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A Study of Simulated Hail Injury in Beans

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No defoliation 33 percent defoliation

Figure 1.—Bean plants showing various stages of defoliation.

SUMMARY

1. In a given bean-producing area, calendar date is a reliable index of plant maturity within a specific variety, unless abnormal weather conditions force late planting, or if temperatures vary considerably from the normal.

2. Loss of terminal buds at emergence, with some accompanying foliage loss, does not usually result in significant yield reductions.

3. Reduced stands, occasioned by early hail storms, affect yields in proportion to the increased spacing of the remaining plants. Increased growth on those that remain will compensate in part for plants lost.

4. Loss of not more than one-third of the total foliage at or prior to first bloom usually results in losses not exceeding 10 percent on an average dry bean crop.

5. Generally speaking, defoliation at any time prior to full bloom, at equal rates, causes about the same amount of yield reduction; that is, there are no great differences between the first-trifoliate leaf stage and the first-bloom stage, although losses are usually heavy when defoliation exceeds 50 percent.

6. Most serious losses are sustained when defoliation occurs at about the full-bloom stage or later.

7. Differences in response to defoliation exist among varieties, and in these studies Topcrop yields were generally reduced more than were Pinto when defoliation rates were equal.

8. When it becomes apparent that a 50 percent yield reduction will be sustained, serious consideration should be given to abandoning the crop entirely as a total loss. Time at which losses are sustained will govern a decision of this sort.

66 percent defoliation

100 percent defoliation

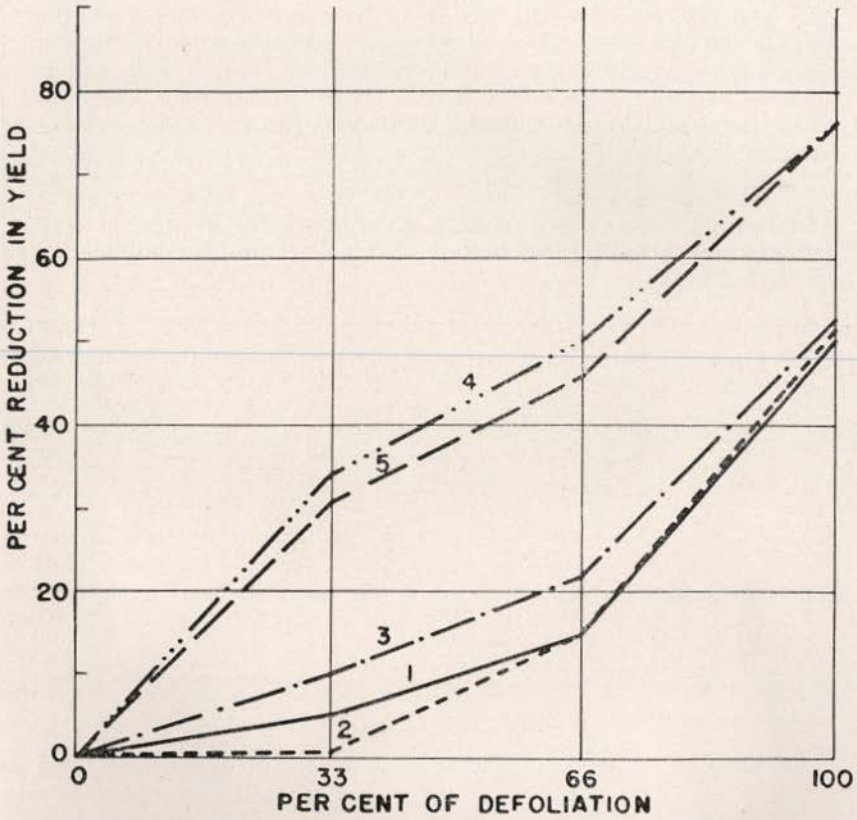

Figure 2.—Average yield reduction of Pinto and Topcrop beans at Lewiston and Twin Falls, at five stages of plant development and four rates of defoliation. Data cover years from 1955 to 1958.

1. First trifoliate leaf
2. Three trifoliate leaves
3. First bloom
4. Full bloom
5. Two weeks after full bloom. Complete pod-set.

This bulletin shows the results of bean investigations over the period 1955 to 1958. These studies are a continuation of similar ones conducted with potatoes and reported elsewhere.* The authors believe that the information herein forms an accurate basis for predicting yield losses in beans, defoliated through one cause or another.

Acknowledgement is made to the Regional Hail Adjustment and Research Association of Chicago, Illinois, for its part in contributing funds for implementation of this work and for publication of this bulletin.

*A *study of Simulated Hail Injury in Potatoes, Idaho Agr. Expt. Sta. Research Bul. 22*

Estimating Hail Injury in Potatoes, Idaho Agr. Expt. Sta Bul. No. 274

Stages of Potato Plant Growth—A guide in estimating losses from defoliation, Idaho Agr. Expt. Sta. Bul. No. 309

A Study of Simulated Hail Injury in Beans

GEORGE W. WOODBURY AND MARSHALL LEBARON*

In the irrigated regions of Idaho, hail storms strike with varying degrees of intensity. Damage to beans (**Phaseolus vulgaris**) from these storms ranges from the loss of a few leaves to complete defoliation. Depending upon the severity of the hail storm, and the time of its occurance, crops may or may not recover. Losses range from none to complete destruction of the crop. Even where the crop is only partially reduced, it sometimes becomes unprofitable for the farmer to continue its culture; thus, such losses are essentially complete.

To establish a standard for predicting or measuring the ultimate crop losses arising from hail injury sustained by beans has been the object of this study. Information gathered from such a study forms a basis for settling claims arising from hail losses, of special value when crops have been protected under hail insurance policies. Benefiting from an accurate appraisal of reduced harvest resulting from hail damage are both farmers and insurance adjustors.

The experiments reported in this bulletin were conducted at two widely separated places, the Twin Falls Branch Experiment Station at Kimberly, and the Lewiston Horticultural Field Station at Lewiston. Average temperatures at Lewiston are higher than at Kimberly, and the frost-free season may be as much as two months longer. This longer growing season is important from the standpoint of recovery from early hail damage.

Severe hail damage occurs in Twin Falls County and losses have been extensive. The Twin Falls area is one of the nation's great bean-producing districts and farmers are interested in covering prospective hail losses by insurance. Both the farmer and the insurance underwriter are desirous of obtaining an equitable settlement.

In Idaho, beans are produced for seed and for food. Chief among the varieties and types produced are Great Northern, Pinto, Red Mexican, Red Kidney and a wide assortment of "contract" beans for seed. These latter are snap or green beans, and their production is an important part of the bean industry. Lima bean seed and snap beans for processing are not of commercial importance in Idaho.

Experimental Procedure

The work reported here covers the period 1955 through 1958—four growing seasons. The Twin Falls data were taken in 1955, 1956 and 1957, while experiments at Lewiston extended from 1955 through 1958. Techniques and methods were similar at both places. Work of a different and supplemental nature was done at Twin Falls in 1958.

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Plot technique was the same at Twin Falls as at Lewiston, and in general a split-plot layout was used with four rates of defoliation and five dates of treatment. Defoliation rates were 1. none; 2. 33 1/3 percent; 3. 66 2/3 percent; and 4. 100 percent (Fig. 1). Time of defoliation was determined by plant development and the stages were as follows:

1. When the first set of trifoliate leaves was fully developed.
2. When the third set of trifoliate leaves was fully developed.
3. When first blooms appeared.
4. When plants were in full bloom.
5. Two weeks after full bloom, or when the pods were nearly all set.

Plants were defoliated in all degrees each time of treatment.

Defoliation was accomplished in two ways. At Twin Falls, a sort of "cat-o'-nine-tails" was used. This consisted of a handle to which were welded several short metal chains. Distally, on the chains were small steel nuts. The other device was simply a small rake made from sheet

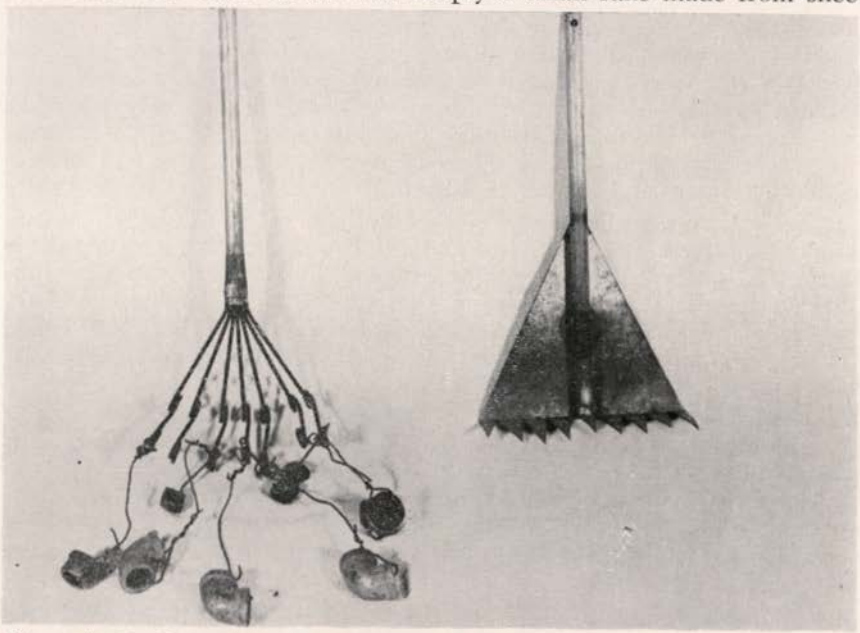

Figure 3.—Implements used for simulating hail damage. The one at right is more satisfactory for small plants.

iron. This was equipped with a short handle and the "blade" of the rake was perhaps 6 inches wide with saw-like teeth about 3/4-inch wide and pointed. Better control could probably be obtained with the latter instrument. These implements are shown in Figure 3.

In the early stages of this work, actual leaf-area measurements were taken to get a rather accurate record of the amount of foliage removed. With experience, however, the operator is able to determine, with a fair amount of accuracy, the actual extent to which defoliation has been accomplished. Some hand picking was necessary in order to accomplish complete leaf removal. Except for defoliation treatment all

plots were handled in a uniform manner; irrigation and fertilization were not altered from one treatment to another. Pinto UI-III and Topcrop were used in these experiments. They represent two rather widely different types of beans, each of which is fairly representative of the beans grown commercially in Idaho.

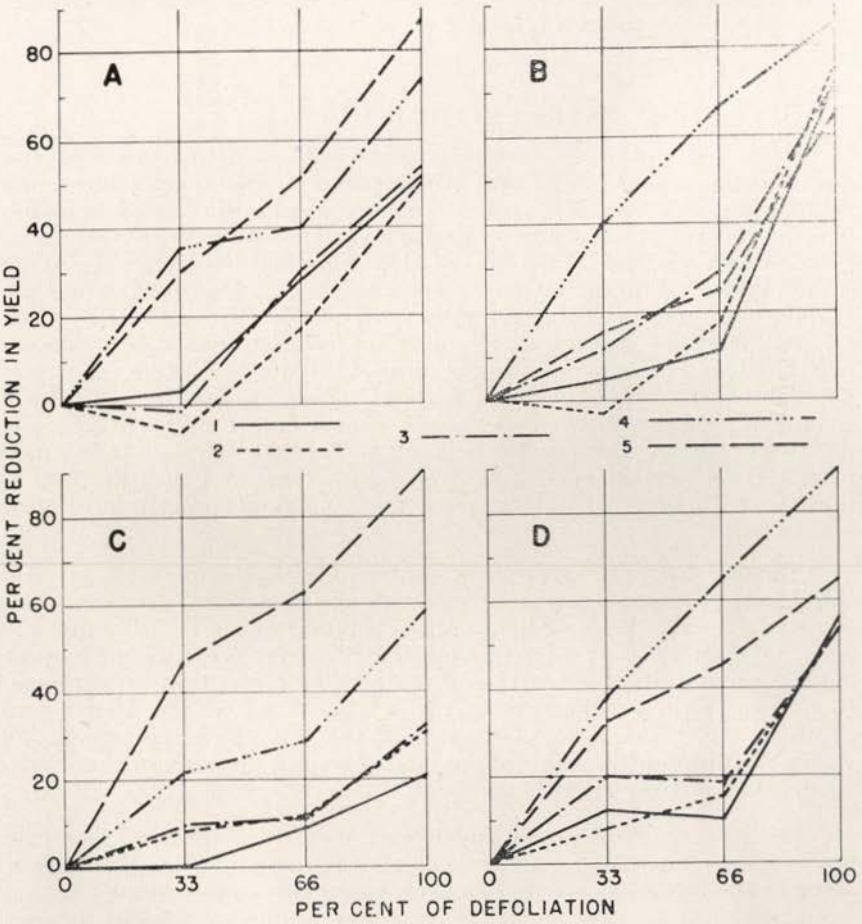

Figure 4.—Topcrop and Pinto beans variously defoliated at five stages of growth at Lewiston and Twin Falls. Data are for the years 1955 to 1958.

A. Lewiston, Topcrop

B. Twin Falls, Topcrop

C. Lewiston, Pinto

D. Twin Falls, Pinto

1. First trifoliate leaf

2. Three trifoliate leaves

3. First bloom

4. Full bloom

5. Two weeks after full bloom. Complete pod-set.

Vines were harvested when mature. Some were threshed in the field from the dry vines. Otherwise, vines were cut, placed in open-mesh bags, and threshed later.

Data for yield were analyzed in all experiments, using analysis of variance method. Results of these analyses are shown in some of the tables. Most of the differences shown in the tables, and on the graphs, are highly significant among treatments, rates of defoliation and varieties, and may be accepted as a basis for estimating yield losses.

RESULTS: TWIN FALLS EXPERIMENTS

Table 1 gives the 3-year average yield of beans that were defoliated and also the percent yield loss as compared to the check, which was not damaged. Figure 4 (B and D) shows, graphically the yield reductions in Topcrop and Pinto, respectively. The yield decreased in all cases except one with Topcrop defoliated at three-trifoliate leaf stage, which showed a slight increase over the check. However, when one examines the data in Table 2 for the years 1955, 1956 and 1957, it will be seen that the differences in yield are not significant between the plants defoliated 33 percent at the three-trifoliate leaf stage, and those not defoliated. This apparent "increase," then, cannot be ascribed to treatment, but principally to chance. The effect of different years on the yield of beans can readily be seen in Table 1. Higher yields were produced the second year of the treatments than in either the first or third years; however, the average of the 3 years accurately indicates a normal yield.

Table 2 lists the days to maturity. This factor has shown considerable variation from year to year and also a greater variation within some years than others. For example, Topcrop in 1957 had a maturity range of about 30 days as compared to 1955 and 1956 when all harvests were made within about a 15-day period. This can best be explained by differences in weather among the 3 years. In 1957 the August temperatures were 2.2 degrees above normal and the injured plants matured rather than producing new growth; and secondly, the area did not have its first killing frost as early as usual.

The first stages of growth which were used to determine time of defoliation were the same for all of the bean experiments. Also, planting was done on about the same date each year. Using the same varieties, then, it would follow that bean plant development from one year to the next would not noticeably change. Thus, if beans were in full bloom on July 20 in 1956, they should be at about the same stage on July 20 in 1957—or any other year; that is, unless there is considerable variability in heat unit accumulation. The data in Table 3 bear this out, except where planting was delayed as at Lewiston in 1957 and 1958.

In 1958, more information was obtained concerning defoliation at time of emergence. Nine treatments were involved. Seven of them were applied at time of emergence, and two variations at time of first bloom.

Table 4 shows yields from bean plants variously pruned at time of emergence and at first bloom. These data show that, in Pinto, considerable damage may be done to bean plants before first bloom without impairing ultimate yields. When defoliation was sustained at first bloom, either with or without bud removal, yields were significantly less than in the non-treated check, both in Pinto and Topcrop. Peculiarly enough, early removal of buds from Topcrop resulted in an increase in yield when accompanied by partial defoliation, but not when buds alone were removed. These data for Topcrop are conflicting, and more study is indicated.

RESULTS: LEWISTON EXPERIMENTS

Pintos were grown in Lewiston in 1955, 1956, 1957 and 1958 and Topcrop in 1955 and 1958. Adverse germinating conditions caused poor stands of Topcrop in 1956 and 1957, and the variety was abandoned.

Generally speaking, results at Lewiston paralleled those obtained at Twin Falls, although the magnitude of yield reduction was not the same at both places. There is some indication that greater loss is occasioned by late defoliation (when most of the pods are set) at Lewiston than at Twin Falls, while the reverse seems to be true when defoliation occurs earlier. The data are shown in Table 5 and in the graphs, Figures 2, and 4 (A & C). It will be noted also from the graphs that there is strong tendency for the data to be grouped; that is, the yield reductions for the first three defoliations are similar, while those for the last two defoliations are also similar but quite different from the others. This relationship is a bit more pronounced with Pintos than with Topcrop and slightly more pronounced at Lewiston than at Twin Falls. The graph (Figure 2) showing the average of both varieties for all years, is fairly conclusive in this respect.

In 1955, data were taken on sample weights of 100 Pinto beans from each plot. These data were analyzed and it was found that beans harvested from plants defoliated 100 percent from the third-trifoliate leaf stage through the remaining three treatments were significantly smaller than the check beans. This accounted for part of the yield reduction, but by no means all of it. Loss of plants, reduced plant size and loss of pods accounted for most of the loss.

Germination tests made on all samples, showed no differences among the treatments.

Discussion

Severe defoliation (75 to 100 percent) at or before first bloom results in yield reductions (Figure 4) which the farmer will be unwilling to sustain. Similarly, yield losses as high as 30 to 40 percent may be expected if 33 percent defoliation takes place at full bloom or thereafter. Yield reductions are in proportion to the amount of damage, but relatively small amounts of injury at late stages of growth may reduce the crop to an unprofitable figure. Here again, depending upon price prospects

and farm practices, it may or may not be profitable to maintain a crop beyond such a point. The differences between the two varieties Topcrop and Pinto are apparent in Figure 4. It is evident that early damage (up to full bloom) is not as serious with Pinto as with Topcrop, especially where defoliation exceeds 50 percent. At Twin Falls, Topcrop, with 100 percent defoliation, was reduced in yield 75 percent when the damage was inflicted at the first-trifoliate leaf stage, while Pinto, defoliated in the same amount, was reduced in yield about 50 percent. These figures maintain through the first three defoliations. At Lewiston the same relationship existed although yield reductions from early defoliations were not as great.

The results in general indicated that yield reduction in damaged beans is a function of the amount and time of defoliation. The time of defoliation is important because there is considerable opportunity for

Figure 5.—Pinto beans defoliated 100 percent and 66 percent on June 18.

plant recovery if damage is inflicted early in the season. The kind of recovery that may be expected is shown in Figure 5, where Pinto beans were defoliated 100 percent and 66 percent on June 18 at the first-trifoliate leaf stage. This picture, taken July 13, shows good recovery where 66 percent defoliation was inflicted but considerably less recovery from 100 percent defoliation. Figure 6 shows Topcrop, which had been defoliated 100 percent at first bloom, with the untreated check at the left. The

treated plants, while in good condition, are not as mature as the check plants. This treatment resulted in yield reduction of 47 percent.

Figure 7 shows two plots of Topcrop, defoliated 100 percent, approximately two weeks apart. The plot at the left showed a yield reduction, from the check, of 47 percent, while the one at the right was reduced 65 percent. Neither yield would be satisfactory. Similarly (Figure 8) Pinto was defoliated 100 percent on July 7 (right) and on August 2. Yield reductions amounted to 31 percent and 56 percent respectively. Where less defoliation occurs (Figure 9) recovery is practically complete. In this picture, beans at the left were defoliated 33 percent on June 30 and those at the right 33 percent on July 9. These were defoliated at the first trifoliate and third trifoliate leaf stage, respectively. Yield reduction for the first trifoliate leaf plants was 12

Figure 6—Topcrop beans. Left, untreated check; right, defoliated 100 percent on July 21, when at first-bloom stage.

percent and for the others there was an actual increase of 17 percent. These differences are not of sufficient magnitude to be ascribed to differences in treatments. (Figure 4, A & B).

There are several factors to be considered in appraising hail damage, and a study of this sort does not purport to answer all of the problems. Some of the problems, however, are as follows:

1. How is yield reduction related to foliage loss?
2. At what stage of development are bean plants most vulnerable?
3. What differences exist among varieties?
4. Do varieties behave the same at different locations?
5. On the basis of information obtained from hail studies, when does it cease to become profitable to maintain a damaged field?

The data herein presented show that losses occasioned by hail damage are proportional to the amount of foliage lost. Differences which occur, however, are also related to the time of defoliation. Thus,

Figure 7.—Topcrop beans. Left, defoliated 100 percent on July 21; right, 100 percent on August 2. These were treated at first-bloom and full-bloom stage respectively.

early defoliation (at first bloom and earlier) is of less importance than late damage. Since rapid recovery is possible in early plant development, good crops of beans may be expected even though foliage losses as high as 75 percent may be realized. After first bloom, with at least two thirds of the foliage lost, yield reduction becomes important to the extent that further maintenance of the crop may be unprofitable. When most of the leaves are destroyed, even in early stages of growth, yields may be reduced to the extent that abandonment of the field may be indicated.

Aside from losses sustained through foliage damage and partial destruction of the growing points is the matter of reduced stand through destruction of small plants. Naturally enough, this damage will not be uniform. Reduced stands should be considered with the following information in mind.

The optimum stand for the semi-vining field bean types such as Pinto is considered to be a plant every 3 inches in a 22-inch row, or 95,000 plants per acre; and for the bush types the optimum stand is a plant every 2 inches in a 22-inch row or 142,000 plants per acre. Variations in stand from 3 to 6 inches will not materially affect the yield of the field bean types, if this stand loss or variation occurs while the plants are still small so that there is ample time for maximum growth. The snap beans, however, will be reduced in yield as the spacing between the plants increases. The yield in a 22-inch row will be roughly as follows: 2 inch—**100** percent, 3 inch—**94** percent, 4 inch—**90** percent, 6 inch—**84** percent, and 10 inch—**65** percent.*

Figure 8.—Left, Pinto beans defoliated 100 percent on August 2; right, defoliated 100 percent on July 7. Those at right were defoliated at first-bloom; at left, full bloom stage.

* From unpublished results. Annual Report, Twin Falls Branch Expt. Station 1953.

Table 1.—Yield of seed in pounds per acre and percent loss in yield from Pinto and Topcrop beans defoliated at four rates of defoliation and at five stages of growth throughout the season. Data from Twin Falls experiments.

		Topcrop					Pinto				
Stage of Treatment	Percent Defoliation	1955	1956	1957	Average	Mean Percent loss In Yield	1955	1956	1957	Average	Mean Percent loss In Yield
1. First trifoliate leaf	33	1350	1820	1350	1506	5	2010	2615	2490	2371	13
	66	1315	1710	1165	1396	12	2095	2875	2350	2440	10
	100	555	483	290	442	72	980	1610	965	1185	56
2. Three trifoliate leaves	33	1750	1990	1190	1643	+ 4	2095	3045	2320	2486	8
	66	1260	1560	1115	1311	17	2225	2580	2240	2348	13
	100	610	372	223	401	75	1240	1600	890	1243	54
3. First bloom	33	1390	1670	1090	1383	12	1690	2630	2170	2163	20
	66	1150	1540	670	1120	29	1910	2600	2130	2213	18
	100	482	632	223	445	72	1870	1260	595	1241	54
4. Full bloom	33	1090	1055	683	942	40	1690	1670	1670	1676	38
	66	760	520	265	515	67	870	980	965	938	65
	100	334	250	148	244	85	238	230	312	260	90
5. Two weeks after full bloom. Complete pod-set.	33	1350	1525	1115	1330	16	1780	1890	1750	1806	33
	66	1040	1150	1165	1118	25	1430	1575	1460	1488	45
	100	238	756	683	559	65	423	1090	1375	962	64
Check		1500	1840	1390	1576	0	2390	3045	2680	2705	0
L.S.D. lbs. per acre	5%	310	330	200			826	435	366		
L.S.D. lbs. per acre	1%	414	427	256			1095	574	490		

Figure 9—Topcrop beans. Left, defoliated 33 percent on June 30; right, 33 percent on July 9. Defoliated at first-trifoliate and third-trifoliate leaf stages respectively.

Table 2.—The maturity in days for each of 3 years and the 3-year average for Topcrop and Pinto beans after defoliation by simulated hail. Twin Falls.

Stage of Treatment	Percent Defoliation	Topcrop				Pinto			
		1955	1956	1957	Average	1955	1956	1957	Average
1. First trifoliate leaf	33	102	92	89	94	100	91	87	92
	66	102	92	92	95	98	94	90	94
	100	108	95	97	100	101	96	110	102
2. Three trifoliate leaves	33	100	92	91	94	98	91	87	92
	66	102	95	92	96	99	94	93	95
	100	110	96	110	105	110	97	110	105
3. First bloom	33	101	95	95	97	98	94	95	95
	66	110	97	102	99	105	97	95	99
	100	112	98	115	108	107	99	110	105
4. Full bloom	33	109	89	90	96	94	90	86	90
	66	101	89	82	90	110	86	83	93
	100	120	86	115	107	120	99	80	99
5. Two weeks after full bloom. Complete pod-set.	33	101	89	89	93	91	89	85	88
	66	94	88	89	90	91	86	85	87
	100	94	86	89	89	91	86	85	87
Check		100	92	89	93	97	91	86	91

Table 3.—Dates of defoliation of Pinto and Topcrop beans at Lewiston and Twin Falls, Idaho, at five stages of development.

Stage of Treatment		Lewiston				Twin Falls		
		1955	1956	1957	1958	1955	1956	1957
1. First trifoliate leaf	Pinto	6/17	6/18	6/26	6/27	6/23	6/22	6/24
	Topcrop ..	6/15			6/30	6/23	6/22	6/24
2. Three trifoliate leaves	Pinto	6/28	6/29	7/ 5	7/ 7	7/ 7	7/ 3	7/ 4
	Topcrop ..	6/27			7/ 9	7/ 7	7/ 3	7/ 4
3. First bloom	Pinto	7/12	7/ 9	7/11	7/21	7/16	7/13	7/13
	Topcrop ..	7/14			7/21	7/16	7/13	7/13
4. Full bloom	Pinto	7/28	7/18	7/18	8/ 2	8/ 2	7/30	7/29
	Topcrop ..	7/29			7/29	8/ 2	7/30	7/29
5. Two weeks after full bloom. Complete pod-set.	Pinto	8/ 8	8/ 3	7/30	8/11	8/16	8/13	8/19
	Topcrop ..	8/ 8			8/ 7	8/16	8/13	8/19

Table 4.—Yield in pounds per acre and percent reduction in yield (as compared with check) of Pinto and Topcrop beans variously defoliated at Twin Falls Station, 1958.

Treatment	Yield lbs. per acre		Percent reduction in yield	
	Pinto	Topcrop	Pinto	Topcrop
1. Check	2865	1780		
2. At time of emergence				
a. 33% buds removed	2820	1705	1.6	4.2
b. 66% buds removed	2890	°1460	+ .9	18.0
c. 100% buds removed	2790	1905	2.6	+ 7.0
d. 33% buds removed 50% primary leaf removed	2700	°2080	5.8	+16.9
e. 66% buds removed 50% primary leaf removed	2840	1660	.9	6.7
f. 100% buds removed 50% primary leaf removed	2840	1605	.9	9.8
3. At time of first bloom				
a. 33% defoliation	°°2320	°1485	19.0	16.6
4. At time of emergence, 33% buds removed At time of first bloom 33% defoliated	°2445	°°1210	14.7	32.0

° Difference between it and check significant at odds of 19:1
°° Difference between it and check significant at odds of 99:1

Table 5.—Yield of seed in pounds per acre and percentage loss in yield from Pinto and Topcrop beans defoliated at three rates and at five stages throughout season. Data from Lewiston experiments.

Stage of treatment	Topcrop					Pinto					
	Percent defoliation	1955	1958	Average	Percent red.	1955	1956	1957	1958	Average	Percent red.
1. First trifoliate leaf	33	1557	2135	1846	3.0	3640	3603	2758	2228	3057	.0
	66	856	1903	1380	28.0	3114	3163	2337	2541	2789	9.0
	100	392	1443	918	52.0	3083	2769	1805	1926	2396	21.0
2. Three trifoliate leaves	33	1310	2823	2067	+ 8.0	3444	3626	1559	2628	2814	8.0
	66	608	2556	1582	17.0	3094	3111	2308	2266	2695	12.0
	100	83	1794	938	51.0	2547	1811	2123	1872	2088	31.0
3. First bloom	33	1475	2398	1937	+ 2.0	3754	3378	1556	2376	2766	9.0
	66	608	2060	1334	30.0	3403	3352	1722	2352	2707	11.0
	100	495	1264	880	54.0	2454	2781	1109	1763	2026	34.0
4. Full bloom	33	877	1591	1234	35.0	3207	3723	1013	1610	2388	22.0
	66	670	1607	1139	40.0	3145	3396	641	1517	2175	29.0
	100	186	837	512	73.0	1598	1933	601	948	1270	58.0
5. Two weeks after full bloom. Complete pod-set.	33	1083	1602	1343	30.0	2362	2196	839	1234	1658	46.0
	66	691	1147	918	52.0	1856	1045	680	859	1110	64.0
	100	175	327	251	87.0	536		245	180	320	90.0
Check		1403	2413	1908		3723	3668	2540	2259	3048	