THESIS

EVALUATING POTATO YIELD LOSS FOLLOWING PLANT INJURY

Submitted by

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In partial fulfillment of the requirements
for the Degree of Master of Science
Colorado State University
Fort Collins, Colorado
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SUMMER, 1978

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY CRAIG W. DENHARD ENTITLED EVALUATING POTATO YIELD LOSS FOLLOWING PLANT INJURY BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

COMMITTEE OF GRADUATE SCHOOL

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Milton [illegible]

Advisor

ABSTRACT OF THESIS

EVALUATING POTATO YIELD LOSS FOLLOWING PLANT INJURY

This information has been developed to make available to the crop insurance adjuster, information previously contained in comprehensive reports as well as information developed especially for this publication.

Determining stage of growth and percent plant damage at time of injury are necessary to accurately predict yield loss. Knowledge of the potato plant and its ability to recover following injury may also aid the adjuster in his evaluation.

Types of injury following hail damage include defoliation, severed stems and bruised and broken stems. Experiments were conducted which showed that yield losses were usually less than visual estimates of vine damage would indicate. Conclusions drawn from the research include: multiple bruising was not more damaging than one bruise 3/4 of the distance below the plant top and was also similar to 50% defoliation and severing stems 50% through; simultaneous bruising and defoliation did not always have an additive effect over either injury separately; the potato stem possesses an interconnected vascular system so if damage occurs it is likely that one or more vessels will remain functional; severe defoliation results in at least a temporary increase in the photosynthetic rate of remaining leaves.

Procedures for the adjuster to follow in the field have been designed to improve the estimate, incorporating the results of the research work.

Symptoms of possible injuries present with hail are also included.

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Summer, 1978

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ACKNOWLEDGEMENTS

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Most importantly, I thank Dr. Milton Workman for his advice and assistance in producing an effective and worthwhile publication.

INTRODUCTION

This handbook is based on previous work supported by the Crop Insurance Research Bureau and the National Crop Insurance Association (NCIA). The comprehensive annual reports are available at the NCIA headquarters in Colorado Springs, Colorado and at the Colorado State University Research Center located near Center, Colorado.

The assumptions and conclusions are drawn partially from previous yearly reports while some of the information was developed specifically for the handbook.

Determining the stage of growth (staging) at the time of injury and the percentage plant damage must be done with reasonable accuracy to predict yield loss. The accuracy of the evaluations is dependent in part on a knowledge of potato growth and how the potato plant responds to injury. The purpose of the handbook is to aid the adjuster to more accurately estimate stage of growth and plant damage, leading to an equitable adjustment for the grower and the insurance company.

The information is not presented as conclusive since much remains unclear. It does present data which is accurate at the present time.

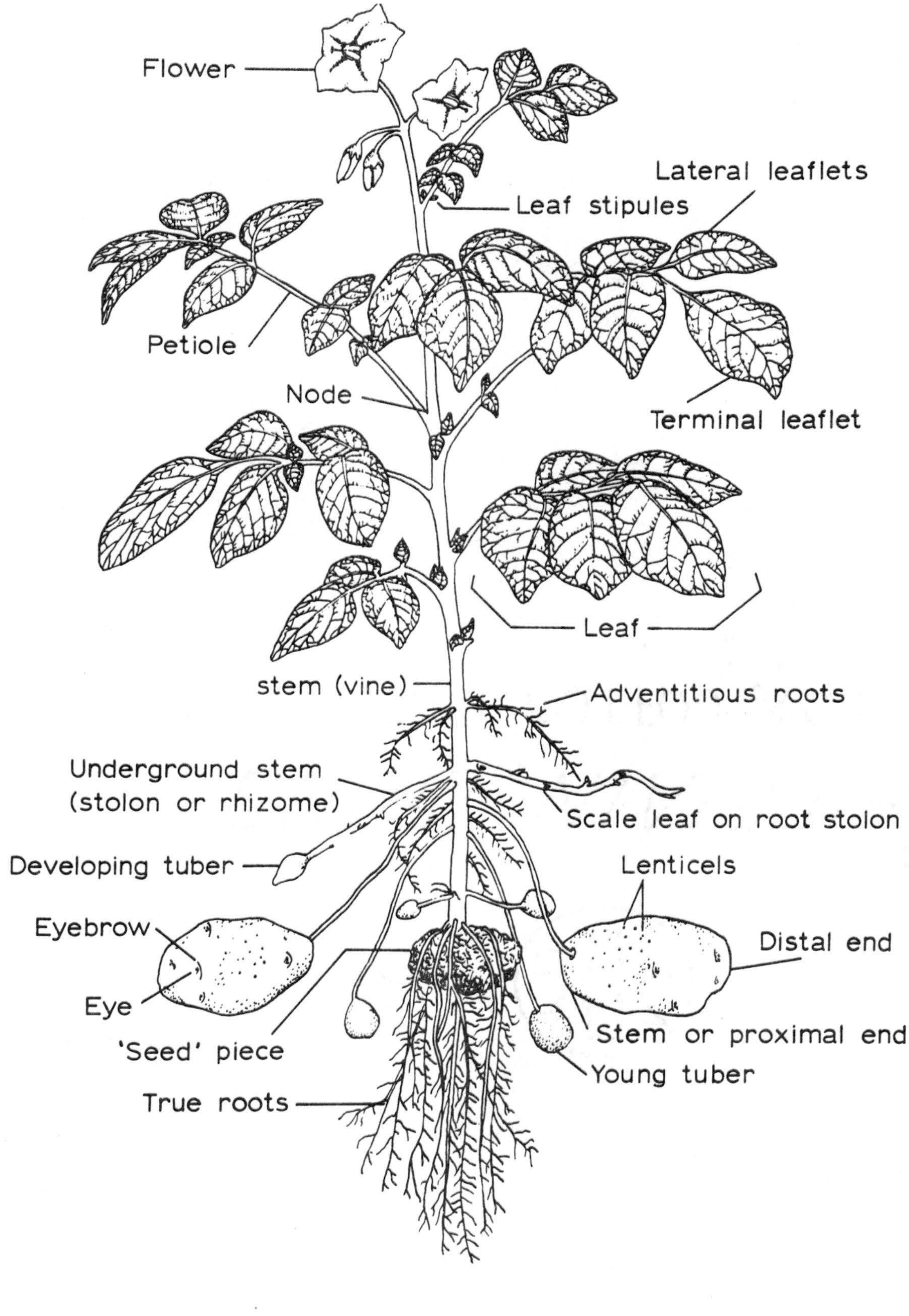
I. Plant Morphology

Figure I-1 shows the morphology of a "single stemmed" potato plant which has grown from a bud on the mother seed piece. In the estimation of plant damage, which will be discussed later, the stem is considered as a unit. Ten to twelve leaves will develop on a mature stem until a flower is formed. Each leaf consists of 6-8 leaflets attached to a petiole and connected to the main stem at a node. The formation of an inflorescence (flowers) will terminate the stem but a branch may develop from a node below the flowers and continue growth of the stem. More than one stem usually develops per plant and a three- or four-stem plant is preferred. Additional lateral stems that develop later from nodes tend to grow horizontally giving the plant a prostrate appearance. Estimation of damage on multi-stemmed plants is difficult since all stems do not contribute equally to tuber yield, requiring recognition of strong and weak stems.

True roots are produced on the new shoot where it emerges from the seed piece but adventitious roots are often produced above this point. Tubers are produced at the ends of underground stems, commonly referred to as stolons, although botanically the term is rhizome. Initiation and development of tubers is controlled by day-length, temperature and plant age. In the San Luis Valley, tubers are initiated about three weeks after plant emergence. Tubers may be initiated later but these may not attain marketable size. Stress, such as severe hail damage, may result in temporary cessation of tuber growth, tuber drop or tuber resorption. Hail damage prior to tuber initiation may delay set until plants have sufficiently recovered. Carbohydrates previously stored in the tubers may provide energy for new vine growth.

Stolons have scale-like leaves which are undeveloped leaves and the tubers themselves possess characteristics of normal stems, dormant buds (eyes) and eyebrows (point of attachment for scale leaves). Lenticels are pores that permit carbon dioxide and oxygen exchange in the tubers and when extremely wet become swollen and are visible as white spots.

Figure I-1 Diagrammatic sketch of the potato plant.


Flower
Lateral leaflets
Leaf stipules
Petiole
Node
Terminal leaflet
Leaf
stem (vine)
Adventitious roots
Underground stem
(stolon or rhizome)
Scale leaf on root stolon
Developing tuber
Lenticels
Eyebrow
Distal end
Eye
'Seed' piece
Stem or proximal end
Young tuber
True roots

II. Growth Patterns

Figures II-1 and II-2 show similar average growth patterns for Russet Burbank and Red McClure, respectively. Tuber growth begins three weeks post-emergence (E-3), with maximum size achieved at 12-13 weeks. At 10 weeks from emergence both cultivars have achieved 70% of their total yield. The first marketable tubers appear 5-6 weeks post-emergence and at 10 weeks 50% of the maximum market yield has been attained.

The bottom of Figures II-1 and II-2 show similar average vine growth patterns for the two cultivars. Maximum vine size is attained 7-8 weeks post-emergence followed by a steady decline toward maturity. The plant is more sensitive to injury at this time since following 7-8 weeks vine growth and vigor are declining, resulting in slower recovery and replacement of damaged leaves. Note that at 10 weeks post-emergence vine weight has declined to 80% of the maximum; rapid tuber development is responsible for this.

The growth patterns discussed above are averages of two or more years. Length of the growing season in the San Luis Valley is extremely variable. Normal planting dates are from May 1 to May 30 with harvest beginning in late August and continuing into early October. Factors such as late spring frost, low fertility, irrigation practice, disease, insects, hail, etc. may delay plant and tuber development and shift the growth curves. Likewise, an early fall frost may prematurely stop growth. Tuber development is recommended as a means for estimating plant age (discussed following), but the adjuster should be aware of the many factors influencing tuber growth.

Figure II-1 Russet Burbank tuber yield and vine growth patterns. Total yield expressed as percent of maximum total yield and market yield as percent of maximum market yield. Dashed rectangle indicates percent of maximum growth at ten weeks.

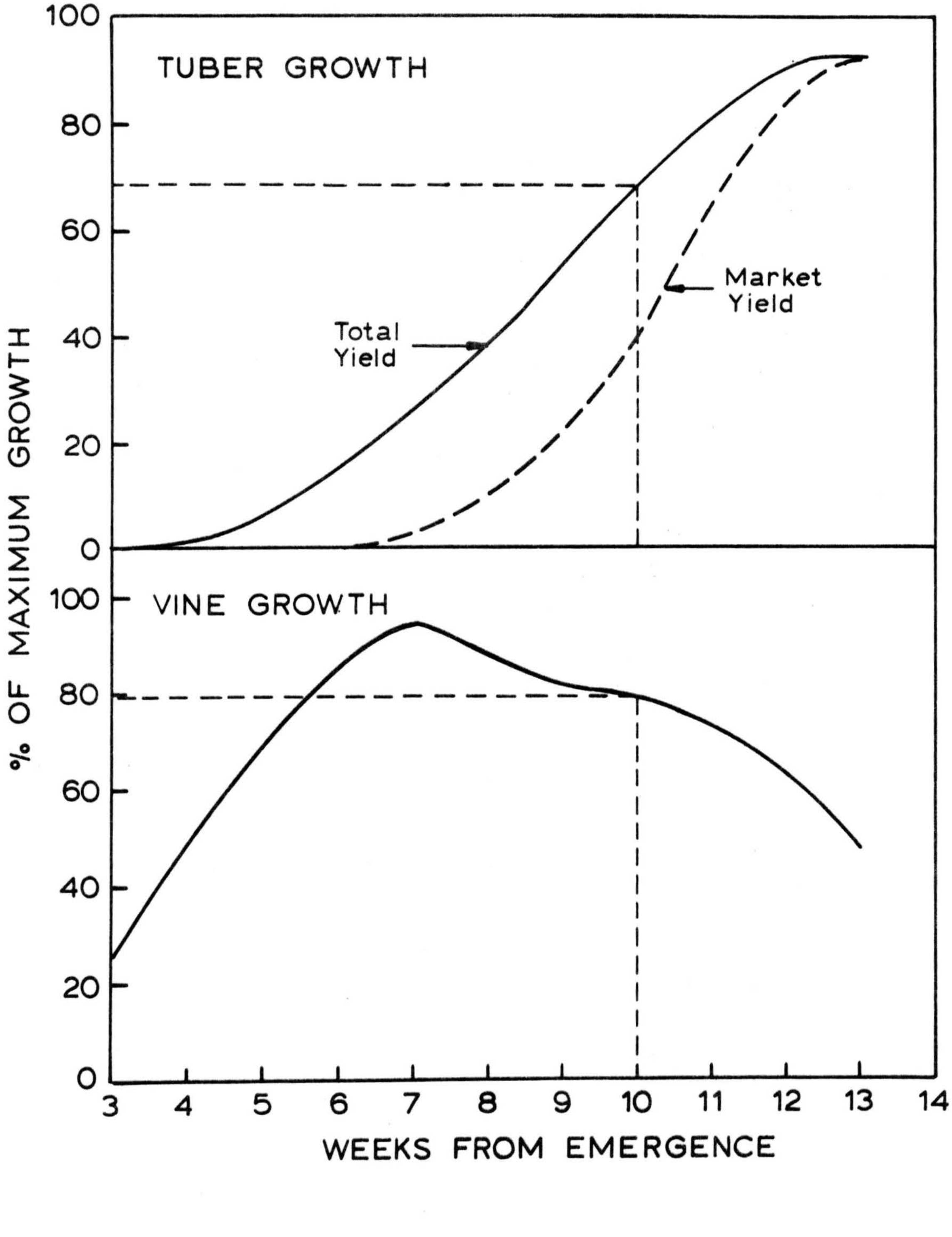
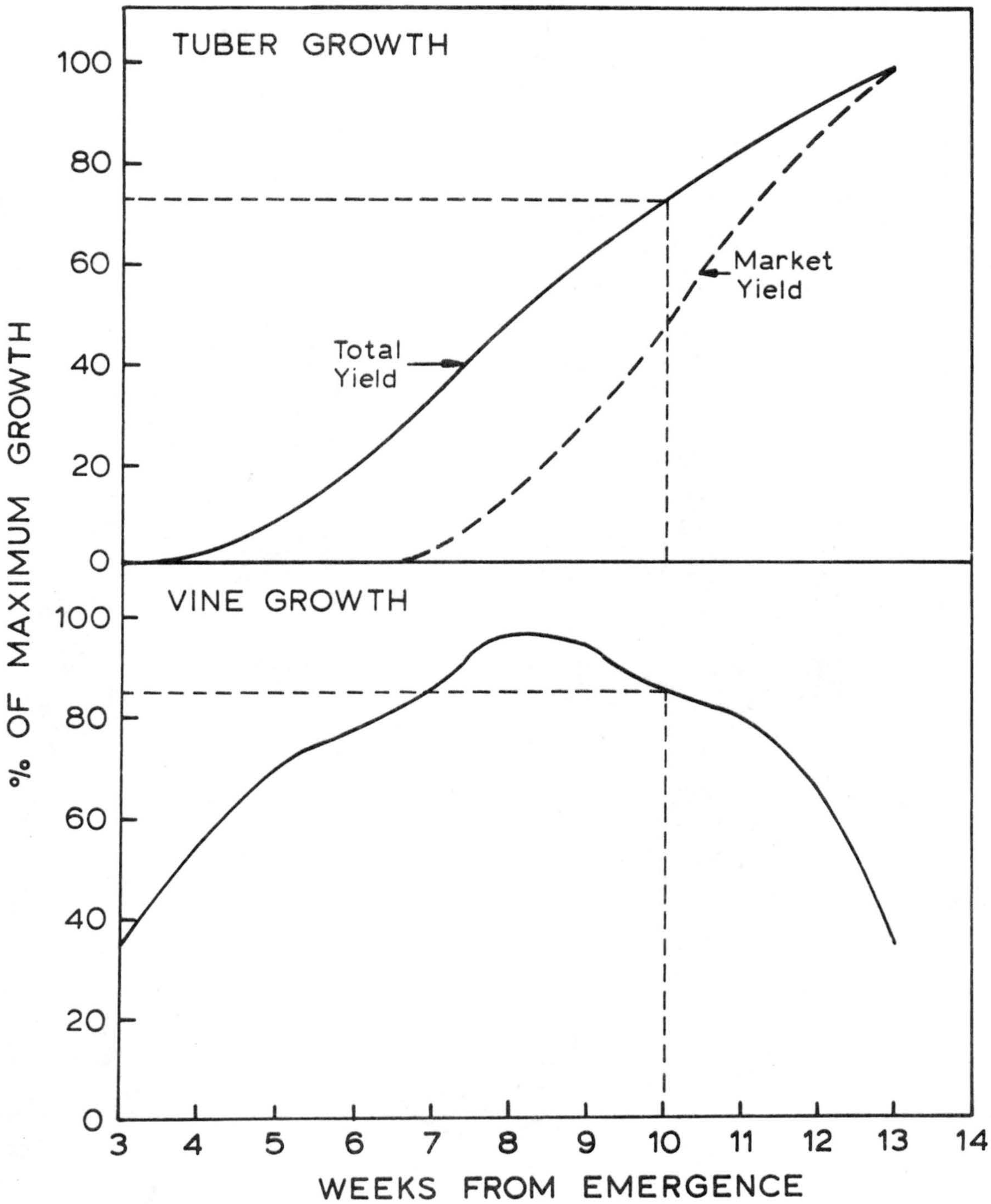

TUBER GROWTH
Total Yield
Market Yield
VINE GROWTH
% OF MAXIMUM GROWTH
WEEKS FROM EMERGENCE
100
80
60
40
20
0
3
4
5
6
7
8
9
10
11
12
13
14

Figure II-2 Red McClure tuber yield and vine growth patterns. Total yield expressed as percent of maximum total yield and market yield as percent of maximum market yield. Dashed rectangle indicates percent of maximum growth at ten weeks.


TUBER GROWTH
100
80
60
40
20
0
Total
Yield
Market
Yield
VINE GROWTH
100
80
60
40
20
0
% OF MAXIMUM GROWTH
3
4
5
6
7
8
9
10
11
12
13
14
WEEKS FROM EMERGENCE

III. Estimating Stage of Growth

A. Research Information

Determining the correct stage of growth at time of injury is essential since a staging error of one week can result in large differences in estimated losses.

Previous research in Idaho identified flower development, node number, and plant height as useful criteria for determining plant age. In Colorado, however, flowering is erratic and more dependent on temperature and soil moisture. Flowers of the first inflorescence may not develop fully and the second inflorescence often is rudimentary. Observations on the number of nodes developed on Russet Burbank and Red McClure plants in the San Luis Valley are shown below.

Table III-1 Number of nodes developed by Russet Burbank and Red McClure plants.

	Time from Emergence	Number of Nodes	
		Russet Burbank	Red McClure
July 3	3 weeks	11.4[a]	9.4[a]
July 17	5 weeks	4.3[b]	2.6[b]
Aug. 1	7 weeks	6.6	3.6
Aug. 14	9 weeks	6.6	5.1

[a] Number of nodes to first inflorescence

[b] Number of nodes beyond first inflorescence

Up to the first inflorescence, number of nodes agreed with the Idaho research. However, beyond the first inflorescence, Idaho reported an additional 11 or 12 nodes to the second inflorescence compared to less than 7 in Colorado.

Inconsistencies in node number and flower development and the loss of plant tops resulting from hail injury required the development of additional criteria for determining plant age. Weeks from emergence and tuber growth have been found useful since one can serve as a check on the other. The development of varietal growth curves similar to those described previously are essential if tuber growth is to be used effectively.

B. Recommended Colorado Procedure

1. Time interval-days from emergence.

Emergence date is that time when 90% of the plants are visible based on one plant expected per seed piece. The grower must be reminded to record this date for the insured field and provide this information to the adjuster if the field is damaged. After obtaining emergence date, calculate the number of days from emergence to the date of injury and record in upper left column on survey sheet (See Table III-2).

2. Tuber size and weight.

Dig a minimum of 5 hills (preferably 10) at random from the damaged area. If the damaged field is large consider subdividing and taking additional hills from more than one location. Weigh the tubers to the nearest ounce from each hill and record in upper right column on survey sheet (Table III-2). Divide the total weight of all hills by the number of hills sampled and record average hill weight as shown in the example.

3. Stage of growth.

The stage of growth of the damaged field should be estimated within 2 or 3 days of injury. Using days from emergence, average hill weight and if possible, plant size and inflorescence development, the stage of growth is determined from information shown in Table III-3 (Russet Burbank potatoes) or Table III-4 (Red McClure potatoes). The stage is selected that most closely agrees with the four characteristics listed in the tables.

As mentioned above, plant and tuber development may be delayed or accelerated by environmental factors. If plant and tuber characteristics do not agree with those predicted from emergence date it may be necessary for the adjuster to use an earlier or later stage of growth to compute losses depending on tuber size and weight.

Table III-2 Sample potato survey sheet currently in use. To be completed by the adjuster at time of crop injury evaluation.

Insured John Doe Policy No. 75109 Loss No. 48

The XYZ Ins. Co. Date of Loss 8-9-78 Date of Insp. 3-13-78

Pol. Item No. 5
No. Acres 9
Variety Russets
Planting Date May 31
Emergence Date June 12
Days from Emerg. 53
Tuber Size(in.) 2"-3½"

STAGE OF GROWTH:

D/L E-8 D/A E-8

HILL #1		HILL #2		HILL #3		HILL #4		HILL #5	
Stem	% Damage	Stem	% Damage	Stem	% Damage	Stem	% Damage	Stem	% Damage
1	33	1	37	1	44	1	16	1	38
2	40	2	40	2	48	2	25	2	40
3	10	3	42	3	28	3	30	3	46
4	26	4	18	4	16	4	10	4	50
5	35	5	26	5	22	5	20	5	29
6	18	6	15	6	40	6		6	32
7		7	45	7	50	7		7	33
8		8	33	8	40	8		8	43
9		9		9	27	9		9	49
10		10		10		10		10	35
	27%		32%		35%		20%		38
6 /	162	8/	256	9/	315	5/	101	10/	385

For Plant Damage per Hill Divide Plant Damage by Number of Stems in Count

SUMMARY		
Hill	Plant Damage	Weight (oz)
1	27	30
2	32	24
3	35	25
4	20	29
5	38	27
		135

5 / 152 = 30.4 Ave.Hill Wt. Ave.P.D.

27 oz

TEST NO. 1

Pol. Item No. 5
No. Acres 9
Variety Russets
Planting Date May 31
Emergence Date June 12
Days from Emerg. 53
Tuber Size(in) 2"-3½"

STAGE OF GROWTH:

D/L E-8 D/A E-8

HILL #1		HILL # 2		HILL # 3		HILL # 4		HILL #5	
Stem	% Damage	Stem	% Damage	Stem	% Damage	Stem	% Damage	Stem	% Damage
1	35	1	30	1	40	1	60	1	75
2	50	2	45	2	45	2	70	2	25
3	45	3	15	3	45	3	40	3	40
4	40	4	20	4	50	4	45	4	40
5	25	5	65	5	15	5	40	5	35
6	10	6	60	6	20	6	50	6	40
7	15	7		7	4-	7	60	7	
8	40	8		8		8	70	8	
9	30	9		9		9	30	9	
10	40	10		10		10		10	
	33%		39%		36%		51%		42
10/	330	6 /	235	7/	255	9/	465	6/	255

For Plant Damage per Hill Divide Plant Damage by Number of Stems in Count

SUMMARY		
Hill	Plant Damage	Weight (oz)
1	33	22
2	39	30
3	36	31
4	51	25
5	42	26
		134

5 / 201 = 40.2 Ave.Hill Wt. Ave.P.D

26.8oz

TEST NO. 2

Table III-3 Criteria for determining stage of growth of Russet Burbank potatoes.

Stage	Time Interval	Plant Height	Inflorescence	Tuber Size	Ave. Hill Wt.(ozs.)
Emergence		½"	None	Seed	
E-1	7 days from emerg.	2" to 5"	None	Seed	
E-2	14 days from emerg.	5" to 8"	None	Seed	
E-3	21 days from emerg.	8" to 10"	Appearance of first buds	¼" to ½"	0.6 ozs
E-4	28 days from emerg.	12" to 20"	First buds beginning to open	½" to 1½"	2.7 ozs
E-5	35 days from emerg.	20" to 22"	2% of flowers open	1½" to 2" tubers elongating	6.5 ozs
E-6	42 days from emerg.	22" to 24"	Most flowers are open	2" to 2½"	11.8 ozs
E-7	29 days from emerg.	24" to 26"	Full bloom	2" to 3" most tubers elongating	19 ozs
E-8	56 days from emerg.	26" to 30"	Early blooms falling	3" to 3½" in length	27 ozs
E-9	63 days from emerg.	30" to 34"	Most blooms have fallen	3½" to 4"	34 ozs
E-10	70 days from emerg.	30" to 34"	All blooms have fallen and lower leaves yellowing	4 or more tubers 4½" in length	40 ozs
E-11	77 days from emerg.	30" to 34"	All leaves yellow or brown	60% of tubers marketable size	46 ozs
E-12	84 days from emerg.	30" to 34"	Leaves drying and falling	Fully matured, stolons drying	49 ozs

Table III-4 Criteria for determining stage of growth of Red McClure potatoes.

Stage	Time Interval	Plant Height	Inflorescence	Tuber Size	Ave. Hill Wt.(ozs.)
Emergence		½"	None	Seed	
E-1	7 days from emerg.	3" to 4"	None	Seed	
E-2	14 days from emerg.	4" to 8"	None	Seed	
E-3	21 days from emerg.	10" to 12"	Appearance of first buds	½" to 1"	2.4 ozs
E-4	28 days from emerg.	14" to 18"	First buds beginning to open	1" to 1¼"	3.5 ozs
E-5	35 days from emerg.	20" to 22"	1% of flowers are open	1¼" to 1½"	3.5 ozs
E-6	42 days from emerg.	22" to 26"	Most flowers are open	1½" to 2"	10.6 ozs
E-7	49 days from emerg.	26" to 28"	Full bloom	2" to 2½"	20 ozs
E-8	56 days from emerg.	26" to 30"	Early blooms falling	2½" to 3"	28 ozs
E-9	63 days from emerg.	26" to 30"	Most blooms have fallen	3" to 3½"	34 ozs
E-10	70 days from emerg.	26" to 30"	All blooms have fallen and lower leaves yellow	3½" to 4"	43 ozs
E-11	77 days from emerg.	26" to 30"	All blooms have fallen and all leaves yellowing	4 or more tubers over 4 inches	47 ozs
E-12	84 days from emerg.	26" to 30"	Leaves drying and yellowing	Fully matured, stolons dry	50 ozs

IV. Estimating Plant Damage

A. Research information

Types of injury resulting from hail damage may include bruised and broken stems, severed stems, defoliation, skinning, etc. The accurate assessment of yield losses requires information regarding the influence of specific types of injury. The following experiments were conducted for this purpose. Plants were hand injured in specific ways and the effect on yield evaluated.

1. Comparison of bruise number and location on stem with severing portions of the plant. Each stem of the plant was treated as follows:

   a. severely bruised in one location 1/4, 1/2, and 3/4 of the distance below the plant top (Figure IV-1).

   b. severely bruised at two or three locations per stem.

   c. severed 1/4, 1/2, and 3/4 of the distance below the plant top.

Figure IV-2 shows the yield losses resulting from the injuries. Market and total yield losses were similar, therefore only market yield is discussed and will be reported hence forth as "yield". Losses increased with increasing distance of the bruise from the plant top. Two or three bruises per stem were no more damaging than one bruise applied 3/4 of the distance below the plant top. Yield losses resulting from severe bruising were less than 15%. Complete removal of the plant top at various locations resulted in a maximum loss of 32%.

A graphic comparison of bruising with plant removal on percent decrease in yield is shown in Figure IV-3. Depending on where the plant was bruised or severed, the bruise/sever yield loss ratio ranged from 0.14 to 0.44; thus bruising was 14% to 44% as damaging as severing the plant at a similar location on the stem.

2. Comparison of defoliation, vine removal, stem bruising, stem severing and skinning on yield loss. The plants were treated as follows:

a. 50% leaf removal
b. severing 50% of vine
c. severing 1/2 through each stem (Figure IV-4)
d. two severe bruises per stem
e. 100% vine removal
f. severely skinning each stem (Figure IV-5)

The influence of each injury on yield loss is shown in Figure IV-6. Treatments were applied 5 and 7 weeks from emergence but due to the similarity in response only the averages are presented.

Removal of 50% of foliage, without damaging stems, reduced yield 27%. Removal of 50% of the vine reduced yield 50% while 100% vine removal resulted in a 97% loss. Cutting each stem 1/2 way through reduced yield 25%. This was similar to 50% defoliation and about 1/2 that resulting from 50% vine removal.

Two bruises per stem reduced yield 19% and was similar to severe skinning which reduced yield 23%.

In summary, a similarity in yield reduction was observed between 50% defoliation, severing stems 50% through, two bruises per stem and severe skinning. Each has a different physiological effect but result in similar yield losses.

3. Comparison of bruising and defoliation when applied separately and in combination.

Experiments were conduced in 1976 with five cultivars and in 1977 with two cultivars. The following injury treatments were applied separately and in combination at three stages of plant growth; 0, 1, and 3 severe bruises per stem and 0, 25, and 75% defoliation. Some minor differences did occur between cultivars; for reasons of brevity only the average cultivar responses at the three stages of growth are presented. The 1976 results are shown in Figure IV-7. Yields were reduced 10% and 15% by one and three bruises per stem, respectively. Similarly, 25% and 75% defoliation (no bruises) reduced yield 8% and 12%, respectively. Simultaneous defoliation and bruising increased losses but the losses were not always additive, i.e. three bruises and 25% defoliation were not much more severe than three bruises and no defoliation.

The 1977 results are shown in Figure IV-8. Yields were reduced 16% and 15% by one and three bruises per stem, respectively; thus three bruises were no more damaging than one. Twenty-five and 75% defoliation reduced yields 10 and 18%. Simultaneous defoliation and bruising did not always increase yield loss beyond that resulting from one or the other injury.

In summary, severe bruising and defoliation reduced yield less than expected and the combined effect was not always additive.

4. Effect of bruising on water flow through the stem.

As seen in the previous sections, severe bruising reduced yield less than one would intuitively expect. Plants severely bruised prior to 7 weeks from emergence resume active growth within a few days above and below the point of damage. This growth continues vigorously and most likely contributes to tuber development (Figure IV-9).

The potato stem posseses an excellent and well protected vascular system. Each stem has two groups of transporting vessels, three large near the outside and three smaller vessels near the center of the stem. Both groups are interconnected so if damage to one vessel occurs, the others can supply water to the plant top. This may be partially demonstrated in the following way. A stem is severely bruised, severed from the plant and allowed to wilt for a brief period. The cut end is then held below the surface of a safranine dye solution and re-cut. Immediately the dye passes up through any still functional vessels. Figures IV-10 and IV-11 show the dye solution in injured and non-injured tissue.

5. Effect of defoliation on photosynthetic rate.

It was also noted in the previous sections that severe defoliation reduced yield less than expected. Prior research with certain other plants has indicated that defoliation can increase the efficiency of remaining leaves. An experiment was conducted to determine the influence of defoliating the potato plant on the photosynthesis of remaining leaves.

Three defoliation treatments were used; 0%, 25%, and 75%. Photosynthesis was measured before, immediately after, three and seven days after leaf removal. Results were calculated for the whole plant and per unit leaf area, however, the photosynthetic rate of the entire plant was depressed immediately after damage then increased after three days (Figure IV-12). Seventy-five percent defoliation would be expected to have the greatest effect on photosynthesis, yet in seven days the photosynthetic rate of these plants equaled that of non-defoliated plants. Photosynthesis of non-defoliated plants for some unexplained reason decreased between three and seven days.

An explanation of the increase in photosynthesis of severely defoliated plants was found when the rate was calculated per unit leaf area. Results in Figure IV-13 show that after a brief decrease, the most rapid increase in photosynthetic rate per square centimeter of leaf occurred on the plants 75% defoliated. This may in turn account for smaller than expected yield losses from severely defoliated plants.

B. Estimating plant damage in the field

The research described above indicates some problems in predicting yield losses based on external appearance. However, at present no other procedure is available. Nevertheless, the adjuster, through information presented in this bulletin and experience, can make reasonably accurate estimates. The following procedures are intended to improve the accuracy of the estimate.

1. The field should be visited as soon as possible after damage and general observations made. The evaluations should be made within a week and the damaged field revisited after two weeks to check for regrowth and field health. Compare with the conditions of other fields in the area.

2. Determine the uniformity of injury throughout the damaged field. If non-uniform, divide the field into sections and evaluate separately.

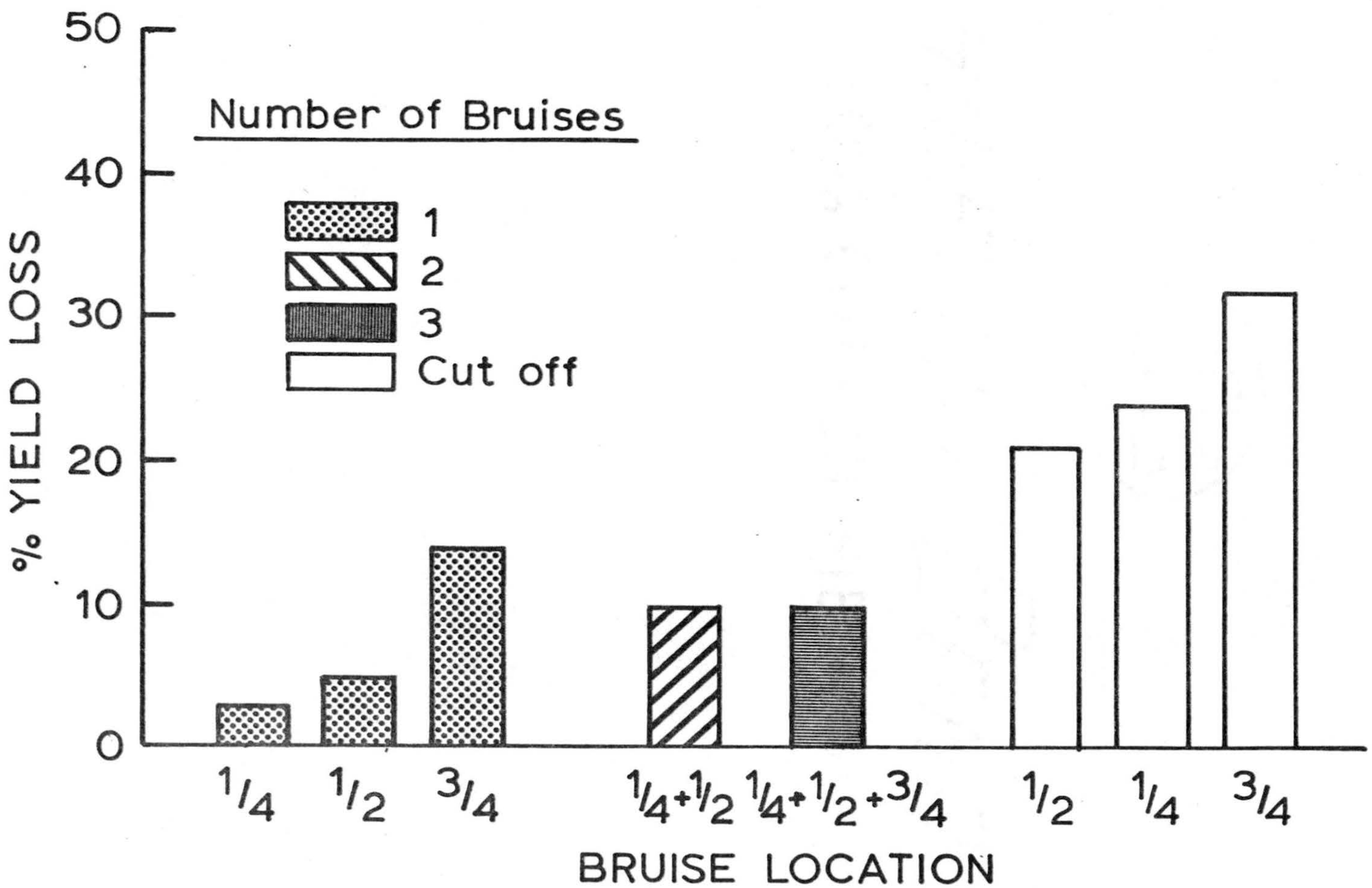
3. In each field or damaged part of a field, select at random a number of hills similar to or the same as those used to determine stage of growth.

4. Examine all stems in a single hill and either discard small spindly stems or place a lesser value on these than on larger stems. Estimate the percent damage to each stem in the hill taking into account; defoliation, cuts, bruises, stem skinning and other types of injury. Particular attention should be given to the portion of the stem remaining, e.g. the number

of intact leaves and whether the stem is capable of supporting new growth. Record the percent damage for each stem on the main body of the survey sheet (Table III-2) and calculate an average for the entire hill. After a sufficient number of hills have been estimated, calculate plant damage for each area and then average plant damage for the entire field. This is recorded at the bottom of the survey sheet (Table III-2).

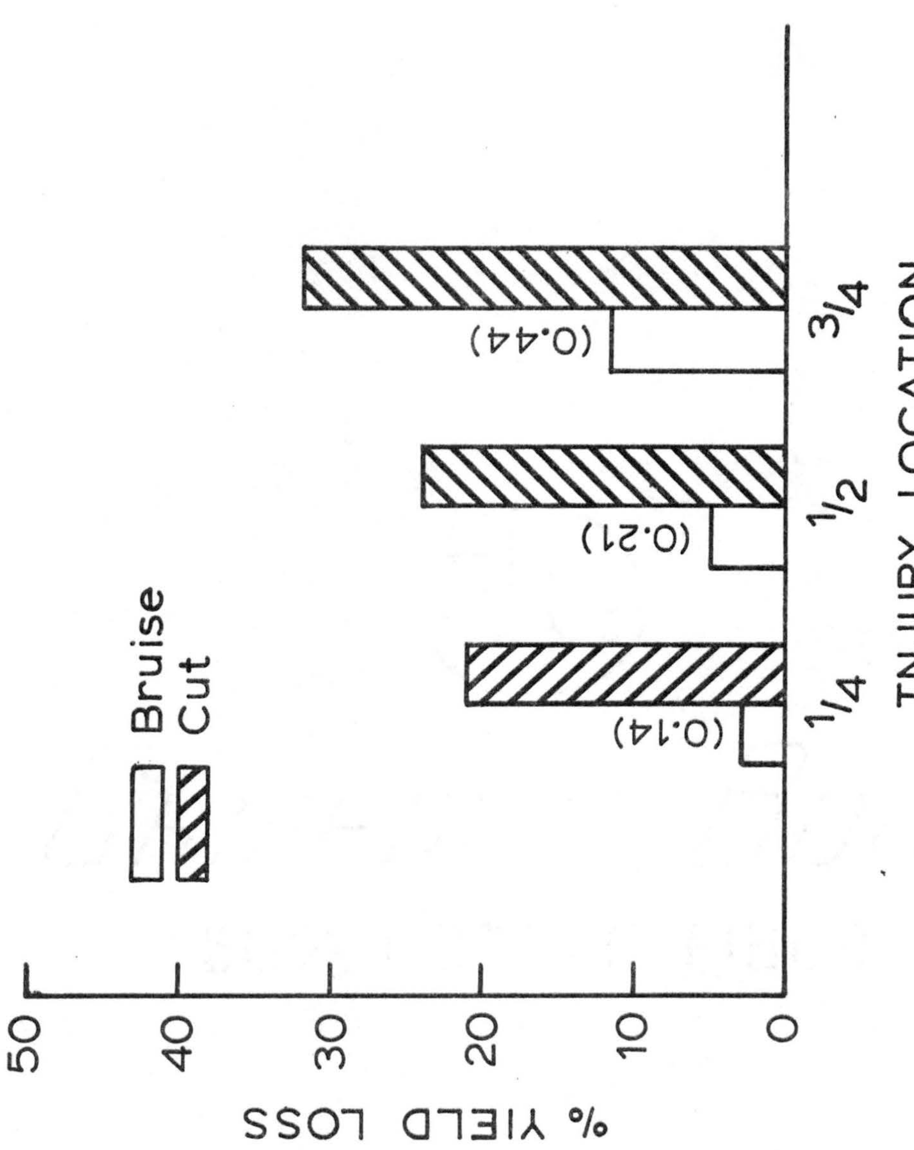
Figure IV-1 Severe bruise in one location two weeks following injury.

Figure IV-2 Influence of bruising and severing portions of plant on percent yield loss. Bruise location refers to distance below plant top. Plant portions were cut off at similar locations. Loss is an average of three injury dates.



% YIELD LOSS
50
40
30
20
10
0
Number of Bruises
1
2
3
Cut off
1/4
1/2
3/4
1/4+1/2
1/4+1/2+3/4
1/2
1/4
3/4
BRUISE LOCATION

Figure IV-3 Comparison of bruising and severing portions of plant on percent yield loss. Injury location refers to distance below plant top. Number in parentheses is the bruise to cut loss ratio.



% YIELD LOSS
0
10
20
30
40
50
Bruise
Cut
(0.14)
(0.21)
(0.44)
1/4
1/2
3/4
INJURY LOCATION

Figure IV-4 Plant stem cut one-half way through.

Figure IV-5 Mature stem injured by severe skinning.

Figure IV-6 Comparison of specific types of injury with regard to their effect on yield. An average of injury at E-5 and E-7.

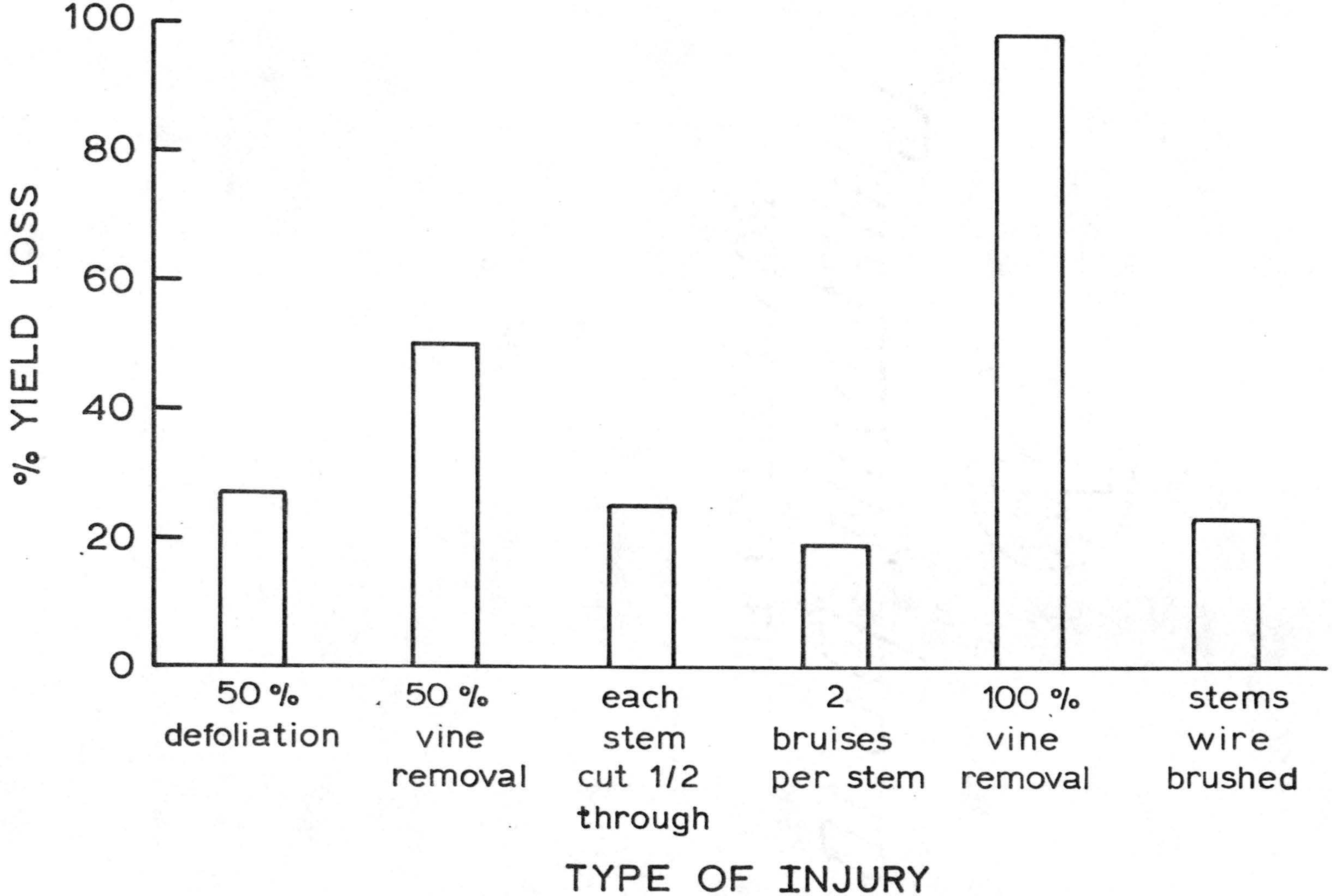
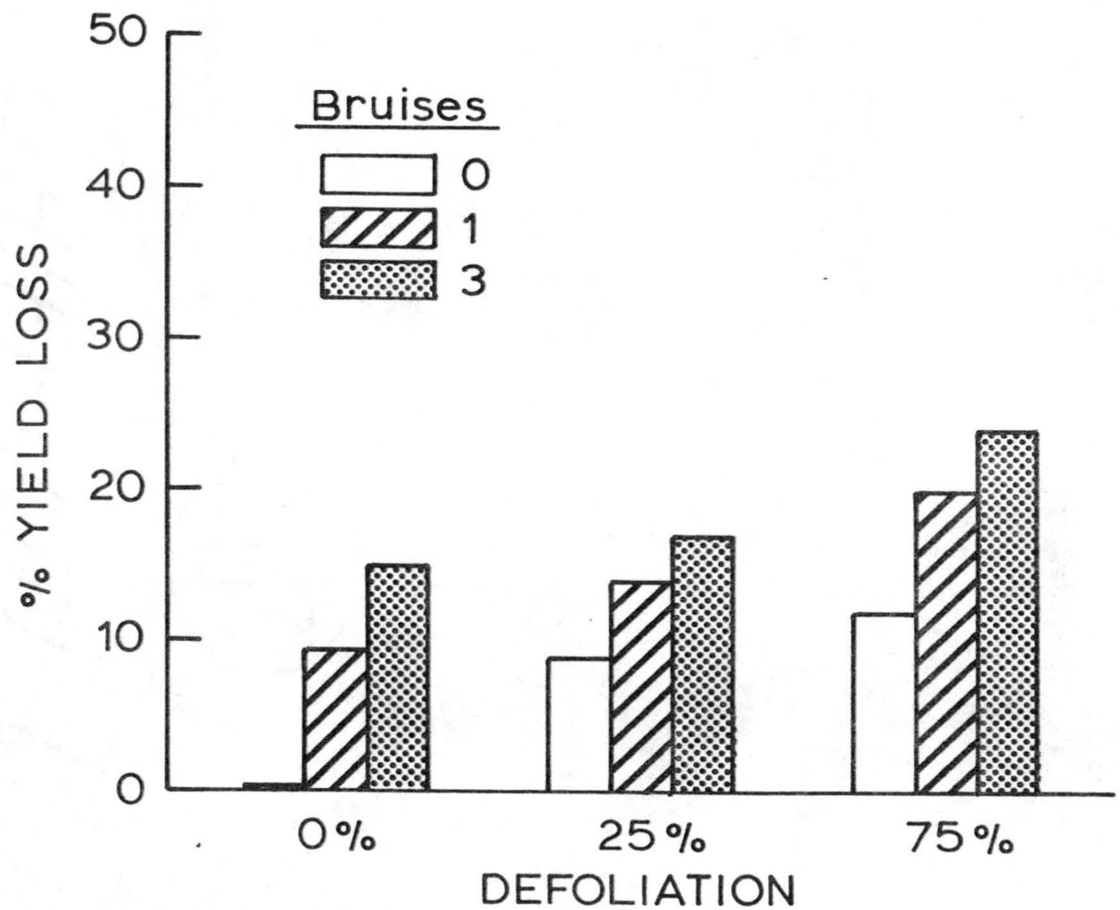

100
80
60
40
20
0
% YIELD LOSS
50 % defoliation
50 % vine removal
each stem cut 1/2 through
2 bruises per stem
100 % vine removal
stems wire brushed
TYPE OF INJURY

Figure IV-7 Percent decrease in yield due to defoliation and bruising for 1976. The height of each bar is a mean of 45 measurements: 5 cultivars x 3 growth stages x 3 replications.



% YIELD LOSS
50
40
30
20
10
0
Bruises
0
1
3
0%
25%
75%
DEFOLIATION

Figure IV-8 Percent decrease in yield due to defoliation and bruising for 1977. The height of each bar is a mean of 18 measurements: 2 cultivars x 3 growth stages x 3 replications.

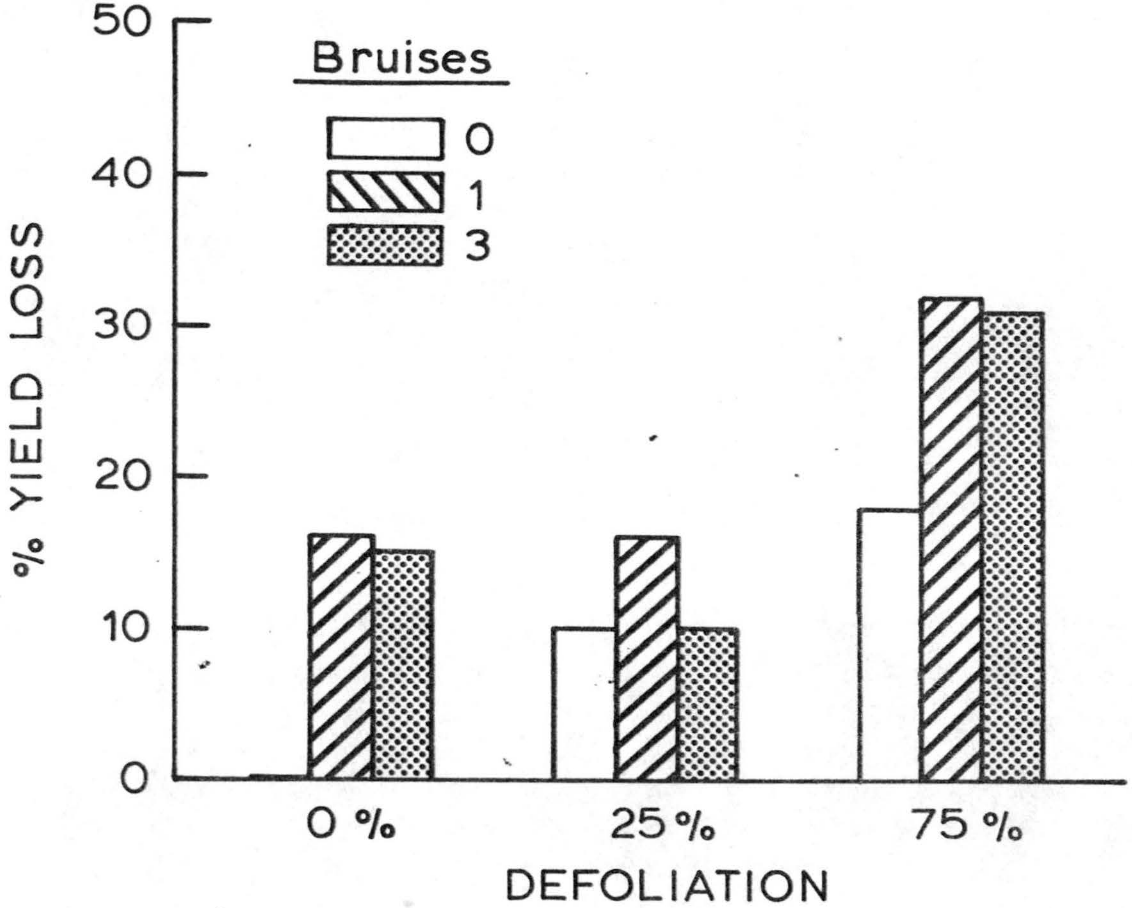

Bruises
0
1
3
% YIELD LOSS
50
40
30
20
10
0
0 %
25 %
75 %
DEFOLIATION

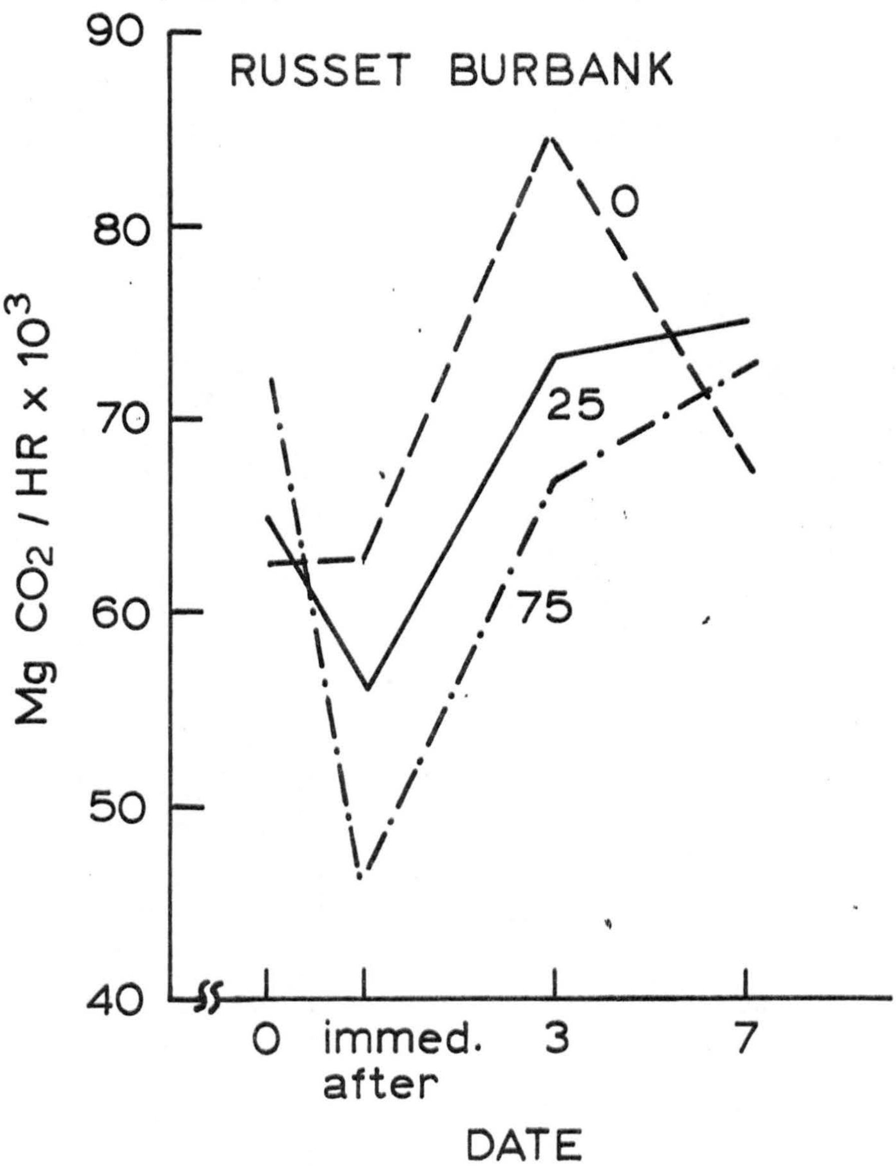
Figure IV-9 Active growth above and below bruised tissue several days following injury.

Figure IV-10 Bruised tissue on right with intact vessel above point of injury on left.


2 F
1$\frac{1}{2}$ F
1 F
$\frac{1}{2}$ F

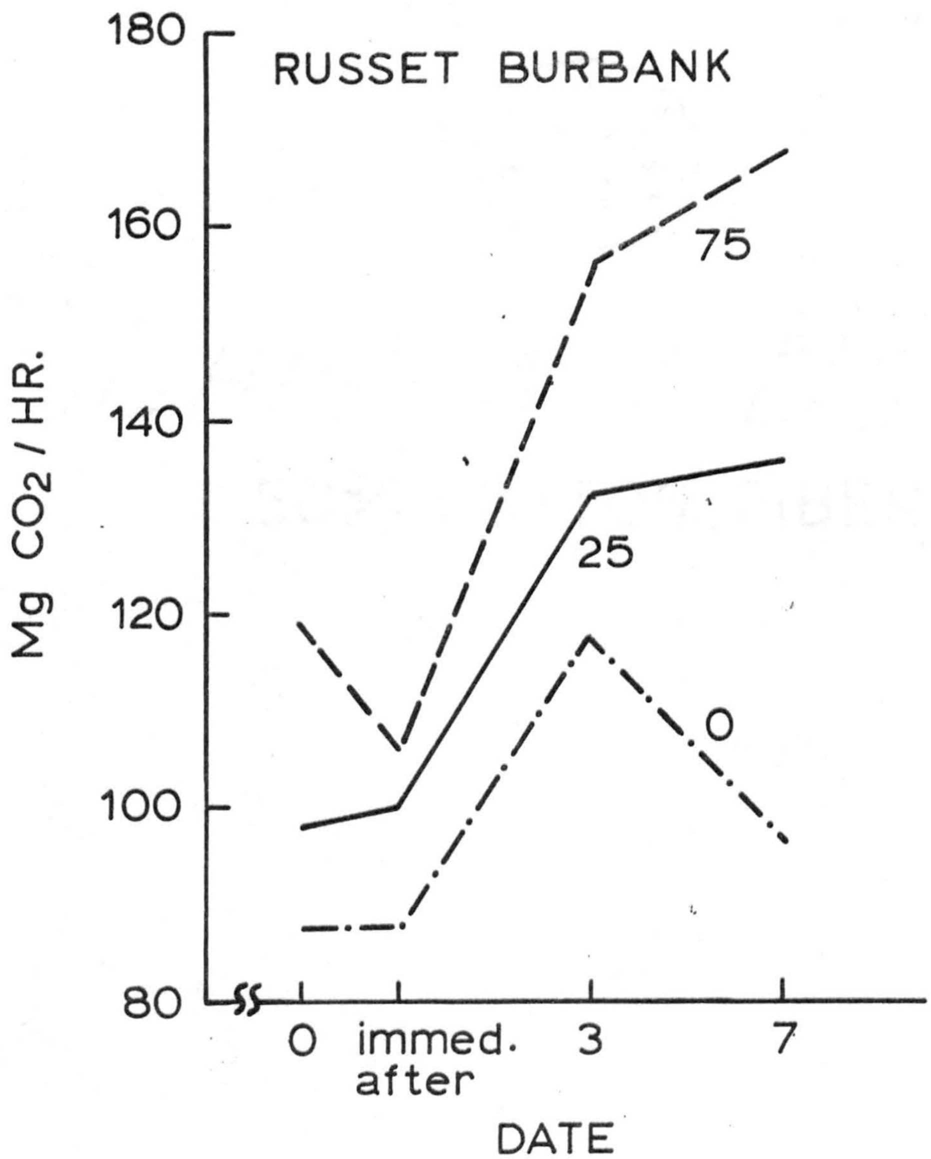
Figure IV-11 Non-bruised tissue with dye in intact vessel.

Figure IV-12 Effect of defoliation on photosynthetic rate of the entire plant before and after injury. 0, 25, and 75 refer to percent defoliation.



RUSSET BURBANK
90
80
70
60
50
40
Mg CO2 / HR x 10^3
0
25
75
0
immed. after
3
7
DATE

Figure IV-13 Effect of defoliation on photosynthetic rate per unit leaf area of the remaining leaves before and after injury. 0, 25, and 75 refer to percent defoliation.


RUSSET BURBANK
180
160
140
120
100
80
Mg CO_2 / HR.
75
25
0
0
immed. after
3
7
DATE

V. Estimating Yield Loss from Loss Tables

A. Development and Interpretation of Loss Tables

Loss tables, prepared for the Russet Burbank and Red McClure cultivars, are shown in Tables V-1 and V-2, respectively. The tables show the anticipated yield losses in relation to the percent plant damage and stage of growth. For example, in Table V-1, 50% injury at six weeks from emergence (E-6) would result in an expected 36% yield reduction. The data were obtained from plants damaged to various degrees with a mechanical flail at different growth stages. The tables are based on three years data for Russet Burbank and two years for Red McClure. The mechanical flail defoliated, bruised, cut, and removed plant parts. The percent plant damage and growth stage, based on emergence date, was recorded for each injury date. Yield from non-injured and injured plants was determined at the end of each season and the percent loss was calculated for each cultivar.

Figure V-1 is an example of a loss curve used to prepare the tables discussed above. The figure shows clearly how the sensitivity to injury shifts with plant age. The most sensitive stage is about 7 weeks from emergence. As shown before, maximum vine growth occurs at this stage. Prior to 7 weeks vine recovery following damage may be quite rapid but later recovery is slow or may not occur. However, after 7 weeks tubers are beginning to attain marketable size, therefore, yield loss decreases with plant age.

B. Comparison of flail and hail simulator

The hail simulator was developed in order to injure plants in a manner that more closely resembles natural hail. The following experiment was done to compare plant response when injured with the flail and hail simulator. Russet Burbank plants were injured similarly with the two methods at 4 and 7 weeks of age. Response at the two plant ages was similar and therefore only averages are shown. Actual and estimated losses following two degrees of injury are shown in Fig. V-2. Following moderate injury, which resulted in 42% plant damage with flail and 55% with hail simulator, the actual yield losses were 10% for flail and 23% for hail simulator. Heavy injury resulted in 70% plant damage with the flail and 75% with the hail simulator, and 38% and 35% yield loss, respectively. Estimated losses exceeded actual loss 15% and 9% for flail injured plants and 9% and 17% for hail simulator injured plants.

C. Use with other cultivars

The loss tables are primarily intended for use with those cultivars used in their development. Hand injury studies to compare other cultivars to Russet Burbank have been done. However, at present sufficient information is not available to recommend the tables for use in all areas and with other cultivars without reservation. Factors to be considered include: (1) days required for growth, (2) vine strength and size, and (3) time of tuber setting. If the loss tables are used elsewhere than the San Luis Valley, Colorado, then conditions such as rainfall, temperature, length of growing season and time of year must be considered.

D. Using the tables

After the stage of growth and percent damage have been estimated, the percent yield loss is determined from the appropriate loss table. The percent loss is then recorded on the bottom of the survey sheet (page 15). Care in staging and plant damage estimation is essential since slight errors in either may greatly change the estimated loss. It is important to realize that the loss tables are based on injury inflicted mechanically and a natural hail storm may deposit a large amount of ice and water. The influence of this is largely unknown but would depend on the quantities and duration. Most likely if the field received a large quantity of ice the plants would be completely destroyed. The best procedure would be to inspect such fields on several occasions.

Table V-1 Loss chart for evaluating yield losses of Russet Burbank potatoes. The body of the chart presents the percent loss in yield.

Stages of Growth	Percent plant damage																		
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
E- 1																			
E- 2	2	3	4	5	6	7	8	9	10	11	13	15	16	18	19	20	21	22	23
E- 3	4	6	8	10	12	14	16	19	21	23	26	28	31	36	38	41	43	45	47
E- 4	4	7	10	12	15	17	19	21	24	25	29	34	39	45	51	56	58	60	62
E- 5	5	8	12	14	17	20	22	24	26	28	31	39	47	55	63	71	74	76	78
E- 6	7	11	15	20	23	27	31	33	36	39	42	49	55	60	67	74	75	76	77
E- 7	9	14	20	25	30	35	39	42	45	49	53	58	63	67	72	77	77	77	77
E- 8	9	14	19	23	28	33	35	38	41	45	48	52	56	60	65	69	69	69	69
E- 9	8	13	18	22	26	31	33	36	38	40	43	46	49	53	56	60	60	60	60
E-10	5	8	11	13	17	20	22	24	26	28	29	31	33	35	37	40	40	40	40
E-11	3	4	6	7	9	10	11	12	12	13	14	15	16	17	18	19	19	19	19
E-12																			

Table V-2 Loss chart for evaluating yield losses of Red McClure potatoes. The body of the chart presents the percent loss in yield.

Stages of Growth	Percent Plant Damage																		
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
E- 1																			
E- 2	0	0	0	1	2	3	4	4	5	5	6	7	7	8	8	9	10	11	12
E- 3	0	1	2	3	4	5	6	7	8	10	11	12	14	16	17	18	19	20	21
E- 4	2	4	6	7	9	11	11	13	15	17	18	20	22	24	26	28	30	32	34
E- 5	5	8	10	12	15	18	19	20	21	22	23	26	29	32	35	38	41	43	45
E- 6	5	8	10	12	15	18	20	22	25	26	28	34	37	42	46	51	53	54	55
E- 7	5	8	10	13	15	18	21	24	28	30	33	39	45	51	57	64	65	65	65
E- 8	5	8	10	13	15	18	22	23	28	31	34	37	43	47	52	56	57	57	57
E- 9	5	8	10	13	16	19	22	25	29	32	35	38	41	44	47	49	50	50	50
E-10	4	6	7	9	10	13	15	17	19	21	24	26	28	32	33	33	33	33	33
E-11	2	3	4	5	5	6	7	8	10	11	12	13	14	15	16	17	17	17	17
E-12																			

Figure V-1 Influence of degree of injury and stage of growth on yield loss of Russet Burbank potatoes. The number on each line is estimated degree of injury. Results are an average of four years.

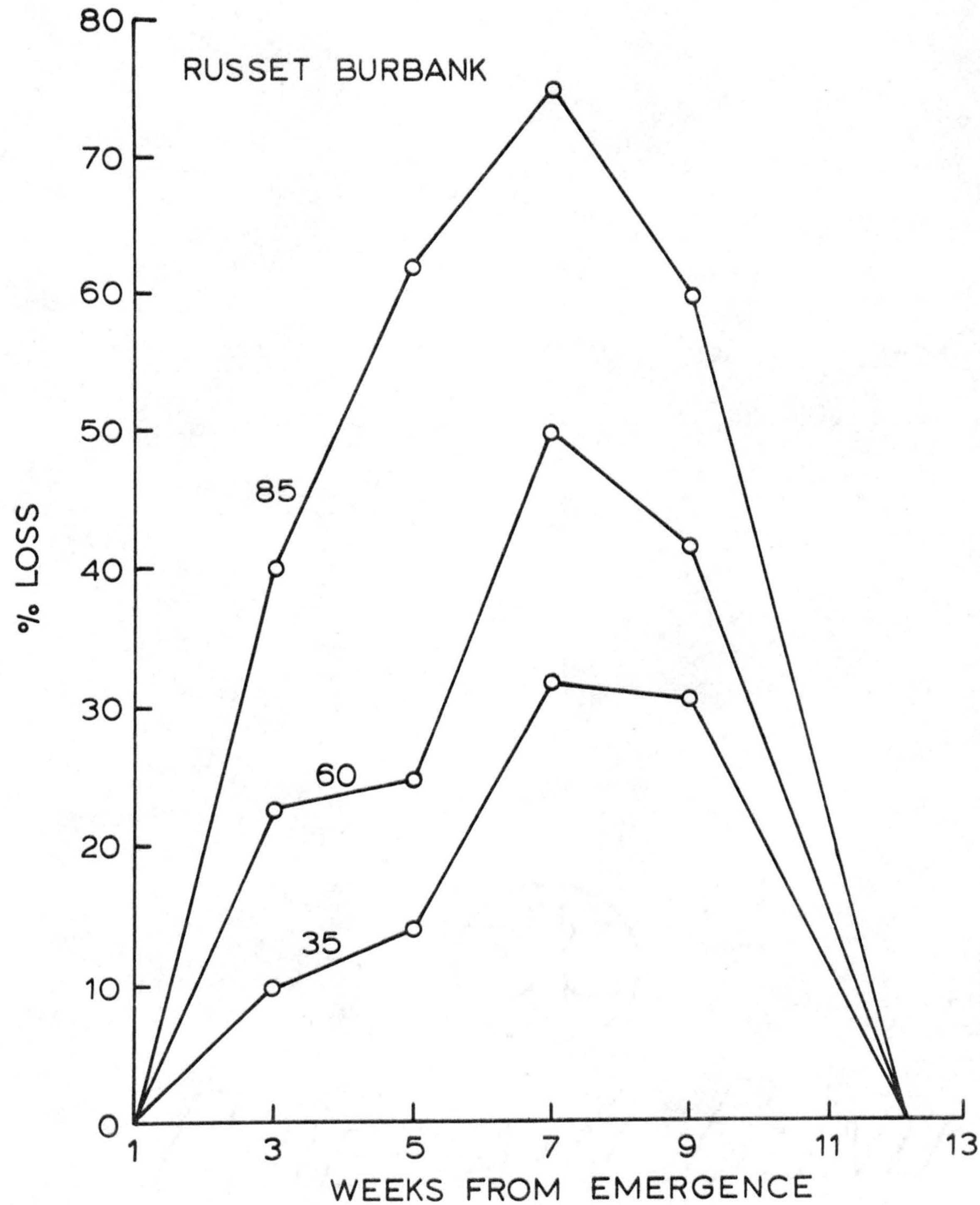
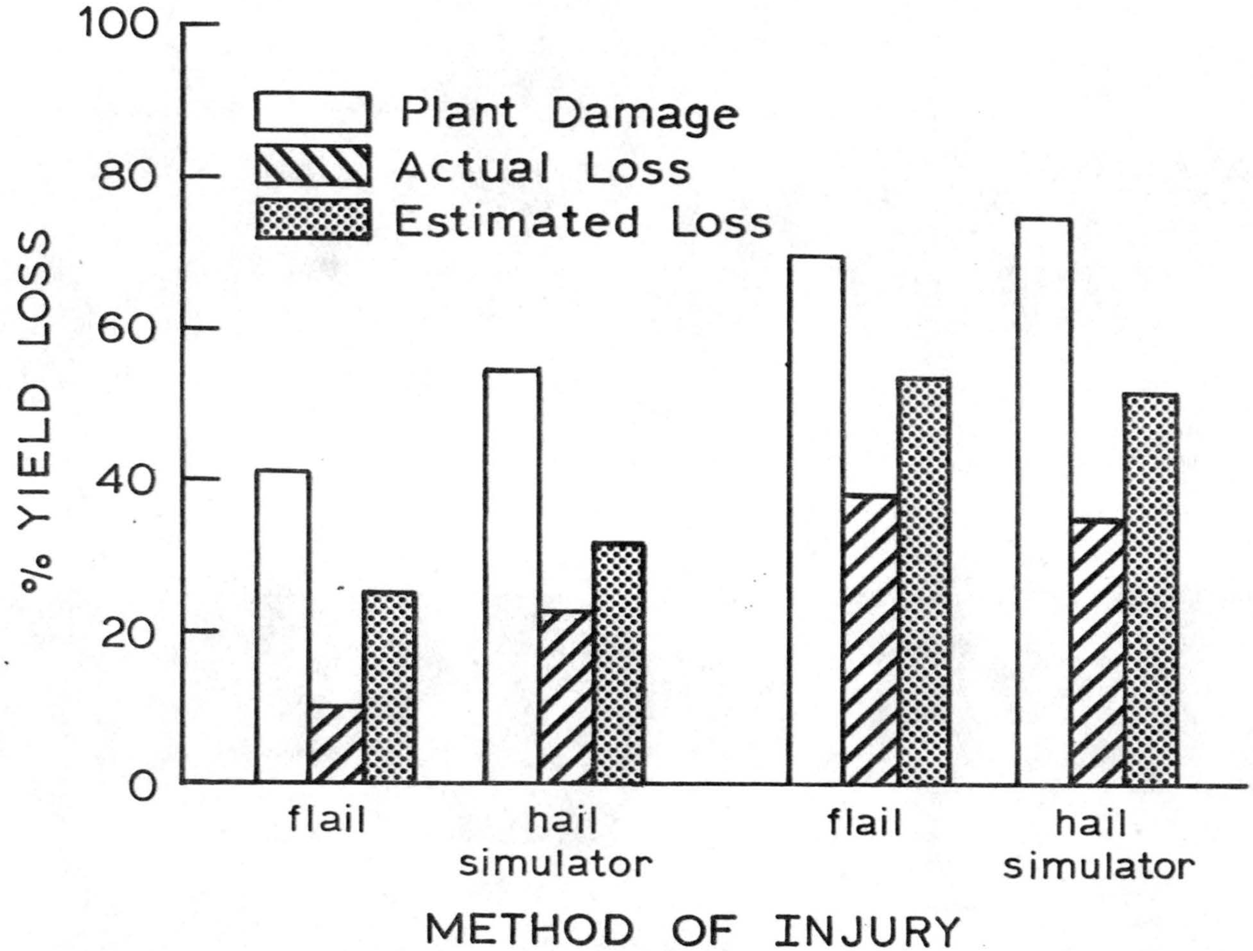

80
70
60
50
40
30
20
10
0
% LOSS
RUSSET BURBANK
85
60
35
1
3
5
7
9
11
13
WEEKS FROM EMERGENCE

Figure V-2 Comparison of flail and hail simulation injured plants; plant damage estimated visually, actual yield loss determined at end of season and estimated loss obtained from loss table. The paired groups represent moderate and heavy injury.



100
80
60
40
20
0
% YIELD LOSS
Plant Damage
Actual Loss
Estimated Loss
flail
hail
simulator
flail
hail
simulator
METHOD OF INJURY

VI. Miscellaneous Information

In the course of adjusting a damaged field, the adjuster may observe certain diseases or abnormalities. Photographs and a brief description of the more common disorders are included in this section.

A. Plant Diseases

1. Leaf roll
2. Early blight
3. Blackleg
4. Ringrot
5. Verticillium wilt
6. Rhizoctonia

B. Freezing Damage

C. Insect induced disorders

1. Psyllid yellows
2. Aster yellows

D. Herbicide Damage

1. Tordon
2. Sencor
3. Amino-triazole

For a more thorough study of potato abnormalities refer to the following:

Hodgson, W.A., D.D. Pond, and J. Munro. 1974. Diseases and Pests of Potatoes. Canada Department of Agriculture. Publ. 1492.

O'Brien, M.J. and A.E. Rich. 1976. Potato Diseases. USDA/ARS. Agric. Handbook No. 474.

Figure VI-1 Foliar symptoms of leaf roll.

Leafroll is an aphid transmitted virus disease causing upward rolling of leaf margins. Leaf tissue thickens, developing a leathery feel. Tubers are often smaller and fewer in number and frequently show strands of brown tissue when cut.

Figure VI-2 Foliar symptoms of Early blight.

Early blight is a fungal disease resulting in dark concentric oval rings on the leaves, most common during warm humid weather.

Figure VI-3 Foliar symptoms of Blackleg

Blackleg is a bacterial infection which first appears about flowering time. Upper leaves turn lighter green to yellow as the plant wilts and eventually dies. Stem frequently develops a black appearance at the soil line which progresses upward. Tubers develop soft rot accompanied by a putrid odor.

Figure VI-4 Foliar symptoms of Ringrot

Bacterial ringrot first appears soon after blooming as a slight rolling of the lower leaves of one or more stems. Affected leaflets turn pale green with pale yellow areas between the veins. Tubers develop a creamy yellow to brown rot in the vascular ring.

Figure VI-5 Foliar symptoms of Verticillium wilt

The Verticillium fungus causes yellowing and dying of leaves from the base of the stem upward. Frequently one or a few stems are affected while the rest of the plant appears normal.

Figure VI-6 Rhizoctonia symptoms on root tissue

The fungus causes dark brown lesions at or below the soil line on roots, stolons and sprouts. Infection after emergence results in leaf thickening, rolling and a reddish appearance. Aerial tubers often occur.

Figure VI-7 Effect of freezing on foliage

Patchy yellowing followed by browning and death of injured tissue which may only affect portions of leaves.

Figure VI-8 Foliar symptoms of Psyllid yellows

Feeding by nymphs of this insect results in symptoms similar to leaf roll. Outer leaves curl and turn light green to yellow. Stems often produce aerial tubers and below ground tubers are smaller with a knobby appearance.

Figure VI-9 Appearance of tubers affected by Psyllids.

Tubers develop as a group of smaller knobby tubers instead of characteristic uniform shape.

Figure VI-10 Tuber symptoms of Aster yellows.

Tuber tissue inside the vascular ring develops a brownish color.

Figure VI-11 Foliar symptoms of Tordon damage.

Tordon applied in excess results in distinctive deformation of leaves; decreased expansion and curling.

Figure VI-12 Foliar symptoms of Sencor.

Young growth appears yellowed with severe browning of older leaves.

Figure VI-13 Foliar symptoms of Amino-triazole.

Yellowing and curling of damaged tissue similar to freezing injury.