CERTAIN PHYSIOLOGICAL AND MORPHOLOGICAL RESPONSES IN POTATOES AND ONIONS INDUCED BY MALEIC HYDRAZIDE

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CERTAIN PHYSIOLOGICAL AND MORPHOLOGICAL RESPONSES IN POTATOES AND ONIONS INDUCED BY MALEIC HYDRAZIDE

By

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Detailed morphological and physiological aspects of the nature of maleic hydrazide (MH) induced sprout inhibition favorable for the commercial long-time storage of potatoes and onions, were studied during a three-year period. A crop of potatoes was grown in 1952 and again in 1953 including 4 and 10 varieties, respectively, and MH at 2500 ppm (3 pounds per acre) was applied as a foliage spray at different stages during the development of each variety. Differences in varietal response to treatment were noted. Chippewa, Sebago, and Kathadin (1953 only) showed the least injury following early applications, 36 days (June 4) and 50 days (June 18) from planting in 1952; and 31 days (June 15) and 45 days (June 29) from planting in 1953. In contrast, Russet Burbank, Kennebec, Irish Cobbler and Triumph were very susceptible to injury from early applications as evidenced by the increase in number of deformed and small tubers, reductions in total yield, and yield of U.S. No. 1 tubers. Whereas varieties individually differed in response to treatments applied on the same dates from time of seeding, applications of the chemical at comparable stages of maturity gave similar results with respect to tuber injury, yield of tubers, and inhibition of storage sprouting. Significant reductions in total yield from all spray treatments were detected in 1952 where all were applied prior to six weeks of harvest. However in 1953, no significant reductions in total yield or yield of U.S. No. 1 tubers were noted with the ten varieties when MH was applied either on August 13 or 25, 41 days and 30 days, respectively, before harvest. Storage data for the ten potato varieties grown in 1953, indicated that satisfactory

inhibition of sprouting resulted from a single preharvest foliar spray of 2500 ppm of MH applied on either July 13, July 31 or August 13, 1953. MH applied July 1, July 15 or August 4 in 1952 showed complete inhibition of sprouting at the apical regions of the tubers but some growth was evident on the basal parts. Tubers harvested from plants sprayed with 2500 ppm of MH applied July 1, July 15, and August 4, in 1952 and planted January 7, 1953 in the greenhouse remained sound but completely dormant for eight weeks, whereas non-treated tubers and those treated June 4 and June 18, 1952 grew normally producing profuse roots and large vegetative tops. Although no post-harvest chemical treatment, among the many tested, was found effective in breaking the dormancy induced by MH in storage of potatoes or onions, field studies on 20 varieties of onions in 1952 showed that a preharvest application of 2,4-D (0.1%) following treatment with MH (0.25%) completely nullified the usual storage growth inhibitory influence induced by MH.

Externally sprout inhibition in potatoes was characterized morphologically by a loss of apical dominance and lack of growth in the apical buds because of inhibition of cell division. From detailed records of plant growth in the field, storage quality, and anatomical observations of sectioned meristems of sprout initials from potato tubers and root primordia from onion bulbs, it was found that treatment with MH resulted in depressing of differentiation of tissues in the buds and root primordia accompanied by a retardation of cell division.

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Differences in the response of potato varieties to treatment with MH were described in light of data reported in other investigations for different varieties of crops treated with MH as well as possible antiauxin effects related to its growth-suppressing properties.

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I. INTRODUCTION

Millions of tons of potatoes and onions are lost every year throughout the world as a direct result of sprout growth during storage. If storage house temperatures could be maintained under 40° F, very little, if any, sprouting would occur. However, it is not always possible nor desirable in the case of potatoes to maintain such temperatures throughout the storage period. As a result, excessive sprout growth and weight losses occur. This is of economic importance to growers, distributors, potato dehydrators, and potato chip manufacturers. Certain chemical treatments have recently made possible storage at higher temperatures, without appreciable shriveling and loss from sprouting in both potatoes and onions held in long-term storage.

It has been demonstrated that maleic hydrazide[1] (MH) is an effective sprout inhibitor on various crops and the effects of concentrations and time of application of this chemical on the storage quality of potatoes and onions have been summarized (68, 69, 72). These observations have suggested a more detailed study of the physiological and morphological responses of potatoes and onions to foliar sprays of MH. It is likely that external differences in

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1. 1,2-dihydro-3,6-pyridazinedione

sprouting of potatoes and onions induced by MH are closely associated with certain cellular characteristics in meristematic tissues pertaining to sprout initiation or inhibition. A knowledge of the histological characteristics associated with the initiation of sprouts, therefore, is of utmost importance and value in any fundamental study of the factors associated with sprout inhibition in onions and potatoes.

During the course of these investigations, studies having to do with morphological responses of various potato varieties to MH were suggestive of marked varietal interactions. Accordingly, data pertaining to differences in yield performance, susceptibility to tuber injury, and the induced sprout inhibition of a number of potato varieties sprayed with MH at various stages of plant development are presented.

II. REVIEW OF LITERATURE

A. Effect of Plant Growth Substances Other Than MH on Histological Responses in Plants

Among the noteworthy investigations on the effects of plant growth regulators, have been the studies of their histological effects on bean plants. Kraus, Brown and Hamner (36) found the endodermis and cambium the most responsive to application of indoleacetic acid, the endodermis proliferating and differentiating into vascular strands, and the cambium cells proliferating rapidly but with delayed differentiation of derivatives. The primary phloem was also highly sensitive with abundant proliferation and frequent radial elongation. The epidermis and pericycle were not very responsive while the pith proliferated slowly but profusely. Hamner and Kraus (26) extended their observations to indolebutyric acid and naphthaleneacetic acid and obtained similar results.

Kraus and Mitchell (37) reported the histological responses of the bean to naphthaleneacetamide. There was less extensive proliferation than with indoleacetic acid and the most evident feature was the great increment of secondary xylem, the decided thickening of the walls of cells of most of the tissues composing the stem and the partial suppression of elongation of axillary buds. The effect was similar in the African marigold and in Mirabilis. Another most obvious characteristic was the increased firmness of the treated internodes, resulting in prevention of abscission, when decapitated and treated. Among other effects were the reduction in the height and total leaf area, and reduction in size of primary leaves.

Mitchell and Stewart (44) compared the effects of naphthaleneacetic acid and naphthaleneacetamide upon the bean. They showed again the tendency of the acetamide to increase the wall material, especially of the xylem and the pericyclic fibers, and not to affect the cortex. They observed that the treated leaves were lighter green in color and thicker, that the abscission of cotyledons was delayed by several days, and that treatment inhibited bud development.

Hamner (24) found that α-naphthaleneacetamide when applied to the bean in nutrient solution reduced top growth and increased root growth, and induced earlier maturity and greater extension of xylem and phloem in the roots. Palser (51) observed that Vicia faba responded to indoleacetic acid histologically with activity to some extent in every parenchymatous tissue, and notable was the somewhat extensive vascularization of derived tissues. Beal (7) applied four substituted phenoxy compounds to Vicia faba and found that in the second internode next to the point of application, with the exception of the epidermis, possibly the pericycle and limited portions of outer cortex, all the other tissues were active, whereas in the first internode and hypocotyl, farther from the point of application, only the endodermis, cambium, phloem and ray parenchyma were activated.

Whiting and Murray (64) reported that histological reactions of bean to phenylacetic acid consisted of marked proliferation of inner cortical parenchyma, endodermis and primary phloem parenchyma, the rays and the peripheral pith, and the cambium with slight response in the pericycle and secondary phloem, with no activity in the epidermis and central pith. Mullison (46) observed that application of tetrahydrofurfurylbutyrate induced responses different from those obtained from other growth substances, among which were the more localized response, an increased activity of the xylem tissues and moderate activity of the endodermis with no differentiation of vascular tissue.

Swanson (58) studied the histological responses of the Red Kidney bean to aqueous sprays of 2,4-dichlorophenoxyacetic acid (2,4-D) and noted the activity in the endodermis, pericycle (if undifferentiated or embryonic), phloem parenchyma, cambium and rays (the latter two zones being very active). He found that the formation of xylary elements was greatly inhibited and when occurring, much disorganized; the cortex showed little response, and epidermis and pith no response. He observed that the effect of 2,4-D was systemic

in nature, even at relatively low concentrations and in this respect, it differed from other growth regulating substances.

Murray and Whiting (47) studied the histological responses of bean stems to low concentrations of indoleacetic acid and compared them with those described by Kraus (35) for tryptophane. The important differences between the two substances were that with tryptophane, the cortical parenchyma was more reactive, vascularization in proliferated endodermis greater, primary phloem less active, pith relatively inactive and the course of vascularization in other tissues different for the two substances.

Borthwick, Hamner and Parker (9) studied the histological response of the tomato stem to indoleacetic acid. The results were similar to those reported for the bean. Cortical enlargement occurred, accompanied by some division; the endodermis divided actively; the phloem and the wood parenchyma proliferated, while the epidermis and pericycle were not very responsive.

Bausor, Reinhart and Tice (4) reported on the response of tomato stems to treatment with β-naphthoxyacetic acid. In the young stem there was enlargement of the cortical cells and great activity of cambium and differentiation of secondary xylem. In older stems the cortex was also activated but the greatest change occurred in the tissues from cambium to endodermis, inclusive, in which proliferation took place rapidly.

Laibach and Fishnich (38) observed the histological effects of indoleacetic acid upon coleus, Vicia faba and the tomato and noted in coleus that new vascular bundles appeared among the three originally present on each side.

Goldberg (19) applied indoleacetic acid to cabbage stems and found that all tissues responded to some extent; most generally responsive were those of phloem, rays and pith. The cambium, cortex, endodermis and xylem were moderately stimulated, while epidermis and pericycle reacted weakly.

Harrison (27) treated Iresine lindenii with indoleacetic acid. The endodermis and cortical parenchyma were not very reactive, while the phloem, pericycle rays and extra fascicular cambium proliferated. Thinning of the walls of the collenchyma was also noted. The fascicular cambium was not very responsive. Rather unusual was the proliferation of cutinized epidermal cells with thickened walls. The general degree of activity of Iresine resembled more clearly that of the tomato than of the bean.

Beal (6) worked on three species of Lilium with indoleacetic acid. The rate of response was much slower than that reported for bean, tomato and Iresine. In Lilium philippinense and Lilium longiflorum, there was proliferation of the parenchyma cells centripetal to the bundles, which later became organized into roots. In these, the outer cortex and the epidermis were only slightly affected. In Lilium *harrisii*, however, the epidermis and the cortex in the axil of the leaf were activated to divide and become organized as buds.

Hamner (25) treated *Mirabilis jalapa* with indoleacetic acid and found wide variation in histological responses of the various tissues. The pericycle, interfascicular parenchyma just inside it and the interfascicular cambium (in the older stems) were the most reactive, while the vascular tissues were generally unresponsive, the epidermis and cortical parenchyma showed little response and the endodermis considerable. The pith was slow to start activity but once activity was initiated it proliferated rapidly, differentiating as internal roots or as strands of vascular tissue.

Blum (8) worked on sunflower stem and found that naphthaleneacetic acid caused marked epinasty, completely inhibited bud development and differentiation of secondary xylem and marked development of activity of the horizontal cambium.

Beal (5) treated the sweet pea with 4-chlorophenoxyacetic acid and observed stem curvature, epinasty, inhibition of buds, swollen root-tips with most proliferation of the pericycle. Pfeiffer (54) applied indolebutyric acid to the aerial roots of *Cissus sicyoides* and found that the cells of the phloem and pericycle proved most reactive, enlarging and dividing with derivations of the pericycle opposite the protoxylem forming the lateral roots.

B. Effect of MH on Histological Responses in Plants

Naylor and Davis (50) have reported that in many instances MH-treated wheat, sunflower and Turkish tobacco plants developed abnormal leaf shapes. In addition, Naylor and Davis (50) observed the following sequential changes in plants after treatment with MH: (a) loss of apical dominance, (b) expansion of leaves already formed, (c) an intensification of green color, (d) increase in anthocyanin pigment, and (e) some chlorosis. The degree of expression of these characters depended largely upon the concentration of MH used and the age of the plant when treated.

Moore (45) noted that MH-treated sweet corn and garden beet plants developed narrower leaves than the controls.

Darlington and Mcleish (14) studying the action of MH on cell division in Vicia faba, noticed that high concentrations of MH, 0.005 molar and above, did not stop mitosis. However, such concentrations inhibited cell division for two days. These investigators (14) further observed that concentrations of MH at 0.005 molar and above induced a large number of breakages in the heterochromatic portion of the chromosomes. It has not as yet been reported as to whether or not chromosome breakages are responsible for the male sterility which MH induces in maize, as reported by Naylor (48).

Greulach and Atchison (20) noted that MH inhibits cell division at low concentrations, but not cell enlargement. They also observed that high concentrations of MH stopped both cell division and cell enlargement.

Currier, Day and Crafts (12) reported that MH may cause the collapse of the phloem elements, thereby allowing certain elaborated foods to differentially accumulate in specific parts of the plant.

There are other unique aspects of the action of MH which distinguish it from most other plant growth regulators. Leopold and Klein (39) noted that MH stimulated the growth of lateral buds while inhibition is usually induced by other plant growth regulators.

Struckmeyer (55) noted that leaves of treated plants were thicker as a result of somewhat large cell size, had a less compact arrangement of the spongy parenchyma cells and larger intercellular spaces. In addition, Struckmeyer observed that the phloem elements of the vascular bundles of both stems and leaves were commonly found in varying stages of collapse. This investigator (56) further explains that the greater diameter of the stems of treated plants is partly due to an increase in size of the cells.

Watson (63) observed the histological effects of MH upon Red Kidney beans and noted that the abscission zone of petioles was in a more advanced stage in treated plants. No abnormal cell division was observed.

C. Effect of MH on Plants in General

Schoene and Hoffman (55) first described MH as a unique growth regulant, and subsequent workers have initiated many varied lines of investigation with this chemical. Miller (43) reported that MH can cause abscission of young flowers or fruits. Crafts, Currier and Day (13) used it as a herbicide; Naylor (48) stated that MH will shift the critical day length of *Xanthium*; White (65) found that this chemical delayed the fruiting of raspberries; and Naylor and Davis (49) reported that MH produced sterile staminate flowers on *Zea*. Accordingly, the specific effects of this chemical on the plants used in this study (onions and potatoes) are reviewed briefly.

Using MH as a herbicide on netted gem potatoes, Barnard and Warden (3) reported a slight increase in tuberization from 1000 ppm of MH applied two weeks after emergence and accompanied by a slight reduction in size. When 5000 ppm of MH were applied, tuber set was further increased but a smaller percentage of the tubers attained U.S. No. 1 size. Many second growth and aerial tubers were formed.

Denison (15) noted the effects of concentrations of MH ranging 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 potatoes resulting from the early application showed marked reductions with each increase in concentration, while the second application gave a smaller yield reduction and the last application resulted in no significant reduction. No influence was reported in the specific gravity of tubers treated with any of the concentrations of MH or from different dates of application.

Marshall and Smith (42) reported effective sprout inhibition from 2500 ppm of MH applied 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 MH exhibited no sprout inhibition.

Zukel (71) first reported that foliar applications of 3000 ppm of MH seven weeks after planting prevented sprouting of potato tubers in storage. Kennedy and Smith (33) showed the effects of concentration of 10, 100, and 1000 ppm of MH on the Sebago variety when applied at four dates during the growing season. A concentration of 1000 ppm of MH applied about the time of initial tuber set caused a large increase in the number of tubers formed, severe injury to the tubers and curling and chlorosis of foliage accompanied by stunting of growth. Foliage and tuber injury decreased with later application and with less concentrated applications of MH. In general, a high concentration of MH early in the growing season caused vine and tuber injury, but applied later resulted in a reduction in amount of sprouting of the tubers in storage.

Kennedy and Smith (34) further reported that increasing the rates of MH applied per acre to the growing crop gave a reduction in sprout growth, a reduction in total weight loss in storage, and an increase in the number of eyes showing activity in tubers stored at 50° F. They also showed that MH-treated tubers exhibiting a reduction in sprouting in storage, upon planting failed to produce as complete a stand as non-treated samples. As the concentration of MH was increased, emergence of plants from treated tubers decreased.

According to Wittwer and Paterson when MH was applied at concentrations of 1000 and 2500 ppm four to six weeks before harvest, sprouting was completely prevented in Irish Cobbler and Pontiac varieties of potatoes even when held in storage for seven months at 55° F (67).

Harris (28) reported that young wild onions, Allium canadense, when treated on November 14, 1949 with 1, 3, 5, 6, and 12 pounds per acre of MH as a herbicide gave 98 per cent control at the 3-pound rate and approached eradication at 12-pound rate. A second treatment in March showed excellent control at all rates, but the onions were not completely eradicated. No onion shoots developed on treated areas in the fall.

Greulach and Atchison (20) made the interesting observation that Southport Yellow Globe onions grown in a solution of 1 ppm of MH produced many more roots than comparable control bulbs indicating a possible root stimulating effect of MH.

Wittwer and Sharma (69) reported that MH inhibited sprouting of Yellow Sweet Spanish onions in storage when the chemical was applied at a concentration of 2500 ppm when one-third of the tops were down, approximately 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 was applied. Bulbs from plants treated with 2500 ppm of MH 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. Thus, a preharvest foliar spray of MH has been the first entirely successful chemical treatment devised for the control of storage sprouting in onions.

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

Wittwer and Paterson (68) have further demonstrated that MH applied at concentrations of 500 to 2500 ppm to the foliage of mature onions of Brigham Yellow Globe, Early Yellow Globe, Downing Yellow Globe and M.S.C. Sweet Spanish in the field prevented subsequent sprouting and breakdown in storage. Losses from sprouting of Y-40, an early hybrid, were greatly reduced in bulk storage (53).

III. THE PROBLEM FOR INVESTIGATION

It has been demonstrated that maleic hydrazide (MH) is an effective inhibitor of storage sprouting in potatoes, onions, sugar beets and vegetable root crops (65). The present investigations were concerned with the effects of various times of application of this chemical on yields, marketability, deformities, size, number of tubers and subsequent sprouting behavior in storage of potato tubers of several leading commercial varieties. The use of 2,4-D as a herbicide in onion fields applied late in the season following MH but prior to harvest was also investigated. The effect of various chemicals on breaking the MH-induced dormancy in both potatoes and onions was studied. Histological preparations of potato eyes and onion stem bases during storage and following treatment with MH were also made.

IV. EXPERIMENTAL

General

The principal parts of these investigations, included three field experiments, one in the greenhouse, storage experiments, and a series of histological studies of potato eyes, periderm and onion stem bases. The first and the second field experiments were conducted in 1952 and a third in 1953. The greenhouse test was carried on during the winter months of 1952-1953. The storage experiments were conducted during the fall and winter months of 1952-1953.

A. Field and Storage Experiments with Potatoes

1. The effect of time of application of preharvest foliar sprays of MH on the total yield of four potato varieties (1952).

Procedure. Certified seed pieces of the Triumph, Irish Cobbler, Chippewa and Sebago varieties were planted April 29 on a Hillsdale sandy loam soil in rows 36 inches apart with seed pieces at 12-inch intervals. A 3-12-12 fertilizer was applied broadcast before planting at 800 pounds per acre, and 10-6-4 was applied as side-dressing June 20th at the rate of 500 pounds per acre. A solution of Nugreen (20 pounds per 100 gallons of water) was sprayed on the foliage three times during the early part of the season. The plants were dusted with DDT, Dithane, and basic copper for prevention and control of insects and diseases.

As outlined in Table 1, a single aqueous spray of 2500 parts per million (ppm) of MH was applied to the foliage of replicated plots of all four varieties June 4, June 18, July 1, July 15, and August 4. Approximately 7 pounds of the diethanolamine salt (30 per cent MH) was applied per acre. The sixth treatment consisted of a control in which no chemical was applied. Three-gallon hand sprayers were utilized in applying the chemicals. "Dreft" (Proctor and Gamble) was added to the spray solution at a concentration of 0.1 per cent as a wetting agent. A split-plot design was employed with varieties as main plots and spray treatments as subplots. Each plot consisted of two 18-foot rows.

Harvesting was completed and the total yield recorded September 17, 1952. Following harvest the potatoes were held in common storage for 25 days to allow suberization of the periderm of the tubers injured during harvest. Following common storage they were placed in a thermostatically controlled storage at $55 \pm 2^{\circ}$ F.

Results. Data in Table 1 show that the control plots gave higher yields, significant at one per cent level, than those sprayed with MH. Sebago gave the lowest yield of the varieties tried in this experiment. Harvest records showed a reduction in yield at the five per cent level with the plants of all the four varieties treated June 18, July 1,

TABLE I

THE EFFECTS OF TIME OF APPLICATION OF MH ON TOTAL YIELD OF POTATO VARIETIES - 1952

Treatment and time of application	Total yield (Bushels per acre)				
	Triumph	Chippewa	Irish Cobbler	Sebago	Treatment averages
MH - 2500 ppm					
1- June 4	464	549	550	412	483
2- June 18	101	370	393	320	296
3- July 1	438	472	424	326	415
4- July 15	445	449	472	264	407
5- August 4	504	497	514	323	460
Control (No chemical treatment)	606	605	595	435	560
Variety averages	423	489	491	347	

	5 per cent	1 per cent
LSD for testing between varieties and treatments	108	148
LSD for testing between varieties	49	90
LSD for testing between treatments	54	74

and July 15 with 2500 ppm of MH in comparison with the control and a reduction in yield significant at the one per cent level between the plants of Triumph, Irish Cobbler and Chippewa varieties sprayed June 18 with 2500 ppm of MH in comparison with the control (Table I).

Also significant reductions in yield (one per cent level) occurred with Triumph and with Irish Cobbler sprayed July 1, and yield reductions significant at the five per cent level were noted with the Chippewa and Sebago sprayed July 1 with 2500 ppm of MH in comparison with the non-treated control. However, the significant yield reductions of all the varieties likely induced in part at least by soil variation rather than chemical treatment leaves doubt as to whether this experiment was an adequate test of either the effects of MH on the yield of potatoes or of the yielding ability of the four potato varieties involved.

2. The effect of time of application of preharvest foliar sprays of MH on the yield, marketability, injuries, the size and number of tubers of ten potato varieties (1953).

Procedure. Certified seed pieces of the Green Mountain, Kennebec, Russet Rural, Triumph, Pontiac, Chippewa, Russet Burbank, Sebago, Irish Cobbler and Kathadin varieties were planted May 15 on Hillsdale sandy loam in rows 48 inches apart and with seed pieces at 15-inch intervals. All the cultural practices were the same as in 1952 except that the Nugreen sprays were omitted.

As outlined in Table II, a single aqueous spray of 2500 ppm of MH was applied to the foliage of all ten varieties June 15, June 29, July 13, July 31, August 13, and August 25. On July 31, an aqueous spray of 1000 ppm of CDAA[2] was also applied. The eighth treatment consisted of a control in which no chemical was applied.

The varieties and treatments were randomized in a split-plot design with three replications. The treatments made up the subplots with varieties constituting the main plots. Each plot consisted of 12 plants.

From time to time, observations were made during the growing season regarding the general appearance of foliage. Prior to harvest, the number of plants in each plot was recorded.

Harvesting was completed on September 24, 1953. The potatoes were held in common storage for 3 weeks to allow for suberization of the periderm of the tubers injured in harvest and were then transferred to a storage in which the temperature was thermostatically controlled at $45 \pm 2^{\circ}$ F. Records were taken regarding the total yield, the yield of U.S. No. 1 potatoes, the yield and number of deformed tubers, the number of small (excluding the deformed and the U.S. No. 1 potatoes) and the size of tubers.

Observations and results. Injury to plants as a result of early (June 4 and June 18 in 1952 and June 15 and June 29

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2. α-cyano-β-(2,4-dichlorophenyl)acrylic acid obtained from Ethyl Corporation, Detroit, Michigan.

in 1953) applications of 2500 ppm of MH has been previously reported (51). The following is an account of the nature and extent of injury resulting from the early applications of the chemical.

The leaves were malformed and dwarfed. This was reflected in ultimate reduction in leaf area. Pronounced upward rolling of leaves was one of the first symptoms of injury (Figure 1). Damage to flower buds and leaf buds was severe. A great number of them were killed. The ultimate result of reduced yield of tubers was, however, attributable to decrease in leaf area, damage to buds and injury to the plant as a whole. While injury itself was a direct result of the treatment, there were certain factors, chiefly light, temperature of the atmosphere at the time of spraying, vigor of the plant, physiological age of the plant, the concentration of the chemical and variety that seemed either to accentuate or to ameliorate the injury. A closer examination of the plants that were injured showed small necrotic areas and brown fleckings on the leaves. Pronounced browning was noticeable in the pith of the stem. Daily observations showed that the opening of flowers was delayed by several days, depending upon the variety and time of application. Delayed foliation and delaying blossoming is related to bud inhibition. Delay in the development of flower buds in celery following treatment with MH has been reported by Jackson (30). In the present experiments, the

Figure 1. Modification of leaf size and shape following MH treatment.

Top: Left to right -- Control (not treated) leaves of Kathadin, Triumph and Irish Cobbler varieties.

Bottom: Left to right -- Leaves of Kathadin, Triumph and Irish Cobbler from plants treated with MH June 15, 1953.

Photographed June 25, 1953.

delay was due to the treatment as shown by formative responses. The greater the injury, the greater was the delay in bud growth.

Harvest records showed a reduction both in yields of U.S. No. 1 tubers (Table III) and total yield (Table II) at the one per cent level with plants of all the ten varieties treated June 15, June 29, July 13 and July 31 with 2500 ppm of MH in comparison with the control, and no significant reduction in yields in comparison with controls among the ten varieties treated August 13 and August 25 with 2500 ppm of MH and 1000 ppm of CDAA applied July 31. The interaction of varieties x treatments was statistically significant with respect to the production of U.S. No. 1 tubers suggesting that the time of treatment was not equally effective on all varieties, but it was not significant in the total yield. Green Mountain, Kennebec, Russet Rural, Triumph, and Pontiac gave high yields in comparison with the other varieties. With respect to yield it is clear that with the depressing effect of early (June 15, June 29 and July 13) applications of MH, the Triumph variety suffered more than any other.

One of the most obvious effects of the early applications of MH was on size, shape and number of tubers. The tubers of the treated plants were smaller and misshapen in most instances. 2500 ppm of MH applied June 15, June 29 and July 13 reduced the average weight per tuber significant

TABLE II

THE EFFECTS OF TIME OF APPLICATION OF MH AND CDAA ON TOTAL YIELD OF POTATO VARIETIES - 1953

Treatment and time of application	Total yield (Bushels per acre)										
	Green Mountain	Kennebec	Russet Rural	Triumph	Pontiac	Chippewa	Russet Burbank	Sebago	Irish Cobbler	Kathadin	Treatment averages
MH - 2500 ppm											
1- June 15 (Plants emerging)	326	458	436	186	423	383	378	326	331	301	355
2- June 29	575	483	476	308	493	592	505	378	430	401	458
3- July 13 (Plants flowering)	842	552	592	517	657	685	528	388	493	458	572
4- July 31	779	605	598	535	720	667	592	448	627	483	605
5- August 13	866	859	836	674	842	866	662	789	645	575	761
6- August 25	866	720	697	650	772	709	657	814	622	639	714
CDAA - 1000 ppm											
July 31	767	692	836	505	662	761	488	598	615	510	643
Control (No chemical treatment)	859	824	802	772	732	650	662	610	570	476	695
Variety averages	735	648	659	519	662	664	552	544	542	481	

	5 per cent	1 per cent
LSD for testing between varieties	101	138
LSD for testing between treatments	68	91

TABLE III

THE EFFECTS OF TIME OF APPLICATION OF MH AND CDAA ON YIELD OF U.S. NO. 1 TUBERS - 1953

Treatment and time of application	U.S. No. 1 tubers (Bushels per acre)										
	Green Mountain	Kennebec	Russet Rural	Triumph	Pontiac	Chippewa	Russet Burbank	Sebago	Irish Cobbler	Kathadin	Treatment averages
MH - 2500 ppm											
1- June 15 (Plants emerging)	104	239	239	40	169	209	134	266	87	204	169
2- June 29	331	291	127	35	244	493	104	244	157	204	228
3- July 13 (Plants flowering)	709	458	448	331	430	610	348	284	371	378	437
4- July 31	674	453	476	423	622	622	488	388	430	493	502
5- August 13	819	615	702	598	737	692	575	622	570	540	646
6- August 25	814	645	592	570	592	650	517	754	510	510	615
CDAA - 1000 ppm											
July 31	685	510	714	470	563	702	465	540	528	483	566
Control (No chemical treatment)	802	697	685	674	657	605	605	540	458	396	612
Variety averages	617	504	498	392	502	566	404	462	397	394	

	5 per cent	1 per cent
LSD for testing between varieties and treatments	167	225
LSD for testing between varieties	87	120
LSD for testing between treatments	56	73

at the one per cent level (Table IV). Reductions in tuber size were greatest with Green Mountain, Russet Rural, Triumph, Russet Burbank and Kathadin. On the other hand, Pontiac, Kennebec, Kathadin and Sebago produced the highest average weights per tuber.

2500 ppm of MH applied June 15 and June 29, 1953 gave significantly higher yields of deformed and also produced more deformed and small tubers compared with non-treated controls (Tables VI, VI, and VII). It is very interesting to note in both 1952 and 1953 years that the second early application of MH applied June 18 in 1952 and June 29 in 1953 had a more pronounced effect on reducing the yields of U.S. No. 1 tubers of some varieties (Russet Rural, Triumph, Russet Burbank, Sebago) than the earliest spray treatments June 4 and June 15, respectively.

Sebago, Chippewa and Kathadin were less subject to injury caused by early applications of MH, than the other varieties. Russet Burbank, Kennebec, Irish Cobbler and Triumph were very susceptible to MH injury which is clearly shown in Tables IV, V, VI and VII. CDAA applied July 31, 1953 did not show any significant ill effects on any of the varieties tried. "Pitted scab-like" lesions were absent except for traces found on the tubers of Irish Cobbler, Pontiac and Chippewa when they were treated with MH on June 29, July 13 or July 31, 1953.

TABLE IV

THE EFFECTS OF TIME OF APPLICATION OF MH AND CDAA ON TUBER SIZE - 1953

Treatment and time of application	Tuber size (Pounds per tuber)										
	Green Mountain	Kennebec	Russet Rural	Triumph	Pontiac	Chippewa	Russet Burbank	Sebago	Irish Cobbler	Kathadin	Treatment averages
MH - 2500 ppm											
1- June 15 (Plants emerging)	0.18	0.26	0.20	0.19	0.30	0.25	0.19	0.29	0.22	0.21	0.23
2- June 29	0.20	0.28	0.15	0.13	0.27	0.26	0.12	0.30	0.19	0.17	0.20
3- July 13 (Plants flowering)	0.27	0.32	0.19	0.19	0.27	0.33	0.24	0.21	0.28	0.29	0.33
4- July 31	0.38	0.38	0.27	0.41	0.45	0.38	0.37	0.45	0.36	0.41	0.39
5- August 13	0.37	0.38	0.32	0.45	0.48	0.34	0.35	0.38	0.34	0.42	0.38
6- August 25	0.46	0.43	0.28	0.40	0.43	0.35	0.36	0.43	0.31	0.52	0.40
CDAA - 1000 ppm											
July 31	0.43	0.43	0.32	0.39	0.43	0.36	0.31	0.36	0.35	0.41	0.38
Control (No chemical treatment)	0.42	0.42	0.30	0.41	0.48	0.38	0.35	0.36	0.35	0.44	0.39
Variety averages	0.34	0.36	0.25	0.32	0.38	0.33	0.29	0.35	0.30	0.36	

	5 per cent	1 per cent
LSD for testing between varieties	0.09	0.12
LSD for testing between treatments	0.03	0.04

TABLE V

THE EFFECTS OF TIME OF APPLICATION OF MH AND CDAA ON YIELD OF DEFORMED TUBERS - 1953

Treatment and time of application	Deformed tubers (Bushels per acre)										
	Green Mountain	Kennebec	Russet Rural	Triumph	Pontiac	Chippewa	Russet Burbank	Sebago	Irish Cobbler	Kathadin	Treatment averages
MH - 2500 ppm											
1- June 15 (Plants emerging)	162	145	82	122	179	87	209	0	204	23	122
2- June 29	157	157	239	232	162	82	244	52	192	122	164
3- July 13 (Plants flowering)	64	35	12	75	70	0	122	40	57	23	50
4- July 31	17	104	5	70	70	0	75	0	99	0	44
5- August 13	12	162	52	17	17	70	82	35	30	12	49
6- August 25	23	30	47	47	47	0	122	0	64	0	36
CDAA - 1000 ppm											
July 31	23	52	40	5	30	0	5	0	30	0	19
Control (No chemical treatment)	23	52	64	75	35	0	52	12	40	0	35
Variety averages	59	92	68	73	75	30	113	17	87	23	

	5 per cent	1 per cent
LSD for testing between varieties	33	45
LSD for testing between treatments	31	42

TABLE VI

THE EFFECTS OF TIME OF APPLICATION OF MH AND CDAA ON NUMBER OF DEFORMED TUBERS - 1953

Treatment and time of application	Deformed tubers (Number per plant)										
	Green Mountain	Kennebec	Russet Rural	Triumph	Pontiac	Chippewa	Russet Burbank	Sebago	Irish Cobbler	Kathadin	Treatment averages
MH - 2500 ppm											
1- June 15 (Plants emerging)	2.93	1.93	2.20	2.83	2.67	1.43	4.63	0	4.30	1.17	2.41
2- June 29	3.13	2.70	4.97	7.77	3.20	1.03	7.77	0.93	4.83	3.20	3.92
3- July 13 (Plants flowering)	0.90	0.57	0.47	2.17	0.63	0	2.40	1.03	1.10	0.43	0.97
4- July 31	0.17	1.83	0.07	0.47	0.60	0	0.60	0	1.33	0	0.47
5- August 13	0.20	1.80	0.50	0.20	0.43	1.50	1.50	0.30	0.33	0.13	0.69
6- August 25	0.23	0.33	0.70	0.40	0.30	0	1.03	0	0.80	0	0.38
CDAA - 1000 ppm											
July 31	0.13	0.50	0.23	0.13	0.30	0	0.07	0	0.30	0	0.16
Control (No chemical treatment)	0.30	0.43	0.80	0.57	0.70	0	0.37	0.03	0.30	0	0.35
Variety averages	1.00	1.18	1.24	1.82	1.10	0.50	2.30	0.29	1.66	0.62	

	5 per cent	1 per cent
LSD for testing between varieties and treatments	1.62	2.15
LSD for testing between varieties	0.65	0.89
LSD for testing between treatments	0.55	0.73

TABLE VII

THE EFFECTS OF TIME OF APPLICATION OF MH AND CDAA ON THE PRODUCTION OF SMALL TUBERS - 1953

Treatment and time of application	Number of small tubers per plant (Less than 1 7/8 inches in diameter and excluding those deformed)										
	Green Mountain	Kennebec	Russet Rural	Triumph	Pontiac	Chippewa	Russet Burbank	Sebago	Irish Cobbler	Kathadin	Treatment averages
MH - 2500 ppm											
1- June 15 (Plants emerging)	4.63	4.63	5.40	1.73	3.20	4.03	3.73	2.10	2.37	2.83	3.57
2- June 29	5.90	3.23	8.87	5.17	4.77	4.37	10.17	2.53	5.47	6.10	5.66
3- July 13 (Plants flowering)	4.57	2.73	7.77	6.83	4.17	3.80	3.50	5.67	3.47	2.87	4.54
4- July 31	3.33	2.03	5.50	1.83	2.63	2.30	1.47	2.90	2.73	1.67	2.64
5- August 13	2.57	3.83	3.67	1.03	1.97	2.77	0.97	2.07	2.57	1.27	2.24
6- August 25	1.30	1.93	3.23	2.13	2.60	2.50	1.50	2.33	3.60	0.77	2.19
CDAA - 1000 ppm											
July 31	2.10	2.17	4.50	0.73	3.83	2.27	1.90	2.63	2.40	1.53	2.31
Control (No chemical treatment)	1.20	2.27	2.93	1.47	0.97	1.73	1.77	2.90	2.57	1.20	1.90
Variety averages	3.20	2.85	5.23	2.62	2.93	2.97	3.42	2.88	3.14	2.28	

	5 per cent	1 per cent
LSD for testing between varieties and treatments	2.25	2.97
LSD for testing between varieties	1.22	1.68
LSD for testing between treatments	0.73	0.96

3. The effect of time of application of MH on storage sprouting of four potato varieties (1952).

Procedure. On October 19, 1952, 9-tuber samples of the four varieties (Triumph, Chippewa, Irish Cobbler, Sebago) were taken from each treatment, placed in paper bags and held at 55° F for photographing at intervals during storage. The varieties and treatments were those listed in Table I. In addition, duplicate 20-tuber samples were taken from both replicates of each treatment and placed in paper bags for measuring the growth of sprouts when stored at 55° F.

On April 2, 1953, after approximately six months, the duplicate 20-tuber samples were removed from storage and desprouted and the weight of sprouts per tuber for each sample of 20 tubers determined.

Results. The weights of sprouts in grams per tuber after six months storage at 55° F for the various treatments applied to the four varieties are given in Table VIII. The weight of sprouts was many times higher for the non-treated control samples than for plants sprayed July 1, July 15, or August 4 with 2500 ppm of MH (Table VIII). There were no significant differences in sprout inhibition between the last two dates of spraying. Spraying the plants on June 4 with MH did not result in a significant reduction in sprout growth during six months of storage in any of the four varieties.

The interaction of varieties x treatments was statistically significant in the weight of sprouts which indicates

TABLE VIII

THE EFFECTS OF TIME OF APPLICATION OF MH ON SPROUTING OF POTATO VARIETIES HELD IN STORAGE AT 55° F FOR 21 WEEKS

Treatment and time of application	Sprout growth (grams per tuber)				
	Triumph	Chippewa	Irish Cobbler	Sebago	Treatment averages
Control	49.80	13.55	11.20	13.20	21.94
MH - 2500 ppm					
June 4	37.25	11.70	10.20	9.05	17.05
June 18	20.00	9.65	10.55	9.60	12.45
Variety averages	35.68	11.63	10.65	10.62	
MH - 2500 ppm					
July 1	3.75	1.70	1.90	2.00	2.49
July 15	0.45	0.75	0.20	0.25	0.41
August 4	0.25	0.35	0.70	0.15	0.36
Variety averages	1.52	0.93	0.93	1.00	

	5 per cent	1 per cent
Values for Control, June 4 and June 18 treatments		
LSD for testing between varieties and treatments	9.02	13.72
LSD for testing between treatments	4.39	6.38
LSD for testing between varieties	3.82	7.01
Values for July 1, 15 and August 4 treatments		
LSD for testing between treatments	0.51	0.74
LSD for testing between varieties and treatments	0.60	1.01

that the treatments were not equally effective on all varieties or that the varieties responded differently to the treatments. In the last three treatments there were no significant differences among varieties. The Triumph variety gave significantly higher weights of sprouts per tuber than Irish Cobbler, Chippewa and Sebago when the averages of two early spray applications (June 4 and June 18) were combined with the control.

Figures 2 through 9 show the effect of 2500 ppm of MH on the development of sprout growth of the four varieties after 6 and 15 weeks storage. After six weeks at 55° F practically no sprouting was evident in Triumph and Irish Cobbler (Figures 2 and 3). However, severe malformations of tubers were noted resulting from June 18 application of MH, with lesser effects observed for the June 4 and July 1 treatments. Tubers harvested from plants sprayed July 15 and August 4 were normal in all instances. In Chippewa a few sprouts one-half to one inch long are seen in controls and tubers treated June 4 (Figure 4). With Sebago, however, on the same date considerable sprouting was evident in controls and those treated June 4 and June 18, with some showing for the July 1 treatment.

After storage for 15 weeks at 55° F tubers treated on July 15 and August 4 showed sprout initials, whereas several sprouts 3 to 4 inches long had developed on the tubers harvested from plants treated June 4, June 18, July 1 and on

Figure 2. The effect of time of application of MH on sprout growth of Triumph potatoes, following six weeks storage at 55° F.

1. Control

<u>MH - 2500 ppm</u>

2. June 4
3. June 18
4. July 1
5. July 15
6. August 4

Photographed December 4, 1952.

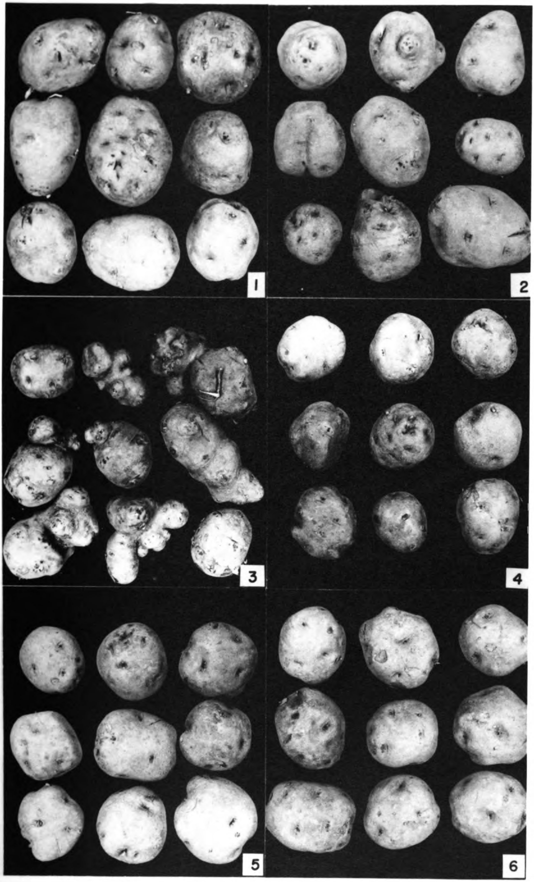
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Figure 3. The effect of time of application of MH on sprout growth of Irish Cobbler potatoes, following six weeks storage at 55° F.

1. Control

MH - 2500 ppm

2. June 4
3. June 18
4. July 1
5. July 15
6. August 4

Photographed December 4, 1952.

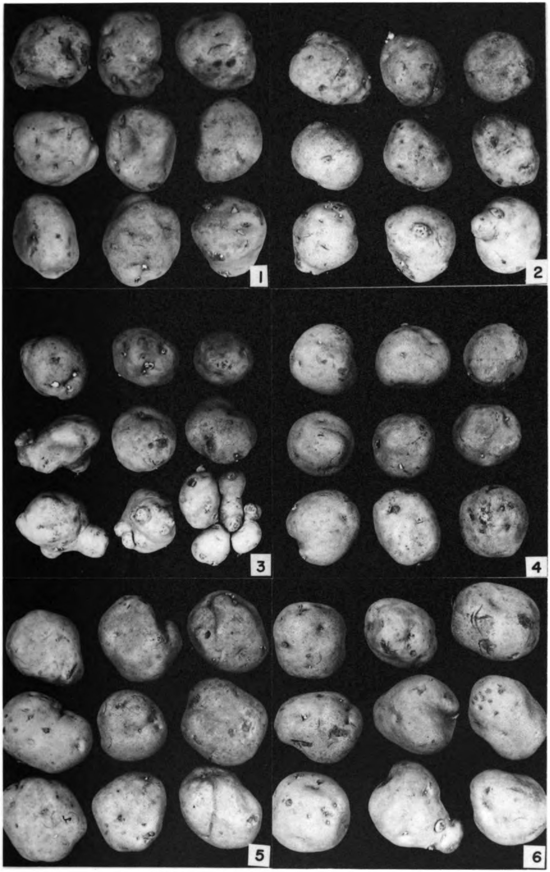
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Figure 4. The effect of time of application of MH on sprout growth of Chippewa potatoes, following six weeks storage at 55° F.

1. Control

<u>MH - 2500 ppm</u>

2. June 4
3. June 18
4. July 1
5. July 15
6. August 4

Photographed December 4, 1952.

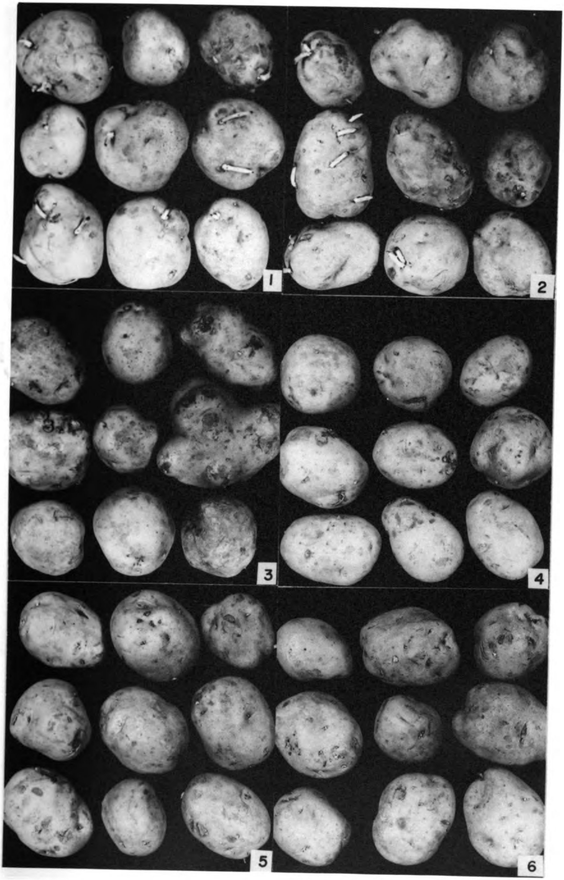
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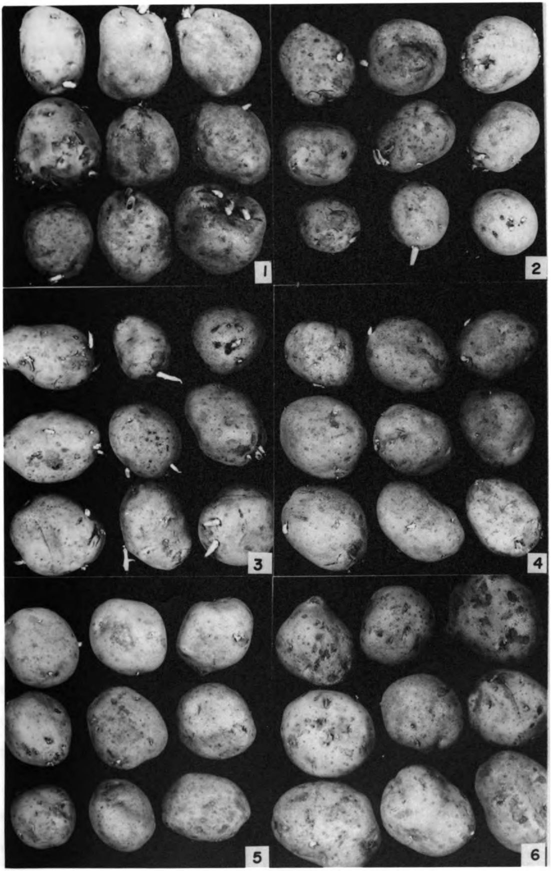
Figure 5. The effect of time of application of MH on sprout growth of Sebago potatoes, following six weeks storage at 55° F.

1. Control

<u>MH - 2500 ppm</u>

2. June 4
3. June 18
4. July 1
5. July 15
6. August 4

Photographed December 4, 1952.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non-treated tubers of Triumph, Chippewa and Sebago (Figures 6, 8 and 9). Irish Cobbler tubers treated July 1 showed very little sprouting (Figure 7). Tubers from plants receiving MH on either July 15 or August 4 were clear, bright, firm and practically free from any sprout growth, even after 15 weeks storage (Figures 6 - 9).

4. The effect of time of application of MH and CDAA on storage sprouting of ten potato varieties (1953).

Procedure. Fifteen-pound samples of the ten varieties were taken on October 10, 1953 from each treatment (Table II), placed in 50-pound onion mesh bags and held at 45° F for 12 weeks and at 60° F for the succeeding four weeks.

On February 10, 1954, after approximately four months of storage the samples were removed from storage and desprouted and the weight of sprouts for each sample determined. The data were evaluated by the analysis of variance method using the original weight values for sprouts and by arc-sine transformation for per cent of original weight (56).

Results. The sprout growth expressed as per cent of original weight for the various treatments applied to the ten varieties is given in Table IX. In general, the sprout growth was many times higher for the non-treated samples (controls) than for plants sprayed July 13, July 31, August 13 and August 25 with 2500 ppm of MH (Table IX). Spraying the plants on July 31 with 1000 ppm of CDAA significantly reduced sprout production in some varieties and increased it in others.

Figure 6. The effect of time of application of MH on sprout growth of Triumph potatoes, following 15 weeks storage at 55° F.

1. Control

MH - 2500 ppm

2. June 4
3. June 18
4. July 1
5. July 15
6. August 4

Photographed February 9, 1953.

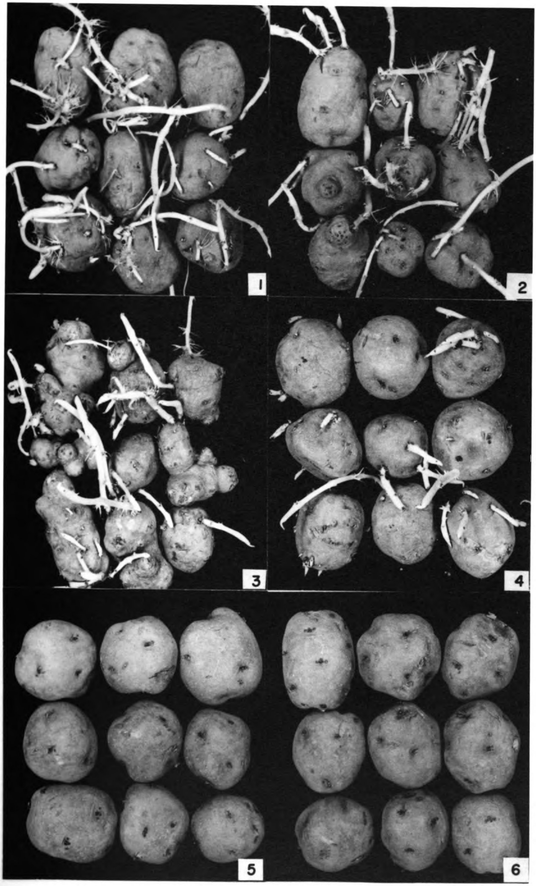
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Figure 7. The effect of time of application of MH on sprout growth of Irish Cobbler potatoes, following 15 weeks storage at 55° F.

1. Control

<u>MH - 2500 ppm</u>

2. June 4
3. June 18
4. July 1
5. July 15
6. August 4

Photographed February 9, 1953.

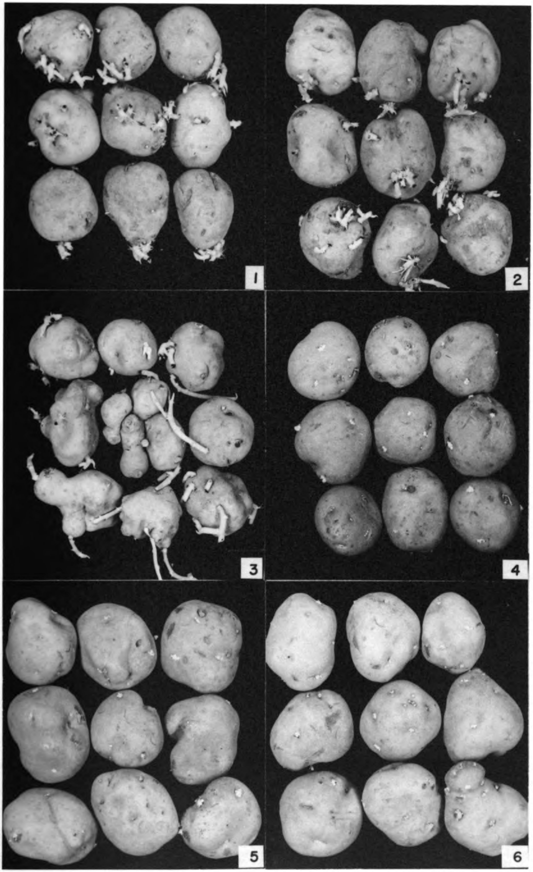
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Figure 8. The effect of time of application of MH on sprout growth of Chippewa potatoes, following 15 weeks storage at 55° F.

1. Control

MH - 2500 ppm

2. June 4
3. June 18
4. July 1
5. July 15
6. August 4

Photographed February 9, 1953.

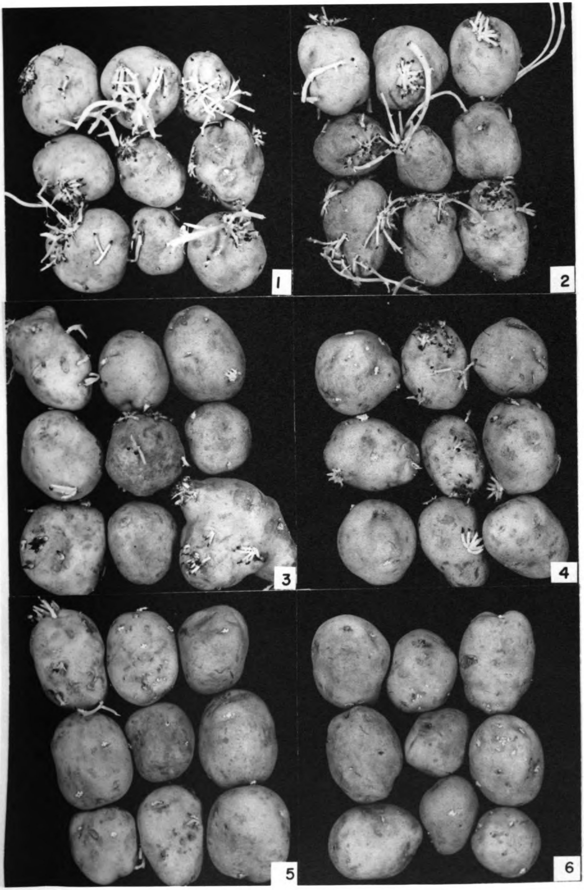
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Figure 9. The effect of time of application of MH on sprout growth of Sebago potatoes, following 15 weeks storage at 55° F.

1. Control

MH - 2500 ppm

2. June 4
3. June 18
4. July 1
5. July 15
6. August 4

Photographed February 9, 1953.

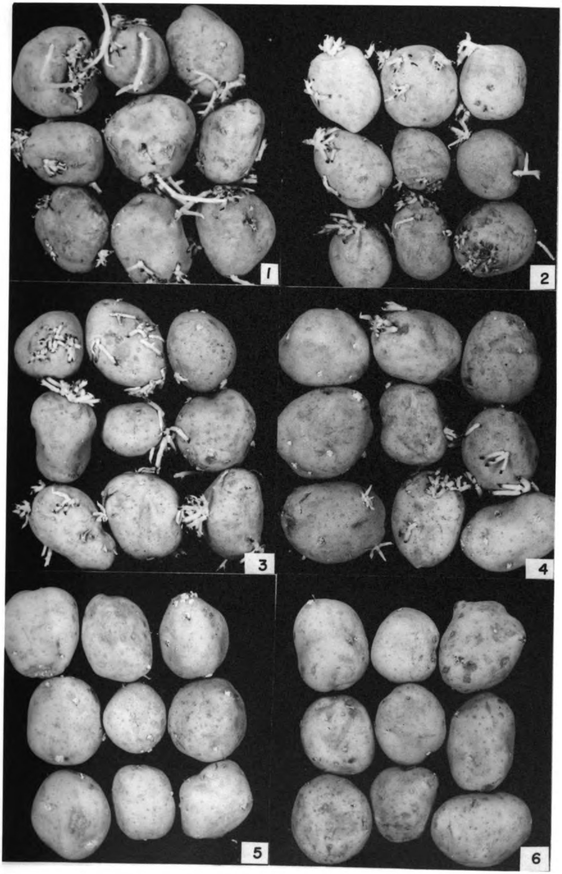
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TABLE IX

EFFECT OF PREHARVEST FOLIAR SPRAYS OF MH AND CDAA ON 10 POTATO VARIETIES AFTER 3 MONTHS STORAGE AT 45° F AND 1 MONTH AT 60° F ON WEIGHT OF SPROUTS – FEBRUARY 10, 1954

Treatment and time of application	Weight of sprouts (Per cent of original weight)										
	Green Mountain	Kennebec	Russet Rural	Triumph	Pontiac	Chippewa	Russet Burbank	Sebago	Irish Cobbler	Kathadin	Treatment averages
MH – 2500 ppm											
1– June 15 (Plants emerging)	0.68	0.46	0.52	1.20	1.70	1.20	0.21	0.74	0.85	0.94	0.85
2– June 29	0.40	0.32	0.56	1.70	1.10	0.70	0.06	0.81	0.34	0.57	0.66
3– July 13 (Plants flowering)	0.09	0.07	0.06	0.01	0.27	0.17	0.00	0.50	0.01	0.06	0.12
4– July 31	0.09	0.01	0.00	0.01	0.27	0.01	0.00	0.46	0.03	0.00	0.09
5– August 13	0.34	0.63	0.08	0.20	0.51	0.23	0.00	0.19	0.24	0.54	0.30
6– August 25	0.25	0.26	0.25	0.47	0.53	0.88	0.01	0.46	0.63	0.15	0.39
CDAA – 1000 ppm											
July 31	0.73	0.78	0.78	1.20	1.90	1.60	0.51	1.10	0.88	1.20	1.07
Control (No chemical treatment)	1.09	0.64	0.66	1.49	1.60	1.95	0.29	1.15	0.97	1.19	1.10
Variety averages	0.46	0.40	0.36	0.78	0.98	0.84	0.14	0.68	0.49	0.58	

	5 per cent	1 per cent
LSD for testing between varieties and treatments	0.05	0.09
LSD for testing between varieties	0.01	0.02
LSD for testing between treatments	0.01	0.02

The interaction of varieties x treatments was statistically significant. This suggests that the treatments were not equally effective on all varieties or that the varieties responded differently to the treatments. Pontiac, Chippewa and Triumph produced significantly more sprout growth than the other varieties when the averages of all the spray applications were combined with the control. Spraying the plants on July 31 with 1000 ppm of CDAA gave significantly more sprout growth in Kennebec, Russet Rural and Pontiac, when compared with non-treated control samples.

5. Effect of post-harvest application of chemicals on the sprout growth of Irish Cobbler tubers which were harvested from non-treated plants.

In order to determine the sprout inhibitory effect of certain newer growth regulators after penetration of the tubers was insured, a number of chemicals were dusted on the tubers or injected by toothpicks into the tuber. It has been reported that CDAA inhibited the growth of tomatoes and the flowering of marigolds (41). The following study was made to ascertain the comparative effects of various concentrations and formulations of CDAA with other reportedly effective substances on inhibiting sprout growth of potatoes in storage.

Procedure. The dusts were applied by placing the tubers in Kraft paper bags and sifting the dust on top of them; the bags were then closed with paper clips and shaken so the dust would become thoroughly distributed. Toothpicks were

injected into tubers as described by Marshall and Smith (41). Ten tubers for each lot and two lots making a total of 20 tubers were used in each treatment. For comparison tubers stuck with toothpicks soaked in distilled water were included. Treatments were applied on November 20, 1952 and all treated potatoes were placed in storage at a temperature thermostatically controlled at 55° F.

Results. Weights of sprouts in grams per tuber were recorded February 10, 1953 and are shown in Table X. The weight of sprouts in grams per tuber was significantly higher for the non-treated control samples than when the tubers were injected with 500 or 1000 ppm of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 500, 1000 or 2500 ppm of ethyl ester of CDAA. Toothpicks soaked in distilled water had no significant effect on weight of sprouts compared with the unpierced control tubers. Treatment with Fusarex[3] did not reduce the weight of sprouts produced; treatment with MENA[4], however, resulted in significant reduction of sprout growth.

6. Apical dominance studies of potato tubers to be used for seed purposes harvested from plants sprayed with 2500 ppm of MH (From Experiment 1).

Since approximately five per cent of the potato crop is used for seed purposes any chemical that retards sprouting

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3. 2,3,5,6-tetrachloronitrobenzene obtained from Sterwin Chemicals, Inc., New York.

4. Methyl ester of α-naphthaleneacetic acid obtained from Dow Chemical Company, Midland, Michigan.

TABLE X

THE EFFECTS OF POST HARVEST APPLICATION OF VARIOUS CHEMICALS ON INHIBITION OF SPROUT GROWTH OF IRISH COBBLER POTATOES STORED AT 55° F FROM NOVEMBER 20, 1952 TO FEBRUARY 10, 1953

Treatment	Rate of application (ppm)	Weight of sprouts (grams/tuber)
Toothpick application		
CDAA (acid formulation)	1000	1.95
	2500	1.65
Sodium salt of CDAA	1000	1.90
	2500	1.80
Ethyl ester of CDAA	500	0.75
	1000	0.85
	2500	0.80
2,4,5-T	500	0.60
	1000	0.30
Maleic hydrazide	1000	2.45
	2500	1.35
Control (distilled water)	None	1.95
Dust application		
MENA	1 gm/bushel	0.10
Fusarex	2 gm/bushel	2.70
Control (no treatment)	None	2.55
LSD at 5 per cent		0.69
LSD at 1 per cent		0.95

or growth of potato sprouts poses the question as to the effect of this chemical on seed stock potatoes. The following study was made concerning the effects of MH applied at various times during the growing season on seed stock potatoes and on the apical dominance of the tubers.

Procedure. Tubers of Irish Cobbler and Chippewa varieties harvested from plants, the vines of which were sprayed at various times during the 1952 growing season with 2500 ppm of MH as outlined in Table XI, were divided into halves and planted January 7, 1953 in 8-inch clay pots of sandy loam soil. Four weeks later plant heights were recorded.

Results. From Table XI it can be seen that a concentration of 2500 ppm of MH applied on July 1, July 14 or August 4 resulted in no growth. The heights resulting from plants grown from seed pieces from the apical and basal positions of the non-treated tubers, are greater than the heights from the treated tubers (Table XI). The mean heights of plants grown from apical-halves of the tubers are significantly higher than the plants grown from basal-halves. The interaction of treatments x tuber-halves was statistically significant which indicates that the treatments were not equally effective on both the positions of the tuber. The June 4 application for Irish Cobbler resulted in greater growth of sprouts from basal than apical half in sharp contrast to the controls of the same variety where growth was

TABLE XI

COMPARATIVE HEIGHTS OF POTATO PLANTS GROWN FROM TUBER-HALVES OF IRISH COBBLER AND CHIPPEWA POTATOES HARVESTED FROM PLANTS SPRAYED WITH MH

Treatment and time of application	Average plant heights (Centimeters per plant)				
	Irish Cobbler		Chippewa		Treatment averages
	Apical half	Basal half	Apical half	Basal half	
MH - 2500 ppm					
1- June 4	1.78	2.80	9.46	5.15	4.80
2- June 18	4.00	2.29	8.19	2.16	4.18
3- July 1	0	0	0	0	0
4- July 15	0	0	0	0	0
5- August 4	0	0	0	0	0
Control	9.97	1.59	17.59	6.73	8.93

Tuber-halves	Irish Cobbler	Chippewa	Averages of tuber-halves
Apical half	5.25	11.75	8.50
Basal half	2.26	4.68	3.45
Variety averages	3.76	8.22	

	5 per cent	1 per cent
LSD for testing between tuber-halves and varieties	2.74	3.62
LSD for testing between treatments	2.37	3.14
LSD for testing between varieties	1.94	2.56
LSD for testing between tuber-halves	1.94	2.56

six times greater from apical halves. Figures 10 and 11 show complete inhibition of sprouting by MH treatment at the apical positions of the tubers but not at the basal positions.

B. Storage Tests with Onion Varieties Treated with a Preharvest Application of MH for Sprout Inhibition and Subsequently with 2,4-D as a Herbicide

The successful use of MH as a sprout inhibitor by Wittwer and Paterson (66, 67) made it desirable to study its effects if followed by a preharvest application of 2,4-D as an herbicide on several hybrid onion varieties. Weeds in onion fields frequently become a serious problem following the maturity of the crop but prior to harvest. In the mechanical harvesting of onions it is desirable that fields be weed free.

Procedure. Onions of 20 inbred and hybrid varieties were grown from greenhouse plants seeded March 15 and transplanted into a field of productive mineral soil May 3, 1952.

In one treatment, an aqueous spray of 2500 ppm of MH was applied to the plants of the 20 varieties on August 7. A second treatment consisted of an aqueous spray of 1000 ppm of 2,4-D to plants of all varieties on August 23. The third treatment consisted of an aqueous spray of 2500 ppm of MH applied August 7 and followed by an aqueous spray of 1000 ppm of 2,4-D applied on August 23. The fourth treatment consisted of a control in which no chemical was applied.

Figure 10. Destruction of apical dominance of Chippewa potatoes induced by an early application of MH (July 1, 1952).

Apical ends facing down.

Left - Controls

Right - Treated

Photographed December 23, 1952.

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Figure 10. Destruction of apical dominance of Chippewa potatoes induced by an early application of MH (July 1, 1952).

Apical ends facing down.

Left - Controls

Right - Treated

Photographed December 23, 1952.

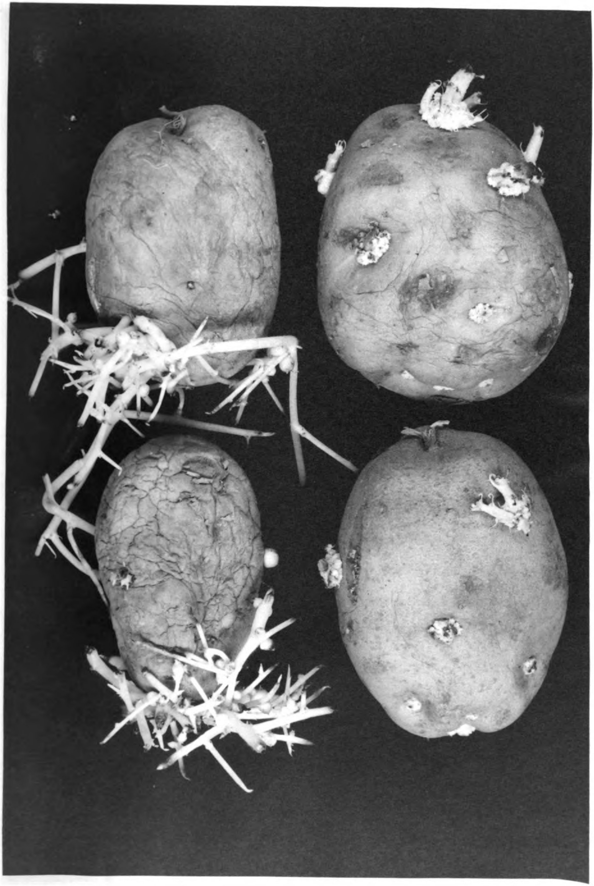
Figure 11. Destruction of apical dominance of Chippewa potatoes induced by an early application of MH (July 1, 1952).

Apical ends facing down.

Left - Controls

Right - Treated

Photographed May 7, 1953.



Three-gallon hand sprayers were utilized in applying the chemicals. The leaves were sprayed to run off. Triton B 1956 (Rohm & Haas, Philadelphia) was added at a concentration of 0.1 per cent as a wetting agent.

Results. The sprouting and breakdown for all the varieties after one month, 4½ months and 9 months in common storage for the various treatments are given in Tables XII, XIII and XIV respectively. MH applied August 7 gave fair control of sprouting (Table XIV) in all the varieties except Y-40 (Asgrow), 620 Sweet Spanish (Harris), 6-51 (Pieters Wheeler), and 5-51 (Pieters Wheeler). 1000 ppm of 2,4-D applied August 23 resulted in marked increases in per cent breakdown and in some instances sprouting when compared with non-treated samples and when not preceded by an application of 2500 ppm of MH. MH applied August 7 followed by 2,4-D on August 23 resulted in the least overall sprouting but breakdown comparable to 2,4-D used alone (Tables XII, XIII, XIV). The desired effect from inhibition of sprouting induced by 2500 ppm of MH is completely nullified by an increase in breakdown resulting from the addition of 1000 ppm of 2,4-D.

C. Storage Tests Concerned with Breaking MH-induced Dormancy in Onion Bulbs and Potato Tubers

Any method or treatment of forcing normally dormant or chemically (MH) induced dormant bulbs and tubers to sprout when desired would be of great advantage for propagation

TABLE XII

SPROUTING AND BREAKDOWN OF 20 VARIETIES OF ONIONS 4 WEEKS AFTER HARVEST AS INFLUENCED BY PREHARVEST FOLIAR SPRAYS OF MH (2500 PPM) AND 2,4-D (1000 PPM) - OCTOBER 15, 1952

No.	Variety and source	Spray treatments							
		MH		2,4-D		MH followed by 2,4-D		Control	
		Sprouting (%)	Breakdown (%)	Sprouting (%)	Breakdown (%)	Sprouting (%)	Breakdown (%)	Sprouting (%)	Breakdown (%)
1.	5-51 - Pieters Wheeler	0	0	2.8	88.9	0	91.4	0	0
2.	6-51 - Pieters Wheeler	2.2	6.7	0	36.4	0	41.7	0	0
3.	Magnifico — Crookham	0	2.1	3.3	50.0	0	71.9	2.5	0
4.	St. G 36 X USS 12 115 - USDA	0	4.8	1.8	89.8	0	100.0	2.4	2.4
5.	15-51 - Pieters Wheeler	0	9.3	0	46.2	0	38.0	0	6.4
6.	EYG 2152 X Mt. Dan - USDA	0	5.7	2.7	8.1	0	15.2	0	7.1
7.	EYG 2129 X Mt. Dan - USDA	0	10.7	3.7	12.5	0	22.2	0	0
8.	EYG 2152 X 2129 Mt. Dan - USDA	0	6.7	0	5.5	0	7.5	0	0
9.	174 - Crookham	0	1.5	1.8	43.6	0	61.5	0	0
10.	175 - Crookham	0	11.1	0	57.7	0	82.3	0	0
11.	620 Sweet Spanish - Harris	0	6.7	0	100.0	0	100.0	0	3.2
12.	Y. 40 - Asgrow	0	11.4	0	29.5	0	48.1	0	2.9
13.	Y. 41 - Asgrow	0	7.0	0	54.0	0	66.7	0	0
14.	Y. 42 - Asgrow	0	2.2	2.2	28.9	0	56.7	0	0
15.	Y. 43 - Asgrow	0	4.4	0	86.7	0	100.0	0	0
16.	PC 501902 Asgrow Y. 44 - USDA	0	2.6	0	13.2	0	60.9	0	0
17.	B-46 - Asgrow	0	2.1	0	44.6	0	62.5	0	0
18.	Downing Yellow Globe - Trapp Bros.	0	0	0	47.2	0	35.3	0	0
19.	Early Yellow Globe - Crookham	0	1.8	0	73.7	0	61.5	0	0
20.	BYG D-8769 - Ferry Morse	0	0	0	48.0	0	58.3	0	0

EYG = Early Yellow Globe
BYG = Brigham Yellow Globe

TABLE XIII

SPROUTING AND BREAKDOWN OF 20 VARIETIES OF ONIONS 18 WEEKS AFTER HARVEST AS INFLUENCED BY PREHARVEST FOLIAR SPRAYS OF MH (2500 PPM) AND 2,4-D (1000 PPM) - JANUARY 23, 1953

No.	Variety and source	Spray treatments: MH Sprouting (%)	MH Breakdown (%)	2,4-D Sprouting (%)	2,4-D Breakdown (%)	MH followed by 2,4-D Sprouting (%)	MH followed by 2,4-D Breakdown (%)	Control Sprouting (%)	Control Breakdown (%)
1.	5-15 - Pieters Wheeler	24.1	0	33.3	88.9	0	92.6	12.0	4.0
2.	6-51 - Pieters Wheeler	4.5	6.7	14.3	40.6	30.0	41.7	6.1	4.1
3.	Magnifico - Crookham	2.2	2.1	17.8	60.4	0	71.9	26.3	0
4.	St. G 36 X USS 12 115 - USDA	0	6.9	1.8	91.7	0	100.0	11.9	2.4
5.	15-51 - Pieters Wheeler	0	11.8	35.7	46.2	0	51.7	8.9	6.4
6.	EYG 2152 X Mt. Dan - USDA	8.8	7.4	33.3	8.1	0	15.2	9.3	7.1
7.	EYG 2129 X Mt. Dan - USDA	2.0	10.7	3.7	12.5	0	22.2	10.6	0
8.	EYG 2152 X 2129 Mt. Dan - USDA	2.4	6.7	30.0	5.5	0	7.5	23.8	0
9.	174 - Crookham	4.9	8.2	41.9	52.6	0	84.5	50.0	0
10.	175 - Crookham	3.6	16.4	54.5	57.7	0	82.3	24.1	6.9
11.	620 Sweet Spanish - Harris	0	6.7	0	100.0	0	100.0	8.3	3.2
12.	Y. 40 - Asgrow	10.2	16.7	18.8	33.4	7.1	64.7	31.8	2.9
13.	Y. 41 - Asgrow	0	9.5	39.1	57.6	0	87.9	9.8	0
14.	Y. 42 - Asgrow	0	2.2	15.4	44.3	0	75.4	2.7	0
15.	Y. 43 - Asgrow	0	4.4	0	86.7	0	100.0	6.8	0
16.	PC 501902 Asgrow Y. 44 - USDA	0	2.6	9.1	16.3	0	77.6	2.4	0
17.	B-46 - Asgrow	0	2.1	0	44.6	0	62.5	0	0
18.	DYG - Trapp Bros.	0	0	0	64.5	0	48.9	0	0
19.	EYG - Crookham	0	1.8	40.0	73.7	0	61.5	0	0
20.	BYG D-8769 - Ferry Morse	0	0	0	84.1	0	58.3	0	0

EYG = Early Yellow Globe
DYG = Downing Yellow Globe
BYG = Brigham Yellow Globe

TABLE XIV

SPROUTING AND BREAKDOWN OF 20 VARIETIES OF ONIONS 36 WEEKS AFTER HARVEST AS INFLUENCED BY PREHARVEST FOLIAR SPRAYS OF MH (2500 PPM) AND 2,4-D (1000 PPM) - JUNE 10, 1953

No.	Variety and source	Spray treatments							
		MH		2,4-D		MH followed by 2,4-D		Control	
		Sprouting (%)	Breakdown (%)	Sprouting (%)	Breakdown (%)	Sprouting (%)	Breakdown (%)	Sprouting (%)	Breakdown (%)
1.	5-51 - Pieters Wheeler	47.1	3.4	100.0	88.9	0	92.6	19.5	4.0
2.	6-51 - Pieters Wheeler	89.4	6.7	56.2	54.7	37.1	78.6	84.8	4.1
3.	Magnifico - Crookham	2.2	2.1	85.7	75.7	0	84.6	95.3	0
4.	St. G 36 X USS 12 115 - USDA	2.0	14.3	50.0	92.4	0	100.0	87.5	2.4
5.	15-51 - Pieters Wheeler	7.7	11.8	85.7	49.2	0	51.7	82.2	6.4
6.	EYG 2152 X Mt. Dan - USDA	9.1	12.3	90.9	14.3	7.4	15.2	84.1	7.1
7.	EYG 2129 X Mt. Dan - USDA	2.0	10.7	71.4	12.5	0	22.2	83.0	0
8.	EYG 2152 X 2129 Mt. Dan - USDA	11.9	6.7	96.0	7.7	0	7.5	100.0	0
9.	174 - Crookham	0	16.7	84.6	67.5	0	84.5	92.0	0
10.	175 - Crookham	9.1	29.1	90.9	64.6	0	82.3	96.3	10.6
11.	620 Sweet Spanish - Harris	37.0	10.4	0	100.0	0	100.0	80.6	6.9
12.	Y. 40 - Asgrow	51.2	16.7	83.9	37.6	7.1	64.7	86.3	5.7
13.	Y. 41 - Asgrow	7.7	10.2	85.7	64.8	0	87.9	79.2	7.5
14.	Y. 42 - Asgrow	0	2.2	77.3	44.3	0	84.7	70.2	2.7
15.	Y. 43 - Asgrow	0	6.7	100.0	86.7	0	100.0	56.5	0
16.	PC 501902 Asgrow Y. 44 - USDA	0	2.6	77.4	16.3	0	77.6	53.5	0
17.	B-46 - Asgrow	0	2.1	46.7	77.5	0	62.5	38.1	0
18.	DYG - Trapp Bros.	0	0	15.8	71.2	0	48.9	75.0	0
19.	EYG - Crookham	0	2.4	60.0	91.4	0	61.5	74.0	0
20.	BYG D-8769 - Ferry Morse	0	0	22.2	84.1	0	58.3	7.7	0

EYG = Early Yellow Globe
DYG = Downing Yellow Globe
BYG = Brigham Yellow Globe

purposes and early crop production. Accordingly the following experiments were designed.

Procedure. In one instance Y-42 (Asgrow) bulbs in which sprouting had been chemically inhibited by a pre-harvest foliar application of MH were kept for 48 hours in air-tight containers which contained 0.1, 0.2, 0.25 and 0.30 per cent of ethylene chlorohydrin. A second method of treatment consisted of using solutions of thiourea, coumarin, dithioxamide, benzo-thiazole-2-oxyacetic acid, levulinic acid, dithiobiuret, potassium thiocyanate and 2,4-D at various concentrations (10, 25, 50, 100, 500, 1000, 5000, 10,000 ppm) which were placed in wide-mouth, round, screw-cap bottles into which the bulbs were inserted in such a manner that the bulb bases were slightly immersed in the solutions. Each treatment consisted of five bulbs. Treatments were initiated February 14, 1953 and the bulb bases were left immersed in the solutions for three weeks. The bottles containing the solutions with the bulbs were kept at laboratory temperature (70-75° F). For a control comparison distilled water was used.

In a third procedure Irish Cobbler tubers were kept for 43 hours in air-tight containers which contained ethylene chlorohydrin, the same as for the onions. A fourth method of treatment consisted of injecting the above chemicals at the various concentrations listed for onions into potato tubers by the toothpick method (41). Round polished

toothpicks were soaked for four days in the chemical solutions. These toothpicks were then allowed to dry for a few minutes and inserted to one-half of their length into tubers. Ten toothpicks were used per tuber. Ten tubers were used in each treatment. Treatments were made December 10 and 11, 1952 and the tubers were immediately placed in storage where the temperature was thermostatically controlled at 55° F and allowed to remain until March 15, 1953.

Results. No chemical treatment had any effect on breaking the artificial dormancy by MH.

D. Histological Studies of Potato Tubers and Onion Bulbs Following Treatment with MH

While some of the effects of MH on the visual external appearance of plants have been described, limited information is available as to its effect upon internal structure. Accordingly, the following study was made to correlate the internal somewhat detailed histological changes with the external evidences of sprout growth and MH-induced sprout inhibition on potatoes and onions.

Collection of material. Samples of buds at three positions (apical, basal and middle) and from MH-treated and control plots of Irish Cobbler tubers were collected beginning July 30, 1951 at intervals of three weeks up to October 20, 1951 and at intervals of 7 days until February 22, 1952. Samples of buds or eyes from MH-treated tubers between the apical and basal ends on the tubers were collected beginning July 15, 1952 at intervals of four weeks up to November 1, 1952 and at intervals of one week until March 15, 1953 (from field experiment A-1, early samples were from plants still growing in the field, while later samples were collected during storage). Samples of buds were also collected from the tubers which were treated with sprout inhibitors in storage (from storage experiment A-4).

Samples of stem bases of onion bulbs (Y-40, Asgrow) from both treated and non-treated plots were collected at three-week intervals beginning August 5, 1951 following treatment with MH and continuing up to October 15, 1951 and then at intervals of one week during storage until March 24, 1952 (onions procured from a field experiment not described in this thesis).

Fixation, sectioning and staining. The materials collected were all fixed in killing solution of the following formulation:

5 ml Formaldehyde
5 ml Glacial acetic acid
50 ml Absolute ethanol
40 ml Distilled water

The tissues were dehydrated with ethanol and cleared with chloroform. The tissues were imbedded in paraffin, then sectioned with a rotary microtome and stained with Conant's quadruple stains (31).

Measurements and drawings. Detailed drawings were made

with a camera lucida to one scale for the same set of comparative materials, to give identical enlargement. Many detailed measurements became unnecessary, because of the obviously large differences resulting from treatment. In studies of this kind, the comparative rather than the absolute measurements stress the nature and extent of responses obtained by treatment.

Results - Potatoes. Figure 12 shows the type of sprouts produced by both non-treated and MH-treated tubers after approximately nine months of storage at 55° F. A study of the internal structure of the buds revealed a few important features as indicated in the photomicrographs (Figure 13) and in the camera lucida drawings (Figure 14).

A typical bud or eye from a non-treated tuber 20 weeks after harvest had two outer scales which were highly parenchymatous. There was slight disintegration of some cells towards the tips of the bracts, possibly caused by dehydration either during handling in storage or during the preparation of the material. These bracts appeared to be a projection of the periderm (Figure 13). The apical meristem, which was very prominent in its meristematic condition, was similar to a stem meristem containing tunica and corpus initials. The cells in the apical region were mostly meristematic and two vascular traces diverged distally and followed through the periderm as they advanced proximally (Figure 14).

Figure 12. The influence of preharvest foliar sprays of MH on the growth and development of sprouts of Irish Cobbler tubers stored at 55° F for 9 months.

Top - Control (Not treated)

Bottom - MH (2500 ppm) applied 62 days before harvest

Photographed July 10, 1953.

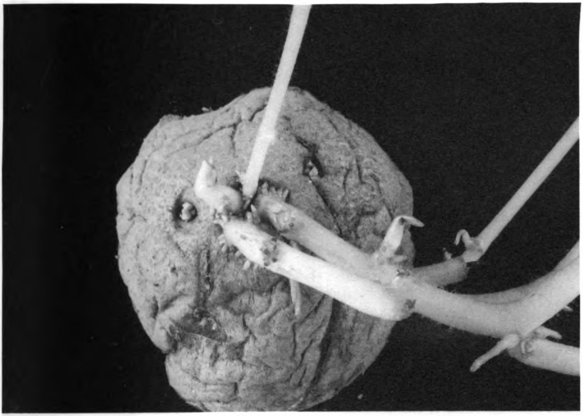


Figure 13. Photomicrographs of the longitudinal sections of the buds of Irish Cobbler tubers (20 weeks after harvest).

Left - Typical bud or eye of a non-treated (control) tuber showing high meristematic activity.
Magnification: x120

Right - Typical bud or eye from a MH-treated tuber showing no meristematic activity. It was evident that the apical cells which would normally be meristematic were enlarged resulting in a flattening of the apical region.
Magnification: x120

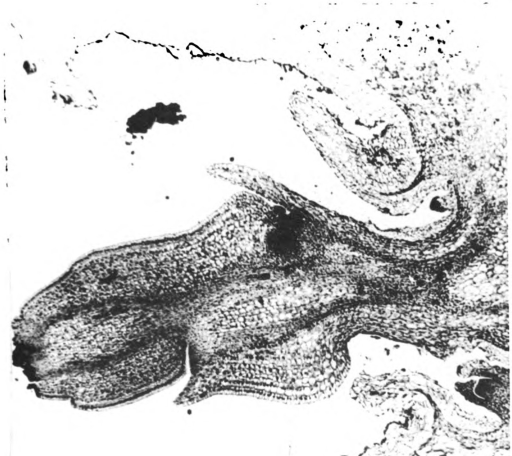


Figure 14. Camera lucida drawings of longitudinal sections of buds of Irish Cobbler tubers.

Top: Left - A bud from a tuber of a control plant, 15 weeks after harvest. Magnification: x75

Right - A bud from a tuber of a MH plant, 15 weeks after harvest. Magnification: x75

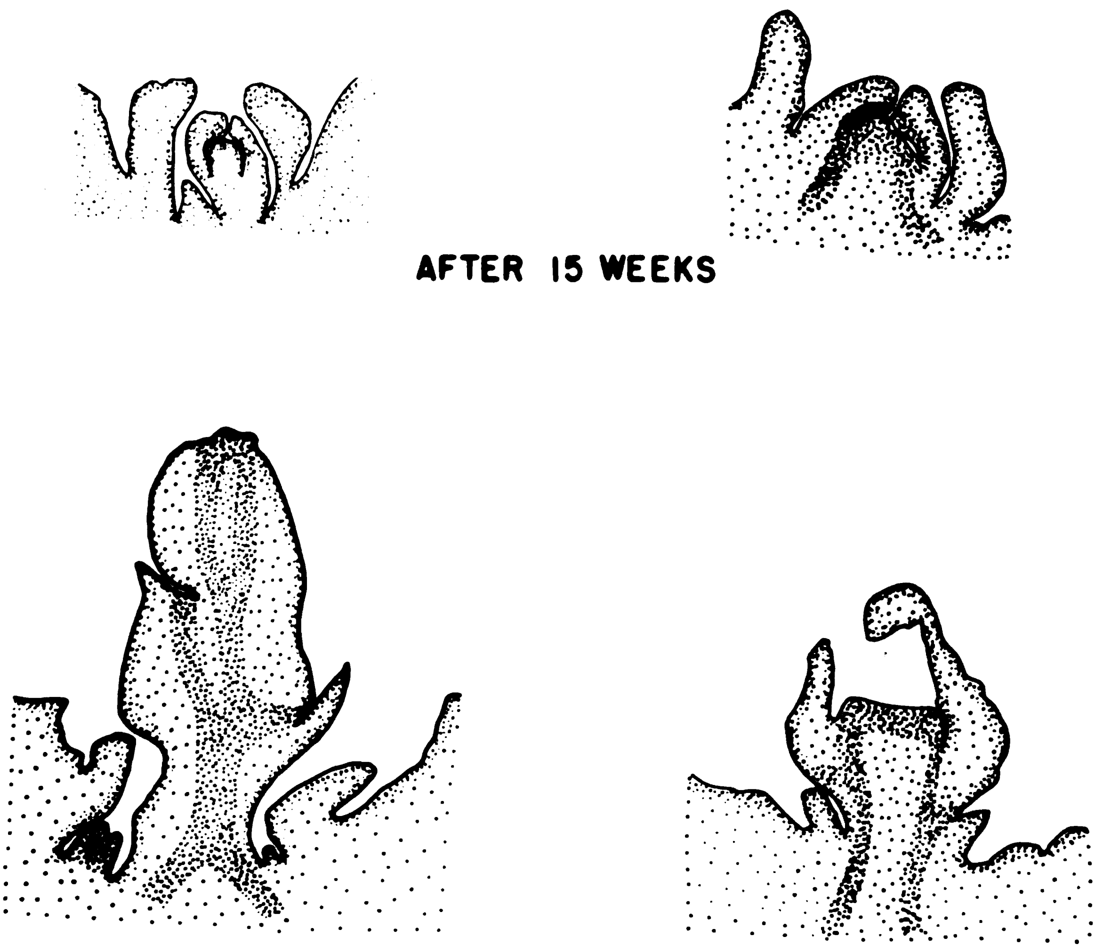
Bottom: Left - A bud from a tuber of a control plant, 20 weeks after harvest. Magnification: x40

Right - A bud from a tuber of a treated plant, 20 weeks after harvest. Magnification: x40

DEVELOPMENT OF BUD

SOLANUM TUBEROSUM

NORMAL TREATED



AFTER 20 WEEKS

A typical bud or eye from a tuber of a treated plant had also a pair of outer bracts which enclosed one more pair of scales which enclosed the meristem. The apical meristem was much flattened and was without meristematic tissue. Most of the cells were differentiated and larger in size. The most typical alteration due to MH was the flattened shape of the apical meristem and the lack of meristematic cells (Figures 13 and 14).

A detailed study of buds or eyes at three positions (apical, basal and intermediate) on the tubers revealed that there were no differences in the structure except in their degree of development. Apical buds on the non-treated (control) tubers were more developed than the intermediate or basal buds. But in the MH-treated tubers when inhibition of sprouting was accomplished, the basal and middle buds were more developed than the apical buds.

The histological study made during the 1952 season revealed that there were no structural differences between buds from non-treated tubers and buds from tubers which were harvested from plants treated with MH early in the season (June 4 and June 18, 1952). The buds of the tubers harvested from plants treated with MH late in the season (July 1, July 15, and August 4) were strikingly different from the controls.

A study of the buds of the tubers which were directly treated (post-harvest application) with sprout inhibitors revealed that there was a slight disintegration and tearing apart of the cells of the buds probably caused by dust applications of MENA (41) and Fusarex (17). The tubers which were injected with MH, CDAA (40) and 2,4,5-T (41) produced buds which were similar in their structure to the MH-treated in the field (July 1, July 15 and August 4, 1952).

Results - Onions. Figure 15 shows comparative gross longitudinal sections of control and MH-treated Y-40 onion bulbs after approximately two months of common storage. Sections of bulbs resulting from treatment with 2500 ppm of MH revealed an internal structure that was very much similar to non-treated controls except for less bud growth.

A study of the anatomy of the bases of the onion stems showing root primordia emerging through the cortex, revealed a few important features as indicated in the photomicrograph (left in Figure 16) of the base of an onion stem of a non-treated (normal) bulb 15 weeks after harvest. Two histogens were present: (a) a well-defined plerome which gives rise to a stele, (b) and overlying it a group of initial cells two layers in thickness from which originate the cells of the root cap, epidermis, and cortex. The cells are highly meristematic, full of protoplasm and actively dividing. In sectioned stem bases from MH-treated bulbs most of the meristematic cells in the root tips were differentiated. Cells are larger in size than those in the control stem bases and no cell division was evident.

Figure 15. Drawings of gross longitudinal sections of Y-40 onions after two months of common storage.

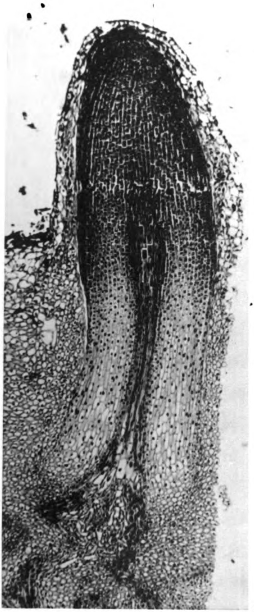
Top - Treated with MH (2500 ppm).

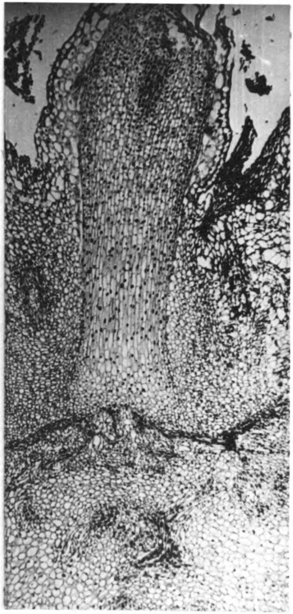
Bottom - Control (no treatment).

Figure 16. Photomicrographs of longitudinal sections of the bases of onion stems (15 weeks after harvest).

Left - Section from a control bulb showing the root primordium with its high meristematic activity.
Magnification: x266

Right - Section from treated bulb. It is evident that the apical cells of the root primordium which would normally be meristematic were enlarged, resulting in a broadening of the apical region.
Magnification: x266





V. DISCUSSION

The effects of foliage applications of MH on the growth and development of plants and tubers of potatoes were dependent largely upon the age and the variety of the plants treated. Results from these studies showed that the age of the plant when treated is very important. Potato plants which received MH applications at an early stage of growth, showed greater injury than those which received late applications of the chemical. The very earliest applications were not as injurious as the second early. Potato plants which received MH treatments late in the growing season undoubtedly were in a physiological condition which permitted greater tolerance to the chemical without observable injury. MH inhibited growth more wherever conditions for growth were more favorable.

In the case of older potato plants, a higher concentration of MH (2500 ppm) was applied with little apparent injury (12). Thus old maturing plants are capable of tolerating 2500 ppm of MH with less injury than young vigorously growing plants. Crafts _et al_. (12) also observed that MH inhibited vegetative plant growth temporarily if physiologically tolerable concentrations were applied. Observations made during the course of these studies showed that 2500 ppm of MH seriously injured the plants which received the

treatments on June 4 and June 18 in 1952 and June 15 and June 29 in 1953. Plants treated with MH on June 18 in 1952 and June 15 and 29 in 1953, were the most severely inhibited. When MH inhibited terminal vegetative growth, some stimulation of lateral bud growth was observed (72). In most cases where terminal buds were killed or permanently injured no later terminal growth took place. Thickening of potato stems above ground was noticed when the growth of terminal buds was stopped. Injury from early applications of 2500 ppm of MH varied according to the variety. Sebago, Chippewa and Kathadin showed more resistance than the other varieties to MH injury. Russet Burbank, Kennebec, Irish Cobbler and Triumph seemed to be the most susceptible to both vine and tuber injury from MH. Differences in varietal responses to MH have been noted also for corn (59) and sweet potatoes (18). Very little "pitted scab-like" injury (42) on potatoes was found when plants were treated at the time the largest tubers were one-half to one inch in diameter. The applications of MH at later stages of growth did not damage the buds or tuber eyes or increase the amount of "pitted scab-like" injury.

It has been reported (48) that MH exerts variable influences on the reproductive processes in various plants. Jackson (30), using 500 to 1000 ppm of MH applied to plants 20 to 22 weeks old inhibited seed stalk elongation. Results of these studies with potato plants showed that the reduced number of flowers, abscission of flower buds, resulting from the application of high concentrations of MH were due primarily to the inhibition of growth and development of flowers subsequent to their initiation.

That the MH sprayed on leaves and stems is translocated to the tubers is indicated by the fact that misshapened tubers resulted in some varieties with the early treatments and also that sprout growth was retarded in tubers harvested from sprayed plants. One of the most puzzling questions is regarding the consistent and definite change of shape of the tubers of certain varieties as a result of early foliage sprays of 2500 ppm of MH. Discussion of the change of shape of the tubers under these experiments is beyond the scope of this paper, except to state the application of plant growth regulators might result in modification of the "field forces" in the tubers. It has been reported by Paterson (52) that early applications of high concentrations of MH affected the size and shape of the tubers. 2500 ppm of MH applied June 15, June 29 and July 13, 1953, reduced the average weight per tuber significant at the one per cent level (Table IV). MH applied June 15 and June 29, 1953, gave significantly higher yields of deformed tubers and also resulted in the production of a greater number of deformed and small tubers compared with non-treated controls (Tables V, VI and VII). It is very interesting to note in both 1952 and 1953 years that the second early application of MH had a more pronounced effect on increasing the yields of deformed tubers, the number of deformed and small tubers, and also in the reduction of tuber size than the earliest spray treatment applied shortly following vine emergence. This might have resulted from the presence of a greater amount of foliage at the second early application of MH and also due to the possibility that tuber formation might have been greater than at the time of the earliest spray treatment.

Although there is some latitude in the time during the growing season that MH can be applied with effectiveness and in the concentrations which can be used, this chemical will decrease the total yield and the yield of U.S. No. 1 potatoes if applied too early in the growing season as is shown in Tables I, II and III and as has been reported by Paterson (52).

Significant reductions in yield from the spray treatments (June 4, June 18, July 1, July 15 and to a lesser extent for August 4, 1952) were detected indicating the necessity for proper timing of application of the chemical if satisfactory results are to be obtained. Sprays of MH at 2500 ppm applied June 15, June 29, July 13 and July 27, 1953, significantly depressed the total yield of most potato varieties, but 1000 ppm of CDAA applied July 27, 1953 did not affect the yields (Tables II and III). With respect to the yield of U.S. No. 1 potatoes, it is clear that with the depressing effect early (June 15 and June 29) applications of MH, and that the Triumph and Irish Cobbler varieties were affected more than any others (Table II).

Even though sprays of MH applied June 4 and June 18, 1952 significantly depressed the yield of potatoes, they did not significantly decrease sprouting in storage. Almost complete inhibition of sprouting for all varieties resulted only from single preharvest foliar spray of MH applied July 15 and August 4, 1952 (Table VIII). The sprouts of potatoes treated earlier (June 4 and June 18) in the growing season were normal in appearance as contrasted with the sprouts shown in Figure 12 (bottom) when the same concentration of the chemical was applied July 15, 1952. Apparently, the MH spray should be applied after the young tubers or the buds on the young tubers have been initiated to give effective sprout inhibition during storage.

In contrast to the results of treatment of the 1952 potato crop, the data obtained for the 1953 crop on storage sprouting (Table IX) and yield of 10 varieties and 8 treatments (Tables II and III) reveal some interesting facts. With Irish Cobbler, Pontiac, Kathadin and Chippewa, sprouting was almost completely controlled by the July 31 application with no reduction in total yield or yield of U.S. No. 1 tubers. In Sebago, Russet Rural, Russet Burbank and Triumph, sprouting was effectively controlled by the August 13 application with no accompanying reduction in total yield or yield of U.S. No. 1 tubers. In Green Mountain, sprouting was effectively

controlled by the July 13 and 31 applications with no reduction in total yield or yield of U.S. No. 1 tubers. An exception was Kennebec, in which the July 13 and 31 treatments with MH gave the most effective control of sprouting but this was accompanied in each instance by a significant reduction in total yield and yield of U.S. No. 1 tubers. These data however, on control of storage sprouting should be considered with some reservation since only a small amount of sprouting had occurred in all treatments and varieties on February 10, 1954. The data nevertheless suggest that although the most desirable time for treatment with MH may vary with variety, storage sprouting may be controlled without reduction in yield (34).

The toothpick technique of treatment which has been described by Marshall and Smith (42) was employed to insure penetration of some newer growth regulators. No significant difference was found between the sprout growth of tubers pierced with toothpicks soaked in distilled water and tubers with no toothpicks. Significant reduction of sprouting was noticed in tubers treated with 500 ppm and 1000 ppm of 2,4,5-T, 500, 1000 and 2500 ppm of ethyl ester of CDAA and MENA at the rate of 1 gram per bushel of potatoes. Fusarex dust at a rate of one pound per five bushels of potatoes did not retard the sprouting (Table IX). It is assumed that one of the reasons for no reduction of sprout growth by Fusarex

was due to its successful use in bin storage but not in bag tests (17). The inhibition of sprouting of tubers by post harvest treatment in storage with chemicals seems to be very temporary, because the treated tubers started to sprout again after 5 weeks.

Paterson (52) and Jackson (30) showed that MH destroys apical dominance in potatoes and celery plants respectively, depending upon the concentration of the chemical and age of the plants. It can be seen from Figures 10 and 11 that there is almost a complete inhibition of sprouting by MH treatment (July 1, 1952) at the apical regions of the tubers but not at the basal regions. It is interesting to note that tubers resulting from treatment with 2500 ppm of MH applied July 1, July 15 and August 4, 1952 and planted January 7, 1953 in the greenhouse remained sound but completely dormant for eight weeks, whereas non-treated tubers and those treated June 4 and June 18, 1952 grew normally producing profuse roots and large vegetative tops.

Any practical method of forcing normally dormant or chemically induced dormant tubers and bulbs to sprout when desired would be of great advantage. The possibility of the artificial chemical stimulation of the tubers and bulbs from a dormant into an active condition was investigated. No chemicals tested had any effect on breaking the dormancy induced by MH. It seems as though the dormancy caused by MH is permanent and no artificial stimulation tested would affect it.

Although no chemical tested had any effect on breaking the dormancy induced by MH in storage, the field studies on onions in 1952 showed that the application of 2,4-D following treatment with MH completely nullified the favorable storage influence induced by MH. Leopold and Klein (39) have demonstrated that indoleacetic acid completely overcomes MH inhibition using four different inhibitory levels. Studies by Leopold and Klein (39) showed that auxins are necessary for apical dominance in plant growth. Work with plant growth regulators such as triiodobenzoic acid, coumarin, 2,4-chloranisole, and trans-cinnamic acid has shown that these substances possess anti-auxin capacities capable of lessening or destroying apical dominance (39). Therefore, these plant growth regulators are classed as anti-auxins because of their inhibitory action on apical growth in plants.

Histological studies other than those reported in this thesis have revealed that among the most significant responses following treatment with growth regulators has been the greater development or influence of the vascular system. In almost all of the literature concerning histological responses to growth regulators, activity of the vascular tissues has been recorded but it seems to the author that only a few have recorded it with the emphasis that it needs. In dealing with the relationship of plant growth regulators and the vascular system, one of the most striking effects of these substances is the tendency for vascularization of derived tissues even outside the normal regions of existence of vascular strands, for example, in such unusual places as the pith, the endodermis, etc. (36, 37). Liabach and Fishnich (38) noted in Coleus that new vascular bundles appeared among the three originally present on each side. There is no doubt that the vascular system has played an important role as a conducting tissue in producing all the responses which we have recorded, such growth responses as the increased thickness of organs -- the stem and the leaf.

With respect to other histological responses, they have been in consonance with the general feature of behavior of growth regulators to the effect as expressed by Kraus, Brown and Hamner (36) that none of the types of cells were fundamentally different from cells occurring in the plant grown under the usual conditions of culture and environment. Histological studies of the bases of onion stems and buds of potato tubers showed a definite inhibition of cell division by MH treatment. The most typical alteration induced by MH is the flattened shape of the apical meristems and the lack of meristematic cells (Figures 13 and 16). These effects of MH on the anatomical structure of onions and potatoes characterize it as a growth inhibitor. Further evidence of this comes from the work of Greulach and Atchison (20) who, working with root tips of Yellow Globe onions, showed that MH inhibited mitosis and cell division in proportion to the concentration used. They also observed that onion roots failed to grow again following MH treatment. It is probable that the internal differences of the meristematic activities of the cells in the roots and buds or eyes are closely associated with the visually observed external differences in sprouting.

VI. SUMMARY

A study of some effects of preharvest foliar sprays of maleic hydrazide (2500 ppm) on certain physiological, morphological and histological responses in potatoes and onions, disclosed the following:

Foliar sprays of MH at 2500 ppm applied June 4 and June 18 in 1952 and June 15 and June 29 in 1953, resulted in delay of the opening of flowers, malformed and stunted leaves, and thickened stems of all the potato varieties. A marked difference in the response of potato varieties to MH was noted. Chippewa, Sebago and Kathadin showed the greatest resistance to injury following early applications of MH. Russet Burbank, Kennebec, Irish Cobbler and Triumph were very susceptible to MH injury. Early applications of MH definitely reduced the tuber size and increased the number of small and deformed tubers.

Significant reductions in total yield from all spray treatments were detected in 1952. However in 1953, no significant reductions in total yield or yield of U.S. No. 1 potatoes were noted with the 10 varieties tested when MH was applied August 13 or 25. CDAA at 1000 ppm applied July 31 resulted in no yield reduction.

Satisfactory inhibition of sprouting resulted from a single preharvest foliar spray of 2500 ppm of MH applied on either July 1, July 15 or August 4, 1952.

Storage data for the 10 potato varieties grown in 1953 (planted May 15 and harvested September 24) indicate that satisfactory inhibition of sprouting resulted from a single preharvest foliar spray of 2500 ppm of MH applied on either July 13, July 31 or August 13, 1953. CDAA at 1000 ppm applied July 31 resulted in no practical reduction of sprouting in storage.

Preliminary experiments conducted in storage using the toothpick technique revealed that the ethyl ester of CDAA may be promising as a sprout inhibitor on potatoes. Fusarex was not as inhibitory to sprouting as was MENA when both were applied in the dust form to potatoes in storage as a post-harvest treatment.

MH applied July 1, July 15 and August 4, 1952 showed complete inhibition of sprouting at the apical regions of the tubers but some growth was evident at the basal regions. Tubers harvested from plants treated with MH early in the growing season, were almost as good as non-treated ones for seed purposes. Sprouts from the basal ends of tubers harvested from plants treated early in the season with MH and those harvested from non-treated plants grew slower than sprouts arising from the apical ends of non-treated tubers.

No chemical treatment was found effective in breaking the dormancy induced by MH in either onions or potatoes. In field studies, however the desired effect from inhibition of sprouting induced by 2500 ppm of MH, is completely nullified by an increase in breakdown resulting from a subsequent spray application of 1000 ppm of 2,4-D.

Histological studies revealed that with MH there was some inhibition of differentiation of tissues in the buds and root primordia of tubers and bulbs, respectively, and there was also a retardation of cell division. The greater diameter of stems of potato plants following treatment with MH can in part be explained by an increase in cell size.

VII. LITERATURE CITED

1. Artschwager, E. 1918. Anatomy of the potato plant with special reference to the ontogeny of the vascular system. J. Agr. Res. 14:221-252.

2. Artschwager, E. 1924. Studies on the potato tuber. J. Agr. Res. 27:809-836.

3. Barnard, E. E. and Warden, R. L. 1950. The effects of various herbicides on weed control, stands and yield of netted gem potatoes. Proc. North Central Weed Control Conference, p. 145.

4. Bausor, S. C., Rinhart, W. L., and Tice, G. A. 1940. Histological changes in tomato stems incident to treatment with β-naphthoxyacetic acid. Amer. J. Bot. 27:769-779.

5. Beal, J. M. 1941. Some telemorphic effects induced in sweet pea by application of 4-chlorophenoxyacetic acid. Bot. Gaz. 105:471-474.

6. Beal, J. M. 1938. Histological responses of three species of Lilium to indoleacetic acid. Bot. Gaz. 99:881-911.

7. Beal, J. M. 1945. Histological reactions of bean plants to certain of the substituted phenoxy compounds. Bot. Gaz. 107:200-217.

8. Blum, J. L. 1941. Responses of sunflower stems to growth promoting substances. Bot. Gaz. 102:737-748.

9. Borthwick, H. A., Hamner, K. C., and Parker, M. W. 1937. Histological and microchemical studies of the reactions of tomato plants to indoleacetic acid. Bot. Gaz. 98:491-519.

10. Burton, D. F. 1947. Formative effects of certain substituted chlorophenoxy compounds on bean leaves. Bot. Gaz. 109:183-194.

11. Compton, W. 1952. The effects of maleic hydrazide on growth and cell division in Pisum sativum. Torrey Bot. Club Bull. 79:205-211.

12. Crafts, A. S., Currier, H. B., and Day, B. E. 1950. Response of several crop plants and weeds to maleic hydrazide. Hilgardia 20:57-80.

13. Currier, H. B., Day, B. E., and Crafts, A. S. 1951. Some effects of maleic hydrazide on plants. Bot. Gaz. 112:272-280.

14. Darlington, D. D. and Mcleish, J. 1951. Action of maleic hydrazide on the cell. Nature 167:407-408.

15. Denisen, E. L. 1950. Maleic hydrazide on potatoes. Proc. North Central Weed Control Conference, p. 145.

16. Eames, A. J. and MacDaniels, L. H. 1947. Introduction to plant anatomy. McGraw Hill Book Company, New York.

17. Ellison, J. Howard. 1952. Inhibition of potato sprouting by 2,3,5,6-tetrachloronitrobenzene and methyl ester of α-naphthaleneacetic acid. Amer. Pot. J. 29(8):176-181.

18. Ezell, B. D. and Wilcox, M. S. 1954. Physiological and biochemical effects of maleic hydrazide on pre- and post-harvest behavior of sweet potatoes. J. Agr. Food Chemistry (in press).

19. Goldberg, E. 1938. Histological responses of cabbage plants grown at different levels of nitrogen nutrition to indole-(3)-acetic acid. Bot. Gaz. 100: 347-369.

20. Greulach, V. A. and Atchison, E. 1950. Inhibition of growth and cell division in onion roots by maleic hydrazide. Torrey Bot. Club Bull. 77:262-267.

21. Greulach, V. A. 1951. The effects of maleic hydrazide on tomato plants in relation to their age at the time of treatment. Plant Physiol. 26:848-852.

22. Greulach, V. A. 1953. Effect on plant growth of some compounds with structural similarities to maleic hydrazide. Science 117:601-603.

23. Greulach, V. A. 1951. The effects of various concentrations of maleic hydrazide on tomato and etiolated bean plants. The Texas Jour. Science, pp. 322-325.

24. Hamner, C. L. 1942. Physiological and chemical responses of bean and tomato plants to α-naphthaleneacetamide and phenylacetic acid. Bot. Gaz. 103:374-385.

25. Hamner, K. C. 1938. Histological responses of Miribilis jalapa to indoleacetic acid. Bot. Gaz. 99:912-954.

26. Hamner, K. C. and Kraus, E. J. 1937. Histological reactions of bean plants to growth promoting substances. Bot. Gaz. 98:735-805.

27. Harrison, B. R. 1937. Histological responses of Iresine lindenii to indoleacetic acid. Bot. Gaz. 99:301-338.

28. Harris, V. C. 1951. Maleic hydrazide as a herbicide on wild onions, Allium canadense. Paper presented Southern Weed Control Conference, Memphis, Tenn.

29. Hayward, E. H. 1948. The structure of economic plants. The Macmillan Company, New York.

30. Jackson, H. 1952. Some effects of maleic hydrazide on certain physiological responses of celery Apium graveolens. Ph.D. Thesis, Michigan State College.

31. Johansen, D. A. 1940. Plant microtechnique. McGraw Hill Book Company, New York.

32. Johannessen, G. A. and Oebker, N. 1951. New treatment promises control of onion sprouting. Farm Res. 17:12-13.

33. Kennedy, E. J. and Smith, O. 1951. Response of the potato to field application of maleic hydrazide. Amer. Pot. J. 28:701-712.

34. Kennedy, E. J. and Smith, O. 1953. Response of seven varieties of potatoes to foliar application of maleic hydrazide. Proc. Amer. Soc. Hort. Sci. 61:395-403.

35. Kraus, E. J. 1941. Histological reactions of bean plants to tryptophane. Bot. Gaz. 102:602-622.

36. Kraus, E. J., Brown, N. A., and Hamner, K. C. 1936. Histological responses of bean plants to indoleacetic acid. Bot. Gaz. 98:370-420.

37. Kraus, E. J. and Mitchell, J. W. 1939. Histological and physiological responses of bean plants to a-naphthaleneacetamide. Bot. Gaz. 101:204-225.

38. Laibach, F. and Fishnich, O. 1935. Kunstlich Wurzelneubildung mittels Wachsstoffpaste. Ber. d. Bot. Gessel. 53:528-539.

39. Leopold, A. C. and Klein, W. H. 1951. Maleic hydrazide as an anti-auxin in plants. Science 114:9-10.

40. Levan, A. 1939. Cytological phenomena connected with the root swelling caused by growth substances. Heriditas 25:87-96.

41. Ligett, W. B., Wolb, C. N., Hay, R. E., and Whl, D. D. 1952. A new plant growth regulator -cyano- - (2,4-dichlorophenyl)-acrylic acid. Science 116:393.

42. Marshall, E. R. and Smith, O. 1950. Effect of field and storage applications of sprout inhibitors on potato tubers. Amer. Pot. J. 27:133-141.

43. Miller, R. R. and Erskine, D. 1949. The prevention of fruit formation on some ornamental trees. Proc. 25th National Shade Tree Conference, pp. 88-99.

44. Mitchell, J. W. and Stewart, W. S. 1939. Comparison of growth responses induced in plants by naphthaleneacetamide and naphthaleneacetic acid. Bot. Gaz. 107:410-427.

45. Moore, R. H. 1950. Several effects of maleic hydrazide on plants. Science 112:52-53.

46. Mullison, W. R. 1940. Histological responses of bean plants to tetrahydrobutyrate. Bot. Gaz. 102:373-381.

47. Murray, M. A. and Whiting, A. G. 1946. A comparison of histological responses of bean plants to tryptophane and to low concentrations of indoleacetic acid. Bot. Gaz. 108:74-100.

48. Naylor, A. W. 1950. Observations on the effects of maleic hydrazide on flowering of tobacco, maize, and cockle-bur. Nat. Acad. Sci. Proc. 36:230-232.

49. Naylor, A. W. and Davis, E. A. 1951. Respiration response of root tips to maleic hydrazide. Torrey Bot. Club Bull. 78:73-79.

50. Naylor, A. W. and Davis, E. A. 1950. Maleic hydrazide as a plant growth inhibitor. Bot. Gaz. 112:112-126.

51. Palser, B. F. 1942. Histological responses of Vicia faba to indoleacetic acid. Bot. Gaz. 104:243-263.

52. Paterson, D. R. 1952. Some effects of foliar sprays of maleic hydrazide on the post-harvest physiology of potatoes, onions, and certain root crops. Ph.D. Thesis, Michigan State College.

53. Paterson, D. R. and Wittwer, S. H. 1954. Further investigations on the use of maleic hydrazide as a sprout inhibitor for onions. Proc. Amer. Soc. Hort. Sci. (in press).

54. Pfeiffer, N. E. 1937. Anatomical studies of root production on application of indolebutyric acid to Cissus aerial roots. Contrib. Boyce Thompson Inst. 8:493-506.

55. Schoene, D. L. and Hoffman, O. L. 1949. Maleic hydrazide, a unique growth regulant. Science 109: 588-590.

56. Snedecor, W. G. 1950. Statistical methods. The Iowa State College Press, Ames, Iowa.

57. Struckmeyer, B. E. 1953. The effect of maleic hydrazide on the anatomical structure of Croft-Easter lilies. Amer. J. Bot. 40:25-29.

58. Swanson, C. P. 1946. Histological response of red kidney bean to aqueous sprays of 2,4-dichlorophenoxyacetic acid. Bot. Gaz. 107:522-531.

59. Tatum, L. A. and Crume, J. H. 1951. Some responses of young corn plants to maleic hydrazide. Plant Physiol. 26:836-839.

60. Tukey, H. B., Hamner, C. L., and Imhofe, B. 1945. Histological changes in bind weed and sow thistle following applications of 2,4-dichlorophenoxyacetic acid in herbicidal concentrations. Bot. Gaz. 107: 62-73.

61. Watson, D. P. 1950. Anatomical modification of velvet bent grass (Agrostis canina L.) caused by soil treatment with 2,4-dichlorophenoxyacetic acid. Amer. J. Bot. 37:424-431.

62. Watson, D. P. 1948. An anatomical study of the modification of the bean leaves as a result of treatment with 2,4-dichlorophenoxyacetic acid. Amer. J. Bot. 35:543-555.

63. Watson, D. P. 1952. Retardation in cell development in leaf and flower buds of Phaseolus vulgaris L. from foliar applications of maleic hydrazide. Torrey Bot. Club Bull. 79:235-241.

64. Whiting, A. G. and Murray, M. A. 1946. Histological response of bean plants to phenylacetic acid. Bot. Gaz. 107:312-332.

65. White, D. C. 1950. Blossoming of fruits delayed by maleic hydrazide. Science 111:303.

66. Wittwer, S. H. and Hansen, C. M. 1951. Progress report on the effects of preharvest foliage sprays of maleic hydrazide on storage losses of sugar beets. Paper presented, Amer. Soc. Sugar Beet Technologists, Detroit.

67. Wittwer, S. H. and Paterson, D. R. 1951. Further investigations on the use of maleic hydrazide for prolonging dormancy in the storage of onions. Abstract of paper presented, Amer. Soc. Hort. Sci., Minneapolis, p. 15.

68. Wittwer, S. H. and Paterson, D. R. 1951. Inhibition of sprouting and reduction of storage losses in onions, potatoes, sugar beets, and vegetable root crops by spraying plants in the field with maleic hydrazide. Mich. Agr. Exp. Sta. Quart. Bull. 34:3-8.

69. Wittwer, S. H. and Sharma, R. C. 1950. The control of storage sprouting in onions by preharvest foliage of maleic hydrazide. Science 112:597-598.

70. Zimmerman, P. W. and Hitchcock, A. E. 1942. Substituted phenocy and benzoic acid growth substances and the relation of structure to physiological activity. Contrib. Boyce Thompson Inst. 12:321-343.

71. Zukel, J. W. 1950. Use of maleic hydrazide as a plant growth inhibitor. Agr. Chemicals 5:35-36.

72. Zukel, J. W. 1953. Literature summary on maleic hydrazide. U.S. Rubber Company, Naugatuck Chemical Division, Bethany 15, Connecticut.