Moscow, October 1952 Research Bulletin No. 22

A Study of Simulated Hail Injury On Potatoes

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These studies were undertaken at the request of individuals whose work has to do with determining the extent of losses sustained from hail damage. Hail is a natural element which occurs frequently in many parts of Idaho and sometimes with alarming intensity, resulting in severe losses to many crops. This work parallels previous investigations only to the extent that simulated hail injury was under study. Defoliation studies conducted by Kraus (9)[1] had to do with the effects of foliage removal on the degree of roughness in tubers. The literature contains no references to the effects of degrees of defoliation upon yield and grade.

Since the potato plant is reproduced vegetatively from a tuber or portion thereof, it has—at least in its early stages—the ability to regenerate new top growth from reserve food in the so-called seed-piece. This peculiarity of the potato sets it apart from most cereal crops as well as from the important truck crops. It follows, therefore, that information from simulated hail injury studies in other crops is of little value in appraising hail damage on potatoes. Thus, with no criterion on which to base his decision, the insurance adjustor has found it difficult to make proper settlements. This has tended to work hardships on both the underwriters and the farmers. The business of underwriting hail losses is of sufficient magnitude in Idaho to warrant investigation of such losses.

In addition to the above problem, there are many others which seem to be related to root-top and tuber-top ratios. The work by Kraus (9) mentioned above is a case in point. The Russet Burbank variety—predominant in Idaho—is subject to tuber abnormalities and roughness. In a popular manner at least, these have been attributed to fluctuations in water supply, checks in growth, fertilizers, and other environmental factors. Accurate information concerning the cause of these defects is of importance to growers in the state regardless of its relation to hail injury studies. Finally, the physiology of the potato is relatively complex. Relationship between tops, tubers, and other plant parts is governed by delicate balances of temperature, photoperiod, nutrition, and moisture. These studies are intended to contribute to a general understanding of potato development.

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[1] Numbers in parenthesis refer to literature citations.

Review of Literature

The damaging effects resulting from the removal of foliage from growing plants have been determined for some of our important crops (1, 4, 5, 12). In general, the data were obtained from hail injury studies and are limited to crops grown in areas where hail incidence is high. Similar information, with respect to potatoes, is not available, at least not where a measured amount of foliage has been removed.

Kraus (9), 1943, limited the number of stems per hill of potatoes. Some of the single-stem hills were partially defoliated. He records a reduction in yield when hills were reduced from four stems to one when plants were 3 to 4 inches in height. Further yield reduction was effected when auxiliary branches were removed as late as July 8. In general, he found that reduction in yield on pruned plants was directly related with size of the plant at the time it was pruned.

Dungan (2), 1930, in Illinois, found a reduction in yield of corn following removal of one leaf per plant, but serious reduction occurred only after removal of 30 percent of the blades. A reduction in yield of 28 percent is reported by Eldridge (3), 1935, who reduced Iowa corn foliage by 50 percent at the milk stage. At the same location, 70 percent defoliation reduced the yield 40 percent. More recent work by Kiesselback and Lyness (7), 1945, in Nebraska, substantiates results reported by Dungan and Eldridge.

Hawthorn (5), 1943, clipped onion tops at weekly intervals beginning 6 weeks prior to harvest. Fifty- and 100-percent defoliation 6 weeks before harvest reduced yields 30 percent and 58 percent respectively. Greater reduction was effected from defoliation 5 weeks prior to harvest but subsequent foliage removal was indirectly related to loss in yield.

The "critical period" of plant growth at which the greatest damage results from leaf removal has been studied in corn by Eldridge (3), Hume & Franzke (6), Kiesselback & Lyness (7), and Loomis & Burnett (11). These writers agree on that period between tasselling and death of the silks. Klages (8) 1933, obtained similar results with flax; placing the critical period between bud formation and anthesis. The fifth week before harvest, as reported by Hawthorn (5), seems to be the time when greatest damage results from defoliation of onions.

Various workers have reported greater yield reduction in flax when stems were mechanically injured than when leaves were removed or partially injured.

Eldridge (4) assigns more loss in yield in small grains from stem damage occurring later in the season after stems have developed, than from loss of leaves. Loss from early damage resulted from leaf reduction rather than stem injury. Knowles (10), 1941, working with small grains attributed most yield re-

duction to broken and bent stems rather than to bruises of the stems.

With potatoes, a loss in grade may be more serious than reduction in total yield. Kraus (9), 1943, showed that removal of axillary branches from single-stemmed hills resulted in a reduction of U. S. 1 potatoes and an increase in U. S. No. 2's. Various tubers were present in the lower grade.

Materials and Methods

Experimental Procedure

The extent of loss from hail injury may be conditioned by both time of the storm and its severity. Consequently, data pertaining to each of these factors would be necessary in studies of this kind. In 1950, plants were defoliated three times. Treatments involved removal of 25 percent of the foliage, 50 percent and 25 percent plus another 25 percent 2 weeks later. First defoliation was done when plants were 6 inches high, a second treatment at the 12-inch stage and a third about August 7 when plants were approaching maturity. Under the conditions of this experiment, this was near maturity. Later defoliation would have been of little importance since "early-dying" **(Verticillium albo-atrum)** usually sets in about the second week in August, invalidating any data which might be gathered from later defoliation. In 1951, an additional treatment was employed in which 100 percent of the foliage was removed at the three stages named above. A general outline of the experiment is shown below.

Treatment number	Date of defoliation 1950	1951	Percentage of foliage removed	Plant Height (inches)
1 (check)	——	——	—	—
2	6/23	6/26	25	6
3	7/16	7/14	25	12
4	7/26	8/7	25	near-maturity
5	6/23	6/26	50	6
6	7/10	7/14	50	12
7	7/26	8/7	50	near-maturity
8	6/23	6/26	25	6
	7/3	7/10	25 (2 weeks later)	
9	7/10	7/14	25	12
	7/23	7/27	25 (2 weeks later)	
10	7/25	8/7	25	near-maturity
	8/9	8/20	25 (2 weeks later)	
11	——	6/26	100	6
12	——	7/14	100	12
13	——	8/7	100	near-maturity

Foliage was removed in two ways: By hand, in which leaves were pinched off at the base of the petiole. If only a part of a leaf was removed, the cut was made at right angles to the midrib. All apical buds were left intact and there was no injury to the main stem and branches. The second method involved the use of a beater—a sort of "cat-o-nine-tails" affair. Several number 9 wires were welded into a handle. At the termini of the wires were loosely attached iron nuts. Plants were flayed with this device upward on both sides and across the top until the approximate desired amount of foliage was removed. Stems

or even whole branches were sometimes broken off by this method. Some hand defoliation always followed the above procedure since it was impossible with the beater, to remove the exact amount of foliage.

In 1950 an attempt was made to measure foliage loss on a weight basis. Generally speaking, the method was unsatisfactory. In later treatments a graduated glass plate was used to measure leaf area in square centimeters.

Plants which were defoliated at the 6- and 12-inch stages of growth made rapid recovery. New leaves were formed, principally from axillary buds on the main stems. Studies were made on the rate at which such recovery was made. Data were obtained by measuring leaf area on tagged plants in each replication both before and immediately after defoliation. Subsequent measurements were made at 3-day intervals until plants had regenerated leaf area equivalent to that which had been lost. The number of days required for such recovery was designated as "set-back". This does not mean, however, that the defoliated plants had reached the same size, as measured in leaf area, as the non-defoliated plants. These plants were finally compared immediately before harvest and if, at that time, the defoliated plants were equal in size or approximately so, to the non-defoliated plants, recovery was considered as complete.

Cultural Methods

These potatoes were grown according to good cultural recommendations at the University of Idaho Aberdeen Branch Experiment Station in southeastern Idaho. Plots were 50 feet long, consisted of four rows; the center two, one hand-defoliated and one mechanically defoliated, were used for record. Plots were replicated five times. Plantings, both years, were made about May 15. The 1950 crop followed manure, while 100 pounds per acre of 33-0-0 was used on the 1951 crop. The soil was principally a Declo sand loam. The 1950 planting followed beans and the 1951 plots were on land just out of alfalfa. Fields were irrigated when the soil at a 12-inch depth showed 9 percent moisture or less.

Harvesting in 1950 took place on October 20, while September 17 was the 1951 harvest date. A potato harvester was used. Small cull potatoes were picked up by hand in 1951, but were not included in the 1950 data. Tubers were stored in burlap bags until graded.

Grading was done according to standards outlined in **Official Grades for the Standardization of Idaho Fruits and Vegetables,** State of Idaho, Department of Agriculture, 1947. All U. S. No. 2's were further divided into knobby and "malformed" tubers.

Experimental Results

Generally speaking, results for the 2 years paralleled each other. Where discrepancies occurred, they will be noted. Other-

wise, the data will be discussed more or less collectively. Total yield, yield of U. S. No. 1's, U. S. No. 2's including malformed and second-growth tubers, and culls were recorded. Data were taken also on set-back and recovery.

Effects of Type of Defoliation on Tuber Production

The principal difference between hand and mechanical defoliation was in the extent of damage to stems. Equal amounts of foliage were removed in each case. It is recognized that a hail storm will do damage to stems; the extent varying with the severity of hail. Since no attempt has been made to separate effects of such stem injury from total effects, the data from the two treatments have been combined to facilitate presentation. Suffice it to say here that there was a significant difference between total yields from the two series. The same thing was true regarding production of U. S. No. 1 potatoes; that is, hand defoliation resulted in less reduction in total yield and a higher incidence of top quality tubers. Conversely, type of defoliation had no effect upon production of U. S. No. 2's and culls.

Effects of Time of Defoliation on Tuber Production

Without regard to the amount of foliage removed, time of defoliation had considerable effect upon tuber production. This is true for total yield as well as yield of U. S. No. 1 potatoes. Table I shows the yields per acre from plots defoliated on June 24, July 15, and August 7 in comparison with yields from the check plots.

TABLE I

Yields of Potatoes in Sacks per Acre from Plots Defoliated at Three Different Times

Date of Defoliation	Total Yield		U. S. No. 1				Knobby Tubers			
	1950	1951	1950		1951		1950		1951	
			Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent
None	328.5	265.8	221.3	67.4	166.1	62.5	40.4	12.3	14.2	5.3
June 24 (6")	307.3	242.8	193.8	63.0	161.4	66.5	41.2	13.4	14.6	6.0
July 15 (12")	282.8	233.0	168.0	59.4	108.1	46.4	48.5	17.1	25.1	10.8
August 7	273.1	212.0	177.9	65.1	121.8	57.5	35.4	13.0	7.8	3.7

Date of Defoliation	Malformed Tubers				Culls			
	1950		1951		1950		1951	
	Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent
None	15.4	4.7	43.1	16.2	51.4	15.7	42.4	16.0
June 24 (6")	13.8	4.5	22.7	9.3	58.6	19.1	44.1	18.2
July 15 (12")	13.5	4.8	53.8	23.1	52.7	18.6	46.0	19.7
August 7	13.6	5.0	28.8	13.6	46.2	16.9	53.6	25.3

Following are pertinent statements which are borne out by the data in Table I. Total yield is decreased as defoliation is delayed. There is some indication, from the 2 years' data that yield and percentage of U. S. No. 1 tubers are most seriously influenced by defoliations made at the blooming stage, when plants were about 12 inches tall. Defoliation at the 12-inch stage produced the highest total and the highest percentage of knobby tubers. These figures are consistent for both years. The data for malformed potatoes—"pointed-ends," "dumbbells," and others

—are less consistent than those for knobby tubers. The 1951 data show a high yield and a high percentage of these tubers from plots defoliated.

In 1950, there was little difference in malformed tubers from any of the treatments, and it is difficult to explain the 1951 data. Generally speaking, more malformed tubers were formed in 1951. It is possible that, under conditions occurring at that time, defoliation at the 12-inch stage was considerably more effective than in 1950, an interaction between treatment and season.

The data for culls are similar for the 2 years, with the exception of those produced in 1951 from plots defoliated on August 7. Much of this difference is reflected in the small amount of knobby tubers produced from the same treatment and will be partially explained later.

Effect of Degree of Defoliation on Tuber Production

These data are shown in Table II. As might be expected, total yield and yield of U. S. No. 1's are in general directly related to the amount of foliage removed. Severe losses were encountered in 1951 from plots which were 100-percent defoliated. Some loss resulted from 100-percent defoliation at the 6-inch stage, as will be seen in Figure I. Later defoliation resulted in greater losses, as pointed out in the preceding paragraphs. Of major importance, however, was the sharp reduction in yield of U. S. No. 1's which followed 100-percent defoliation. Loss in this treatment is reflected in greater percentages of knobby tubers, malformed tubers, and culls than were produced in the other treatment.

TABLE II

Yields of Potatoes in Sacks per Acre from Plots Defoliated at Four Different Rates

Amount of Defoliation	Total Yield		U. S. No. 1				Knobby Tubers			
	1950	1951	1950		1951		1950		1951	
			Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent
None	328.5	265.8	221.3	67.4	166.1	62.5	40.4	12.3	14.2	5.3
25 percent	295.5	247.0	188.3	63.7	153.2	62.0	42.7	14.5	12.4	5.0
50 percent	287.0	242.0	173.9	60.6	150.2	62.1	45.1	15.7	11.7	4.8
25 plus 25 percent	280.9	235.9	177.8	63.3	142.3	60.3	37.2	13.2	14.9	6.3
100 percent		192.1			76.1	39.6			24.4	12.7

Amount of Defoliation	Malformed Tubers				Culls			
	1950		1951		1950		1951	
	Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent
None	15.4	4.7	43.1	16.2	51.4	15.6	42.4	16.0
25 percent	14.0	4.7	32.5	13.2	50.5	17.1	48.9	19.8
50 percent	13.6	4.7	32.5	13.4	54.4	19.0	47.6	19.7
25 plus 25 percent	13.3	4.7	30.9	13.1	52.6	18.7	47.9	20.3
100 percent			44.5	23.2			47.2	24.6

Interaction Between Amount of Defoliation and Time of Defoliation

Total Yield

The above discussion was based on data which have been segregated either for degree of defoliation or time of treatment. Obviously, each of these factors has a bearing upon tuber produc-

tion. It is also safe to postulate that 100-percent leaf-loss early in the season might not have so serious effects as a later loss of 25 percent. Such a statement is fairly well borne out from the data. Figure I gives an accurate picture of the manner in which these two factors are related. All plots yielded less than un-

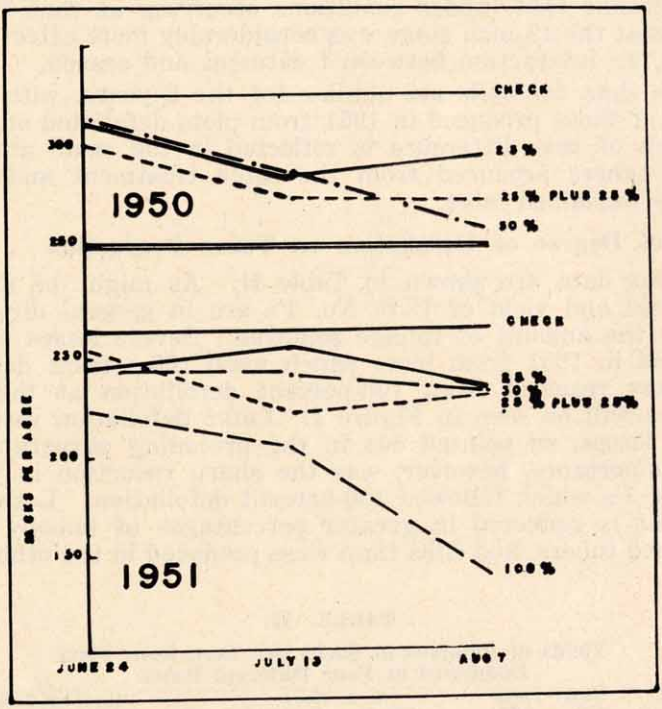

Figure 1. Yield in sacks per acre of potatoes from plots variously defoliated at three different dates.

treated plots, and usually significantly so. In 1950, yields generally were higher than in 1951.

Where two defoliations of 25 percent were made at 2-week intervals beginning July 15, there was greater loss than in other treatments except where all leaves were removed. In other words, two moderate hail storms might appear to do more damage than one severe one. However, 100-percent defoliation on August 7 served to reduce the total crop almost 50 percent.

Yield of U. S. No. 1 Potatoes

Grades are set forth by federal and state standards and this class constitutes that portion most suitable for market and therefore most important to the potato grower.

Figure II shows the interaction between date of defoliation and the degree of defoliation as reflected in yield of first quality potatoes. In 1950 and in 1951, greatest reduction in yield of

U. S. No. 1's came as a result of defoliation at blossoming time (July 15). The single exception is in those plots 100 percent defoliated on August 7 and this difference is not great. Furthermore, when calculated on a percentage basis, this July 15 treatment has the most serious effect. As a matter of fact, throughout all the treatments but one, smallest percentages of U. S. No. 1 potatoes came from plants defoliated on July 15. The exception occurs in 1950 data in plots defoliated 25 percent at 2-week intervals. In this instance, as in the rest of the 1950 data, the difference is not great.

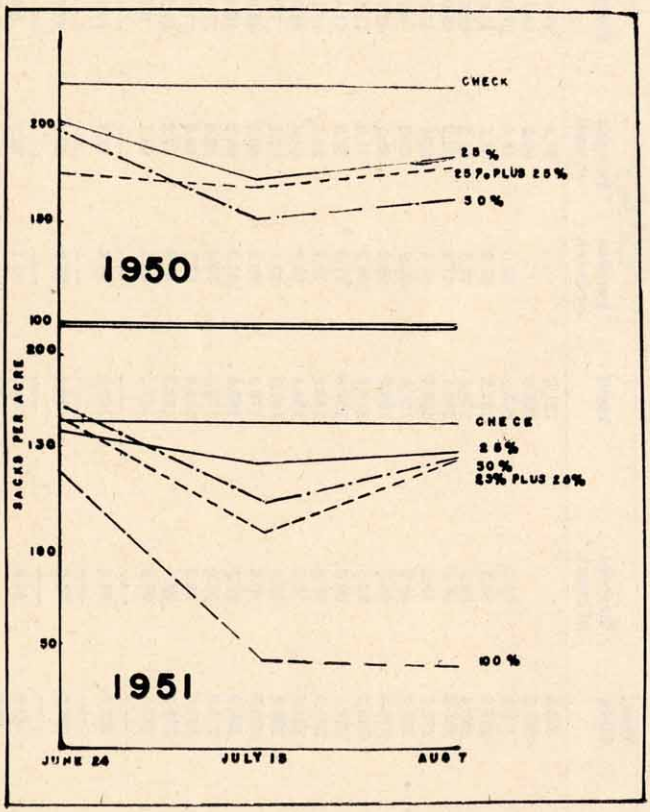

Figure 2. Yields in sacks per acre of U. S. No. 1 potatoes variously defoliated at three different dates.

The percentage of U. S. No. 1 potatoes is related to the number of off-types and culls produced. Table I is of interest in this respect. It will be noted that in 1950 and 1951 the yields and percentages of knobby tubers were less in those plots which were defoliated on August 7 than in any other treatments, and in 1951 the percentages were lower than the check. This matter will be taken up in the discussion which follows. Complete data are shown in Table III.

TABLE III

Classification of potatoes harvested from 13 treatments in 1951 and 1952 showing totals, percent of check and percent of total in each class.

Treatment		Total Yield	Percent of check	U. S. No. 1 Yield	U. S. No. 1 Percent of check	U. S. No. 1 Percent of total	Knobby Tubers Yield	Knobby Tubers Percent of check	Knobby Tubers Percent of total
1. Check	1950	328.5		221.3		67.4	40.4		12.3
	1951	265.8		166.1		62.5	14.2		5.3
2. 25% 6"	1950	310.1	94.4	203.5	92.0	65.6	37.9	93.7	12.2
	1951	247.8	93.2	162.5	97.8	65.6	11.6	82.0	4.7
3. 25% 12"	1950	283.4	86.3	174.5	78.9	61.5	46.6	115.3	16.4
	1951	255.3	96.0	146.1	87.9	57.2	19.0	133.0	7.4
4. 25% 8/7	1950	293.1	89.2	186.9	84.4	63.7	43.7	108.1	14.9
	1951	238.0	89.5	151.0	90.9	62.5	6.7	47.1	2.8
5. 50% 6"	1950	316.5	96.3	199.7	90.2	63.1	42.7	105.4	13.5
	1951	246.0	92.5	174.7	105.2	71.0	11.6	81.6	4.7
6. 50% 12"	1950	289.1	88.0	157.0	71.0	54.3	61.4	152.0	21.2
	1951	241.0	91.8	128.5	77.4	53.3	16.2	114.3	6.7
7. 50% 8/7	1950	254.6	77.5	164.1	74.2	64.4	31.2	77.2	12.3
	1951	236.0	88.8	147.3	88.7	62.4	7.3	51.2	3.1
8. 25% - 25% 6"	1950	295.5	90.0	178.2	80.5	60.3	42.9	106.1	14.5
	1951	252.0	94.8	168.3	101.3	66.8	18.4	129.7	7.3
9. 25% - 25% 12"	1950	275.8	84.0	172.5	78.0	62.6	37.6	93.0	13.6
	1951	224.8	84.6	111.4	67.1	49.6	17.6	124.0	7.8
10. 25% - 25% 8/7	1950	271.5	82.7	182.7	82.6	67.3	31.2	77.5	11.4
	1951	231.1	87.0	147.1	88.5	63.7	8.7	61.5	3.8
11. 100% 6"	1950	——	——	.....	.....	.....	.....	.....	.....
	1951	225.5	84.8	140.2	84.4	62.2	16.9	119.5	7.5
12. 100% 12"	1950	——	——	.....	.....	.....	.....	.....	.....
	1951	208.0	78.2	46.4	27.9	22.3	47.6	335.7	22.9
13. 100% 8/7	1950	——	——	.....	.....	.....	.....	.....	.....
	1951	142.9	53.8	41.7	25.1	29.2	8.6	60.5	6.0
L.S.D. 5%	1950	23.9		8.6			N.S.		
	1951	21.8		19.4			6.6		
L.S.D. 1%	1950	32.1		16.5			.....		
	1951	29.0		25.7			8.7		

TABLE III (continued)

Treatment		Malformed			Culls		
		Total	Percent of check	Percent of total	Total	Percent of check	Percent of total
1. Check	1950	15.4		4.7	51.4		15.6
	1951	43.1		16.2	42.4		16.0
2. 25% 6" *	1950	13.4	87.2	4.3	55.3	107.6	17.8
	1951	25.5	59.1	10.3	48.2	113.7	19.5
3. 25% 12"	1950	13.4	86.8	4.7	48.9	95.2	17.2
	1951	45.8	106.3	17.9	44.4	104.8	17.4
4. 25%" 8/7	1950	15.2	98.5	5.2	47.3	92.1	16.1
	1951	26.3	60.9	11.1	54.0	127.4	22.7
5. 50% 6"	1950	13.7	88.7	4.3	60.5	117.6	19.1
	1951	16.0	37.0	6.5	43.7	103.1	17.8
6 50% 12"	1950	13.7	89.1	4.7	57.0	110.8	19.7
	1951	56.1	130.2	23.3	43.1	101.7	17.9
7. 50% 8/7	1950	13.5	87.7	5.3	45.8	89.1	17.9
	1951	25.4	58.6	10.8	56.1	132.2	23.8
8. 25% - 25% 6"	1950	14.3	93.1	4.8	60.1	117.0	20.3
	1951	23.2	53.7	9.2	42.1	99.3	16.7
9. 25% - 25% 12"	1950	13.4	86.8	4.8	52.3	101.8	18.9
	1951	45.4	105.3	20.2	50.5	119.1	22.5
10. 25% - 25% 8/7	1950	12.2	79.3	4.5	45.5	88.4	16.7
	1951	24.1	55.8	10.4	51.3	120.9	22.2
11. 100% 6"	1950	.....	.....	.....	.....	.....	.....
	1951	26.1	60.4	11.6	42.3	99.9	18.8
12. 100% 12"	1950	.....	.....	.....	.....	.....	.....
	1951	67.8	157.1	32.6	46.2	108.9	22.2
13. 100% 8/7	1950	.....	.....	.....	.....	.....	.....
	1951	39.6	91.9	27.7	53.0	125.0	37.1
L.S.D. 5%	1950	N.S.			N.S.		
	1951	14.8			N.S.		
L.S.D. 1%	1950	.....			.....		
	1951	19.7			.....		

The Effects of Time and Severity of Defoliation on "Set-Back" and Recovery

"Set-back" has been previously explained as the length of time it takes for the plant to recover an amount of foliage equal to that which was removed. Actually, this is a rather remarkably short period. About 6 days were required for plants to renew their leaves after having been 25-percent defoliated at the 6-inch stage. From 7 to 8 days were needed when plants were similarly defoliated at the 12-inch stage. After 100-percent defoliation at the 6-inch stage, 11 days were required to renew the lost foliage, and 21 days were required for renewal in plants where all leaves were removed at the 12-inch stage. Plants which were defoliated 25 percent twice at 2-week intervals responded in a manner similar to those which were defoliated 100 percent.

Some difficulty was encountered in determining set-back on those plants defoliated on August 7. An infection of verticillium wilt obscured the true data. Some new leaves were produced, but foliage was being destroyed by the disease at the same time. It is particularly interesting to note that some of the defoliated plots exhibited resistance to verticillium wilt. This resistance was most pronounced in those plots 100 percent defoliated at the 12-inch stage.

The plots 25-percent defoliated at the 6-inch stage were the only ones which, at harvest time, had an amount of foliage equal to that in the check plots.

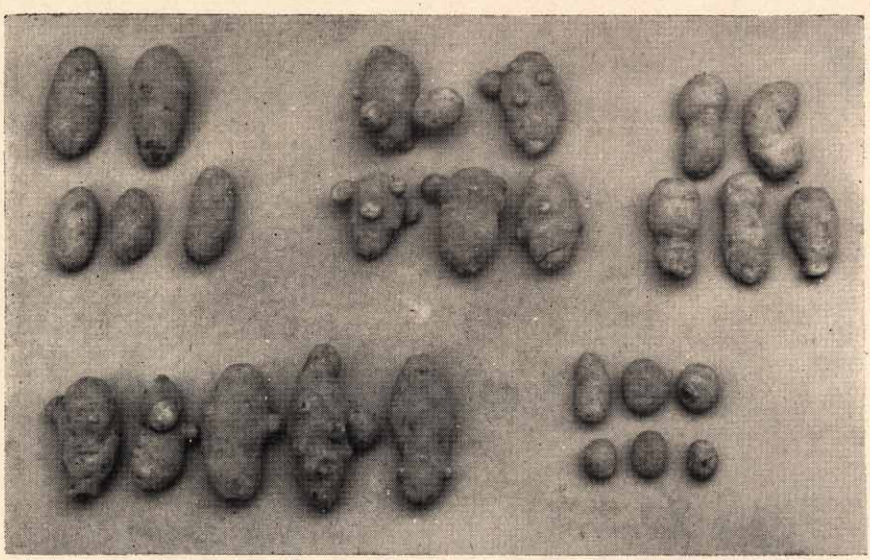

Figure 3. Types of tubers classified in hail injury studies. Upper left, U. S. No. 1; center, knobby second growth; right, second growth including malformed types as "dumbbells" and "pointed ends." Lower left, both types of second growth on same tubers; right, cull tubers.

Discussion of Results

When this work was inaugurated in 1950, it was hoped that some definite information could be obtained relative to the response of potatoes to hail injury. As previously stated, it was fairly obvious that such damage would be dependent upon the extent of hail injury and the time of its occurrence. Consequently, these two variables were given most attention in these studies. As a result of 2 years' experiments, considerable light has been shed on some of the problems.

It is clear, from the data presented that partial or complete defoliation has a marked influence upon (1) the total yield of potatoes produced, and (2) the grade or quality of these potatoes. Since profits from potato production result chiefly from the higher grades of potatoes rather than total yield, this second factor must be given particular attention. It has been shown that the extent of leaf removal is directly related to total yield and this influences yield of U. S. No. 1 potatoes. The data show, also, that time and amount of defoliation have a marked influence upon percentage of first quality potatoes. It is likely, then, that a hail storm of any consequence whatever will result in some loss to the grower. As the season progresses, greater losses may be expected, depending, of course, upon the amount of foliage lost. By referring to Figure II (page 10) it becomes obvious, that a so-called "critical" period develops. This is about time the buds are formed and is associated with tuber initiation. The greatest losses in quality are likely to occcur from damage at this time. A hail storm occurring earlier in the season has little effect upon potato grade unless all foliage is destroyed.

While it cannot be stated definitely just why the above phenomenon occurred, there is some reason to believe that damage to potato plants early in the season results in little loss in tuber quality simply because the tubers are not yet in the formative stage. Since these plants make rapid recovery, tuber-set will ultimately take place under conditions similar to those in undamaged plants. As the season progresses, rapid development of the tubers takes place until the plant becomes more or less senile. Carbohydrate production in the leaves slows down to a point where little surplus is available for tuber enlargement and growth is at a standstill. Hail damage occurring as this period approaches, apparently effects quality of potatoes but little since there is no resumption of tuber growth following damage to the tops. So, while tuber quality may not be affected from late damage, total yield may be altered as a result of this cessation of growth. This is fairly well demonstrated in Table I (page 7) and in Figure I (page 9).

The phenomenon which seems to result in a reduction of knobby tubers in those plots defoliated late in the season is difficult to explain. The data, however, as shown in Table I (page

7), and Table III (page 11) are too consistent, and the differences are too great to be wholly ignored.

Perhaps, during the early part of the season there is an accumulation of growth substances which may be translocated to the tuber; and, due to stimulus, the tubers start to grow from the eyes and thus produce knobby tubers. But during the middle portion of the season the partial-foliage removal does not allow for the accumulation of the growth-promoting substances, and no knobby tubers result. During the latter part of the season, the growth-promoting substances have already accumulated and have caused the second growth to begin. Thus the late removal of the foliage from the vine merely stops the growth of the already initiated knobby tubers.

The whole story of hail damage is not to be gained from 2 years of investigations. In a variety such as Russet Burbank, which is particularly susceptible to roughness from various causes, minor changes in environmental conditions may seriously affect potato quality. It might be added, too, that other varieties would not necessarily respond in the same manner as this one. Total reduction in yield need not vary; but certainly, in a variety such as Bliss Triumph, the incidence of rough tubers should be far less than in Russet Burbank regardless of field conditions.

Summary

1. This study was made in an effort to get information relative to the effects of simulated hail injury on Russet Burbank potatoes.

2. In 1950 replicated plots were defoliated 25 percent, 50 percent, 25 plus 25 percent at three different dates. The dates corresponded with a 6-inch and 12-inch stage and one approaching maturity.

3. Similar studies were made in 1951 with the addition of a 100-percent defoliation treatment.

4. Results from these experiments show:
   a. That any defoliation involving loss of leaves of 25 percent or more will reduce total yield.
   b. That extent of foliage loss is directly associated with reduction in both total yield and yield of U. S. No. 1's.
   c. That partial or complete defoliation at a time when tubers are being initiated will reduce the grade of potatoes in direct proportion to the amount of foliage removed.
   d. That early damage, before tubers are set, has little effect upon potato grade but may actually improve it.
   e. That late damage occurring as senility of the potato plant approaches will not reduce potato grade but reduces total yield since small potatoes will result.

f. That renewal of growth takes place rapidly when foliage is lost either in the 6-inch or 12-inch stages of growth; the time required being directly related to the amount of foliage removed. Complete recovery apparently does not take place if much more than 25 percent of the foliage is lost at any time.

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Funds for the implementation of this work and the publication of this bulletin were in part contributed by the Regional Hail Adjustment and Research Association, Chicago, Ill.