Urea Formaldehyde Concentrate-85, a Promising Control for Potato Scab

J. F. BARTZ and K. C. BERGER

Department of Soils, University of Wisconsin, Madison, Wis.

Urea formaldehyde concentrate-85 (UF-85) when applied broadcast at a rate of 150 gallons per acre, was effective for controlling common potato scab on the Irish Cobbler variety in 1956 and the Chippewa variety in 1957. Treatments including fertility levels and pentachloronitrobenzene were also compared. Stands were reduced by 42% when potatoes were planted immediately after the UF-85 had been applied broadcast at a rate of 250 gallons per acre, while rates of 50 and 150 gallons had no effect on stand. At a rate of 150 gallons per acre, UF-85 reduced the scab index from 14.5 in the check to 0.8 in 1956 and in 1957 this rate reduced the scab from 22.0 to 1.5. Scab incidence with the 50-gallon rate of the pentachloronitrobenzene treatment was higher than with the previously mentioned treatment.

Common scab of potato, incited by *Streptomyces scabies* (Thaxt.) Wakesman and Henrici, is one of the most important and least satisfactorily controlled of potato diseases. The incitant is present in almost all of the potato-growing areas of Wisconsin. To date, the only practical means of control for nonresistant varieties is to maintain soil pH in the range of 4.9 and 5.4. In many cases, the pH range required for scab control is too low for the red clover grown in many rotations.

Recently several soil fumigants have been evaluated for control of potato scab. Of these, pentachloronitrobenzene (PCNB) (*3, 4*) and sodium-*N*-methyl dithiocarbamate, dihydrate (Vapam) (*2*) have been found to reduce scab effectively.

This paper presents a preliminary evaluation of the effectiveness of urea formaldehyde concentrate-85 (UF-85) for controlling scab. This material is composed of approximately 26% urea and 60% formaldehyde. UF-85 has a urea-to-formaldehyde mole ratio of 0.217 and is a polymethylol urea in contrast to the common or polymethylene urea-form fertilizers which have a urea-to-formaldehyde mole ratio of greater than one. UF-85 contains a high concentration of formaldehyde which is less volatile than formaldehyde alone; this property would tend to make UF-85 more effective as a soil fungicide than formaldehyde. In addition to its fungicidal properties, UF-85 provides a source of nitrogen fertilizer. The first application of this material as a soil fumigant was for celery seedbed sterilization in Florida (*1*).

Experimental

Field plots were located on the State Certified Seed Potato Farm at Three Lakes, Wis., in an area known to be uniformly infested with *S. scabies.* The soil, Vilas sand, has an average pH of 5.5 to 5.9 on the plot site used in 1956; and in 1957 the plot site was moved to an area which had an average pH of 6.0 to 6.5. Available nitrogen, phosphorus, and potassium levels in pounds per acre for the 1956 site were approximately 175, 130, and 150, respectively, and 175, 90, and 100, respectively, for the 1957 site.

Individual plots were four rows wide and 30 feet long from which 25 feet of the center two rows were harvested. Each treatment was replicated four times. All fertilizer and lime materials were applied broadcast with the exception that a portion of the nitrogen was sidedressed on the 1957 plots (Table III).

The UF-85, supplied by the Allied Chemical and Dye Corp., was received in the form of a water-miscible viscous liquid. The material was mixed with water in a ratio of 3 parts of water to 1 part of UF-85 and applied to the soil with a garden sprinkling can. The soil was disked twice following application of the UF-85 and the potatoes were planted on the same day.

PCNB was supplied by the Olin Mathieson Chemical Corp. and was included in this trial as a control for comparing the effectiveness of UF-85 as a soil fungicide. The commercial formulation used was Terraclor 20% dust, which contains 20% PCNB. This material was applied broadcast; the soil was disked twice following application and potatoes were planted on the same day.

The scab-susceptible Irish Cobbler variety was employed for the 1956 test and Chippewa, another scab-susceptible variety, was used in 1957. Plants in both plots were subjected to the same cultivation and spray program as those in the production acreage.

Methods of Evaluation

In addition to scab control, the effect of UF-85 on germination and vegetative growth was noted. Germination was determined by plant-stand counts, 25 plants in 30 feet of row constituting a perfect stand. Tissue samples for chemical analyses were taken from the top 6 inches of plants when they were in a late vegetative growth stage. Nitrogen was determined by the standard Kjeldahl method. Total phosphorus, potassium, magnesium, and calcium were determined on the nitric-perchloric acid wet-ashed tissue from the 1956 plots. Potassium, magnesium, and calcium were determined with a Beckman Model DU flame photometer. Phosphorus was determined colorimetrically by the molybdate-vanadate method using a Bausch & Lomb Spectronic 20.

Tubers were harvested on October 1 in 1956, and on September 23 in 1957 and plot yields were obtained. A random sample consisting of 25 to 50 tubers was removed from each plot for scab index readings.

Scab indexes were determined for tubers from each plot according to a modification of the method used by Walker, Larson, and Albert (*5*). Tubers were divided into five classes: 0 to 5%, 5 to 25%, 25 to 50%, 50 to 75%, 75 to 100% of surface area scabbed. The number of tubers in each class was then multiplied by 0, 1, 2, 3, and 4, respectively. The sum of the products was then divided by the product of four times the total number of tubers. The quotient was then multiplied by 100 for the scab index. A scale of 0, for clean tubers, to 100, for all severely scabbed tubers, results.

1956 Results

Growing conditions during 1956 were excellent, with cool temperatures and ample moisture throughout the entire season.

Chemical analyses of tissue show a marked increase in percentage of nitrogen with increasing rates of UF-85 applied (Table I). Plants in the complete treatment plots showed severe nitrogen deficiency symptoms during late August and September, whereas plants in those plots, which were treated with UF-85 at rates of 150 and 250 gallons per acre, remained fully green until killed by frost. Plants in those plots treated with UF-85 at a rate of 50 gallons per acre showed slight nitrogen deficiency symptoms in mid-September. Increasing rates of UF-85 application had no apparent effect on the percentage phosphorus in the tissue. The percentage of potassium increased with increasing rates of UF-85 application, whereas the percentage of calcium was depressed. UF-85 at all rates of application increased the percentage of magnesium in the tissue over that in the complete treatment.

Potato yields (Table II) were significantly higher from plots receiving UF-85 at 150 and 250 gallons per acre than from plots receiving either UF-85 at a rate of 50 gallons per acre or no UF-85. This increase in yield can be attributed both to larger amounts of nitrogen added and to a lower rate of nitrogen loss due to leaching from urea than from ammonium nitrate nitrogen. A difference in loss of nitrogen due to leaching is indicated from a comparison of the complete treatment, in which 150 pounds per acre of nitrogen was applied as ammonium nitrate, and of the treatment in which 100 pounds per acre of nitrogen was applied—half as ammonium nitrate and half as UF-85. The latter resulted in plants having a higher percentage of nitrogen in the tissue and a slightly higher tuber yield than the former. The yield from the treatment which received UF-85 at a rate of 250 gallons per acre was significantly greater than that of the treatment which contained complete fertilizer but no UF-85—even though the stand of the former was reduced by 42%. The high levels of nitrogen which resulted in larger tuber yield increases had no effect on the specific gravity of the tubers.

High soil moisture conditions, which prevailed for most of the growing season, contributed the relatively low range of scab indexes (Table II). In 1956, application of nitrogen, phosphorus pentoxide, and potassium oxide caused a reduction in scab index (treatment 1 *vs.* 2, Table II), however, in 1957 this difference was not observed (treatment 1 *vs.* 6, Table III). This apparent reversal of results may have been caused by: a difference in soil microflora due to crop residues incorporated (in 1956 potatoes followed by potatoes; in 1957 red clover followed by potatoes,) or the action of Cl^- and SO_4^{--} in the fertilizer materials on the strongly acid soils used in 1956 may have resulted in liberation of toxic quantities of manganese, thus reducing scab, while in 1957, because the soil was less acid, such a reaction may not have taken place.

UF-85 at rates of 150 and 250 gallons per acre proved very effective for controlling the pitted type scab lesions. Less than 2% of the tubers examined from these treatments had pitted lesions as contrasted to approximately 10% for the complete and more than 50% for the check treatments. The scab index

Table I. Contents of Major Nutrient Elements in Upper Fourth of Irish Cobbler Potato Tops

(Plants variously treated with fertilizers and chemicals were grown on scab infested Vilas sand soil, 1956)

	Amount in Tissue (% on Dry Weight Basis)				
Treatment	N	P	K	Ca	Mg
Check (untreated)	2.68	0.78	4.15	1.96	0.86
Complete[a]	2.25	1.08	2.15	2.30	0.92
UF-85 (50)[b]	2.63	0.80	2.15	2.48	1.13
UF-85 (150)[b]	3.72	0.78	2.65	2.16	1.47
UF-85 (250)[b]	4.20	0.98	3.45	1.90	1.35
PCNB	2.66	0.68	2.50	2.02	1.05

[a] All treatments contained 230 pounds per acre of P_2O_5 and 300 pounds per acre of K_2O. The complete and PCNB treatments contained 150 pounds per acre of nitrogen as ammonium nitrate. The UF-85 treatments contain 50 pounds per acre of nitrogen as ammonium nitrate in addition to 50, 150, and 250 pounds per acre of nitrogen, respectively, from the UF-85.

[b] UF-85 rate of application in gallons per acre.

Table II. Results of Treatment of Irish Cobbler Potatoes Grown on a Scab Infested Vilas Sand Soil, 1956

Treatment Number	Fertilizer N Applied Lb./Acre[a]	Scab Treatment UF-85 in Gal./Acre PCNB in Lb./Acre	Yield, Bushel/Acre[b]	Stand[c]	Scab Index	Tubers Free from Scab, %[d]	Specific Gravity, G./Ml.
1	0	0	140	24	14.5	48	1.084
2	150	0	266	25	3.3	86	1.086
3	150	50 UF-85	276	25	2.0	94	1.092
4	200	150 UF-85	408	22	0.8	97	1.088
5	300	250 UF-85	372	14	2.2	92	1.084
6	150	50 PCNB[e]	254	25	1.0	96	1.090

[a] All treatments except number 1 contained 230 pounds per acre of phosphorus pentoxide and 300 pounds per acre of potassium oxide. The nitrogen total includes nitrogen from UF-85 which contains approximately 1 pound of nitrogen per gallon of material. All fertilizer was applied broadcast and worked into soils before planting.

[b] LSD 5% level, 56 bushels per acre.

[c] Number of plants in 30 feet of row. Average of two rows and four replicates.

[d] Tubers having 5% or less of surface area covered with scab.

[e] Applied Terraclor containing 20% active material.

Table III. Results of Treatment of Chippewa Potatoes Grown on a Scab Infested Vilas Sand Soil, 1957

Treatment Number	Fertilizer and Lime Applied, Lb./Acre[a] N	Lime	Scab Treatment, UF-85 in Gal./Acre PCNB in Lb./Acre	Scab Index	Tubers Free from Scab, %[b]	N in Tissue, %[c]	Yield Bushel/Acre[d]
1	0	0	0	22.0	30	4.30	249
2	50	0	50 UF-85	11.5[g]	63	4.62	259
3	150	0	150 UF-85	2.5[h]	90	5.02	284
4	100[e]	0	50 UF-85	7.8[g]	70	4.84	315[g]
5	150	0	150 UF-85	2.5[h]	90	4.80	362[g]
6	100[e]	0	0	25.8	16	4.84	315[g]
7	150	500	150 UF-85	1.5[h]	89	5.04	289
8	150	2000	150 UF-85	2.5[h]	90	4.96	238
9	100[e]	500	0	19.2	35	4.80	332[g]
10	100[e]	500	100 PCNB[f]	12.8[g]	50	4.75	275

[a] All treatments except numbers 1, 2, and 3 contained 200 pounds per acre of phosphorus pentoxide and potassium oxide. Treatment numbers 1, 2, and 3 contained no phosphorus or potassium fertilizer. Fertilizer and lime applied broadcast and worked into soil before planting except where noted. Nitrogen total includes nitrogen from UF-85 which contains approximately 1 pound of nitrogen per gallon of material.

[b] Tubers having 5% or less of surface area covered with scab lesions.

[c] Tissue samples taken from top fourth of plants on August 24, 1957.

[d] LSD 5% level = 50.0 bushels.

[e] Fifty pounds per acre of nitrogen applied as sidedressing when plants were 10 to 12 inches high.

[f] Twenty per cent active material.

[g] Significant at 5% level.

[h] Significant at 1% level.

or tubers from plots receiving 250 gallons per acre UF-85 was slightly higher than for those receiving 150 gallons per acre because the former treatment resulted in a greater percentage of russeted tubers. It is not definitely known whether the russeting observed was caused by *S. scarbies* or was a result of the high rate of UF-85 application. PCNB, applied at a rate of 50 pounds per acre, was also effective for controlling the pitted-type scab lesions.

1957 Results

High temperatures and near-drought conditions during July and August precluded optimum potato growth. However, these growing conditions were conducive to a higher incidence of scab than was reported for 1956.

There were no marked differences in tissue nitrogen between either amount or type of nitrogen fertilizer applied (Table III). This is in contrast to results of 1956 because of both a lack of leaching rains and the split application of the ammonium nitrate nitrogen. From a single application of UF-85, the urea nitrogen was apparently retained over the entire growing season and released at a rate which was not limiting for plant growth. The retention in the soil of the nitrogen from urea as UF-85 would suggest either an effective reduction of the nitrifying soil microorganism due to the free formaldehyde released or the presence of a series of urea-formaldehyde complexes which slowly break down to urea and formaldehyde.

Tuber yields were significantly higher for treatment numbers 4, 5, 6, and 9 than for the unfertilized potatoes. Lime at 2000 pounds per acre slightly reduced yields whereas at 500 pounds per acre, no effect on the yield was found. Tuber yields would have been considerably higher had the nitrogen, phosphorus, and potassium fertilizers been applied in the row instead of broadcast.

Dry soil conditions which prevailed during much of the 1957 growing season contributed toward a higher incidence of scab than was noted in 1956. Germination was not affected by a 150-gallon rate of UF-85 even though the potatoes were planted less than 2 hours after the UF-85 was applied. The data (Table III) show a definite and highly significant reduction of scab from UF-85 applied at a rate of 150 gallons per acre under conditions of low and high soil fertility and high soil fertility plus ground limestone. UF-85 applied at a rate of 50 gallons per acre also significantly reduced the scab under conditions of low and high soil fertility. These results indicate that UF-85 is effective for controlling scab under soil and weather conditions conducive to severe disease development.

Literature Cited

(1) Darby, J. F., Florida Univ. Agr. Expt. Sta. Research Rept., July 1956.

(2) Fink, H. C., *Plant Disease Reptr.* **40,** 190–2 (1956).

(3) Hooker, W. J., *Ibid.,* **38,** 187–92 (1954).

(4) Houghland, G. V. C., Cash, L. C., *Ibid.,* **38,** 777–80 (1954).

(5) Walker, J. C., Larson, R. H., Albert, A. R., *Am. Potato J.* **15,** 246–52 (1938).

Received for review November 13, 1957. Accepted May 14, 1958. Division of Fertilizer and Soil Chemistry, 132nd Meeting, ACS, New York, N. Y., September 1957. Contribution from Department of Soils, University of Wisconsin, Madison 6, Wis. Published with permission of the director of Wisconsin Agriculture Experiment Station and supported in part by Allied Chemical and Dye Corp., Nitrogen Division.

QUICK CURING OF SUPERPHOSPHATE

Effect of Ball Mill Grinding on Acidulation of Phosphate Rock

R. R. ROUNSLEY[1] and D. R. BOYLAN

Chemical Engineering Department, Iowa State College, Ames, Iowa

An investigation was undertaken to determine the effect of grinding during the acidulation of phosphate rock. Bench-scale work was carried out in a 1-quart, laboratory ball mill made of stainless steel, which was equipped with a heating chamber so that the material could also be dried in the mill. A normal superphosphate product suitable for commercial use was obtained within an hour after the addition of the first acid. Successful pilot plant operation showed that the bench-scale results could be duplicated on a larger scale and on a continuous or semicontinuous basis. An economic comparison of the process with an equivalent standard normal superphosphate process indicated that this quick-curing process was competitive, if not favored.

In the usual manufacture of normal superphosphate, the required amounts of sulfuric acid and phosphate rock are mixed and allowed to "set up" in some kind of closure. The resulting porous solid is mechanically disintegrated and transferred to piles for curing while the chemical reactions are allowed to go to completion. During this curing period of from 4 to 6 weeks, the free acid and free moisture contents are reduced and the available phosphorus content is increased.

Processes in which the curing period is reduced or eliminated entirely are referred to as quick-curing processes. Their advantages (*3, 5*) include: product can be shipped directly from process, thus reducing bulk storage space required and working capital tied up in inventory; opportunities for producing a granular product are greater; operating conditions can be chosen with more flexibility for attaining maximum conversion; and production rates can be adjusted to meet an almost instantaneous demand because the final product can be produced in a matter of hours.

Previous Work

A close approach to a quick-curing process was first achieved in this country when the Davison Chemical Corp. (*19*) granulated fresh superphosphate in a rotary drum and dried it in a rotary dryer. Bridger and Kapusta (*5*) developed a quick-curing process at Iowa State College in 1952 in which 50 to 65% sulfuric acid was used and a product, ready for immediate shipping was produced.

In 1953, a process was announced in Japan (*15*) in which the reaction between sulfuric acid and rock was promoted by

[1] Present address, Mead Corp. Chillicothe, Ohio.