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TESTING OF COPPER FUNGICIDES FOR CONTROL  
OF TOMATO BLIGHT IN SOUTHWEST VIRGINIA

by

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A Thesis Submitted to the Graduate Faculty  
for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Plant Pathology

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## INTRODUCTION

The defoliation diseases of tomato are probably responsible for a greater percentage of the losses experienced in the tomato crop than any other group of tomato diseases. It is extremely rare to find a tomato planting without some foliage disorder.

Premature defoliation of tomatoes may be caused by a number of agents. The most conspicuous of these agents, and therefore the causes which seem most subject to direct control, are three fungi which may occur singly or in a complex of two or more. The destructiveness of these fungi, like that of most pathogens attacking the aerial parts of plants, is influenced by a number of environmental factors, rainfall and temperature being especially important. The mean average temperature in different sections of the country is usually considered to determine which particular pathogen will predominate. In the Southern states where temperatures are high, Alternaria solani (E. and M.) Jones and Grou, the cause of early blight, predominates and is extremely destructive if the moisture conditions are favorable. In the more temperate regions, as Wisconsin, Michigan, Indiana, Ohio and New Jersey, Septoria lycopersici Speg. the cause of Septoria leaf spot develops abundantly and A. solani is less important. In the intervening areas between the Northern and Southern states these organisms are widespread and are probably of equal importance.

Phytophthora infestans (Mont.) de By., the cause of late blight of tomato, is limited to areas where the humidity is moderately high and the night temperatures are low. Severe losses of tomatoes caused by P. infestans have been reported from southwest Virginia, West Virginia, New York, Connecticut and Massachusetts.

The diseases caused by these foliage pathogens bring about a progressive defoliation of the plants beginning with the lower leaves and, if the environment is favorable, extending to the upper-most leaflets. As a result, the yield and quality of fruit are greatly reduced. Alternaria solani and Phytophthora infestans may also attack the fruits causing large surface lesions which are soon invaded by rot producing organisms.

The control measures applied to the tomato foliage diseases by the growers have been generally unsuccessful or unprofitable. Certain fungicides, as Bordeaux mixture, properly applied to tomato plants will definitely protect the plants against infection. But Bordeaux mixture, applied in a sufficient number of sprays to give adequate protection throughout the growing season, frequently stunts the growth of the plants, delays the maturity of the crop and, under certain conditions, results in treated plants yielding less than the untreated plants.

Of the many new fungicides developed in recent years, the fixed or insoluble coppers are now widely used on a variety of crops, especially vegetables. They are relatively cheap, easily applied and appear to be less injurious to plant growth than Bordeaux mixture. An investigation of the value of two of these fungicides, cuprous oxide and tribasic copper sulfate, for the control of tomato diseases in Southwest Virginia is here reported.

## PERTINENT LITERATURE

The organisms that produce the foliage diseases of tomato have been known for many years and have been found to cause crop losses in certain seasons wherever tomatoes are grown. Late blight is the oldest of these diseases, first having been observed on tomatoes in England in 1847 by Payen (69) who described the symptoms on the fruit as follows: "This substance, of a russet brown colour, had consolidated the tissue, more or less deeply, around the point of insertion of the stalk." He observed the mycelium in the diseased tissue as well as the ovoid spores with a protuberance at the apex. He concluded from his studies that the disease on tomato fruits was caused by the same fungus as was the late blight of potato Botrytis (Phytophthora) infestans. In America, Thaxter (93) observed late blight on tomato leaves and fruit in 1889 in Connecticut and Maine. A little later in 1897, Beach (7) reported what was undoubtedly late blight on tomato fruits on plants growing in a forcing house in New York. Selby (85) observed a similar disease on tomatoes in forcing houses and gardens in Ohio about this same time. According to Smith (88) the winter tomato crop in certain sections of southern California was completely ruined by late blight in 1906. The prevailing temperature in these sections was warm in the day time and cool at night.

In 1911 Reed (77) reported that the culture of tomatoes in southwestern Virginia had become increasingly difficult during the previous five years, due to a serious leaf blight and fruit rot caused chiefly by Phytophthora infestans. Similar reports (18, 27, 46, 77, 91) from other sections of the United States show that late blight has caused serious losses in the tomato crop during certain seasons. It is quite evident

from these reports that late blight is a very destructive disease and that its development is largely dependent on seasonal factors.

Payen (69), as well as many other workers who followed, observed the similarity between the late blight of tomato and late blight of potato. Plowright (70), McAlpine (53) and Read (78) considered the pathogens from the two hosts identical but later workers, as Berg (8), Giddings and Berg (28), Melhus (58) and Roder (80), reported that the degree of pathogenicity of the organisms obtained from the two hosts was not the same. While the evidence indicated that the initial infections of tomato originated from potato, it was not until recently that the complete story was known.

Reddick and Mills (79) showed that the virulence of the potato strain of the late blight pathogen could be increased by passing it through a series of relatively resistant varieties of potato. These authors also demonstrated that the virulence of the tomato strain for tomato was lost after the organism had been grown on slices of raw potato tuber for a few generations. Mills (60) found that the virulence of the potato strain for tomato could be built up until it was identical with that of the tomato strain by seven serial passages through tomato. In nature, this number of generations would cover a period of four to six weeks, which he contends, accounts for tomato blight always occurring later in the season than potato blight. He concludes that the inoculum for the initial infection of tomato by the late blight pathogen in nature usually comes from potato.

Septoria leaf spot was first reported on tomatoes in Argentina in 1882 by Spegazzini (90) who named the pathogen Septoria lycopersici. The disease was first observed in England by Güssow (33) in 1908. In the United States, Earle (19) states that Septoria leaf spot first attracted attention in Alabama about 1894. In a survey made in 1916, Levin (48)

found that *Septoria* leaf spot was reported from every state in the eastern half of the United States and also from California. Norton (67) in 1924 described leaf spot as the most common and destructive disease of tomato in Maryland. He observed that it was more severe during seasons, and on soils that are relatively unfavorable for vigorous plant growth. Humbert (43) in 1918 observed that *Septoria* leaf spot occurred in nearly every garden and field in Ohio. The losses were said to vary from slight to very severe. Pritchard and Porte (74) showed that there was a correlation between humidity and the occurrence of *Septoria* leaf spot. The average relative humidity was found to be highest in sections where the disease was most severe, namely, New Jersey, Delaware, Maryland, and Virginia. They explained the absence of leaf spot in the South in mid-summer on the basis that the high temperatures which prevail during this period inhibit sporulation of the pathogen. The maximum temperature for sporulation was given as 80.5° F. (27° C.).

Pritchard and Porte (74) found that the minimum temperature for sporulation for *S. lycopersici* was 59° F. (15° C.). On the basis of this information, they recommended that large vigorous plants be set early in the season, and that cultural practices be adopted that will bring about as much growth as possible before temperatures favorable for infection are encountered. Muncie (64) reported that under conditions existing in Pennsylvania the leaf spot fungus first appears in the field on a few plants during the early part of July and then spreads from these primary infections to the rest of the crop. He concludes that wind, rain, and man are the principal agents of dissemination.

Early blight of tomato was definitely known to occur in the United States as early as 1897. The causal fungus was observed first on potato by Ellis and Martin (22) who in 1882 named it *Macrosporium solani* E. and

M. In 1897 Jones and Grout (45) re-named it Alternaria solani (E. and M.) Jones and Grout on the basis that spores were sometimes borne in chains.

The most serious losses from early blight have been reported from the Southern states, especially Louisiana and Mississippi (20). The occurrence of early blight in destructive proportions in these southern areas may be accounted for in part by the rather high optimum temperature requirement of the pathogen which was determined by Rands (76) and by Nightingale and Ramsey (66) to be 80° F. (26.6° C.).

The influence of plant nutrition on the occurrence of the foliage diseases on tomato plants has been investigated to a limited extent. Pritchard and Forte (73) studied the development of Septoria leaf spot on plants grown in soil supplied with varying amounts of different plant nutrient elements. The data from their experiments are not published in full but are illustrated graphically. It appears from the graphs that on plants supplied with a normal amount of phosphorus and potassium and 0, 50, 150, 300 and 500 parts per million of nitrogen, the average number of lesions per square inch of leaf surface decreased from approximately ten at 0 p.p.m. of nitrogen to about four at 500 p.p.m. Varying the supply of phosphorus and holding the nitrogen and potassium constant did not appear to cause a consistent fluctuation in the number of lesions. If the nitrogen and phosphorus were deficient and increasing amounts of potassium were applied, there was a regular increase in the number of lesions developing per given area. These experiments were not extensive enough to warrant any definite conclusion, but the data suggest that nutrition may influence to a limited degree the reaction of tomato plants to the foliage disease pathogens.

No reports are available to show the influence of plant nutrition on the development of Phytophthora infestans on tomato but Vowinkel (98) made studies of this nature on potato. In his studies nitrogen, potassium, phosphorus and magnesium were each in turn omitted from the nutrient solution applied to potato plants growing in sterilized sand. The growth of the fungus on these plants was then observed. Sporulation was profuse on the plants that received a complete nutrient solution and on plants that received a solution with either nitrogen, phosphorus or magnesium omitted but it was sparse on plants that received a nutrient solution with potassium omitted.

McNew (55) in tests conducted in New York found that increases in yields as a result of spraying or dusting were directly correlated with the effectiveness of the fertilizer used in promoting plant productivity. No fertilizer treatment, however, prevented defoliation on unprotected plants.

Horsfall and Heuberger (40) and, more recently, Barratt and Richards (6) have demonstrated that factors which hasten "physiological" maturity of tomato plants, such as, early planting, heavy fruit load and deleafing, hasten defoliation of the plants by Alternaria solani while factors that retard "physiological" maturity, such as, defruiting and late planting, retard defoliation. Norton (67) observed that plants injured by prolonged wilting in dry weather were attacked more readily by Septoria lycopersici than actively growing plants. Moore and Thomas (62) showed that young plants that were allowed to remain in a wilted condition for a period of time before transplanting were more susceptible to injury by Alternaria solani than plants not permitted to wilt. The use of fertilizers, pruning,

time of planting, etc., while influencing the response of the tomato plant to the pathogens, do not appear to offer any indications of serving as control methods.

The most efficient control of the tomato foliage diseases must be based on a thorough knowledge of the source and method of transfer of the inoculum. It has been demonstrated for each of these diseases that the pathogen may be transmitted on infected crop refuse and on seed taken from diseased fruits. Boyd (11) reported that Phytophthora infestans appeared to have been carried overwinter on refuse in one field in Massachusetts where a late crop of tomatoes had grown the previous season. Later, he found that seed taken from diseased tomato fruits were often infested with P. infestans and that seedlings grown from such seed frequently developed primary infections by the late blight organism. Pritchard and Porte (75) found that Septoria lycopersici overwintered on old diseased plants but not in the soil. On the basis of this information they recommended that crop refuse be plowed under in the fall. Endrinal and Celino (23) working in the Philippine Islands showed that spores of S. lycopersici remained viable for as long as six months on dried leaves and that this pathogen persisted from one season to the next in the form of spores or mycelium on diseased plant material. They also found that the fungus could be transmitted on the seed.

Massee (52) in 1914 found hibernating mycelium of Alternaria solani on the surface of tomato seed and within the seed-coat. More recently, Miller and Crosier (59) examined 468 lots of tomato seed for seed borne pathogens and found an average of 1.84 per cent of the seed in these lots

infested with A. solani. Treatment of the seed with bichloride of mercury reduced the percentage of infestation to 1.01 per cent. The failure of the surface disinfection to eliminate the pathogen from all of the infested seeds indicates that some of the fungus was internal. One lot of the seed, which was found to contain 1.57 per cent infested seed, was planted in virgin soil along with another lot of disease-free seed. The seedlings that grew from the lot containing infested seed became heavily infected with A. solani while the seedlings from the disease-free seed were healthy.

Moore, Thomas and Vaughan (63) made extensive studies over a period of four years to determine whether the incidence of seedling infection by A. solani could be reduced by seed treatment. Several methods of treatment were employed including a hot water treatment which would destroy the organism within the seed as well as on the surface. The treated seed was then planted in the open in soil known to have been free of solanaceous crops for ten years or more. With one possible exception, the results of their tests indicated that seed treatments were of no value in reducing seedling infection under field conditions. In 1939 seedlings from seed treated with a double treatment of liquid Ceresan followed by Cuproicide dust showed significantly fewer infections than seedlings from untreated seed. In the other three years of the test the Ceresan-Cuproicide treatment gave no reduction in the number of infections.

Sampson, Nugent and Shenberger (84) found only two seeds internally infected with A. solani in 5659 examined from a lot of seed taken from cull fruits showing an abundance of early blight infection. In 15,590 seeds extracted from fruits of marketable quality none was found internally

infected. They concluded from their studies that the initial infection of seedlings growing under field conditions could not be accounted for on the basis of seed transmission of the pathogen. Sampson and Thomas (85) state that A. solani occurs naturally in the soil in all parts of Indiana, regardless of the previous tomato crops. Moore, Thomas and Vaughan (63) claim that there is a widespread occurrence of A. solani in the soil of certain sections of the South but their data on this subject have not been published. In a test conducted in Indiana, Thomas (94) grew tomato seedlings from disease-free seed in soil that had grown tomatoes the previous season and in soil that had grown soy beans. In the seedlings following tomatoes, 5.9 per cent contracted collar rot infection caused by A. solani while in those following soy beans only 0.4 per cent showed collar rot infection. In Georgia, Van Haltern (96) showed that A. solani could overwinter in soil that had grown tomatoes the previous season, but the results of his tests indicated that diseased seed was a more important source of inoculum for seedling infection than infested soil.

The available reports cited above show that the pathogens causing tomato foliage diseases overwinter in the field on crop refuse and may be transmitted on the seed. In addition, Phytophthora infestans is transmitted in seed potatoes and spreads from the early potato crop to tomatoes. Therefore, a control program for the tomato foliage diseases should include crop rotation, the use of disease-free seed, isolation of the tomato crop from potatoes and general sanitation measures to reduce the amounts of the primary inocula.

The application of measures to reduce the amount of the primary inoculum has not proven effective enough to control the tomato foliage diseases; and, therefore, other control measures have been sought. The most desirable control measure would be the use of resistant varieties and a number of studies on varietal resistance have been made.

Reed (77) observed that the "Cherry" and "Plum" varieties were able to withstand late blight while the large fruited varieties were completely destroyed. Jatzynina (44) working in Russia tested several varieties for resistance to Septoria leaf spot and late blight and found the varieties Mikado and Modern No. 1 to be the most resistant of those tested but the degree of resistance was not recorded. In Germany, Boock (9) found the Lucullus variety to be partially resistant to late blight. In the United States, Manns (50) tested some of the popular commercial varieties and found them all to be very susceptible to early blight. Andes (3) observed that a few of the commercial varieties of tomato possess partial resistance to early blight and Septoria leaf spot. Crosses were made between some of these varieties that showed partial resistance, in an attempt to incorporate the resistance factors into one line. This investigation is still in progress. Wright and Lincoln (107) and Alexander, Lincoln and Wright (1) tested 448 tomato accessions representing five species of the genus Lycopersicon for resistance to the diseases occurring in the United States. Only one accession of L. esculentum P. I. No. 129069 was found to be resistant to Alternaria solani. Six of the accessions of Lycopersicon hirsutum proved to be resistant to Alternaria solani and Septoria lycopersici. Locke (49) succeeded in crossing Lycopersicon esculentum and

a resistant accession of L. hirsutum. The  $F_1$  plants of this cross were resistant to Septoria lycopersici and moderately susceptible to Alternaria solani.

Since desirable varieties of tomato resistant to the foliage diseases are not available at present, it is necessary that other more temporary control-measures, such as the application of fungicides, be employed. An intensive investigation into the use of fungicides has been made, especially during the last ten years.

The first experiments with the use of a fungicide to control the foliage diseases of tomato (probably late blight and early blight) were carried on by Halsted (34) in 1894 and 1895. He found that Bordeaux mixture gave partial control of these diseases, especially on the fruits. About that same time Earle (19) reported using Bordeaux mixture on tomatoes for the control of Septoria leaf spot and early blight in Alabama. In his experiments, one application of Bordeaux mixture prevented the spread of the Septoria leaf spot but it apparently required three or four applications to control early blight. Powell (71) reported in 1898 that variable results were obtained from the use of Bordeaux mixture on tomatoes in Delaware. In some cases the unsprayed plants yielded more than the sprayed ones while in other cases they yielded less. The first extensive testing of different fungicides on tomatoes was probably that carried on by Reed (77) in Virginia in 1911. Three applications of a 4-5-50 Bordeaux mixture gave excellent control of late blight and Septoria leaf spot but the same number of applications of a 1-33 lime-sulfur spray only gave slight control. Fromme (25) in experiments conducted in 1918-1919 was able to

increase the yields of sound fruit about 70 per cent by applying Bordeaux mixture with resin-fish-oil soap as a wetting agent. In his tests copper-lime dust also proved to be very effective in the control of *Phytophthora* fruit rot. In experiments conducted in eastern Virginia, Geise, Zimmerley and Spencer (26) and Davis, Spencer and Zimmerley (16) showed that spraying with Bordeaux mixture or dusting with copper-lime dust increased the yield of tomatoes. On the basis of the results of experiments conducted in a number of localities, Pritchard and Clark (72) rated the efficiency of the fungicides used in their tests as follows: copper-soap spray, first; soap-Bordeaux mixture, second; and, Bordeaux mixture, third.

While it has been clearly demonstrated that the use of Bordeaux mixture on tomatoes under certain conditions gives substantially increased yields, it has been equally as well proven that under other conditions no increase, or even a decrease may occur. Edgerton (21), Boyle (13), Martin (51), Whipple and Walker (100), Horsfall, Magie and Suit (42) and Wilson and Runnels (106) have shown that Bordeaux mixture delays the date when the highest yield of ripe fruit is obtained and frequently results in decreased total yields.

The possibility of using other fungicides that would be less injurious to the plants than Bordeaux mixture received little attention until about 1935 when Horsfall and Hamilton (38) and Wilson and Runnels (106) began studies on the use of such materials as copper oxychloride, copper phosphate and cuprous oxide. These forms of copper were found to be much less injurious to tomato plants than Bordeaux mixture and at the same time gave considerable protection against infection. It was observed by Muncie

and Knight (65) in Michigan and Wilson (101) in Ohio, however, that these materials caused a reduction in yield, but to a less extent than Bordeaux mixture, if the foliage diseases were not a factor.

Gilbert (29) compared the relative efficiency of 12 fungicides for the control of foliage diseases on tomatoes in Rhode Island in 1939. The highest yields of marketable fruits were obtained with a Cuprocide-celite dust mixture. In his test the fungicides applied as dusts gave higher yields of No. 1 fruits than the same fungicides applied as sprays. Harrison (35) found that tomato plants treated with Cuprocide spray for the control of early blight produced more marketable fruits than plants sprayed with homemade Bordeaux mixture, commercial Bordeaux mixture or Copper Hydro "40".

Green and Ashworth (32) tested seven fungicides in an experiment conducted in England on the control of Phytophthora infestans on tomatoes. The best results were obtained with two proprietary copper-containing mixtures designated as C and D. Bordeaux mixture and Burgundy mixture gave the next best control and lime sulfur was practically worthless. In Denmark, Gram and Thomsen (31) obtained partial control of P. infestans on tomatoes by spraying with "Nosperit" (a product of Hoechst Farbwerke). Drummond (17) used "Nosprasil" on tomatoes in Brazil for the control of Septoria lycopersici. Twenty-five plants sprayed with "Nosprasil" yielded 609 fruits while the same number of unsprayed plants yielded only 175 fruits.

In Queensland, Veitch (97) found that the insoluble copper fungicides were as effective in controlling tomato foliage diseases as Bordeaux

mixture and had the advantage of not reducing the yield to as great an extent as Bordeaux mixture. Basic copper carbonate with kaolin and dehydrated copper sulfate with lime, applied as dusts, gave as effective disease control as spray mixtures during seasons only moderately favorable for infection, but the dusts were less effective than the sprays during seasons favorable for an epiphytotic.

Göpfert (30) in Germany used Wacker's Bordeaux mixture at 1.0, 1.5 and 2.0 per cent dilutions for the control of Phytophthora infestans on tomatoes. The highest yields were obtained from plants sprayed with the 2.0 per cent dilution which gave practically complete control of late blight. In Trinidad, Bryant (14) recommended using Burgundy mixture on tomatoes for the control of Septoria lycopersici.

Taylor, Child and Leach (92) tested the value of six fungicidal sprays for controlling tomato early blight in 1942. In their test Fermate proved superior to all the other fungicides used. In 1943, Fermate was further tested but in that year it was applied in several dust mixtures. The effectiveness of these different dusts for controlling Alternaria solani on tomatoes in 1943 were rated in the following descending order: 10% Fermate, 5% Fermate plus 10% sulfur, 5% Fermate, 2.5% Fermate and 6% copper oxychloride.

Heuberger and Hanns (36) reported in 1943 that the addition of zinc sulfate and lime to certain spray mixtures increased their efficiency in controlling A. solani on potatoes. Disodium ethylene bisdithiocarbamate (He 175) used alone gave 40% control but used with zinc sulfate and lime it gave 92% control; Yellow Cuproside used alone gave 68% control and with

zinc sulfate and lime, 86% control.

The practicability of applying fungicides on the commercial plantings of tomatoes in eastern Virginia remains in doubt. While the early investigations conducted in this section indicated that a considerable increase in yield might be obtained from spraying or dusting (16), more recent tests have shown that this may not be true for all seasons (68). Cook and Nugent (15) stated that observations over a period of years indicate that the foliage diseases are not of economical importance more often than about one year in five in eastern Virginia. Considering the low margin of profit in the tomato crop, it would not be economical to spray every year in order to obtain protection during the occasional year when foliage diseases are destructive. This observation, however, does not apply to southwest Virginia where the diseases are moderate to severe nearly every year.

The reports from the various sections where fungicides have been employed on tomatoes appear to indicate that the value of fungicidal applications in bringing about larger yields is dependent on the severity of the epiphytotic. According to Wilson (103), increases in yield from dusting or spraying with fixed coppers are seldom obtained unless the defoliation of untreated plants is at least 20 per cent. For Bordeaux mixture the defoliation of unsprayed plants must be from 30 to 40 per cent before increases in yield can be obtained (102).

## EXPERIMENTAL

The present investigation into the control of tomato leaf diseases in southwest Virginia may be conveniently grouped into three phases as follows: (1) 1940-1942 field experiments, in which tribasic copper sulfate and cuprous oxide, used as sprays and as dusts, were compared with Bordeaux mixture and with an untreated check; (2) 1943 field experiment, in which tribasic dust was compared with cuprous oxide dust and with an untreated check, the fungicidal treatments being made on plots receiving normal fertilization and on plots receiving supplemental applications of nitrate of soda; and (3) laboratory and greenhouse studies, in which the fungicidal dusts were further compared by a standardized technique suggested by the American Phytopathological Society, Committee on Standardization of Fungicidal Tests.

### Field Experiments 1940-1942

The field experiments were all conducted on the experimental farm of the Virginia Agricultural Experiment Station, Blacksburg, Virginia. The plan of the field studies was not changed during the three years, 1940-1942. In 1940 an early killing frost terminated the experiment when approximately one-third of the fruit of the later varieties had ripened. Therefore, the results of the 1940 test are only briefly presented for the single early variety which matured 80 to 90 per cent of its fruits before the frost occurred.

### Materials and Methods

The plots were arranged in a split-plot design in which three varieties and six treatments were used. The varieties were Earliana (early), Pritchard (medium early), and Marglobe (late). Since these varieties differ in date of maturity and yielding ability, the data on each variety have been analyzed separately. In the statistical analyses the data for each year were handled separately, because 1941 was extremely dry in late summer and conditions were unfavorable for the foliage disease organisms, while in 1942 heavy rains occurred and the environmental conditions were quite favorable for these organisms. The same area of ground was used for the experiment each year. It was first planted to tomatoes in 1940. Previous to that date it had grown various field crops.

The field was approximately 66 feet wide by 450 feet long. It was divided lengthwise into three sections that were planted to the three varieties. The treatment plots were arranged crosswise or at right angles to the varietal section. Each individual plot contained  $1/121$  acre in which 30 plants were planted in five rows 4 feet apart with the plants 3 feet apart in the row. The treatments were replicated four times. The plants were grown in the greenhouse and transplanted to the field about June 1. A 4-12-4 fertilizer was broadcast at the rate of 600 pounds per acre just before setting. A side application of nitrate of soda (about 50 pounds per acre) was made after the first fruits were set.

The fungicidal applications were started on July 1 and repeated at about ten-day intervals. In 1940 weather conditions delayed setting of the plants two weeks and the fungicidal applications were started the first

week of July. Five applications were made. In 1941 the July 1 application was omitted on Pritchard and Marglobe since they were not sufficiently advanced in maturity at that time. The last application in 1941 was made on August 20, making a total of six applications on Earliana and five on Pritchard and Marglobe. In 1942 all varieties received five applications, the last being made on August 15.

The early sprays were applied with a small motor driven sprayer of the wheelbarrow type. A pressure of about 150 pounds was maintained. The last two spray applications in 1941 and the last one in 1942 were made with a large power sprayer, operated at a pressure of about 225 pounds (see Plate 1A). The sprays were applied from a single nozzle on a short rod. The plants were sprayed thoroughly but were not drenched.

The dusts were applied with a motor driven duster (Messinger). This duster was made for row dusting, being equipped with four dust outlets, but for these tests, three of the openings were closed and a long flexible tube connected to the fourth. A man held this tube and applied the dust to the plants from all sides. In this way the foliage was uniformly covered with a minimum amount of dust. In order to prevent drifting of the dust on to the adjacent plot a heavy cloth was spread over the border row while the dust was being applied (See Plate 1B).

The fruits were harvested at frequent intervals and graded into four grades : No. 1, No. 2, culls, and rots. Each grade was then weighed and recorded as pounds per plot. The specifications for U. S. grades were followed except for color. The fruits were sold for table use and it was necessary to pick them when they were only partially colored; otherwise the

Plate 1

Views showing the methods of applying fungicides to tomatoes on experimental plots. A, Applying a spray by means of a power sprayer. The spray applications in early season were made with a smaller spray rig. B, Applying a dust with a Messinger motor-driven duster.



A



B

No. 1 and No. 2 grades met U. S. specifications for canning stock. The weights of rotted fruits in 1942 do not represent all the fruits that should have been in this class, since many fruits destroyed by soft rot were mashed and lost in picking. In 1941 soft rot was of minor importance.

The materials employed in these studies were tribasic copper sulfate and cuprous oxide, each used in the form of a dust and spray, and Bordeaux mixture spray. The tribasic copper sulfate dust used was mixed especially for our test by the Tennessee Copper Company. It contained  $12\frac{1}{2}$  pounds of tribasic copper sulfate (53.0 per cent metallic copper), 20 pounds of wheat flour, and  $67\frac{1}{2}$  pounds of clay. The cuprous oxide used in the preparation of the copper oxide dust was manufactured by Rohm and Haas Company, but the dust mixture was prepared by Southern States Cooperative especially for our use. Red cuprous oxide was used in 1941 and the dust mixture contained 5.1 per cent metallic copper; whereas in 1942, the yellow cuprous oxide was used and the metallic copper content of the dust mixture was reduced to 4.1 per cent. The copper oxide dust used in the first three applications in both seasons contained, in addition to the copper, 20 per cent calcium arsenate. The dust used in subsequent applications, however, contained no calcium arsenate.

The tribasic copper sulfate used as a spray was manufactured by the Tennessee Copper Company and it analyzed 53.9 per cent metallic copper. The spray mixture contained four pounds tribasic copper sulfate and one pound soybean flour to 100 gallons water. The soybean flour was made into a thin paste by stirring with a small amount of water, after which it was added to the spray tank.

The copper oxide for the spray was manufactured by Rohm and Haas Company and sold under the trade name of "Yellow Cuprocide." It contained 83 per cent metallic copper and was used at the rate of 1½ pounds to 100 gallons of water.

The Bordeaux mixture used in these tests was a standard 4-5-50 Bordeaux mixture prepared from powdered copper sulfate and agricultural hydrated lime.

#### Results of 1940 Test

As mentioned above, the yield records on Pritchard and Marglobe were incomplete as a result of an early frost. The data obtained on Earliana and the incomplete data on Pritchard and Marglobe, however, clearly showed that the yields of tomatoes could be greatly increased by the use of fungicides. The greatest increases in the short season of 1940 were with tribasic copper sulfate and cuprous oxide, applied either as a spray or a dust. The yields of the plots sprayed with Bordeaux mixture were significantly less than those from the plots treated with the other fungicides. The Bordeaux mixture sprayed plots were found not to differ significantly from the unsprayed check. On Earliana the average yield was slightly higher than that of the check, but on Pritchard and Marglobe it was lower than the checks. The calculated per-acre yields of ripe fruits for the different treatments on Earliana were as follows:

Cuprous oxide spray - - - - -	14.14 tons <sup>1/</sup>
Cuprous oxide dust - - - - -	14.77 tons
Tribasic copper sulfate spray - - - - -	12.35 tons

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1 The yields given were calculated from the average of four plots of 25 plants each. In 1940 the fruits were not graded; therefore, these yields include some fruits that should have been classed as culls.

Tribasic copper sulfate dust - - - - -	14.54 tons
Bordeaux mixture spray - - - - -	9.96 tons
Check - - - - -	9.19 tons

### Results of 1941 Test

The yield data obtained from the 1941 experiment are given in table 1 and graphically illustrated in figure 1 and 2. The yields at the several pickings have been grouped so as to give the total yields for 10-day periods, beginning August 8. It will be noted that no fruits were picked from the Pritchard variety during the first 10-day period nor from the Marglobe variety during the first two 10-day periods. This means that Pritchard began ripening fruit 10 days later than Earliana, and Marglobe 20 days later than Earliana. In 1941 there was a significant difference in yields of the three varieties. The total yield of No. 1 and No. 2 fruits from all treatments was 6469 pounds for Earliana, 5264 pounds for Pritchard, and 4494 pounds for Marglobe. A study of the weather records given in table 3 will reveal the reason for the larger yield of the earlier maturing varieties. There was an abundance of rainfall in June and July, but in August and September the rainfall was deficient. Earliana, having made all of its initial growth in the favorable season of June and July, ripened an abundance of fruit in the dry month of August. On the other hand, the growth of the later maturing varieties was not sufficiently advanced to escape damage from the dry weather in August and September. Marglobe, the latest of the three varieties, was affected most by the drouth. Because of the influence of this seasonal factor, a comparison between varieties is not justified, although there may have been some differences in varietal susceptibility.

Table 1.—Yield of tomatoes in 1941 from plots approximately 1/30 acre <sup>1</sup>

Treatment	Harvest dates	Earliana				Pritchard				Marglobe			
		No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Tribasic dust	8/2-8/11	16.8	8.8	6.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12-8/21	50.3	39.5	22.0	12.3	6.3	3.8	12.0	0.8	0.0	0.0	0.0	0.0
	8/22-8/31	201.8	106.5	52.5	20.8	64.5	19.0	12.0	1.8	17.0	12.8	2.8	1.9
	9/1-9/10	284.3	197.3	74.5	18.0	294.3	79.8	24.5	9.8	150.2	35.0	5.2	5.9
	9/11-9/20	102.0	77.5	53.3	9.0	268.3	113.5	43.3	8.3	253.3	92.4	21.8	4.0
	9/21-9/30	20.3	24.5	33.8	6.3	59.5	31.5	60.5	4.5	97.0	58.5	58.5	6.3
	10/1-10/10	2.0	4.3	12.3	2.5	5.3	13.3	62.5	5.5	25.3	45.3	67.2	5.3
Total		677.5	458.4	254.4	73.4	689.2	260.9	204.8	30.7	542.8	244.0	155.5	28.4
Copper oxide dust	8/2-8/11	15.8	8.8	7.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12-8/21	64.5	37.5	31.3	11.5	3.3	3.3	1.5	0.8	0.0	0.0	0.0	0.0
	8/22-8/31	177.5	121.5	64.0	22.3	67.2	18.1	15.1	4.9	16.3	16.1	4.6	1.2
	9/3-9/10	301.0	144.3	96.8	19.8	261.0	75.3	21.6	10.5	135.2	38.3	7.7	5.4
	9/11-9/20	114.0	68.3	79.5	8.3	266.1	138.2	50.9	5.9	255.2	114.3	29.7	6.7
	9/21-9/30	27.3	30.0	32.3	3.5	36.6	29.3	50.9	3.5	77.7	42.5	56.9	5.6
	10/1-10/10	1.5	3.3	4.3	2.0	4.5	10.3	43.5	4.0	14.5	22.4	52.4	4.8
Total		701.6	413.7	315.2	65.2	638.7	274.5	183.5	29.0	498.9	233.6	151.3	23.7
Copper oxide spray	8/2-8/11	19.5	10.8	6.3	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12-8/21	71.8	37.5	25.0	7.3	5.5	3.5	2.5	1.8	0.0	0.0	0.0	0.0
	8/22-8/31	216.0	111.5	55.0	15.5	58.8	21.3	11.8	2.3	16.1	16.5	5.1	2.5
	9/3-9/10	322.8	148.3	69.5	19.8	252.3	53.8	18.0	10.3	120.3	34.0	4.7	5.5
	9/11-9/20	119.0	67.8	48.5	10.5	229.3	117.5	35.0	6.8	255.6	99.4	25.3	7.6
	9/21-9/30	60.8	32.0	41.5	7.0	67.5	49.5	58.0	3.3	103.9	62.1	55.4	4.2
	10/1-10/10	6.0	4.0	10.0	3.3	12.0	20.0	64.5	6.8	17.3	32.0	54.0	4.1
Total		815.9	411.9	255.8	61.2	625.4	265.6	189.8	31.3	513.2	244.0	144.5	23.9
Check	8/2-8/11	17.6	9.8	8.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12-8/21	58.9	51.6	57.7	14.3	7.8	4.8	2.3	1.5	0.0	0.0	0.0	0.0
	8/22-8/31	169.3	123.4	79.2	24.1	87.3	28.0	30.3	4.0	34.0	18.2	11.5	3.7
	9/3-9/10	118.4	85.0	86.2	21.4	207.0	89.5	48.5	16.8	158.0	61.9	22.7	8.3
	9/11-9/20	24.2	21.3	65.8	13.3	124.0	85.3	70.8	14.3	179.3	105.8	61.1	8.8
	9/21-9/30	0.3	1.8	8.8	2.3	4.3	5.5	56.3	4.0	31.1	25.9	62.1	3.1
	10/1-10/10	0	0.5	1.8	1.5	0.3	2.5	24.5	5.5	4.7	13.8	40.1	4.1
Total		388.7	293.4	307.8	82.7	406.2	215.6	232.7	46.1	407.1	226.6	197.5	27.5
Tribasic spray	8/2-8/11	21.9	9.8	5.8	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12-8/21	83.2	54.8	34.5	7.8	4.8	3.3	1.3	0.3	0.0	0.0	0.0	0.0
	8/22-8/31	198.6	104.3	60.1	18.3	58.3	22.0	14.5	2.3	21.8	18.1	5.9	3.8
	9/3-9/10	328.4	175.2	102.2	13.1	287.5	66.3	23.8	9.5	195.7	46.6	7.3	9.2
	9/11-9/20	119.9	58.6	58.9	7.8	272.3	115.8	46.5	4.3	227.9	96.1	33.0	7.6
	9/21-9/30	42.2	29.7	45.1	7.0	45.5	36.5	56.3	4.5	81.0	53.8	65.4	1.7
	10/1-10/10	3.3	2.8	12.6	4.8	11.0	21.5	84.5	6.8	24.4	43.3	81.6	7.0
Total		797.5	435.2	319.2	66.1	679.4	265.4	226.9	27.7	550.8	257.9	193.2	29.3
Bordeaux	8/2-8/11	22.8	6.3	6.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/12-8/21	59.8	44.8	33.3	8.0	4.5	2.0	1.8	1.0	0.0	0.0	0.0	0.0
	8/22-8/31	177.5	84.3	67.8	16.3	54.0	21.3	15.0	1.5	17.7	14.4	6.2	1.4
	9/3-9/10	260.5	154.0	76.8	16.0	260.3	61.8	18.5	13.0	125.9	36.3	8.7	4.5
	9/11-9/20	86.5	64.8	63.5	11.5	175.8	122.3	30.3	6.0	169.1	62.6	25.2	5.8
	9/21-9/30	58.0	39.5	52.0	7.3	97.0	65.0	70.5	5.5	148.9	64.4	56.3	6.7
	10/1-10/10	10.8	10.5	16.8	4.0	20.8	33.8	82.3	6.3	67.0	69.2	103.5	10.0
Total		675.9	404.2	316.2	66.4	612.4	306.2	218.4	33.3	528.6	246.9	199.9	28.4

<sup>1</sup> Yields given are from four 1/121-acre plots of 30 plants each which is equivalent to approximately 1/30 acre.

Table 2.—Percentage of fruit in the four grades from plots treated with different fungicides

Treatment	Earliana				Pritchard				Marglobe			
	No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots
1941	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>
Tribasic dust.....	46.3	31.3	17.4	5.0	58.1	22.0	17.3	2.6	56.2	25.3	16.1	2.4
Cu <sub>2</sub> O dust.....	46.9	27.6	21.1	4.3	56.7	24.4	16.4	2.6	55.0	25.7	16.6	2.6
Cu <sub>2</sub> O spray.....	52.8	26.6	16.5	3.9	56.2	23.8	17.1	2.8	55.4	26.4	15.6	2.6
Check.....	36.2	27.4	28.7	7.7	46.5	23.3	25.2	5.0	47.4	26.4	23.0	3.2
Tribasic spray.....	49.3	26.9	19.7	4.1	56.6	22.1	18.9	2.3	53.4	25.0	18.7	2.8
Bordeaux.....	46.2	27.6	21.6	4.5	52.3	26.2	18.7	2.8	52.7	24.6	19.9	2.8
1942												
Tribasic dust.....	8.8	45.4	37.7	8.1	43.0	35.7	19.1	2.1	48.0	34.5	14.9	2.6
Cu <sub>2</sub> O dust.....	10.0	42.1	39.2	8.8	43.7	35.8	18.0	2.5	52.8	31.2	13.6	2.4
Cu <sub>2</sub> O spray.....	9.1	41.2	39.3	10.4	39.8	37.9	18.3	3.9	51.4	32.0	13.4	3.2
Check.....	6.3	32.8	45.7	15.2	18.0	41.9	33.3	6.7	19.5	44.8	29.7	6.0
Tribasic spray.....	10.6	43.6	38.2	7.6	42.0	38.6	17.1	2.3	46.9	34.3	16.2	2.6
Bordeaux.....	12.0	45.4	35.5	7.1	51.8	30.5	14.7	2.9	57.2	26.7	13.5	2.6

Table 3.—The monthly precipitation at Blacksburg, Va. during the summer of 1941 and 1942. From the U. S. Weather Bureau records

Month	Precipitation in inches	
	1941	1942
June.....	6.94	5.66
July.....	6.08	2.68
August.....	1.29	4.77
September.....	1.49	3.59

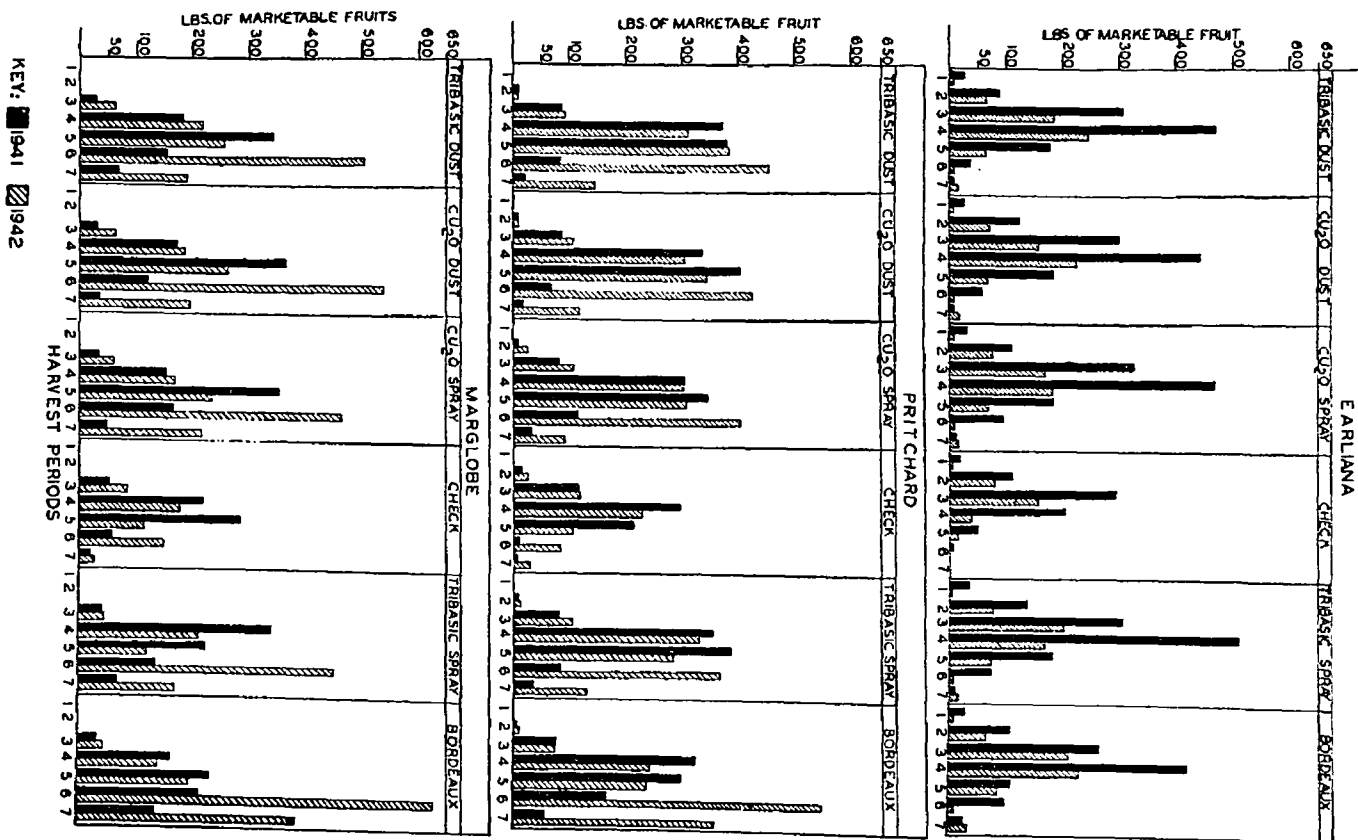


Figure 1.—Pounds of marketable fruit harvested from 1/30-acre plots treated with the different fungicides. Each harvest period represents a 10-day interval and includes all the fruit picked during that period.

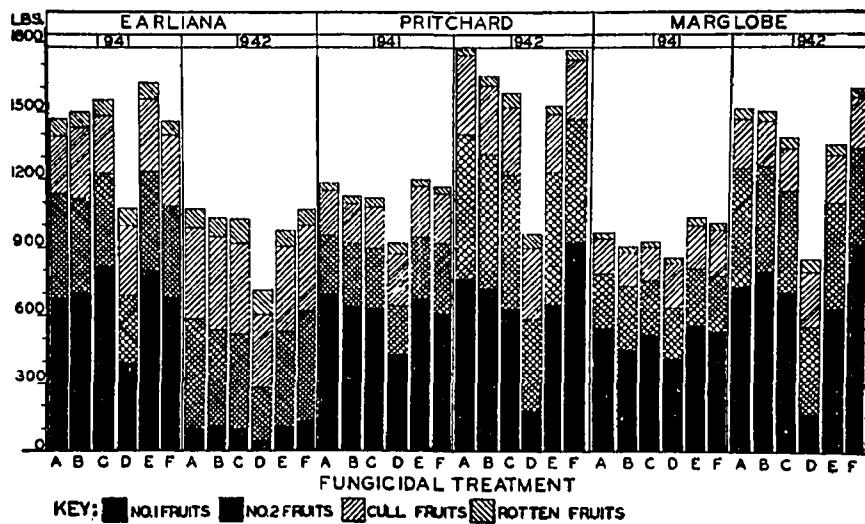


Figure 2.—Yield of fruit from 1/30-acre plots treated with different fungicides in 1941 and 1942. The fungicidal treatments are: (A) tribasic copper sulfate dust; (B) copper oxide dust; (C) copper oxide spray; (D) untreated check; (E) tribasic copper sulfate; and (F) Bordeaux spray.

There was a marked difference in the degree of defoliation of the plants on the treated and untreated plots. The photographs shown in plate 2 and 3 give a visual comparison of sprayed and unsprayed plants. Many of the fruits from the plants on the untreated plots were infected with Phytophthora infestans and Alternaria solani (see Plate 4).

The yield data from the various treatments were subjected to an analysis of variance according to the method of Snedecor (89). A summary of this analysis is given in table 5. The yields of the Earliana and Pritchard varieties from plots receiving fungicidal applications were significantly better (1 per cent level) than those from the untreated check plots but the yields of Marglobe from treated plots were just short of being significantly better than those of the untreated check plots.

The analysis of variance of the yields of marketable fruit of all the sprayed and dusted plots showed that there was no difference between fungicidal treatments when yields alone were considered. But, when the influence of the treatment on date of ripening (pickings x treatments) was considered, there was a significant difference between the Bordeaux mixture and the other fungicidal treatments. This significant difference existed for all three varieties in 1941.

A comparison of the picking trends is graphically illustrated by the regression lines in figure 3. The influence of Bordeaux mixture on the picking yields appears to be greater for Marglobe than for Pritchard and Earliana. Since the slope of these regression lines is influenced by the total yield as well as by the date of ripening, the differences in the slope of the lines cannot be attributed to a difference in the date of ripening unless there is an insignificant variation in the yields of the plots concerned. Therefore, the regression lines for the plots of Earliana and Pritchard that received fungicidal applications cannot be

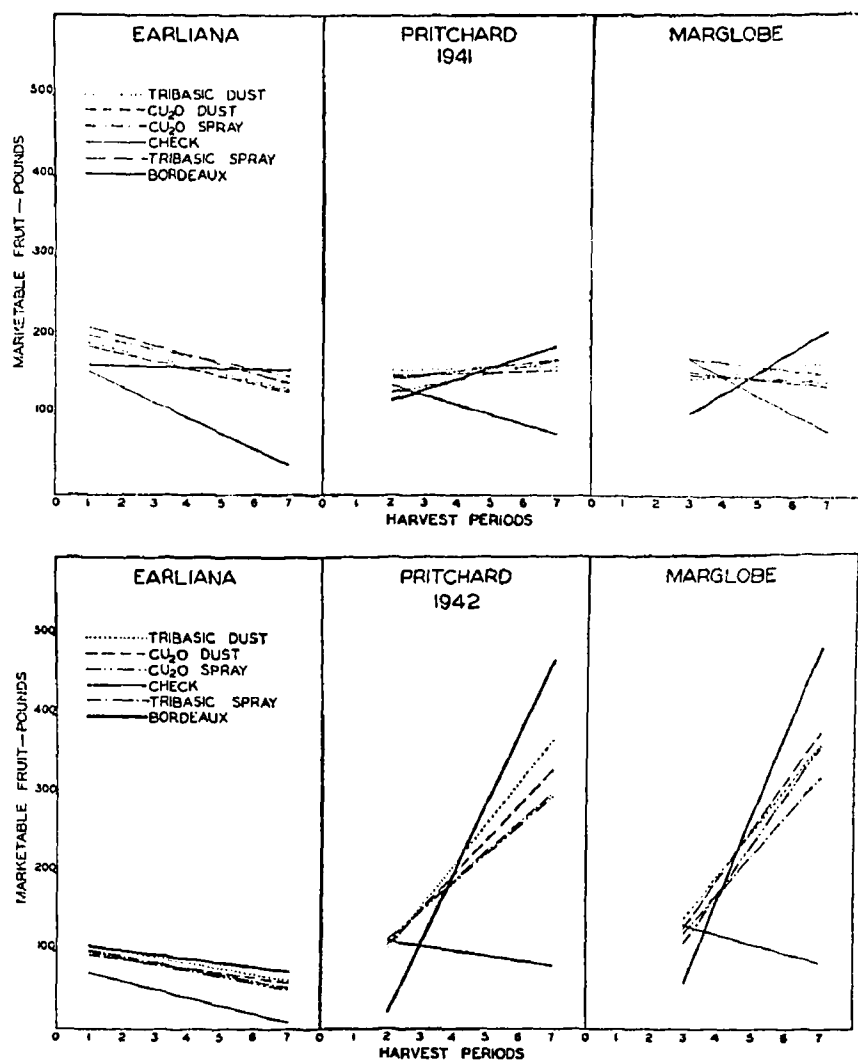


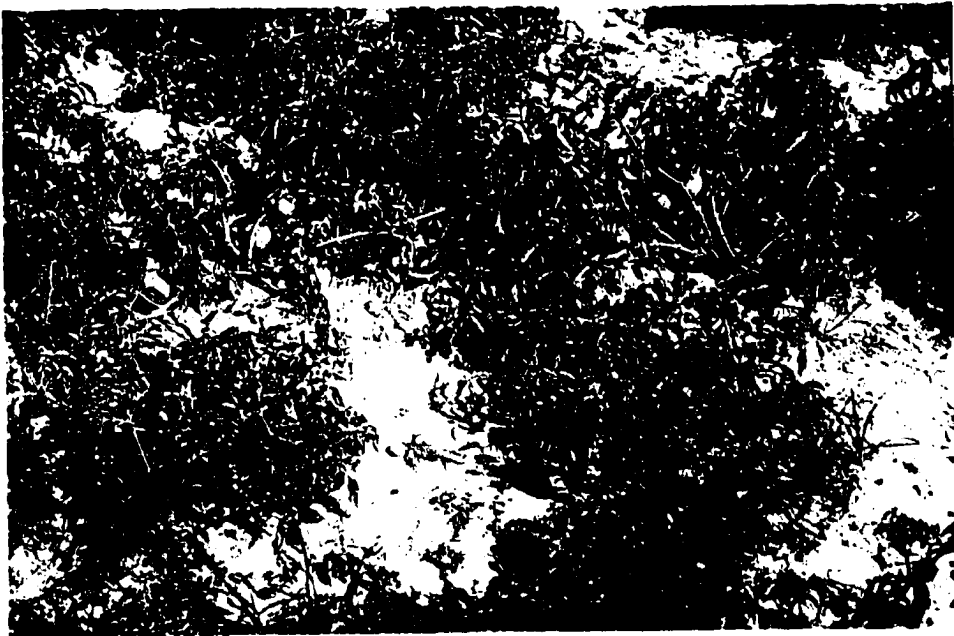
Figure 3.—Regression of yield of marketable fruit on harvest period (pickings).

Plate 2

Photographs of unsprayed plants (A) and tribasic copper sulfate sprayed plants (B) of the Pritchard variety. Note the abundance of healthy foliage on the sprayed plants. Photographed August 25, 1941.



A



B



Plate 3

Photograph of two adjacent plots, one unsprayed (left), the other sprayed with cuprous oxide (right). Photographed August 9, 1941.

Plate 4

Diseased fruits illustrating the types of injury occurring on tomatoes in southwest Virginia.

A, Lesions caused by Phytophthora infestans.

B, Lesions caused by Alternaria solani.

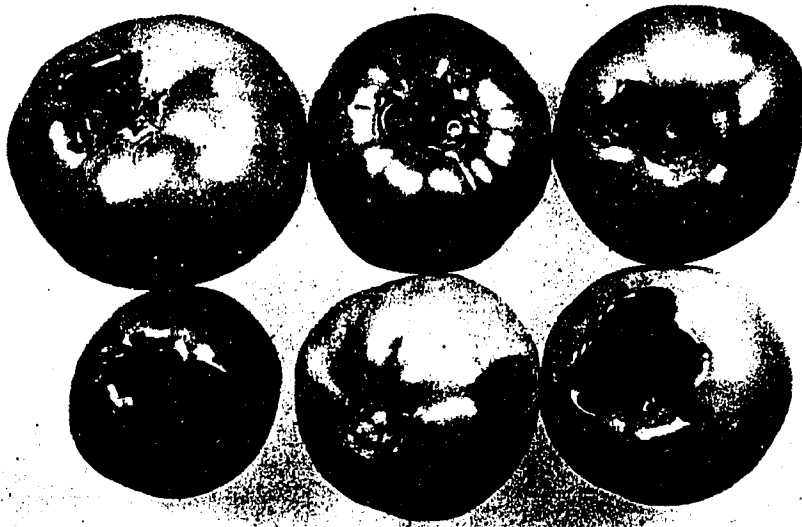
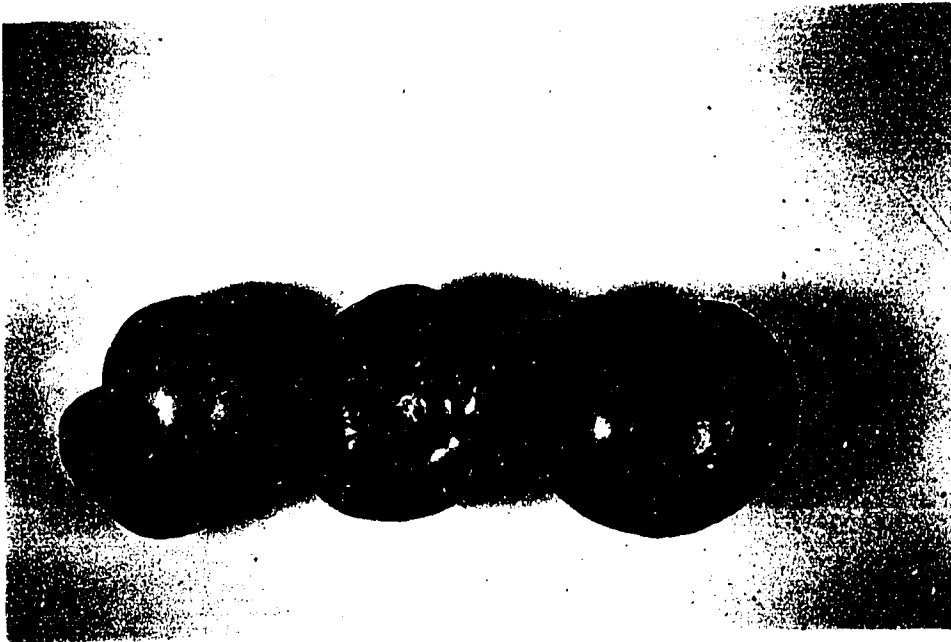


Plate 4

Table 4.—Yield of tomatoes in 1942 from plots of approximately 1/30 acre

Treatment	Harvest dates	Earliana				Pritchard				Marglobe			
		No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Tribasic dust	7/27-8/5	3.0	3.3	2.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6-8/15	17.5	48.0	37.0	22.8	4.8	4.0	2.3	1.5	0.0	0.0	0.0	0.0
	8/16-8/25	31.5	161.3	96.3	24.5	33.8	58.0	11.5	23.1	27.3	36.7	8.1	5.0
	8/26-9/4	15.0	229.5	168.0	25.0	130.3	180.8	22.5	12.0	78.3	141.2	18.3	7.5
	9/5-9/14	21.3	42.3	51.3	4.8	246.8	138.0	48.0	8.3	162.0	97.2	21.2	6.2
	9/15-9/24	1.3	5.5	13.8	4.0	266.0	192.5	134.5	11.8	337.4	169.7	74.8	17.9
	9/25	5.0	7.3	36.8	4.8	83.8	61.8	121.5	2.3	118.3	74.8	102.3	3.1
Total....		94.6	487.2	405.2	86.9	765.5	635.1	340.3	38.2	723.3	519.6	224.7	39.7
Copper oxide dust	7/27-8/5	2.3	0.3	3.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6-8/15	19.5	50.0	42.8	32.3	2.8	6.0	3.0	2.5	0.0	0.0	0.0	0.0
	8/16-8/25	28.0	125.0	73.0	25.8	40.8	63.3	14.3	4.3	21.6	40.8	11.0	5.2
	8/26-9/4	24.8	198.5	172.5	17.8	143.8	161.3	23.3	11.3	86.2	101.0	23.3	6.0
	9/5-9/14	23.0	43.0	62.8	7.0	224.8	121.8	47.5	6.0	172.0	92.7	22.3	6.2
	9/15-9/24	2.3	5.5	21.5	3.8	235.0	191.8	103.8	14.5	382.8	157.5	62.1	14.4
	9/25	3.3	11.3	29.0	3.5	72.8	46.3	104.8	3.3	124.5	73.5	83.9	4.0
Total....		103.2	434.6	404.6	91.0	721.0	590.5	296.7	41.9	786.6	465.5	202.6	35.8
Copper oxide spray	7/27-8/5	3.5	5.0	1.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6-8/15	26.0	48.5	37.8	27.5	7.5	5.0	3.0	2.0	0.0	0.0	0.0	0.0
	8/16-8/25	24.3	144.3	88.8	32.3	35.3	70.5	19.5	10.0	25.0	35.4	7.9	6.3
	8/26-9/4	14.8	166.8	169.8	31.8	119.8	182.3	29.5	19.0	62.7	107.5	24.0	11.2
	9/5-9/14	19.0	46.3	62.0	8.0	179.3	129.0	39.5	10.8	138.5	95.4	18.1	6.7
	9/15-9/24	2.3	3.5	14.3	3.0	237.5	167.0	88.3	15.5	344.9	120.6	52.5	14.8
	9/25	3.5	7.5	29.0	3.0	47.5	42.5	108.5	4.5	136.0	81.9	80.8	5.0
Total....		93.4	421.9	403.2	106.6	626.9	596.3	288.3	61.8	707.1	440.8	183.8	44.0
Check	7/27-8/5	0.0	1.3	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6-8/15	19.8	54.8	42.8	24.8	9.0	13.5	2.8	3.5	0.0	0.0	0.0	0.0
	8/16-8/25	21.8	133.0	114.3	48.8	35.8	81.8	35.3	10.5	21.2	52.7	14.1	10.9
	8/26-9/4	0.3	34.8	140.8	31.0	47.5	179.3	95.3	29.3	24.9	152.7	62.5	19.0
	9/5-9/14	2.8	8.8	25.8	3.0	35.5	66.5	65.3	7.8	46.3	67.4	37.6	6.0
	9/15-9/24	0.0	0.0	0.0	0.0	33.8	47.8	84.0	11.5	65.8	84.2	96.1	12.5
	9/25	0.0	0.0	0.0	0.0	11.8	14.8	38.5	2.3	5.7	19.8	39.8	2.4
Total....		44.7	232.7	324.0	108.1	173.4	403.7	321.2	64.9	163.9	376.8	250.1	50.8
Tribasic spray	7/27-8/5	0.3	1.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6-8/15	21.3	52.8	29.8	22.3	5.0	6.3	1.0	1.5	0.0	0.0	0.0	0.0
	8/16-8/25	43.5	156.8	95.5	20.5	51.5	55.8	9.0	3.0	18.3	26.3	9.2	4.0
	8/26-9/4	14.0	152.0	152.0	21.3	133.5	196.3	24.3	11.5	80.6	132.1	26.9	9.0
	9/5-9/14	19.8	51.0	57.8	4.8	155.5	128.3	50.5	6.8	119.2	90.5	25.8	5.8
	9/15-9/24	0.5	4.5	15.3	2.3	220.5	148.8	91.8	10.3	302.0	151.3	74.8	13.4
	9/25	3.8	7.8	22.0	2.8	73.8	53.3	83.5	2.5	109.6	60.6	80.7	2.1
Total....		103.2	425.9	373.2	74.0	639.8	588.8	260.1	35.6	629.7	460.8	217.4	34.3
Bordeaux	7/27-8/5	2.3	1.3	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/6-8/15	20.8	40.0	28.5	18.3	4.5	5.3	0.8	2.3	0.0	0.0	0.0	0.0
	8/16-8/25	42.8	165.3	78.5	21.3	30.0	42.0	11.5	3.5	17.5	26.4	8.4	2.7
	8/26-9/4	22.3	204.8	137.8	22.0	115.5	125.5	24.0	13.3	61.3	79.4	14.5	7.6
	9/5-9/14	22.5	51.8	69.8	4.8	147.0	89.3	31.0	9.5	137.5	60.0	21.5	4.2
	9/15-9/24	6.0	4.3	19.8	3.5	376.0	170.3	74.3	16.8	472.7	152.6	66.1	21.0
	9/25	12.0	18.8	44.8	5.3	246.5	108.8	119.8	6.0	221.5	106.9	104.3	5.5
Total....		128.7	486.3	379.7	75.7	919.5	541.2	261.4	51.4	910.5	425.3	214.8	41.0

compared with those of the untreated plots because the means of these plots vary significantly. There was no significant difference in the yield of the treated and untreated plots of Marglobe; therefore, the great difference in the slope of the regression lines for the treated and untreated plots of Marglobe is largely due to the difference in the date of ripening of the fruit.

In summarizing, it is quite clear, as shown by the regression lines and by the test of significance of the interaction pickings x treatments, that Bordeaux mixture retards the harvest to a much greater extent than the other fungicides.

The yields for each grade of fruit from the treated and untreated plots were also calculated on a percentage basis as given in table 2. The percentage of No. 1 fruits was greatly increased by all the fungicidal treatments. For Earliana, only 36.2 per cent of the fruits from the check plots were rated in the No. 1 grade, while 52.8 per cent of those from the cuprous-oxide-sprayed plots were rated in this grade. For Pritchard and Marglobe, there was also an increase in the percentage of No. 1 fruits from the treated plots, but the increase was slightly smaller than that for Earliana. The statistical analysis of the percentage of No. 1 fruits is summarized in table 6. On the Earliana variety the percentage of No. 1 fruits for the two sprays (cuprous oxide and tribasic copper sulfate) was higher (5 per cent level) than that for the same materials when used as dusts. There was no difference, however, between the two materials when used as dusts nor between them when used as sprays; nor was there any difference between the average yield when using cuprous oxide and tribasic copper sulfate, as dusts and sprays, and when using Bordeaux mixture spray. It is evident that the average percentage of No. 1 fruits from the plots sprayed with cuprous oxide and tribasic copper

sulfate was significantly better than that from the plots sprayed with Bordeaux mixture but this is not brought out in the comparisons made in the analysis of variance. The average percentage of No. 1 fruits from the plots receiving fungicides was significantly higher (1 per cent level) than that from the untreated plots.

On Pritchard and Marglobe, there was no significant difference in the percentage of No. 1 fruits between the different fungicides. The percentage of No. 1 fruits from the plots receiving fungicidal applications, however, was higher (5 per cent level) than that from the untreated plots.

All the fungicides used in 1941 gave a significant increase in yield on Earliana and Pritchard, but not on Marglobe, which was severely injured by the drought in late summer. No one fungicide proved to be better than another when total yields of marketable fruits were compared. In every case, however, the picking yields from the Bordeaux mixture treatment were smaller than those from the other treatments in the first part of the season and larger in the latter part of the season.

#### Results of 1942 Test

The foliage diseases were very abundant in 1942, especially on Earliana. As a result, the yields for Earliana were approximately one-half those for 1941; but, because of more favorable rainfall during the latter part of the season, the yields for Pritchard and Marglobe were considerably above those of the previous year. The yields for the various treatments are tabulated in table 4. As in the data for 1941, each amount represents the total yield over a 10-day interval, beginning with the first picking on July 27. The analysis of variance of the yield data is

summarized in table 5.

None of the fungicides used gave effective control of the foliage diseases on Earliana and, as a result, very low yields were obtained on this variety. Disease control on Pritchard and Marglobe was very satisfactory in spite of the rainy season. A killing frost on September 29 cut short the harvest period for Marglobe, which probably accounted for the lower yield of marketable fruit than was obtained from Pritchard. All the fungicides used in the test gave a highly significant increase in yield of marketable fruit over the untreated check on all three varieties. On Earliana no one fungicide was superior to another but on Marglobe and Pritchard, Bordeaux mixture gave higher yields of marketable fruit than did the other fungicides. On Pritchard the two dusts appeared to be superior to the same two fungicides (cuprous oxide and tribasic copper sulfate) when applied as sprays, the difference being significant at the 5 per cent level. There was no difference in yield between the dusts and sprays on Earliana and Marglobe.

The tendency for the pickings from the plots receiving fungicidal applications to be smaller than those from the untreated plots during the early part of the season and larger during the latter part of the season, as was noted in 1941, was also apparent in 1942; but the rapid falling off of yields from the untreated plots near the end of the season makes it difficult to distinguish between what might be a delay in date of ripening on the treated plants and the increased yields due to the lengthening of the bearing period. For this reason, the regression lines given in figure 3 may be misleading. It will be readily seen, however, in examining the regression lines and in observing the yield data in table 4 that the Pritchard and Marglobe plots sprayed with Bordeaux mixture gave smaller yields in the early part of the season than did the untreated plots or the

Table 5.—Summary of analysis of variance on pounds of marketable fruit (No. 1 and No. 2)

Comparison	D/F	1941		1942	
		Sum of Squares	Mean Square	Sum of Squares	Mean Square
<b>EARLIANA</b>					
Blocks.....	3	968.63	-----	1,364.35	-----
Treatments:					
(1) Trib. dust vs. Cu <sub>2</sub> O dust.....	1	8.64	8.64	33.02	33.02
(2) Cu <sub>2</sub> O spray vs. Trib. spray.....	1	0.17	0.17	3.01	3.01
(3) Dusts vs. sprays.....	1	405.08	405.08	48.89	48.89
(4) Others vs. Bordeaux.....	1	96.94	96.94	165.03	165.03
(5) Treatments vs. Check.....	1	7,047.01	7,047.01**	2,336.67	2,336.67**
Blocks X Treatment (Error A).....	15	1,949.19	129.95	717.40	47.83
Pickings.....	6	206,767.02	34,461.17**	53,270.31	8,578.39**
Interactions:					
(1) T. dust vs. Cu <sub>2</sub> O dust X Pickings.....	6	209.86	34.97	135.37	22.56
(2) Cu <sub>2</sub> O S. vs. Trib. S. X Pickings.....	6	372.72	62.12	161.87	26.98
(3) Dusts vs. sprays X Pickings.....	6	240.26	40.07	932.72	155.45**
(4) Others vs. Bord. X Pickings.....	6	1,989.08	331.51**	255.60	42.60
(5) Treatment vs. Check X Pickings.....	6	11,893.49	1,982.25**	4,845.28	807.55**
Error B.....	108	8,536.43	79.04	4,538.00	42.02
Total.....	167	240,484.52	-----	68,807.52	-----
<b>PRITCHARD</b>					
Blocks.....	3	677.41	-----	1,193.45	-----
Treatments:					
(1) Trib. dust vs. Cu <sub>2</sub> O dust.....	1	31.69	31.69	176.34	176.34
(2) Cu <sub>2</sub> O spray vs. Trib. spray.....	1	54.19	54.19	1.03	1.03
(3) Dusts vs. sprays.....	1	7.03	7.03	698.76	698.76*
(4) Others vs. Bordeaux.....	1	1.20	1.20	960.50	960.50*
(5) Treatments vs. Check.....	1	2,641.17	2,641.17**	19,489.60	19,489.60**
Blocks X Treatment (Error A).....	15	2,276.30	151.75	1,966.55	131.10
Pickings.....	5	167,573.95	34,061.84**	142,451.23	28,490.24**
Interactions:					
(1) T. dust vs. Cu <sub>2</sub> O dust X Pickings.....	5	263.94	52.79	238.67	47.73
(2) Cu <sub>2</sub> O S. vs. Trib. S. X Pickings.....	5	575.09	115.04	490.35	98.07
(3) Dusts vs. sprays X Pickings.....	5	544.84	108.98	1,484.80	296.96
(4) Others vs. Bord. X Pickings.....	5	2,728.63	545.73**	16,530.26	3,306.05**
(5) Treatment vs. Check X Pickings.....	5	4,546.68	909.34**	21,913.69	4,382.74**
Error B.....	90	11,452.04	127.24	25,982.00	288.69
Total.....	143	198,374.16	-----	233,577.23	-----
<b>MARGLOBE</b>					
Blocks.....	3	1,050.49	-----	2,406.49	-----
Treatments:					
(1) Trib. dust vs. Cu <sub>2</sub> O dust.....	1	70.23	70.23	3.61	3.61
(2) Cu <sub>2</sub> O spray vs. Trib. spray.....	1	70.23	70.23	78.40	78.40
(3) Dusts vs. sprays.....	1	31.24	31.24	819.20	819.20
(4) Others vs. Bordeaux.....	1	0.36	0.36	948.64	948.64*
(5) Treatments vs. Check.....	1	800.42	800.42	18,916.93	18,916.93**
Blocks X Treatment (Error A).....	15	2,689.76	179.32	2,785.46	185.75
Pickings.....	4	75,594.47	18,898.62**	127,068.95	31,767.23**
Interactions:					
(1) T. dust vs. Cu <sub>2</sub> O dust X Pickings.....	4	821.65	80.41	260.16	65.04
(2) Cu <sub>2</sub> O S. vs. Trib. S. X Pickings.....	4	1,161.65	290.41	570.86	142.71
(3) Dusts vs. sprays X Pickings.....	4	197.51	49.88	681.93	170.48
(4) Others vs. Bord. X Pickings.....	4	5,120.34	1,280.09**	7,349.12	1,837.28**
(5) Treatment vs. Check X Pickings.....	4	2,518.08	629.52**	20,431.28	5,107.82**
Error B.....	72	12,447.50	172.88	8,560.30	118.89
Total.....	119	102,073.93	-----	190,881.33	-----

\* Values show significance at 5 percent level.

\*\* Values show significance at 1 percent level.

plots receiving either of the other fungicides. The analysis of variance showed that the pickings from the Bordeaux mixture plots were significantly different (1 per cent level) from those from the plots treated with other fungicides (table 5). There appeared to be no difference between cuprous oxide and tribasic copper sulfate in their effect on the yield of fruit at the different picking dates. On Earliana the dusts retarded the picking yields more than the sprays but on the other varieties there was no difference between these treatments.

The yields by grades, calculated on a percentage basis, are given in table 2. The amount of No. 1 fruit from the untreated plot of Earliana was 6.3 per cent; of Pritchard, 18.0 per cent; and of Marglobe, 19.5 per cent. Bordeaux mixture increased the amount of the No. 1 fruit of Earliana to 12.0 per cent; of Pritchard to 51.8 per cent, and of Marglobe to 57.2 per cent. The other fungicides also brought about a considerable increase in the proportion of No. 1 fruits, but the proportion was somewhat less than that for Bordeaux mixture. A summary of the analysis of variance on the percentage of No. 1 fruits is given in table 6. The average percentage of No. 1 fruits for all the fungicidal treatments was significantly higher (1 per cent level) than that for the check on all three varieties. Bordeaux mixture was significantly better than the other fungicides on Pritchard and Marglobe but not on Earliana.

Table 6.—Summary of analysis of variance on percentage of No. 1 fruits

Comparison	D/F	1941		1942	
		Sum of Squares	Mean Square	Sum of Squares	Mean Square
<b>EARLIANA</b>					
Blocks.....	3	47.46		161.29	
Treatments:					
(1) Trib. dust vs. Cu <sub>2</sub> O dust.....	1	.50	.50	2.64	2.64
(2) Cu <sub>2</sub> O spray vs. Trib. spray.....	1	24.50	24.53	4.06	4.06
(3) Dusts vs. sprays.....	1	72.23	72.23*	.77	.77
(4) Others vs. Bordeaux.....	1	22.05	22.05	18.53	18.53
(5) Treatments vs. Check.....	1	468.07	468.07**	56.08	56.08**
Error.....	15	198.79	13.25	63.45	4.23
Total.....	23	883.63		306.77	
<b>PRITCHARD</b>					
Blocks.....	3	19.46		119.78	
Treatments:					
(1) Trib. dust vs. Cu <sub>2</sub> O dust.....	1	4.50	4.50	.50	.50
(2) Cu <sub>2</sub> O spray vs. Trib. spray.....	1	1.11	1.01	12.50	12.50
(3) Dusts vs. sprays.....	1	3.07	3.07	20.25	20.25
(4) Others vs. Bordeaux.....	1	90.32	90.32	296.45	296.45**
(5) Treatments vs. Check.....	1	255.21	255.21*	2349.67	2349.67**
Error.....	15	467.29	31.15	310.47	20.70
Total.....	23	840.96		3109.62	
<b>MARGLOBE</b>					
Blocks.....	3	978.79		194.79	
Treatments:					
(1) Trib. dust vs. Cu <sub>2</sub> O dust.....	1	0.12	0.12	40.50	40.50
(2) Cu <sub>2</sub> O spray vs. Trib. spray.....	1	10.13	10.13	32.00	32.00
(3) Dusts vs. sprays.....	1	6.26	6.26	9.00	9.00
(4) Others vs. Bordeaux.....	1	51.20	51.20	204.80	204.80*
(5) Treatments vs. Check.....	1	185.00	185.00*	3381.41	3381.41**
Error.....	15	359.46	23.96	357.46	23.81
Total.....	23	1590.96		4219.96	

\* Values show significance at 5 percent level.

\*\* Values show significance at 1 percent level.

Table 7.—Comparison of yields from plots receiving fungicidal applications and plots receiving no treatment

Treatment	Tons of fruit per acre*					
	1941			1942		
	Number 1	Number 2	Total	Number 1	Number 2	Total
<b>Earliana:</b>						
Treated.....	11.10	6.43	17.53	1.22	6.82	8.04
Check.....	5.79	4.43	10.22	.68	3.52	4.20
Increase.....	5.31	2.00	7.31	.54	3.30	3.84
<b>Pritchard:</b>						
Treated.....	9.82	4.14	13.96	11.12	8.92	20.04
Check.....	6.50	3.27	9.77	2.62	6.11	8.73
Increase.....	3.32	.87	4.19	8.50	2.81	11.31
<b>Marglobe:</b>						
Treated.....	7.97	3.71	11.68	11.36	6.99	18.35
Check.....	6.16	3.43	9.59	2.43	5.70	8.18
Increase.....	1.81	.28	2.09	8.88	1.29	10.17

\* Per acre yields are calculated from the average of four 1/121-acre plots for the checks and from twenty similar plots for treatments; that is, all plots receiving fungicides were averaged together.

### Field Experiment 1943

The results of the experiments conducted during the years 1940 to 1942 inclusive showed that tribasic copper sulfate and cuprous oxide applied either as a dust or as a spray effectively controlled the tomato foliage diseases and thereby brought about a considerable increase in the yield of marketable fruits. These experiments showed also that the dusts were about as effective as the sprays in controlling these diseases. This, together with the fact that dusts seem to be more practicable to use from the standpoint of ease of application, led to the making of a more precise comparison of the effectiveness of cuprous oxide and tribasic copper sulfate applied as dusts. Because of the recent report by McNew (56) that the yields resulting from fungicidal applications could be greatly increased by high nitrogen fertilization, the 1943 experiment was designed to include tests with side applications of nitrate of soda.

### Materials and Methods

The same plot of ground used in the previous tests was used in the 1943 experiment. A split-plot design was employed. The field was first divided lengthwise into three plots which were planted to three varieties, namely, Rutgers, Pritchard, and Marglobe. Then it was divided crosswise into four blocks (replicates) and each block into two plots, one plot to receive only the basic fertilizer application made on all plots, and the other to receive side-applications of nitrate of soda in addition. Each of these plots was in turn divided into three sub-plots and treated as

follows: (1) dusted with tribasic copper sulfate<sup>1</sup>/, (2) dusted with yellow cuprous oxide<sup>2</sup>/, and (3) untreated. The size of the sub-plot planted to each variety was 1/121 acre. The basic fertilizer applied to all plots was a 2-12-8 mixture applied in a double band at the side of the row at the rate of 500 pounds per acre just previous to setting. The tomato plants were grown in the greenhouse and transplanted to the field on May 28. The first side-application of nitrate of soda was made on July 7 at the rate of 100 pounds per acre. During the two days following this application there was 4.86 inches of rainfall and, consequently, it is probable that very little of the nitrate of soda was ever available to the plants. A second application, at the rate of 50 pounds per acre, was made on July 20 and a third on August 3, at the rate of 100 pounds per acre. The fungicidal dusts were applied by means of a motor driven row duster. Dust applications were made on July 14, July 22, July 30, August 10, August 14, and August 22. The fruits were harvested as they ripened, and then graded and weighed in a similar manner to the method followed in previous years.

The weather conditions in southwest Virginia during June and July 1943 were extremely favorable for infection by the tomato pathogens. The rainfall at Blacksburg was 6.76 inches in June and 6.58 inches in July. The

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1 A commercial dust mixture prepared by a local distributor from tribasic copper sulfate manufactured by the Tennessee Copper Company. The metallic copper content was 6 per cent.

2 A commercial dust mixture prepared by a local distributor from yellow cuprous oxide manufactured by Rohn and Haas Company. The metallic copper content was 4.1 per cent.

mean temperature was 5.5 degrees higher than normal in June and 0.5 of a degree higher in July. Under such favorable conditions the pathogens developed abundantly on the lower leaves during June and by early July many leaves on the upper part of the plant were infected. The lower leaves on the plants on the experimental plots were practically all destroyed by July 14, the date of the first fungicidal application. The weather remained favorable for the fungi until after the first fruits were picked on August 11. After this date rainfall was extremely deficient throughout the remainder of the season. The mean temperature in August, at Blacksburg, was 2.6 degrees above normal. The hot dry weather of August probably hastened abscission of the diseased leaves. It can be safely stated that the 1943 season in the vicinity of Blacksburg was extremely favorable for the development of the tomato pathogens and relatively unfavorable for plant growth.

#### Results of 1943 Test

The yields of ripe fruit from the various plots are given in table 8 and graphically illustrated in figure 4. An analysis of variance on the yields of marketable fruit (No. 1's and No. 2's combined) is given in table 9. The average yield of the Rutgers variety was slightly higher than either of the others, but the difference between varieties was found to be insignificant. It was also found that there was no difference in the response (interaction) of the varieties to the dust treatments. The average yield of marketable fruit for the three varieties from the plots dusted with cuprous oxide was 597 pounds, for tribasic copper sulfate

Table. 8.- Summarized yields of tomatoes in 1943 from plots of approximately 1/30 acre

Treatment	Grade	Rutgers		Britchard		Perglobe		Av. of 3 varieties	
		No Nitrate	Nitrate	No Nitrate	Nitrate	No Nitrate	Nitrate	No Nitrate	Nitrate
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Tribasic dust	No. 1	328.5	280.5	242.3	243.8	248.8	212.5	273.2	245.6
	No. 2	265.5	266.3	278.8	275.0	287.3	260.0	277.2	267.1
	Culls	250.5	279.0	368.5	323.5	262.3	273.8	293.8	291.9
	Rots	24.5	40.3	22.5	26.0	27.5	28.5	24.8	31.6
Cuprous oxide dust	No. 1	388.3	304.0	307.5	305.3	334.0	261.5	343.3	290.3
	No. 2	243.3	236.5	343.8	293.3	283.8	275.3	290.3	268.3
	Culls	219.3	237.0	314.5	325.8	240.5	235.3	258.1	266.2
	Rots	71.5	58.5	39.0	30.5	43.3	39.3	51.3	42.8
Check	No. 1	264.0	237.0	187.5	193.3	190.0	178.0	213.8	202.8
	No. 2	219.5	217.5	210.8	204.3	251.0	210.0	227.4	210.6
	Culls	271.0	275.5	310.0	312.8	308.5	312.5	296.5	300.3
	Rots	42.8	35.0	25.5	22.0	29.5	33.3	32.6	30.1
Average of all treatments	No. 1	326.9	273.8	245.8	247.5	257.6	217.3	276.8	246.2
	No. 2	242.8	240.1	277.8	257.5	274.4	248.4	265.0	248.7
	Culls	246.9	263.8	331.0	320.7	270.4	274.0	282.8	286.2
	Rots	46.3	44.6	28.8	26.2	33.4	33.7	36.2	34.8

Table 9.- Summary of analysis of variance on pounds of marketable fruits in 1943

Comparison	Degrees of Freedom	Sum of Squares	Mean Squares
Blocks	3	11,328.94	. . . .
Varieties	2	1,458.25	729.13
Error (a)	6	2,253.97	375.66
Nitrogen levels	1	2,473.38	2,473.38**
Nitrogen X Varieties	2	457.53	228.77
Error (b)	9	2,740.76	304.53
Dusts:			
Cu <sub>2</sub> O vs. Tribasic	1	3,152.52	3,152.52**
Dusts vs. Check	1	18,564.06	18,564.06**
Dusts X Varieties	4	1,799.42	449.86
Dusts X Nitrogen	2	441.20	220.60
Dusts X Nitrogen X Varieties	4	60.14	15.04
Error (c)	<u>36</u>	<u>7,433.33</u>	<u>207.87</u>
Total	71	52,213.50	. . . . .

\*\*Values show significance at 1 percent level.

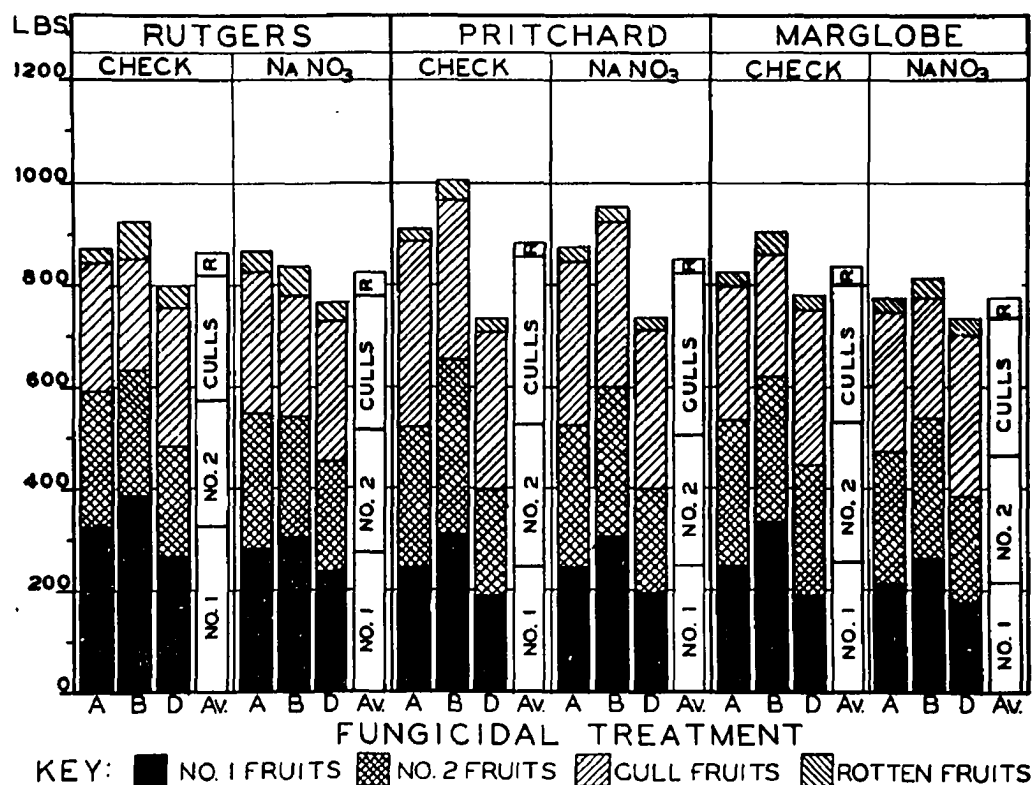


Figure 4

Comparison of yields of fruit from the series of plots that received a basic application of fertilizer (check) with that from the series that received nitrate of soda in addition to the basic application. The unshaded column (Av.) represents the average yield for the series. The fungicidal treatments are: (A) tribasic copper sulfate dust; (B) cuprous oxide dust; (D) untreated.

532 and for the undusted check 426 pounds. The differences between these yields are highly significant; that is, cuprous oxide gave better results than tribasic copper sulfate, and tribasic copper sulfate gave better results than no dust.

The plots that received only the basic fertilization gave significantly higher yields than those that received both the basic fertilization and the supplementary applications of nitrate of soda; the average yield (three varieties) of marketable fruit being 542 pounds and 495 pounds, respectively. The first four pickings from the plots which received nitrate of soda were larger than those from the plots which received no nitrate of soda, but all the later pickings were small (See table 10). The comparative picking yields from Pritchard are illustrated in figure 5. There was no interaction between varieties and nitrate fertilization, although the difference in favor of no nitrate fertilization in the Pritchard variety was much less than that in the other varieties.

The uneven distribution of rainfall in July and August, as shown in figure 5, probably accounts for the plots side-dressed with nitrate of soda yielding less than those not side-dressed. During the period in early August when rainfall was sufficient, the picking yields from the side-dressed plots were larger than those from the plots not side-dressed but with the onset of the drought in late August the yields were smaller. This depression of yield during the dry period is probably explained in Weaver and Clements (99) findings that plants side-dressed with nitrate of soda had shallower root systems and were injured more severely by drought than plants not side-dressed.

Table 10. Yield of Tomatoes by Pickings in 1943 from Plots of Approximately 1/30 Acre

Treatment	Harvest Period	Pritchard				Marglobe				Rutgers			
		No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots	No. 1	No. 2	Culls	Rots
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
No dust without nitrates <sup>2/</sup>	1	68.8	23.3	7.5	4.0	45.5	21.8	10.3	6.0	20.8	7.0	5.5	6.3
	2	88.7	83.3	84.0	10.3	74.3	75.0	81.5	11.5	95.0	43.8	50.8	16.0
	3	26.8	84.8	164.5	9.0	50.3	110.0	151.3	9.5	111.0	106.0	140.3	17.6
	4	3.3	19.5	54.0	2.3	20.0	45.3	65.5	2.5	37.3	62.8	74.5	2.8
Totals		187.6	210.9	310.0	25.6	190.1	252.1	308.6	29.5	264.1	219.6	271.1	42.9
Cu <sub>2</sub> O dust without nitrates <sup>2/</sup>	1	50.5	30.3	14.0	8.3	34.8	11.8	7.0	2.8	20.5	4.5	3.0	6.0
	2	94.3	54.5	54.5	13.8	76.5	45.0	36.3	18.5	81.5	34.5	41.5	24.0
	3	121.8	196.5	175.8	13.5	154.3	135.8	125.3	17.0	177.3	108.8	103.3	32.8
	4	31.0	62.0	70.3	3.5	68.5	91.3	72.0	5.0	109.0	95.5	71.5	8.8
Totals		307.6	343.3	314.6	39.1	334.1	283.9	240.6	43.3	388.3	243.3	219.3	71.6
Frib. dust without nitrates <sup>2/</sup>	1	50.8	21.5	8.3	7.0	46.3	13.5	7.5	5.0	15.5	8.0	2.8	4.5
	2	96.0	72.5	92.0	10.0	92.5	73.5	59.3	9.3	91.0	36.8	39.3	6.8
	3	80.3	149.5	191.0	4.3	74.0	127.5	127.3	9.8	157.3	134.3	116.3	10.5
	4	15.3	35.3	77.3	1.3	36.0	72.8	68.3	3.5	64.8	86.5	92.3	2.8
Totals		242.4	278.8	368.6	22.6	248.8	287.3	262.4	27.6	328.6	265.6	250.7	24.6
No dust with nitrates	1	87.5	37.3	16.5	7.0	46.3	17.0	11.5	7.0	31.0	9.3	5.3	9.0
	2	84.8	70.0	80.3	7.8	82.3	75.8	80.0	13.3	97.3	53.0	70.5	14.8
	3	18.5	82.8	159.8	6.5	41.8	79.5	156.3	10.5	86.5	115.5	139.3	9.3
	4	2.5	14.3	54.3	0.8	7.8	37.8	64.8	2.5	22.3	39.8	60.5	2.0
Totals		193.3	204.4	312.9	22.1	178.2	210.1	312.6	33.3	237.1	217.6	275.6	35.1
Cu <sub>2</sub> O dust with nitrates	1	77.8	21.5	8.5	6.0	25.8	11.3	7.0	5.3	25.0	4.8	4.5	8.3
	2	117.0	71.8	71.8	12.8	78.0	46.8	34.3	11.3	83.8	37.0	40.8	22.3
	3	92.3	154.5	168.5	8.8	115.8	132.0	126.8	18.3	142.8	122.3	124.5	22.3
	4	18.5	46.5	77.0	3.0	42.0	85.3	67.8	4.5	52.5	72.5	67.3	5.8
Totals		305.6	300.3	325.8	30.6	261.6	275.1	235.9	39.4	304.1	236.6	237.1	58.7

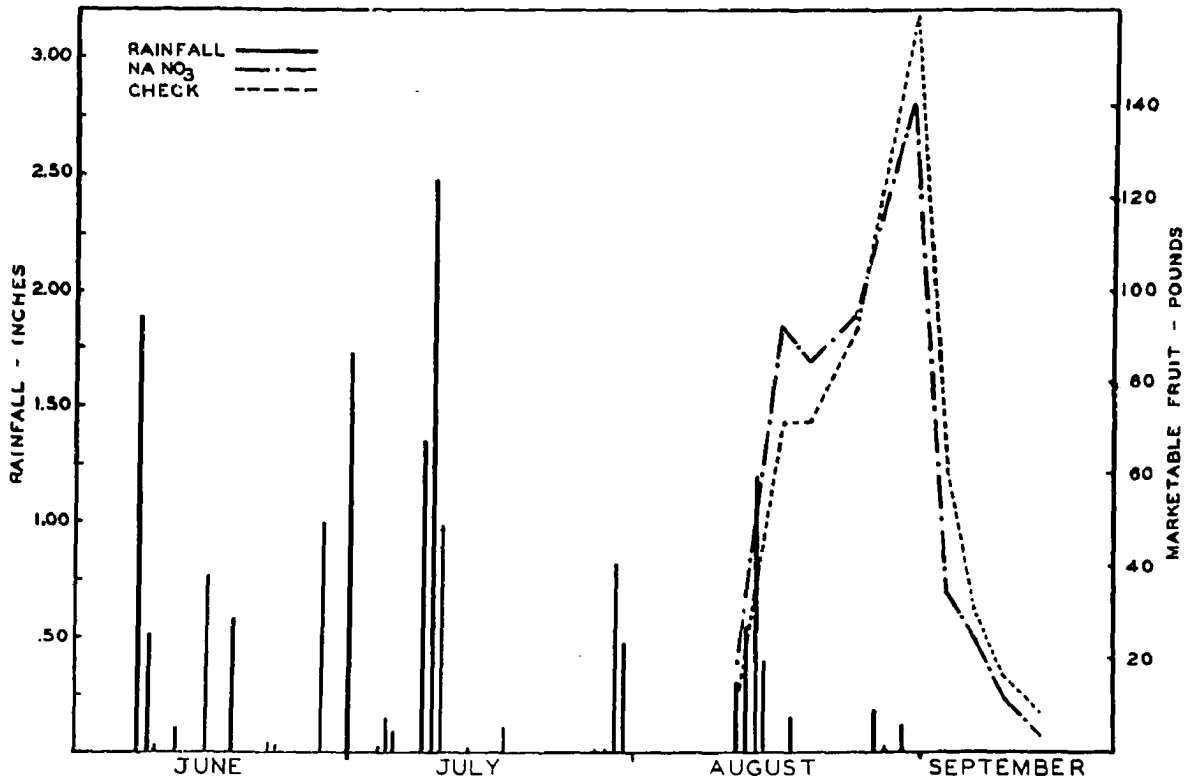


Cu <sub>2</sub> O dust without nitrates <sup>2/</sup>	1	50.5	30.3	14.0	8.3	34.8	11.8	7.0	2.8	20.5	4.5	3.0	6.0
	2	94.3	54.5	54.5	13.8	76.5	45.0	36.3	18.5	81.5	34.5	41.5	24.0
	3	121.8	196.5	175.8	13.5	154.3	135.8	125.3	17.0	177.3	108.8	103.3	32.8
	4	31.0	62.0	70.3	3.5	68.5	91.3	72.0	5.0	109.0	95.5	71.5	8.8
Totals		307.6	343.3	314.6	39.1	334.1	283.9	240.6	43.3	388.3	243.3	219.3	71.6
Trib. dust without nitrates <sup>2/</sup>	1	50.8	21.5	8.3	7.0	46.3	13.5	7.5	5.0	15.5	8.0	2.8	4.5
	2	96.0	72.5	92.0	10.0	92.5	73.5	59.3	9.3	91.0	36.8	39.3	6.8
	3	80.3	149.5	191.0	4.3	74.0	127.5	127.3	9.8	157.3	134.3	116.3	10.5
	4	15.3	35.3	77.3	1.3	36.0	72.8	68.3	3.5	64.8	86.5	92.3	2.8
Totals		242.4	278.8	368.6	22.6	248.8	287.3	262.4	27.6	328.6	265.6	250.7	24.6
No dust with nitrates	1	87.5	37.3	18.5	7.0	46.3	17.0	11.5	7.0	31.0	9.3	5.3	9.0
	2	84.8	70.0	80.3	7.8	82.3	75.8	80.0	13.3	97.3	53.0	70.5	14.8
	3	18.5	82.8	159.8	6.5	41.8	79.5	156.3	10.5	86.5	115.5	139.3	9.3
	4	2.5	14.3	54.3	0.8	7.8	37.8	64.8	2.5	22.3	39.8	60.5	2.0
Totals		193.3	204.4	312.9	22.1	178.2	210.1	312.6	33.3	237.1	217.6	275.6	35.1
Cu <sub>2</sub> O dust with nitrates	1	77.8	21.5	8.5	6.0	25.8	11.3	7.0	5.3	25.0	4.8	4.5	8.3
	2	117.0	71.8	71.8	12.8	78.0	46.8	34.3	11.3	83.8	37.0	40.8	22.3
	3	92.3	154.5	168.5	8.8	115.8	132.0	126.8	18.3	142.8	122.3	124.5	22.3
	4	18.3	46.5	77.0	3.0	42.0	85.3	67.8	4.5	52.5	72.5	67.3	5.8
Totals		305.4	293.3	325.8	30.6	261.6	275.4	235.9	39.4	304.1	236.6	237.1	58.7
Trib. dust with nitrates	1	76.0	34.0	12.0	5.3	37.5	15.8	7.0	4.5	27.8	9.0	5.0	10.8
	2	115.8	77.8	79.3	11.3	81.8	68.5	49.0	10.3	107.0	57.0	51.0	15.8
	3	42.8	135.3	173.0	7.5	70.8	108.0	139.3	11.3	111.3	133.8	135.3	11.5
	4	9.3	28.0	58.8	2.0	22.5	67.8	78.5	2.5	34.5	66.5	87.8	2.3
Totals		243.9	275.1	323.6	26.1	212.6	260.1	273.8	28.6	280.6	266.3	279.1	40.4

1/ The harvest periods represent ten-day intervals as follows: 1, August 9-August 18; 2, August 19-August 28; 3, August 29-September 7; 4, September 8-----.

2/ These plots received no side-applications of nitrate of soda.





**Figure 5**

Yield of marketable fruit by pickings from the Pritchard variety from 1/30 acre plots that received a basic application of fertilizer (check) as compared to that from plots that received nitrate of soda in addition to the basic application, and the relation of these to rainfall. The rainfall data are from the U. S. Weather Bureau records for Blacksburg, Va.

### Laboratory and Greenhouse Tests

The results of the field test in 1943 showed that the commercial dust mixture of cuprous oxide was more toxic to the tomato foliage pathogens than tribasic copper sulfate dust as judged on the basis of increase in yield of marketable fruit. It is recognized that other factors may have been involved in this increase. Certain laboratory and greenhouse tests were conducted to determine, if possible, some of the basic reasons why the field performance of cuprous oxide dust was better than the tribasic copper sulfate.

In the laboratory, the dusts were compared on the basis of their toxicity to spores of Alternaria solani, and in the greenhouse, they were compared on the basis of their effectiveness in preventing infection of young tomato plants.

### Materials and Methods

The slide test technique outlined by the Committee on Standardization of Fungicidal Tests, American Phytopathological Society (2) for testing the toxicity of fungicidal dusts was followed. A settling tower similar to that designed by Heuberger and Turner (37), ten inches in diameter and six feet high constructed of "Glas-o-net", with the upper end closed and a set of removable shelves below, was used for dispensing the dusts on the slides. A one gram charge of dust was introduced into the tower through a one-fourth inch metal tube inserted in the lower end, by a short blast of compressed air at approximately 15 pounds pressure. After an interval of about 35 seconds, during which the coarse particles of dust settled, the first shelf at the bottom of the tower was removed, thus exposing the

slides on the second shelf. After an interval of 30 to 60 seconds this shelf with the slides in place was carefully slipped out, exposing in turn the next series of slides. The length of time that each set of slides was exposed was predetermined to produce a desired dosage. Preliminary tests indicated that the dosage could not be regulated by timing the exposure with any degree of accuracy. For this reason a tared lantern slide cover  $3\frac{1}{4} \times 4$ " was placed on the shelf with each set of slides and after the exposure was removed, weighed and the amount of dust deposited on the slides calculated in terms of milligrams per square decimeter. Thus, the dosage on each set of slides was known.

The test fungus used was a non-chromogenic, pathogenic, sporulating strain<sup>1/</sup> of Alternaria solani. After five to six days when the mycelial growth covered the potato dextrose agar in a 90 mm. petri dish, sporulation was stimulated by Kunkel's method (47). This method consisted of wounding the hyphae by scraping the surface of the culture with a sterile scalpel after which the dish was covered with a freshly autoclaved petri dish cover containing a wetted filter paper. An abundance of spores developed on the surface of the culture in 40 to 50 hours. The spore suspension was prepared in freshly autoclaved distilled water by adding a small quantity of water into the petri dish, rubbing the surface of the culture lightly with the end of a stirring rod to dislodge the spores and then pouring off the liquid into a beaker. Water was added to give the desired dilution of spores which was about 12 to 15 per low power field (10 x ocular, 10 x obj.). Three 1/20 c.c. drops of spore suspension from a medicine dropper were placed at different points on each of four slides for a test. The slides were then left in moist chambers at room

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<sup>1/</sup> The culture of this strain of Alternaria solani was supplied by Dr. E. K. Vaughan who had obtained it from Dr. W. D. Moore, and is probably the same strain as that described by Thomas (95).

temperature for about 15 hours before determining the percentage germination. The germinated spores from a total of 150 to 200 spores were counted on each slide of the four in a test to determine the percentage germination for that test. In the first three of the four runs the dusts were used as received in the package without any special mixing. In the last one, each dust was carefully mixed to assure a uniform blending of the toxicant with the diluent.

The greenhouse tests were made on tomato plants of the Bonny Best variety as recommended by McCallan and Wellman (54). The plants were grown in a fertile potting soil in four inch pots and were about eight to ten inches high at the time the dusts were applied. The procedure followed was to select the desired number of uniform plants and divide them into lots of five plants each. The different lots were then removed singly to a room adjoining the greenhouse where they were dusted with the fungicides.

The fungicides were applied with a plunger-type duster. Care was taken to cover the upper and lower surfaces of the leaves as uniformly as possible but no given quantity of dust was applied. The foliage was dry at the time the applications were made and the amount of dust that would adhere to the leaves was limited. The plants were jarred lightly after dusting to dislodge the excess dust that fell on the more exposed leaves. After dusting, the plants were placed in the moist chamber and left there a few hours before the inoculum was applied.

The moist chamber was a glass enclosed box large enough to accommodate about 30 plants at one time. The floor of the box was covered with wetted sphagnum moss. During the day the moist chamber was protected from direct sunlight to avoid over heating. The temperature in the chamber ranged between 21° and 28° C.

A spore suspension of Alternaria solani was sprayed onto the upper and lower surfaces of the leaves by means of a hand-operated atomizer. A sufficient amount of the suspension was applied to wet the surface of the leaves without causing run-off. After being atomized the plants were returned to the moist chamber where a high relative humidity was maintained. The plants were occasionally atomized with distilled water to assure a film of water being present on the leaf surface during the 36 hours the plants remained in the chamber.

Early blight lesions were visible on the leaves of inoculated plants in about three days but they were not counted until the sixth or seventh day. The fourth, fifth, sixth and seventh leaves from the base were removed from the plant and all the lesions on all the leaflets counted and recorded as total number of lesions per plant.

A total of five greenhouse tests were run. In the first four, the full strength dust as received in the package was used, but in the fifth test the dusts were used full strength and diluted with talc in the ratio of one to three, one to one, and three to one. The checks consisted of a series of undusted plants and a series dusted with talc.

#### Results of Laboratory Tests

The data from the first three laboratory tests, in which the dusts were used without re-mixing, are given in table 11 and are presented graphically in figure 6. These data appear to show that the degree of toxicity of the two dusts was similar although the results were extremely variable. The results with low dosages of cuprous oxide were consistent while those with corresponding dosages of tribasic copper sulfate were variable. In low dosages cuprous oxide seemed to be slightly more toxic

Table 11. Percentage germination of spores of Alternaria solani on slides with various dosages of fungicidal dusts.

Fungicide	Experi- ment No.	Mgm. dust per sq. dm.	Slide Number				Average per slide
			1	2	3	4	
Tribasic copper sulfate	1	3.33	94.36	93.38	91.02	91.66	92.61
	1	5.96	98.80	96.90	96.66	95.39	96.94
	3	6.76	55.19	72.31	75.16	64.77	66.87
	2	7.27	91.28	91.52	94.73	91.49	92.25
	3	15.14	36.36	27.35	24.64	25.52	28.48
	3	15.85	0.0	12.95	1.49	2.61	4.26
	1	17.52	1.67	0.53	45.85	43.70	22.91
	2	17.64	53.06	59.59	41.51	77.21	57.84
	3	20.02	3.57	2.63	10.57	0.00	4.19
	2	20.98	0.00	4.73	0.00	2.16	1.72
Cuprous oxide	1	2.02	87.62	95.38	89.82	90.62	90.84
	1	3.69	88.16	91.10	90.84	92.71	90.70
	2	6.76	84.49	74.27	84.68	84.18	81.91
	1	7.15	75.58	67.94	66.35	47.76	64.41
	3	9.06	66.04	73.72	58.22	68.45	66.66
	3	14.42	6.96	7.14	37.03	14.71	16.49
	2	15.02	19.31	16.67	23.03	16.43	18.86
	2	17.76	65.37	58.16	61.31	59.93	61.19
	3	18.36	27.90	12.87	12.74	21.47	18.76
	3	20.38	0.72	0.00	0.00	0.00	0.18
Check	1	---	97.07	93.23	96.61	89.80	94.18
	2	---	98.60	97.97	98.65	97.43	98.16
	3	---	97.46	90.57	94.52	95.51	94.61

Figure 6

Inhibition of germination of Alternaria solani spores by dosages of tribasic copper sulfate and cuprous oxide dusts. (The lines were drawn by estimate.) The numerals indicate the number of the experiment.

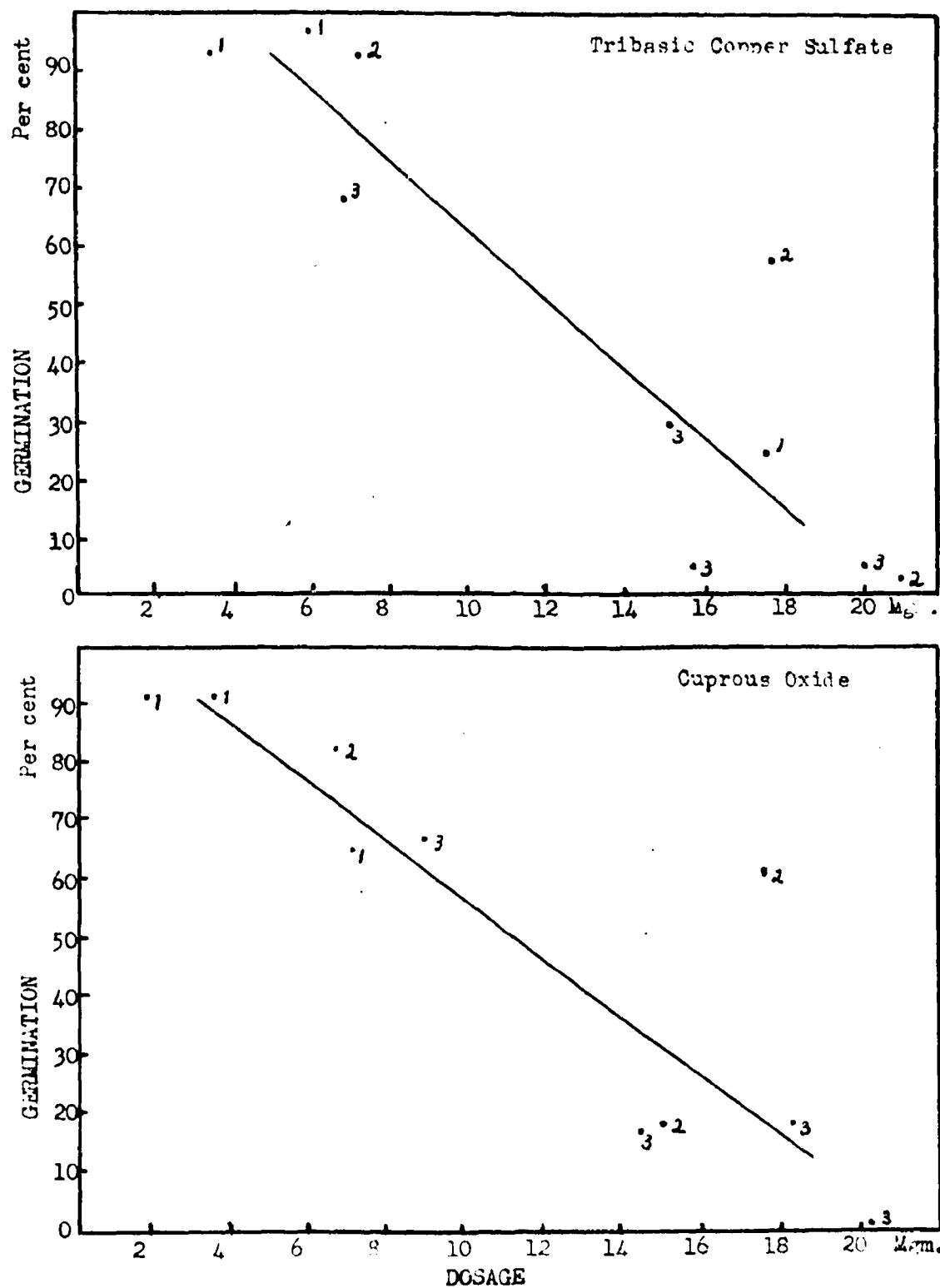


Figure 6

than tribasic copper sulfate. The heavy dosages (12 to 20 mgm.) of both dusts gave variable results.

The percentage germination on replicate slides was in close agreement with two or three exceptions. The most noticeable variation between slides was with tribasic copper sulfate when the germination on two slides averaged about 1 per cent and on the other two about 44 per cent. The generally small variability in replicates indicates that the dispersion of the dusts on the slides was uniform. There was considerable variation, however, between dosages of similar amounts. For example, a dosage of 15.85 mgm. of tribasic copper sulfate dust gave an average germination of 4.26 per cent while a dosage of 17.64 mgm. gave 57.84 per cent. Again, a dosage of 15.02 mgm. of cuprous oxide dust gave 16.86 per cent germination while a dosage of 17.76 mgm. gave 61.19 per cent. The reason for the inconsistent results with different dosages did not appear to be due to the technique because the replicates were less variable. Therefore, other explanations were sought.

An examination of the tribasic copper sulfate dust revealed that many small clumps of the copper compound were not blended with the diluent. These clumps were best seen after water was added to the dust which brought out the greenish blue color of the tribasic copper sulfate. It would be improbable that one-gram samples taken from this improperly mixed dust would contain the same amount of toxicant. The cuprous oxide dust appeared to be more uniformly mixed. A quantity of each of the fungicidal dusts was re-mixed for use in future tests.

The data from the fourth toxicity test in which re-mixed dusts were used are given in table 12. The percentage germination on the slides containing tribasic copper sulfate dust decreased uniformly as the dosage increased. In figure 7 the percentage germination is plotted against dosage. The trend of toxicity for tribasic copper sulfate dust appeared to follow a curve which suggested that the degree of toxicity becomes greater as the dosage was increased.

The results with the re-mixed cuprous oxide dust were not in line with those obtained from tribasic copper sulfate. The percentage germinations on the slides with the 7.98 mgm. and 10.13 mgm. dosages average 70.02 and 50.77 per cent, respectively, which are about 10 per cent lower than that for the corresponding dosages of tribasic copper sulfate. An increase in dosage of cuprous oxide dust from 10.13 mgm. to 13.59 mgm. and to 17.76 mgm. resulted in a slightly higher percentage germination, which is contrary to what would be expected. The germ tubes from spores in these drops were short, many of them being only one-half to three-fourths as long as the width of the spore. The germ tubes on the slides with lower dosage of dust were two to three times the length of the spore. A plausible explanation of the irregular results is suggested in the fact that cuprous oxide dust does not easily wet with water. When the spore suspension was placed on the slide the dust floated on the surface of the drop. With heavy dosages the dust particles collected in a mass and gave an uneven distribution. It is probable that the dust floating on the surface of the drops was ineffective in preventing germination; at least, it would be slower in imparting its maximum toxicity.

Table 12. Percentage germination of spores of Alternaria solani on slides with various dosages of re-mixed fungicidal dusts.

Fungicide	Experiment No.	Mgm. dust per sq. dm.	Slide Number				Average per slide
			1	2	3	4	
Tribasic copper sulfate	4	6.08	86.97	87.16	95.12	79.13	87.09
	4	8.46	71.30	75.52	78.26	77.78	75.71
	4	12.28	37.81	44.04	37.85	29.88	37.39
	4	13.94	0.78	0.74	4.84	5.71	3.02
Cuprous oxide	4	7.98	63.37	70.52	84.13	64.48	70.62
	4	10.13	55.42	72.77	58.70	24.17	52.77
	4	13.59	53.71	59.18	56.15	49.97	53.75
	4	17.76	58.82	58.01	56.56	56.69	57.52
Check	4	---	99.03	99.18	98.94	99.32	99.12

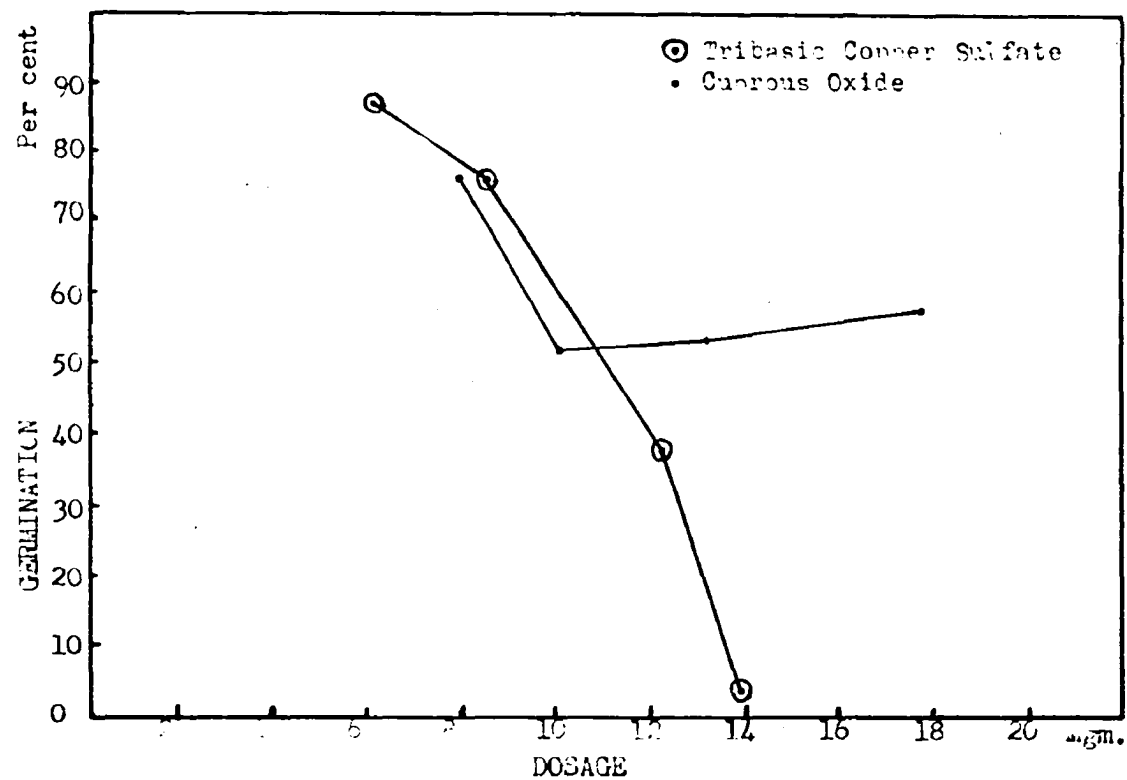


Figure 7

Inhibition of germination of Alternaria solani spores by dosages of re-mixed tribasic copper sulfate and cuprous oxide dusts.

### Results of Greenhouse Tests

The dusts applied on tomato plants in the greenhouse reduced the number of infections of Alternaria solani from an average of 120.25 per plant on the check to 7.05 for tribasic copper sulfate and 1.85 for cuprous oxide (Table 13). In four trials cuprous oxide consistently gave better control than tribasic copper sulfate.

Dilution of re-mixed tribasic copper sulfate dust with talc gave less control of early blight as the dilution was increased (Table 14). The one-fourth strength dust gave an average of 21.75 lesions per plant while one-half and three-fourth strengths gave 18.25 and 14.50 lesions, respectively. Dilution of cuprous oxide dust with talc did not give a proportionate reduction in the degree of control. The one-fourth strength gave 13.25 lesions per plant, one-half strength 9.25 and three-fourth strength 10.75.

Table 13. Number of lesions developed on dusted and undusted tomato plants inoculated with Alternaria solani in the greenhouse.

Treatment	Test No.	Plant Number					Average per plant
		1	2	3	4	5	
Check Undusted	1	104	67	83	115	96	93.00
	2	128	27	118	56	90	83.80
	3	42	29	60	75	102	61.80
	4	241	206	467	66	233	242.60
Average		128.75	82.26	182.00	78.00	130.25	120.25
Tribasic dust	1	16	6	19	1	11	10.60
	2	6	7	3	3	1	4.00
	3	3	6	14	5	1	5.80
	4	4	10	5	2	18	7.80
Average		7.25	7.25	10.25	2.75	7.75	7.05
Cuprous oxide dust	1	3	2	5	2	0	2.40
	2	0	1	1	3	1	1.20
	3	1	5	0	3	0	1.80
	4	4	6	0	0	0	2.00
Average		8	14	6	8	1	1.85

Table 14. Number of early blight lesions developed on tomato plants dusted with different dilutions of fungicides

Treatment	Ratio Dust:talc	Plant Number				Average per plant
		1	2	3	4	
Check		202	168	71	311	188.00
Talc		52	30	39	29	37.50
Tribasic dust	1 : 3	19	24	19	25	21.75
	1 : 1	11	12	36	14	18.25
	3 : 1	6	24	24	4	14.50
	1 : 0	10	15	2	1	7.00
Average		11.50	18.75	20.25	11.00	15.38
Cuprous oxide dust	1 : 3	5	13	16	19	13.25
	1 : 1	11	16	9	1	9.25
	3 : 1	6	17	17	3	10.75
	1 : 0	5	11	4	3	5.75
Average		6.75	14.25	11.5	6.5	9.75

## DISCUSSION

During the four years of the investigation the foliage diseases of tomato caused a reduction in yield each year in southwest Virginia of 30 to 40 per cent on unprotected plants. This consistent occurrence of these diseases indicates that spraying or dusting of tomatoes in this area would be profitable each year. The returns from applying a fungicide depend not only on disease control but also on seasonal factors and soil fertility which determine the growth and productivity of the crop. For example, fungicidal applications on the Pritchard variety in the unfavorable growing season of 1941 gave an increase in yield of 4.19 tons per acre, while in the more favorable growing season of 1942 the increase was 11.31 tons per acre. The foliage pathogens were more difficult to control in 1942 than in 1941 yet the returns from spraying and dusting were much greater. The results of fungicidal treatments on the Earliana variety in 1941 and 1942 were in reverse order to those obtained on the Pritchard variety, the largest increase, 7.31 tons per acre, occurred in 1941 and the smallest, 3.84 tons, in 1942. The Earliana variety, being ten days earlier than the Pritchard variety, escaped injury from the drought in August 1941 and produced about four tons more per acre than the Pritchard variety. In 1942 the fungicides did not give adequate protection on the Earliana variety even though the same number of applications were made as in the previous season. This result is in line with observations made by Wilson (104) that early varieties showed more diseased foliage throughout the season than late ones. Thus, the returns from spraying or

dusting tomatoes depends on the variety employed as well as environment.

The value of Bordeaux mixture for controlling the tomato foliage diseases has been a debatable question (Muncie (65), Mugent (68), Whipple and Walker (100)). On the basis of increased yield, Bordeaux mixture gave results equally as good as any other fungicide used in 1941 and it was superior to the other fungicides on the Pritchard and Marglobe varieties in 1942. A disadvantage of using Bordeaux mixture, however, is that it definitely delays the date of harvest (Edgerton (21), Horsfall, Magie and Suit (42)). From the data in table 1 it will be seen that in 1942 for the Pritchard and Marglobe varieties about 25 per cent of the total yield of marketable fruit from the plots sprayed with Bordeaux mixture was obtained in the last ten-day harvest period, while in the same period the average portion of the crop obtained from the plots treated with other fungicides was 9.4 per cent for the Pritchard variety and 16.4 per cent for the Marglobe variety. This means that the yields from the Bordeaux mixture sprayed plots were lower than those from the plots receiving other fungicides up until the last harvest period. A portion of the yields recorded in the last harvest period was from green or partially ripe fruit picked after a killing frost on September 27 and was unfit for commercial usage. The use of Bordeaux mixture on tomatoes in southwest Virginia is of doubtful value since the gain in yield from disease control may be counteracted by such losses from frost on the Bordeaux mixture-delayed crop.

It appears from the results of the 1941 and 1942 tests that fungicidal dusts can be expected to give equally as good control of the tomato foliage diseases as fungicidal sprays. In each year and on each variety the dusts gave increases in yields that were as good as those for the sprays, and in

1942 on the Pritchard variety the dust gave a significantly higher yield than the sprays. The choice between spraying and dusting must depend on factors, such as, the equipment and time available for applying the fungicide. The cost of dusts will exceed the cost of spray materials but they can be more quickly applied with less labor and the application can be made with less difficulty in wet seasons when fungicides are most needed.

The tribasic copper sulfate dust used in the 1943 experiment was definitely inferior to the cuprous oxide dust in preventing the foliage diseases. This inferiority was shown in the field tests where yield was the criterion and in greenhouse tests where the number of infection by Alternaria solani was the criterion. A comparison of the two materials in the laboratory by the spore toxicity test suggested cuprous oxide was more toxic to A. solani spores than tribasic copper sulfate in low dosages but these tests were unsatisfactory for the following reasons: 1, cuprous oxide dust, being difficult to wet with water, gave irregular results in large dosages; 2, the commercial mixture of tribasic copper sulfate dust was not uniformly mixed and for this reason gave variable results. The poor blending of the toxicant with the diluent undoubtedly accounts in part for the tribasic copper sulfate dust giving lower yields than cuprous oxide in the field experiment. The results of the one test in the greenhouse with a re-mixed dust suggests that a properly blended tribasic copper sulfate dust also is less effective in preventing infection by Alternaria solani than cuprous oxide dust. The average number of early blight lesions on plants treated with the re-mixed tribasic copper sulfate dusts was 15.38 while on plants treated with cuprous oxide dusts the average was 9.75. This evidence is not conclusive but it indicates that the toxicity of tribasic copper sulfate to A. solani is less than cuprous oxide. Horsfall

and Heuberger (39) showed that the more finely divided forms of copper, as cuprous oxide, were more toxic to fungi than the less finely divided forms as tribasic copper sulfate.

## SUMMARY

The efficiency of five copper fungicides in controlling early blight, late blight and Septoria leaf spot of tomatoes was investigated over a four-year period in the field at Blacksburg, Virginia and in the laboratory at Iowa State College. The data accumulated warrant the following conclusions:

1. The yield and quality of marketable fruits on tomatoes in southwest Virginia was greatly increased by the use of five or six applications of a copper fungicide. In 1942 the increase in yield on the Pritchard variety was 11 tons per acre.
2. Cuprous oxide and tribasic copper sulfate applied either as a dust or as a spray successfully controlled the tomato foliage diseases as judged by increased yields from treated plants.
3. Cuprous oxide and tribasic copper sulfate applied as dusts were equal to and in one instance superior to the same materials applied as sprays.
4. Bordeaux mixture was as effective as the other fungicides used in bringing about an increased yield as a result of foliage disease control in 1941 when the rainfall was deficient during August and September and was more effective in 1942 when the rainfall was slightly excessive during August and September.
5. Bordeaux mixture applied to tomato plants delayed the date of maximum yield seven to ten days more than either cuprous oxide or tribasic copper sulfate.
6. In 1942, which was a favorable season for the development of the pathogens of the three foliage diseases, fungicides were 15 to 20 per cent

less efficient in controlling the foliage diseases, as judged by increased yields, on the Earliana variety than on the Fritchard and Marglobe varieties.

7. In 1943 when August and September were abnormally dry, side applications of nitrate of soda depressed the yield of marketable fruit about 8 per cent.

8. Applications of the commercially mixed cuprous oxide dust available to growers in 1943 in southwest Virginia gave about 10 per cent higher yields than the commercially mixed tribasic copper sulfate.

9. The commercially mixed cuprous oxide dust was more effective than tribasic copper sulfate dust in preventing infection of tomato foliage by Alternaria solani under greenhouse conditions. This difference in efficiency was due in part to the toxicant in the tribasic copper sulfate dust not being sufficiently blended with the diluent.

## LITERATURE CITED

1. Alexander, L. J., Ralph E. Lincoln, and Vedder Wright. A survey of the genus *Lycopersicon* for resistance to the important tomato diseases occurring in Ohio and Indiana. U. S. Dept. Agr. Plant Dis. Rptr. Supplement 136:51-85. 1942.
2. American Phytopathological Society, Committee on Standardization of Fungicidal Tests. The slide-germination method of evaluating protectant fungicides. *Phytopath.* 33:627-632. 1943.
3. Andes, J. O. Difference in susceptibility of tomato varieties to *Septoria* and *Macrosporium* leaf spots. *Phytopath.* 29:750. 1939.
4. Andrus, C. F. Tomato defoliation diseases. U. S. Dept. Agr. Plant Dis. Rptr. 24:475-476. 1940.
5. \_\_\_\_\_, G. B. Reynard, and B. L. Wade. Relative resistance of tomato varieties, selections, and crosses to defoliation by *Alternaria* and *Stemphylium*. U. S. Dept. Agr. Circular 652. 1942.
6. Barratt, R. W., and M. C. Richards. Investigations in the relationship between *Alternaria* blight and "physiological" maturity in the tomato plant. (Abs.) *Phytopath.* 33:1. 1943.
7. Beach, S. A. Notes on a tomato disease. N. Y. (Geneva) Agr. Exp. Sta. Bul. 125:305-306. 1897.
8. Berg, Anthony. Tomato blight and its relation to late blight on potatoes. W. Va. Agr. Exp. Sta. Bull. 206. 1926.
9. Boeck, K. Tomatosorten und ihre verschiedene Widerstandsfähigkeit gegen Krankheiten. *Gartenwelt* 31:221. 1927. (Original not seen. *Abst. Rev. Appl. Myc.* 6:645. 1927.)
10. Boyd, O. C. Overwintering of *Phytophthora infestans* in tomato fields. U. S. Dept. Agr. Plant Dis. Rptr. 19:240-242. 1935.
11. \_\_\_\_\_. Evidence of the seed-borne nature of late blight (*Phytophthora infestans*) of tomatoes. (Abst.) *Phytopath.* 25:7. 1935.
12. \_\_\_\_\_. Diseases in Massachusetts in 1942. U. S. Dept. Agr. Plant Dis. Rptr. 27:96-99. 1943.
13. Boyle, J. G. Tomato investigations. Ind. Agr. Exp. Sta. Bull. 165. 1913.

14. Bryant, A. K. Tomato diseases in Trinidad. *Tropical Agric.* 9:63-71. 1932.
15. Cook, Harold T., and T. J. Nugent. Tomato diseases in the Norfolk area and on the Eastern Shore of Virginia. U. S. Dept. Agr. Plant Dis. Rptr. 25:446-447. 1941.
16. Davis, Ray J., Herbert Spencer, and H. H. Zimmerley. Dusting and spraying tomatoes. Va. Truck Exp. Sta. Bull. 46:317-327. 1924.
17. Drummond, O. A. Notas sobre o combate a septoriose do Tomateiro. *Rodriguesia* 2, Num. esp. (1936) 333-336. 1937.
18. Dunlap, A. A. Late blight of tomatoes. Conn. (New Haven) Agr. Exp. Sta. Circ. 98:43-46. 1934.
19. Earle, F. S. Tomatoes. Ala. Agr. Exp. Sta. Bull. 108. 1900.
20. Edgerton, C. W. and C. C. Moreland. Diseases of tomato in Louisiana. La. Agr. Exp. Sta. Bull. 142. 1913.
21. \_\_\_\_\_. Delayed ripening of tomatoes caused by spraying with Bordeaux mixture. La. Agr. Exp. Sta. Bul. 164. 1918.
22. Ellis, J. B., and G. B. Martin. Macrosporium solani E. and M. *Am. Nat.* 16:1003. 1882.
23. Endrinal, D. M., and M. S. Celino. Septoria leaf spot of tomato. *Philipp. Agric.* 29:593-610. 1940.
24. Fenne, S. B. Tomato leaf blight severe in middle and southwest Virginia. U. S. Dept. Agr. Plant Dis. Rptr. 24:333. 1940.
25. Fromme, F. D. Experiments in spraying and dusting tomatoes. Va. Agr. Exp. Sta. Bull. 230. 1922.
26. Geise, F. W., H. H. Zimmerley, and H. Spencer. Spraying and dusting vegetable crops in 1922. Va. Truck Exp. Sta. Bull. 41. 1922.
27. Giddings, N. J. Potato and tomato diseases. W. Va. Agr. Exp. Sta. Bull. 165. 1917.
28. \_\_\_\_\_, and Anthony Berg. A comparison of the late blights of tomato and potato. A preliminary report. *Phytopath.* 9:209-210. 1919.
29. Gilbert, Basil E. Field tomato disease control with fungicides. Rhode Island Agr. Exp. Sta. Annual Rept. 1939:42-43. 1939.

30. Göpfert, J. Bekämpfung der Krautfäule bei Tomaten. Obst- u. Gemüsebau. 82:43-44. 1936. (Original not seen. Abst. Rev. Appl. Mycol. 15:539. 1936.)
31. Gram, E. and M. Thomsen. Oversigt over Sygdomme hos Landbrugets og Havebrugets Kulterplanter i 1925. (Survey of the diseases of agricultural and horticultural cultivated plants in 1925.) Tidsskrift for Planteavl. 33:84-148. 1927. (English summary.) (Original not seen. Abst. Rev. Appl. Mycol. 6:335. 1927.)
32. Green, D. E. and Dorothy Ashworth. Blight of outdoor tomatoes - spraying tests 1942. Jour. Roy. Hort. Soc. 68:179-183. 1943.
33. Güssow, H. T. Septoria spot, a new fungous disease of tomatoes. Gard. Chron. series. 3. 44:121-122. 1908.
34. Halsted, B. D. Report of the botanist. N. J. Agr. Exp. Sta. Ann. Rpt. 16:293-297. 1895.
35. Harrison, A. L. Tomato diseases. Texas Agr. Exp. Sta. Rept. 1938:77. 1939.
36. Heuberger, J. W., and T. F. Manns. Effect of zinc sulfate-lime on protective value of organic and copper fungicides against early blight of potato. (Abstract) Phytopath. 33:1113. 1943.
37. \_\_\_\_\_, and N. Turner. A laboratory apparatus for studying settling rate and fractionation of dusts. Phytopath. 32:166-171. 1942.
38. Horsfall, J. G., and J. M. Hamilton. Some fungicidal possibilities of red copper oxide. Phytopath. 25:21. 1935.
39. Horsfall, J. G. and John W. Heuberger. Relation of color to fungicidal value in insoluble copper compounds. (Abstract) Phytopath. 30:11. 1940.
40. \_\_\_\_\_, and John W. Heuberger. Cause, effects and control of defoliation of tomatoes. Conn. (New Haven) Agr. Exp. Sta. Bull. 456. 1942.
41. \_\_\_\_\_, R. O. Magie, and C. H. Cunningham. Effect of copper sprays on ripening of tomatoes. Phytopath. 27:132. 1937.
42. \_\_\_\_\_, R. O. Magie, and R. F. Suit. Bordeaux injury to tomatoes and its effect on ripening. N. Y. (Geneva) Agr. Exp. Sta. Tech. Bull. 251. 1938.
43. Humbert, J. G. Tomato diseases in Ohio. Ohio Agr. Exp. Sta. Bull. 321:157-196. 1918.

44. Jatzynina, Mme. K. (On tomato diseases) (Garden and Kitchen Garden, Moscow), 44:97-102. 1926. (Original not seen. Abst. Rev. Appl. Mycol. 6:132. 1927.)
45. Jones, L. R. and A. J. Grout. Notes on two species of *Alternaria*. Torrey Bot. Club. Bull. 24:254-258. 1877.
46. Kern, F. D., and C. R. Orton. *Phytophthora infestans* on tomatoes. Phytopath. 6:284-287. 1916.
47. Kunkel, L. O. A method of obtaining abundant sporulation in cultures of *Macrosporium solani* E. & M. Brooklyn Bot. Gard. Mem. 1:306-312. 1918.
48. Levin, Ezra. The leaf-spot disease of tomato. Mich. Agr. Exp. Sta. Tech. Bull. 25. 1916.
49. Locke, S. B. Resistance in South American *Lycopersicon* species to early blight and Septoria blight. (Abstract) Phytopath. 32:12. 1942.
50. Manns, T. F. Breeding and selection of tomatoes resistant to disease. Del. Agr. Exp. Sta. Rept. 1938. (Bull. 214):32-33. 1938.
51. Martin, W. H. Studies on tomato leaf-spot. N. J. Agr. Exp. Sta. Bull. 345. 1920.
52. Massee, I. On the presence of hibernating mycelium of *Macrosporium solani* in tomato seed. Royal Bot. Gard. Kew. Misc. Inform. Bull. 4:145-146. 1914.
53. McAlpine, D. Some points of practical importance in connection with the life-history stages of *Phytophthora infestans* (Mont.) de Bary. Annales Mycologici 8:156-166. 1910.
54. McCallan, S. E. A., and R. H. Wellman. A greenhouse method of evaluating fungicides by means of tomato foliage diseases. Boyce Thompson Inst. Contributions 13:93-134. 1943.
55. McNew, George L. Factors influencing the response of tomatoes to sprays for leaf-blight control. (Abstract) Phytopath. 33:9. 1943.
56. \_\_\_\_\_. The economical use of copper in tomato spraying. The Canner 96:(16) 16, 36-40. 1943.
57. McWhorter, F. P. Early blight diseases of tomatoes. Va. Truck Exp. Sta. Bull. 59-547-566. 1927.

58. Melhus, I. E. Infection and resistance studies of Phytophthora infestans on the tomato. (Abstract) Phytopath. 6:107. 1916.
59. Miller, J. H., and W. F. Crosier. Pathogenic associates of tomato seed; their prevalence, relation to field disease and elimination. Proc. Ass. Off. Seed Anal. N. Am. 1936:108-111. 1936.
60. Mills, W. R. Phytophthora infestans on tomato. Phytopath. 30:830-839. 1940.
61. Moore, W. D. Some factors affecting the infection of tomato seedlings by Alternaria solani. Phytopath. 32:399-413. 1942.
62. \_\_\_\_\_, and H. Rex Thomas. Some cultural practices that influence the development of Alternaria solani on tomato seedlings. Phytopath. 33:1176-1184. 1943.
63. \_\_\_\_\_, \_\_\_\_\_, and Edward K. Vaughan. Tomato seed treatment in relation to control of Alternaria solani. Phytopath. 33:797-805. 1943.
64. Muncie, J. H. Tomato leaf spot and experiments with its control. Pa. Agr. Exp. Sta. Bull. 177. 1922.
65. \_\_\_\_\_, and G. Ken Knight. Tomato spraying trials. Mich. Agr. Exp. Sta. Quart. Bull. 20:247-250. 1938.
66. Nightingale, A. A., and G. B. Ramsey. Temperature studies of some tomato pathogens. U. S. Dept. Agr. Tech. Bull. 520:26-29. 34-35. 1936.
67. Norton, J. B. S. Tomato diseases. Md. Agr. Exp. Sta. Bull. 180:102-114. 1914.
68. Nugent, T. J. Tomato spraying experiment. (Unpublished manuscript.)
69. Payen, M. On the vegetation of Botrytis infestans in the interior of the tomato. Gard. Chron. and Agr. Gaz. 1848:51-52. 1848.
70. Plowright, Chas. B. On the fungoid diseases of the tomato. Gard. Chron. 16:620-621. 1881.
71. Powell, G. Harold. Experiments with tomato blight 1898 and 1899. Del. Agr. Exp. Sta. Rept. 11:153-156. 1900.
72. Pritchard, Fred J. and W. Blair Clark. Effect of copper soap and of Bordeaux soap spray mixtures on control of tomato leaf-spot. Phytopath. 9:554-564. 1919.

73. \_\_\_\_\_, and W. S. Porte. Effect of fertilizers and lime on control of tomato leaf spot (Septoria lycopersici). *Phytopath.* 11:433-445. 1924.
74. \_\_\_\_\_, and \_\_\_\_\_. The relation of temperature and humidity to tomato leaf spot (Septoria lycopersici Speg.). *Phytopath.* 14:156-169. 1924.
75. \_\_\_\_\_, and \_\_\_\_\_. The control of tomato leaf spots. U. S. Dept. Agr. Dept. Bull. 1288. 1924.
76. Rands, R. D. Early blight of potato and related plants. *Wis. Agr. Exp. Sta. Bull.* 42. 1917.
77. Reed, H. S. Tomato blight and rot in Virginia. *Va. Agr. Exp. Sta. Bull.* 192. 1911.
78. \_\_\_\_\_. Does Phytophthora infestans cause tomato blight? *Phytopath.* 2:250-252. 1912.
79. Reddick, Donald, and Wilford R. Mills. Building up virulence in Phytophthora infestans. *Amer. Potato Jour.* 15:29-34. 1938.
80. Röder, Kurt. Untersuchungen über die Phytophthorakrankheit (Phytophthora infestans) der Tomate. Unter besonderer Berücksichtigung der biologischen Spezialisierung des Erregers. *Phytopath. Zeitschr.* 8:589-614. 1935.
81. Rosenbaum, J. A Macrosporium foot-rot of tomato. *Phytopath.* 10:415-422. 1920.
82. Sampson, R. W. Seed transmission of early blight of tomato. *Ind. Agr. Exp. Sta. Rept.* 1938:39-40. 1938.
83. \_\_\_\_\_, and H. Rex Thomas. Tomato diseases in Indiana. *Ind. Agr. Exp. Sta. Circ.* 257. 1940.
84. \_\_\_\_\_, T. J. Nugent, and L. C. Shenberger. Importance of seed transmission of early blight and Fusarium wilt of tomatoes. *Phytopath.* 32:16. 1942.
85. Selby, Augustine D. Investigation of plant diseases in forcing house and garden. *Ohio Agr. Exp. Sta. Bull.* 73:221-246. 1896.
86. Sherbakoff, C. D. Tomato diseases. *Fla. Agr. Exp. Sta. Bull.* 146:117-132. 1918.
87. Small, T. The relation between potato blight and tomato blight. *Ann. Appl. Biol.* 25:271-276. 1938.

88. Smith, Ralph E. Tomato diseases in California. Calif. Agr. Exp. Sta. 175. 1906.
89. Snedecor, George W. Statistical Methods. 2d. ed. Collegiate Press (Ames, Iowa). 1938.
90. Spegazzini, C. Fungi Argentini. Pugellus IV. Buenos Aires.  
(Original not seen, citation taken from Martin, W. H.  
Studies on tomato leaf-spot. N. J. Agr. Exp. Sta. Bull. 345.  
1920)
91. Taubenhause, J. J., and Walter N. Ezekiel. Late blight of tomatoes and potatoes. Texas Agr. Exp. Sta. Circ. 60. 1931.
92. Taylor, Carlton F., W. H. Childs, and J. G. Leach. Fomate for control of early blight on tomato. (Abstract) Phytopath. 33:1119. 1943.
93. Thaxter, R. Diseases of tomatoes. Conn. (New Haven) Agr. Exp. Sta. Rept. 1890;95-96. 1891.
94. Thomas, H. R. Collar-rot infection on direct-seeded tomatoes. U. S. Dept. Agr. Plant Dis. Rptr. 24:8-10. 1940.
95. \_\_\_\_\_. A nonchromogenic sporulating variant of Alternaria solani. Phytopath. 33:729-731. 1943.
96. Van Haltern, F. Control of tomato seedbed diseases of southern plants. Ga. Agr. Exp. Sta. Bull. 187. 1935.
97. Veitch, R. Report of the director of Plant Industry (Research). Dept. Agr. Queensland Rept. 1941-1942;5-8. 1942. (Original not seen. Abst. Rev. Appl. Mycol. 22:163. 1943.)
98. Vowinkel, O. Die Anfälligkeit deutscher Kartoffelsorten gegenüber Phytophthora infestans (Mont.) De By. unter besonderer Berücksichtigung der Untersuchungsmethoden. Arb. Biol. Reichsanst. Land-u. Forstw. 14:588-641. 1926.
99. Weaver, John E., and Frederic E. Clements. Plant Ecology. McGraw-Hill Book Company, Inc., New York. 1929.
100. Whipple, O. C., and J. C. Walker. Dusting tomatoes may be better than spraying. Wis. Agr. Exp. Sta. Bull. 451 (part two):63-67. 1941.
101. Wilson, J. D. Certain injurious effects of spraying vegetables with the fixed coppers. Ohio Agr. Exp. Sta. Bimonthly Bull. 25:36-43. 1940.
102. \_\_\_\_\_. Spraying versus dusting of canning tomatoes with early and delayed applications. Ohio Agr. Exp. Sta. Bimonthly Bull. 25:76-84. 1940.

103. \_\_\_\_\_. Farther studies on the use of fixed copper compounds for the control of vegetable diseases. Ohio Veg. and Potato Growers Assoc. Proc. 26:20-33. 1941.
104. \_\_\_\_\_. Tomato varieties and the timing of spray schedule. Ohio Agr. Exp. Sta. Bimonthly Bull. 28:75-82. 1943.
105. \_\_\_\_\_, and W. D. Moore. Comparison of sprayed tomato plants grown as seedlings in Georgia and Ohio. Ohio Agr. Exp. Sta. Bimonthly Bull. 27:17-25. 1942.
106. \_\_\_\_\_, and H. A. Runnels. Five years of tomato spraying. Ohio Agr. Exp. Sta. Bimonthly Bull. 22:13-18. 1937.
107. Wright, Vedder, and R. E. Lincoln. Resistance to defoliation diseases in tomato. Ind. Agr. Exp. Sta. Ann. Rept. 53(1940):42-43. 1940.

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