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TITLE SOME EFFECTS OF FOLIAR SPRAYS OF MALEIC HYDRAZIDE ON THE POST-HARVEST PHYSIOLOGY OF POTATOES, ONIONS, AND CERTAIN ROOT CROPS

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By

Donald Robert Paterson

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

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AN ABSTRACT

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Approved Sylvan H. Wittwer

Single aqueous sprays of 500, 1000 and 2500 ppm of maleic hydrazide, benzo-thiozole-2-oxyacetic acid and 2,4,5-trichlorophenoxyacetic acid were applied to field plots of potatoes, onions and six root crops at different intervals before harvest in 1950 and 1951. After yields were determined, the various crops were placed in 35°, 45°, and 55° F storage rooms for several months. The potatoes and onions were analyzed both before and after this storage period for dry matter, total nitrogen, starch, reducing sugar, and non-reducing sugar. The amount of storage sprouting and breakdown as well as the loss in weight due to respiration, transpiration and other vital processes was determined at the end of the storage period for the various crops.

Five hundred, 1000 and 2500 ppm of maleic hydrazide applied to the foliage of potato plants one to seven weeks before harvest were effective in prolonging dormancy of Irish Cobbler, Pontiac, Russet Rural, and Sebago tubers held in storage for seven months at temperatures of 45° and 55° F. Complete inhibition of sprouting resulted from single preharvest foliar sprays of 2500 ppm of maleic hydrazide applied four to seven weeks before harvest and the inhibition was more pronounced than that obtained with preharvest foliar treatments of 2,4,5-trichlorophenoxyacetic acid or with post-harvest applications of the methyl ester of alpha-naphthaleneacetic acid. Maleic hydrazide induced sprout inhibition was accompanied by an absence of shriveling with little or no deterioration of quality and with no reduction in yield of U.S. No. I potatoes in 1950. Reductions in yield from the spray treatments were detected, however, in 1951 indicating the necessity for proper timing of application of the chemical if satisfactory results are to be obtained. Apical dominance of both tubers and individual sprouts on the tubers was destroyed. The percentages of reducing and non-reducing sugars were lower in maleic hydrazide treated potatoes stored at 45° F in 1950, while extensive storage studied of treated and non-treated potatoes held at 35°, 45°, and 55° F the following year showed no differences in reducing sugar, non-reducing sugar or starch percentages. Early post-emergence sprays of maleic hydrazide at 2500 ppm did not reduce storage sprouting of potato tubers, and low concentrations of maleic hydrazide applied shortly before harvest stimulated sprout growth on potato tubers.

Sprays of 500, 1000 and 2500 ppm of maleic hydrazide applied to the foliage of onion plants seven to ten days before harvest resulted in marked reductions of sprout and root growth during storage. Foliage sprays of maleic hydrazide at 2500 ppm applied three weeks or more before harvest resulted in an increase in storage breakdown of all onion varieties. There was a decrease in the percentage of reducing sugar in the control samples of Y-40 onions over a four and one-half month storage period, while similar samples treated with a 2500 ppm foliar spray of maleic hydrazide showed no decrease in reducing sugar. No alterations in the amount of dry matter, total nitrogen, or non-reducing sugar in the Y-40 onions was induced by the maleic hydrazide treatments. The percentage of weight loss not resulting from sprouting, rooting or breakdown was nearly identical when both treated and non-treated Y-40 onion bulbs were held under bulk storage conditions.

Preharvest foliar sprays of maleic hydrazide at 2500 ppm applied ten days before harvest reduced the amount of sprout growth of carrots, beets, rutabagas, turnips, and sugar beets held in storage at 55° F.

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I. INTRODUCTION

Since antiquity, man has been dependent on a measure of control of temperature and humidity to prevent loss in tuber, bulb, and root crops held in storage. In recent years the subject of numerous investigations has been a more thorough analysis of these factors in controlling storage losses (1, 2, 3, 7, 9, 34, 35, 39, 49, 55, 56, 58, 59, 82, 83).

In the last decade, chemical control of storage sprouting of potatoes has been achieved since Guthrie (31) reported that the methyl ester of alpha-naphthaleneacetic acid or other growth substances was effective if applied to potato tubers after harvest. Subsequent workers have reported similar results (10, 11, 15, 16, 17, 47, 68). Progress in the chemical control of storage sprouting was evolved still further by Smith, Baeza, Ellison and McGoldrick (24, 25, 64, 65) when they were successful in inhibiting the sprouting in storage of potato tubers harvested from plants sprayed in the field with various growth regulating chemicals. In 1950, Wittwer, Sharma <u>et al</u> (78, 79, 80) found preharvest foliar sprays of maleic hydrazide* to be effective in preventing the storage sprouting of onions and carrots.

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*Water soluble diethanolamine salt of 1,2-dihydro-3,6-pyridazinedione.

As the application of sprout inhibitors to growing crops is much simpler than treating the produce after harvest with crops that are ordinarily sprayed for the control of diseases or insects, and as maleic hydrazide has been demonstrated to be an effective sprout inhibitor on various crops (79, 80, 86), the effects of various concentrations and times of application of this chemical on the storage quality and chemical composition of potatoes, onions, and certain root crops were investigated. In some tests other chemicals in addition to maleic hydrazide, having proven sprout inhibiting effects, were included as control comparisons for maleic hydrazide in addition to the non-treated controls.

II. REVIEW OF LITERATURE

Schoene and Hoffman (62) first described maleic hydrazide as a unique growth regulant, and subsequent investigators have initiated many varied lines of investigation with this chemical. Miller (48) reported that maleic hydrazide can cause abscission of young flowers or fruits; Crafts et al (13) used it as a herbicide; Naylor (50) stated that maleic hydrazide will shift the critical day-length of Xanthium; White (72) found that this chemical delayed the fruiting of black raspberries; and Naylor and Davis (51) reported that maleic hydrazide produced sterile staminate flowers on Zea. Accordingly, the specific effects of this chemical on the plants used in this study are reviewed briefly.

Effects of maleic hydrazide on potatoes

Using maleic hydrazide as a herbicide on Netted Gem potatoes, Barnard and Warden (6) reported a slight increase in tuberization from 1000 ppm of maleic hydrazide applied two weeks after emergence and accompanied by a slight reduction in size. When 5000 ppm of maleic hydrazide were applied, tuber set was further increased but a smaller percentage of the tubers attained No. 1 size. Many second growth and aerial tubers were formed.

Denison (14) noted the effects of concentrations from 375 ppm to 6000 ppm on the Kennebec variety when applied as a herbicide on July 6, July 20, and July 28, 1950. Yields of the early application showed a marked reduction increasing with concentration, while the second application gave a smaller yield reduction and the last application resulted in no significant reduction. No difference was reported in the specific gravity of tubers from treatments or dates of application.

Marshall and Smith (46) have reported effective sprout inhibition from 2500 ppm of maleic hydrazide treatments to potato tubers when the material was injected into the tuber by sticking impregnated toothpicks in the tuber. Tubers immersed in a 2500 ppm solution of maleic hydrazide exhibited no sprout inhibition.

Zuckel (86) first reported that foliar applications of 3000 ppm of maleic hydrazide seven weeks after planting prevented sprouting of potato tubers in storage.

Kennedy and Smith (42) showed the effects of concentration of 10, 100, and 1000 ppm of maleic hydrazide on the Sebago variety when applied at four dates during the growing season. A concentration of 1000 ppm of maleic hydrazide applied about the time of initial tuber set caused a large increase in the number of tubers formed, severe injury to formed tubers and curling and chlorosis of foliage accompanied by stunting of growth. Foliage and tuber injury decreased with later applications and with less concentrated applications of maleic hydrazide. In general, a high concentration of maleic hydrazide early in the growing season caused vine and tuber injury, but applied late resulted in a reduction in amount of sprouting in storage.

Salunkhe, Wittwer _et al_ (61) reported that preharvest foliar sprays of maleic hydrazide (2500 ppm) applied to Russet Rural, Irish Cobbler and Sebago potatoes resulted in a larger number of tubers in higher specific gravity groupings than was found in comparable tubers harvested from non-treated plants. Following harvest the color quality of chips processed from maleic hydrazide treated Sebago potatoes of the same specific gravity groupings as compared with control lots was superior. Subsequent to five months storage at 37° F and again following 43 days of conditioning at 78° F, Russet Rural, Irish Cobbler and Sebago potatoes harvested from vines sprayed with maleic hydrazide and placed in various specific gravity groupings were within each group given superior arbitrary chip color ratings.

Effects of maleic hydrazide on onions

Maleic hydrazide was first used on onions as an herbicide. Harris (32) and Harris and Leonard (33) reported that young wild onions, Allium canadense, when sprayed on November 14, 1949 with 1.5, 3, 6, and 12 pounds per acre of maleic hydrazide as a herbicide gave 98 per cent control at the 3 pound rate and approached eradication at the 12 pound rate. A second treatment in March showed excellent control at all rates but the onions were not eradicated. No onion shoots developed on treated areas in the fall.

Freisen and Howat (27) stated that maleic hydrazide applied one month after planting at 2500 and 5000 ppm had no apparent effect on onion plants.

Greulach and Atchison (30) made the interesting observation that Southport Yellow Globe onions grown in a solution of one ppm of maleic hydrazide produced many more roots than comparable control bulbs indicating a possible root stimulating effect of maleic hydrazide.

Wittwer, Sharma _et al_ (76, 77, 78, 80) stated that maleic hydrazide inhibited sprouting of onions in storage when applied at concentrations of 2500 ppm when one-third of the tops were down, two weeks before harvest. There was a significant reduction in sprouting accompanied by a reduction in storage rots five months after storage when 500 ppm had been applied. Bulbs from plants treated with 2500 ppm of maleic hydrazide showed normal internal structure with no effect on flavor, color or odor. The onions were planted at the end of the five month storage period but remained dormant and sound for eight weeks.

Johannessen and Oebker (38) observed that a preharvest foliar spray of 2500 ppm of maleic hydrazide applied to Early Yellow Globe and Brigham Yellow Globe onions reduced sprouting in a 16 week storage test at 32° and 40° F and also reduced sprouting under simulated retail store conditions five weeks after this storage period.

Effects of maleic hydrazide on vegetable root crops

Barnard and Warden (5) applied maleic hydrazide at 1000 ppm one week after germination of several vegetable crops and observed little effect on the yield of beets and carrots.

Howat (36) observed that post-emergence maleic hydrazide sprays applied at 1.5, 3.0, and 6.0 pounds per acre did not effect yields and appearances of Detroit Dark Red beets.

Freisen and Howat (27) showed that 5000 ppm spray of maleic hydrazide one month after planting reduced the yield of beets.

Crafts *et al* (13) observed that young vegetable crops such as carrots and lettuce are more susceptible to injury from maleic hydrazide sprays than are older plants.

Wittwer, Sharma *et al* (77, 78, 79, 80) reported that sprout growth of carrots held at 50° F for three months was almost completely inhibited by foliar sprays of 2500 ppm of maleic hydrazide applied four days before harvesting. The maleic hydrazide produced no significant alteration in the amount of dry matter, carotene, carbohydrates, or Kjeldahl nitrogen in the stored carrots. Sprouting in these carrots was also significantly reduced by a foliar spray of 500 ppm of maleic hydrazide.

Effects of maleic hydrazide on sugar beets

Wittwer and Hansen (73, 74, 75) reported that sugar beets treated with a 2500 ppm spray of maleic hydrazide approximately 3 weeks before harvest and then stored for

35 days in bins of 5 ton capacity showed no change in sugar composition, while the average percentage of sugar in comparable non-treated beets was reduced by more than 4 per cent of the original. Corresponding weight losses were more than 9 per cent in controls, with, again almost negligible loss in the bin of treated beets. A loss of 13.06 per cent of the total original sugar, arising from sizeable losses in both total weight and composition was realized in the controls, compared with 0.72 per cent in the beets receiving the preharvest spray of maleic hydrazide. Practically all top growth, root growth and storage breakdown was eliminated in the roots from plants receiving the preharvest foliage spray of maleic hydrazide. The average temperatures within the bin containing the beets treated with maleic hydrazide ran several degrees cooler throughout the 35 day storage.

Peto et al (53) likewise reported that the temperature in a control bin of sugar beets rose to a minimum of 6° F above that of a similar bin of sugar beets sprayed with maleic hydrazide before harvest, and that treated beets exceeded the controls by 0.25 per cent sugar at the beginning of storage and 0.38 per cent after 34 days storage.

Ririe and Mikkelsen (57) found that foliar sprays of maleic hydrazide produced significantly higher percentages of sucrose in sugar beets but did not influence root yield.

Contrary to the above, Stout (67) reported that 1250, 2500 and 5000 ppm of maleic hydrazide applied 13 days before harvest showed no significant difference between treatments in yield and sugar percentage. There was no significant difference in respiration rate and sugar loss during the 38 day storage period at 72° F.

III. EXPERIMENTAL

Potatoes

A. The Effect of Concentration and Time of Application of Preharvest Foliar Sprays of Maleic Hydrazide on the Yield, Sprout Inhibition and Storage Quality

Procedure. Field tests were conducted on a productive Hillsdale sandy loam soil using certified seed of the Irish Cobbler and Pontiac varieties planted May 19, 1950, in rows 36 inches apart and with seed pieces at 12-inch intervals.

As outlined in Table I, single aqueous sprays of 500, 1000, and 2500 parts per million (ppm) of maleic hydrazide* were applied to the foliage of the Irish Cobbler variety 37 days (July 15), 19 days (August 2), 10 days (August 11), or 2 days (August 19) before harvest. Plants of the Pontiac variety were treated similarly 49 days (July 15), 31 days (August 2), 22 days (August 11), or 2 days (September 2) before harvest. Treatments were replicated on rows 15 feet in length. Three-gallon hand sprayers were utilized in applying the chemicals and the leaves were sprayed until the solution dripped from the leaves. "Dreft" (Proctor and Gamble) was added at a concentration of 0.1 per cent as a

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*Water soluble diethanolamine salt of 1,2-dehydro-3,6-pyridazinedione.

wetting agent. At the earliest spray application on July 15 tubers of both varieties ranged from one-fourth to two and one-half inches in diameter. Forty-eight hours after the latest treating dates, August 19 for Irish Cobbler and September 2 for Pontiac, the vines of all plots were cut off; and the tubers were harvested four days later.

Three controls were included to determine the relative merits of the various preharvest foliar sprays of maleic hydrazide (Table II): 1. Successive sprays of 50, 100, and 200 ppm of 2,4,5-trichlorophenoxyacetic acid were applied to both varieties on July 15, August 2, and August 11. This treatment was included because of favorable results reported by Marshall and Smith (45). 2. A post-harvest treatment with the methyl ester of alpha-naphthaleneacetic acid as a dust formulation, "Barsprout" (American Cyanamid Company, New York), was used. Approximately the equivalent of 0.9 gram of the active ingredient was applied per bushel at the time the potatoes were placed in storage. 3. A third control received no chemical treatment.

Harvests were made and the yields were recorded on August 25 for the Irish Cobbler variety and on September 9, 1950 for the Pontiac variety. Immediately after harvest, duplicate 10-tuber samples were taken from the replicates of each treatment and placed in paper bags. With the Pontiac variety, individual tubers in all samples were labelled and initial weights recorded. One of the duplicate 10-tuber samples from each of the two replicates of all treatments of both varieties was then placed in a storage maintained at 45 ± 2° F and the other at 55 ± 2° F. On March 29, 1951, after approximately seven months, the potatoes were removed from storage, photographed, weighed, and desprouted. The weight of the sprouts for each sample of 10 tubers was determined.

Subsequent to the seven months of storage at 45 and 55° F, samples of Irish Cobbler tubers harvested from plants sprayed with 2500 ppm of maleic hydrazide on July 15, 1950, along with comparable non-treated control lots, were analyzed for total nitrogen, starch, reducing and non-reducing sugar (4, 63).

<u>Results</u>. Harvest records showed no reduction in the yield, size, or quality of potatoes within a given variety resulting from any of the chemical spray treatments. No (visible) tuber injury was evident in any instance. There was however, a difference in the productivity of the two varieties with a mean acre yield of 268 bushels of U.S. No. I potatoes for Irish Cobbler compared with 435 bushels for Pontiac (Table I).

Data on the weight of sprouts in grams for 10 tubers after seven months storage at 45 and 55° F for the various treatments applied to the two varieties are given in Table II. The relatively greater effectiveness of preharvest foliar sprays of maleic hydrazide as contrasted with 2,4,5-trichlorophenoxyacetic acid and the post-harvest application of the methyl ester of alpha-naphthaleneacetic acid is apparent from the data. Especially striking were the differences in sprout growth at 55° F. Applications of 2500 ppm of maleic hydrazide 19 to 49 days before harvest resulted in nearly complete inhibition of sprouting at both temperatures, while control lots sprouted profusely. Some reductions in sprout growth resulted when maleic hydrazide was applied 48 hours before the vines were cut off. Greater dormancy resulted when the sprays were applied on August 11. This application date was approximately 10 days prior to harvesting Irish Cobbler and 22 days before harvesting the Pontiac variety. Tubers from plants receiving 2500 ppm of maleic hydrazide on either July 15 or August 2 were clean, bright, firm, and practically free from any evidence of sprout growth, even after seven months storage. The data in Table II indicate that a spray of 1000 ppm of maleic hydrazide, if applied at the proper time, may be sufficient for the induction of dormancy. It also appears that 1000 ppm and even 500 ppm of maleic hydrazide compare favorably with 2,4,5-trichlorophenoxyacetic acid as preharvest foliage spray applications for inhibition of storage sprouting in potatoes.

No differences were found in percentages of dry matter, starch, or other acid-hydrolyzable polysaccharides, total carbohydrate, or nitrogen (Kjeldahl). However, lower values were found for both reducing and non-reducing sugars in tubers stored at 45° F which had received the preharvest foliar spray of 2500 ppm of maleic hydrazide 37 days before harvest. Similar, though less striking, trends were also evident when tubers were stored at 55° F (Table III).

Although initial and final weights after storage of ten individual tubers of the Pontiac variety were recorded for all treatments, there was no consistent reduction in average weight losses when tubers and the attached sprouts were weighed together after storage at 45 and 55° F for seven months (Table IV). Similar results for post-harvest treatments using the methyl ester of alpha-naphthalene-acetic acid on the Irish Cobbler variety have been reported by Gandarillas and Nylund (28).

TABLE I

THE YIELD OF IRISH COBBLER AND PONTIAC POTATOES AS AFFECTED BY THE CONCENTRATION AND TIME OF APPLICATION OF MALEIC HYDRAZIDE AND 2,4,5-TRICHLOROPHENOXYACETIC ACID SPRAYS

Spray treatments				Yield (Lbs./15 ft. row)		Treatment mean
Chemical	ppm	Days before harvest				
		Cobbler	Pontiac	Cobbler	Pontiac	
Maleic hydrazide	500	37	49	23.5*	25.5*	24.5*
	1000			16.0	22.5	19.3
	2500			14.5	24.0	19.3
	500	19	31	17.0	30.5	23.8
	1000			21.0	27.0	24.0
	2500			18.0	23.0	20.5
	500	10	22	16.5	20.5	18.5
	1000			11.5	28.0	19.7
	2500			16.5	36.5	26.5
	500	2	2	13.5	30.5	22.0
	1000			14.5	27.5	21.0
	2500			18.0	27.5	22.8
2,4,5-trichlorophenoxyacetic acid	50	37	49			
	100	19	31			
	200	10	22	13.5	23.0	18.2
Control				18.5	31.0	24.8
Variety means				16.6	26.9	

*Each value represents means of samples harvested from two replicates.

TABLE II

THE EFFECTS OF CONCENTRATION AND TIME OF APPLICATION OF MALEIC HYDRAZIDE AND 2,4,5-TRICHLOROPHENOXYACETIC ACID ON THE SPROUTING OF COBBLER AND PONTIAC POTATOES SUBSEQUENTLY HELD AT STORAGE TEMPERATURES OF 45° AND 55° F FOR 7 MONTHS

Spray treatments				Sprouting (Grams/10 tubers)			
Chemical	ppm	Days before harvest		Cobbler		Pontiac	
		Cobbler	Pontiac	45° F	55° F	45° F	55° F
Maleic hydrazide	500	37 (July 15)	49	42.5*	110.0*	88.5*	110.5*
	1000			9.0	28.0	9.5	50.5
	2500			0.0	2.0	1.0	3.0
	500	19 (Aug. 2)	31	17.5	39.0	10.5	40.0
	1000			14.0	12.5	3.0	3.5
	2500			2.0	12.0**	0.0	0.0
	500	10 (Aug. 11)	22	27.5	66.0	40.0	68.0
	1000			15.0	37.0	22.5	24.5
	2500			7.0	30.5	00.0	26.0
	500	2	2	58.5	124.0	145.5	156.5
	1000			39.5	108.5	94.5	133.0
	2500			26.0	96.0	51.5	75.5
2,4,5-trichlorophenoxyacetic acid	50	37 (July 15)	49				
	100	19 (Aug. 2)	31				
	200	10 (Aug. 11)	22	28.0	53.5	2.0	47.5
Barsprout (post-harvest application)				13.0	66.5	0.0	56.0
Control (no treatment)				47.0	98.5	96.0	115.0

*Each value represents the means of samples harvested from two replications.

**9.0 grams removed from 2 tubers

TABLE III

THE SUGAR CONTENT OF IRISH COBBLER POTATOES AFTER 7 MONTHS STORAGE AT 45° AND 55° F AS AFFECTED BY A PREHARVEST FOLIAR SPRAY OF MALEIC HYDRAZIDE

(Expressed as per cent of dry weight)*

Treatment	Reducing sugar		Non-reducing sugar	
	Replication I	Replication II	Replication I	Replication II
<u>45° F</u>				
Maleic hydrazide	1.63	1.65	0.69	0.76
Control	3.26	2.68	1.21	1.02
<u>55° F</u>				
Maleic hydrazide	0.56	0.42	1.05	0.77
Control	0.62	0.52	1.63	1.25

*Each value represents the mean of duplicate determinations

TABLE IV

THE EFFECTS OF FOLIAR SPRAYS OF MALEIC HYDRAZIDE AND 2,4,5-TRICHLOROPHENOXYACETIC ACID ON THE PER CENT FRESH WEIGHT LOSS IN STORAGE OTHER THAN FROM SPROUTING IN PONTIAC POTATOES

Spray treatments			Weight loss (per cent)	
Chemical	ppm	Days before harvest	45° F	55° F
Maleic hydrazide	500	49 (July 15)	11.5*	10.5*
	1000		6.5	10.0
	2500		7.5	8.5
	500	31 (Aug. 2)	8.5	9.0
	1000		9.0	9.0
	2500		12.5	9.0
	500	22 (Aug. 11)	9.5	11.0
	1000		9.0	10.5
	2500		7.5	11.5
	500	2 (Sept. 2)	10.5	12.5
	1000		10.5	12.5
	2500		10.0	11.0
2,4,5-trichlorophenoxyacetic acid	50	49 (July 15)		
	100	31 (Aug. 2)		
	200	22 (Aug. 11)	6.5	8.5
Control (no treatment)			10.0	13.0

*Each value represents means of samples harvested from two replications.

B. <u>Yield, Storage Sprouting and Composition of Potatoes as Affected by the Time of Application of Foliar Sprays of Maleic Hydrazide and the Starch-Sugar Relationships of the Tubers Subsequently Stored at Various Temperatures</u>

<u>Procedure</u>. Certified seed of the Irish Cobbler, Sebago, and Russet Rural varieties were planted May 24 on a Hillsdale sandy loam soil in rows 36 inches apart and with seed pieces at 12-inch intervals. 3-12-12 fertilizer was applied in bands on either side of the seed piece at 800 pounds per acre.

In one treatment, an aqueous spray of 2500 ppm of maleic hydrazide was applied to the vines of the three varieties 64 days before harvest (July 19). A second treatment consisted of a similar application to vines of all three varieties 50 days before harvest (August 2). The third treatment consisted of a control in which no chemical was applied (Table V).

A split plot design was employed. Each of the four replicates consisted of two 75 foot rows each of the three varieties. As in 1950, the plants were sprayed to run-off with the appropriate solution of maleic hydrazide and a 0.1 per cent concentration of "Dreft" was used as a wetting agent.

At the July 19, 1951 spray application, tubers of the Irish Cobbler, Sebago, and Russet Rural varieties ranged in size from three-fourths to two inches in diameter. This date also coincided with the end of blossoming of the potatoes. On August 2, 50 days prior to harvest, the vines of all varieties were still green when sprayed with maleic hydrazide.

Harvesting was completed and the yields were recorded on September 21, 1951. The potatoes were held in common storage for 25 days to allow for suberization of the periderm of the tubers injured in harvest before being placed in thermostatically controlled storages at 35, 45, and 55° F.

On October 16, 1951, triplicate 40-tuber samples of the Irish Cobbler variety were taken from the replicates of each treatment and placed in 50-pound mesh onion bags for later chemical analyses. In addition, triplicate 10-tuber samples of all varieties were taken from each of the replicates of each treatment and placed in paper bags for observing the growth of sprouts when stored at 55° F. One of the triplicate 40-tuber samples from each of the four replicates of the three treatments of the Irish Cobbler variety along with one of the triplicate 10-tuber samples from each of the four replicates of the three treatments of all varieties was then placed in each of three storages maintained at 35 ± 2° F, at 45 ± 2° F, and at 55 ± 2° F, respectively.

On April 4, 1952, after approximately six months, the potatoes were removed from storage and desprouted, and the weight of the sprouts for each sample of 10 tubers determined.

Twenty-five days after harvest, and subsequent to 14 and 25 weeks of storage at 35, 45, and 55° F, samples of Irish Cobbler tubers harvested from plants sprayed with 2500 ppm of maleic hydrazide 64 and 50 days before harvest along with comparable non-treated control lots, were analyzed for total nitrogen, starch, reducing and non-reducing sugar (4, 63).

Results. Harvest records showed a reduction in yield significant at the one per cent level with the plants of all three potato varieties sprayed 64 days before harvest (July 19) with 2500 ppm of maleic hydrazide in comparison with the control and a reduction in yield significant at the five per cent level between the plants of all three potato varieties sprayed 50 days before harvest (August 2) with 2500 ppm of maleic hydrazide in comparison with the control (Table V). However, the low average yield per acre of potato tubers likely caused in part by poor soil drainage leaves doubt as to whether this experiment was an adequate test of either the effects of maleic hydrazide on the yield of potatoes or of the yielding ability of the three potato varieties involved.

The weight of sprouts in grams per 10 tubers after six months storage at 55° F was many times higher for the non-treated control samples than when the plants were sprayed either 64 or 50 days before harvest with 2500 ppm of maleic hydrazide (Table V). There was no difference in sprout inhibition at the two dates of spraying.

Tables VIa, VIb, VIc, and VII show a highly significant decrease in percentage dry weight between potatoes sprayed July 19 with 2500 ppm of maleic hydrazide and the non-treated controls and a significant decrease in percentage dry weight between potatoes sprayed August 2 with 2500 ppm of maleic hydrazide and the controls. There was a significantly higher percentage of total nitrogen in the tubers harvested from plants sprayed August 2 than from those harvested from the plants sprayed July 19 and the controls. No differences were found in percentages of starch, reducing or non-reducing sugars from treatment with maleic hydrazide (Table VII).

At the 35° F storage temperature the percentage of reducing and non-reducing sugar was higher than at the 45 and 55° F temperatures. Again at the 35° F storage temperature the starch percentage was lower than in either the 45 or 55° F storage. A similar starch-sugar relationship was observed between the 45 and 55° storages but was less pronounced. These results are in agreement with numerous reports in the literature (3, 18, 20, 21, 22, 35, 49, 58, 59, 83). The lower sugar and the higher starch percentages at the 25-week sampling as compared with the 14-week sampling in the 35° F storage (Tables VIb and VIc) were in part due to a mechanical failure of this storage one week before the potatoes were prepared for analysis on April 4, 1952. The degree of control of these storages ($\pm$ 2° F) permitted at least a significant difference in the sugar values since Denny and Thornton (20) observed that a $\pm$ 1° C difference gave a significant change in percentage total sugars and sucrose.

TABLE V

YIELD AT HARVEST, AND SPROUTING OF IRISH COBBLER, SEBAGO AND RUSSET RURAL POTATOES AFTER 6 MONTHS STORAGE AT 55° F AS AFFECTED BY THE TIME OF APPLICATION OF MALEIC HYDRAZIDE SPRAYS

Spray treatments			Yield of tubers	Sprouting
Chemical	ppm	Days before harvest	Lbs./150 ft. row	Grams/ 10 tubers
Maleic hydrazide	2500	64 (July 19)	104.2	1.83
	2500	50 (Aug. 2)	113.9	2.08
Control			130.3	132.30
Treatments				
LSD 5 per cent			16.64	--
LSD 1 per cent			22.79	--

TABLE VIa

THE EFFECT OF MALEIC HYDRAZIDE ON THE COMPOSITION OF IRISH COBBLER POTATOES 25 DAYS AFTER HARVEST

(Expressed as per cent dry weight)*

Treatments	Days before harvest	Dry weight	Total N	Starch	Reducing sugar	Non-reducing sugar
Treated	64 (July 19)	20.54	1.53	69.98	0.93	1.45
	50 (Aug. 2)	20.84	1.56	70.05	0.53	0.91
Control		20.64	1.55	67.28	0.80	0.95

*Each value listed represents an average of samples from four replications.

TABLE VIb

THE EFFECT OF MALEIC HYDRAZIDE AND TEMPERATURE ON THE COMPOSITION OF IRISH COBBLER POTATOES AFTER 14 WEEKS STORAGE

(Expressed as per cent dry weight)*

Treatments	Days before harvest	Dry weight	Total N	Starch	Reducing sugar	Non-reducing sugar
35° F						
Treated	64 (July 19)	19.19	1.64	56.46	15.77	4.28
	50 (Aug. 2)	19.48	1.66	58.75	13.31	3.59
Control		19.95	1.64	58.76	13.04	3.94
45° F						
Treated	64 (July 19)	19.70	1.53	68.98	2.42	0.78
	50 (Aug. 2)	19.30	1.50	68.63	2.52	0.72
Control		19.77	1.64	68.01	2.44	0.77
55° F						
Treated	64 (July 19)	21.19	1.43	69.46	0.38	0.38
	50 (Aug. 2)	19.59	1.66	67.57	0.33	0.62
Control		19.74	1.54	67.69	0.61	0.53

*Each value listed represents an average of samples from four replications.

TABLE VIc

THE EFFECT OF MALEIC HYDRAZIDE AND TEMPERATURE ON THE COMPOSITION OF IRISH COBBLER POTATOES AFTER 25 WEEKS STORAGE

(Expressed as per cent dry weight)*

Treatments	Days before harvest	Dry weight	Total N	Starch	Reducing sugar	Non-reducing sugar
35° F						
Treated	64 (July 19)	19.37	1.77	59.96	10.80	3.10
	50 (Aug. 2)	19.70	1.72	60.61	9.63	2.72
Control		19.82	1.69	59.23	9.06	2.89
45° F						
Treated	64 (July 19)	19.50	1.67	64.91	3.30	1.19
	50 (Aug. 2)	19.93	1.77	66.15	2.94	1.18
Control		20.59	1.52	65.35	3.46	1.20
55° F						
Treated	64 (July 19)	20.18	1.61	69.84	0.18	1.08
	50 (Aug.2)	21.72	1.72	70.03	0.30	0.74
Control		23.19	1.57	68.75	0.19	1.17

*Each value listed represents an average of four replications.

TABLE VII

SUMMARY OF THE EFFECTS OF MALEIC HYDRAZIDE ON THE COMPOSITION OF IRISH COBBLER POTATOES AFTER 25 WEEKS STORAGE AT 35, 45, AND 55° F

(Expressed as per cent dry weight)

Treatments	Days before harvest	Dry weight	Total N	Starch	Reducing sugar	Non-reducing sugar
Treated	64	20.18	1.59	65.65	4.84	1.74
	50	20.22	1.65	65.97	4.22	1.50
Control		20.81	1.59	65.00	4.23	1.63
LSD 5 per cent		0.46	0.058	No Significant Differences		
LSD 1 per cent		0.62	0.079			

C. The Yield and Storage Sprouting of Three Varieties of Potatoes as Affected by Post-Emergence Foliar Sprays of Maleic Hydrazide

Procedure. Since young potato tubers were already initiated before the time of spray application in the previous two experiments, it was suggested that foliar sprays of maleic hydrazide be applied to the potato vines on emergence from the soil to determine whether such early spray applications would effect the yield or storage sprouting of the potato tubers. Accordingly, such a single aqueous spray of 2500 ppm of maleic hydrazide was applied to the foliage of the Irish Cobbler and Sebago varieties on June 15, 1951. Plants of the Russet Rural variety were similarly treated on June 20, 1951. Treatments were replicated on rows 15 feet in length.

Harvests were made and the yields were recorded on September 18, 1951. Ten-tuber samples were taken from the replicates of each treatment and placed in paper bags which were then placed in storage at $55 \pm 2^{\circ}$ F.

On April 4, 1952, after approximately 6 months, the potatoes were removed from storage and desprouted. The weight of the sprouts for each sample of 10 tubers was determined.

Results. Post-emergence sprays of maleic hydrazide at 2500 ppm significantly reduced the yield of Irish Cobbler, Sebago and Russet Rural potatoes but did not significantly affect the weight in grams of sprouts per 10 tubers between maleic hydrazide treated and comparable non-treated samples after six months storage at 55° F (Table VIII).

TABLE VIII

THE EFFECTS OF POST-EMERGENCE FOLIAR SPRAYS OF MALEIC HYDRAZIDE APPLIED APPROXIMATELY 4 WEEKS AFTER PLANTING ON THE YIELD AT HARVEST AND STORAGE SPROUTING OF POTATOES AFTER 6 MONTHS STORAGE AT 55° F (MEAN VALUES FOR IRISH COBBLER, SEBAGO AND RUSSET RURAL)

Treatment	Yield	Sprouting
	Pounds of tubers per 15 foot row	Grams of sprouts per 10 tubers
Maleic hydrazide (2500 ppm)	14.8	80.5
Control	20.5	103.5
LSD 5 per cent	4.86	No Significant Diff.
LSD 1 per cent	8.91	

D. Storage Sprouting and Quality of Sebago Potatoes as Affected by Concentration of Preharvest Foliar Sprays of Maleic Hydrazide and Soil Type

Procedure. Single aqueous sprays of 500, 1000, and 2500 ppm of maleic hydrazide were applied August 10, 1951, to the foliage of the Sebago variety grown both on mineral and muck soil. These treatments were replicated on five hill plots on the two soil types.

Harvests were made on September 30, 1951, and ten-tuber samples were taken from the replicates of each treatment and placed in paper bags which were then placed in storage at 55 ± 2^{o} F. On April 4, 1952, after approximately 25 weeks storage, the potatoes were removed from storage, photographed and desprouted. The weight of the sprouts for each sample of ten tubers was determined.

Results. Foliar sprays of maleic hydrazide at 500, 1000, and 2500 ppm applied approximately seven weeks before harvest on the Sebago variety grown on either mineral or muck soil resulted in a reduction in weight of sprouts when any of the three spray concentrations were compared with control samples (Table IX, Figures 1 and 2). No differences were noted as to any possible influence of soil type and the effectiveness of the three concentrations of the chemical used. However, the non-treated potatoes on the mineral soil had fewer sprouts than those grown on muck soil.

TABLE IX

SPROUTING OF SEBAGO POTATOES ORIGINALLY GROWN ON TWO SOIL TYPES AFTER 6 MONTHS AT 55° F AS AFFECTED BY VARIOUS SPRAY CONCENTRATIONS OF MALEIC HYDRAZIDE

Treatments	Grams of sprouts per 10 tubers		
	Muck soil	Mineral soil	Mean
Treated			
500 ppm	7.5	7.5	7.5
1000 ppm	7.0	0.5	3.8
2500 ppm	0.0	0.0	0.0
Control	138.0	60.5	99.2
Means	38.1	17.1	

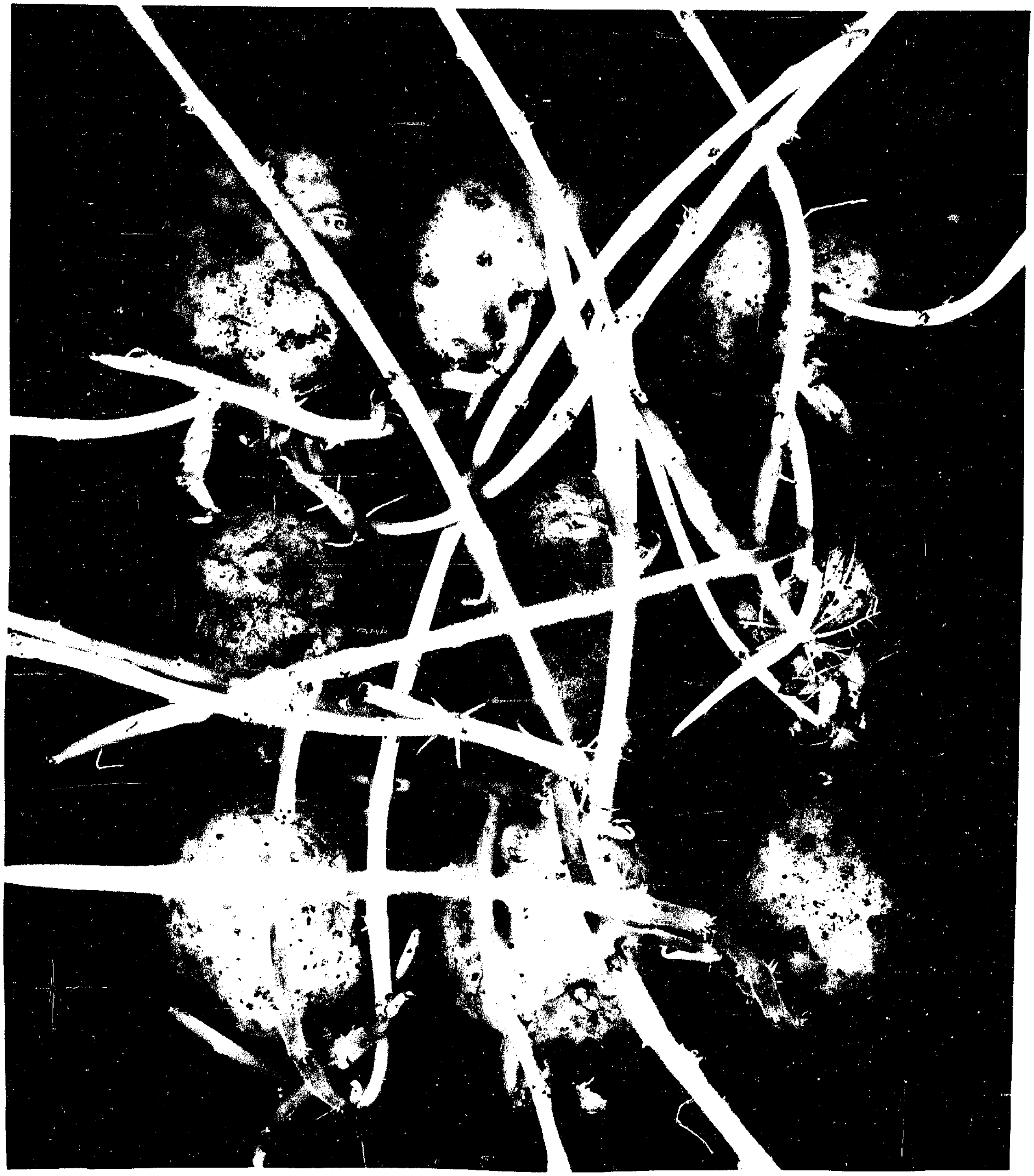

Figure 1. Non-treated Sebago potatoes after 6 months storage at 55° F

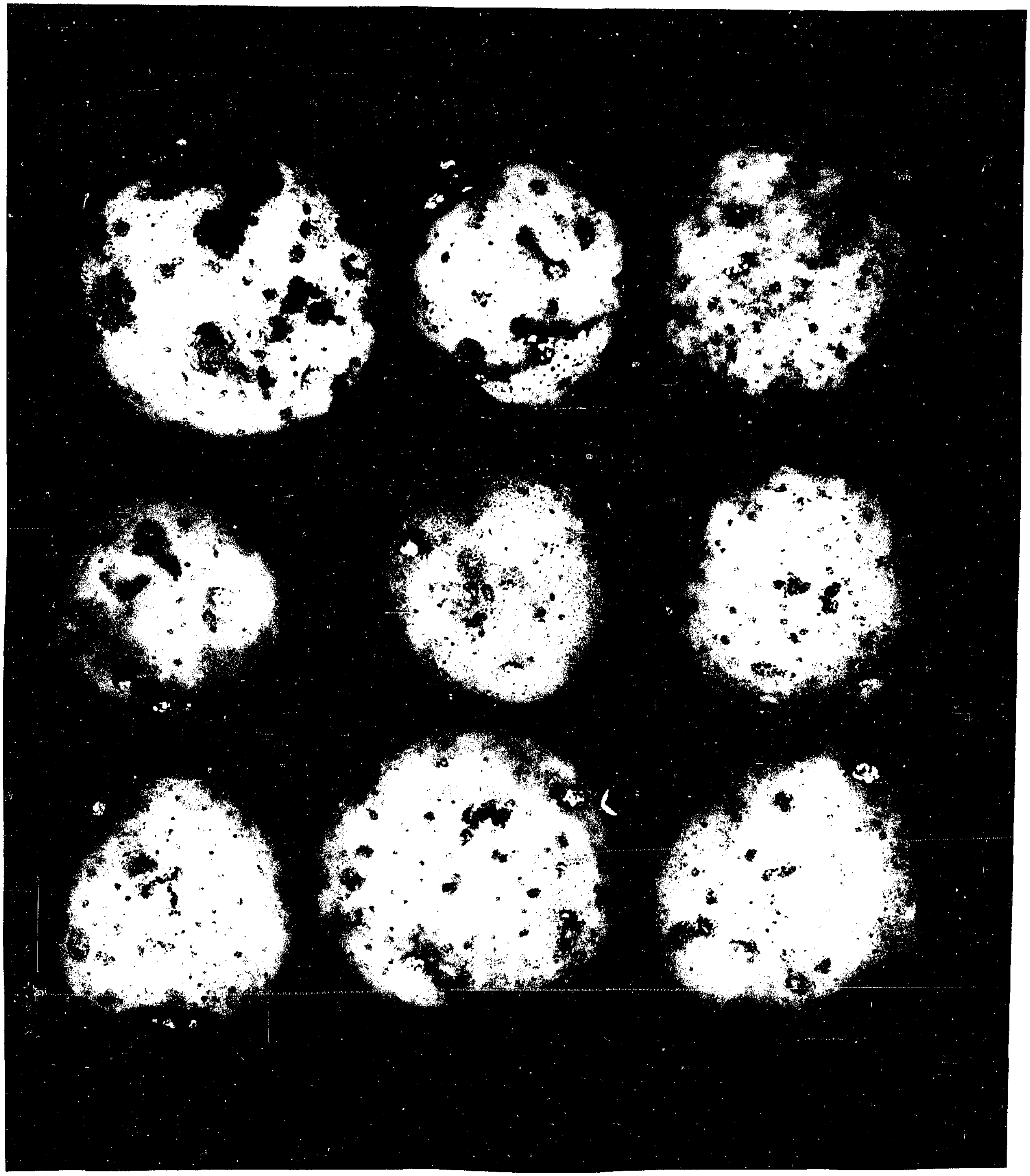

Figure 2. Sebago potatoes treated with 2500 ppm of maleic hydrazide seven weeks before harvest and after six months storage at 55° F

E. Yield of Potato Plants Grown from Tubers Which Were Harvested from Plants Sprayed with Maleic Hydrazide

Procedure. Since approximately five per cent of the annual 375 million bushel potato crop in this country is used for seed purposes (58), any chemical that retards sprouting or growth of potato vines poses the question as to the effect of this chemical on seed stock potatoes. Therefore, tubers of the Pontiac variety harvested from plants, the vines of which were sprayed with the maleic hydrazide concentrations in 1950 as outlined in Table X, were planted May 5, 1951, on a productive Hillsdale sandy loam soil in twice replicated 10-tuber rows.

Results. From Table X it can be seen that concentrations of 1000 and 2500 ppm on July 15, 1950; 500, 1000, and 2500 ppm on August 2, 1950; and 2500 ppm of maleic hydrazide on August 11, 1950, resulted in no yield or a marked reduction in the harvest of tubers in comparison with comparable non-treated control samples.

Five hundred ppm of maleic hydrazide applied September 2, 1950, 48 hours before the vines were cut off, increased the yield of tubers in the 1951 crop about 90 per cent as compared with non-treated control samples. The 2,4,5-trichlorophenoxyacetic acid treatments resulted in a reduction in yield approaching the five per cent level of significance.

TABLE X

THE COMPARATIVE YIELDS OF POTATO PLANTS (1951) GROWN FROM PONTIAC TUBERS, HARVESTED FROM PLANTS SPRAYED (1950) AT VARIOUS TIMES AND WITH VARIOUS CONCENTRATIONS OF MALEIC HYDRAZIDE AND 2,4,5-TRICHLOROPHENOXYACETIC ACID

Spray treatments			Yield
Chemical	ppm	Days before harvest	Lbs./10 hills
Maleic hydrazide	500	49 (July 15)	28.0
	1000		4.5
	2500		3.0
	500	31 (Aug. 2)	1.5
	1000		0.0
	2500		0.0
	500	22 (Aug. 11)	19.5
	1000		10.0
	2500		0.0
	500	2 (Sept. 2)	40.5
	1000		30.0
	2500		21.0
2,4,5-trichloro-phenoxyacetic acid	50	49	
	100	31	
	200	22	11.0
Control			21.0

Onions

A. The Effect of Concentration and Time of Application of Preharvest Foliar Sprays of Maleic Hydrazide on the Yield and Storage Sprouting and Breakdown of Five Onion Varieties

Although both sprouting and rooting of onion bulbs can be controlled by low temperature at a low humidity (39, 82), most of the northern onion crop is held in common storage. Depending upon the variety, location, and the weather, commercial onion producers can expect a 5 to 50 per cent loss in the storage of their harvested crop (7, 12, 26, 29, 41, 44, 70). Sprouts and root growth account for approximately 85 per cent of this loss according to Gaylord (29).

The successful use of maleic hydrazide as a sprout inhibitor by Wittwer et al (78, 79, 80) made it desirable to find out the optimum concentration and time of application for applying this chemical to a commercial onion crop. Accordingly, the following experiment was designed.

Procedure. On May 8, 1950, seed of Brigham Yellow Globe, Early Yellow Globe, Downing Yellow Globe and Michigan State College Sweet Spanish onions was planted in 14-inch rows on Carlyle muck soil and fertilized with 1000 pounds of a 0-20-20 fertilizer plus 25 pounds of copper sulphate per acre.

As outlined in Table XI, single aqueous sprays of 500, 1000, and 2500 ppm of maleic hydrazide were applied to the foliage of the four onion varieties at 29, 11, and 2 days before harvest. Treatments were replicated on rows 15 feet in length. Three-gallon hand sprayers were utilized in applying the chemical. The leaves were sprayed to run-off. Triton B 1956 (Rohm and Haas, Philadelphia, Pa.) was added at a concentration of 0.1 per cent as a wetting agent.

The Early Yellow Globe and Brigham Yellow Globe varieties were pulled and piled in windrows to cure on August 31, and the Downing Yellow Globe and the Michigan State College Sweet Spanish varieties on September 1. On September 4 and 5 all four varieties were hand topped and the yields were recorded. After approximately three weeks of field curing in bushel crates, 10-bulb samples were taken from the replicates of each treatment and placed in paper bags on September 23. With the Early Yellow Globe variety, individual bulbs in all samples were labelled and initial weights recorded. The bagged onion samples were then placed on shelves in a common onion storage.

Yellow Sweet Spanish onions were grown from greenhouse plants seeded March 1 and transplanted into a field of productive mineral soil the second week in May, 1950. As outlined in Table XIII, single aqueous sprays of 500, 1000, and 2500 ppm of maleic hydrazide were applied to two 15 foot row replicates at 45, 11, and 2 days before harvest in a manner similar to that already described for the onions grown on muck soil. The samples were field cured, topped and yield data recorded as previously described. On September 20, 10-bulb samples were taken from the replicates of each treatment and placed in paper bags. These samples were then placed in common storage along with the four other onion varieties. On May 19, 1951, after approximately eight months, the five onion varieties were removed from storage, weighed and the per cent of sprouting and breakdown determined for each 10-bulb sample.

Results. Harvest records showed no reduction in the yield of onions resulting from any of the spray treatments (Table XI).

The per cent sprouting for 10-bulb samples after eight months common storage for the various treatments applied to the four varieties grown on muck soil is given in Table XI. All treatments gave a reduction in per cent sprouting with the exception of 500 ppm of maleic hydrazide applied 48 hours before the onions were pulled. Twenty-five hundred ppm of maleic hydrazide applied 29 and 11 days before harvesting gave complete sprout inhibition (Table XI). There was no difference in the per cent breakdown of the four onion varieties for any spray treatment applied 2 and 11 days before harvesting or for the 500 ppm of maleic hydrazide applied 29 days before harvesting. Both the 1000 and 2500 ppm concentration of maleic hydrazide applied 29 days before harvest resulted in marked increases in per cent breakdown when compared with comparable non-treated samples (Table XI).

Although initial and final weights after storage of individual bulbs of the Early Yellow Globe variety were recorded for all treatments, there was no significant reduction in weight losses when bulbs and the attached sprouts were weighed together (Table XII).

With the Yellow Sweet Spanish variety, a preharvest foliar spray of maleic hydrazide applied 45 days before harvest not only resulted in from 9.5 to 62.0 per cent unmarketable spongy onions at harvest (Figure 3) but also greatly increased the breakdown of these onions in storage (Table XIII).

TABLE XI

YIELD AT HARVEST AND STORAGE SPROUTING AND BREAKDOWN OF BRIGHAM YELLOW GLOBE, DOWNING YELLOW GLOBE, EARLY YELLOW GLOBE AND MICHIGAN STATE COLLEGE SWEET SPANISH ONIONS AFTER 8 MONTHS IN COMMON STORAGE AS AFFECTED BY VARIOUS SPRAYS OF MALEIC HYDRAZIDE

Spray treatments			Yield (Lbs./15 ft. row)	Sprouting (Per cent)	Breakdown (Per cent)
Chemical	ppm	Days before harvest			
Maleic hydrazide	500	29	16.8*	5.0*	8.75*
	1000		16.5	2.5	22.50
	2500		15.1	0.0	25.00
	500	11	15.9	32.5	6.25
	1000		16.3	21.3	1.25
	2500		14.4	0.0	7.50
	500	2	16.4	56.3	3.75
	1000		13.6	35.0	3.75
	2500		16.1	20.0	2.50
Control			15.4	68.8	5.00

*Each value represents the mean of samples harvested from two replications.

TABLE XII

THE EFFECTS OF FOLIAR SPRAYS OF MALEIC HYDRAZIDE ON PER CENT WEIGHT LOSS OTHER THAN FROM SPROUTING IN EARLY YELLOW GLOBE ONIONS HELD 8 MONTHS IN COMMON STORAGE

Spray treatments			Per cent fresh weight lost per 10 bulbs
Chemical	ppm	Days before harvest	
Maleic hydrazide	500	29	4.3
	1000		7.1
	2500		7.5
	500	11	8.5
	1000		5.8
	2500		5.3
	500	2	7.5
	1000		7.5
	2500		7.6
Control (no treatment)			9.1

Treatments
LSD 5 per cent
LSD 1 per cent

No Significant Diff.

TABLE XIII

THE INDUCTION OF SPONGINESS AT HARVEST AND THE STORAGE SPROUTING AND BREAKDOWN OF SWEET SPANISH ONIONS AFTER 8 MONTHS IN COMMON STORAGE AS AFFECTED BY CONCENTRATION AND TIME OF APPLICATION OF MALEIC HYDRAZIDE SPRAYS

Spray treatments			Sponginess (Per cent)	Sprouting (Per cent)	Breakdown (Per cent)
Chemical	ppm	Days before harvest			
Maleic hydrazide	500	45	9.5*	60.0*	25.0*
	1000		62.0	0.0	85.0
	2500		34.5	0.0	85.0
	500	11	0.0	30.0	15.0
	1000		0.0	15.0	10.0
	2500		0.0	5.0	15.0
	500	2	0.0	55.0	10.0
	1000		0.0	15.0	10.0
	2500		0.0	25.0	5.0
Control			0.0	90.0	0.0

*Each value represents the mean of samples harvested from two replications.

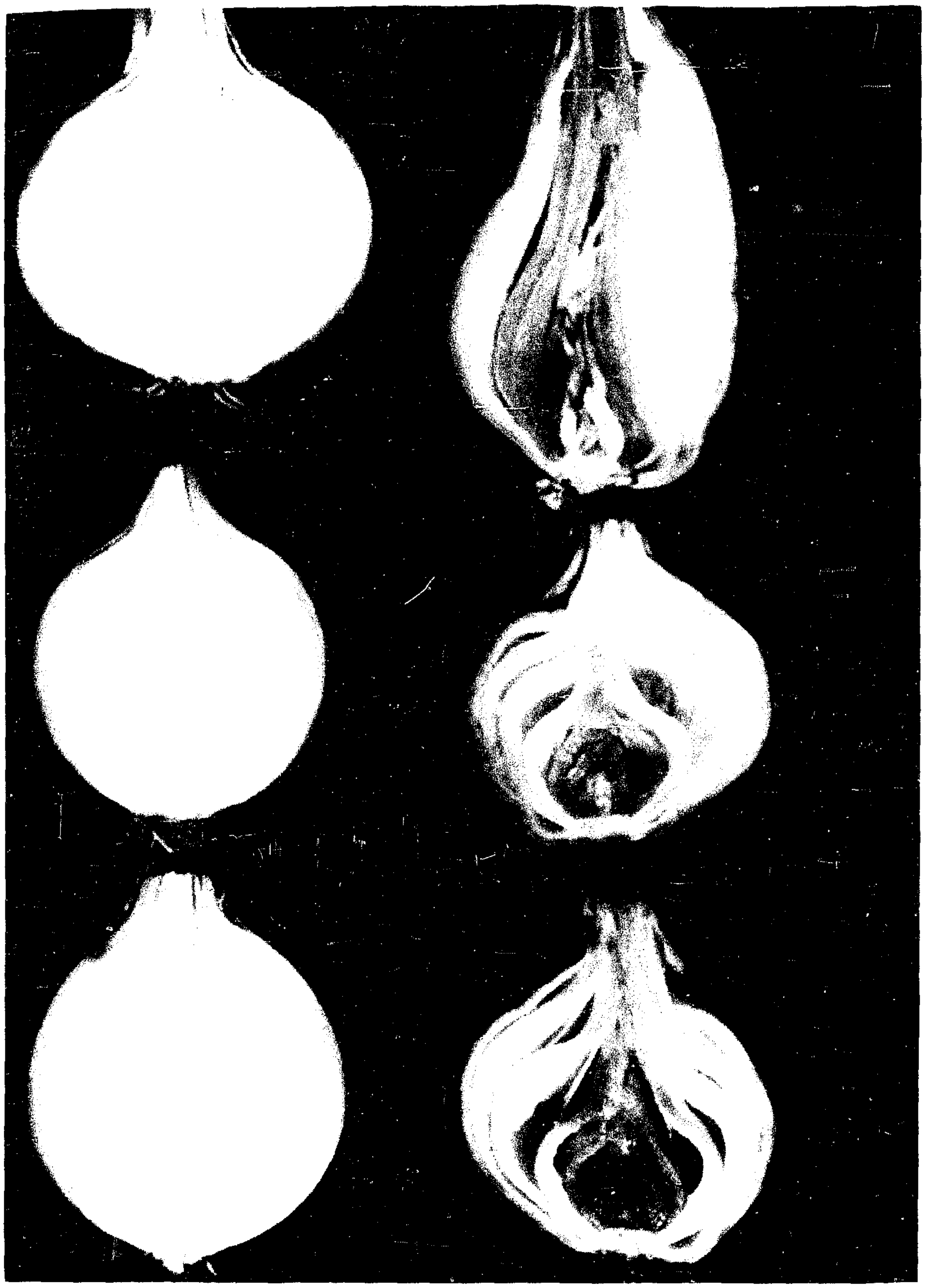

Figure 3. Injury of Yellow Sweet Spanish onions caused by early foliar sprays of maleic hydrazide.

Left, normal control bulbs; right, spongy bulbs resulting from maleic hydrazide applied too early as a foliage spray

B. <u>The Composition, Yield and Storage Sprouting and Breakdown of Y-40 Onions Held under Bulk Storage Conditions</u>

Many recently introduced high yielding hybrid onion varieties have poor keeping qualities, Foskett *et al* (26) and Wittwer and Paterson (77). The possible use of these high yielding onion varieties in combination with the control of sprouting of onions established by Wittwer *et al* (76, 77, 78, 79, 80) and verified by Johannessen and Oebker (38) suggested the following experiment in which the hybrid onion variety Y-40 was given a preharvest foliar spray of maleic hydrazide and then held with comparable controls under bulk storage conditions.

<u>Procedure</u>. On May 9, 1951, Y-40 hybrid onion seed (Associated Seed Co.) was planted in 14-inch rows on Carlyle muck soil and fertilized with 1000 pounds of 4-10-20 fertilizer plus 25 pounds of copper sulphate per acre.

A single aqueous spray of 2500 ppm of maleic hydrazide was applied to the foliage of the Y-40 onions 21 days before harvest. This treatment was replicated 40 times on 1/113 acre four row beds. Forty adjacent and paired non-treated beds served as controls. Three-gallon hand sprayers were utilized in applying the chemical and the leaves were sprayed to run-off. Approximately 226 gallons of spray were used per acre. Triton B 1956 was added at a concentration of 0.1 per cent as a wetting agent. On August 8, at the time of the spray application, the tips of the onion leaves were dead and about one-third of the tops had fallen over. One week after the spray application, Blast was rapidly spreading throughout the field and over one-half of the onion tops were dead.

On August 29, the treated and non-treated onions were harvested with a Chickering vegetable harvester and the yields for 14 treated and 14 non-treated plots were recorded. At the time of harvest, 10-bulb samples were taken from the 40 replicates of each treatment and placed in paper bags. These 10-bulb samples were held four months in common storage and three months at $55 \pm 2^{\circ}$ F. On March 21, 1952, the 10-bulb samples were removed from storage and the per cent of sprouting and breakdown and of marketable onions was determined. Immediately after harvest, weighed samples of both treated and non-treated onions were placed in ventilated bins (8) of approximately 200 bushels capacity. In addition, weighed crate samples of both treated and non-treated onions approximating a total of 500 pounds of each were placed in common storage after curing in the field.

Both the bin containing the maleic hydrazide treated onions and the bin containing the non-treated onions were equipped with thermocouples installed at two, four and one-half, and seven feet from the bottom of each bin to record the temperature within the separate bins during the storage period.

On January 17, 1952, after approximately four and one-half months in common storage, the two bin and crate samples of Y-40 onions were graded and weighed. Five comparable bushel crate samples were removed from both the treated and the non-treated bin as they were unloaded for grading. The per cent of sprouting and breakdown of marketable onions was determined.

At the time of loading the bins on August 29, 1951, and subsequent to the four and one-half months of common storage on January 17, 1952, samples of marketable Y-40 onion bulbs from plants sprayed August 8, 1951, with 2500 ppm of maleic hydrazide along with comparable non-treated control lots were analyzed (4, 84, 85) for total nitrogen, reducing and non-reducing sugar. Per cent dry weight was determined by evaporating 100-gram samples of onion tissue preserved in 80 per cent ethyl alcohol to dryness, then drying the residue for five hours at 100° C before weighing the tared flasks for a final weight determination.

Results. Both the bin and crate samples of Y-40 onions sprayed with maleic hydrazide before harvest had a higher percentage of marketable onions than did comparable control samples; although neither had as high a percentage of marketable onions as did the untreated Downing Yellow Globe variety held in a comparable bin storage (Table XIV). The untreated Y-40 onions had a higher percentage of rotting and sprouting in both bins and crate samples than did the maleic hydrazide treated Y-40 onions. There was, however, a lower percentage of rotting as well as sprouting in the Downing

Yellow Globe non-treated onions than in either the treated or non-treated Y-40 onions. The per cent weight loss not due to sprouting or rotting was nearly identical for both the treated and non-treated bin samples of Y-40 onions.

An analysis of four random 50-pound samples in both the treated and non-treated bins of Y-40 onions showed a highly significant increase in the per cent of marketable onions, per cent breakdown of onions and a definite decrease in the per cent sprouting of the maleic hydrazide treated onions as compared with comparable non-treated control samples (Table XV). Harvest records showed no reduction in the yield of the Y-40 onion variety resulting from the preharvest spray of maleic hydrazide (Table XVI).

As in the bin and crate samples, the per cent marketable onions and per cent breakdown of onions in the 10-bulb samples held four months in common storage and three months at 55° F, was greater for maleic hydrazide treated onions when compared with comparable non-treated control samples. Also there was a decrease in the per cent sprouting of maleic hydrazide treated onions in comparison with non-treated samples (Table XVI, Figures 4 and 5).

No differences were found in percentage dry matter, total nitrogen, or non-reducing sugar. However, a significantly higher value was found for reducing sugar in the control sample of Y-40 onions when compared with maleic hydrazide treated onions immediately after harvest (Table

XVII). At the end of the four and one-half month storage period, there was a highly significant decrease in reducing sugar in the control sample of Y-40 onions compared with almost no decrease in the maleic hydrazide treated sample over the same storage period.

Although periodic temperature determinations in both treated and non-treated bin storages showed no significant differences between the temperature in the maleic hydrazide treated bin of onions and the comparable non-treated bin, Table XVIII shows that the control bin averaged a warmer temperature than the treated bin and also that the non-treated bin got progressively warmer from top to bottom while the bin containing onions treated with maleic hydrazide evidenced no such temperature gradient from top to bottom (8).

TABLE XIV

COMPARATIVE STORAGE QUALITY OF MALEIC HYDRAZIDE TREATED AND NON-TREATED Y-40 AND NON-TREATED DOWNING YELLOW GLOBE FOLLOWING VENTILATED BIN AND CRATE STORAGE CONDITIONS*

Treatments	Condition after $4\frac{1}{2}$ months storage		
	Marketable (Per cent by weight)	Rotting and sprouting (Per cent by weight)	Shrinkage (Per cent by weight)
Y-40 Maleic hydrazide			
Bin	61.31	26.95	11.74
Crate	74.61	13.97	11.42
Y-40 Control			
Bin	37.99	50.24	11.77
Crate	63.18	20.11	16.71
Downing Yellow Globe Control			
Bin	72.34	13.40	14.26
Crate	85.29	5.71	9.00

*Data for Downing Yellow Globe onions provided by Boyd and Davis (8).

TABLE XV

THE EFFECTS OF A FOLIAR SPRAY OF MALEIC HYDRAZIDE ON THE KEEPING QUALITY OF ONIONS, VARIETY Y-40, HELD IN VENTILATED STORAGE BINS OF 200 BUSHEL CAPACITY FOR 4½ MONTHS

Detailed Analysis of Random Samples

Treatment	Average of 4 random 50-pound samples in each bin			
	Marketable (Per cent by weight)	Sprouting (Per cent by weight)	Breakdown (Per cent by weight)	Sprouting and rotting (Per cent by weight)
Treated	68.23	11.50	20.27	31.77
Control	48.42	36.56	15.02	51.58
LSD 1 per cent	8.20	12.72	2.93	8.19

TABLE XVI

YIELD AT HARVEST AND THE KEEPING QUALITY OF ONION, VARIETY Y-40, AFTER 4 MONTHS IN COMMON STORAGE AND 3 MONTHS AT 55° F AS AFFECTED BY MALEIC HYDRAZIDE SPRAYS

Treatment	Yield (Lbs. per 1/113 A)	Marketable* (Per cent)	Sprouting* (Per cent)	Breakdown* (Per cent)
Treated	396.4	78.66	1.84	19.50
Control	382.6	6.85	88.15	5.00

*Each value represents the mean of four samples.

Figure 4. Non-treated Y-40 onions after four months in common storage and three months at 55° F

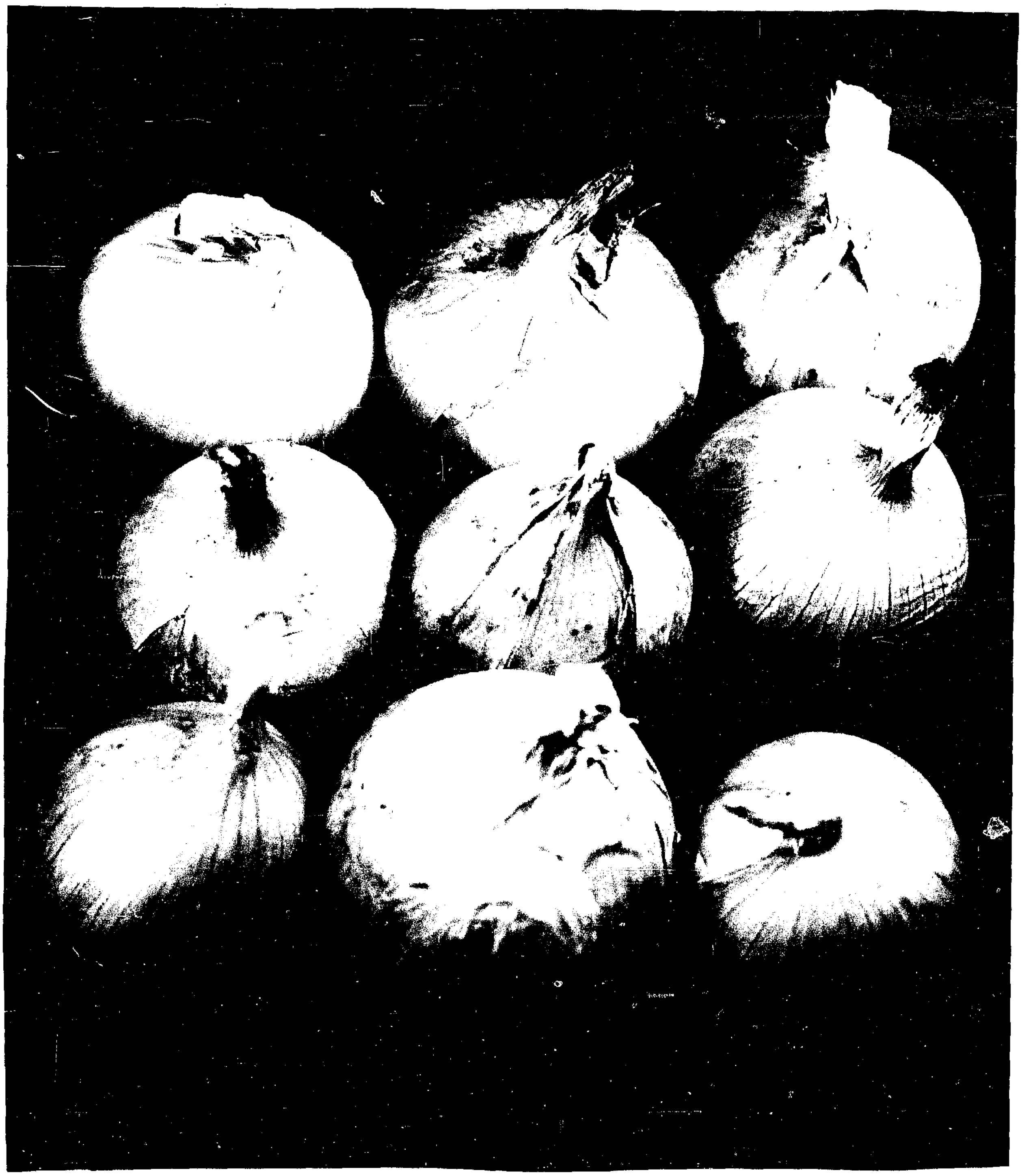

Figure 5. Y-40 onions treated with 2500 ppm of maleic hydrazide 18 days before harvest, and after four months in common storage and three months at 55° F

TABLE XVII

THE EFFECT OF MALEIC HYDRAZIDE ON THE COMPOSITION OF Y-40 ONIONS DURING 4½ MONTHS OF COMMON STORAGE

(Expressed as per cent dry weight)

Treatments	Dry weight	Total N	Reducing sugar	Non-reducing sugar
Before storage				
Treated	7.70	2.71	42.04	13.06
Control	7.35	2.76	45.51	16.13
After storage				
Treated	7.30	1.91	42.13	12.40
Control	7.49	2.22	39.37	12.24
LSD 5 per cent	No significance		3.08	No significance
LSD 1 per cent			5.11	

TABLE XVIII

STORAGE BIN TEMPERATURES OF Y-40 ONION BULBS AS AFFECTED BY A FOLIAR SPRAY OF MALEIC HYDRAZIDE

Height of thermocouples in storage bins (feet)	Treatments (Average of 17 temperature determinations)	
	Treated °F	Non-treated °F
2.0	52.53	52.91
4.5	52.29	53.50
7.0	52.45	54.44
Means	52.42	53.61

Root Crops

A. <u>The Effect of Concentration and Time of Application of Preharvest Foliar Sprays of Maleic Hydrazide on the Yield at Harvest and the Storage Sprouting and Breakdown of Sugar Beets and Five Vegetable Root Crops</u>

Although vegetable root crop storage is not as important in the northern states as the storage of potatoes and onions, still food processors have to hold such crops as carrots and sugar beets for some time after the peak of harvest, and storage losses from sprouting may be excessive (60, 73, 74, 75). Also home gardeners may desire to store root crops for several months in the Fall and Winter. The successful use of a sprout inhibitor such as maleic hydrazide would represent a great saving in such stored produce.

As Wittwer <u>et al</u> (76, 77, 78, 79, 80) have shown maleic hydrazide to be an effective sprout inhibitor of such crops as onions and carrots, it was suggested that maleic hydrazide could also be used as a sprout inhibitor on other vegetable root crops. The following experiment was conducted to find out the effect of concentration and time of application of maleic hydrazide on carrots, rutabagas, turnips, beets, parsnips and sugar beets.

<u>Procedure</u>. The crops were planted on a productive Hillsdale sandy loam soil in 1950 as follows:

Parsnip, variety Hollow Crown Thick Shoulder - June 5

Carrot, varieties Chantenary, Danvers, and Nantes - June 6

Sugar beets - June 9

Rutabaga, variety American Purple Top - June 15

Beet, variety Detroit Dark Red - July 3

Turnip, variety Purple Top White Globe - July 14

As outlined in Tables XIX, XXII, XXIII, XXV, XXVII, and XXVIII, aqueous sprays of various growth substances were applied to the foliage of these root crops at definite intervals before harvest in the same manner as previously described for potatoes and onions. Treatments were replicated twice on rows 15 feet in length.

From October 7 to October 28, these root crops were harvested and the yields recorded. Duplicate 10-root samples were taken from the replicates of each treatment for each variety of each crop and placed in paper bags. With the Chantenay carrot variety, individual roots in all samples were labelled and initial weights recorded. One of the duplicate 10-root samples from each of the two replicates of all treatments of all crops was then placed in storages maintained at $45 \pm 2^{\circ}$ F and $55 \pm 2^{\circ}$ F.

At harvest, the three carrot varieties were observed to have a heavy infection of Aster Yellows. Although only sound-appearing roots were selected in sampling, many of these roots developed typical Aster Yellows symptoms in storage.

On January 6, 1951, after approximately three months, the produce was removed from the 55° F storage, weighed and desprouted. The weight of sprouts for each sample of 10 roots was determined. Subsequent to the three months of storage the sugar beets were analyzed for sucrose.

In 1951, this same work was repeated with the following exceptions: Sugar beets were not included. A single aqueous spray of 2500 ppm only of maleic hydrazide was applied ten days before harvest to the foliage of the various root crops. Treatments were replicated on three row plots 15 feet in length. All crops were stored at $55 \pm 2^{\circ}$ F.

Results. In 1950 and 1951 harvest records showed no reduction in the yield, size, or quality within a given variety of any crop resulting from any of the maleic hydrazide spray treatments (Tables XIX, XXI, XXII, XXIII, XXIV, XXV, XXVI, XXVII, XXVIII). However, the September 6, 1950, application of 1000 ppm of benzo-thiozole-2-oxyacetic acid resulted in a highly significant decrease in yield (Table XIX). The carrot roots from this spray application had a white corky area on the shoulder. In general, spraying the various root crops in 1950 and 1951 with maleic hydrazide resulted in a reduction of sprouting. This chemical did not seem to prevent the breakdown in storage of any of the root crops except carrots, while the benzo-thiozole-2-oxyacetic acid resulted in a greater storage loss of carrots. The specific response of the individual crops are as follows:

Carrots: The increase in the sprouting of the carrots sprayed September 6, 1950, with 1000 ppm of maleic hydrazide approached statistical significance and there was a significant increase in sprouting with those sprayed September 30 with 500 ppm of maleic hydrazide, otherwise, there was no difference on any of the spray treatments or the controls (Table XIX). The September 30 spray of 2500 ppm of maleic hydrazide gave a highly significant decrease in per cent breakdown when compared with the control samples. The October 5 spray of 2500 ppm of maleic hydrazide resulted in a significant decrease in per cent breakdown during storage (Table XIX). A significant increase in storage breakdown resulted when the three carrot varieties were sprayed with 1000 ppm of benzo-thiozole-2-oxyacetic acid September 30, 1950 (Table XIX).

Although initial and final weights after storage of individual roots of the Chantenay variety were recorded for all treatments, there was no apparent reduction in weight losses when roots and the attached sprouts were weighed together (Table XX).

In 1951, there was a pronounced reduction (Table XXI) in the sprouting of carrots sprayed 10 days before harvest with a 2500 ppm concentration of maleic hydrazide as compared to non-treated samples (79, 80).

The various treatments of the different root crops in the 45° F storage responded similarly to the treatments in the 55° F storage except that sprouting at the 45° F temperature was reduced. In some instances no sprouting at all was evident.

TABLE XIX

THE EFFECTS OF MALEIC HYDRAZIDE AND BENZO-THIOZOLE-2-OXYACETIC ACID ON THE YIELD AT HARVEST AND STORAGE SPROUTING AND BREAKDOWN OF CHANTENAY, DANVERS, AND NANTES CARROTS AFTER 3 MONTHS AT 55° F (1950)

Spray treatments			Yield (Lbs./15 ft. row)	Sprouting (Per cent)	Breakdown (Per cent)
Chemical	ppm	Days before harvest			
Maleic hydrazide	500	31 (Sept. 6)	18.3	7.5	35.0
	1000		16.8	10.5	23.3
	2500		17.8	9.0	20.0
	500	6 (Sept. 30)	15.5	12.3	20.0
	1000		16.7	9.6	23.3
	2500		15.3	5.8	11.7
	500	2 (Oct. 5)	16.8	8.5	31.7
	1000		15.3	7.5	30.0
	2500		15.0	6.5	16.7
Benzo-thiozole-2-oxyacetic acid	1000	31 (Sept. 6)	8.2	2.5	45.0
	1000	6 (Sept. 30)	14.8	2.3	60.0
	1000	2 (Oct. 5)	16.8	4.8	48.3
Control			15.2	5.5	36.7
LSD 5 per cent			4.77	5.44	17.07
LSD 1 per cent			6.40	7.30	23.95

TABLE XX

PER CENT WEIGHT LOSS OTHER THAN FROM SPROUTING IN CHANTENAY CARROTS DURING 3 MONTHS STORAGE AS AFFECTED BY FOLIAR SPRAYS OF MALEIC HYDRAZIDE AND BENZO-THIOZOLE-2-OXYACETIC ACID (1950)

Spray treatments			Per cent fresh weight loss per 10 roots	
Chemical	ppm	Days before harvest	Storage at 45° F	Storage at 55° F
Maleic hydrazide	500	31	14.9	17.9
	1000		14.7	14.1
	2500		11.1	14.7
	500	6	15.4	14.8
	1000		11.8	14.4
	2500		10.7	19.6
	500	2	12.3	18.2
	1000		10.4	16.9
	2500		14.8	14.2
Benzo-thiozole-2-oxyacetic acid	1000	31	18.9	19.3
	1000	6	19.0	18.8
	1000	2	14.9	17.4
Control			10.8	13.9

TABLE XXI

THE EFFECTS OF MALEIC HYDRAZIDE ON THE YIELD AT HARVEST AND STORAGE SPROUTING OF CHANTENAY, DANVERS, AND NANTES CARROTS AFTER 11 WEEKS AT 55° F (1951)

Treatment	Yield (Lbs./15 ft. row)	Sprouting (Gms./10 roots)
Treated	16.0*	2.4*
Control	15.4	17.0

*Each value represents the mean of two replications.

Turnip: In 1950, there were no apparent reductions in sprouting or breakdown among any of the treatments. However, there was less sprouting of the roots harvested from plants sprayed with 2500 ppm of maleic hydrazide 24, 6 and 2 days before harvest (Table XXII). There was, however, 13 times the weight of sprouts on the non-treated samples as on comparable roots from plants sprayed 10 days before harvest with 2500 ppm of maleic hydrazide in 1951 (Table XXIV).

Rutabaga: The 2500 ppm spray of maleic hydrazide applied 31, 7, and 2 days before harvest in 1950 resulted in a decrease in sprouting in comparison with non-treated controls (Table XXIII). The 1000 ppm spray of maleic hydrazide applied 31 and 2 days before harvest as well as the 500 ppm of maleic hydrazide applied 7 days before harvest gave a decrease in sprouting of the treated rutabagas in comparison with those not treated (Table XXIII). Variation in the plant material prevented any accurate analysis of the comparison of breakdown between any of the maleic hydrazide treatments and the control samples (Table XXIII). There was more than 100 times the weight of sprouts on the non-treated roots as on those roots harvested from plants sprayed with 2500 ppm of maleic hydrazide 10 days before harvest in 1951 (Table XXIV).

TABLE XXII

YIELD AT HARVEST AND STORAGE SPROUTING AND BREAKDOWN OF PURPLE TOP WHITE GLOBE TURNIPS AFTER 2 MONTHS STORAGE AT 55° F AS AFFECTED BY MALEIC HYDRAZIDE SPRAYS (1950)

Spray treatments			Yield (Lbs./15 ft. row)	Sprouting (Gms./10 roots)	Breakdown (Per cent)
Chemical	ppm	Days before harvest			
Maleic hydrazide	500	24	27.5*	21.0*	75.0*
	1000		30.0	61.0	35.0
	2500		27.0	13.0	60.0
	500	6	31.0	15.0	70.0
	1000		35.5	24.0	55.0
	2500		31.0	14.5	35.0
	500	2	25.0	29.5	35.0
	1000		25.5	16.5	55.0
	2500		28.0	21.5	65.0
Control			22.5	35.5	55.0

*Each value represents the means of samples harvested from two replications.

TABLE XXIII

THE EFFECTS OF MALEIC HYDRAZIDE ON THE YIELD AT HARVEST AND STORAGE SPROUTING AND BREAKDOWN OF AMERICAN PURPLE TOP RUTABAGAS HELD 3 MONTHS AT 55° F (1950)

Spray treatments			Yield (Lbs./15 ft. row)	Sprouting (Gms./10 roots)	Breakdown (Per cent)
Chemical	ppm	Days before harvest			
Maleic hydrazide	500	31	50.0*	74.0*	0.0*
	1000		46.0	39.0	30.0
	2500		44.0	6.5	50.0
	500	7	49.5	27.5	50.0
	1000		47.0	55.0	5.0
	2500		48.5	1.5	15.0
	500	2	50.5	82.0	0.0
	1000		42.5	36.5	15.0
	2500		41.0	7.5	35.0
Control			42.5	106.5	5.0

*Each value represents the means of samples harvested from two replications.

TABLE XXIV

YIELD AT HARVEST AND STORAGE SPROUTING OF PURPLE TOP WHITE GLOBE TURNIPS AND AMERICAN PURPLE TOP RUTABAGA AFTER 3 MONTHS STORAGE AT 55° F AS AFFECTED BY FOLIAR SPRAYS OF MALEIC HYDRAZIDE (1951)

Treatments	Turnip		Rutabaga	
	Yield of roots (Lbs./15 ft. row)	Sprouting (Gms./10 roots)	Yield of roots (Lbs./15 ft. row)	Sprouting (Gms./10 roots)
Treated	68.0*	12.0*	44.7*	1.0*
Control	69.7	160.0	60.7	101.0

*Each value represents the mean of samples harvested from two replications.

Beets: The 2500 ppm spray of maleic hydrazide applied September 20, 1950, resulted in a decrease in sprouting of beets when compared with comparable non-treated samples (Table XXV). In 1951 there was a reduction in sprouting of beet roots from plants sprayed with maleic hydrazide in comparison with non-treated samples (Table XXVI). Shriveling was pronounced in all storage tests.

Parsnip: There was no reduction of sprouting in storage between roots from treated and non-treated plants (Table XXVII). In both 1950 and 1951 the parsnip roots shriveled badly while in storage (1, 9, 54, 57).

Sugar beet: The 2500 ppm spray of maleic hydrazide applied 50, 6, and 2 days before harvest resulted in a decrease in the sprouting of sugar beet roots in comparison with roots from non-treated control samples (Table XXVIII) (73, 74, 75, 77). There was no significant difference in the per cent sucrose between any of the treatments (Table XXVIII).

TABLE XXV

THE EFFECTS OF MALEIC HYDRAZIDE ON THE YIELD AT HARVEST AND STORAGE SPROUTING OF DETROIT DARK RED BEETS AFTER 3 MONTHS AT 55° F (1950)

Spray treatments			Yield (Lbs./15 ft. row)	Sprouting (Gms./10 roots)
Chemical	ppm	Days before harvest		
Maleic hydrazide	500	24 (Sept. 20)	16.5*	7.5*
	1000		25.0	4.5
	2500		20.0	0.5
	500	6 (Oct. 8)	17.5	4.5
	1000		21.0	4.0
	2500		26.0	1.5
	500	2 (Oct. 12)	31.0	12.0
	1000		22.0	8.0
	2500		23.0	5.5
Control			22.0	5.5

*Each value represents the mean of samples harvested from two replications.

TABLE XXVI

YIELD AT HARVEST AND STORAGE SPROUTING OF DETROIT DARK RED BEETS AFTER 3 MONTHS STORAGE AT 55° F AS AFFECTED BY FOLIAR SPRAYS OF MALEIC HYDRAZIDE (1951)

Treatment	Yield (Lbs./15 ft. row)	Sprouting (Gms./10 roots)
Treated	10.7*	0.3*
Control	9.3	4.7

*Each value represents the mean of samples harvested from two replications.

TABLE XXVII

THE EFFECTS OF TIME OF APPLICATION AND CONCENTRATION OF MALEIC HYDRAZIDE SPRAYS ON THE YIELD AT HARVEST AND STORAGE SPROUTING OF HOLLOW CROWN THICK SHOULDER PARSNIPS AFTER 3 MONTHS AT 55° F

Spray treatments			Yield (Lbs./15 ft. row)	Sprouting (Gms./10 roots)
Chemical	ppm	Days before harvest		
Maleic hydrazide	500	50	30.0*	5.0*
	1000		27.5	4.5
	2500		25.0	3.0
	500	6	30.0	14.5
	1000		26.0	7.5
	2500		31.5	7.0
	500	2	32.0	13.0
	1000		29.0	6.0
	2500		30.5	12.5
Control			29.0	5.5

*Each value represents the mean of samples harvested from two replications.

TABLE XXVIII

YIELD AT HARVEST, STORAGE SPROUTING AND SUCROSE CONTENT OF SUGAR BEETS AFTER 3 MONTHS STORAGE AT 55° F AS AFFECTED BY FOLIAR SPRAYS OF MALEIC HYDRAZIDE

Spray treatments			Yield (Lbs./15 ft. row)	Sprouting (Gms./10 roots)	Sucrose (Per cent fresh wt.)
Chemical	ppm	Days before harvest			
Maleic hydrazide	500	50	44.0*	73.5*	15.8*
	1000		44.5	64.5	14.5
	2500		42.0	11.0	15.7
	500	6	48.5	120.0	15.2
	1000		51.0	53.5	14.9
	2500		38.0	17.5	15.5
	500	2	40.0	32.0	15.7
	1000		40.0	46.5	15.6
	2500		45.5	21.0	15.6
Control			42.5	76.5	15.7

*Each value represents the mean of samples harvested from two replications.

TABLE XXIX

THE EFFECT OF MALEIC HYDRAZIDE TREATED POTATOES ON THE PARTIAL PRESSURE OF CARBON DIOXIDE IN PLIOFILM BAGS AND THE RELATIONSHIP OF THIS ALTERED CARBON DIOXIDE ATMOSPHERE TO THE SUGAR COMPOSITION OF THE TUBERS AFTER 6 WEEKS STORAGE AT 45° F

Treatments		Carbon dioxide (Per cent)	Oxygen (Per cent)	Reducing sugar (Per cent fresh wt.)	Non-reducing sugar (Per cent fresh wt.)
Treated	7/19/51	0.00	12.1	1.67	0.47
	8/2/51	1.00	18.1	1.66	0.54
Control		1.85	10.0	1.36	0.32

IV. DISCUSSION

Potatoes

Several chemicals (11, 16, 65) have been suggested as effective for the inhibition of sprouting of potatoes during storage. Applications of sprout inhibitors to growing crops may have distinct advantages with crops that are ordinarily sprayed for the control of diseases and insects. The relative effectiveness of the chemical may be much greater on growing crops because of the rapid absorption, penetration, and translocation to the desired plant organs, which usually occurs with foliar applications to growing crops as contrasted with post-harvest treatments which may fail unless special provisions facilitating penetration are provided (25, 46). Formulations of alpha-naphthaleneacetic acid and 2,4,5-trichlorophenoxyacetic acid, when sprayed on growing potato plants to reduce or inhibit subsequent sprouting during storage, have frequently resulted in tuber injuries and in a reduction of quality (25, 64, 81). In this connection, maleic hydrazide induces no apparent abnormalities or loss of quality if the chemical is applied at the proper time and at concentrations which effect permanent dormancy.

Prolonging dormancy with maleic hydrazide is unique in that apical dominance is apparently destroyed in both the tuber and in the potential individual sprouts on the tuber. Unlike the knobby suppressed sprouts which may eventually develop on the apical ends of tubers following treatments with the methyl ester of alpha-naphthaleneacetic acid and 2,4,5-trichlorophenoxyacetic acid, maleic hydrazide inhibits completely the apical region of the potato and growth, when it occurs, is initiated at the basal end of the tuber.

Several economic problems exist in the storage of potatoes. At relatively low temperatures (32 to 45° F) a degradation of starch occurs and sugars accumulate resulting in a sweetened product of poor quality for dehydration, chip manufacture, and ordinary table use. Conversely, if relatively high (above 40° F) storage temperatures are utilized, losses from sprouting and shriveling occur along with rapid deterioration of edible quality. According to Arreguin-Lozano and Bonner (3), the regulation of starch degradation and sugar synthesis by temperature in potato tubers resides in a powerful phosphorylase enzyme rather than an amylase system. At least three reactions are involved in the temperature effects: (1) regulation of the amount of phosphorylase enzyme inhibitor which is produced at high temperatures, (2) regulation of the activity of the glucose-fructose interconverting system which is increased at low temperatures, and (3) regulation of the activity of the sucrose synthesizing enzyme which is increased in amount at low temperature storage.

According to Denny and Thornton (18, 20, 22), the browning of potato chips is essentially a carmelization of sugar; while Patton and Pyke (52) reported in 1946 that this browning is not caused solely by the presence of reducing sugar but by the combined effect of reducing sugar and amino acids.

The results of Salunkhe and Wittwer (61) tend to support the hypothesis of Patton and Pyke, since potatoes treated with maleic hydrazide in the field gave superior quality chips yet there was no difference in the reducing sugar of treated and non-treated tubers (Tables VI and VII).

The differences found in both reducing and non-reducing sugars between maleic hydrazide treated and control potatoes in the 1950-51 storage period but not in 1951-52 may have resulted from the use of different types of containers in the two storage experiments. In 1950-51 the potatoes were held in kraft paper bags, while in 1951-52 they were held in open mesh onion bags. There has been assembled considerable evidence that maleic hydrazide is a selective respiratory inhibitor (37, 66). In this connection it should be emphasized that the carbon dioxide content of the atmosphere surrounding non-treated tubers in pliofilm bags increased to nearly two per cent over a six weeks period, while no carbon dioxide could be detected with a Haldane gas analyzer in pliofilm bags containing potatoes treated with the early application of maleic hydrazide (Table XXIX). Therefore, during the seven months storage period in 1950-51 a difference in the partial pressure of carbon dioxide of the atmospheres surrounding the treated and non-treated tubers in kraft paper bags could have influenced the relative amounts of reducing and non-reducing sugars in the treated and non-treated samples of potato tubers. Such conclusions are reasonable in view of the reports of Denny and Thornton (19, 21, 23), Thornton (69) and Kardas and Blood (40).

Although there is a considerable latitude in the time during the growing season that maleic hydrazide can be applied with effectiveness and in the concentrations which can be used, this chemical will decrease the yield of U.S. No. 1 potatoes if applied too early in the growing season as is shown in Table V and has been reported elsewhere (6, 14, 42). Sprays of maleic hydrazide at 2500 ppm applied soon after the potato vines have emerged from the soil significantly depressed the yield of potatoes but did not significantly decrease sprouting in storage. The sprouts of potatoes treated at this early date were normal in appearance as contrasted with the sprouts shown in Figure 2 when the same concentration of chemical was applied seven weeks before harvest. Apparently, the maleic hydrazide spray has to be applied after the young tubers or the buds on the young tubers have been initiated to give effective sprout inhibition.

One of the interesting effects of maleic hydrazide is the stimulation of plant growth at low concentrations.

This effect has previously been noted by Greulach and Atchison on onion roots (30). As shown in Table II, the 500 ppm concentration of maleic hydrazide, applied 2 days before the vines were destroyed, stimulated subsequent sprout growth on both Pontiac and Irish Cobbler potatoes in storage. This same spray treatment resulted in 90 per cent increase in the yield of Pontiac potatoes grown from tubers harvested from plants treated the previous year with low concentrations (500 ppm) of maleic hydrazide shortly before digging (Tables II and X).

Onions

Although concentrations of maleic hydrazide ranging from 500 to 2500 ppm will prevent sprouting of onions in storage, the 2500 ppm concentration is necessary for total sprout inhibition at the storage temperatures employed. Maleic hydrazide should be applied not earlier than two weeks before harvest, otherwise there is danger of increasing breakdown of the onion bulbs in storage. As shown in Figure 3, the maleic hydrazide stops the initiation of new leaves of the onion plant, while the leaves already formed continue to grow which results in a "spongy" elongated bulb. Secondary organisms already present or later gaining entrance into this spongy bulb will cause early decay and breakdown (Table XIII and Figure 3).

Zeller (85) has demonstrated that onions with a low percentage of sugars, especially non-reducing sugars, have poor keeping qualities. From Table XVII it can be seen that the relative proportion of non-reducing sugar in the Y-40 onion is relatively low in comparison with the percentage of reducing sugar. Tables XIV, XV, and XVI show this variety to be a poor keeping onion.

Although only marketable Y-40 onion bulbs were used for the various chemical analyses, all of the non-treated samples were rooting profusely by the end of the four and one-half month storage period. In addition, cross sections through the non-treated bulbs in every case revealed the presence of leaf and flower primordia. In contrast, the maleic hydrazide treated bulbs did not show the presence of either roots or sprouts (Figure 5). The highly significant decrease of reducing sugar in the non-treated Y-40 onions over the storage period, is probably in part due to this rooting, sprouting, and other metabolic processes which occurred in the non-dormant onion bulbs.

Root Crops

Maleic hydrazide at 2500 ppm proved to be an effective sprout inhibitor on all five vegetable root crops and sugar beets at 55° F storage temperatures. In 1950, the three carrot varieties did not show any sprout inhibition because a heavy Aster Yellows virus infection promoted a rapid breakdown of carrots in all treatments. In 1951, the three carrot varieties behaved as in 1949 as reported by Wittwer, Sharma et al (78, 79, 80). Maleic hydrazide gave no control over the shriveling of beet and parsnip roots in storage at 55° F.

As to the possible mechanism involved in maleic hydrazide induced sprout inhibition in the crops studies, Leopold and Klein (43) have demonstrated that an antagonism exists between maleic hydrazide and auxin in two ways: First, the inhibition of growth resulting from low concentrations of maleic hydrazide can be overcome completely by the addition of auxin; and second, the inhibition resulting from excessive concentrations of auxin can be overcome by the addition of maleic hydrazide. The stopping of sprout initiation of potato tubers, the prolonging of the dormancy of onion bulbs, and the sprout inhibition of the several root crops could in part be explained by this antagonism since auxin is needed to promote growth in meristematic tissues (71).

According to Pincus and Thiman (54), a respiratory enzymatic reaction is an integral part of the growth process and auxin in some way accelerates or acts as a coenzyme for this reaction. If maleic hydrazide antagonizes auxin as noted above, this would help explain the highly significant reduction in reducing sugar in the storage bin of non-treated onions since simple carbohydrates such as reducing sugars may be used in the process of respiration to furnish energy for various metabolic processes. Isenberg et al (37) have actually found that maleic hydrazide affects the respiration of onion tissue through the partial inactivation or inhibition of one or more of the dehydrogenases.

V. SUMMARY

Some effects of preharvest foliar sprays of maleic hydrazide on sprout inhibition, storage quality, and chemical composition of potatoes, onions, sugar beets, and vegetable root crops were determined.

With potatoes in tests applied to crops grown in 1950 and 1951, sprays of 500, 1000, and 2500 ppm of maleic hydrazide applied to the foliage approximately one to seven weeks prior to harvest were effective in prolonging dormancy of Irish Cobbler, Pontiac, Russet Rural, and Sebago tubers subsequently held in storage for seven months at temperatures of 45 and 55° F. Complete inhibition of sprouting resulted from single preharvest foliar sprays of 2500 ppm of maleic hydrazide applied four to seven weeks before harvest and the inhibition was more pronounced than that obtained with preharvest foliar treatments of 2,4,5-trichlorophenoxyacetic acid or with post-harvest applications of the methyl ester of alpha-naphthaleneacetic acid. Maleic hydrazide induced sprout inhibition on potatoes was accompanied by an absence of shriveling with little or no deterioration of quality and with no reduction in yield of U.S. No. 1 potatoes in 1950. Significant reductions in yield from the spray treatments were detected, however, in 1951 indicating the necessity for proper timing of application

of the chemical if satisfactory results are to be obtained. Apical dominance of both tubers and individual sprouts on the tubers was destroyed.

The percentages of reducing and non-reducing sugars were lower in maleic hydrazide treated potatoes stored at 45° F in 1950, while extensive storage studies of treated and non-treated potatoes held at 35, 45, and 55° F the following year showed no significant differences due to chemical treatment in reducing sugar, non-reducing sugar or starch percentages.

Post-emergence sprays of maleic hydrazide at 2500 ppm did not reduce storage sprouting of potato tubers, while low concentrations of maleic hydrazide applied shortly before harvest stimulated sprout growth on potato tubers.

Sprays of 500, 1000, and 2500 ppm of maleic hydrazide applied to the foliage of onion plants seven to ten days before harvest reduced or completely eliminated sprout and root growth during storage. These same treatments did not increase the breakdown of onions in storage. The 2500 ppm concentration of maleic hydrazide gave complete inhibition of sprouting while the lower concentrations, although highly effective, did not show the same degree of complete sprout inhibition. Foliage sprays of maleic hydrazide at 2500 ppm applied three weeks or more before harvest resulted in an increase in storage breakdown of all onion varieties. Lower concentrations gave decreasing amounts of storage breakdown. Although marketable bulbs from maleic hydrazide treated

Y-40 hybrid onions were increased by approximately 25 per cent, the storage quality was not equal to non-treated Downing Yellow Globe onions.

There was a highly significant decrease in the percentage of reducing sugar in the control samples of Y-40 onions over a four and one-half month storage period, while similar samples treated with a 2500 ppm foliar spray of maleic hydrazide showed no decrease in reducing sugar. Maleic hydrazide produced no significant alteration in the amount of dry matter, total nitrogen, or non-reducing sugar in the Y-40 onions. The percentage of weight loss not resulting from sprouting, rooting, or breakdown was nearly identical when both treated and non-treated Y-40 onion bulbs were held under bulk storage conditions.

Preharvest foliar sprays of maleic hydrazide at 2500 ppm applied 10 days before harvest reduced the sprouting of carrots, beets, rutabagas, turnips, and sugar beets in storage. This same spray treatment resulted in marked reductions in the storage breakdown of three varieties of carrots. With the other root crops, there was no difference between any of the treatments in the percentages of storage breakdown other than from sprouting. Preharvest foliar sprays of maleic hydrazide did not prevent excessive shriveling of either parsnips or red beets held in storage.

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