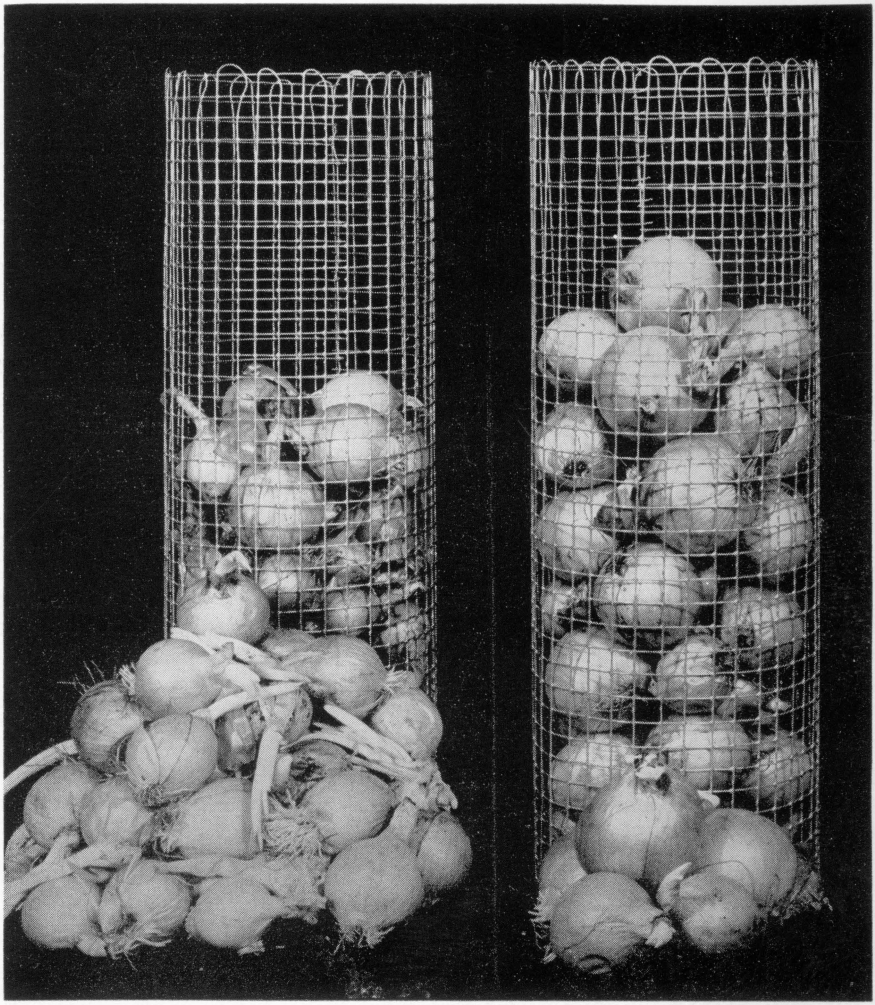
RESEARCH BULLETIN 874 MARCH 1961

INHIBITING SPROUTING OF POTATOES AND ONIONS IN STORAGE IN OHIO

DONALD COMIN



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ON THE COVER:

Both these baskets of onions were kept for 10 months in common storage. Seventeen percent sprouted in the untreated onions at left, but only three percent (right) sprouted when maleic hydrazide was applied to onions 14 days before harvest.

INHIBITING SPROUTING OF POTATOES AND ONIONS IN STORAGE IN OHIO

DONALD COMIN

The use of maleic hydrazide as a sprout inhibitor for potatoes and onions was welcomed by growers since it could be quickly sprayed on the crops sometime prior to harvest, one spray application was sufficient, and the cost was moderate. However, from time to time growers have reported that maleic hydrazide had not given consistent sprout inhibition results in Ohio even when applied several weeks before potato vines started to die down or before onions had matured. Some growers noticed that potato yields were seriously decreased, especially with some varieties and during some seasons and likewise onion growers experienced soft bulbs coming out of storage even though they showed no sprouts.

Grower experiences clearly called for further study and investigation of the use of maleic hydrazide on these two crops. Such a study was initiated in 1955 in order to relate these variations in response to differences in time of application, concentrations of inhibitor, and growth status of the plant.

PREVIOUS WORK

The first report on the growth regulating properties of maleic hydrazide (MH-30) was made by Schoene and Hoffman (9). The following year (1950) Zukel (12) published the first work on the effect of this material on potatoes. He found no inhibition of vine growth and no yield reductions with concentrations of maleic hydrazide up to 0.3 percent applied to Green Mountain potato vines seven weeks after planting. When tubers from the highest dosage plants were kept at room temperature for five months, no sprouts developed whereas numerous sprouts developed on the controls. Others soon followed with their reports on the use of this chemical on potato vines and tubers.

Friesen and Howat (3) found that early (two weeks after the plants emerged) applications to potato foliage stunted growth when used at the rate of 0.25 and 0.50 percent. Barnard and Warden (1) applied MH-30 at 0.1 and 0.5 percent two weeks after emergence, they found an increased set but smaller tubers with both concentrations and many second growths and aerial tubers from the higher concentrations

Kennedy and Smith (5) reported an increase in numbers of tubers set when applications of MH-30 at 0.1 percent concentration were made at/or shortly after the time of initial tuber set. What is important is that they noticed a marked decrease in injury and numbers of tubers per plant as applications were made later in the season and an increased number of tubers per plant with increased dosages of MH-30. A considerable reduction in sprouting occurred when potatoes were sprayed at 0.1 percent from six to ten weeks before harvest.

Wittwer and Paterson (10) suggested a concentration of 2,500 ppm for almost complete sprout inhibition if applied four to six weeks before harvest. Paterson et al (6) reported lower percentages of reducing and non-reducing sugars in Irish Cobbler tubers from maleic hydrazide treated plots when stored at 45 degrees F and that lighter colored potato chips were obtained from the tubers with the lower content of reducing sugars.

Highlands, Licciardello and Cunningham (4) found no significant reduction in accumulation of reducing sugars and no significant differences in appearance and color of chips with tubers of the Kennebec and Katahdin varieties from maleic hydrazide treated plots. Denisen (2), after extensive tests with Kennebec potatoes, concluded that the difference in ages of potato plants at the time of treatment has a marked effect on the response of the plants and emphasized the importance of the age factor in conducting and interpreting experiments with maleic hydrazide.

Onions sprout and root in storage and the extent of this damage depends largely on temperature and humidity. Most of the northern onion crop is still held in common storage. Depending upon variety, location, and weather conditions, commercial onion producers expect from five to 50 percent loss in storage of their harvested crop, 85 percent of which is accounted for by sprouting and rooting.

The first report of the use of maleic hydrazide as a sprout inhibitor with onions was made by Wittwer et al (11). Further investigations were undertaken by Paterson and Wittwer (7) who showed that two considerations are important with this crop. Maleic hydrazide applied to onion foliage either in too large dosages or too early can cause unmarketable onions due to spongy bulbs and also increased storage breakdown. They suggest that 2,500 ppm (0.25%, or five pounds of the actual chemical per acre) applied as a spray one to two weeks before harvest will result in complete inhibition of sprouting regardless of temperature and will reduce loss from breakdown and eliminate soft onions.

If 500 to 1,000 ppm (0.05 to 0.1%) sprays are used, sprouting will not be entirely eliminated but will be delayed and reduced compared with the controls.

The timing of the spray must be such that only mature bulbs are sprayed but the tops must still be green to insure the absorption and translocation of the maleic hydrazide to the growing points of the bulbs. This is best accomplished by spraying one to two weeks before harvest when the tops are beginning to fall but are still showing green. Peterson (8) applied 2,500 ppm of maleic hydrazide to 150 onion hybrids ten days before harvest.

Although most of the highest yielding hybrids have poor storage qualities maleic hydrazide had no effect in the control of shrinkage, top sprouts or root growth until after the normal period of dormancy of about six months in a good storage. After this period the treated bulbs showed less scale splitting due to root activity, delayed sprout activity and minimum sprouting losses due to poor or unusually prolonged storage.

The author suggests that this chemical should not be relied upon to make storage onions out of poor-keeping varieties or as a substitute for proper storage but rather as added insurance against losses from sprouting and rooting.

MATERIALS AND METHODS

The experiments were carried out in Huron County, Ohio, on the muck soils of the Muck Crops Substation during the years 1955, 1957, and 1958. No work was in progress during 1956 because no test area was available. It should be pointed out that at the time of the initiation of the work it was considered advisable that the material used as the maleic hydrazide inhibitor should be commercially and readily available to vegetable growers. For this reason MH-40 (6-hydroxy-3-(2H) - pyridazinone) the sodium salt of maleic hydrazide was used exclusively during 1955 and in comparison with MH-30 (the diethanolamine salt)[1] during 1957 and 1958.

The treatments were distributed in a randomized block plot layout with four replications used during 1955 and 1957 and eight replications during 1958. The individual plots were approximately 1/500 of an acre in size. Potatoes were grown in two row plots using the Katahdin variety. Onions were planted in three row plots using the varieties Ohio

[1]These formulations were obtained from the only supplier at that time: The U. S. Rubber Company, Naugatuck Division, Naugatuck, Connecticut

Yellow Globe (1955), Aristocrat (1957), and Abundance (1958). Yields were taken at harvest, off grade specimens discarded and the specific gravity of both crops determined by means of the National Potato Chip Institute potato hydrometer. It was necessary to counter weight the hydrometer for use with the onion bulbs since they float in water. The onions were cured and dryed for two or three weeks in an open shed and the potatoes were also cured for 10 to 15 days in a closed room under high relative humidity and temperature before moving to storage. The tubers and bulbs were then moved in half-bushel baskets to two separate bank-barn common storages supplied with ventilation.

No special care was given to either stored lot except to ventilate during cool periods especially at night until 40° F was reached in the potato storage and 32 to 35° F in the onion storage. The potatoes were held in storage close to eight months and the onions from 10 to 12 months after which the sprouts were removed and weighed and the weights recorded as grams of sprouts per kilogram of tubers or onion bulbs. Variations in this procedure are noted in the discussion of 1955 results.

In this work several variables were studied including spray formulation, dosage or spray concentration, and time of spray application as related to stage of plant maturity and to humidity of the air. Maleic hydrazide was available only as the sodium salt (MH-40) during 1955 while both the salt and liquid (MH-30) forms were obtainable for the later tests.

All dosages given in the tables are expressed as pounds of MH-40 applied per acre to correspond to the recommendations of the sole supplier of this growth inhibitor at the time these tests were initiated. In order to interpret these dosages in terms of fluid measure of MH-30 which came on the market after these experiments were started and to relate these dosages to actual percent and parts per million (ppm) of maleic hydrazide, a conversion table was prepared, Table 1.

During 1955 the tests were exploratory in nature to the extent that a wide range and number of dosages were used, i.e., 1, 2, 5, and 7 pounds of MH-40 per acre for potatoes, and 1, 2 and 5 pounds for onions. Thereafter 3 and 5 pounds were used on potatoes and 2, 4 and 6 pounds per acre on onions. Some difficulty is encountered in specifying or conveying understanding of the proper time of application of the sprays. With onions the spray of MH is timed in relation to time of maturity or even harvest.

TABLE 1.—Dosages of MH-40 per acre (per 100 gallons of water) and equivalent dosages of MH-30

MH-40 pounds per acre	Maleic Hydrazide		MH-30* pints or quarts per acre
	%	ppm	
1	0.05	500	1 pint
2	0.10	1000	1 quart
3	0.15	1500	1 quart 1 pint
4	0.20	2000	2 quarts
5	0.25	2500	2 quarts 1 pint
6	0.30	3000	3 quarts
7	0.35	3500	3 quarts 1 pint

*Rounded off values. 40 and 30 refer to the percentage of actual maleic hydrazide in the two MH commercial formulations. For actual total pints in column 4 multiply total pints by 1.07.

The concept of maturity of onions may vary among different growers. In these tests the MH supplier's recommendations were adhered to, i.e., two weeks before harvest or when the bulbs are mature and the tops begin to fall but still show green. With this as a basis for comparison the onions were sprayed during 1956 at two and seven days before harvest in addition to the standard two weeks before harvest. During the remaining years of the tests all sprays were applied at 1, 2, 3 and 4 weeks before harvest. Timing of the sprays is important since spraying too early, that is before bulbs have matured, may result in spongy, hollow-neck bulbs which are more subject to storage breakdown than bulbs which are allowed to develop to maturity before spraying. The amount of spray may be adjusted for complete inhibition of sprouting or for delay or partial sprout inhibition.

With potatoes, the supplier's recommendations for the use of MH-40 or MH-30 are to apply the material one week after blossom fall. If blossoms do not appear due to variety used or for other reasons such as a seasonal effect the recommended time of spray application is four to six weeks before potatoes are mature and ready for harvest. This time for spraying is said to correspond to about the time that a few lower leaves start to turn yellow and die.

It is also suggested that this timing of spraying might be defined as two weeks before top-killing or three weeks after full bloom. In any case it is essential that the tubers have formed and the spray applied while the vines are still green to allow movement of the MH into the

tubers. If the spray is applied before blossoms fall it can result in a serious decrease in yields and if applied later than two weeks after blossom fall poor sprout control may result.

During the first season of these experiments the timing of the sprays was 2, 4 and 6 weeks before harvest with potatoes which, in the light of the above discussion, would correspond approximately to four weeks, and two weeks after blossom fall and at blossom fall. During the following years of 1958 and 1959 the sprays were applied during early bloom, full bloom, blossom fall and two weeks and four weeks after blossom fall.

In addition to the two variables in these experiments just discussed, i.e., dosage and time of sprays, formulation and relative humidity at time of spraying were also included during 1957 and humidity as a variable eliminated during 1958. It has been reported that relative humidity had the most striking effect on rate of absorption of MH. With the highest humidity during the night hours the MH absorption should be many times faster than during the daylight hours. This is apparently related to the greater turgidity of the epidermal cells at night which aids absorption and to the dissolving of the sodium salt of MH when it occurs in the crystalline form on the leaf surface after evaporation has dissipated a portion of the water present.

During the period of these experiments a new formulation of MH was made available, commercially, as a solution of MH as the diethanolamine salt containing 30 percent MH acid equivalent by weight, or three pounds active MH per gallon. The addition of a wetting agent was not necessary as it had been added at the time the solution was prepared. This formulation was compared with the (MH-40) sodium salt of maleic hydrazide during 1957 and 1958.

EXPERIMENTAL RESULTS

POTATO SPROUT INHIBITION

Preliminary studies—1955–1956

Work with maleic hydrazide was instituted during the spring of 1955 in response to reports from growers that variable results with the use of this chemical were being obtained. It was felt that the first tests should include a rather wide range of dosage and time of spray application in order to induce effects on tuber yields as well as sprout growth if possible. Accordingly, MH 40 was applied at the rate of 1, 2, 5 and 7 pounds per acre at 2, 4 and 6 weeks before harvest. In this instance the six and the four weeks before harvest sprays occurred approximately at blossom fall and at one week after blossom fall respectively.

Four replications were used and one-half bushel lots from each replicate were moved to a bank-barn common storage room with ventilation and held at no less than 40° F for eight months. The tubers were weighed as they came from the field after sorting to produce a U. S. No. 1 grade and weighed again at the end of the storage period just prior to removing and weighing sprouts as well as after desprouting.

The specific gravity of each lot was determined after desprouting at the end of the storage period. The actual sprouts removed from each replication of each treatment are shown in Figure 1. Since there were no significant effects of treatments on yields nor on specific gravity of the tubers it appears that the MH 40 was not applied early enough to reduce yields as is sometimes reported. The data for grams of sprouts per kilogram of tubers are presented in Table 2.

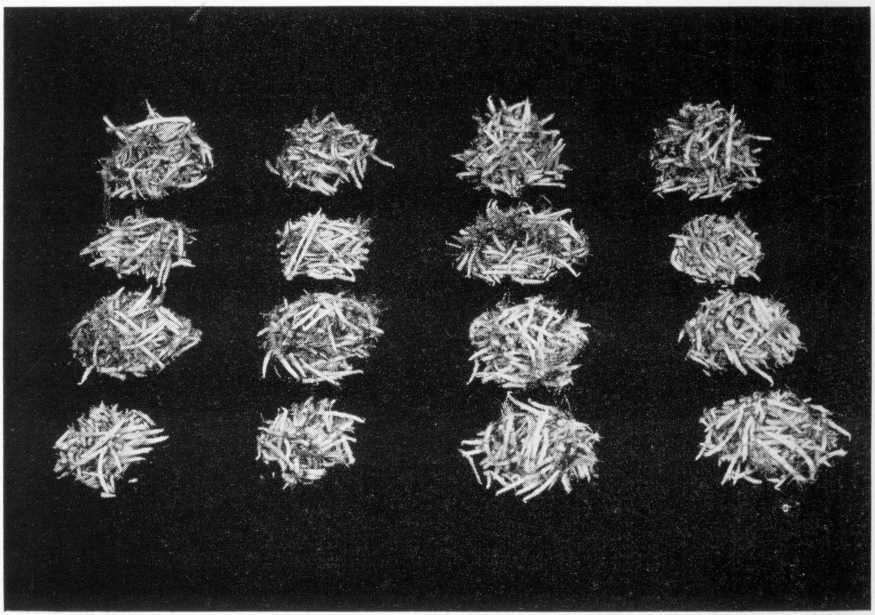

Fig. 1.—The Effect of MH-40 on Sprouting of Potatoes.

Sprouts removed from four replicates (left to right) of potatoes treated by spraying the plants with MH-40 during 1955. Dosage and time of application were as follows: Rows top to bottom.

(1) Control.
(2) Five pounds per acre at six weeks before harvest.
(3) Two pounds per acre at six weeks before harvest.
(4) Seven pounds per acre at six weeks before harvest.

Note: Arranged to compare rows 4 and 2 (best treatments) with rows 1 and 3 (control and poor treatment).

TABLE 2.—The effect of maleic hydrazide sprays on the development of potato sprouts during eight months in common storage, 1955-1956

Pounds MH 40 per acre	Spray application, weeks before harvest	Weight of sprouts in grams per kilogram of tubers
None	None	24.54
7	6	13.21**
5	6	15.20**
1	6	19.59*
2	6	20.30
7	4	22.48
1	4	23.66
2	4	24.70
5	2	26.80
LSD .01	7.29 ** Significant .01	
LSD .05	4.70 * Significant .05	

The results of this preliminary work strongly suggest that time of application of maleic hydrazide is of first importance for the greatest inhibition of sprouting was obtained when the sprays were applied six weeks before harvest irrespective of the dosage, followed by applications made four and two weeks before harvest. Six weeks before harvest is close to the period of blossom fall. An earlier than six week application could have well reduced sprouting still further, judged by the fact that sprouting at the eight month storage period was not entirely inhibited. On the other hand an earlier application could well have resulted in reduced tuber yields.

When dosages are compared the seven pound per acre application of MH 40 resulted in less sprouting than the five pound dosage but not significantly less. The small one pound application reduced sprouting significantly (.05 level) below that of the controls. However, it did not reduce sprouting as much as the larger five and seven pound dosages. It is suggested again that larger dosages and earlier applications should have been used to test the effect on sprout inhibition particularly in relation to yields and tuber specific gravity.

The data in Table 2 presents evidence that at six weeks before harvest a dosage larger than seven pounds would not result in significantly less sprouts than the minimum five pounds per acre, based on the fact that five pound dosage was not significantly better than seven pounds. In summary, the preliminary evidence seems to indicate that the dosage need not be increased beyond five pounds per acre of MH 40

or its equivalent but there is an indication that applications earlier than six weeks before harvest may still further reduce sprouting with this crop. With greater refinement of testing this point of whether more than seven pounds would be useful may be made more clear.

Studies During 1957–1958

No results with potatoes or onions were obtained during 1956-1957 due to the decision to uniformly crop the experimental area in order to survey the yield potential and degree of uniformity of the muck soil of the farm. During 1957-1958 potatoes and onions were again grown as in the past for testing maleic hydrazide as a sprout inhibitor. In addition to MH 40 previously used, MH 30, a liquid formulation, was also studied at dosages of five and three pints per acre which corresponds with five and three pounds of MH 40 per acre, Table 1; actually 5.35 and 3.21 pints were used.

It seemed advisable to introduce a new variable during the 1957-1958 season, i.e., the relative humidity of the air during the few hours after application. Accordingly, MH sprays were made during the close of the day (5:00 P. M.) and during the early morning (8:00 A. M.) to encompass moist and dry air (leaf surface conditions), respectively. The spread of the time of spraying schedule was also widened to include a period of from early bloom to four weeks after blossom fall, inclusive. The mid point of this period of blossom fall to one week after this stage was considered to be four to six weeks before the potatoes are mature and ready for harvest.

The data were subjected to an analysis by the variance method and it was found that none of the experimental variables imposed resulted in significant yield differences. It must be remembered that only four replications were employed this season. The greatest difference between any of the treatment means was 43 bushels of potatoes per acre. A similar analysis of the data for specific gravity of the tubers likewise showed no effects from the dosage treatments or from spray dates. However, the spray date—dosage treatment interaction was highly significant with an F value of 6.9 vs. 1.94 required at the 1 percent level of significance. This means that the treatments had different effects on specific gravity of the tubers depending on what date the sprays were applied.

It is questionable if any significance can be attached to this interaction under the conditions obtained in the test. Actually the specific gravity of the tubers from the plots sprayed at early bloom varied only from 1.0733 to 1.0760 with no apparent relation to treatment. At the

last spraying, four weeks after blossom fall, the range in specific gravity was considerably wider, i.e., from 1.0715 to 1.0775. The average of the seven control plots was 1.0711.

After plotting the specific gravity values for the eight treatments vs. the spray dates no pattern of response offering an explanation was secured. The highest specific gravity values on the last spraying date were obtained from plots receiving MH 30 under high humidity conditions while the lowest values were obtained from plots receiving MH 30 under low humidity conditions.

Potato sprout inhibition was very effectively obtained through the use of maleic hydrazide sprays as is evident by the data presented in Table 3. The analysis of the original data showed that treatment effects were highly significant. It also showed that the effect of spray date on sprout inhibition was highly significant. What was more important was the interaction between treatment and spray date. This means that the treatments acted differently on the different dates of spraying. This was expected since it has been known that the absorption and translocation of maleic hydrazide to the growing points or eyes of tubers is dependent on many factors, the most important of which is the stage in the growth of the plant and tuber at which the inhibitor is applied. For this reason the data were separated into the five dates of spraying and analysis computed for treatment effects for each date.

It was found that all the treatments were highly significant in their effects on sprouting of tubers as revealed in Table 3. In examining the results presented in Table 3, it is well to keep in mind that the grams of sprouts per kilogram of tuber may be compared with the mean value of the control or untreated plots not shown in the table of 15.85 grams.

One of the important variables in connection with the control of potato tuber sprouting in storage is the amount or dosage of maleic hydrazide to be applied per acre. An examination of the upper half of Table 3 reveals that in every one of the 20 comparisons available between the effect of five pounds or pints rate per acre of either MH40 or MH 30 and the three pounds or pints rate, the larger dosage resulted in fewer potato sprouts during the storage period.

The question immediately arises as to the advisability or advantage of using more than five pounds or pints of the respective formulation. This question is not answerable with the data secured here. However, attention may be called to the data and discussion given above (page 8) that indicates during 1955 five pounds of MH 40 was as effective in sprout inhibition as seven pounds per acre. Several other considerations

TABLE 3.—The effect of maleic hydrazide sprays on the development of potato sprouts during eight months in common storage, 1957-1958

Weight of sprouts in grams per kilogram of tubers, mean of four replications

Pounds or pints of spray per acre	Time Prior to Harvest Sprays Were Applied									
	Early bloom		Full bloom		Blossom fall		Two weeks after blossom fall		Four weeks after blossom fall	
	MH 40	30	40	30	40	30	40	30	40	30
	Under low humidity conditions									
3	9.33	10.13	10.09	9.50	14.96	8.15	11.73	8.89	9.27	8.38
5	5.97	5.73	8.09	6.24	4.97	5.40	7.57	3.01	7.13	5.79
	Under high humidity conditions									
3	7.13	5.24	7.88	7.76	7.71	4.59	15.11	7.37	6.73	14.78
5	6.44	3.65	3.56	5.32	3.21	2.98	9.21	4.23	2.95	7.60
LSD 01	2.62									
	Average differences between treatments*									
3 vs 5	—2.51		—3.01		—4.71		—4.77		—3.92	
MH 40 vs 30	—1.03		—1.08		—2.44		—5.03		2.62	
Low vs high humidity	—2.18		—2.35		—3.75		1.18		0.37	
LSD 01	.877		1.08		1.97		.490		.492	

*The negative (—) sign indicates the second treatment resulted in lower sprout weights by the grams indicated.

must be included in any discussion on dosage. Formulation, relative humidity of the air up to six hours after spraying and how much and how long after harvest inhibition is desired, all have some bearing on the quantity of spray applied at any given spray date. If the spray cannot be applied at the proper stage of plant growth, more maleic hydrazide may be the answer to effective sprout inhibition. Another aspect of the dosage question is that of economy versus effectiveness. Five pounds or pints of MH reduced grams of sprouts produced per kilogram of tubers over the three pounds or pints dosage by from 4.77 to 2.51 depending upon spray date, Table 3.

Selecting the best spray material and conditions as given in Table 3, i.e., MH 30 applied at blossom fall under high humidity conditions, it may be seen that the five pint dosage resulted in 2.98 grams of sprouts per kilogram of tubers after eight months storage, while three pints resulted in 4.59 grams of sprouts, both to be compared with the controls resulting in 15.85 grams of sprouts per kilogram of tubers. The five pint over the three pint dosage reduced sprouts by 1.61 grams.

Others (10) have reported that although 2,500 ppm of maleic hydrazide (five pints of MH 30) will give complete inhibition of sprouting, 500 to 1000 ppm (one to two pints of MH 30) will give almost complete sprout inhibition if applied four to six weeks before harvest. Results of further experiments in 1958 reported here (page 15) are quite similar to these 1957 results. It is well to point out further that gallonage of spray is important in connection with any discussion on dosage. The quantity of spray should be sufficient to completely cover the plant foliage to the point of drip which may require 150 gallons of spray per acre although as little as 100 gallons appeared to be sufficient.

The second variable listed in the bottom half of Table 3 is the MH 40 salt compared with the MH 30 liquid formulation. Faster and more complete absorption of maleic hydrazide is claimed for the liquid spray formulation. The results obtained here show the liquid to be superior in every instance except the last spray date (four weeks after blossom fall) as an average, or in 15 instances out of 20 comparisons.

The greatest advantage of the liquid over the salt MH was obtained at the two-weeks-after-blossom-fall spray date where an average of 5.03 grams less sprouts per kilogram of tubers were present at the end of the storage period. This may be compared with the value of 2.44 grams associated with the best spray date, i.e., at blossom fall. It is interesting to note that no advantage of the MH 30 over MH 40 could be demonstrated during 1958 when eight replications were used compared with the four used during 1957.

A third variable included only during 1957 was that of time of spraying relative to the time of day to take advantage of high relative humidity usually occurring during the night hours. To make this comparison identical sprays were applied in the early morning and late in the after noon or evening. The results in Table 3 show that the evening sprays were superior 14 times out of 20 comparisons available. In the bottom half of Table 3 it may be seen that average values for sprout development were lower by from 2.18 to 3.75 grams per kilogram of tubers during the first three spray periods, i.e., early bloom, full bloom

and blossom fall. The reverse was true during the two later sprays of two weeks and four weeks after blossom fall, although the value for the last spray was not significant. It would appear that if the sprays are made close to blossom fall a better sprout inhibition could be expected by evening spraying.

The remaining variable considered in these tests, i.e., timing of the maleic hydrazide spray relative to stage of plant growth, is a most important one. It has been pointed out earlier that the response to maleic hydrazide depends on many factors (including the weather) associated with the operation of spraying. This is indicated by the weight of sprouts obtained under the varying conditions of these tests.

However, by an examination of the data in Table 3 it may be seen that if the data were averaged by spray dates or periods under high humidity conditions, blossom fall sprays resulted in the lowest sprout weight. The sprout weights per kilogram of tubers for early bloom to four weeks after blossom fall are, 5.61, 6.13, 4.62, 9.98 and 8.01 grams. Thus, although under varying circumstances other dates of spraying for sprout control might prove best, indications are that best results will usually be obtained when the potato vines are sprayed at or near blossom fall. This will correspond to four to six weeks before the potatoes are mature and ready for harvest. This agrees with the data secured during 1958-1959 given below and with the experience of other investigators.

Studies During 1958–1959

The tests carried out during 1957 were repeated during 1958 except that the variable of humidity at time of spraying was eliminated and thereby allowing the number of replications to be increased from four to eight. Again, as during the previous year, an analysis of the potato yield data showed there were no differences that could be attributed to the treatments applied, that is the maleic hydrazide sprays.

Likewise, applying analysis of variance to the specific gravity values obtained on the tuber samples from each treatment revealed that spray formulation, concentration and time of application had no significant effect. This is similar to the results secured in tests during 1957-1958 and those reported elsewhere.

It appears from the data presented in Table 4 that five pounds of MH 40 or five pints of MH 30 were greatly superior to three pounds or pints of these formulations, for the purpose of reducing sprouting of tubers in storage for nine months. Actually, of the ten comparisons available in Table 4, nine show a smaller weight of sprouts where five

TABLE 4.—The effect of maleic hydrazide sprays on the development of potato sprouts during nine months in common storage, 1958-1959

Weight of sprouts in grams per kilogram of tubers, mean of eight replications

Pounds or pints of spray per acre	Time Prior to Harvest Sprays Were Applied									
	Early bloom		Full bloom		Blossom fall		Two weeks after blossom fall		Four weeks after blossom fall	
	MH 40	30	40	30	40	30	40	30	40	30
3	17.90	14.49	13 67	14 11	8.96	9 11	12.28	16.01	24.89	25 17
5	9.88	9.87	11.14	8 19	6.96	8.23	12 67	7 28	19.20	18.31

Mean values according to:

Concentration		Time of spraying	
pounds or pints of spray per acre			
3	15.66	Early bloom	13.04
		Full bloom	11.78
		Blossom fall	8.32
5	11.17	Two weeks later	12.06
		Four weeks later	21.89

LSD 01 1 29

pounds or pints of the two formulations were used. The difference in weight of sprouts produced from the two dosages taking all comparisons into account was 4.49 grams per kilogram of tubers. Some growers might consider this difference as a minor one and choose to economize and use three instead of five pounds or pints as their dosage per acre. Others might select a greater dosage than the maximum used here and possibly reduce sprouting still further. Selecting the data for blossom fall spray application, the five pound MH 40 dosage resulted in two grams less sprouts per kilogram of tubers when compared with the three pound dosage.

The same comparison made where MH 30 was used, the difference was 0.88 grams of sprouts. If these two values are averaged, the difference due to dosage becomes only 1.44 grams, a considerably smaller

figure than the 4.49 grams given above for the average of all treatments regardless of the time of spraying. It may be pointed out that heavier dosages should tend to insure longer retarding of sprouting although this phase of sprout inhibition was not studied here. It is known that after about eight ppm of maleic hydrazide accumulates in the eyes of the tubers no increase will have any effect as the above concentration results in complete inhibition of sprout growth and excess chemical would be wasted.

It appears then that dosage is only one of many factors affecting the concentrating of this chemical in the meristematic eye or bud section of the tuber and as such will give results which will vary with conditions at the time of spraying. For this reason it is well to follow instructions for the use of maleic hydrazide as suggested here and elsewhere if dosages of moderate size (five pounds or pints) are to be successful.

As with the dosage data, the time of spraying data were unmistakeably clear in showing that blossom fall was the proper time to spray potatoes during 1958. Table 4 reveals that when all data were included the average sprout weight in grams per kilogram of tubers was 8.32 for the blossoms fall spray, 11.78 grams for the full-bloom spray and 12.06 grams when the spray was applied two weeks after blossom fall. Examining the data for the individual sprays in the upper portion of Table 4 it is clear that the sprays applied before blossom fall were in general more effective than those applied after blossom fall, especially those applied four weeks after blossom fall.

The recommendation for maleic hydrazide sprays would continue to be to apply three to five pounds of MH 40 or the same in pints of MH 30 at blossom fall to one week after blossom fall. Note, however, should be made of the fact that if the spray is to be applied much earlier or later than the optimum period of blossom fall, then the heavier applications will be considerably better in causing sprout inhibition than the minimum dosages. Again it may be seen that the factors are so interrelated that results obtained are strongly affected by the combination of factors during the time of spraying. It also means that somewhat greater latitude in spraying date is tolerable when the larger dosage is used.

ONION SPROUT INHIBITION

Preliminary studies—1955–1956

During the first season of investigation with onions MH 40 was applied at the rate of 1, 2 and 5 pounds per acre and the range of spray application dates was from two to 14 days before harvest including a seven day application. Instead of removing and weighing the sprouts,

the number of sprouted onions in the uniform half bushels secured from the plots were counted and expressed in Table 5 as percent of the total number of onions in the half bushel container. The sprouts were then measured and the data recorded as average length in inches per onion counted as having sprouted. These data were obtained on four replications and the averages are presented in Table 5.

TABLE 5.—The effect of maleic hydrazide sprays on the development of onion sprouts during ten months in common storage, 1955-1956

Pounds MH 40 per acre	Spray application, days before harvest	Percent of onions sprouted	Average sprout length per onion in inches
None	None	16.93	2.80
5	14	2.97**	0.72**
1	14	6.25**	1.62*
2	14	9.32*	1.82*
2	7	8.25*	1.69*
5	7	8.27*	2.90
1	7	14.06	2.60
5	2	8.22*	2.07
2	2	9.90*	3.12

** Significant .01
* Significant .05

All sprays but the one pound application made at seven days before harvest appeared to have some effect on sprout development since they reduced the percent of sprouted bulbs significantly below that of the controls. The intensity of sprouting, on the other hand, was significantly reduced under the controls only with the sprays made at 14 days before harvest and at seven days with the two pound dosage of MH 40.

However, since the only application that resulted in a highly significant reduction in sprout length was the five pound dosage at 14 days before harvest, it may be assumed that at least five pounds should be employed when spraying onions and the application should be made at least 14 days before harvest or maturity of the bulbs. These are, perhaps, the only valid conclusions that may be drawn from these preliminary studies.

It is of interest to note that one pound of MH 40 gave good results although not nearly as good results as five pounds when both were

applied at the same 14 days before harvest. Therefore it would appear that five pounds of MH 40 and two weeks before harvest are logical values from which to vary the two factors during the succeeding seasons.

Studies During 1957–1958

This season the dosage of maleic hydrazide was widened to include 2, 4 and 6 pounds of MH 40 and in addition MH 30 was available and included in dosages of 2, 4 and 6 pints per acre on onions. Also the spread of the spray timing was increased to include 1, 2, 3 and 4 weeks before harvest. Actually the mid point of the spray schedule, between two and three weeks before harvest, was timed to coincide with the period when it could be said the bulbs were mature and the tops were beginning to fall but still were showing green.

An analysis of variance applied to the onion bulb weights secured from the four replicates of each treatment revealed no significant effect of any of the treatments nor was there any significant interaction relative to yield between treatments and spray dates under the conditions of these tests. Usually the application of maleic hydrazide so late in the growth of the onion would not be expected to have any appreciable effect on the yields of the crop. To be sure, if the spray had the effect of reducing the solidity of the bulbs, the total final weight at harvest time could be affected. On the other hand specific gravity would be a more precise index of solidity.

The specific gravity of the bulbs making up each sample was determined and these data subjected to an analysis of variance. Although there was no significant effect of the treatments on specific gravity and the treatment—spray dates interaction was not significant, the date the sprays were applied did have a significant effect on specific gravity, but only at the five percent level. When comparing spray date means for specific gravity it was found that the sprays applied four and three weeks before harvest resulted in values of 1.8774 and 1.8782 respectively. With an LSD at the five percent level of 0.0061, no significant difference exists between these two values. However, the specific gravity data for onions sprayed two weeks before harvest showed a mean value of 1.8785 which is significantly higher (more solid bulbs) than that for the earlier sprayed onions.

The spray applied one week before harvest resulted in a specific gravity value close to that given for the spray applied two weeks before harvest, i.e., 1.8783. Thus, although the effect of spray date was not outstanding, it did have a measurable and significant effect on the solidity of the bulbs in that it tended to reduce bulb solidity the earlier the spray was applied before harvest. With one to two weeks before harvest

being a common recommended time for applying maleic hydrazide to onions for sprout inhibition, a spray applied four weeks before harvest could very well affect the solidity of the bulbs as it has here.

Considering now, the sprout weights resulting from the maleic hydrazide sprays, it was found that the spray dates had a profound effect on the response to the treatments, that is, the interaction between treatments and spray dates was so great, it was necessary to evaluate the differences due to treatment by spray date. The actual onion sprout weights obtained under each different set of conditions are given in Table 6.

First it must be pointed out that due to the great variations between values as found in Table 6 resulting in a rather large LSD, differences between treatments that may appear significant may not be the result of the treatments but to other uncontrollable variables. This analysis also makes clear that response to be expected from maleic hydrazide on onions will be greatly dependent upon the combination of the variable factors introduced in connection with any one treatment such as weather, time of day, age of crop, dosage, formulation, etc. The best

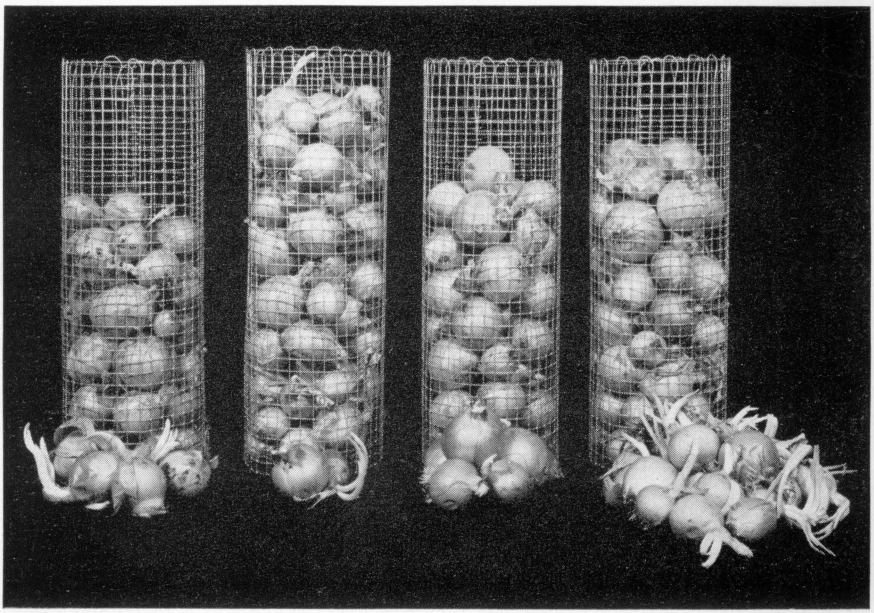

Fig. 2.—The Effect of MH-40 on Sprouting of Onions.

Sprouted onions and non-sprouted onions of four replicates treated by spraying the foliage with five pounds per acre of MH-40 14 days before harvest during 1955. Compare with figure 3.

TABLE 6.—The effect of maleic hydrazide sprays on the development of onion sprouts during eight months in common storage, 1957-1958

Weight of sprouts in grams per kilogram of bulbs, mean of four replications

Pounds or pints of spray per acre	Number of weeks prior to harvest sprays were applied							
	1		2		3		4	
	MH 40	30	40	30	40	30	40	30
2	157.5	138.0	173.5	182.3	70.5	125.5	68.0	107.5
4	56.3	26.0	197.5	81.8	29.0	8.5	36.2	36.5
6	14.5	79.5	170.3	138.8	8.5	21.0	40.8	27.3
							LSD 01	35.59

interpretation that may be made of the data in Table 6 is that the smallest weight of sprouts probably indicates the best combination of factors to obtain the best inhibition of sprouting.

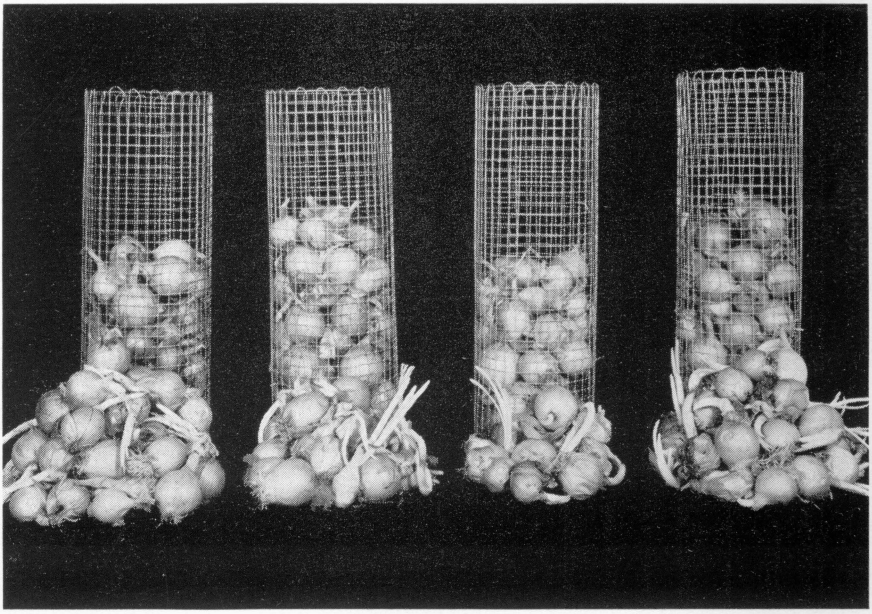

Fig. 3.—Four Onion Replicates Receiving No Maleic Hydrazide (control) Compare with Figure 2.

It appears that the best spray date would be close to three weeks before harvest when either the liquid or salt formulation is used. It should be pointed out here that observations of the condition of the onion tops at the one week before harvest spray date showed the tops to be further along towards death than was desirable and thus the three weeks before harvest date might have been closer to that of a two weeks before harvest stage. In this connection it is well to point out that during 1958-1959 results showed the lowest sprout weights for the sprays applied one week before harvest although this result was not significantly different than that obtained when the spray was applied two weeks before harvest. More reliable results and therefore a more exacting recommendation on when and with what should onions be sprayed for sprout inhibition are obtainable with refinements in the experimental procedure which include the use of more replications. This was followed during the 1958 season when eight replications were employed and closer attention to foliage condition at time of spraying improved the selection of the spray date in relation to maturity of the tops and bulbs.

Studies During 1958–1959

Maleic hydrazide sprays used as sprout inhibitors do not seem to affect either potato or onion yields when used according to manufacturers' directions. During this season no significant differences in onion yields due to treatments were found after statistical analysis of the data. Likewise, no differences in specific gravity of the bulbs due to treatments could be demonstrated this season, although some effect of this nature was found the previous year.

Sprout inhibition was good during the ten months of storage this season. With eight replications the greatest weight of sprouts was 16.75 grams per kilogram of onion bulbs. This control plot average value may be compared with the mean values for the treated plots as given in Table 7. The lowest value in this table for sprout weight is 0.31 grams obtained when MH 30 was applied one week before harvest at a concentration of six pints per acre. However, where four pints were used under the same conditions the sprout weight was 0.61, not a sufficient increase in total weight to be significant. However, the best and most accurate measure of the value of the treatment in inhibiting sprout growth in storage is the mean values of all plots bearing on any one variable.

TABLE 7.—The effect of maleic hydrazide sprays on the development of onion sprouts during ten months in common storage, 1958-1959

Weight of sprouts in grams per kilogram of bulbs, mean of eight replications

Pounds or pints of spray per acre	Number of weeks prior to harvest sprays were applied							
	1		2		3		4	
	MH 40	30	40	30	40	30	40	30
2	2.27	3.93	4.74	4.93	6.50	4.47	8.25	6.67
4	2.04	0.61	2.08	1.97	3 68	4.96	7.77	5.77
6	1.58	0.31	0.74	1.10	2.31	4.21	6.06	8.50

Mean values according to:

Concentration		Time of spray	
pounds or pints of spray per acre		weeks before harvest	
2	5.22	1	1.79
4	3.61	2	2.59
6	3.10	3	4.36
		4	7.17
LSD 01	1.24		1.43

It would appear from the data in the bottom half of Table 7 that there must be something of a linear relation between dosage and sprout inhibition and similarily between time of spray application and sprout inhibition. The analysis of variance does indicate this to be true but of course only within the range of these tests. However, the four pound or pint dosage was significantly better than the two pound or pint concentration but not significantly different in its effect than the six pound or pint dosage.

This would indicate that more than six pounds or pints would not be needed with this crop, although it has been emphasized earlier that the response to maleic hydrazide with both potatoes and onions seems to depend largely upon the combination of factors of dosage, formulation, time of spraying, humidity and probably others occurring during the season of operation. For average conditions and the proper use of materials it appears that five pounds or pints of these formulations should be successful with onions as well as with potatoes. More than

this dosage will cost more but under adverse conditions could very well improve results over this recommended dosage. The six pound or pint dosage was better seven out of eight trials, but not significantly so in each instance.

Timing of the spraying operation is also important. The data in Table 7 also indicate a linear relation between time of spraying and sprout growth as was apparent with dosage and sprout growth. However, the data reveal that there is no significant difference in sprout inhibition between the sprays applied one and two weeks before harvest. There is, however, a significantly greater sprout growth when the spray date was increased to three weeks before harvest and again when this was still further increased to four weeks before harvest. This indicates that based on these results the recommended time for applying sprout inhibition sprays for onions would be one to two weeks before harvest.

No data are presented for formulation comparison since the data obtained this season show no significant difference in sprout control and therefore, it can be concluded that either the salt or the liquid forms of MH could be used with equal success. This was not true other years and the liquid would have preference over the salt or MH 40 formulation. This is now of academic interest only since the salt or MH 40 formulation is no longer marketed.

SUMMARY AND CONCLUSIONS

In any discussion of maleic hydrazide as a sprout inhibitor for use with potatoes and onions it should be realized that the effectiveness of this chemical is entirely dependent upon how much of the chemical reaches the meristematic growing points, in this case the "eyes" of the tubers and the stem plate of the onion bulbs. The factors affecting this transfer of maleic hydrazide have been discussed in some detail in this publication.

From these data it becomes clear that there are strong interactions between the factors of dosage, time of application of the MH relative to the stage of plant growth, time of application relative to the relative humidity of the air surrounding the plants and undoubtedly many others. This means that the results obtained by growers in the use of this chemical will depend largely on how closely they adhere to the recommended dosage and time of spraying relative to the recommended stage of growth, etc. Undoubtedly, the variable results obtained by research workers as well as commercial users of maleic hydrazide may be explained on this basis.

At the present time the only commercial formulation of maleic hydrazide available is the diethanolamine salt of 6-hydroxy-3-(2H)-pyridazinone as a liquid and equivalent to 30 percent maleic hydrazide and sold as MH-30 for use as a plant growth inhibitor and herbicide. The data presented here indicate that this formulation is superior to the sodium salt known as MH-40 now discontinued and replaced by MH-30.

Time of spraying and dosage are somewhat inter-related. Denisen (2) working with potatoes found that the blossom drop stage was very safe and 6,000 ppm could be used with no damaging effect on the tubers. He considered this time as eight days after full bloom. He pointed out that if the spray were applied at a later date than suggested above, 5,000 ppm were required to obtain the same results as were obtained with 2,500 ppm earlier. Thus, if good results are to be obtained with the minimum dosage, the timing is rather important.

Sawyer, in a letter in 1955, reported that maleic hydrazide had not given consistent sprout inhibition results on Long Island even when applied several weeks before vines started to die down. He found applications made before blossom fall could give serious decreases in yields, while applications later than two weeks from blossom fall could give poor sprout control. In the work here reported, no significant reduction in yields of potatoes or onions occurred even in connection with the earliest sprays applied.

The data do show, conclusively, that with either dosage of five or three pounds of MH-40 or close to five or three pints of MH-30, the lowest sprout weights were obtained when the material was applied to potatoes at close to blossom fall. With onions, irrespective of dosage, the best time to apply the spray was one to two weeks before harvest. Thus it is clear that from the standpoint of the timing of the spray of maleic hydrazide for onions and potatoes the stage of plant growth is rather critical for lowest sprout growth and particularly at the lowest dosages. Under certain sets of circumstances the data do show that greater sprout inhibition occurred at spray periods other than those just mentioned but not when mean values are considered. The reasons for this observation have been pointed out earlier.

Considering now the variable of concentration or dosage of maleic hydrazide to be used it is well to point out that some recommendations made by other workers and the manufacturer of MH-30 and MH-40 are somewhat in excess of those found best or ample in these trials. Some of this difference could be attributed to the terminology used in designating dosage. Dosage refers to either the pounds of actual maleic hydrazide applied per acre or to the pounds or pints of the commercial formulation used.

Concentration, on the other hand, more strictly refers to the amount or quantity of the active ingredient (in this case maleic hydrazide) per volume of water used in making up the spray. If the concentration is based on 100 gallons of solution (water) and 100 gallons of the solution are applied per acre, the dosage in pounds of commercial material or maleic hydrazide (or active ingredient) per 100 gallons is the same as the dosage in pounds per acre of either.

Since it is usually conceded that closer to 150 gallons of solution is required to wet the foliage of the plants on an acre than 100 gallons, it is well to make it clear that pounds of material used per acre (commercial material or active ingredient) is of the greatest importance from the standpoint of sprout inhibition. This also simplifies making up the spray solution for the commercial grower for he then knows how much material to place in his particular spray tank. The concentration will naturally be the same regardless of the gallons of spray applied per acre as fifty percent more material is used in 150 than in 100 gallons and is usually expressed in parts per million (ppm) of solution or percent. In Table 1 are given dosages based on pounds per acre of MH-40 and MH-30 and the corresponding ppm of actual maleic hydrazide in water solution (concentration) when either salt is dissolved in 100 gallons of water.

If the grower wished to make up 150 gallons in one spray for one acre he would use 7½ pounds of MH-40 or 7½ pints of MH-30 (50 percent more than for 100 gallons) to maintain the 2,500 ppm concentration chosen as desirable. Referring again to Table 1 the 2,500 ppm concentration represents, in actual quantities, 5.2 pounds per 100 gallons of MH-40 and 5.35 pints (five pints × 1.07) of MH-30.

The data in this publication support the view that four to six pounds per acre of MH-40 or 4½ to 7 pints of MH-30 would most often give very good control of sprouting with both potatoes and onions when properly applied. The exact quantity of maleic hydrazide used may best be decided on the basis of degree of sprout inhibition desired and the consideration of economy.

In summary, the recommendations that seem warranted from this work are:

1. The quantity of maleic hydrazide used should be the same for both potatoes and onions.
2. MH-30 is the only material commercially available at present and is satisfactory.

3. It seems advisable to use 150 gallons of spray mixture per acre in order to sufficiently wet the foliage to run off.

4. The concentration of maleic hydrazide resulting in good sprout inhibition is approximately 1,750 ppm. This requires approximately four pints of MH-30 per 100 gallons of water or approximately six pints per 150 gallons of water. This is then six pints of MH-30 per acre (five pounds of MH-40 per acre). When applied at the proper time 3½ pints per acre in several instances gave as good control and can be recommended. More MH (2,500 ppm) will give close to complete sprout inhibition regardless of temperature. Less MH (500 to 1000 ppm) should result in a delay and reduction of sprouting. This is not fully proved by this work.

5. The time of application of the maleic hydrazide may be critical and is surely an important factor in the results to be obtained when using this chemical. For onions it is suggested that they should be sprayed one to two weeks before harvest, that is, when the tops are beginning to fall over but still showing green. It is cautioned that the onions not be sprayed too early as soft onions may result. The tops must be alive however to readily translocate the maleic hydrazide to the stem plate.

   Apply the spray to potatoes at blossom fall or soon thereafter. Applications later than two weeks after blossom fall may give poor sprout control and early applications have been known to reduce yields. This suggested time for spraying corresponds close to a period from four to six weeks before harvest. Some success may be obtained if the spraying is delayed to two weeks before harvest but the sprout inhibition will be less.

6. Since rain occurring too soon after a spray application may wash off the material applied, no applications of MH salts should be made when rain is forecast within 24 hours of an intended spray date. Others have suggested that under high humidity conditions less gallonage should be used and with low humidity higher gallonage will prove best. High gallonage with high humidity causes excessive run off and less absorption of active material from foliage surfaces.

   Other information regarding compatability of MH-30 with other spray materials, effect of spray on respiration rates, storage rots, sugar changes, and other effects may be found in the literature and manufacturer's printed material and reviews