STUDIES OF THE INFLUENCE OF VARIETY, SOURCE OF SEED, AND ENVIRONMENTAL EFFECTS ON THE GERMINATION AND EMERGENCE OF COMMON GARDEN BEANS (PHASEOLUS VULGARIS) AND LIMA BEANS (PHASEOLUS SP.)

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STUDIES OF THE INFLUENCE OF VARIETY, SOURCE OF SEED, AND ENVIRONMENTAL EFFECTS ON THE GERMINATION AND EMERGENCE OF COMMON GARDEN BEANS

(PHASEOLUS VULGARIS)

AND LIMA BEANS

(PHASEOLUS SP.)

By

Thomas Vivian Morris

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INTRODUCTION AND STATEMENT OF PROBLEM

Many varieties of common garden beans (Phaseolus vulgaris) and lima beans (Phaseolus sp.) germinate slowly or fail to germinate at low soil temperatures. Parasitic fungi in the soil may cause decay of the seed if germination is delayed. In order to prevent seed decay, the use of seed protectants has become a standard practice.

The specific purpose of these experiments was to determine to what extent varieties differ in their response to adverse weather conditions and whether through the use of chemical seed protectants these differential responses may be modified.

Because of the possible value to bean growers, a study of the various influences of variety and environmental effects on the germination of common garden beans and lima beans appears to be warranted.

REVIEW OF LITERATURE

Chemical treatment of bean seeds prior to planting is becoming a common practice among bean growers and gardeners. There has been considerable work by Crosier (3), Felix (5), Leukel (13), Cunningham and Sharvell (4), Hay (9), Horsfall (10), McNew (15), and others to indicate its importance in protecting seeds from the destructive effects of soil microflora. Recent trends in the use of chemical seed protectants tend to favor the use of chemical Tetrachloroparabenzoquinone (Spergon) on beans. Studies by Crosier (3) indicated that Tetrachloroparabenzoquinone gave good results when used on many garden beans and lima beans.

Hay (9) found that infestations of the mold genera Cladosporium, Penicillium, Rhizopus, and Alternaria caused decreased germination of bean seed. These experiments indicated that there was little difference in laboratory and field tests, and gave evidence that Uspulun and Sterocide treatments of the seeds tended to reduce the number of mold infested plants, both under laboratory and field conditions.

McGuffey (14) reported that coated lima beans failed to germinate, possibly due to injury received during the coating process. He also stated that germination percentage of coated wax and green bean seeds was slightly higher than that of the uncoated ones.

Kotowski (12) showed that the optimum temperature for germination and the fastest rate of emergence in beans was in the range of 70°-86° F. He also found that the time rate of production of seedlings at different temperatures agreed well with Van't Hoff's temperature coefficient. He stated that the course of biochemical change was related to the chemical composition of the seed.

Goss (7) indicated in his work on the germination of Fordhook lima beans that, because of the cracking of the seed coats of many seeds used in his experiment, fungi in the soil more readily attacked them and caused a lower percentage of germination.

Crocker (2) reported that seed coats which excluded oxygen caused delay in germination. He also found that in nature, growth of the delayed seeds came about through the disintegration of the seed coat structures by a longer or shorter exposure to germinative conditions, and that the length of delay depended upon the persistence of the structures.

Harrington (8) stated that by using alternating temperatures (15-20° C., 15-25° C., 15-30° C., 20-25° C.) on the following seeds--carrots, cucumbers muskmelons, millet, onions, watermelon, timothy, sorghum, parsley, red top, beets, upland cotton, cowpea, beans, peas, and vetch--all germinated equally well with all alternations. He also found that the smallest number of days required for the production of bean seedlings in soil was four days and that beans produced the first seedlings in the smallest number of days during the moderately warm weather of May or during the latter half of June.

Clark (1) in his work on germination in onion seeds found that the actual stand of onion plants in the field was not as high as in the laboratory germination due to adverse weather conditions in the field.

Seavers and Clark (17) have done a considerable amount of work on conditions favoring the development of micro-organisms in heated soils, and have concluded that the increased concentration of the soil solution after heating favored fungus growth.

Johnson (11) stated that practically all soils when sterilized in the ordinary manner by heat at temperatures approximating 100-115° C. produced temporary retardation in seed germination and plant growth followed by increased rate of growth. He showed that germination in beans increased after the soil was aerated for 90 hours or more after sterilization. However, he stated that the _Solonaceae_ and _Leguminoseae_ were quite susceptible to the injurious action of high soluble salts. But with seeds resistant to the toxic action, marked acceleration of the rate of germination may result from heating soils. He further stated that on heating a soil to different temperatures, a gradual increase in toxicity usually occurred to seed germination and to early plant growth which reached its maximum at 250° C., but gradually decreased to practically no toxicity on soils heated to 350° C. or above.

Walker (22) stated that for the common bean (Phaseolus vulgaris), a satisfactory treatment has not been perfected as yet for the chief seed borne pathogens: bacterial blight (Xanthomonas phaseoli); bacterial wilt (Corynebacterium flaccumfaciens); and anthracnose (Colletotrichum lindemuthianum). He also reported that Arasan and Spergon have been adopted widely as a protectant on sweet corn, onions (pelleted), lima beans, and other vegetables.

Aeration of the soil has an important influence on germination, and is related to soil texture, moisture content of the soil, and the oxygen requirement for germination of seed of different kinds of plants (21). Shull (18) found that a rise in temperature lowered the oxygen minimum needed by Xanthium for germination, and suggested that this might be due to the increase in anaerobic respiration at higher temperatures.

Munn (16) reported that seeds that showed weakened vitality in laboratory tests gave poor results in the field. However, Fuhr (6) concluded from her experiments that soil is the best medium for germination of all seeds.

Toole, Miles, and Toole (21) conducted germination experiments in which they used soils containing varying quantities of moisture. They reported that germination was significantly poorer at 60% moisture than at lower moisture levels. They also showed that germination in light sandy soils was greater than on blotters.

Whetzel (23) found that in saturated soils there was a greater infection by damping-off organisms than in unsaturated soils and that Pythium debaryanum requires a temperature between 70° and 86° F. for infection and optimum development.

METHODS AND MATERIALS

Experiment I

The varieties used in these studies were obtained from each of the following sources: Ferry-Morse Seed Company; Cornell Seed Company; Associated Seed Growers, Inc.; and Rogers Brothers Seed Company, hereafter referred to as sources A, B, C, and D, respectively.

The following varieties of beans were used:

Snap Beans	Lima Beans
Idaho Refugee	Peerless
Red Valentine	Henderson Bush
Black Valentine	Thorogreen
Tendergreen	
Rival	
Pencil Pod Black Wax	
Brittle Wax	

The object of this experiment was to study the effect of variety and source, incubation temperature, soil sterilization, seed treatment, and soil moisture level on germination and emergence. The ten varieties from four sources were arranged in a complete factorial design with four temperatures (40° F, 50° F, 60° F and 70° F), in both sterilized and unsterilized soil, following treatment of half the seed with tetrachloroparabenzoquinone, and in two moisture levels (60% and 70% of water holding capacity). Thus, there were 1280 distinct treatments.

Half the seeds of each of the 10 varieties from each of the four sources was treated with tetrachloro-parabenzoquinone, while the other half was left untreated. Half the treated and untreated seeds were placed in sterilized mineral soil which was later maintained at 60% and 70% moisture of the water holding capacity, and the other half was placed in unsterilized mineral soil to be maintained at the same two moisture levels. All were germinated at four different temperatures.

The designated amount of soil was sterilized in live steam for three hours, after which it and the unsterilized soil was allowed to stand in baskets in the greenhouse for approximately 12 days. At the end of this time the moisture content of both soils was determined by weighing out 100 grams of each soil and drying in an oven. Then the soil was weighed again with the difference between initial weight and the final weight being calculated as the moisture content.

The moisture holding capacity was determined as follows:

One hundred grams of each (sterilized and unsterilized) oven dried soils were placed into different suction funnels on top of filter paper and the funnels were allowed to stand in small beakers filled with water until the soil was completely saturated with water. After this, the funnels were removed from the water and all free water allowed to drain by gravity. The soil was again weighed and the difference between the initial weights and final weights represented percent water holding capacity.

After these procedures were carried out, a flat each, of sterilized and unsterilized soil was weighed to determine the weight of soil in a flat, then the moisture content was subtracted from the total weight to determine the weight of soil. The remainder was then multiplied by the percent moisture holding capacity. The product was then multiplied by the percentage moisture desired for each soil.

Results are shown in Table I.

TABLE I

DATA ON CALCULATIONS OF THE AMOUNT OF WATER

ADDED TO FLATS

Total wt. of soil per flat gms.	Moisture content %	Wt. of Moisture gms.	Moisture holding capacity %	Moisture holding capacity gms.	Amt. water added for 70% * ml.	Amt. water added for 60% * ml.
Sterilized Soil						
13608	5	680.4	72	9309.16	6,516	5,585
Unsterilized Soil						
12247	3	367.4	72	8,553	5,987	5,131

* Percent of the moisture holding capacity

The seeds were germinated in wooden flats 15" X 21" X 4" inside dimensions. The soil in the flats was firmed to within 1½ inches of the top with a marking board. After each lot of seed had been treated at the rate of 2 ounces of chemical per bushel of seed, 10 rows of 20 seeds each (1 row per variety) were planted in sterilized and unsterilized soil with a flat (of each sterilized and unsterilized soil) representing a source. An equal amount of untreated seeds were planted in both sterilized and unsterilized soil.

After the seeds were placed on top of the bottom layer of soil, enough water was added to the soil in half of the flats to bring the moisture content up to 70% of the water holding capacity, and to the other half was added enough water to bring the moisture content up to 60% of the water holding capacity. The seeds were then covered with 1½ inches of soil and water was again added for the desired moisture.

The flats in which the seeds had been planted were than placed in four walk-in type controlled temperature chambers, in which the temperature was maintained at 40°, 50°, 60°, and 70° F. respectively, with a relative humidity of approximately 85%.

Thirty-two flats were stacked in each chamber in groups of four, and the stacking sequence was rotated every thirty-six hours. The flats placed in the 70°F. chamber were allowed to remain for five days, after which they were moved to the greenhouse. Severe etiolation of the seedlings resulted when they remained in the chamber for 10 days. The flats placed in the 40°, 50°, and 60°F. incubators were allowed to remain for ten days after which they were moved to the greenhouse, where they were allowed to remain 10 days. They were completely randomized in the greenhouse. Greenhouse temperatures averaged approximately 75±5°F. during the day and approximately 60±5°F. during the night.

To obtain a weighted average of the number of days to emergence, the number of seedlings that emerged each day was multiplied by the number of days to emergence, and the sum of these products was divided by the total number of seedlings that emerged.

Experiment II

The object of this experiment was to study the influence of variety, source of seed, incubation temperature, and seed treatment on germination and emergence in a sterile artificial medium.The medium selected was expanded mica. The ten varieties from four sources were arranged in a complete factorial design with four temperatures

(40°, 50°, 60°, and 70° F.) following treatment of half of the seed with tetrachloroparabenzoquinone. In this experiment, 32 flats were planted, and contained a total of 320 distinct treatments.

The seeds used in 16 of these flats were treated with the seed protectant at the rate of 2 ounces per bushel, and an equal amount was left untreated. For each of the four temperatures 8 flats were planted (4 treated and 4 untreated) with each flat representing a source in which 10 varieties were planted (1 variety per row) as in experiment I.

A one and one-half inch layer of expanded mica was placed in each of the thirty-two flats and saturated with water, after which ten rows at two inch intervals were marked off with a marking board. The seeds were planted on top of the expanded mica, again using 20 seeds per row. After the seeds were planted they were covered with one inch of expanded mica and the mica moistened with water.

Eight of the 32 flats were placed in each of the four walk-in type controlled temperature chambers, as in experiment I, and allowed to remain for the following lengths of time:

Temperature	Period in temperature chamber
70°F.	5 days
50°F.	10 days
60°F.	10 days
70°F.	10 days

The flats were then moved into the greenhouse for the remaining ten days of the germination period, where they were watered daily and where daily emergence counts were made. The average days to emergence were calculated as in experiment I.

Experiment III

The object of this experiment was to study the influence of variety, source of seed, seed treatment, and planting date under field conditions on germination and emergence. Arrangement was such as to have all treatments, except those including seed treatments in randomized blocks. Each source of each variety consisted of a three row plot and each of the three rows was a different seed treatment, thus constituting a plot split.

This experiment was conducted on the experimental plots of the Department of Horticulture at East Lansing.

The soil on these plots is Hillsdale sandy loam. The same varieties from the same sources as used in the greenhouse experiment were used in the field experiments. One third of the seeds used in this experiment were untreated Checks; one third were treated with 2 ounces of tetrachloroparabenzoquinone per bushel; and the remaining third were coated with the following materials on the indicated sources:

	Coating materials*
	1.5% Tetrachloroparabenzoquinone
	1.5% Tetramethylthiuramdisulphide
Source A and B	5.0% Superphosphate
	4.0% Parathion
	fly ash, feldspar, methylcellulose
	1.5% Tetrachloroparabenzoquinone
	1.5% Tetramethylthiuramdisulphide
Source C and D	4.0% Superphosphate
	3.0% Methoxychlor
	fly ash, feldspar, methylcellulose

* Per 100 grams of seeds

One hundred seeds were planted $1\frac{1}{2}$" deep in rows 10 feet long and 3 feet wide, with each tier containing the samples from one source.

The first planting was made May 14, 1949. During the first five days after planting, soil temperatures averaged $64 \pm 10^{\circ}$F. Temperatures averaged $68 \pm 5^{\circ}$F. for the remaining 15 days of observation. The second planting was made May 30, 1949. Soil temperatures averaged $70 \pm 8^{\circ}$F. for the duration of the experiment.

The rate of emergence of the seedlings was observed for 20 days for the first planting and 15 days for the second planting and the average days to emergence calculated as in experiments I and II.

EXPERIMENTAL RESULTS

Experiment I

The Influence of Variety, Source of Seed, Incubation Temperature, Soil Sterilization, Seed Treatment, and Moisture Level on Germination and Emergence of Common Garden Beans (Phaseolus Sp.) and Lima Beans (Phaseolus Sp.).

The data obtained with respect to percent germination of the 1280 lots of seed was analyzed by the method of analysis of variance.[19] Table II is a summary table of the analysis for Experiment I. Second order and higher interactions are placed in the error term.

The data on percent germination are arrayed in Tables III to XXVIII, respectively, and the data on average number of days to emergence are arrayed in Tables XXVIIIA and XXVIIIB.

Based on all factors, the relative percent of all lima beans was significantly lower than that of the common garden beans with lowest percent germination in the variety Peerless. However, three varities of common beans--Brittle Wax, Rival, and Tendergreen--showed a significantly lower percentage germination than the others. Black Valentine and Pencil Pod Black Wax germinated significantly better than any of the other varieties. Table III.

TABLE II

PERCENT GERMINATION IN FLATS OF SOIL

ANALYSIS OF VARIANCE SUMMARY

Source of Variance	D.F.	Sums of Squares	Mean Square	F.Value	Sig.
Total	1279	47,496.07			
Variety	9	10,618.18	1,179.09	91.04	**
Temperature	3	2,201.39	733.796	56.66	**
Sources	3	405.87	135.29	10.44	**
Seed Treatment	1	1,042.21	1,042.21	80.47	**
Soil Sterilization	1	86.44	86.44	6.67	**
Soil Moisture	1	7,464.29	7,464.29	576.39	**
V x T	27	1.713.86	63.476	4.9	**
V x S	27	1,341.55	49.687	3.83	**
V x ST.	9	2,496.85	277.42	21.42	**
V x S.S.	9	140.74	15.63	1.2	N.S.
V x SM	9	1,816.99	201.88	15.58	**
T x S	9	354.93	39.54	3.03	**
T x ST.	3	274.18	91.393	7.05	**
T x S.S.	3	69.68	23.226	1.7	N.S.
T x S.M.	3	839.40	279.8	21.60	**
S x ST.	3	295.02	98.34	7.55	**
S x S.S.	3	589.83	196.61	15.18	**

TABLE II (Cont.)

Source of Variance	D.F.	Sums of Squares	Mean Square	F.Value	Sig.
S x S.M.	3	468.76	156.25	12.06	**
ST x S.S.	1	207.40	207.40	16.01	**
ST x S.M.	1	61.12	61.12	4.71	*
S.S.x S.M.	1	108.75	108.75	8.39	**
Error	1150	14,900.63	12.95		

* Significant at 5% level

** Highly significant at 1% level

TABLE III

INFLUENCE OF VARIETY ON THE PERCENT GERMINATION OF COMMON GARDEN AND LIMA BEANS

Variety	Idaho Refugee	Red Valentine	Black Valentine	Tendergreen	Rival	Pencil Pod Black Wax	Brittle Wax
Percent Germination	45.89*	45.03	49.84	41.91	33.39	50.81	26.79
Variety	Peerless	Henderson Bush	Thoro-green				
Percent Germination	5.62	25.93	17.45				

Difference required for significance 5%--4.4, 1%--5.8
* Each figure is an average of 128--20 seed samples

TABLE IV

INFLUENCE OF INCUBATION TEMPERATURE ON THE PERCENT GERMINATION OF BEANS

Incubation Temperature	40° F.	50° F.	60° F.	70° F.
Percent Germination	23.59*	36.44	35.52	41.51

Difference required for significance: 1% level-3.6%
5% level-2.78
*Each figure is an average of 320--20 seed samples

The influence of incubation temperature on the overall percent germination of the beans used in this experiment is expressed in Table IV which indicates the relative influence of each of the four temperatures. The percent germination was highest at the highest incubation temperature with the lowest incubation temperature giving the lowest percent germination. There was little difference between percent germination at 50° F and 60° F.

The overall average percent germination of those bean seeds obtained from sources C and D was higher than the seeds obtained from source A and B. (Table V)

Seed treated with tetrachloroparabenzoquinone germinated on an overall average of 10% higher than the untreated ones. (Table VI)

There was a slight but highly significant difference in the overall average percent germination of seeds in sterilized soil as compared with the overall average percent germination of seeds in unsterilized soil, Table VII.

As shown in Table VIII, the overall average percent germination was twice as great in the soil with a moisture level of 61% of the water holding capacity than with that of 70%.

Table IX expresses the relative influence of

TABLE V

INFLUENCE OF SOURCE ON THE PERCENT GERMINATION OF BEANS

Source	A	B	C	D
Percent Germination	31.1*	32.05	38.1	34.2

Difference required for significance 1% level-3.60
5% level-2.78

* Each figure is an average of 320-20 seed samples

TABLE VI

INFLUENCE OF SEED TREATMENT ON THE GERMINATION OF BEANS

Seed treatment	Treated with Spergon	Untreated
Percent germination	40.08*	29.7

TABLE VII

INFLUENCE OF SOIL STERILIZATION ON PERCENT GERMINATION

OF BEANS

Soil sterilization	Sterilized Soil	Unsterilized Soil
Percent germination	35.4*	32.8

TABLE VIII

INFLUENCE OF SOIL MOISTURE ON PERCENT GERMINATION OF BEANS

Soil Moisture	70%	60%
Percent germination	22.27*	46.5

Required for significance: 1% level-2.59

* Each figure is an average of 640-20 seed samples

TABLE IX

INFLUENCE OF INCUBATION TEMPERATURE ON THE PERCENT GERMINATION OF 10 VARIETIES OF BEANS

Variety	Incubation Temperature				Average for Variety
	40° F.	50°F.	60°F.	70°F.	
	Percent Germination				
Idaho Refugee	38.12*	52.03	42.34	51.09	45.89
Red Valentine	21.56	49.68	54.37	54.53	45.03
Black Valentine	32.5	55.62	56.71	54.53	49.84
Tendergreen	31.09	41.56	49.53	45.46	41.91
Rival	25.62	35.93	35.46	36.56	33.39
Pencil Pod Wax	33.59	64.06	52.5	53.12	50.81
Brittle Wax	16.71	28.59	32.18	29.68	26.79
Peerless	1.87	2.65	2.03	15.93	5.62
Henderson Bush	23.28	17.5	17.03	45.93	25.93
Thorogreen	11.56	16.84	13.12	17.45	17.45
Av. for Temp.	23.59	36.44	35.52	41.51	

Difference required for significance (V x T interaction)
1% level-11.11%
5% level- 8.82%

* Each figure is an average of 32-20 seed samples

incubation temperature on the percent germination of the 10 varieties of beans. The lowest percent germination was obtained with respect to all snap bean varieties when they were incubated at 40° F. Two varieties--Idaho Refugee and Pencil Pod Black Wax--gave a significantly better germination at 50° F. than at 60° F. Peerless and Henderson Bush lima beans germinated significantly better at 70° F. than at any other temperature, while temperature had no significant influence on the germination of Thorogreen lima beans.

The figures in Table X indicate that varieties from different sources differed in relative percent germination. Five of the varieties from source C germinated significantly better than those obtained from the other three sources.

Seed treatment markedly improved the germination of Thorogreen, Brittle Wax, and Tendergreen and significantly increased the germination of all but Henderson Bush, Peerless, and Pencil Pod Black Wax. (Table XI)

Soil sterilization improved the germination of Idaho Refugee and Brittle Wax, but did not significantly improve germination of any of the other varieties, Table XII.

The relative influence of soil moisture on the percent germination of each of the 10 varieties of beans

TABLE X

INFLUENCE OF SOURCE OF SEED
ON THE PERCENT GERMINATION
OF 10 VARIETIES OF BEANS

Variety	Source				Average for Variety
	A	B	C	D	
	Percent Germination				
Idaho Refugee	40.78*	43.75	52.18	46.87	45.89
Red Valentine	55.46	31.56	41.71	51.4	45.03
Black Valentine	46.4	41.56	60.15	51.25	49.84
Tendergreen	35.15	37.18	49.21	46.09	41.9
Rival	29.68	35.31	33.12	35.46	33.39
Pencil Pod Wax	45.93	47.81	51.09	58.43	50.81
Brittle Wax	20.46	27.18	27.03	32.5	26.68
Peerless	2.81	2.96	12.18	4.53	5.62
Henderson Bush	27.34	32.34	29.53	14.5	25.92
Thorogreen	7.03	20.93	25.46	14.37	16.94
Av. for Source	31.0	32.05	38.1	34.2	

Difference required for significance--5% level-8.8%

* Each figure is an average of 32-20 seed samples

TABLE XI

INFLUENCE OF SEED TREATMENT ON THE PERCENT GERMINATION OF 10 VARIETIES OF BEANS

Seed Treatment	Variety										
	Idaho Refugee	Red Valentine	Black Valentine	Tendergreen	Rival	Pencil Pod Black Wax	Brittle wax	Peerless	Henderson Bush	Thorogreen	Average for Treatment
	Percent Germination										
Treated with Spergon	49.06*	50.7	53.59	49.53	37.57	52.65	39.29	6.64	27.96	33.9	40.0
Untreated	42.73	42.34	43.98	34.29	29.21	48.98	14.29	4.6	23.9	12.73	29.7
Average for Variety	45.8	46.5	49.6	41.9	33.3	50.8	26.7	5.6	25.9	19.5	

Difference required for significance: (V x ST interaction)
1% level-8.2%
5% level-6.28%

*Each figure is an average of 64-20 seed samples

TABLE XII

INFLUENCE OF SOIL STERILIZATION ON PERCENT GERMINATION

OF 10 VARIETIES OF BEANS

Soil Sterilization	Variety										
	Idaho Refugee	Red Valentine	Black Valentine	Tendergreen	Rival	Pencil Pod Wax	Brittle Wax	Peerless	Henderson Bush	Thoregreen	Average for S.S
	Percent Germination										
Unsterilized Soil	41.09*	47.26	51.71	40.62	33.82	50.23	21.71	2.34	25.15	15.23	32.8
Sterilized Soil	50.7	42.81	47.96	43.20	39.96	51.4	31.87	8.9	26.71	18.67	35.4
Average for variety	45.8	46.5	49.6	41.9	33.3	50.8	26.7	5.6	25.9	19.5	

Required for significance: (V x S.S. Interaction)
1% level-8.2%
5% level-6.28%

*Each figure is an average of 64-20 seed samples

used in the experiment is shown in Table XIII, which indicates that all varieties except Peerless germinated significantly better with 60% soil moisture than with 70% soil moisture. However, both moisture levels appear to be higher than optimum as indicated by the work of (Toole, Miles, and Toole) who reported better germination at soil moistures less than 60% of the water holding capacity.

The influence of incubation temperature on seed obtained from different sources as shown in Table XIV indicate that the responses were variable.

The response to seed treatment was greater at the 50° F. incubation temperature than at all other temperatures used, as indicated in Table XV. The influence of soil sterilization on the average percent germination at four temperatures is expressed in Table XVI. Significant increases in average percent germination in sterilized soil over unsterilized soil were found at 40 and 50° F.

Table XVII expresses the influence of soil moisture at different incubation temperatures on the percent germination. The most pronounced decrease in germination at 70% moisture as compared with 60% moisture was at 70° F.

Table XVIII expresses the influence of seed treatment on seed from each of the four sources and indicates that seed source C gave greater response to treatment than seed from other sources.

TABLE XIII

INFLUENCE OF SOIL MOISTURE ON PERCENT GERMINATION

OF 10 VARIETIES OF BEANS

Soil Moisture	Variety										
	Idaho Refugee	Red Valentine	Black Valentine	Tendergreen	Rival	Pencil Pod Wax	Brittle Wax	Peerless	Henderson Bush	Thorogreen	Average for Soil Moisture
	Percent Germination										
70% Moisture	34.76*	27.18	33.28	25.62	20.07	32.5	11.48	3.9	20.07	13.04	22.27
60% Moisture	56.95	62.89	67.2	58.20	46.71	69 14	42.1	7.37	30.93	23.39	46.5
Average for Variety	45.8	46.5	49.6	41.9	33.3	50.8	26.7	5.6	25.9	19.5	

Required for significance: (V x SM Interaction)
1% level-8.2%
5% level-6.28%

*Each figure is an average of 64-20 seed samples

TABLE XIV

INFLUENCE OF INCUBATION TEMPERATURE
ON PERCENT GERMINATION
OF BEAN SEEDS FROM FOUR SOURCES

	Incubation Temperature				
	40° F.	50° F.	60° F.	70° F.	Av. for Source
Source	Percent Germination				
A	21.06*	25.43	36.87	39.5	31.0
BB	25.81	35.37	29.56	37.5	32.0
C	24.37	42.31	39.56	46.43	38.1
D	21.56	43.75	36.12	42.62	34.2
Average for temperature	23.2	36.4	35.5	41.5	

Difference required for significance:(S x T Interaction)
1% level-8.2%
5% level-6.28%

*Each figure is an average of 80-20 seed samples

TABLE XV

INFLUENCE OF SEED TREATMENT AT DIFFERENT INCUBATION TEMPERATURES ON PERCENT GERMINATION OF BEANS

	Incubation Temperature				
	40°F.	50°F.	60°F.	70°F.	Average
Seed treatment	Percent germination				
Untreated seeds	21.06*	30.6	32.59	37.31	
Treated seeds	26.12	44.62	38.4	45.71	
Diff: Treated -Untreated	5.06	14.02	4.81	8.4	

Difference required for significance: (T x ST Inter-action)
1% level-3.6%

TABLE XVI

INFLUENCE OF SOIL STERILIZATION ON PERCENT GERMINATION OF BEANS AT FOUR INCUBATION TEMPERATURES

Soil Sterilization	Percent Germination				
Unsterilized Soil	21.5*	33.5	34.6	41.9	32.8
Sterilized Soil	25.5	38.9	36.4	41.1	35.4
Diff: Sterilized -Unsterilized	4.0	4.3	1.8	-.8	2.6

Difference required for significance:
(ST x T Interaction) 1% level-3.6%
5% level-2.78&

*Each figure is an average of 160-20 seed samples

TABLE XVII

INFLUENCE OF SOIL MOISTURE AT DIFFERENT TEMPERATURES ON THE PERCENT GERMINATION OF BEANS

	Incubation temperature			
	40° F.	50° F.	60° F.	70° F.
Soil Moisture	Percent Germination			
70%	18.34*	23.31	21.34	25.62
60%	28.84	49.18	49.71	57.4
Diff. 60% - 70%	10.50	25.87	28.37	31.78

Difference required for significance:SM x T Interaction 1% level-3.6%

*Each figure is an average of 160-20 seed samples

TABLE XVIII

INFLUENCE OF SEED TREATMENT FOR DIFFERENT SOURCES OF SEED OF BEANS

	Source			
	A	B	C	D
Seed Treatment	Percent Germination			
Treated with Spergon	32.35*	35.84	46.43	40.46
Untreated	28.96	28.28	29.9	30.68
Diff. Treated -Untreated	3.39	7.56	16.53	9.78

Difference required for significance: (S x ST. Interaction) 1% level-3.6%
5% level-2.78%

*Each figure is an average of 160-20 seed samples

The response of seed from each of the four sources to soil sterilization is expressed in Table XIX, which indicates that responses were significant in sources B and C and not significant in A and D.

Table XX expresses the influence of soil moisture level on the average percent germination of bean seed from each of the four sources. All sources germinated better in soil with a moisture level of 60% than with 70% with a greater increase in percent germination being obtained in seed from source C.

There was an overall increase in percent germination of seed treated with Tetrachloroparabenzoquinone and planted in sterilized soil over the untreated ones. Table XXI.

Table XXII indicates the influence that seed treatment had on the overall percent germination of seed planted at different moisture levels. The response to treatment at both moisture to treatment was practically the same.

Table XXIII expresses the influence of soil moisture levels on percent germination in sterilized and unsterilized soil. A higher percent germination occurred in unsterilized soil with a moisture level of 70% than in unsterilized soil with the same moisture level. The percent germination in sterilized soil was greater than in unsterilized soil at the 60% moisture level. However, germination

TABLE XIX

INFLUENCE OF SOIL STERILIZATION ON PERCENT GERMINATION OF BEAN SEEDS FROM DIFFERENT SOURCES

	Source			
	A	B	C	D
Soil Sterilization	Percent Germination			
Unsterilized Soil	31.15*	29.56	35.84	35.59
Sterilized Soil	31.06	34.87	40.5	36.34
Diff: Sterilized - Unsterilized soil	-.09	5.31	4.66	.75

Difference required for significance:(S x S.S.Interaction) 1% level-3.6%
5% level-2.78%

TABLE XX

INFLUENCE OF SOIL MOISTURE ON THE PERCENT GERMINATION OF BEAN SEEDS FROM DIFFERENT SOURCES

Soil Moisture	Percent Germination			
70%	18.21*	21.12	22.09	26.87
60%	43.59	44.18	53.62	44.21
Diff. 60% -70%	25.38	23.06	31.53	17.34

Difference required for significance: 1% level-3.6%
5% level-2.78%
(S x S.M.Interaction)

* Each figure is an average of 160-20 seed samples

TABLE XXI

INFLUENCE OF SEED TREATMENT IN STERILIZED AND UNSTERILIZED SOIL ON THE GERMINATION OF BEANS

	Seed Treatment	
	Treated	Untreated
Soil Sterilization	Percent Germination	
Sterilized Soil	34.34*	23.20
Unsterilized Soil	28.33	24.33

Difference required for significance:
(ST x S.S. Interaction) 1% level-2.59%
5% level-1.96%

TABLE XXII

EFFECT OF SEED TREATMENT AT DIFFERENT MOISTURE LEVELS ON THE PERCENT GERMINATION OF BEANS

	Spergon Treated	Untreated
Percent Moisture	Percent Germination	
60%	53.05*	42.95
70%	27.84	16.46

Difference required for significance:
(ST x S.M. Interaction)
1% level-2.59%
5% level-1.96%

* Each figure is an average of 320-20 seed samples

TABLE XXIII

INFLUENCE OF SOIL MOISTURE IN STERILIZED AND UNSTERILIZED SOIL ON THE PERCENT GERMINATION OF BEANS

	Soil Sterilization	
	Unsterilized Soil	Sterilized Soil
Percent Moisture	Percent Germination	
70%	22.37*	21.93
60%	43.46	49.1

Difference required for significance:

(S.S.x S.M. Interaction)

1% level-2.59%

5% level-1.96%

*Each figure is an average of 320-20 seed samples

in both soils was higher at the 60% moisture level than at the 70% level.

The average number of days to emergence as expressed in Tables XXIII (A) and (B) was practically the same with beans incubated at 40° and 50° F. while the average number of days to emergence of beans incubated at 60° F was 4 days less than those incubated at 40° and 50° F.

Seeds treated with Tetrachloroparabenzoquinone germinated slightly slower than the untreated checks; those in sterilized soil slightly slower than unsterilized soil; while those planted in soil containing 70% moisture germinated slightly slower than the ones planted in soil containing 60% moisture.

There was practically no difference in days to emergence in lima and common garden beans incubated at 40° F and 50° F. However, in beans incubated at 60° and 70° F the average number of days to emergence in lima beans was greater than in snap beans, with very little difference being noted in varieties of snap beans.

TABLE XXIII(A)

AVERAGE DAYS TO EMERGENCE OF 10 VARIETIES OF BEANS AT 4 INCUBATION TEMPERATURES [1]

Variety	Temperature 40° F.	50° F.	60° F.	70° F.	Average for Variety
Idaho Refugee	18.7	19.0	14.1	8.1	14.9
Red Valentine	19.4	19.2	14.3	8.5	15.3
Black Valentine	19.4	19.1	14.6	8.8	15.4
Tendergreen	19.5	19.4	14.9	9.0	15.7
Rival	19.3	18.9	14.4	8.5	15.2
Pencil Pod Wax	19.4	19.0	14.6	9.8	15.7
Brittle Wax	18.6	18.9	13.8	8.3	14.9
Peerless	19.0	19.1	16.6	10.5	16.3
Henderson Bush	19.5	18.6	17.2	11.8	16.7
Thorogreen	19.5	19.4	17.6	10.8	16.8
Av. for Temperature	19.2	19.0	15.2	9.4	

[1] When cotyledons of ballheads and snakeheads had emerged 1 inch above soil level, the counts were made on emergence and when primary leaves were formed and plants stood fairly erect, emergence counts were made on normal plants.

TABLE XXIII(B)

AVERAGE DAYS TO EMERGENCE

OF 10 VARIETIES OF BEANS

	Soil Sterilization		Seed Treatment		Soil Moisture	
Variety	Non-Sterilized	Sterilized	Non-Treated	Treated	70%	60%
Idaho Refugee	14.9	15.0	15.0	15.4	15.3	14.8
Red Valentine	14.0	17.6	15.1	15.6	16.3	15.1
Black Valentine	15.4	15.5	15.2	15.7	16.3	14.6
Tendergreen	15.5	15.9	15.3	15.8	16.1	15.3
Rival	15.1	15.5	15.5	15.4	15.9	15.0
Pencil Pod Black Wax	15.5	16.0	15.7	15.8	16.2	15.3
Brittle Wax	14.2	14.9	14.0	15.4	14.5	14.1
Peerless	*10.2	13.8	11.5	13.7	11.4	11.1
Hehderson Bush	17.7	17.0	17.3	16.8	18.1	16.0
Thorogreen	16.0	16.6	16.8	15.8	17.0	15.8
	14.8	15.7	15.1	15.5	15.7	14.7

Experiment II

The Influence of Variety, Source of Seed, Temperature, and Seed Treatment on Germination and Emergence in Expanded Mica.

The data obtained with respect to percent germination of the 320 lots of seeds used in this experiment was analyzed by the method of analysis of variance.[19] Table XXIV is a summary table of the analysis for experiment II. Second order and higher interactions are placed in the error term. The data on percent germination are arrayed in tables XXV to XXXIV, respectively and the data on average number of days to emergence is arrayed in tables XXXV and XXXVI.

Based on all factors, germination of all lima beans was considerably lower than that of the common garden beans. The variety Peerless gave the overall average lowest percent germination in lima beans and the variety Rival gave the lowest percent germination of the snap bean varieties tested (Table XXV).

The influence of incubation temperature on percent germination is arrayed in Table XXVI and shows that a higher percent germination was obtained at the higher temperatures.

TABLE XXIV

PERCENT GERMINATION IN EXPANDED MICA

ANALYSIS OF VARIANCE SUMMARY

Source of Variance	D.F.	Sums of Squares	Mean Square	F. Value	Sig.
Total	319	10,169			
Variety	9	6,190.50	678.83	156.05	**
Temperature	3	696.07	232.023	53.33	**
Sources	3	369.31	123.103	28.29	**
Seed Treatment	1	5.52	5.52	1.26	NS
V x T	27	1.166.18	43.19	9.92	**
V x S	27	443.44	16.423	3.77	**
V x ST	9	42.23	4.629	1.06	NS
T x S	9	167.62	18.62	4.28	**
T x ST	3	107.56	35.85	8.24	**
S x ST	3	0.15	.05		**
Error	225	980.42	4.35		

* Significant at 5% level

** Significant at 1% level

TABLE XXV

INFLUENCE OF VARIETY ON THE PERCENT GERMINATION

OF BEANS IN EXPANDED MICA

Variety	Idaho Refugee	Red Valentine	Black Valentine	Tendergreen	Rival	Pencil Pod Black Wax	Brittle Wax	Peerless	Henderson Bush	Thorogreen
Percent Germination	87.65	88.43	89.99	84.68	72.65	89.53	91.56	20.0	55.78	57.4

Required for significance 1% level-6.38
5% level-4.83

*Each figure is an average of 32-20 seed samples

Seed obtained from source C germinated on an overall average better than seed obtained from each of the other sources, with seed obtained from source A giving lowest average percent germination. (Table XXVII)

The germination of seed treated with tetrachloro-parabenzoquinone was slightly more than 1% less than the untreated checks. (Table XXVIII)

Table XXIV expresses the relative influence of each of the four incubation temperatures on the percent germination. There was a pronounced difference between percent germination of lima beans and common garden beans incubated at the same temperature, with the difference being more pronounced at the lower incubation temperatures than at the other temperatures. There was practically no germination of the lima bean variety Peerless at incubation temperatures below 60° F. Germination in the common bean varieties Tendergreen and Rival was much lower at the 40° F. incubation temperature than that of the other varieties. However, with the same varieties incubated at 70° F. the differences were less pronounced.

Table XXX indicates the influence of source of seeds on percent germination of each of the ten varieties. Most varieties obtained from source C germinated better than varieties obtained from the other three sources. However, seeds of Red Valentine, obtained from source A,

TABLE XXVI

INFLUENCE OF INCUBATION TEMPERATURE ON THE PERCENT GERMINATION OF BEANS IN EXPANDED MICA

Incubation Temperature	40° F.	50° F.	60° F.	70° F.
Percent Germination	64.18*	69.12	76.81	84.99

Difference required for significance
1% level-4.29
5% level-3.25

*Each figure is an average of 160-20 seed samples

TABLE XXVII

INFLUENCE OF SOURCE ON THE PERCENT GERMINATION OF BEANS IN EXPANDED MICA

Source	A	B	C	D
Percent Germination	67.93*	69.68	80.68	76.9

Difference required for significance
1% level-4.29
5% level-3.25

*Each figure is an average of 80-20 seed samples

TABLE XXVIII

INFLUENCE OF SEED TREATMENT ON GERMINATION OF BEANS IN EXPANDED MICA

Seed Treatment	Treated with Spergon	Untreated
Percent Germination	73.12*	74.43

*Each figure is an average of 160-20 seed samples

TABLE XXIX

INFLUENCE OF INCUBATION TEMPERATURE ON PERCENT GERMINATION OF 10 VARIETIES OF BEANS IN EXPANDED MICA

Variety	Incubation Temperature 40° F.	50° F.	60° F.	70° F.	Average for Variety
	Percent Germination				
Idaho Refugee	83.75*	85.0	89.37	92.5	87.65
Red Valentine	80.00	90.0	89.37	94.37	88.43
Black Valentine	88.75	87.5	94.37	89.37	89.99
Tendergreen	75.62	83.75	89.37	90.00	84.68
Rival	60.00	61.87	83.75	85.00	72.65
Pencil Pod Black Wax	85.00	92.5	88.75	91.87	89.53
Brittle Wax	87.5	86.87	95.00	96.87	91.56
Peerless	1.25	0.0	6.25	72.5	20.0
Henderson Bush	40.00	53.75	60.00	69.37	55.78
Thorogreen	40.00	50.00	71.87	68.12	57.4
Average for Temperature	68.18	69.12	76.81	84.99	

Difference required for significance: 1% level-13.57%
5% level-10.2

*Each figure is an average of 8-20 seed samples

TABLE XXX

INFLUENCE OF SOURCE OF SEEDS ON THE PERCENT GERMINATION OF BEANS IN EXPANDED MICA

	Source				
	A	B	C	D	Av. for Variety
Variety	Percent Germination				
Idaho Refugee	83.13	86.25	93.75	87.5	87.65
Red Valentine	92.5	85.62	85.00	90.62	88.43
Black Valentine	86.87	85.00	100.00	88.12	89.99
Tendergreen	75.00	81.25	96.25	88.12	85.15
Rival	56.87	71.25	87.5	75.0	72.65
Pencil Pod Black Wax	83.12	90.62	91.87	92.5	89.52
Brittle Wax	88.75	86.87	96.25	94.37	91.56
Peerless	15.0	23.12	22.5	19.37	19.99
Henderson Bush	60.62	43.12	65.62	53.75	55.77
Thorogreen	37.5	43.75	68.12	80.00	57.34
	67.93	69.68	80.68	76.93	

Difference required for significance: 1% level-13.57%
5% level-10.2

* Each figure is an average of 8-20 seed samples

and Black Valentine, obtained from source D, gave higher average percent germination than seeds obtained from other sources.

As shown in Table XXXI, seeds of most of the varieties did not germinate any better when treated than the untreated checks. However, treatment significantly reduced the germination of Henderson Bush.

The percent germination of seeds obtained from source C was higher than other sources at all incubation temperatures except 70^{o} F. where the percent germination of seeds obtained from source D was highest. At all incubation temperatures except 70^{o} F. and 40^{o} F. the percent germination of seed obtained from source A was lower than other sources, Table XXXII.

Table XXXIII expresses the influence of seed treatment at different temperatures and indicates that treatment was not affective on an overall average with seed germinated in expanded mica.

Table XXXIV gives figures that indicate the influence of seed treatment on seed obtained from different sources. No significant increase was noted on sterile media.

The average days to emergence as expressed in Tables XXXV and XXXVI was practically the same with all varieties when incubated at 40 and 50^{o} F. However, the average days

TABLE XXXI

INFLUENCE OF SEED TREATMENT ON PERCENT GERMINATION OF BEANS IN EXPANDED MICA

	Variety									
	Idaho Refugee	Red Valentine	Black Valentine	Tendergreen	Rival	Pencil Pod Black Wax	Brittle Wax	Peerless	Henderson Bush	Thorogreen
Seed Treatment		Percent Germination								
Treated with Spergon	89.06*	86.87	90.31	83.75	74.06	88.43	92.18	20.31	50.93	55.31
Untreated	86.25	90.0	89.62	85.62	71.25	90.62	90.93	19.68	60.62	59.68

Difference required for significance: 1% level-6.38%
5% level-4.83%

*Each figure is an average of 16-20 seed samples

TABLE XXXII

INFLUENCE OF INCUBATION TEMPERATURE ON THE PERCENT GERMINATION OF BEANS FROM 4 SOURCES IN EXPANDED MICA

	Temperature			
	40° F.	50° F.	60° F.	70° F.
Source	Percent Germination			
A	60.75*	57.0	71.0	83.0
B	59.25	66.5	75.0	78.25
C	72.0	78.75	84.0	88.25
D	65.0	74.25	77.25	90.5

Difference required for significance:
1% level-6.38%
5% level-4.83%
*Each figure is an average of 20-20 seed samples

TABLE XXXIII

INFLUENCE OF SEED TREATMENT AT DIFFERENT TEMPERATURES ON THE GERMINATION OF BEANS IN EXPANDED MICA

	Temperature			
	40° F.	50° F.	60° F.	70° F.
Seed Treatment	Percent Germination			
Treated with Spergon	63.5*	68.87	77.0	83.12
Untreated	64.87	69.37	76.62	86.87

Difference required for significance:
1% level-4.29% 5% level-3.25%

*Each figure is an average of 40-20 seed samples

TABLE XXXIV

INFLUENCE OF SEED TREATMENT ON PERCENT GERMINATION OF BEANS FROM 4 SOURCES IN EXPANDED MICA

	Source			
	A	B	C	D
Seed Treatment		Percent Germination		
Spergon treated	68.62*	67.75	79.5	76.6
Untreated	67.25	71.75	81.87	76.87

Required for significance
1% level-4.29%
5% level-3.25%

*Each figure is an average of 40-20 seed samples

to emergence of limas incubated at 60 and 70° F. was greater than the common garden beans. The average days to emergence of beans incubated at 60° F. was 3 days less than those incubated at 40 or 50° F. while the average days to emergence of beans incubated at 70° F. was 9.2 days less. In almost all lots treatment with tetrachloroparabenzoquinone slightly delayed germination.

The average percent germination of beans planted in expanded mica and subjected to the same incubation temperatures as the lots planted in soil was higher than that obtained in soil.

TABLE XXXV

AVERAGE DAYS TO EMERGENCE OF BEANS

AT FOUR DIFFERENT INCUBATION TEMPERATURES

	Temperatures				
	40° F.	50° F.	60° F.	70° F.	Average for Variety
Variety	Average Days to Emergence				
Idaho Refugee	18.7	18.6	15.2	9.3	15.4
Red Valentine	18.7	18.5	15.1	8.9	15.3
Black Valentine	18.5	18.3	14.9	9.4	15.2
Tendergreen	18.8	18.7	15.6	8.6	15.4
Rival	18.5	18.4	15.5	8.8	15.3
Pencil Pod Black Wax	18.5	18.7	14.9	9.3	15.3
Brittle Wax	18.6	17.9	14.7	8.7	14.9
Peerless	16.5	~~0.0~~	14.9	9.2	13.5
Henderson Bush	18.6	18.8	17.2	9.7	16.0
Thorogreen	18.7	18.8	17.0	10.1	16.1
Average for Temperature	18.4	18.5	15.5	9.2	

TABLE XXXVI

INFLUENCE OF SEED TREATMENT ON AVERAGE DAYS TO EMERGENCE OF BEANS

Variety	Source A		Source B		Source C		Source D		T	NT
*	T	NT	T	NT	T	NT	T	NT		
Idaho Refugee	15.9	14.8	15.8	15.6	15.3	15.2	15.9	15.2	15.7	15.2
Red Valentine	15.7	13.9	15.7	14.8	15.3	15.7	15.8	15.3	15.6	14.9
Black Valentine	15.8	15.9	15.5	15.1	14.7	14.6	15.6	15.0	15.4	15.1
Tendergreen	15.6	15.2	15.2	14.6	15.2	15.3	16.5	15.8	15.6	15.4
Rival	15.5	15.2	15.4	15.3	15.5	14.9	15.6	15.0	15.5	15.1
Pencil Pod Wax	15.6	15.2	15.8	14.8	15.4	15.1	15.6	15.3	15.6	15.1
Brittle Wax	15.4	15.1	14.9	14.6	14.6	14.8	14.7	14.5	14.9	14.7
Peerless	8.8	9.3	13.3	10.2	13.6	12.3	13.2	9.6	12.2	10.3
Henderson Bush	16.1	16.0	15.8	16.6	16.6	16.4	15.8	15.3	16.0	16.0
Thorogreen	15.0	16.5	17.0	15.8	16.6	16.5	16.2	15.8	16.2	16.1
Average for Source	14.9	14.8	15.4	14.7	15.2	15.0	15.4	14.6	15.2	14.7

* T--Treated
NT--Non-treated

Experiment III

The Influence of Variety, Source of Seed, Seed Treatment, and Planting Under Field Conditions on Germination and Emergence of Beans.

All data obtained with respect to percent germination of the 480 lots of seed used in this experiment were analyzed by the method of analysis of variance.(19) Table XXXVII is a summary table of the analysis for experiment III. All main plot effects and interactions of main plot effects are placed in the main plot analysis summary, with all other effects and interactions being placed in the main plot error term.

Seed treatment effects and first order interactions are placed in the sub-plot analysis with all other interactions expressed in the sub-plot error term.

The data obtained with respect to percent germination are arrayed in Tables XXXVIII to XLV, respectively, and the data on average number of days to emergence are arrayed in Table XLVI.

The percent germination of seed planted May 30, 1949, when soil temperatures were moderately high, germinated on an overall average of 13.67 percent higher than seed planted May 14, 1949, when soil temperatures were moderately low.

TABLE XXXVII

PERCENT GERMINATION IN FIELD ANALYSIS

OF VARIANCE SUMMARY

Source of Variation	D.F.	Sums of Squares	Mean Square	F.Value	Sig.
Total	479	284,882.45			
Main Plots					
Planting Date	1	22,399.67	22,399.67	24.83	**
Replication	1	2.27	2.27	.0025	NS
VARIETY	9	129,267.30	13,918.58	15.43	**
V x P.D.	9	13,393.45	1,488.16	1.65	NS
Source	3	12,699.29	4,233.09	4.69	**
P.D.xS	3	273.81	91.27	.1009	NS
S x V	27	11,800.44	437.05	.48	NS
Main Plot Error	106	95,598.38	901.87		
Sub-plots					
Seed Treatment	2	26,757.61	13,378.8	10.21	**
ST x P.D.	2	1,582.55	791.27	6.04	**
ST x V	18	16,809.85	933.88	7.13	**
ST x S	6	12,209.32	2,034.88	15.53	**
Sub-plot Error	292	38,239.05	130.95		

**Significant at 1% level

*Significant at 5% level

The influence of planting date is expressed in figures in Table XXXVIII.

Table XXXVIII(A) expresses the relative influence of source of seed on the percent germination of beans under field conditions. As shown in the table, bean seed obtained from source C gave a higher percent germination than those obtained from each of the other sources.

Table XXXIX expresses the relative influence of variety on percent germination. The results indicate that less than 50% germination was obtained in lima bean varieties Peerless and Thorogreen and only slightly above 50% with Henderson Bush. Varieties Brittle Wax and Rival gave lower average percent germination in the field than other varieties, with the varieties Red Valentine and Black Valentine giving the highest average percent germination.

The relative influence of planting date on each of the 10 varieties is expressed in Table XL. The percent germination of the variety Brittle Wax and all lima varieties was highly significantly higher in the second planting than the first. The percent germination of all varieties was higher during the second planting but with the exception of the above mentioned varieties there were no significant increases. The lowest percent germination occurred with lima bean varieties at both plantings. Brittle Wax germinated poorer than other common bean varieties

TABLE XXXVIII

INFLUENCE OF PLANTING DATE ON PERCENTAGE GERMINATION OF BEANS UNDER FIELD CONDITIONS

Planting Date	
Planting I 5/14/1949	Planting II 5/30/1949
Percent Germination	
60.53*	74.2

Difference required for significance:
1% level-6.99%   5% level-5.33%
*Each figure is an average of 240-100 seed samples

TABLE XXXVIII(A)

INFLUENCE OF SOURCE OF SEED ON THE GERMINATION OF BEANS UNDER FIELD CONDITIONS

Source			
A	B	C	D
Percent Germination			
60.07*	62.27	74.58	69.4

Difference required for significance:
1% level-9.97%   5% level-7.6%
*Each figure is an average of 120-100 seed samples

TABLE XXXIX

INFLUENCE OF VARIETY ON PERCENT GERMINATION

OF BEANS UNDER FIELD CONDITIONS

Variety	Idaho Refugee	Red Valentine	Black Valentine	Tendergreen	Rival	Pencil Pod Black Wax	Brittle Wax	Peerless	Henderson Bush	Thorogreen
Percent Germination	74.3*	84.8	83.1	74.1	66.5	72.9	66.6	41.0	53.6	40.0

Difference required for significance: 1 % level-15.7
5% level-11.5

*Each figure is an average of 120-100 seed samples

TABLE XL

INFLUENCE OF PLANTING DATE ON PERCENT GERMINATION OF BEANS

	Planting		
	Planting I	Planting II	Difference
Variety	Percent Germination		
Idaho Refugee	71.04	77.54	6.5
Red Valentine	83.33	87.95	4.62
Black Valentine	80.87	85.2	4.33
Tendergreen	79.25	82.91	3.66
Rival	60.0	73.1	13.10
Pencil Pod Wax	78.79	81.45	2.66
Brittle Wax	62.1	80.2	18.1
Peerless	25.16	56.87	31.91
Henderson Bush	40.0	61.91	21.91
Thorogreen	25.33	55.21	29.88
Average for P.D.	60.5	71.2	13.7

Difference required for significance:
1% level-15.7
5% level-11.5
*Each figure is an average of 24-100 seed samples

during the first planting but was better than Idaho Refugee and Rival during the second planting. However, they did not germinate significantly better than Rival or Idaho Refugee.

Table XLI expresses the relative influence of planting date on the percent germination of seed obtained from different sources. The relationships that existed during the first planting prevailed during the second planting, with seed obtained from source C being highly significantly better than seed obtained from source A and significantly better than seed obtained from source B at each planting.

Seed treated with tetrachloroparabenzoquinone and planted in the field germinated on an overall average of 4.35 percent higher than the checks, while those coated germinated on an average of 12.81 percent lower than the untreated checks. Therefore, coating decreased the overall percent germination and tetrachloroparabenzoquinone treatment increased significantly the overall percent germination, Table XLII.

Table XLIII expresses the influence of seed treatment at different planting dates on percent germination of beans under field conditions. The overall average increase in percent germination of seed treated with tetrachloroparabenzoquinone and planted May 14, 1949, was 7.7% higher

TABLE XLI

INFLUENCE OF PLANTING DATE ON PERCENT GERMINATION OF DIFFERENT SOURCES OF BEANS

	Source			
	A	B	C	D
Planting	Percent Germination			
I 5/14/49	55.4*	56.1	66.7	64.1
II 5/30/1949	68.8	69.9	82.5	75.7
Av. for Source	62.1	63.0	74.6	69.9

Required for Significance: 1% level-9.97%
5% level-7.6%

*Each figure is an average of 60-100 seed samples

TABLE XLII

INFLUENCE OF SEED TREATMENT ON PERCENT GERMINATION OF BEANS UNDER FIELD CONDITIONS

Seed Treatment	Checks	Spergon Treated	Coated
Percent Germination	70.05*	74.9	57.24

Difference required for significance:
1% level-2.67%
5% level-2.04%

*Each figure is an average of 160-100 seed samples

TABLE XLIII

INFLUENCE OF SEED TREATMENT AT DIFFERENT

PLANTING DATES ON PERCENT GERMINATION

OF BEANS UNDER FIELD CONDITIONS

	Seed treatment		
	Checks	Spergon Treated	Coated
Planting	Percent Germination		
Planting I 5/14/49	60.8*	68.5	52.4
Planting II 5/30/49	79.2	81.4	62.0

Required for significance:

1% level-2.67
5% level-2.04

*Each figure is an average of 80-100 seed samples

than the untreated checks, and germination in the coated seeds was reduced by 8.4%. However, seed treated and planted May 30, 1949 germinated only on an overall average of only 2.2% higher than the untreated checks, while germination in the coated seed was reduced by 7.2%.

Table XLIV expresses the influence of seed treatment on the percent germination of each of the 10 varieties. Coating had the effect of reducing germination in all varieties except Brittle Wax; however, the percent of the coated seed was not as high as the seed treated with Spergon. Coating had the most pronounced detrimental effect on lima bean varieties. Spergon treatment caused all varieties except Idaho Refugee, Red Valentine, and Black Valentine to show an increase in percent germination.

The influence of seed treatment on percent germination of seed from each of the four sources is expressed in Table XLV and indicates that the coating material used on seeds obtained from sources A and B was relatively more detrimental on germination than that used on sources C and D, while there was an increase in germination of Spergon treated seed over the untreated checks in seed obtained from source C.

TABLE XLIV

INFLUENCE OF SEED TREATMENT ON THE PERCENT GERMINATION OF DIFFERENT VARIETIES OF BEANS UNDER FIELD CONDITIONS

	Seed Treatment			
	Untreated Checks	Spergon Treated	Coated	Average for Variety
	Percent Germination			
Idaho Refugee	81.75*	78.06	63.06	74.3
Red Valentine	89.06	88.87	70.0	84.8
Black Valentine	87.68	87.56	74.0	83.1
Tendergreen	82.75	86.62	73.8	74.1
Rival	66.68	69.06	63.93	66.5
Pencil Pod Wax	84.00	86.18	70.18	72.9
Brittle Wax	60.06	80.5	73.12	66.6
Peerless	42.18	51.25	29.62	41.0
Henderson Bush	60.25	67.5	25.12	53.6
Thorogreen	46.12	54.06	20.62	40.0
Av. for Treatments	70.05	74.9	57.24	

Difference required for significance: 1% level-10.38
5% level-7.91

*Each figure is an average of 16-100 seed samples

TABLE XLV

INFLUENCE OF SEED TREATMENT ON PERCENT GERMINATION OF SEED FROM EACH OF SOURCES UNDER FIELD CONDITIONS

	Source			
	A	B	C	D
Seed Treatment	Percent Germination			
Checks	67.2*	71.4	72.4	69.2
Spergon Treated	71.5	74.1	80.2	74.0
Coated	47.6	43.5	71.2	66.6

Required for significance:

1% level-11.9%

5% level-9.1%

*Each figure is an average of 40-100 seed samples

Table XLVI gives the average number of days to emergence of each variety planted in the field. There was little variation in number of days to emergence with respect to common garden beans. However, lima beans were slower germinating than common garden beans. Coating delayed germination during the first planting by 1.3 days and during the second planting by .6 days.

Based on an average of all seed and all treatments, the average time to emergence during the second planting was 6.9 days less than during the first planting.

TABLE XLVI

AVERAGE DAYS TO EMERGENCE OF 10 VARIETIES OF BEANS UNDER FIELD CONDITIONS

	Planting							
	First Planting, 5/14/49				Second Planting, 5/30/49			
*	NT	ST	C	Av	NT	ST	C	Av
Variety	Average Days to Emergence							
Idaho Refugee	14.8	15.2	16.1	15.3	8.9	8.9	9.8	9.2
Red Valentine	15.0	15.3	16.5	15.6	8.8	8.9	9.5	9.0
Black Valentine	14.1	15.1	16.8	15.3	8.5	8.7	8.9	8.7
Tendergreen	15.3	15.4	16.8	15.8	9.7	8.8	9.4	9.3
Rival	15.3	15.4	16.3	15.8	8.4	8.6	9.0	8.6
Pencil Pod Wax	15.1	15.0	16.8	15.6	8.3	8.6	8.7	8.5
Brittle Wax	16.1	15.8	16.7	16.2	8.3	8.5	9.0	8.6
Peerless	18.5	17.2	18.5	18.0	9.9	10.1	10.6	10.2
Henderson Bush	17.3	17.1	18.6	17.6	9,9	10.1	11.6	10.5
Thorogreen	17.4	17.4	18.5	17.7	10.3	10.4	11.1	10.6
Av. for Treatment	15.8	15.8	17.1	16.2	9.1	9.1	9.7	9.3

* NT-No Treatment
ST-Spergon Treated
C -Coated
Av-Average

TABLE XLVII

SUMMARY TABLE OF PERCENT GERMINATION OF BEANS IN EACH OF THE THREE TESTS

Variety	Soil test	Artificial Sterile Media Test	Field Test	Av.
Idaho Refugee	45.8	87.6	74.3	69.2
Red Valentine	45.03	88.4	84.8	72.7
Black Valentine	49.8	89.9	83.1	74.2
Tendergreen	41.9	84.6	74.1	66.8
Rival	33.3	72.6	66.5	57.4
Pencil Pod Wax	50.8	89.5	72.9	71.0
Brittle Wax	26.6	91.5	66.6	61.0
Peerless	5.6	20.0	41.0	22.2
Henderson Bush	25.9	55.7	53.6	45.0
Thorogreen	16.9	57.4	40.0	38.1
Av. for Tests	34.09	73.7	65.6	

DISCUSSION

The aim in the studies here reported has been to investigate the influence of variety, source of seed, and several environmental factors, namely temperature, germinating medium, and soil moisture, on the germination of beans. In addition to studying these influences, studies were undertaken to determine whether through chemical seed treatment germination may be increased under adverse environmental conditions.

The experimental data give evicence which shows that the delay in emergence and the reduced percent germination in bean seed may be associated with low soil temperature, which cause longer exposure of the seed to attack by soil pathogens. However, source of seed and variety had a great deal of influence on the percent germination.

These studies indicated the necessity of germinating bean seed at an optimum temperature if good stands are to be obtained. It is possible that oxygen supply might cause a difference in germination, and that also differences in soil moisture resulting in differences in soil temperature might also be involved. For example, bean seed incub ted in expanded mica which was well aerated germinated much better at all temperatures than seed incubated in soil which was compact.

Statements to the effect that any temperature below optimum decreases germination and retards the rate of emergence in seed are found in much of the literature on vegetable growing. Kotowski (12) showed in his work that the optimum temperature for germination and most rapid rate of emergence in beans was in the range of 70° to 86° F.

In our investigations the temperature for germination did not exceed 80° F., either in the controlled temperature chambers or in the field, but results indicated that beans incubated at the higher temperatures (70° F. in controlled temperature chambers and 80° F. under field conditions) germinated faster and at a higher percentage than seed incubated at 40° F., 50° F., and 60° F. These results are in accord with the findings of Harrington(8) who states that the smallest number of days required for the production of bean seedlings in soil was four days and that beans produced the first seedlings in the smallest number of days during the moderately warm weather of May and June. Apparently germination did not occur in bean seeds incubated at 40° and 50° F., until they were moved to the greenhouse where temperatures were higher. (Tables XXIII A and B and XXXVI).

Several points stand out clearly after a study of the data showing the influence of temperature on the germination of different varieties in different media. It is particularly interesting to note the very marked influence of relatively low incubation temperatures (40°-50° F.) for 10 days on the germination and emergence in soil as compared with that in expanded mica. For example, the ov r all average germination of seed incubated at 40° in soil was only 23.5% while those incubated in expanded mica gave an av rage of 64%. The overall average percent germination of seed incubated at 50° F. in soil was only 36.4% while seed incubated in expanded mica gave an average of 69.1% germination.

Factors observed which may have caused lower germination in soil than occurred in expanded mica may have been: (1) soil compaction, (2) high moisture, (3) poor aeration, and (4) the presence of soil pathogens which caused decay of the seed.

From the evidence at hand, it seems clear that some change took place in seed incubated at low temperatures which did not take place at high temperatures. In the case of seeds subjected to relatively low temperatures for short periods, some change must have taken placé during the low-temperature treatment in expanded mica which was altogether different from the changes or influences of soil and temperature on seed incubated in soil.

The nature of the changes brought about by the low temperature treatment was not determined, but comparative data and observations indicate the possibility of the presence of soil organisms which may have caused decay of seeds in the soil. However, some molds were observed growing on seeds of the lima bean varieties and the common bean varieties Brittle Wax and Tendergreen in expanded mica.

Considering all varieties and all factors involved, the relative percent germination of all lima beans was significantly lower than the common garden beans, with Peerless giving the lowest percent germination. However three varieties of common beans--Brittle Wax, Rival, and Tendergreen showed a significantly lower percentage germination than the others.

In view of the fact that significantly poorer germination was associated with the seed of the above mentioned varieties at low temperature, it seems possible that there may be a definite relationship between seed coat color and susceptibility to decay organism, since all varieties mentioned above are either black or tan and white or varying from black to tan with large white spots. This, of course, does not prove that there is any causal relation between seed-coat color and susceptibility to soil borne diseases. It may be that some other factor or factors, not determined, was the cause, and seed-coat color may have been associated with this factor causing germination. However, when these same varieties were incubated at low temperatures in expanded mica, a sterile media, germination was as good or better than the varieties Black Valentine, Red Valentine, Idaho Refugee, and Pencil Pod Wax which had predominantly black or red seed coats. It was observed however, that as soon as the variety Rival imbibes water, the seed coats burst thereby leaving the naked embryo uncovered and open to infection.

Results of influence of soil moisture indicates that 70% soil moisture is above optimum for bean germination, as better germination was obtained at 60% moisture than at 70%. Observations revealed that molds grow more profusely on sterilized soil with a moisture content of 70% than on soil with a moisture content of 60% and more damping-off occurred at the 70% moisture level. Although determinations were not made on the oxygen content of each soil, it is probable that oxygen was less abundant in the etc.

soil with the 70% moisture than in the soil with the 60% moisture. All varieties except Peerless germinated significantly better at the 60% moisture level. (Table XXIII)

The response to chemical seed treatment was greatest at 50° F. in soil, and germination was improved markedly in the varieties Thorogreen, Brittle Wax, and Tendergreen, and germination was significantly increased in all other varieties except Henderson Bush, Peerless, and Pencil Pod Black Wax. The data from all studies indicate that seeds that are susceptible to soil disease organisms respond to seed treatment best whereas seeds that are less susceptible give less response. The great response to seed treatment at 50° F. may be due to the fact that disease organisms are quite active at this temperature.

Soil sterilization significantly improved the germination of Idaho Refugee and Brittle Wax, but did not significantly improve the germination of other varieties. These facts indicate a possibility which may exist in which the varieties which give significant increases may be highly susceptible to certain organisms, which are present in soil and killed by sterilization, thereby resulting in significant increases in germination. The significant increase in germination of seed in sterilized soil at 50° F. here again may be due to the less activity of organisms at this temperature.

Results from all three experiments show that seed source had a marked influence on percent germination. Seed obtained from source C germinated on an overall average at a higher percentage than seed obtained from the other three sources. However, germination was not significantly higher than germination of seed obtained from source D. It seems probable that the differences in germination may be due to: (1) the condiaions under which seed were grown (2) harvesting technique (3) and methods of storage.

It should be noted that the production of seedlings in soil involves not only germination of the seed but the penetration of the soil by the seedlings--a process which is influenced by the vigor of the seedlings and may be retarded by excessively high temperatures. However, the higher rate of emergence and higher percentage germination at the highest temperatures in each of the experiments is a result of a higher rate of metabolic activity at the higher temperatures which enables the seed to germinate before soil pathogens attach severely enough to cause decay. It should be noted that when any severe check in rate of emergence occurred whether in the field test or in soil test in the greenhouse, the use of the seed treatment chemical tetrachloroparabenzoquinone significantly increased germination of seed over that of the untreated checks. On the other hand, when conditions were favorable for rapid germination the increases were not as significant.

The detrimental effect of coating was more severe on lima bean varieties than on common garden bean varieties. However, there was an increase in the germination of coated beans of the variety Brittle Wax over the uncoated checks but germination was lower than the Spergon treated beans. This is in accord with McGuffey's (14) findings in which he reported that coated wax beans germinated slightly higher than uncoated ones. However, different coating materials were used in his experiments. Results show that the coating material used on sources A and B decreased germination by 23.8% whereas the coating material used on sources C and D decreased germination by only 1.9%. The cause of this variation was not determined. It is possible that the amount of superphosphate used could have caused the harmful effect on germination along with phosphorus containing parathion which was used to coat sources A and B.

Coating delayed germination during the first field planting by 1.3 days whereas during the second planting germination was delayed only by 0.6 days. This was probably due to increased moisture of the soil during the second planting since dry weather prevailed during the first planting. Other factors which may have caused decreased germination and delayed emergence in coated seed could possibly have been (1) decreased water absorption, (2) a reduced gaseous exchange and (3) too high a concentration of some of the chemicals used in the coat.

Comparative data from the experiments show that the germinating medium had a significant effect on the germination of beans. For example, the overall percent germination in expanded mica was significantly higher than that obtained in the field and nearly doubled that obtained in soil in flats. However, some varieties responded differently and no definite conclusions are drawn as to what caused these effects.

CONCLUSIONS

Delay in emergence and reduction in percent germination in bean seed may be associated with low soil temperatures, high soil moisture, and poor soil structure which may cause longer exposure of the seed to attack by soil pathogens.

On the basis of 2080 observations involving 10 varieties of beans in 3 experiments, the following conclusions relative to the influence of variety, source of seed, and environmental conditions on germination and rate of emergence in bean seed appear warranted:

1 Lima beans give very low percent germination when incubated for 10 days at temperatures below 70° F. The variety Peerless showed the lowest percentage germination.

2 The influence of temperature was quite variable. The varieties Brittle Wax, Tendergreen, and Rival were affected most by low temperature, which caused them to give a poorer percentage germination due to possible susceptibility to soil pathogens.

3 Higher germination was obtained in seed treated with tetrachloroparabenzoquinone (Spergon) than in untreated seed.

4 The shorter the number of days to emergence, the less effective is Spergon treatment.

5 The highest percent germination in soil was obtained with 60% moisture.

6 Better germination was attained in expanded mica than in the field, or in soil in flats.

7 Coating reduced germination in all varieties except Brittle Wax, with lima beans being most seriously affected by the process.

8 The variety of lima beans Peerless did not germinate appreciably when incubated in temperatures below 60° F. whether in soil, expanded mica, or in the field.

Observations revealed a possible relation between seed-coat color and the ability of seed to withstand adverse weather conditions which result in longer exposures of the seed to soil pathogens. While no definite conclusions are drawn from these observations, the possibility exists that the pigment might contain anti-biotic properties.

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