The University of Maine
DigitalCommons@UMaine

Technical Bulletins | Maine Agricultural and Forest Experiment Station

6-1-1972

TB57: Effects of Cultural Methods for Controlling Aphids on Potatoes in Northeastern Maine

W. A. Shands

Geddes W. Simpson

H. J. Murphy

Follow this and additional works at: https://digitalcommons.library.umaine.edu/aes_techbulletin

Part of the Entomology Commons

Recommended Citation

Shands, W.A., G.W. Simpson, and H.J. Murphy. 1972. Effects of cultural methods for controlling aphids on potatoes in northeastern Maine. Life Sciences and Agriculture Experiment Station Technical Bulletin 57.

This Article is brought to you for free and open access by DigitalCommons@UMaine. It has been accepted for inclusion in Technical Bulletins by an authorized administrator of DigitalCommons@UMaine. For more information, please contact um.library.technical.services@maine.edu.

EFFECTS OF CULTURAL METHODS FOR CONTROLLING APHIDS ON POTATOES IN NORTHEASTERN MAINE

W. A. Shands, Geddes W. Simpson and H. J. Murphy

A Cooperative Publication of the Life Sciences and Agriculture Experiment Station, University of Maine at Orono, and the Entomology Research Division, Agricultural Research Service, United States Department of Agriculture

Technical Bulletin 57 June, 1972

Contents

Acknowledgment

We gratefully acknowledge the assistance of Corinne C. Gordon, Biological Technician, Entomology Research Division, Agricultural Research Service, USDA, Orono, Maine 04473, who made the graphs, and aided in summarizing the data; and of Donald Merriam, Technician, Life Sciences and Agriculture Experiment Station, Aroostook Farm, Presque Isle, Maine 04769, and F. E. Manzer, Professor of Plant Pathology, University of Maine, Orono, Maine 04473, who made the field readings of leaf roll.

Effects of Cultural Methods for Controlling Aphids[1] on Potatoes in Northeastern Maine

W.A. Shands[2], Geddes W. Simpson[3] and H. J. Murphy[4]

INTRODUCTION

Controlling aphids on potatoes in northeastern Maine is so imperative it is considered an integral part of cultural management employed by commercial growers of potatoes for both culinary and seed-potato purposes. Feeding on potato plants by sufficiently large numbers of aphids results in reduced yields (28, 25, 26). Aphids, when feeding on and moving among the plants, can serve as vectors of several plant viruses causing diseases which reduce both quality and yield of tubers (15, 9, 11, 12, 2, 3, 4, 13, 31).

The more common potato viruses transmitted by aphids in northeastern Maine include leaf roll, *Corium solani* Holmes, potato mild-mosaic virus (virus A or solanum virus 3), *Marmor solani* Holmes, potato virus Y, *Marmor cucumeris* var. *upsilon* Holmes, but probably not spindle tuber, *Acrogenus solani* var. *vulgaris* Holmes.

Potato leaf roll is caused by the leaf roll virus. Spindle tuber is caused by the spindle tuber viroid.

The diseases mild mosaic and rugose mosaic result from infections of potato virus A or potato virus Y, respectively, introduced into plants previously infected with potato virus X (potato-mottle virus), *Marmor dubium* var. *vulgare* Holmes(7).

The four species of aphid commonly infesting potatoes in the area are the buckthorn aphid, *Aphis nasturtii* Kaltenbach, the potato aphid, *Macrosiphum euphorbiae* (Thomas), the foxglove aphid, *Acyrthosiphon solani* (Kaltenbach), and the green peach aphid, *Myzus persicae* (Sulzer). The green peach aphid is by far the most effective vector of three of the four potato viruses, particularly two of these, leaf roll and potato virus Y (15, 9, 10, 23, 14, 29). The buckthorn and potato aphids are effective vectors of potato virus A (8, 23). The foxglove aphid is not a particularly effective vector of leaf roll. Aphids are not important vectors of the spindle tuber viroid (26), if indeed they are involved in the spread of this virus.

---

[1] Hemiptera: Aphididae.

[2] Visiting Professor of Entomology, University of Maine, Orono, Maine 04473; formerly, Research Entomologist, Agr. Res. Serv., USDA.

[3] Professor of Entomology, University of Maine, Orono.

[4] Associate Professor of Agronomy, University of Maine, Orono.

All four species of these aphids over-winter as eggs on primary hosts in northeastern Maine: the buckthorn, potato and green peach aphids on certain woody plants, and the foxglove aphid principally on *Hieracium* spp. (33, 19, 18, 22). Beginning with progeny of the stem mother (fundatrix) and continuing during the following generation or longer, alate spring migrants mature on the primary hosts and fly to secondary, summer hosts, including potatoes.

Generally speaking, aphid abundance on potatoes has been dependent on the number of spring migrants infesting the plants (17, 26). Thus, we found larger populations of aphids developing on early-planted potatoes than on late-planted ones, largely because the plants emerged early enough to be infested by spring migrants throughout most of the aphids' spring migrations (27, 5, 22). Along with larger aphid populations which developed in early plantings, the seasonal spread of leaf roll was often greater in early than late plantings. Spread of leaf roll, however, in late plantings was appreciable, largely because of the numbers of alate aphids on the wing in late summer (27, 5, 30).

A study was conducted at Aroostook Farm, near Presque Isle, Maine, 1954 to 1958, inclusive, to determine the effects of certain agronomic cultural practices designed to delay emergence of potato plants and to decrease their exposure to infestation by spring migrants. This bulletin reports the results of that study.

MATERIALS AND METHODS

Varieties, plot sizes and separations, and cultural practices

The Green Mountain variety of potato was planted in 1954. From 1955 through 1958, the Katahdin variety was used.

Each plot consisted of four rows 34-in. apart and 56 ft. long. The 2 oz. seed-pieces were planted by hand 1 ft. apart. Alleys between rows of plots were 9 ft. wide in two years, 6 ft. wide in one year, and 4½ ft. wide in two years. Between blocks of plots, the alleys varied in width among years from 19 to 30 ft. The alleys were seeded with oats at the time of the first planting of potatoes (25).

Fertilization, at planting only, was with an 8-12-12 commercial formulation containing 1½-2% of magnesium. The application rates were 1,500 lb/acre in 1954 and 1,800 lb/acre in the years 1955 to 1958, inclusive.

No insecticide was applied in any of the plots. Fungicides were applied at least once each week or at intervals of three to six days, depending upon weather, during epiphytotics of late blight, *Phytophthora infestans* (Mont.) De Bary. The fungicidal dust mixture, applied at 35 lb/acre in 1954, 1955, and 1956, was a yellow cuprous oxide-clay preparation containing 6% of copper; in 1957, a zineb[5]-clay mixture containing 6% zinc was used. The tank-mix zineb spray mixture used in 1958 contained 0.8 lb zinc/100 gal and was applied at 125 gal/acre under 200 psi with a specially designed sprayer (32).

Cultural treatments

Cultural treatments were designed to result in differences in the length of exposure of young potato plants to incoming spring migrants of the potato-infesting aphids. To accomplish this, varying combinations were made of planting dates and timing of the "hilling" cultivations. Each year there were either two or three planting dates and two or three hillings. Hilling consisted of raising and broadening the row ridges by moving the soil from the row middles to the ridges with a tractor-mounted cultivator.

The planter left a bed about 2 in. above the level of the field. Following two or three hillings, the top of the row was ultimately 12 to 14 in. above the trough of the row middle.

There were variations among years in the timing of the hillings in relation to the specific objective of each year's experiment; these are described in the discussion of results for each year.

Experimental design

The cultural treatments were formed by combining the gradients of the two factors of culture, viz., dates of planting and timing of hillings. In relation to planting dates and timing of hillings, the factorial arrangements were a 2 x 3 in 1954, a 3 x 3 in 1955, and a 3 x 2 in each of the three remaining years. The field plot arrangement consisted of 9 x 6 randomized complete blocks in 1955, and 6 x 6 Latin squares in the other four years.

Leaf roll reservoir abundance

Five percent of the seed-pieces planted in 1954, 1957, and 1958 were known to be infected with leaf roll virus. The leaf roll-infected seed pieces were of the same variety as the healthy seed-pieces being planted. To insure an adequately distributed, stipulated level of leaf roll in the stands, appropriate numbers of healthy and leaf-roll-infected seed-pieces were randomly mixed before planting each plot. The resulting leaf roll plants were allowed to grow throughout the summer in all plots. Only healthy seed-pieces were planted in the plots in 1955 and in 1956.

[5] "Zineb-clay" preparation
Zinc ethylene bisdithiocarbamate ($C_4 H_6 N_2 S_4 Zn$).

Determination of disease spread

Immediately prior to or during harvest in each plot, one tuber was taken from each of 100 plants per plot which grew from healthy seed-pieces in 1954 and from 50 similar plants per plot in 1957 and 1958. These sample plants were located in a screen grid over the sample portion of each plot which consisted of the center 50 ft of the two middle rows. The sample tubers were stored over-winter and planted in the field in late May. Leaf roll symptoms were recorded when the plants were 12 to 18 in. tall.

Prevalence and severity of Rhizoctonia. Records were made in 1955 to ascertain the degree to which the cultural treatments influenced prevalence and size of lesions caused by the rhizoctonia fungus, *Rhizoctonia solani* Kuhn[6], on the underground portions of stems of Katahdin potatoes. This was done by pulling all stems of 12 plants[7], located in a screen grid over the sample portions of all plots in three blocks of the 9 x 6 randomized blocks. After removing any soil on the stems, a record for each was made to show the total number of rhizoctonia lesions, and the number exceeding approximately ½ in. in diameter. Those in the latter category were called "severe" lesions.

Yield of tubers. In 1958, an application of herbicide was made on August 26 or on September 9 to plots planted on May 12 or May 26, respectively, in order to terminate plant growth after a period of 106 days from planting; the plots planted on June 3 were killed by frost on September 18, or 108 days from planting. Harvesting of all plots in 1958 was done after the plants in plots not sprayed with herbicide were killed by frost. Harvesting in 1954 to 1957, inclusive, was done after the plants in all plots were killed by frost or had died from other natural causes.

All tubers in the sample portion of each plot were dug by machine, collected by hand, weighed in bulk, then graded and weighed by grade sizes. The sample portion of each plot was raked by hand after the tubers were collected to recover any that had not been found. Tuber counts by grade sizes were made also. The weights and numbers of tubers by grade sizes in the leafroll-spread sample comprised part of the total yield.

Abundance of aphids. Weekly counts of aphids were made on the potatoes in all plots from soon after plant emergence until about September 10 or, in 1958, until the plants were killed with an herbicide. At each count, records were made of the numbers of apterous and alate

---

[6] The name of the perfect stage of this fungus is *Pellicularia filamentosa* (Pat.) Rogers.

[7] The usage of *plants* in this bulletin refers to all growth arising from one potato seed-piece.

aphids by species on 25 sample plants located in a screen grid over the sample portion of each plot. Until the potatoes were about 8 in. tall, all of the foliage of sample plants was examined for aphids; when the plants were larger than this, only three compound leaves per plant (randomly located within the top, middle, and bottom thirds of stem length of each sample plant) or parts of these three leaves on 25 plants per plot were examined (16, 21). Examinations of the potato leaves were made *in situ.*

Expression of aphid abundance. The basic expression of aphid abundance was average number per whole plant until the plants were about 8 in. high; thereafter, it was average number on three leaves per plant (top, middle, bottom). When the subunit of sample was less than three whole leaves per plant, conversions were made to the 3-leaf basis (21).

The 3-leaf averages were converted to a whole-plant basis by applying as a correction factor the average number of 3-leaf groups per plant at a particular time corresponding to the date of count (20). Estimates of the average number of 3-leaf groups per plant for any given year were made by adjustments in the averages obtained from weekly leaf counts of field-grown plants of both Green Mountain and Katahdin varieties throughout the summers of 1967, 1968, and 1969 (20). A study of these leaf-count data indicated that the average number of leaves per plant of these varieties during the latter part of August, after reaching a maximum number, bore a close linear (positive) relationship to the amount of rainfall during May and June. The rates of increase in average number of leaves per plant was rather well approximated by the slope of a line drawn between a point in time representing plant emergence and one representing the date when the number of leaves per plant reached a peak. During the 5-year study for Green Mountains in one year and Katahdins in four, at each aphid count, the average number of leaves per plant was approximated by reading the figure from a graph on which was plotted the estimated potato plant growth for that year. The graphs for each year were made by drawing a straight line between the points in time of plant emergence and estimated peak number of leaves per plant in plots representing each cultural treatment. The latter point was approximated by adjusting the average number of leaves per plant at the season's peak in 1969 by the factor:

$$x = \frac{\text{In. rainfall May 1 to June 30 of specified year}}{\text{In. rainfall May 1 to June 30, 1969}}$$

For example, the average number of leaves per plant at the peak for the year in question was considered to be 90% of the comparable 1969 figure when rainfall during May and June of that year was 90% of the rainfall during the same period of 1969. Slight retardations in estimated time of peak plant size in plots representing certain cultural treatments during each of the five years were made on the basis of the length of time between plant emergence and of peak plant size of the appropriate variety during the years 1967 to 1969, inclusive.

The all-season expression of aphid abundance was average number of aphid-days of infestation by the apterae on a per plant basis. This was derived by measuring the average height of the area beneath a curve (1) made by plotting against time the average number of apterae per plant of all species of aphids found at each count. The average height of the curve, or average all-season number of apterae per plant, was multiplied by the number of days that the potato plants in the appropriate series of plots were infested by aphids as known from the weekly counts.

RESULTS AND DISCUSSION

Effects of cultural treatments upon aphid populations

Variations in total-season and relative abundance. During this 5-year experiment, a concurrent study was conducted to determine the time of maturation of spring migrants of the buckthorn and potato aphids on their primary hosts in the vicinity of Presque Isle (19, 22).

For each of these five years, the daily percentage of the total numbers of winged aphids of each species recorded in these studies was plotted against the percentage of the total plant stand for that day as recorded in all plots having each of the cultural treatments (Figures 1 to 5, incl.).

During each of these five years the buckthorn aphid was the predominant species, followed by the potato aphid (Table 1). The other two species of aphids were relatively scarce except in 1958 when the green peach and potato aphids were about equal in abundance, and in 1956 and 1958 when the foxglove aphid comprised up to 16% of the total aphid population in plots receiving certain cultural treatments. For these reasons, the present evaluation of cultural treatments upon the aphids is restricted largely to all-season abundance and percentages of the all-season aphid populations comprised by the buckthorn and potato aphids.

Aphid populations in 1954. In 1954, the spring migration of the potato aphid occurred largely between June 8 and July 6, with the peak about June 20 (Figure 1). Corresponding dates for the buckthorn aphid were between June 15 and July 20, with the peak about June 23. Potato plants in plots planted early (May 14) were up and exposed to spring migrants of both aphids throughout most of these aphids' spring migrations. In the late plantings of June 1, spring migrations of the potato and

Table 1

Average all-season composition of populations of apterous aphids infesting potatoes in relation to cultural treatments, 1954 to 1958, inclusive.

Treatment		Percent of total population			
Planting date	Hilling dates	Buck-thorn Aphid	Green peach Aphid	Potato Aphid	Fox-glove Aphid
		1954			
May 14	June 14, July 7[a]	70.8	1.8	24.1	3.4
	June 9, July 7	63.9	7.6	24.9	3.6
	June 14, 19	71.4	8.4	17.4	2.9
June 1	June 22, July 7[a]	59.5	6.3	31.8	2.5
	June 14, July 7	56.0	4.4	36.9	2.7
	June 14, 19	51.6	2.9	41.2	4.4
		1955			
May 4	June 16, 25, July 5[a]	94.5	2.6	1.8	1.2
	June 6, 25, July 5	94.0	2.8	2.3	.9
	June 6, 15, July 5	95.0	2.4	2.2	.4
May 20	June 20, 29, July 8[a]	93.5	3.4	2.8	.3
	June 10, 29, July 8	93.3	1.7	4.4	.7
	June 10, 15, July 8	93.9	1.8	3.7	.6
June 3	June 29, July 5, 19[a]	92.4	1.7	5.8	.2
	June 18, July 5, 19	92.1	2.6	5.0	.4
	June 18, 22, July 19	92.6	1.8	5.3	.3
		1956			
May 12	June 26, July 6, 19[a]	67.7	6.8	9.1	16.5
	June 14, 18, July 19	74.3	9.1	9.0	7.6
May 25	June 26, July 6, 19[a]	70.5	8.7	6.6	14.3
	June 16, 18, July 19	82.9	5.9	3.8	7.5
June 2	July 5, 12, 19[a]	68.1	15.7	7.7	8.4
	June 18, 23, July 19	69.9	10.2	11.8	8.1
		1957			
May 9	June 19, 28, July 3[a]	86.3	5.2	3.0	5.5
	June 4, 10, July 3	89.1	3.3	3.8	3.7
May 23	June 28, July 8, 12[a]	80.1	4.5	13.1	2.4
	June 14, 19, July 12	35.1	7.1	48.7	9.1
June 1	July 8, 13, 18[a]	32.0	6.0	56.9	5.1
	June 21, 24, July 18	24.1	2.4	68.7	4.8
		1958			
May 12	June 30, July 7, 11[a]	34.6	32.5	20.9	12.0
	June 7, 13, July 11	54.7	14.4	23.9	7.0
May 26	July 7, 11, 17[a]	45.8	31.8	17.1	5.3
	June 13, 23, July 23	50.7	12.9	20.6	15.9
June 3	July 11, 17, 23[a]	39.6	21.5	23.8	15.1
	June 23, 30, July 23	52.4	18.0	24.9	4.7

[a] Normally timed hillings.

buckthorn aphids had been in progress several days before potato plants began to emerge. Not all of the emerged plants were covered by any hilling; consequently, some plants were continuously exposed to infestation by aphids, but the percentage of stand that had emerged varied

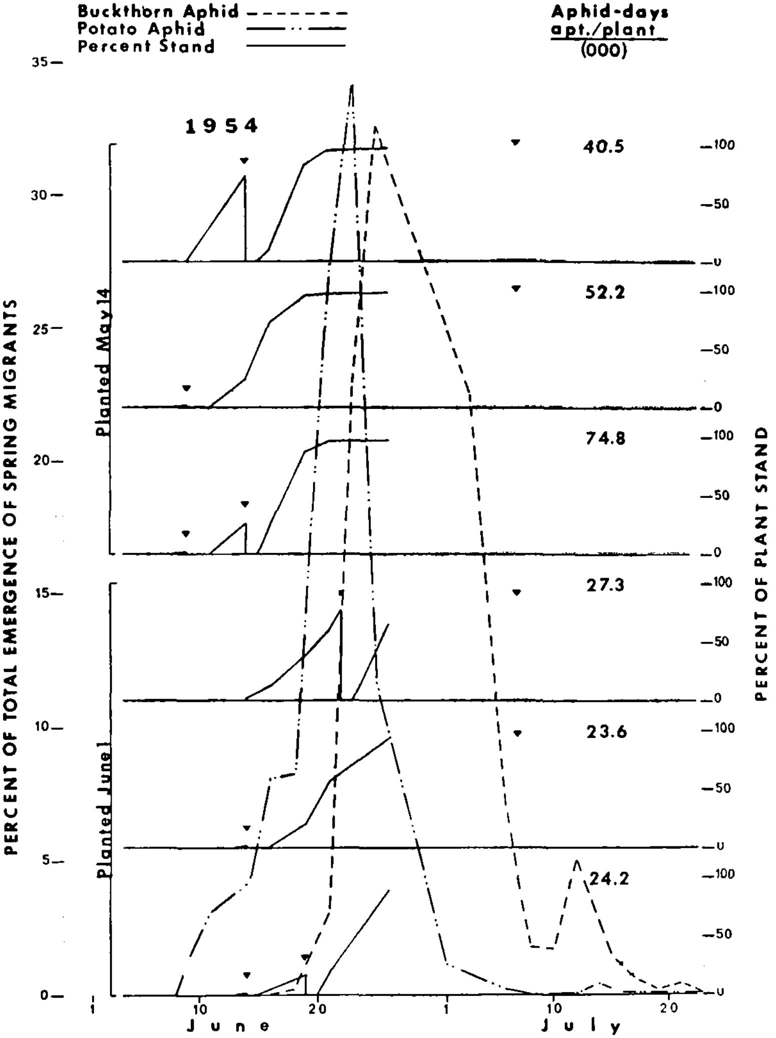

FIGURE 1. Cultural treatments in relation to spring migrations of buckthorn and potato aphids and effects upon all-season abundance of apterous aphids on Green Mountain potatoes in 1954. Shaded triangles indicate dates hillings (cultivations) were applied to the potato plants.

with planting date and time of hilling (Figure 1). Under these conditions, the all-season average number of aphid-days of infestation by apterae on a per plant basis was smaller by 55% in late-planted plots than in those planted early (Table 2).

Table 2

Effect of cultural practices upon apterous aphid population trends and tuber yield of potatoes, 1954 to 1956[a]

Treatment		Aphid populations		
Planting date	Hilling dates	All-season avg no. aphid-days of infestation/plant	% reduction	Avg. lb tubers[b] 100 ft row
		(000)		
		1954		
May 14	June 14, July 7[c]	40.5	—	153.7
	June 9, July 7	52.2	-28.8	157.5
	June 9, 14	74.8	-84.5	153.2
June 1	June 22, July 7[c]	27.3	—	142.0
	June 14, July 7	23.6	13.4	147.3
	June 14, 19	24.2	11.4	144.7
LSD $P=0.05$				NS
Avg for planting dates				
	May 14 (early)	55.8	—	154.8
	June 1 (late)	25.0	55.1	144.6
LSD $P=0.05$				7.6
$P=0.01$				NS
Avg for timing of hillings				
	Two, normal	33.9	—	147.8
	First one early; second, normal	37.9	-11.8	152.4
	Two early, closely spaced	49.5	-46.1	148.9
LSD $P=0.05$				NS
		1955		
May 4	June 16, 25, July 5[c]	58.3	—	200.2
	June 6, 25, July 5	80.6	-38.3	204.5
	June 6, 15, July 5	61.2	- 4.9	199.5
May 20	June 20, 29, July 8[c]	32.8	—	186.1
	June 10, 29, July 8	21.8	33.5	188.1
	June 10, 15, July 8	18.1	44.8	198.0
June 3	June 29, July 5, 19[c]	12.4	—	159.9
	June 18, July 5, 19	16.3	-31.4	167.0
	June 18, 22, July 19	13.0	- 5.0	169.9
LSD $P=0.05$				11.4
$P=0.01$				14.7

Table 2 (cont.)

Treatment: Planting date	Treatment: Hilling dates	Aphid populations: All-season avg no. aphid-days of infestation/plant	Aphid populations: % reduction	Avg. lb tubers[b] 100 ft row
Avg for planting dates				
	May 4 (early	66.7	—	201.4
	May 20 (inter)	24.2	63.7	190.7
	June 3 (late)	13.9	79.1	165.6
LSD $P=0.05$				6.4
$P=0.01$				8.5
Avg for timing of hillings				
	Three, normal	34.5	—	182.1
	First one early; next two normal	39.6	-14.7	186.5
	First two early closely spaced; third, normal	30.8	10.8	189.1
LSD $P=0.05$				NS
		1956		
May 12	June 26, July 6, 19[c]	15.6	—	234.7
	June 14, 18, July 19	21.0	-34.7	223.5
May 25	June 26, July 6, 19[c]	25.2	—	223.7
	June 16, 18, July 19	36.3	-44.2	237.8
June 2	July 5, 12, 19[c]	14.6	—	224.5
	June 18, 23, July 19	12.5	14.5	231.4
LSD $P=0.05$				NS
Avg for planting dates				
	May 12 (early)	18.3	40.5	229.1
	May 25 (inter)	30.7	—	230.7
	June 2 (late)	13.6	55.8	227.9
LSD $P=0.05$				NS
Avg for timing of hillings				
	Three, normal	18.5	—	227.6
	First two early, closely spaced; third, normal	23.3	-26.0	230.9
LSD $P=0.05$				NS

[a] Green Mountain was the variety in 1954; Katahdin, in 1955 and in 1956.
[b] Over 2 inches in diameter.
[c] Normally timed hillings.

Close spacing of the first two hillings affected the size of aphid populations on both early and late plantings but to a much lesser extent than did the time of planting (Table 2). The all-season level of aphid abundance was lowest in plots receiving two normally timed hillings, somewhat higher in plots receiving one early hilling, with the second one at the normal time, and highest in plots receiving two rather closely spaced, early hillings. We attribute this to the effect of early hilling upon increased rapidity of emergence and rates of growth of the plants (Figure 1). The early hillings resulted in earlier and more rapid emergence and growth of plants than normally timed, delayed hillings. Because of this the early-hilled plots probably had larger initial populations of the spring migrant aphids than did those receiving the normally timed hillings. The all-season average number of apterous aphids per plant was larger by 12% in plots given one early hilling and a second one at the normal time and by 46% in those given two early hillings than in those having two normally timed hillings (Table 2).

The percentages of the all-season total population of aphids comprised by the buckthorn and potato aphids were affected by the cultural treatments in 1954 (Table 1). In early plantings, the percentage of the aphid population comprised by potato aphids in plots having two early hillings was smaller than in those having one early hilling and one normally timed; the latter percentage did not differ from that in plots receiving the two normally timed hillings in the late plantings. However, the percentage of the aphid population comprised by the potato aphid was larger in plots having two early hillings than in those having one early hilling and one normally timed, and it was smallest in those having two normal hillings. Comparable relationships differed somewhat in the instance of the buckthorn aphid. For early plantings, the percentage of total aphid population comprised by this species was much smaller in plots having one early hilling, followed by one at the normal time, than in those having two early hillings or two normally timed ones. The differing responses of the two species of aphids appeared to be related in the early-planted plots to the duration of plant exposure to infestation by the spring migrants. The latter resulted from effects of the cultural treatments upon emergence and rate of plant growth in relation to duration and peak times of the aphids' spring migration (Figure 1, Table 1).

Aphid populations in 1955. In 1955, potato plants in early-planted (May 4) plots were exposed to infestation throughout the spring migrations of the potato and buckthorn aphids, especially the plants in the plots having three normally timed hillings (Figure 2). Plants in plots of intermediate (May 20) and late (June 3) planting dates emerged at successively later dates and, consequently had shorter exposure periods for infestation by spring migrant aphids. Under these conditions, the percentages of all-season aphid abundance in the intermediate and late plantings differed from that in the early planting by 64 and 79, respectively (Table 2).

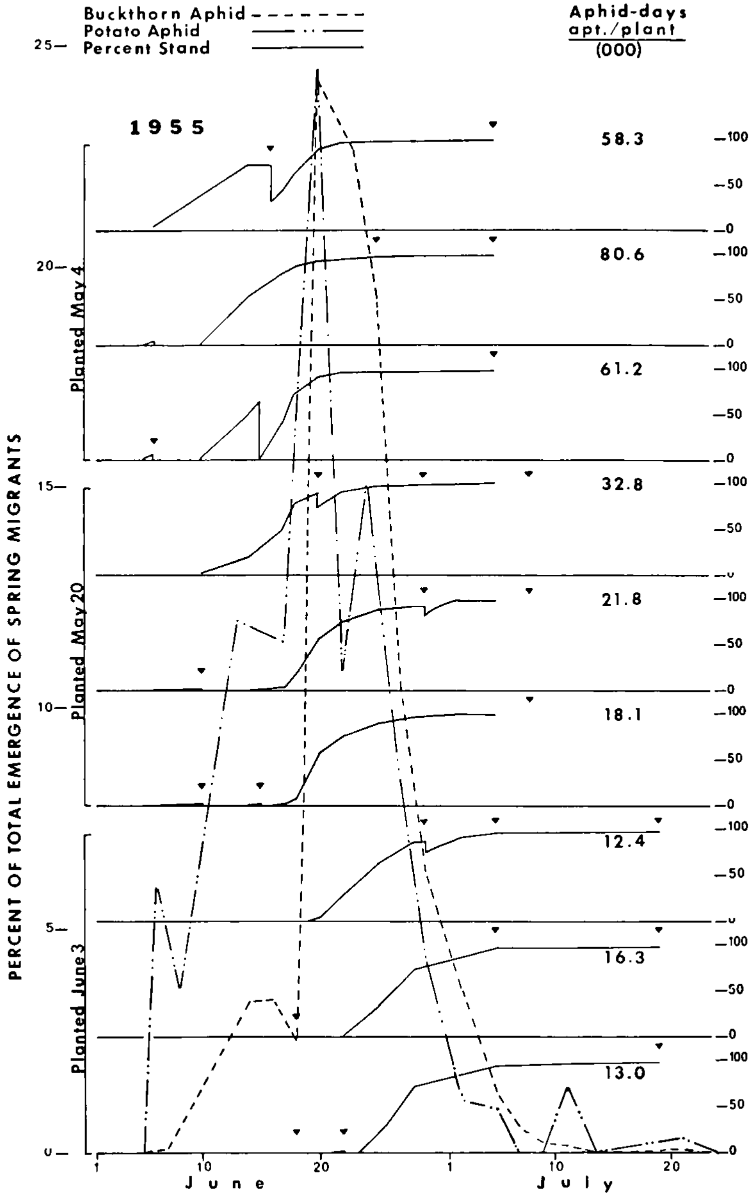

FIGURE 2. Cultural treatments in relation to the spring migrations of buckthorn and potato aphids, and effects upon all-season abundance of apterous aphids on Katahdin potatoes in 1955. Shaded triangles indicate dates hillings (cultivations) were applied to the potato plants.

Plots having an intermediate planting date and one early hilling followed by two hillings at the normal times exhibited a 34% decrease in aphid abundance, as compared to three normally timed hillings. Two early hillings followed by a third one at the normal time resulted in a 45% decrease as compared to aphid abundance in plots having three normally timed hillings.

Late-planted potatoes that were hilled early showed an increase in abundance of aphids in 1955, as compared to three normally timed hillings (Table 2). The increase was 31% in plots having one early hilling, followed by two at the normal times, but only 5%in plots given two closely spaced early hillings followed by a third one at the normal time. In this instance, the increased protection of plants from aphids by covering them with soil or by keeping them covered, by hilling, did not reduce aphid abundance. In most instances, some of the plants had emerged before hilling was done and not all plants were covered during hilling. Aphid populations were rather small due to time of planting, and the numerical increases associated with the early hilling treatments were relatively smaller than indicated by the percentages of increase.

The timing of the three hillings applied to the plots in 1955 also had effects upon aphid abundance but they differed somewhat from those from two hillings applied in 1954. Although associated with the timing of hillings, especially in early summer when the weather and undisturbed soil were still cool, apparently the plant response to early hilling was not as pronounced in 1955 as in 1954. In 1955, in early-planted plots two early hillings, followed by a third one at the normal time resulted in a 5% increase in total-season aphid abundance while one early hilling followed by two hillings at the normal times gave an increase of 38% (Table 2).

The hillings in 1955 were applied when very few of the plants were up, whereas in 1954 some plants were up and not all were covered by either of the hillings (Figures 1, 2). The early hillings in 1955 decreased the length of the period of plant exposure to infestation by spring migrant aphids. The protection from infestation by the potato aphid occurred when its spring migration was well advanced. The buckthorn aphid was in the early stages of its spring migration during this period (Figure 2).

The percentages of total aphid population comprised by the buckthorn and potato aphids were not altered appreciably by the cultural treatments in 1955 (Table 1). The spring migrants of both species matured over a rather long period (Figure 2); consequently, the proportion of one species to the other varied little throughout the period of the spring migrations.

Aphid populations in 1956. Irrespective of cultural treatments, aphid populations in 1956 were small; however, the percentages of change in size of population were appreciable for the three planting dates and for the two timings of the three hillings (Figure 3, Table 2). Aphid populations were largest in plots of the intermediate planting date (May 25); they were only 41% as large as this in the early plantings of May 12, and only 56% as large in the late plantings of June 2. In the early and intermediate plantings, aphid populatons were larger by 35% and 44% respectively, in plots having two closely spaced, early hillings, followed by a third one at the normal time, than in plots having three normally timed hillings. The two early hillings delayed plant emergence somewhat but the increase in growth rate from early hilling apparently resulted in little added protection of the plants from being infested by the spring migrant aphids. The plants were available for being infested throughout most of the spring migration in all plots of the early-and intermediate-date plantings, irrespective of the timing of hillings. As in 1954, the early hillings in 1956 were not made until some plants were up and not all of these were covered by either of the early hillings (Figure 3). Only in the late plantings did the abnormal timing of hillings provide enough protection to the plants from infestation by spring migrant aphids to be reflected as smaller aphid populations; in that instance, the resulting aphid population was 15% smaller in plots having two early, closely spaced hillings, followed by a third one at the normal time, than in plots having three normally timed hillings.

There was little, if any, protection of potato plants from infestation by spring migrants of the potato and buckthorn aphids in the early and intermediate plantings in 1956, except for a short period during the early part of the potato aphid's spring migration (Figure 3). Apparently the slight delay in plant emergence in plots of the intermediate planting date having two early hillings was not enough to offset the effect of the increased rate of plant growth resulting from the early hillings (Table 2). The 15% reduction in aphid population in late plantings that had two early hillings, followed by a third hilling at the normal time (as compared to three normally timed hillings) appeared to reflect added protection from early-season infestation by aphids afforded by the hillings during the early part of the aphids' spring migrations.

Some differences occurred among cultural treatments in percentages of aphid population comprised by each of the four species of aphids in 1956 (Table 1). For all planting dates, the percentage of total aphid population comprised by the buckthorn aphids was larger in plots having two early hillings, followed by a third one at the normal time, than in those having three normally timed hillings or in those having one early hilling followed by two hillings at the normal times. Comparable treatment differences in percentages for the potato aphid were not consistent. There were no data to indicate the degree to which the percentage differences observed in the instances of the green peach and foxglove aphids were caused by the treatments; however, the differences in percentages of the buckthorn and potato aphids appeared to reflect largely the differences due to the cultural treatments in duration and degree of plant exposure to infestation by the spring migrants of these two species (Figure 3).

Aphid populations in 1957. Aphid populations in 1957 were much larger in the early plantings of May 9 having three normally timed hillings than in those planted later and given early or normally timed hillings (Table 3). The reductions in sizes of population in plots of intermediate

Table 3

Effect of cultural practices upon apterous aphid populations, tuber yield, and spread of leaf roll in Katahdin potatoes in 1957 and 1958.

Treatment		Aphid populations			
Planting date	Hilling dates	Avg. all-season no. aphid days infestation/ plant[a]	% reduction	Avg lb tubers/ 100 ft row[b]	% spread of leaf roll
		(000)			
		1957			
May 9	June 19, 28, July 3[c]	110.8	—	195.8	8.64
	June 4, 10, July 3	56.7	48.8	194.4	9.54
May 23	June 28, July 8, 12[c]	13.3	—	181.8	8.05
	June 14, 19, July 12	2.7	79.7	195.1	11.18
June 1	July 8, 13, 18[c]	2.9	—	173.1	7.31
	June 21, 24, July 18	14.0	-382.8	183.4	0.67
LSD $P=0.05$				9.6	NS
$P=0.01$				13.1	
Avg for planting dates					
	May 9, (early)	83.8	—	195.1	9.09
	May 23, (inter)	8.0	90.5	188.4	9.63
	June 1, (late)	2.2	97.4	178.2	4.00
LSD $P=0.05$				6.8	5.50
$P=0.01$				9.3	NS
Avg for timing of hillings					
	3 normally spaced	42.3	—	185.5	7.80
	2 early, 3rd normal	20.3	52.0	190.9	7.17
LSD $P=0.05$				5.5	NS

Table 3 (cont.)

Treatment: Planting date	Treatment: Hilling dates	Aphid populations: Avg. all-season no. aphid days infestation/ plant[a]	Aphid populations: % reduction	Avg. lb tubers/ 100 ft row[b]	% spread of leaf roll
		1958			
May 12	June 30, July 7, 11[c]	6.7	—	162.8	11.07
	June 7, 13, July 11	6.1	9.0	180.8	6.02
May 26	July 7, 11, 17[c]	13.0	—	199.4	13.67
	June 13, 23, July 17	9.7	25.4	191.2	3.95
June 3,	July 11, 17, 23[c]	5.4	—	204.6	10.67
	June 23, 30, July 23	6.3	-16.7	202.6	6.00
LSD $P=0.05$				8.2	NS
$P=0.01$				11.1	
Avg for planting dates					
	May 12 (early)	6.4	43.9	171.4	8.54
	May 26 (inter)	11.4	—	195.3	8.77
	June 3 (late)	5.8	49.1	203.6	8.33
LSD $P=0.05$				5.8	NS
$P=0.01$				7.9	
Avg for timing of hillings					
	3 normally spaced	8.4	—	194.3	11.80
	2 early, 3rd normal	7.4	11.9	186.0	5.31
LSD $P=0.05$				4.8	4.20
$P=0.01$				6.5	5.73

[a] Includes population trends only to the seasonal peak in plots of each planting date.
[b] All tubers over 2 in. diameter in 1957; over 1 7/8 in (US 1-grade) in 1958.
[c] Normally timed hillings.

and late plantings of May 23 and June 1 were 91% and 97%, respectively, when compared to those of the early plantings. These large reductions appeared to result from decreases in duration of plant exposure to infestation by spring migrant aphids resulting from delaying the time of planting in a year with earlier-than-usual spring migrations of the aphids (Figure 4).

Two early hillings in the early plantings followed by a third hilling at the normal time reduced the period of plant exposure enough to cause a 49% reduction in total-season aphid infestation, and an 80%

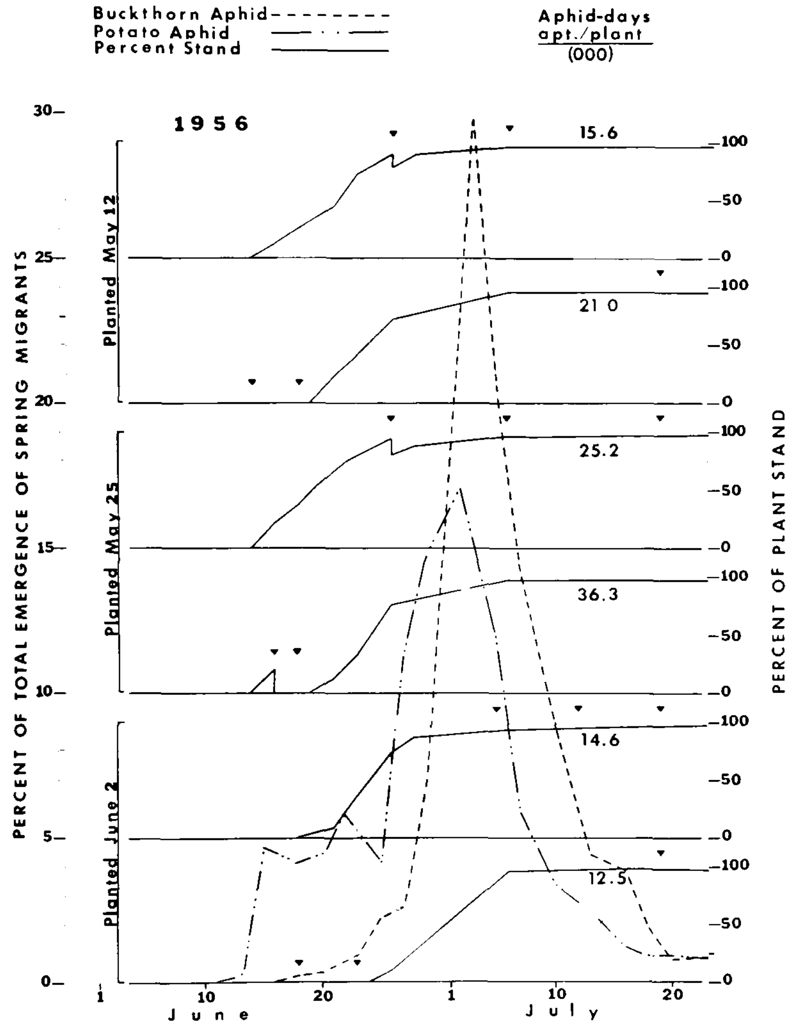

FIGURE 3. Cultural treatments in relation to the spring migrations of buckthorn and potato aphids, and effects upon all-season abundance of apterous aphids on Katahdin potatoes in 1956. Shaded triangles indicate dates hillings (cultivations) were applied to the potato plants.

reduction in that of the intermediate-date plantings (Table 3). There is no apparent explanation for the absence of a similar reduction in late plantings having two early hillings. In late plantings, there was an increase of 383% in number of aphid-days of infestation per plant.

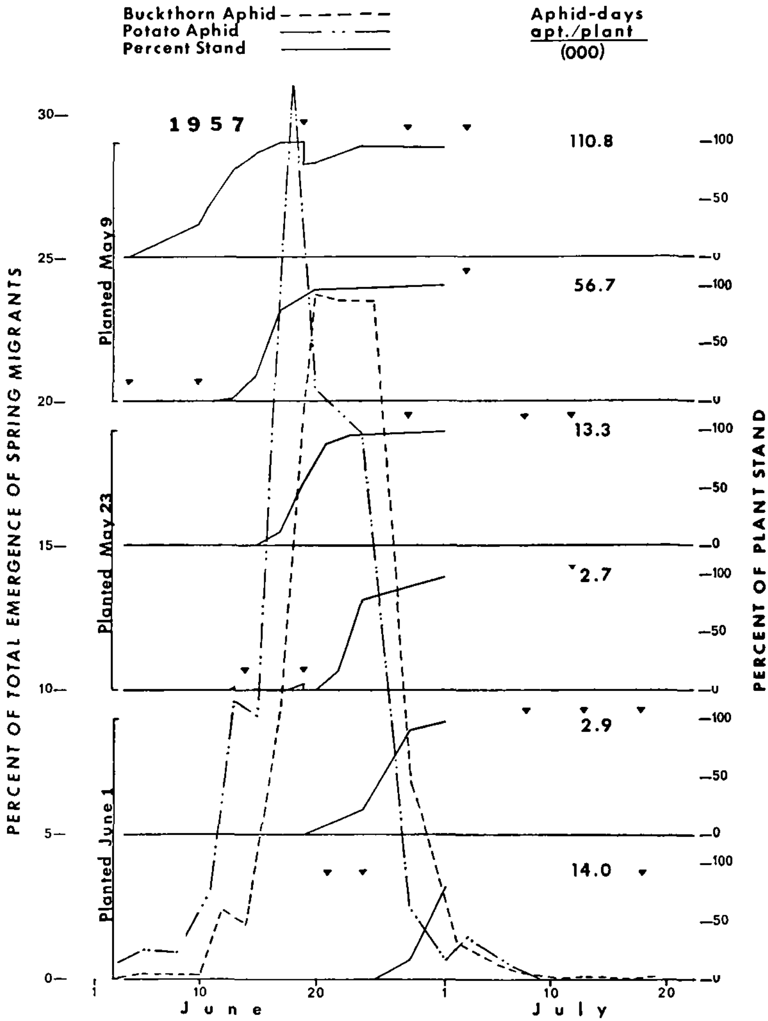

FIGURE 4. Cultural treatments in relation to the spring migrations of buckthorn and potato aphids, and effects upon all-season abundance of apterous aphids on Katahdin potatoes in 1957. Shaded triangles indicate dates hillings (cultivations) were applied to the potato plants.

Combining all planting dates, the abnormally timed hillings resulted in a 52% reduction in size of aphid population as compared to normally timed hillings.

The composition of the average all-season aphid population as to species of aphids in 1957 was affected markedly by the cultural treatments (Table 1). The buckthorn aphid comprised a much smaller percentage of the population in later plantings than in early ones. The comparable relationship was reversed for the potato aphid. Reasons were not clear for this reversal; however, because of the small sizes of aphid populations, the reversal in percentage relationships represented relatively small differences in numbers of aphids (Table 3, Figure 3).

As in earlier years' tests, with two exceptions, the percentages of total aphid population comprised by potato or buckthorn aphids were larger in plots given two early hillings, followed by a third one at the normal time, than in those having three normally timed hillings. This may have resulted from the effect of the early hillings in causing increases in growth rate and in plant stands during the aphids' spring migrations. The percentages of total aphid population comprised by buckthorn aphids in intermediate and late plantings were smaller in plots having the two early hillings, followed by one hilling at the normal time, than in those having three normally timed hillings. The reason for this is unclear.

Aphid populations in 1958. Aphid populations in 1958 were small; those in the early and late plantings of May 12 and June 3, respectively, were slightly less than half the size of those in the intermediate plantings of May 26 (Table 3). The peak size of aphid populations in early plantings might have been larger had the plants not been killed with herbicide 106 days from planting. In the intermediate plantings, also killed with herbicide 106 days from planting, the aphids were 25% less abundant in plots having two early hillings followed by a third at the normal time, than in plots having three normally timed hillings. The reduction in similarly hilled early-planted plots was only 9%, while there was a 17% increase in those planted late. The plants in all plots, except possibly in late plantings, were exposed to infestation by aphids throughout much of the spring migrations of the buckthorn and potato aphids. (Figure 5).

The percentage composition of the all-season aphid populations consisting of buckthorn and potato aphids varied with the cultural treatments in 1958 (Table 1). The larger percentages of buckthorn and potato aphids in plots hilled twice early, followed by a third hilling at the normal time, than in those having three normally timed hillings may have reflected increased rate of plant growth and infestation by spring migrant aphids commensurate with the stimulation of plant growth from the early hillings in plots of each planting date.

The changes in percentage composition of aphid population consisting of green peach and foxglove aphids, with one exception, were similar to those of the buckthorn and potato aphids in relation to timing of hillings. A larger percentage of population comprised by foxglove aphids occurred in plots of the intermediate planting date that were hilled twice early, followed by a third one at the usual time, than in those given three normally timed hillings.

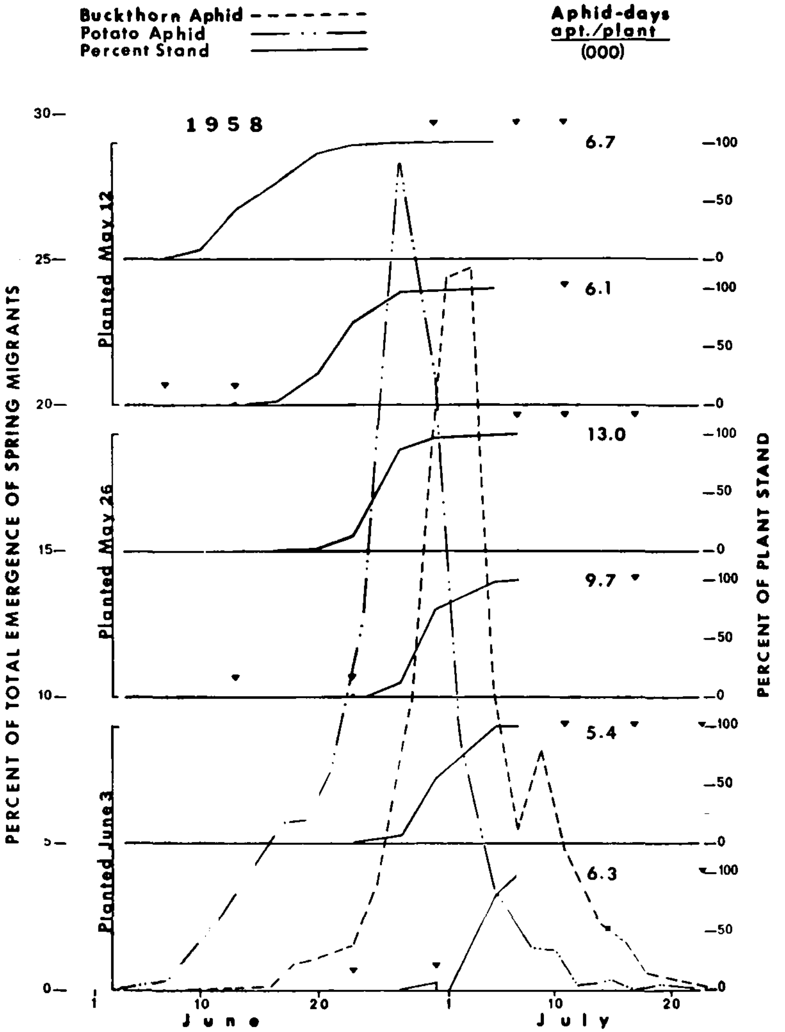

FIGURE 5. Cultural treatments in relation to the spring migrations of buckthorn and potato aphids, and effects upon all-season abundance of apterous aphids on Katahdin potatoes in 1958. Shaded triangles indicate dates hillings (cultivations) were applied to the potato plants.

Effects of cultural treatments upon yield of tubers

In 1954, the weight per 100 ft. row of Green Mountain tubers over 1⅞ in. diam. was affected ($P<0.05$) by planting date but not by timing of the three hillings or by the six individual cultural treatments formed by gradients of these two factors (Table 2). The yield of this size of tubers in the early plantings of May 14 was 7% larger than that in the late plantings of June 1.

In 1955, the greatest weight of Katahdin tubers over 1⅞ in. diameter was produced by the early plantings of May 4 (Table 2). The weight of tubers in the late plantings of June 3 was smaller ($P<0.05$) than in the intermediate plantings of May 20 which, in turn, was smaller than in the early plantings. Although not quite significant ($P = 0.05$), plots given two closely spaced, early hillings, followed by a third one at the normal time, outyielded those given one early and two normally timed hillings which, in turn, outyielded the plants in plots given three normally timed hillings.

In 1956, differences in weight of Katahdin tubers over 1 ⅞ in. in diameter due to culture factors or to individual cultural treatments were not significant at the 5-percent level (Table 2). Apparently, the differences in effects of the cultural treatments upon aphid abundance were not of sufficient magnitude to cause differences in aphid feeding damage large enough to be reflected as reduced weight of US 1-grade tubers.

In 1957, weight of the Katahdin tubers per 100 ft. row over 2 in. in diameter was affected significantly ($P<0.05$) by the treatment factors and by some of the individual cultural treatments (Table 3). The weight of tubers in the early plantings of May 9 was greater than in potatoes of the intermediate planting date of May 23 which, in turn, was larger than in the late plantings of June 1. The reductions of tuber weight in the intermediate and late plantings, compared to early plantings, were 3.5% and 8.9%, respectively. When comparing timing of hillings within planting dates, the only yield differences of significance ($P<0.05$) occurred in plots of intermediate and late plantings; in both instances, the yield was larger in plots having two early, closely spaced hillings, followed by a third one at the normal time, than in plots having three normally timed hillings.

Tuber yields in 1958 differed strikingly from those in the preceding four years' experiments. The weights of tubers over 2 in. in diameter were affected by date of planting, timing of hillings, and by several of the individual cultural treatments formed by combining gradients of these two factors. Contrary to the general results from tests in the preceding four years, in 1958 the later plantings of June 3 significantly ($P<0.05$) outyielded by 16% the intermediate plantings of May 26 and by 19% the early plantings of May 12. The intermediate plantings, in turn, significantly ($P<0.05$) outyielded the early plantings by 14%. Also, plants given three normally timed hillings gave a statistically significant ($P<0.05$) 4.5% increase as compared to two closely spaced, early hillings, followed by a third one at the normal time. These differences in the Katahdin variety may have been due largely to the imposed growing-period limitation of 106 days from planting; they are in agreement with yield responses of the King Edward variety to imposed growing periods of uniform length (6).

Effect of cultural treatments upon plant diseases

Spread of leaf roll. With 5% of the stand consisting of leaf roll reservoirs, the differential in spread of leaf roll (due to cultural factors or to combined gradients of these factors) in 1954 was insufficient to justify including the data here. The minute amount of leaf roll spread in that year probably resulted from the small size of green peach aphid populations (Tables 1, 2).

In 1957, spread of leaf roll was affected by planting date, but not by timing of hillings or by individual cultural treatments formed by combining the gradients of these factors. There was significantly ($P<0.05$) less spread in the late plantings of June 1 than in the intermediate plantings of May 23 and almost significantly less than in the early plantings of May 9. The spread of leaf roll in late plantings was reduced by 58.5% or by 56% as compared to that in the intermediate and early plantings, respectively.

In 1958, percentage of leaf roll spread was unaffected by date of planting. The spread in plots having two closely-spaced, early hillings, followed by a third one at the normal time, resulted in a significant ($P<0.01$) 55% reduction of spread as compared to that in plots having three normally timed hillings.

Prevalence and severity of Rhizoctonia. In 1955, the levels of abundance and of severity of rhizoctonia infection probably were not high enough to affect tuber yield (Table 4). Planting date exerted a significant ($P<0.05$) effect upon average total number of rhizoctonia lesions on underground portions of potato stems but not upon the percentage of stems having lesions or of those having severe (over ½ in. diameter) lesions (Table 4). Late plantings of June 3 had 72.9% fewer lesions per stem than did early plantings of May 4. The number of lesions per stem in the intermediate plantings of May 20 did not differ ($P>0.05$) from that in either the early or late plantings. Although not different at the 5-percent level, there were decreases in percentages of stems having lesions or having severe lesions as the date of planting was delayed from May 4 to June 3.

Table 4

Effect of cultural practices upon prevalence and severity of rhizoctonia lesions on underground stems of Katahdin potatoes in 1955.

Treatments: Planting date	Treatments: Hilling dates	No. stems examined	Percent of stems having lesions	Avg no. lesions per stem	Percent of stems with severe lesions
May 4	June 16, 25, July 5[a]	67	28.4	0.463	7.5
	June 6, 25, July 5	72	19.4	.444	19.4
	June 6, 15, July 5	64	20.3	.328	7.8
May 20	June 20, 29, July 8[a]	72	6.9	.083	0
	June 10, 29, July 8	71	26.8	.479	4.2
	June 10, 15, July 8	73	21.9	.219	8.2
June 3	June 29, July 5, 19[a]	73	11.0	.164	1.4
	June 18, July 5, 19	61	6.6	.115	1.6
	June 18, 22, July 19	81	4.9	.062	1.2
LSD P = 0.05			20.2	0.394	15.2
P = 0.01			NS	NS	NS
Avg for Planting dates					
May 4			22.7	0.414	11.8
May 20			18.5	.259	4.2
June 3			7.4	.112	1.4
LSD P = 0.05			NS	0.286	NS
P = 0.01				NS	
Avg for timing of hillings					
	Normal		15.1	0.231	2.8
	First one early, 2nd & 3rd normal		18.1	.358	8.8
	First two early, 3rd normal		15.1	.193	5.5
LSD P = 0.05			NS	NS	NS

[a] Normally timed hillings.

The timing of the three hillings in 1955 did not affect significantly ($P>0.05$) prevalence or severity of rhizoctonia lesions on underground portions of potato stems (Table 4). Several of the cultural treatments did affect significantly ($P<0.05$) the prevalence and severity of rhizoctonia lesions on underground portions of the stems. Early plantings with three normally timed hillings had a larger percentage of stems with lesions than did intermediate plantings that were normally hilled, or late plantings that had either one or two early hillings followed by the remaining one or two hillings at the normal times. The number of lesions per stem in normally hilled, early-planted plots was larger than in late-planted plots given two closely spaced, early hillings followed by a third one at the normal time. Severe lesions were most common on stems of early-planted potatoes having one early hilling followed by two hillings at the normal times; they were less common on stems in late plantings; irrespective of timing of hillings. Stems of plants in normally hilled plots of the intermediate date of planting were free of rhizoctonia lesions.

SUMMARY AND CONCLUSIONS

A 5-year study was conducted on Aroostook Farm, near Presque Isle, Maine, to examine the effects of several cultural practices in growing potatoes upon abundance of aphids on the potato plants, yield of tubers, spread of leaf roll virus, and abundance and severity of rhizoctonia lesions on underground portions of potato stems. The cultural treatments included combinations of two or three dates of planting and two or three hillings with different timings in relation to planting. Differences among cultural treatments upon aphid populations and spread of leaf roll probably were due to delaying plant emergence during the early part of the aphids' spring migrations and, thus to reducing the duration of exposure of the young plants to infestation by spring migrant aphids. Five percent of the seed pieces planted were infected with leaf roll in the three years during which data on spread of leaf roll virus were obtained. Records were made of plant emergence in all plots and of maturation at two or three day intervals of the spring migrants of two of the four species of potato-infesting aphids, viz., the buckthorn and potato aphids, on their primary host plants. This was done to better understand treatment effects in relation to plant stands and time and duration of plant exposure to infestation by spring migrant aphids.

The cultural treatments affected the all-season abundance of aphids and percentage composition of the aphid populations as to species on the potatoes. In most years, aphid populations were largest on potatoes planted early, May 4 to 14, smaller on those planted on the intermediate dates of May 20 to 26, and smallest in the late plantings made June 1 to 3. When compared to early plantings, except in two years, the range in reduction of total-season aphid abundance in intermediate-date plantings was 64 to 91%, while in late plantings it was 55 to 97%. In 1956 and 1958, when aphids were not abundant, their populations were largest in plots of the intermediate planting dates and reductions in size of populations in the early and late plantings were from 41 to 44% and 40 to 55%, respectively.

The timing of the first and second hillings, out of a total of two or three altogether, resulted in more variable and smaller percentages of aphid reductions than did time of planting, especially in 1954, 1955, and 1956 when not all of the early hillings were applied before some of the plants had emerged and not all of the emerged plants were covered by the hillings. When the hillings were timed so that the plants first emerged following the second hilling, the reduction in size of aphid population from hilling was 52% in 1957 and 12% in 1958.

The reduction in aphid abundance appeared to be correlated with decreased duration of the exposure period of young potato plants to infestation by spring migrant aphids. This came about either in time of planting or of plant emergence resulting from one or two early hillings. The increased duration of protection from initial aphid infestation from two closely-spaced, early hillings was less than that gained by delays in time of planting.

The cultural treatments had marked, but somewhat variable, effects upon the composition of the all-season aphid population developing on the plants. The differences in percentages of aphid population comprised by the buckthorn or potato aphids due to date of planting were larger than those due to timing of hilling operations. These differences appeared to be caused by differences in duration and degree of plant exposure to infestation by the spring migrant aphids in relation to the relative parts of their maturation curves on the primary hosts.

In three out of the five years, the weight of 1⅞ in. or 2-in. diameter tubers at regular harvest decreased as the time of planting was delayed. In 1958, the opposite occurred when the plants of each planting date were allowed a growing period of 106 or 108 days from planting. Yield differences among planting dates were not significant ($P>0.05$) in 1956. The reduction in pounds of tubers in intermediate or late plantings in 1954 and 1955, or in 1957 averaged 3.4 to 5%, or 6.6 to 17.8%, respectively. In 1958, the increased yield of intermediate and late planted potatoes over early-planted potatoes averaged 13.9% and 18.8%, respectively.

Except in two years, the timing of hilling operations had no significant effect ($P>0.05$) upon pounds of tubers of this size. When compared to three normally timed hillings, in 1957, two early hillings, followed by a third one at the normal time gave a 1.9% increase in yield, while in 1958 this combination of timing of hillings resulted in a 4.3% decrease in yield.

The spread of leaf roll was not affected by the cultural treatments in one of three years when 5% of the plant stand consisted of leaf roll reservoirs (1954). In 1957, the percentage of spread in plots of early and intermediate planting dates was not different at the 5-percent level of significance, but the 56% decrease of leaf roll spread in late plantings, as compared to early plantings, was significant ($P<0.05$). In 1958, when the plants had a 106 to 108-day growing season, the percentage spread of leaf roll was not affected significantly by planting dates but the 55% decrease of spread in plots having two closely spaced, early hillings, followed by a third one at the normal time was significantly less ($P<0.05$) than in plots having three normally timed hillings.

In 1955, when abundance and severity of underground stem infections were relatively inconsequential, the 72.9% reduction in number of rhizoctonia lesions in late plantings, as compared to early plantings, was significant ($P<0.05$). The timing of hillings did not affect ($P>0.05$) the number of lesions per stem or the percentage of stems with lesions. The tendency for a smaller percentage of stems to have severe lesions as date of planting was delayed was not significant at the 5-percent level.

The results of this study are of potential importance in the commercial production of potatoes for culinary and seed purposes in view of the high degrees of control of aphids and of leaf roll spread afforded by some of the cultural treatments tested. The observations reported here are also important in view of the relatively minor extent to which the modified culture affected yield of tubers. It would appear that the best time to plant table-stock potatoes, in most years may be May 20 to 25, and that each of the first two hillings should be applied when the soil cracks caused by emerging plants first appear, before any parts of the plants are visible.

There is some doubt as to whether or not a planting date as late as June 1 to 3 will be best for seed-potatoes except possibly for Katahdins shown by the Florida Test to be free of leaf roll, and in years when few green peach aphids are expected. The problem associated with late planting of the seed-potato crop may be inability to rogue the fields adequately in July before summer dispersal forms of the aphids are on the wing. Irrespective of the time of planting, the timing of hillings in plantings of potatoes for use as seed-potatoes should be the same as that indicated for culinary purposes.

References Cited

1. Ascovitz, S. I. 1955. Rapid method for determining mean values and areas graphically. Science (Washington, D. C.) 121: 212-3.

2. Bonde, R. 1937-38. Spread of virus diseases in Aroostook County. *In* Maine Agr. Exp. Sta. Bull. 391: 233-340 (297-8).

3. ———, and E. S. Schultz. 1939-40. Effect on potato yield of different percentages of viruses. *In* Maine Agr. Exp. Sta. Bull. 400: 185-300 (262-3).

4. ———, ———, and W. P. Raleigh. 1943. Rate of spread and effect on yield of potato virus diseases. Maine Agr. Exp. Sta. Bull. 421, 28 p.

5. Broadbent, L., P. H. Gregory, and T. W. Tinsley. 1952. The influence of planting date and manuring on the incidence of virus diseases in potato crops. Ann. Appl. Biol. 39: 509-24.

6. Broadbent, L., G. D. Heathcote, N. McDermott, and C. E. Taylor. 1957. The effect of date of planting and of harvesting potatoes on virus infection and yield. Ann. Appl. Biol. 45: 604-22.

7. Holmes, F. O. 1941. Handbook of pathogenic viruses. Burgess Publishing Company, Minneapolis, Minn. 221 p.

8. Folsom, D. 1920. Potato Mosaic. Maine Agr. Exp. Sta. Bull. 292: 157-84.

9. ———. 1921. Potato leaf roll. Maine Agr. Exp. Sta. Bull. 297: 37-52.

10. ———. 1932. Potato degeneration diseases: Natural and experimental transmission in Green Mountains in Central Maine. *In* Maine Agr. Exp. Sta. Bull. 363: 233-314 (276).

11. ———, E. S. Schultz, and R. Bonde. 1926. Potato degeneration diseases: Natural spread and effect upon yield. *In* Maine Agr. Exp. Sta. Bull. 397: 695-854 (57-112).

12. ———, W. C. Libby, G. W. Simpson, and O. L. Wyman. 1938. Net necrosis of potatoes. Maine Ext. Serv. Bull. 246, 12 p.

13. LeClerg, E. L., P. M. Lombard, A. H. Eddins, H. T. Cook, and J. C. Campbell. 1944. Effect of different amounts of spindle tuber and leaf roll on yields of Irish potatoes. Amer. Potato J. 21: 60-71.

14. Robert, Y. 1971. Epidemiologie de l'enroulement de la pomme de terre: capacite vectrice de stades et de formes des pucerons *Aulacorthum solani* Kltb., *Macrosiphum euphorbiae* Thomas, et *Myzus persicae* Sulz. Potato Res. 14: 130-9.

15. Schultz, E. S., and D. Folsom. 1921. Leaf roll, net necrosis, and spindling-sprout of the Irish potato. J. Agr. Research 21: 47-80.

16. Shands, W. A., and G. W. Simpson. 1953. Survey methods: Aphid populations on potatoes in the Northeast. Plant Protection Programs, USDA, Coop. Econ. Insect Rep. 3: 181-2.

17. ———, and ———. 1959. Characteristics of aphid-population growth on potatoes in northeastern Maine. Ann. Entomol. Soc. Amer. 52: 117-21.

18. ———, ———, and H. E. Wave. 1968. Canada plum, *Prunus nigra* Aiton as a primary host of the green peach aphid, *Myzus persicae* (Sulz.) in northeastern Maine. Maine Life Sciences and Agr. Exp. Sta. Tech. Bull. 39, 32 p.

19. ———, and ———. 1971. Seasonal history of the buckthorn aphid and suitability of alder-leaved buckthorn as a primary host in northeastern Maine. Maine Life Sciences and Agr. Exp. Sta. Tech. Bull. 51, 24 p.

20. ———, ———, and C. C. Gordon. 1971. Growth characteristics of potato plants useful in studies of population dynamics and biological control of aphids. Amer. Potato J. 48: 439-49.

21. ———, ———, and L. B. Reed. 1954. Subunits for estimating aphid abundance on potatoes. Jour. Econ. Entomol. 47: 1024-7.

22. ———, ———, and H. E. Wave. 1972. Seasonal population trends and productiveness of the potato aphid on swamp rose in northeastern Maine. Maine Life Sciences & Agr. Exp. Sta. Tech. Bull. 52, 35 p.

23. ———, R. E. Webb, and E. S. Schultz. 1961. The importance of the spring migrants of the buckthorn aphid in the spread of potato virus Y. Amer. Potato J. 38: 114-6.

24. ———, ———, and ———. 1962. Tests with milk and rice polish to prevent infection of Irish potato with virus Y transmitted by aphids. Amer. Potato J. 39: 36-9.

25. ———, G. W. Simpson, P. M. Lombard, R. M. Cobb, and P. H. Lung. 1950. Control of aphids on potatoes with DDT when used with fungicides. Maine Agr. Exp. Sta. Bull. 480, 41 p.

26. ———, ———, B. A. Seaman, F. S. Roberts, and C. M. Flynn. 1972. Effects of differing levels of aphids and of certain virus diseases upon yield and virus disease spread in potatoes. Maine Life Sciences and Agr. Exp. Sta. Tech. Bull. 56, 40 p.

27. Simpson, G. W. 1940. Aphids and their relation to the field transmission of potato virus diseases in northeastern Maine. Maine Agr. Exp. Sta. Bull. 403: 189-305.

28. ———, and W. A. Shands. 1954. Fewer applications of DDT with proper timing produce equal yields at less cost. Maine Agr. Exp. Sta. Bull. 533, 28 p.

29. ———, and ———. Unpublished manuscript. Differential spread of potato leaf roll by three species of potato-infesting aphids in northeastern Maine.

30. ———, ———, and H. E. Wave. Unpublished manuscript. Flight studies of potato-infesting aphids in northeastern Maine.

31. Singh, R. P., R. E. Finne, and R. H. Bagnall. 1971. Losses due to potato spindle tuber virus. Amer. Potato J. 48: 262-7.

32. Slosser, J. W. 1945. An improved sprayer boom for potatoes and other row crops. Agric. Eng. 26: 453-55.

33. Wave, H. E., W. A. Shands, and G. W. Simpson. 1965. Biology of the foxglove aphid in northeastern United States. Agr. Research Serv. USDA. Tech. Bull. 1338, 40. p.