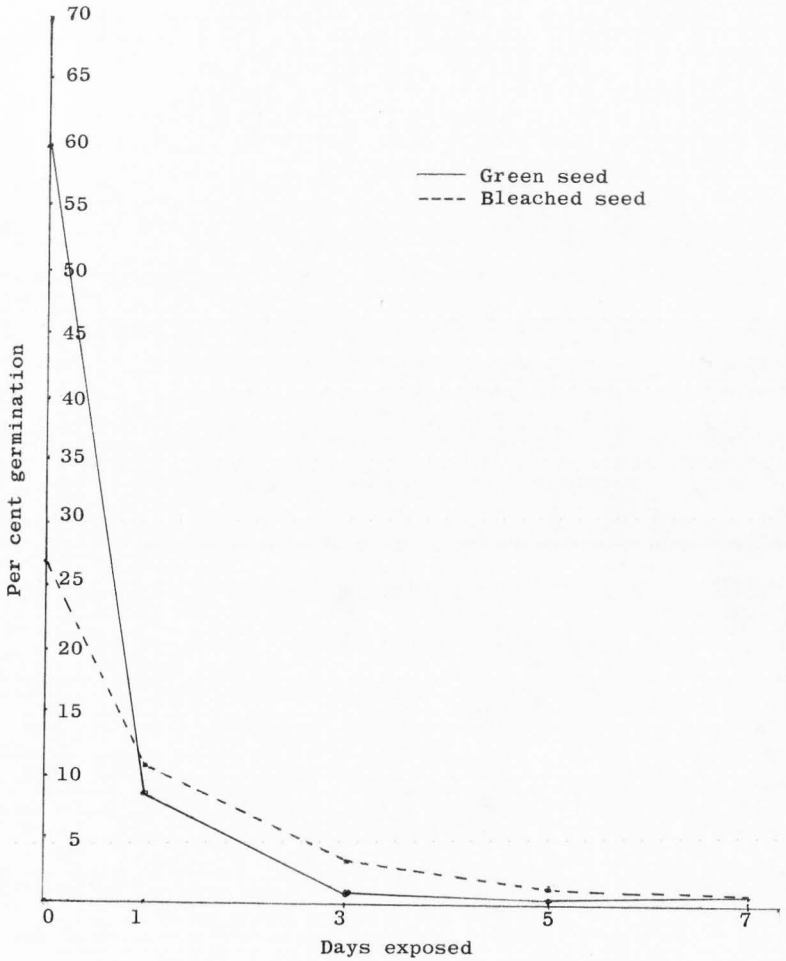

Figure 5. Effect of exposure to sun on the germination of the Early Thorogreen lima bean seed. July 2-9, 1961.

SUMMARY AND CONCLUSIONS

The five experiments described earlier were conducted Farmington Research Station, Farmington, Utah. Lima beans were placed in randomized split plots on May 1, 1961, threshed and after cleaning run through electric eye sorter to sort bleach from green. Germination test of each plot was conducted in the greenhouse.

Experiment 1

Early maturing pods when turned brown, were hand picked. Less bleaching was observed in the early hand picked plots than those threshed later. This was observed in Wasatch Bush as well as Early Thorogreen variety. Germination tests do not show any difference between green and bleached seed.

Experiment 2

After harvesting the crop was piled in three bunch sizes. For the large size of bunch only one bunch was made in a plot, 2 bunches were made for the medium size and four for the small size. No valid difference was observed between the different bunch sizes as far as production of bleached seed was concerned.

In the sub-experiment of shading it was observed that shading failed to influence the production of bleached seed. The emergence of green and bleached seed was alike.

Experiment 3

In this experiment simulated rain was created by means of sprinkling. The windrows were sprinkled three times in a period of eight days.

Care was taken to avoid excessive soaking of the windrows. Windrows which were not sprinkled were covered with plastic sheeting when natural precipitation was anticipated.

The data show that sprinkled plots definitely produced more bleached seed than unsprinkled plots, but germination tests are not in favor of showing any difference between green and bleached seed.

Experiment 4

There were three types of lima bean seed planted, Wasatch Bush, as well as green and bleached seed of Early Thorogreen. When the crop matured, 100 plants of approximately the same maturity were pulled and each plant was allowed to dry or cure separately on the ground.

After six days the crop was threshed and the seed of each plant placed in an individual bag. From each variety 20 plants showing high green and high bleaching were

designated. Varieties and individual plants differed statistically in production of bleached seed. Wasatch Bush and bleached seed of Early Thorogreen significantly produced more green seed per plant than green seed of Early Thorogreen.

Experiment 5

Green and bleached seed of Early Thorogreen was exposed to sunlight. For 1, 3, 5, and 7 days respectively. Half of each lot was sprinkled on the fifth and seventh day of exposure and half were left unsprinkled. In the case of green seed germination on one day exposure dropped down from 60 per cent to 8 per cent, in bleached seed it dropped down from 27 per cent to 11 per cent. The sprinkled lots failed to germinate at all.

APPENDIX

Appendix Table 1. Analysis of variance for hand picked and late threshed lima beans

Sources of variation	d.f.	S.S.	M.S.	F.	Level of Significance
Total	23	3148.74	136.90		
Replication	5	77.39	15.47		
Variety	1	338.55	338.55	106.2	**
R x V	5	15.92	3.18		
Treatment (Hand picking)	1	2628.80	2628.80	328.3	**
T x V	1	3.51	3.51	0.4153	NS
Error	10	84.55	8.45		

**Significant at 0.01 level
NS = Non significant

Appendix Table 2. Analysis of variance for size of bunch

Sources of variation	d.f.	S.S.	M.S.	F.	Level of Significance
Total	29	248.14	8.55		
Replication	4	31.50	7.87	2.39	NS
Variety	1	7.10	7.10	.002	NS
V x R	4	13.15	3.28		
Treatment (Size of bunch)	2	22.13	11.16	1.17	NS
T x V	2	28.66	14.33	1.50	NS
Error	16	152.41	9.52		

NS = Non significant

Appendix Table 3. Analysis of variance for shading and sun curing

Sources of variation	d.f.	S.S.	M.S.	F.	Level of Significance
Total	29	529.153	18.246		
Replication	4	38.557	9.639	0.4170	NS
Size of bunch	2	65.914	32.957	1.393	NS
B. size x rep	8	221.389	27.673		
Shade	1	13.707	13.707	0.8237	NS
B. size x shade	2	13.034	6.517		
Error	12	199.586	16.632	0.3917	NS

NS = Non significant

Appendix Table 4. Analysis of variance for sprinkling and non sprinkling

Sources of variation	d.f.	S.S.	M.S.	F.	Level of Significance
Total	23	690.43	30.01		
Replication	5	278.69	55.73	2.71	NS
Variety	1	73.78	73.78	3.59	NS
Rep x variety	5	102.54	20.50		
Treatment (sprinkling)	1	117.57	117.57	12.43	**
T x V	1	23.32	23.32	2.46	NS
Error	10	94.52	9.45		

**Significant at 0.01 level
NS - Non significant

Appendix Table 5. Chi-square test of goodness of fit for detecting bleaching differences of the varieties individual plants

Sources of variation	d.f.	Probability of success	X^2 Value	Significance
Difference in the green quality of the three varieties	2	.499	240.09	**
V_1 and V_3	1	.55	1.79	NS
V_2 and V_3	1	.4189	241.00	**
Difference in the bleaching quality of three varieties	2	.5076	10.00	**
V_1 and V_3	1	.4569	3.79	NS

**Significant at 0.01 level
NS = Non significant
V_1 = Wasatch Bush
V_2 = Green seed of Early Thorogreen
V_3 = Bleached seed of Early Thorogreen

Appendix Table 6. Chi-square test of goodness of fit for detecting differences in the individual plants

Variety	Sources of variation	d.f.	Probability of success	X^2	Level of significance
Wasatch Bush	Individual plants	99	0.5999	600.01	**
Bleached seed of Early Thorogreen	Individual plants	96	0.4846	509.79	**
Green seed of Early Thorogreen	Individual plants	95	0.3445	231.80	**

**Significant at 0.01 level

Appendix Table 7. Chi-square of goodness to fit to determine the effect of sunlight on the viability of lima bean seed

Sources of variation	d.f.	Probability of success	X^2	Level of Significance
1 Green lot exposure to sun all treatments	4	0.02812	196.30	**
1 day and 3 day	1	0.0001	51.05	**
2 Bleach lot exposure to sun all treatments	4	0.01728	57.89	**
1 day and 3 day	1			

**Significant at 0.01 level

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