THE EFFECT OF DITHANE SPRAYS ON SOME PHYSIOLOGICAL FUNCTIONS OF THE PLANT

A

Thesis

by

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INTRODUCTION

Since its original discovery by Millardet in 1882, Bordeaux mixture has come into general use throughout the world as a control measure for many fungus diseases. It has been found, however, that Bordeaux mixture has a detrimental effect on the growth of many plants, and considerable work has been carried out in an attempt to find some fungicide equal in fungicidal power to Bordeaux mixture, but not having as great a detrimental effect on the growth of the plant.

About twenty-five years ago Bordeaux mixture was to some extent replaced by copper-lime dust, and for at least ten years both were to some degree replaced by the fixed coppers. At present a varied group of organic compounds are being presented as a substitute for copper-containing materials. A promising group among these materials are those derived from dithiocarbamic acid.

As early as 1931 investigations were carried out by the duPont Company on the fungicidal value of a number of dithiocarbamic acid derivatives. During the war years, 1939-1945, a threatened shortage of copper compounds accelerated the research of these organic compounds with the result that in 1941 the fungicidal properties of disodium ethylene bisdithiocarbamate (Dithane) were discovered (Diamond, Heuberger and Horsfall (1943)).

AIM AND SCOPE OF WORK

Studies that have been conducted to compare the relative fungicidal value of Bordeaux mixture and Dithane spray have indicated that the two fungicides are about equally effective in controlling the diseases of the potato. Bordeaux mixture, however, as well as having fungicidal value also acts to some extent as an insecticide, and gives some control of flea beetles and leaf hoppers. The insecticidal properties of Bordeaux mixture give it some advantage over Dithane spray which has no insecticidal qualities, so that in fields where insect injury is not important Bordeaux has usually given better results than Dithane. It has also been found that the application of Bordeaux mixture to plants grown in areas where the soil is deficient in copper results in a more vigorous plant growth than the application of Dithane spray. This apparent stimulation of the plants by Bordeaux mixture seems to be due to the fact that the copper in the Bordeaux mixture is taken up by the plant and utilized as a substitute for that normally supplied by the soil.

Bordeaux mixture is known to have an adverse effect on such physiological functions of the plant as photosynthesis, transpiration, and the rate of maturing and growth of the plant. No investigations have been conducted to determine the physiological effect of Dithane spray on plants, but the published results of several field tests reveal that where

the insects controlled by Bordeaux are not important, and when there is no deficiency of copper in the soil, Dithane spray gives higher yields than Bordeaux mixture.

The increased yield resulting from the use of Dithane spray suggested to the writer that Dithane spray was less toxic to the plant than Bordeaux, and in order to determine if this were so, investigations were conducted to compare the effect of the two fungicides on the foliage growth, rate of maturing, tuber development, and starch formation of the potato, and the cuticular transpiration of the tomato.

LITERATURE REVIEW

There are a number of physiological processes carried on by the plant that may be effected by fungicides. The ones most commonly thought to be effected are transpiration, photosynthesis, and the formation and translocation of carbohydrates.

Most of our knowledge concerning the effect of fungicides on plants has been obtained through a study of how plants react to the application of Bordeaux spray. For that reason a determination of the physiological effects of a new fungicide may best be made by comparing its effect, not only to the reaction of an untreated plant, but also to one that has been treated with Bordeaux.

The physiological response of a plant following spraying with Bordeaux mixture has been made the subject of repeated study. The most commonly studied effect has been that on transpiration. Prior to 1914, observations on the effect of Bordeaux mixture on the rate of transpiration were incidental to other experimental work, so that reports on the subject previous to that date are very brief, with little or no information concerning the state of the plants or the condition under which the observations were made.

Rumm, Bayer and Shander are quoted by Miller (1931) as having found that Bordeaux mixture causes a decrease in

transpiration. Clinton (1910) was also of the opinion that a decrease in transpiration followed spraying with Bordeaux mixture.

Since 1914, experimental work in considerable detail has been undertaken by various investigators to determine the effect of Bordeaux mixture on the rate of transpiration. Duggar and Cooley (1914) found that the transpiration rate of tomato plants grown in the greenhouse was increased as much as 40% and 25% by spraying with 4-6-50 and 2-3-50 Bordeaux mixture respectively. Martin (1916) found, in the case of potted tomato, cabbage, eggplant and pepper, that the increase in transpiration of sprayed plants over unsprayed was respectively 8, 3, 11 and 20%. Lutman (1916) found that the transpiration of potted plants was only slightly increased by spraying with Bordeaux mixture under the conditions of his experiment. The increase that he noted amounted to only 1%.

Shive and Martin (1917) determined, by means of the cobalt chloride method, that spraying with Bordeaux mixture caused from 18%-29% increase in transpiration. Duggar and Bonns (1918) observed that Bordeaux mixture increased the rate of transpiration of potted tobacco and tomato plants. They found little or no difference in the rate of transpiration during the day, the increase in rate occurring mainly, if not entirely, at night. Martin and Clarke (1929)

reported that the application of 5-5-50 Bordeaux mixture to potato plants resulted in an increase in transpiration rates. Miller (1931) stated that he, in a series of experiments during four growing seasons, studied the effect of Bordeaux mixture on the transpiration of tomato plants grown outside, and was unable to obtain any of the striking results on transpiration that had been reported by other investigators. Wilson and Runnels (1933a) found that the influence of Bordeaux mixture on increasing the rate of transpiration was much greater during the night than during the day. Bordeaux mixture, they thought, might be a deterrent to stomatal transpiration at all times, but it caused a decided acceleration to cuticular transpiration during the night period. Wilson and Runnels (1933c) found that if the amount of copper in a given volume of Bordeaux mixture is kept constant, each additional increment of lime accentuates the influence of the mixture on the transpiration rate, until the quantity of lime exceeds that of copper by one and one-half times. Wilson and Runnels (1934) found it to be generally true that untreated plants which lost only a small amount of water during the night period showed the greatest response following the application of Bordeaux mixture. They also found that the increase in transpiration following treatment was somewhat greater in tests conducted in the greenhouse than in those conducted outdoors. Childers (1935) reported that, in tests conducted over a ten-day period on mature tomato plants grown in the

greenhouse, the application of 3-4-50 Bordeaux mixture was virtually without effect on the total amount of water transpired. Wilson and Runnels (1935b) found that Coleus plants showed a marked increase in transpiration immediately after the drying of Bordeaux spray on the leaves, and that the effect remained for twelve days after application. Krausche and Gilbert (1937) reported that copper sprays increase the transpiration of tomato plants, particularly at night, and concluded that this increase is largely due to an effect of the spray on the cuticle. Wilson and Runnels (1937) found that a Bordeaux mixture with a high hydrated lime and a low copper sulphate content was usually more injurious to the plants than one in which the proportions were reversed. Horsfall and Suit (1938) were of the opinion that Bordeaux containing an excess of lime applied on a hot day furnished ideal conditions for the dissolution of the cuticle. Horsfall and Harrison (1939) found that cuticular transpiration was increased by the application of lime-water alone, and Wilson and Runnels (1935a) found Burgundy mixture prepared with sodium hydroxide caused a greater water loss than when prepared with sodium carbonate. Horsfall (1945) points out that this type of evidence suggests a saponification of the fatty or waxy cuticular layer. Southwick and Childers (1941) found that Bordeaux mixture and its component parts appear to have either no effect or a retarding influence on the rate of transpiration. Yarwood (1943) noted that potato plants sprayed

with Bordeaux mixture appeared to sustain greater injury from frost than did unsprayed plants. Investigating the relation of Bordeaux injury to low temperature he found that Bordeaux sprays increased the transpiration of bean plants over a temperature range from 0° - 37°C., and concluded that the injury at low temperature caused by Bordeaux is directly associated with the water relations of the plant, and is probably a result of the increased water loss due to Bordeaux, combined with decreased absorption and translocation of water at low temperatures.

The results obtained by the investigators mentioned above leaves little doubt that Bordeaux mixture has some effect on the transpiration rate of the plant. As their results indicate, however, there is an apparent disagreement as to just what effect Bordeaux has on the transpiration rate. Some workers have found that Bordeaux mixture increased transpiration and still others claim that it has no effect. Horsfall (1945) states that it is probable all are right, and points out that the total transpiration of any plant is the resultant of the transpiration occurring through the stomata and through the cuticle. In general it is accepted that the application of Bordeaux mixture to plants results in an increase in cuticular transpiration, and a decrease in stomatal transpiration. The relative importance of these two under any set of conditions will therefore de-

termine whether or not there is an increase or a decrease in total transpiration.

No literature is available as yet on the effect of Dithane on the transpiration of the plant. Observations on the effect of frost on potato experiments in which both Dithane and Bordeaux were included, however, give some indication of the probable effect. During 1946 nation-wide field tests were conducted in the United States (1946 Fungicidal Tests, U.S. Dept. Agr., 1947) and in Indiana it was found that, in tests comparing Dithane and Bordeaux spray frost killed the Bordeaux-sprayed plants, but not those sprayed with Dithane. The same result was also reported from Delaware in similar nation-wide tests carried on during 1947 (Plant Disease Reporter, Supplement 174). These results would indicate that Dithane does not cause as great an increase in water loss as does Bordeaux.

If, as first suggested by Amos (1907), and later by Krausche and Gilbert (1937) and Horsfall and Harrison (1939), Bordeaux mixture plugs stomata, the effect should be reflected in a lower rate of photosynthesis. Amos (1907) carried out experiments to determine the effect of Bordeaux on the assimilation of the leaves of hops, vine, and artichoke, and found that it caused a decline in the assimilation of carbon dioxide for a time, but that the effect passed off both in cases where the leaves began to age, and also while the leaves

still kept vigorous. Hoffman (1932) reported that the photosynthesis of apple leaves was reduced by the application of Bordeaux mixture, and that the rate of carbon dioxide absorption recovered to its pre-spray relationship following spray removal. He suggested that probably the shading influence of Bordeaux was suffciently great to retard the rate of photosynthesis. Gassner and Goeze (1933) found that the removal of the wax layer from the surface of leaves greatly enhanced the reduction of photosynthesis resulting from the application of Bordeaux mixture. Clore (1935) reported that the carbon dioxide assimilation of the leaves of two-year old apple whips treated with Bordeaux mixture did not differ appreciably from those not treated. Southwick and Childers (1941) found that three applications of Bordeaux spray at 70°, 82° and 100°F. reduced the rate of photosynthesis by 9% - 14%, but that on removal of the spray residue there was complete recovery. Bordeaux spray applied three times at 50° - 60°F. reduced the rate of photosynthesis by 2%-52%, and there was no recovery when the spray was removed. Southwick and Childers (1941) reported that lime did not appear to have a detrimental influence on the rate of photosynthesis while copper sulphate distinctly retarded the process. They concluded from their results that the influence of Bordeaux mixture on the photosynthetic process is primarily physiological rather than mechanical, and that the soluble copper fraction within Bordeaux appears to be directly

related to the retarding influence of this spray on photosynthesis.

DeLong (1940) has shown that copper is able to penetrate the tissue of a leaf in appreciable quantities. Mader and Blodgett (1935c) state that potato plants sprayed with Bordeaux mixture yield tubers which contained from 2.5 - 5.5 p.p.m. of copper, while unsprayed checks contained only 2.0 - 2.5 p.p.m. of copper. Therefore copper from Bordeaux mixture has not only been found to penetrate leaf tissue, but to remain at least partially mobile therein.

It is known (Miller, 1931) that the enzyme diastase, which converts starch into sugar in the leaf so that it may be translocated, is inactivated by copper. If, as has been shown by the above-mentioned workers, copper from Bordeaux mixture is able to penetrate leaf tissue, it is not improbable that the action of diastase in such leaves will be retarded and starch will accumulate.

Frank and Kruger, and Ewert are quoted by Lutman (1916) and Butler (1922) as having observed that Bordeaux-treated leaves retained starch in their chloroplasts longer than leaves left untreated. Ewert, as quoted by Lutman (1916), was of the opinion that the action of diastase was retarded by copper compounds, resulting in the increased accumulation and retention of starch in the chloroplasts.

He attributed this accumulation of starch not to any increase in starch manufacture following the application of Bordeaux, but rather to a decrease in the rate of starch hydrolysis. Miller (1931) states that it is generally considered that an accumulation of starch within the chloroplasts impairs their activity by interfering with the photosynthetic process, which some believe occurs at the surface of the plastids, and that the reduction of photosynthesis following the application of Bordeaux mixture may be directly related to a greater accumulation of starch in the treated leaves.

Horsfall (1945) states that other evidence of the sluggish translocation of elaborate foodstuffs from Bordeaux-sprayed leaves is the fact that more leaves per tuber are required for sprayed than for unsprayed plants. Mader (1934) reported that after the first application of Bordeaux sprays of various copper concentrations, the total number of leaves of the untreated potato plants was greater than that of the plants treated. After the second application, plants treated with high copper Bordeaux showed a substantially larger foliage development than the plants receiving smaller amounts of copper, or no copper. The enlargement of tubers, however, was greater in the untreated plots, and on those receiving low copper concentrations.

A lowering in the rate of photosynthesis would cause a decline in the rate at which physiological processes

occurring in the plant take place, and this decline would ultimately be reflected in the rate of growth and maturing of the plant, and in the case of the potato, in the ultimate tuber yield.

As pointed out by Horsfall (1945), the dwarfing effect of fungicides may escape casual observation unless untreated plants are immediately adjacent. If the untreated plants also happen to be dwarfed by insects and disease, the dwarfing of the sprayed plants may still escape detection.

Wilson and Runnels (1933b) noted that Bordeaux mixture checked the growth of tomatoes. Childers (1935) reported that in field tests with Bordeaux mixture a noticeable reduction in plant growth occurred during dry weather. Horsfall, Magie and Cunningham (1937) concluded that stunting of tomato plants may occur as a result of spraying with Bordeaux mixture. Horsfall and Suit (1938) found that high-lime Bordeaux caused stunting. Horsfall, Hervey and Suit (1939) reported that the copper of Bordeaux mixture does not seem to be the primary cause of dwarfing of cucumbers and mushmelons unless it is rendered soluble by low hydrogen ion concentration, whereas lime definitely causes dwarfing. They found that the hydrogen ion concentration of the spray appeared to be of chief importance, and optimum growth of plants was obtained with a spray mixture of approximately pH 7, while more acid and more alkaline sprays

reduced growth irrespective of whether copper was present or not. They tentatively concluded that dwarfing may result from the effect of Bordeaux on transpiration, from calcium hardening the cell walls, and from the reduced photosynthesis caused by stomatal clogging. Horsfall and Turner (1943) found that the dwarfing effect decreased with concentrations of Bordeaux from 30.3% for 16-16-100 through 25.9% for 5.4-5.4-100 to 13.8% for 1.8-1.8-100. Heuberger and Manns (1945) found that Dithane plus zinc sulphate and lime gave more vigorous vine growth than did Bordeaux 6-6-100. Richards and Jones (1946) reported no definite injury to the foliage as a result of Dithane sprays, but that stunting of the plants was indicated with Bordeaux. Wilson and Sleesman (1947) found that Bordeaux and Dithane plus zinc sulphate and lime caused severe stunting of seedling cucumbers. They also found that on potatoes Dithane plus zinc sulphate and lime caused leaf necrosis and that Bordeaux caused stunting and marginal leaf injury. On tomatoes they found that both Bordeaux and Dithane plus zinc sulphate and lime caused some leaf deformation.

It has been suggested that Bordeaux mixture caused a delay in the rate of maturing of many plants. Fairchild (1894) claimed that Bordeaux mixture caused a delay in the ripening of grapes, and Halsted (1895) made a similar claim for tomatoes. Clinton (1910) agreed that the application of Bordeaux prolonged the vitality of plants, and Rosa (1923)

found that potatoes remained green three weeks longer when sprayed with Bordeaux mixture. Miller (1931) states that spraying with Bordeaux mixture has been observed to prolong the life of potato plants for twenty-five days. Mader and Blodgett (1935a) reported that Bordeaux mixture caused a delay in the setting and enlargement of the tubers of the potato varieties Irish Cobbler, Green Mountain and Rural Russet. In their experiments they found that the unsprayed Irish Cobblers, sixty days after planting, still yielded more than those sprayed. For Rural Russet this was true seventy-eight days after planting, but for Green Mountains those unsprayed showed the highest yield up until ninety-five days after planting. In these experiments there was a considerable amount of tip-burn present in all untreated plots, and the sprayed plots in all three varieties finally outyielded the unsprayed. Shutak and Christopher (1938) agree that Bordeaux mixture retards the ripening of potatoes. Fernow and Smith (1944) state that potatoes not sprayed set tubers earlier than those sprayed with Bordeaux, and develop them more rapidly up to the time when the yield is approximately one-half the final yield. After that the rate of increase falls off rapidly for unsprayed potatoes while those heavily sprayed continue to make rapid gains. Horsfall (1945) points out that if no pests are present the sprayed plants remain smaller than the checks all season, and the yield is reduced. If, however, insect and disease attack

the check, the sprayed plots may overtake them and produce more.

Horsfall (1945) ascribed the supposed delay in the ripening and maturing of tomatoes to be primarily due to two factors, dwarfing and defloration. He is of the opinion that since tomato plants set fruit in accordance with their size, any dwarfing by Bordeaux or other sprays would cause them to set their fruit load late in the season. According to Horsfall and Turner (1943) the explanation for the delayed maturity of potatoes is similar to tomatoes. Since the potato also sets fruit in accordance with its size it sets tubers late when dwarfed by Bordeaux sprays.

An indication of the comparative rate at which treated and untreated plants mature can be obtained from noting the time each comes into bloom. Mader and Mader (1937) found that the application of copper in the form of Bordeaux mixture retarded the blooming of Irish Cobbler and Green Mountain potatoes. Horsfall, Magie and Cunningham (1937) reported that stunting of young tomato plants by Bordeaux mixture may delay blooming and setting of blossoms.

As pointed out by DeLong (1940), the yield of a plant is always an indication of the conditions effecting plant growth and plant physiologic processes or changes. The effect of a fungicide in changing potato yields should

therefore furnish added proof of the physiologic changes brought about by the spray.

The effect Bordeaux has on the yield of a plant, as well as its effect on certain physiologic functions, has long been a controversial subject. Early workers, such as Sturgis (1895), Stewart et al. (1910) and Lutman (1912) were all of the opinion that Bordeaux mixture increased the yield of potatoes in the absence of disease and insects. However, as pointed out by Horsfall (1945), up until 1910 the Pasteurian theory of disease etiology so dominated the field that tip-burn was excluded from the category of disease, and it is probable that the increase in yield due to the use of Bordeaux mixture was due to tip-burn control. Some later workers, however, have also claimed a stimulative effect resulting from the application of Bordeaux to plants. Mader and Bodgett (1935b) found that spraying potatoes with Bordeaux mixture proved profitable even when no late blight was present. Folsom and Bonde (1926) were also of the opinion that Bordeaux mixture has a stimulative effect on the potato plant.

Many workers, however, are of the opinion that increases in yield resulting from the use of Bordeaux mixture on potatoes is due to insect and disease control. Lutman (1916) changed the opinion he expressed in 1912, and ascribed

the increases in yield resulting from the use of Bordeaux mixture on potatoes to the control of tip-burn and flea beetle injury. Rosa (1923) also found that Bordeaux increased the yield of potatoes and attributed this to the control of tip-burn and leafhopper. Folsom and Bonde are quoted by DeLong (1940) as having indicated to him in personal correspondence that they had changed their opinion as regards the effect of Bordeaux, and believed that the increased yields of potatoes resulting from its use were due to its control of plant disease and insect pests. Wilson and Runnels (1933b), Childers (1935) and Wilson and Moore (1942) found that Bordeaux mixture caused a reduction in the yield of tomatoes. Horsfall and Turner (1943) after a detailed study of the so-called stimulation of potatoes by Bordeaux mixture came to the conclusion that Bordeaux mixture can be expected to reduce potato yields unless the injuriousness is offset by pest control.

Although not generally accepted, it has become increasingly evident that Bordeaux mixture, far from having a stimulative effect on plant growth, has a deleterious action. Much research has been carried on during the past fifty years in an attempt to find some compound equal in fungicidal efficiency to Bordeaux mixture, but not having as high a phytotoxicity. One of the most promising compounds that has been found to present these requirements is disodium ethylene bis-

dithiocarbamate, first known as Hel75 and later given the trade name Dithane. The fungicidal properties of this material were discovered in 1941, and it was described and patented in 1943. Dimond, Heuberger and Horsfall (1943) reported the material to be quite fungicidal, but stated that, because of its surface activity, drain-off during spraying occurred sooner than for particulate protectants. Ruehle (1944) observed jointly with Dr. Heuberger that the addition of zinc sulphate and lime to Dithane caused a flocculation, and it was believed that this combination might prove more effective as a fungicide. This discovery of the influence of zinc sulphate and lime on Dithane elevated it from the level of mediocrity into a promising material for plant disease control. Heuberger and Manns (1945) found that the combination of Dithane (Hel75), zinc sulphate and lime gave significantly higher yields than did Bordeaux 6-3-100. In tests carried on by Ruehle (1944) Bordeaux was not included because tests conducted in Southern Florida in previous years had resulted in lower yields. However, in comparative tests with other copper fungicides he found that Dithane plus zinc sulphate and lime gave significantly higher yields. Godfrey (1944) carried out tests in the Lower Rio Grande Valley of Texas, using Dithane plus zinc sulphate and lime, and a number of copper fungicides other than Bordeaux, and concluded that in the event of a serious shortage of copper, the requirements of the potato growers for an efficient fungicide could be met

by the use of Dithane spray. Thurston (1944) reported that in tests carried on in Pennsylvania Dithane showed some promise but was not better than Bordeaux. Wilson (1945) found that in two years of testing in Ohio, Dithane plus zinc sulphate and lime gave excellent results, and in 1943 gave the highest yield in an experiment which included over twenty different treatments. He stated that organic compounds offer sufficient promise to justify a prediction that they may possibly replace copper-containing materials within a few years. Berkeley, Thompson and Richardson (1946) reported that in experiments carried out in Ontario during 1945, Dithane plus zinc sulphate and lime and Bordeaux gave good control of early and late blight of potatoes, but the highest yield was obtained with Dithane plus zinc sulphate and lime plus D.D.T. List and Edmundston (1946) found that Bordeaux plus D.D.T. and Dithane plus D.D.T. gave equal yields. Heuberger and Stearns (1947) reported that in tests carried out during 1945 and 1946, Dithane plus zinc sulphate and lime plus D.D.T. gave excellent control of both early and late blight, and gave a high yield response. Berkeley, Thompson and Richardson (1947) reported that in tests carried out in Ontario during 1946, a no-blight year, Dithane plus zinc sulphate and lime plus D.D.T. gave higher yields of potatoes than Bordeaux plus D.D.T. Vaughn and Leach (1947) found that Dithane plus zinc sulphate and lime plus D.D.T. when used in potato experimental plots was equal to Bordeaux plus D.D.T., but when used on a commercial

scale in one locality where potato late blight was early and severe, it was inferior to Bordeaux. Davidson and Rich (1947) reported that in tests carried out in Rhode Island on potato plots which had received two applications of 5% D.D.T., Dithane used alone gave lower yields than Bordeaux. Horsfall and Turner (1947) found in tests conducted in Connecticut during 1944, a year in which there was severe draught and in which no potato late blight appeared, that Dithane plus zinc sulphate and lime without D.D.T. gave a higher yield of Green Mountain potatoes than did Bordeaux alone. In tests conducted on Katahdin potatoes during 1945, a severe potato late blight year, it was found that Dithane plus zinc sulphate and lime without D.D.T. gave higher yields than did Bordeaux, even though it produced no better blight control. It was also found that although plots receiving D.D.T. up until July 30, and Dithane plus zinc sulphate and lime during the remainder of the season, showed equal blight control they gave a lower yield than plots receiving Dithane plus zinc sulphate and lime all season. Insects, they state, were not serious during 1945. In other tests of 1946, a severe blight year, it was quite clear again that Dithane and Bordeaux gave essentially equal disease control, but that Dithane out-yielded Bordeaux by approximately 20%. They suggested that the reason for this was that Bordeaux caused more injury, and were of the opinion that the injury was due to lime, and since Dithane contained less lime than Bordeaux, it was less

phytotoxic. Bonde and Snyder (1946) obtained significantly higher yields from Dithane plus zinc sulphate and lime plus D.D.T. than from Bordeaux plus D.D.T.

During 1946, a committee was formed in the United States for the coordination of field tests with new fungicides. Tests were conducted on potatoes with Dithane plus zinc sulphate and lime in thirteen states and in one province of Canada, and were reported in 1947 (1946 Fungicidal Tests, U.S.D.A., 1947). In four states, Connecticut, New York, West Virginia and Massachusetts, where late blight was present, Dithane plus zinc sulphate and lime gave equal or higher yields than Bordeaux. In Massachusetts, Dithane plus zinc sulphate and lime was reported not effective enough in the control of late blight. In three states, Iowa, Indiana and Tennessee, in which early blight was present, Dithane plus zinc sulphate and lime was equal to or better than Bordeaux on the basis of control and yield. In Ohio, Delaware and Florida, where both early and late blight were present, Dithane plus zinc sulphate and lime was superior to Bordeaux in control and yield. In Michigan, Alabama, Ontario, North Dakota and New York disease was absent, and in all except Michigan, where neither Dithane nor Bordeaux was consistently best, Dithane plus zinc sulphate and lime gave higher yields than did Bordeaux.

During 1947 a similar coordinated program was conducted in fourteen states, the results of which were published in 1948. (Plant Disease Reporter, Supplement 174). In tests in Maine, Connecticut, Rhode Island, New York, Pennsylvania, and Ohio, where late blight was present, the results were as follows: in Maine and Rhode Island, Dithane plus zinc sulphate and lime gave significantly higher yields than Bordeaux; in Connecticut, and in one test in Ohio, yields were about equal; in New York and Pennsylvania and in two tests in Ohio, Bordeaux gave higher yields. In Delaware, New Jersey, Indiana, Michigan, Iowa, Mississippi, South Dakota, North Dakota, and in another set of test conducted in Ohio, late blight was absent and the results were as follows: in New Jersey, Iowa and South Dakota, Dithane plus zinc sulphate and lime gave significantly higher yields than Bordeaux; in Ohio, Delaware, Indiana, Michigan, Mississippi and North Dakota, Dithane plus zinc sulphate and lime gave higher yields than Bordeaux, but the differences were not significant.

The plant disease survey conducted during 1948 (Plant Disease Reporter - Supplement 178) showed that Dithane spray gave good control in the following states: Michigan, Pennsylvania, South Carolina, Delaware, Indiana, Ohio, Alabama and Louisiana. Fair to good control of late blight was obtained with Dithane spray in Massachusetts and Wisconsin.

The control obtained in South Dakota, West Virginia and Tennessee was poor to fair. In Iowa, the use of Dithane spray resulted in a yield of 428 bushels per acre while Bordeaux gave 377 bushels per acre. In Alabama an increase of 10%-25% in yield was reported from fields receiving Dithane spray, while only 5%-20% was reported from fields receiving fixed coppers.

THE EFFECT OF DITHANE SPRAY ON FOLIAGE AND TUBER DEVELOPMENT

It has been pointed out by Wilson and Runnels (1936b), Childers (1935), Horsfall and Suit (1938) and others that the application of Bordeaux mixture to plants causes stunting. Mader and Blodgett (1935a) found that spraying with Bordeaux mixture caused a delay in the setting and enlargement of the tubers of the potato varieties Irish Cobbler, Green Mountain and Rural Russet. Horsfall and Turner (1943) state that the late setting of tubers results from the dwarfing caused by Bordeaux mixture. Horsfall, Hervey and Suit (1939) found that one of the primary symptoms of lime injury was dwarfing of the treated plants, and Horsfall and Turner (1947) suggested that Dithane-sprayed potato plants gave a greater yield than Bordeaux-treated plants, because Dithane spray contains less lime and is therefore less injurious to the plant.

In the following sections experiments are reported which were undertaken to determine the comparative effect of the application of Bordeaux with D.D.T. and Dithane spray of various lime concentrations, with and without D.D.T., on (1) the development of tubers; (2) the growth of the foliage; (3) the rate of maturing, and (4) the final yield of Green Mountain potatoes. These points were investigated in field experiments at Charlottetown, Prince Edward Island during the summers of 1947 and 1948.

In 1947 the plots used were four rows wide, the rows were forty-nine feet in length and forty inches apart. All plots were planted on June 14th., and in order to obtain as uniform a stand as possible, fifty sets were planted in each row. Seven different treatments were used, and each treatment was replicated at random three times. The treatments used were as follows:

(1) Dithane - zinc sulphate - lime (four pounds per eighty Imperial gallons).

(2) Dithane - zinc sulphate - lime (one-half pound per eighty Imperial Gallons).

(3) Dithane - zinc sulphate - lime (four pounds per eighty Imperial Gallons) - D.D.T.

(4) Dithane - zinc sulphate - lime (one-half pound per eighty Imperial gallons) - D.D.T.

(5) Dithane - zinc sulphate - lime (one-half pound per eighty Imperial gallons) - D.D.T.

(6) Bordeaux 4-2-40 - D.D.T.

(7) Check.

Treatments one, two, three and four were applied at approximately seven-day intervals on the following dates: July 25th., August 1st., August 12th., August 22nd., August 29th., September 6th, September 12th., and September 19th. Treatments five and six were applied at approximately ten-day intervals on the following dates: July 26th., August 4th., August 15th., August 25th., September 6th., September 14th., and September 24th. One application of D.D.T.

was made to plots receiving treatments one, two and seven in order to prevent their complete destruction by the Colorado potato beetle. All treatments were applied with a three-row power take-off type sprayer at the approximate rate of one hundred and fifty gallons per acre. All plots were sprayed both ways, the two center rows of each plot therefore received a double treatment at each spraying date.

In 1948 the number of treatments was reduced and the size of the plots greatly increased. All plots were planted on June 15th., in rows forty inches apart and one hundred and thirty feet in length. One hundred and thirty sets were planted in each row. Each plot consisted of three rows, and treatments were replicated six times. The treatments used were as follows: Bordeaux 4-4-40 - D.D.T.; Dithane - zinc sulphate - D.D.T.; and D.D.T. alone. Bordeaux spray was applied seven times at approximately ten-day intervals on the following dates: July 22nd., July 31st., August 10th., August 19th., August 30th., September 14th., and September 25th. Dithane spray (1) was applied at approximately ten-day intervals early in the season, and at five to eight-day intervals late in the season when late blight (Phytophthora

(1) In accordance with the manufacturers' recommendations, no lime was used with Dithane during 1948. All references to Dithane spray in work done during 1948 refer to a mixture having the following formula:

Dithane D-14	two quarts
Zinc sulphate	one pound
Water	eighty Imperial gallons.

infestans (Mont.) deBy.) appeared. Nine applications of Dithane spray were made on the following dates: July 22nd., July 31st., August 10th., August 19th., August 30th., September 6th., September 14th., September 20th., and September 25th.

Through the co-operation of Mr. F.M. Cannon, officer-in-charge, Dominion Entomological Laboratory, Charlottetown, an experiment was also conducted during 1948 to determine the effect of Bordeaux and Dithane spray, used alone and in combination with D.D.T., on the yield of Irish Cobbler potatoes.

THE EFFECT OF DITHANE SPRAY ON TUBER DEVELOPMENT

It has been found by many workers that the application of Bordeaux mixture to healthy plants results in a lower yield. This lowering of the yield has been attributed by Horsfall and Turner (1947) to the toxic effect of lime.

One of the primary purposes of the field experiment conducted at Charlottetown during the summer of 1947 was to determine whether or not a high-lime Dithane spray would cause a lowering in the yield of Green Mountain potatoes. The experiment was also designed to observe the effect of applying Dithane spray at seven and ten-day intervals, and of adding D.D.T. to Dithane spray.

In order to observe when the effect, if any, of

Dithane spray was most pronounced, tuber samples were taken at three widely separated dates during the season. Tuber samples were taken on the following dates: August 6th., August 26th., and September 6th. At each sampling date sixteen plants were pulled at random from each plot, eight plants from each of the outside rows. The tubers obtained from these plants were weighed and the results are shown in Table I.

TABLE I

THE EFFECT OF DITHANE SPRAY OF A HIGH AND LOW LIME CONCENTRATION ON THE DEVELOPMENT OF TUBERS

Treatment	Formulae	WEIGHT OF TUBERS IN GRAMS August 6	August 26	September 6
(1) Dithane-zinc sulphate lime	2-1-4-80	1466	9199.6	19267.9
(2) Dithane-zinc sulphate lime	2-1-½-80	1834	9071.6	18340.7
(3) Dithane-zinc sulphate lime-D.D.T.	2-1-4-2-80	1506	9659.2	23738.2
(4) Dithane-zinc sulphate-lime-D.D.T.	2-1-½-2-80	1538	8977.2	23250.6
(5) Dithane-zinc sulphate-lime-D.D.T.	2-1-½-2-80	1469	8460.6	21059.3
(6) Bordeaux-D.D.T.	4-2-40-1	1637	8570.5	19518.6
(7) Check		1756	9458.4	22631.5
D.R.S.(1)		N.S.(2)	N.S.	N.S.

(1) Difference required for significance at the 5% point.
(2) Not significant.

Treatments one to four were applied at approximately seven-day intervals, and treatments five and six at approximately ten-day intervals.

Analysis of variance of the samples shows that there was no significant difference between plots receiving high-lime Dithane and those receiving low-lime Dithane, and none of the Dithane treatments was significantly different from the Bordeaux treatment or from the check.

The application of Dithane spray at seven-day intervals gave no significant increase in tuber development over its application at ten-day intervals, and the addition of D.D.T. to Dithane spray had only a slight effect upon tuber yield. These results were probably partly due to the fact that in this experiment disease and insects, excepting aphids and the Colorado potato beetle, were not an important factor at any time during the season. The Colorado potato beetle was effectively controlled in all plots not normally receiving D.D.T. by one application of D.D.T. at the height of this insect's infestation.

No decisive results were obtained from the field experiment carried out during 1947, and this was attributed mainly to the fact that the samples taken were too small. It was therefore decided to reduce the number of treatments included in the field experiment carried out during 1948,

and to confine efforts to determining the comparative effect upon tuber development of Dithane spray and Bordeaux 4-4-40. The reduction in the number of treatments made it possible to increase the size of each plot, and thus provide sufficient plants for larger samples to be taken throughout the season. In order to eliminate the effect of insect injury, D.D.T. was included in both treatments used and applied to the check plots at ten-day intervals.

During 1948 Mr. D.B. Robinson and Mr. A.B. Williams, members of the staff of the Dominion Laboratory of Plant Pathology at Charlottetown, assisted in the taking of all samples.

Tuber samples were taken on the following dates: July 27th., August 3rd., August 11th., August 18th., August 26th., September 3rd., September 20th., and October 6th. At each sampling date, twenty-four plants were taken at random from each plot, twelve from each outside row. As treatments were replicated six times, a total of one hundred and forty-four plants was taken from each treatment at each sampling date. The tubers produced by these plants were collected and taken to the laboratory, where each tuber was placed in one of five weight ranges. The weight ranges were as follows: 0 - 1.9 g.; 2.0 g. - 5.9 g.; 6 g. - 34.9 g.; 35 g. - 64.9 g.; 65 g. and greater. The tubers in each range were counted and their total weight obtained. Tables II and III show the result

TABLE II

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE FORMATION OF TUBERS BY GREEN MOUNTAIN POTATOES

NUMBER OF TUBERS

DATE OF SAMPLING	Range 1			Range 2			Range 3			Range 4			Range 5		
	Treatment			Treatment			Treatment			Treatment			Treatment		
	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.
July 27	743	941	823	68	91	64	--	--	--	--	--	--	--	--	--
August 3	618	755	673	338	332	369	295	341	415	--	--	--	--	--	--
August 11	582	643	618	74	106	74	468	504	472	208	243	208	--	--	--
August 18	598	561	627	90	194	73	438	429	418	238	281	302	40	74*	65*
August 26	486	573	523	52	83	69	223	244	269	254	260	314*	271	278	269
September 3	398	468	392	55	65	47	175	211*	228*	238*	185	206	384	443	423
September 20	198*	205*	118	56	55	58	170	161	145	190	178	183	598	658	598
October 6	96	95	66	40	36	35	138	155	161	131	146	183	578	653	595

* Indicates significance at the 5 per cent point.

TABLE III

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE FORMATION OF TUBERS BY GREEN MOUNTAIN POTATOES

DATE OF SAMPLING	TOTAL NUMBER OF TUBERS		
	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.
July 27	811	1030	896
August 3	1251	1428	1457
August 11	1332	1496	1372
August 18	1404	1439	1485
August 26	1287	1438	1444
September 3	1250	1372	1296
September 20	1202*	1277*	1102
October 6	983	1085	1040

* Indicates significance at the 5 per cent point.

of all counts made of tubers obtained at the eight sampling dates. There is some slight indication that Bordeaux has a retarding effect on tuber formation. At all sampling dates the total number of tubers obtained from the plots receiving Bordeaux-D.D.T. was less than the number of tubers obtained from the plots receiving Dithane-D.D.T. The number of tubers obtained from the plots receiving Bordeaux-D.D.T. was also less than the number obtained from the plots receiving D.D.T. alone at all sampling dates excepting the last two, when late blight was present. As a result of late blight, the total number of tubers obtained on September 20th. from the plots receiving D.D.T. alone was significantly below that obtained from the other two treatments. This was the only date, however, on which the difference in the total number of tubers obtained was significant. In the samples taken on August 18th., the number of tubers in range five of the plots receiving Bordeaux-D.D.T. was significantly greater than the number in plots receiving Dithane-D.D.T. and D.D.T. alone. In all subsequent samples, the number of tubers in range five in the plots receiving Dithane-D.D.T. was greater than the number in plots receiving Bordeaux-D.D.T. After August 18th., however, the differences were not significant.

Tables IV and V show the weight of tubers in each weight range, and the total weight of all tubers obtained on each of the eight sampling dates. There was no significant difference between treatments on the first three sampling

TABLE IV

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE YIELD OF GREEN MOUNTAIN POTATOES AT VARIOUS DATES THROUGHOUT THE GROWING SEASON

WEIGHT OF TUBERS

DATE OF SAMPLING	Range 1			Range 2			Range 3			Range 4			Range 5		
	Treatment			Treatment			Treatment			Treatment			Treatment		
	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.
July 27	255.0	324.8	302.6	201.8	341.1	252.6	--	--	--	--	--	--	--	--	--
August 3	259.5	317.7	262.0	1013.7	1014.6	1094.0	2746.1	3314.9	3786.4	--	--	--	--	--	--
August 11	281.4	269.9	304.4	288.3	394.6	313.2	7389.8	7947.9	8271.1	7731.1	8635.0	8336.7	--	--	--
August 18	282.2	259.1	283.1	357.2	406.9	277.4	8420.7	9375.6	9092.5	11147.1	13264.0	13969.3	3189.5	5897.8*	5439.5*
August 26	241.5	255.1	277.5	214.5	351.0*	308.0*	4595.5	4862.0	5835.0	12673.5	13336.5	15759.5*	24852.0	27171.0	23943.5
September 3	185.5	203.5	179.5	232.0	246.0	187.5	3932.5	4203.5	4760.5	11946.0	9415.5	10473.0	40987.0	48150.0	46254.4
September 20	161.0	159.0	108.0	219.0	164.0	221.0	3254.0	3749.0	2709.0	9117.1	9344.0	9071.8	85185.9	92897.1	76340.8
October 6	85.7	95.0	57.3	181.0	162.0	162.0	3039.0	3538.2	3628.7	6758.6	7574.9	9661.7*	88859.4*	102397.3*	76068.3

* Indicates significance at the 5 per cent point.

TABLE V

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE YIELD OF GREEN MOUNTAIN POTATOES AT VARIOUS DATES THROUGHOUT THE GROWING SEASON

	TOTAL WEIGHT OF TUBERS		
DATE OF SAMPLING	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.
July 27	455.7	635.8	555.2
August 3	4019.3	4647.2	5142.4
August 11	15690.6	17202.4	17225.4
August 18	24396.7	29218.2*	29062.0*
August 26	42576.5	45975.6	46123.0
September 3	57282.5	62218.5	61796.0
September 20	97937.0	106313.1*	88450.6
October 6	98923.7*	114267.4*	89578.0

* Indicates significance at the 5 per cent point.

dates. On August 18th., the fourth sampling date, the weight of tubers in the largest weight range from the plots receiving Bordeaux-D.D.T. was significantly less than that of the other two treatments. The low yield in this range resulted in a significantly lower total yield for the Bordeaux-D.D.T. treatment. At the fifth sampling date, August 26th., the plots receiving D.D.T. alone had a significantly greater yield of tubers in range four than did the other two treatments. On September 20th., the seventh sampling date, the total yield of the plots receiving Dithane-D.D.T. was significantly greater than the yield in the other two treatments. On the last sampling date, the plots receiving D.D.T. alone gave a significantly higher yield in range four, but a significantly lower yield in range five, and the total yield was significantly lower than in the other two treatments. The total yield of tubers and the yield in range five for the plots receiving Dithane-D.D.T. was significantly greater at the last sampling date than the yield in the plots receiving Bordeaux-D.D.T.

The application of Bordeaux-D.D.T. seems to have had some effect on tuber development, for at all sampling dates, the total yield of tubers in this treatment was less than the yield of tubers of plots receiving Dithane-D.D.T. The total yield for the first six sampling dates of the plots receiving Bordeaux-D.D.T. was also lower than the total yield of the plots receiving D.D.T. alone. Due to the damage caused

by late blight, however, the total yield at the seventh and eighth sampling dates was lower for the plots receiving D.D.T. alone than for those receiving Bordeaux-D.D.T.

THE EFFECT OF DITHANE SPRAY ON FOLIAGE DEVELOPMENT

Studies to determine the effect of Bordeaux mixture on the growth of plants have yielded conflicting results. Some workers are of the opinion that Bordeaux has a stimulative effect upon plant growth, and that the application of Bordeaux mixture is beneficial to the plant even when disease is not present. The majority of workers, however, favour the view that Bordeaux is deleterious to the plant and causes a reduction in the growth of the foliage, and in the case of potatoes, a consequent reduction in yield.

Observations made by a few workers (Heuberger and Manns (1945) and Richards and Jones (1946)) indicate that Dithane spray is not as injurious to plant growth as Bordeaux mixture, and the increase in yield resulting from the use of Dithane spray has been attributed to this fact (Horsfall and Turner (1947)).

The comparative effect of Bordeaux and Dithane spray on the foliage development of Green Mountain potatoes was observed in the field experiment conducted during the summer of 1948. The roots of the plants from which tuber samples were obtained on July 27th., August 3rd., August 11th.,

August 18th., August 26th., and September 3rd., were cut off at ground level and the foliage weighed; in order to eliminate variations due to the loss of weight in drying, the weight of the foliage was taken as soon as possible after the plants were pulled. The total foliage-weight of the one hundred and forty-four plants from each treatment on each of the six sampling dates is shown in Table VI.

TABLE VI

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE GROWTH OF POTATO FOLIAGE

FOLIAGE-WEIGHT IN GRAMS

TREATMENT	July 27	August 3	August 11	August 18	August 26	September 3
Bordeaux-D.D.T.	30903.2	43133.3	61136.1	73039.1	76700.6	76646.9
Dithane-D.D.T.	31526.0	40639.0	62029.1	79064.8	85034.8	86865.6
D.D.T.	29927.2	41276.7	56571.8	70260.9	76501.8	80754.2
D.R.S.[1]	N.S.[2]	N.S.	N.S.	N.S.	N.S.	N.S.

(1) Difference required for significance at the 5 per cent point.

(2) Not significant.

A considerable difference is apparent in the total foliage-weights of the three treatments, especially in samples taken on August 18th., August 26th., and September 3rd. The plots receiving Dithane-D.D.T. had a greater total foliage-weight from August 11th., to September 3rd., than the plots receiving Bordeaux-D.D.T. or D.D.T. alone. Analysis of variance,

however, shows that none of the differences are significant.

THE EFFECT OF DITHANE SPRAY ON THE RATE OF MATURING OF POTATO PLANTS.

The application of Bordeaux mixture to plants has long been thought to cause a delay in their maturing. As early as 1894 Fairchild (1894) claimed that Bordeaux mixture caused a delay in the ripening of grapes, and Miller (1931) states that Bordeaux mixture has been observed to prolong the life of potato plants for twenty-five days. Bonde and Snyder (1946) found that potatoes sprayed with Dithane-D.D.T. died down earlier than those sprayed with Bordeaux-D.D.T. The delayed maturing of potatoes that have been sprayed with Bordeaux mixture has been explained by Horsfall (1945) as resulting from the dwarfing of the plant caused by the fungicide.

The delay in maturing of potato plants resulting from the application of Bordeaux mixture, if any such delay does occur, should be indicated by the time required after planting for the plants to bloom.

During the summers of 1947 and 1948, observations were made on the effect of Bordeaux and Dithane spray on the rate of maturing of Green Mountain potatoes. The observations took the form of counts of the number of plants in bloom in each plot, beginning at the time blossoms first appeared and continuing until no blossoms remained. In 1947,

counts were made of the plants in bloom in the two centre rows of each plot, and in 1948 counts were made of the plants in the single centre row.

The experiment conducted during 1947 gave information not only on the effect of Bordeaux and Dithane spray, but also on the effect of lime and D.D.T. Counts of the number of plants in bloom in each treatment were made forty-seven, forty-nine, sixty-seven, seventy-seven, eighty-six, ninety and ninety-two days after the potatoes were planted. The number of plants in bloom in each plot was expressed as a percentage of the total number of plants in the two centre rows of the plot, and analysed by the analysis of variance method. Table VII shows the percentage of plants in bloom in each treatment throughout the blooming period.

Forty-seven days after planting, there were significantly more plants in bloom in treatment two than in all other treatments, excepting treatments three and four. Forty-nine and sixty-seven days after planting, however, no treatment had significantly more plants in bloom. The counts taken seventy-seven days after planting showed that treatments three, four and five had significantly more plants in bloom than treatments one, two and seven. Seventy-seven days after planting, treatment six had significantly more plants in bloom than treatment seven. Treatment five had significantly more plants in bloom than

treatments one and seven eighty-six days after planting. Counts taken ninety and ninety-two days after planting showed that there was no significant difference between treatments.

TABLE VII

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS WITH AND WITHOUT D.D.T. ON THE BLOOMING OF GREEN MOUNTAIN POTATOES - 1947

Treatment*	Formulae	PERCENTAGE OF PLANTS IN BLOOM Number of days after planting 47	49	67	77	86	90	92
(1) Dithane-zinc sulphate lime	2-1-4-80	11.3	29.1	79.0	31.4	4.4	1.2	0.0
(2) Dithane-zinc sulphate-lime	2-1-½-80	21.6	32.1	75.3	31.7	1.9	1.5	0.0
(3) Dithane-zinc sulphate-lime-D.D.T.	2-1-4-2-80	10.8	26.5	87.1	78.3	40.6	4.8	0.0
(4) Dithane-zinc sulphate-lime-D.D.T.	2-1-½-2-80	16.3	30.2	83.3	66.7	15.5	1.5	0.0
(5) Dithane-zinc sulphate-lime-D.D.T.	2-1-½-2-80	16.3	32.1	86.9	78.0	30.1	2.4	0.0
(6) Bordeaux-D.D.T.	4-2-40-2	11.6	27.9	81.7	62.1	7.9	2.1	0.0
(7) Check		11.0	31.5	75.1	27.5	3.9	0.3	0.0
D.R.S.[1]		6.9	NS[2]	NS	32.9	37.4	NS	-

(1) Difference required for significance at the 5% point.

(2) Not significant.

* Treatments one to four were applied at approximately seven-day intervals, and treatments five and six at approximately ten-day intervals.

Although significant differences were shown to exist between the treatments at various dates of counting, no definite difference was apparent in the effect of Bordeaux and Dithane spray on blooming. The application of Dithane spray containing an excessive amount of lime had no apparent effect on the time plants began to bloom, or the length of time they remained in bloom. The plants that were not regularly treated with D.D.T. lost their blossoms more quickly than plants that were sprayed with D.D.T. at seven or ten-day intervals. This effect was attributed to the control of aphids obtained by the D.D.T. rather than to any effect on the plants exhibited by the D.D.T. itself.

In the field experiment conducted during 1948, the number of treatments was reduced, and the size of the plots and number of replications increased. Table VIII shows the result of the counts made of the percentage of plants in bloom at various dates. The number of days after planting before the plants came into bloom, and the length of time the plants stayed in bloom was the same for all treatments. The only difference in blooming resulting from the treatments was a reduction in the plants blooming in the plots treated with Bordeaux and D.D.T. This difference first became apparent about fifty-four days after planting, and continued up until about ninety days after planting.

TABLE VIII

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE BLOOMING OF GREEN MOUNTAIN POTATOES - 1948

PERCENTAGE OF PLANTS IN BLOOM

Number of days after planting	Treatment		
	Bordeaux-D.D.T.	Dithane-D.D.T.	D.D.T.
37	0.0	0.5	0.4
39	0.1	0.7	1.7
42	1.3	1.7	2.7
43	5.3	5.7	5.6
44	12.6	10.5	13.4
46	22.6	21.6	24.2
49	62.4	61.5	64.8
51	73.8	78.7	79.5
54	84.4	90.5	89.4
56	86.3	93.1	93.6
59	79.7	88.5	81.1
64	68.9	73.9	72.0
67	66.5	69.5	67.8
74	48.3	53.3	55.6
77	14.8	22.9	20.0
79	6.5	10.5	8.9
88	5.6	10.3	9.3
90	3.9	8.4	7.4
93	0.8	0.9	0.5
95	0.0	0.0	0.0

The counts made during 1947 and 1948 showed that the treatments used had no effect on the number of days required after planting for the plants to reach the blooming stage. The treatments also had no effect on the length of time the plants remained in bloom. In the experiment conducted in 1948, the application of Bordeaux mixture caused a reduction in the number of plants in bloom during the latter part of the blooming period. This, however, was caused by the death and fall of the blossoms as noted by Lodeman (1895) on apples,

and by Horsfall, Magie and Cunningham (1937) on tomatoes, and not by any effect of the fungicide on the rate of maturing of the plant.

THE EFFECT OF DITHANE SPRAY ON THE YIELD OF THE POTATO.

Early workers such as Sturgis (1895), Stewart et al. (1910) and Lutman (1912) were of the opinion that Bordeaux mixture increased yields even in the absence of disease and insects. This idea was also held by Mader and Blodgett (1935b), and Folsom and Bonde (1926) concluded that Bordeaux mixture has a stimulating effect on the potato plant. Lutman (1916), Rosa (1923) and DeLong (1940), however, were of the opinion that the increased yields resulting from the use of Bordeaux mixture were caused by the control of insects and disease. Horsfall and Turner (1943) came to the conclusion that Bordeaux mixture may be expected to reduce yields, unless the injuriousness of the spray is offset by pest control. In field tests in which Bordeaux and Dithane spray have both been used, it has been found that the control of late blight may be about the same, but that the yields from plants sprayed with Dithane spray are higher (Horsfall and Turner (1947)).

The comparative effect of Dithane and Bordeaux sprays on the final yield of potatoes was determined in the field experiments conducted during 1947 and 1948.

Green Mountain potatoes were used in the field experiment of 1947. The plots were four rows in width and

fifty feet in length, and treatments were replicated three times. The plants in the two center rows of each plot were allowed to mature, and they alone were used to obtain data on the effect of the treatments on yield. The total yield from all plots, and the total yield for each treatment are shown in Table IX.

TABLE IX

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS WITH AND WITHOUT D.D.T. ON THE YIELD OF GREEN MOUNTAIN POTATOES - 1947

TREATMENT*	FORMULAE	YIELD IN POUNDS Replicate Number 1	2	3	TOTAL
(1) Dithane-zinc sulphate lime	2-1-4-80	53.0	94.5	22.5	150.0
(2) Dithane-zinc sulphate-lime	2-1-½-80	43.5	88.5	37.0	169.0
(3) Dithane-zinc sulphate-lime-D.D.T.	2-1-4-2-80	47.5	97.5	42.0	187.0
(4) Dithane-zinc sulphate-lime D.D.T.	2-1-½-2-80	47.5	83.0	33.0	163.5
(5) Dithane-zinc sulphate-lime-D.D.T.	2-1-½-2-80	45.0	85.0	36.5	166.5
(6) Bordeaux-D.D.T.	4-2-40-1	40.0	84.0	23.0	147.0
(7) Check		55.5	92.5	33.0	181.0

* Treatments one to four were applied at approximately seven-day intervals, and treatments five and six at approximately ten-day intervals.

The application of Dithane spray of a high lime concentration did not seem to have any consistent effect on the yield. The yield of treatments one and two and the check was not materially effected by the absence of a regular application of D.D.T. This was due to the fact that late blight and other diseases were absent, and that insects were not serious. The lowest yield was obtained from plots receiving Bordeaux-D.D.T. Analysis of variance, Table X shows, however, that there was no significant difference between treatments.

TABLE X

ANALYSIS OF VARIANCE

Source of variation	D.F.	S.S.	M.S.	F	F5%	S.E.
Treatments	6	432.7	72.1	2.348N	3.00	
Replications	2	12552.3	6276.1			
Remainder	12	368.7	30.7			5.54
Total	20	13353.7				

N Not significant at the 5 per cent point.

Table XI shows the yield of Green Mountain potatoes obtained in one of the field experiments conducted during 1948. The plots used in this experiment were three rows in width and treatments were replicated six times. All yield data was obtained from the plants in the center row of each plot. Analysis of variance of these results, Table XII,

TABLE XII

ANALYSIS OF VARIANCE

Source of variation	D.F.	S.S.	M.S.	F	F1%	S.E.	D.R.S. P=0.05	D.R.S. P=0.01
Treatments	2	6578.8	3289.4	17.23 XX	7.56		106.58	151.59
Replicates	5	1031.3	206.2					
Remainder	10	1908.6	190.8			13.815		
Total	17	9518.7						

XX Indicates significance at the 1 per cent point.

The experiment conducted during 1948 to determine the comparative effect of Bordeaux and Dithane spray on the yield of Irish Cobbler potatoes was made possible by the co-operation of Mr. F.M. Cannon, officer-in-charge, Dominion Entomological Laboratory, Charlottetown. Mr. David Barwise, member of the staff of the Dominion Entomological Laboratory, Charlottetown, supervised the preparation and application of all treatments. The plots used in this experiment were three rows in width; the rows were ninety feet in length, and all treatments were replicated four times. Six different treatments, including a check, were used in the experiment. The treatments used are shown in Table XIII. Treatments were applied at approximately ten-day intervals on the following dates: July 23rd., August 2nd., August 12th., August 22nd., and September 4th. All yield data was obtained from the plants in the center row of each plot. Table XIII shows the total yield of the plants harvested in each treatment.

TABLE XIII

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS WITH AND WITHOUT D.D.T. ON THE YIELD OF IRISH COBBLER POTATOES.

TREATMENT	FORMULAE	YIELD IN POUNDS 1	2	3	4	TOTAL
Bordeaux	4-4-40	127.0	79.5	74.0	127.5	408.0
Dithane-zinc sulphate	2-1-80	114.0	92.0	84.0	113.0	403.0
Dithane-zinc sulphate-D.D.T.	2-1-2-80	144.5	134.0	117.5	115.5	511.5
Bordeaux-D.D.T.	4-4-40-1	102.5	94.0	93.0	134.5	424.0
D.D.T.	2-80	100.5	81.0	91.0	105.0	377.5
Check		85.5	70.5	76.0	87.0	319.0

Late blight was present about September 1st., in the check plots and in the plots receiving D.D.T. alone, but did not become severe until about September 15th., when the plants in all treatments began to die.

Analysis of variance, Table XIV, shows that Dithane-D.D.T. gave significantly higher yields than did Bordeaux-D.D.T. It will be noted that the yields obtained from the plots receiving Bordeaux and Dithane spray alone were about the same, and that the addition of D.D.T. to Bordeaux mixture did not result in a significant increase in yield. However, when D.D.T. was added to Dithane spray a highly significant increase in yield was obtained. All fungicide treatments gave

significantly higher yields than the check, which received no fungicide or insecticide. The Dithane-D.D.T. treatment, however, was the only one that gave a significantly higher yield than the D.D.T. treatment.

TABLE XIV

ANALYSIS OF VARIANCE

Source of Variation	D.F.	S.S.	M.S.	F.	F1%	S.E.	D.R.S. P=0.05	D.R.S. P=0.01
Treatments	5	4960.1	992.02	6.141**	4.56		76.59	105.91
Replications	3	3063.5	1021.16					
Remainder	15	2422.9	161.52			12.709		
Total	23	10446.5						

** Indicates significance at the 1 per cent point.

THE EFFECT OF DITHANE SPRAY ON THE STARCH CONTENT OF POTATO LEAVES

Some of the field experiments that have been conducted to determine the comparative fungicidal value of Bordeaux mixture and Dithane spray in controlling the diseases of the potato have indicated that the two substances, when properly used, give about equal control of disease. The yield of plants that have been treated with Bordeaux mixture, however, has been found to be considerably lower than the yield of plants treated with Dithane spray.

There have been a number of reasons suggested as the probable cause of the reduction in yield of potatoes resulting from the application of Bordeaux mixture. Amos (1907) suggested that Bordeaux mixture plugs the stomata and in that way reduces the rate of photosynthesis. Hoffman (1932) thought that the shading influence of Bordeaux mixture was sufficiently great to retard photosynthesis, and Southwick and Childers (1941) attributed it to some physiological effect of the copper fraction of Bordeaux.

Copper is known to be toxic to the enzyme diastase that converts the starch formed in the leaf into sugar so that it may be translocated. If the hydrolytic action of this enzyme is retarded, starch accumulates in the leaf, and according to Miller (1931) an accumulation of starch within the leaf interferes with the photosynthetic process. The determination of the daily variation in starch content of

the leaves of plants that have been sprayed with (a) Bordeaux mixture; (b) Dithane spray, and (c) no fungicide, would, therefore, indicate whether or not there is any effect on starch formation resulting from the application of Bordeaux, and whether or not such an effect is also produced by Dithane spray.

Data on the comparative effect of Bordeaux and Dithane spray on the starch content of leaves was obtained in the experiment conducted on Green Mountain potatoes during the summer of 1948. The plots used in this experiment were three rows in width, the rows were one hundred and thirty feet in length, and each treatment was replicated six times. The following treatments were used: Bordeaux-D.D.T.; Dithane spray-D.D.T., and D.D.T. alone.

On July 23rd-24th and August 20th-21st, leaf samples were taken over a twenty-four hour period from the plants in the center row of the three plots in each of the first three replicates. Each of the samples collected consisted of twenty-five grams of leaf tissue. All leaves were taken from the upper portion of the plant, and only leaves in an exposed position were picked. Immediately upon collection the samples were placed in eighty per cent ethyl alcohol for two hours in order to prevent any change in the starch content; they were then stored in fifty per cent ethyl alcohol.

The first treatment was applied to all plots on the evening of July 22nd., and the first leaf samples were taken about fourteen hours after on the morning of July 23rd.

Leaf samples were collected seven times on July 23rd., and three times in the early morning of July 24th. The times at which these ten samples were taken are shown in Table XV.

Four treatments were applied to all plots before the second series of samples was taken. Treatments were applied on the following dates: July 22nd., July 31st., August 10th., and August 19th. The first leaf sample was taken on the morning of August 20th., about sixteen hours after the last application of fungicides. Leaf samples were collected six times on August 20th., and three times in the early morning of August 21st. The times at which the samples were taken are shown in Table XVI.

Mr. A.B. Williams, Miss Phyllis MacMillian and Miss Velma Carmody, members of the staff of the Laboratory of Plant Pathology, Charlottetown, assisted in collecting and analysing the samples.

The starch present in each sample was converted to sugar and extracted. The method of extraction used was that given by Clements (1930). The reducing power of all sugar samples was determined according to the Shaffer and Hartman (1920) method. In order to prevent the copper present on the Bordeaux-treated leaves from interfering with the determination of the reducing power of the sugar solution, it was necessary to wash all leaf samples for a few minutes in a two per cent solution of sulphuric acid, and then to wash them thoroughly with water before beginning the extracting process.

The starch present in all samples was reported as milligrams of glucose. The result of the analysis of samples, and the starch content of each sample expressed as a percentage of the green weight, taken on July 23rd-24th and August 20th-21st., are shown in Tables XV and XVI respectively. The variation in the percentage starch content, over a twenty-four hour period, of the samples taken on July 23rd-24th., and August 20th-21st is shown in Figures I and II respectively.

TABLE XV

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE STARCH CONTENT OF LEAF SAMPLES TAKEN ON JULY 23-24

Time of Sampling	Milligrams of Glucose			Percent Green Weight		
	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T	Bordeaux D.D.T.	Dithane D.D.T.	D.D.T.
July 23:						
7:45- 8:30 am	443.1	373.8	336.2	0.591	0.498	0.448
9:45-10:15 am	333.8	417.0	387.2	0.445	0.556	0.516
11:40-12:10 am	281.6	217.4	203.4	0.375	0.289	0.271
1:45- 2:15 pm	379.6	333.1	337.5	0.506	0.444	0.450
3:45- 4:15 pm	504.9	658.1	635.9	0.673	0.877	0.847
5:40- 6:25 pm	418.9	413.3	443.1	0.558	0.551	0.590
7:35- 8:20 pm	329.3	381.5	248.6	0.439	0.508	0.331
July 24:						
1:40- 2:10 am	72.4	78.7	95.5	0.096	0.104	0.127
5:45- 6:30 am	93.4	106.0	128.1	0.124	0.141	0.170
8:10- 8:45 am	220.0	194.2	206.8	0.293	0.258	0.275

TABLE XVI

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE STARCH CONTENT OF LEAF SAMPLES TAKEN ON AUGUST 20-21

Time of Sampling	Milligrams of Glucose			Percent Green Weight		
	Bordeaux D.D.T	Dithane D.D.T	D.D.T	Bordeaux D.D.T	Dithane D.D.T	D.D.T.
August 20:						
10:10-10:30 am	202.7	231.2	209.2	0.270	0.308	0.278
11:20-11:50 am	345.4	261.5	276.2	0.460	0.349	0.368
2:05- 2:35 pm	246.2	178.5	202.8	0.328	0.238	0.270
4:20- 4:50 pm	363.2	303.3	347.0	0.484	0.403	0.462
7:00- 7:30 pm	182.9	166.0	165.2	0.243	0.221	0.220
8:10- 8:40 pm	88.8	67.1	117.7	0.118	0.089	0.156
August 21:						
1:45- 2:25 am	49.5	42.0	51.1	0.066	0.056	0.068
6:00- 6:45 am	73.1	75.3	105.6	0.097	0.100	0.186
8:20- 9:00 am	111.7	119.8	144.0	0.148	0.159	0.192

The analysis of both series of samples shows that there was little apparent difference in the daily variation in the starch content of the leaf samples taken from the three treatments.

The starch content of the first leaf samples taken from the Bordeaux-treated plots on the morning of July 23rd., was slightly higher than the amount present in the samples taken from the other two treatments. Samples taken throughout the remainder of the day, however, indicate that there was no

FIGURE I

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE VARIATION IN THE PERCENTAGE STARCH CONTENT OF LEAF SAMPLES TAKEN ON JULY 23-24

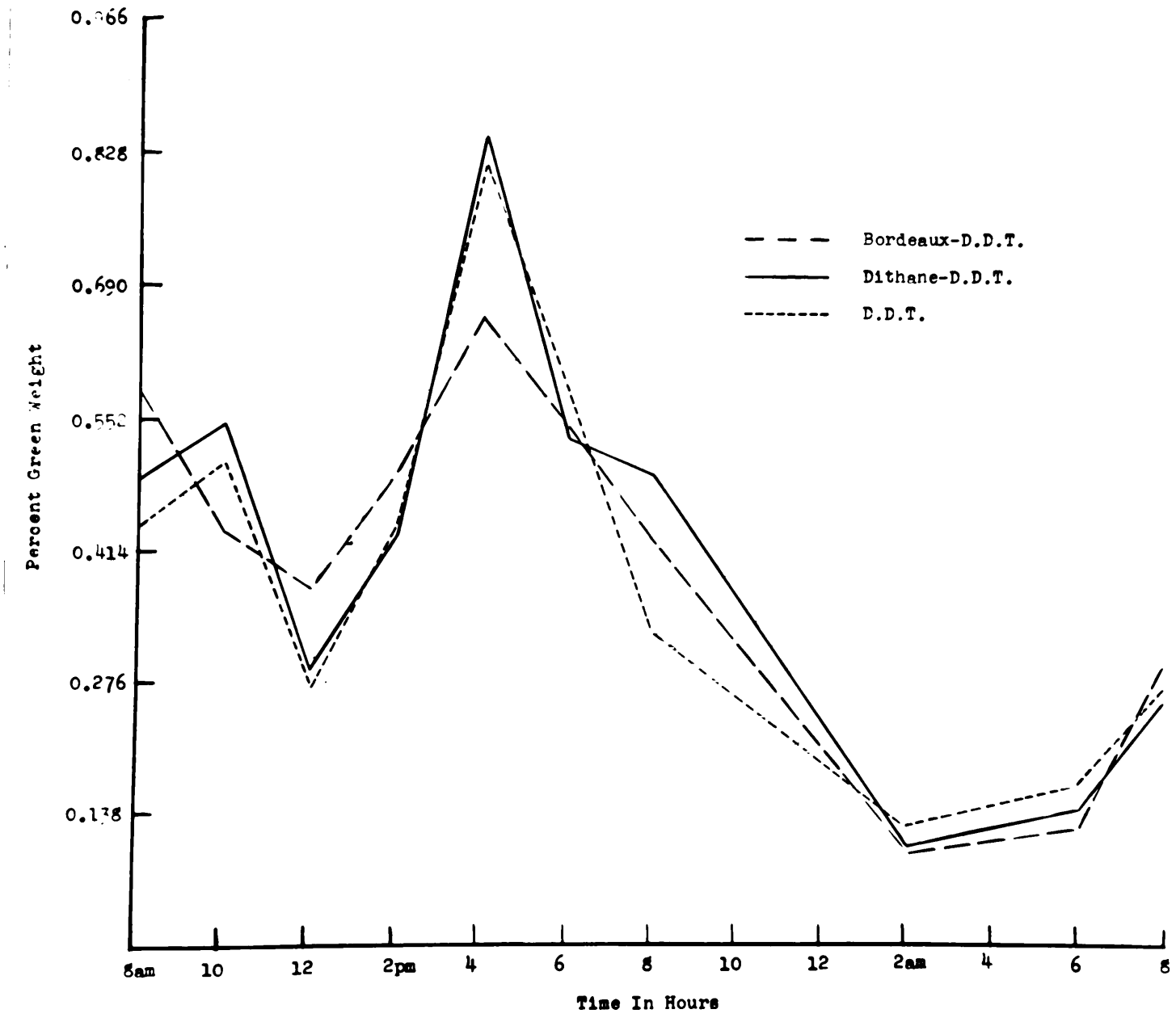
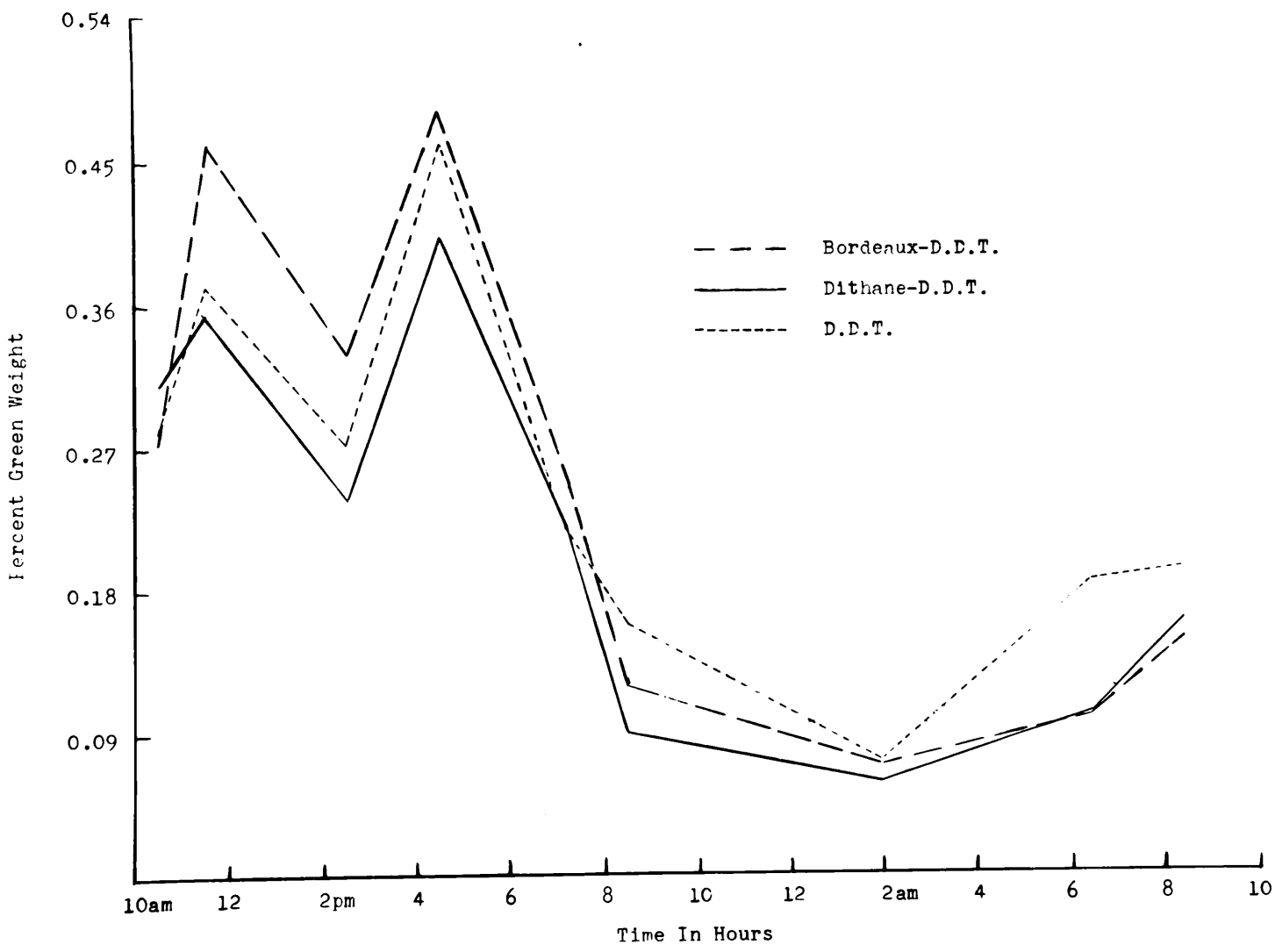


FIGURE II

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS PLUS D.D.T. ON THE VARIATION IN THE PERCENTAGE STARCH CONTENT OF LEAF SAMPLES TAKEN ON AUGUST 20-21



accumulation of starch in the leaves of plants treated with Bordeaux mixture. The starch content of Bordeaux-treated leaves during the night of July 23rd., and early morning of July 24th., was not appreciably different from that of the other two treatments.

There was no difference in the starch content of the first samples taken on the morning of August 20th. The samples taken from the Bordeaux-treated plants up until four-thirty in the afternoon of August 20th., were slightly higher in starch content than the samples taken from the other two treatments. Little difference was apparent, however, among the samples taken during the night and the early morning of August 21st.

THE EFFECT OF DITHANE SPRAY ON CUTICULAR TRANSPIRATION

The effect of fungicidal sprays, particularly Bordeaux, on the transpiration of plants has long been a controversial question and reports can be found in the literature of both increases and decreases having been obtained. In general it is agreed that Bordeaux mixture increases cuticular transpiration and decreases stomatal transpiration. According to Horsfall and Harrison (1939) the increase in cuticular transpiration is due to the saponification of the cuticle.

In the work reported here the effect of Bordeaux and Dithane sprays on cuticular transpiration only was studied. The method employed was similar to that said by Horsfall (1945) to have been first used by Duggar and Cooley (1914). Tomato plants from eight to ten inches in height were cut off at ground level, the cut ends covered with vaseline to prevent loss of moisture from this area, and the plants immediately weighed. After weighing, the plants were dipped in the treatment solution and spread out on a wire frame constructed on the greenhouse bench. The plants began to wilt shortly after being cut and, as stomatal transpiration was then reduced to a minimum due to the closure of the stomata (Horsfall 1945), further loss of moisture was largely due to cuticular transpiration.

The effect of the fungicides on cuticular transpiration was determined by weighing the plants when the spray material had dried on the foliage and again four, seven, twelve and twenty-three hours after treatment. The loss in weight of the plants in each replicate for any time interval, was determined by subtracting the weight recorded at the end of that interval from the initial weight. In order to equalize, as much as possible, any difference in loss of weight due to variations in the initial green weight, the total weight of plants in each replicate was made as nearly equal as possible, and the loss in weight of the plants in each replicate for the various time intervals was calculated on the basis of the loss in weight per gram of initial weight.

Two sets of experiments were conducted. In the first set, the effect of Dithane spray (1) was compared with the effect of 4-4-40 and 4-1-40 Bordeaux mixture and with plants treated with tap water. In the second set of experiments 4-1-40 Bordeaux mixture was replaced by 4-2-40 Bordeaux mixture. Each experiment was run three times. In each trial, three plants were included in each replicate and treatments were replicated four times. The results were

(1) In accordance with the recommendations made by the manufacturers up until 1948, the formula used here for Dithane spray was as follows: Dithane D-14 - two quarts; Zinc sulphate - 1 pound; lime - $\frac{1}{2}$ pound; water - eighty Imperial gallons.

analysed by the analysis of variance method.

The loss of weight in grams per gram of initial weight of the plants in each replicate was determined for all time intervals, and the loss in the four replicates added to give the total effect of the treatment. The total loss of weight in grams per gram of initial weight in each treatment of the two experiments is shown in Table XVII, and graphs typical of the effect of the treatments are shown in Figures III and IV. The application of Dithane spray resulted in a significant increase in cuticular transpiration over the checks in from seven to twelve hours after treatment. In all cases 4-4-40 Bordeaux mixture caused a significant increase in cuticular transpiration over the Dithane-treated plants in two to four hours. 4-1-40 Bordeaux mixture caused a significant increase in transpiration over the Dithane-treated plants after seven hours in one case, but in the other two not until twenty-three hours after treatment. In one trial 4-2-40 Bordeaux mixture caused a significant increase in cuticular transpiration over the plants treated with Dithane spray after four hours, and in the other trials, twenty-three and twelve hours after treatment. Although the increase in cuticular transpiration over the Dithane-treated plants resulting from the 4-2-40 and 4-1-40 treatments are very much the same, a greater increase resulted from the use of

TABLE XVII

THE EFFECT OF BORDEAUX AND DITHANE SPRAY ON THE CUTICULAR TRANSPIRATION OF TOMATO PLANTS

LOSS OF WEIGHT IN GRAMS PER GRAM OF INITIAL WEIGHT

TREATMENT	Experiment I: Hours after treatment: 2			4			7			12			23		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
Bordeaux 4-4-40	0.318	0.464	0.338	0.831	0.996	0.773	1.171	1.538	1.272	1.649	1.921	1.913	2.388	2.821	2.765
Bordeaux 4-1-40	0.273	0.383	0.397	0.633	0.751	0.633	0.953	1.063	0.994	1.361	1.362	1.477	2.115	2.103	2.175
Dithane Spray	0.259	0.386	0.373	0.565	0.703	0.599	0.795	0.973	0.973	1.042	1.270	1.362	1.498	1.875	1.959
Check	0.226	0.394	0.357	0.523	0.720	0.557	0.686	0.970	0.900	0.855	1.239	1.211	1.317	1.883	1.727
D.R.S.[1]	0.090	N.S.[2]	N.S.	0.131	0.095	0.074	0.150	0.166	0.105	0.217	0.178	0.109	0.242	0.156	0.102
Experiment II:															
Bordeaux 4-4-40	0.105	0.284	0.209	0.644	0.659	0.504	0.918	1.135	0.851	1.251	1.403	1.113	2.053	2.013	1.576
Bordeaux 4-2-40	0.114	0.229	0.116	0.477	0.400	0.356	0.773	0.716	0.627	1.102	0.954	0.843	1.942	1.378	1.277
Dithane Spray	0.103	0.250	0.147	0.351	0.362	0.329	0.614	0.629	0.542	1.041	0.787	0.715	1.621	1.203	1.068
Check	0.103	0.171	0.080	0.347	0.268	0.314	0.493	0.419	0.460	0.674	0.523	0.587	1.092	0.809	0.888
D.R.S.	N.S.	N.S.	0.074	0.095	0.165	0.052	0.118	0.214	0.101	0.204	0.182	0.113	0.235	0.287	0.121

(1) Difference required for significance at 5% point.
(2) Not significant.

FIGURE III

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS ON THE CUTICULAR TRANSPIRATION OF TOMATO PLANTS

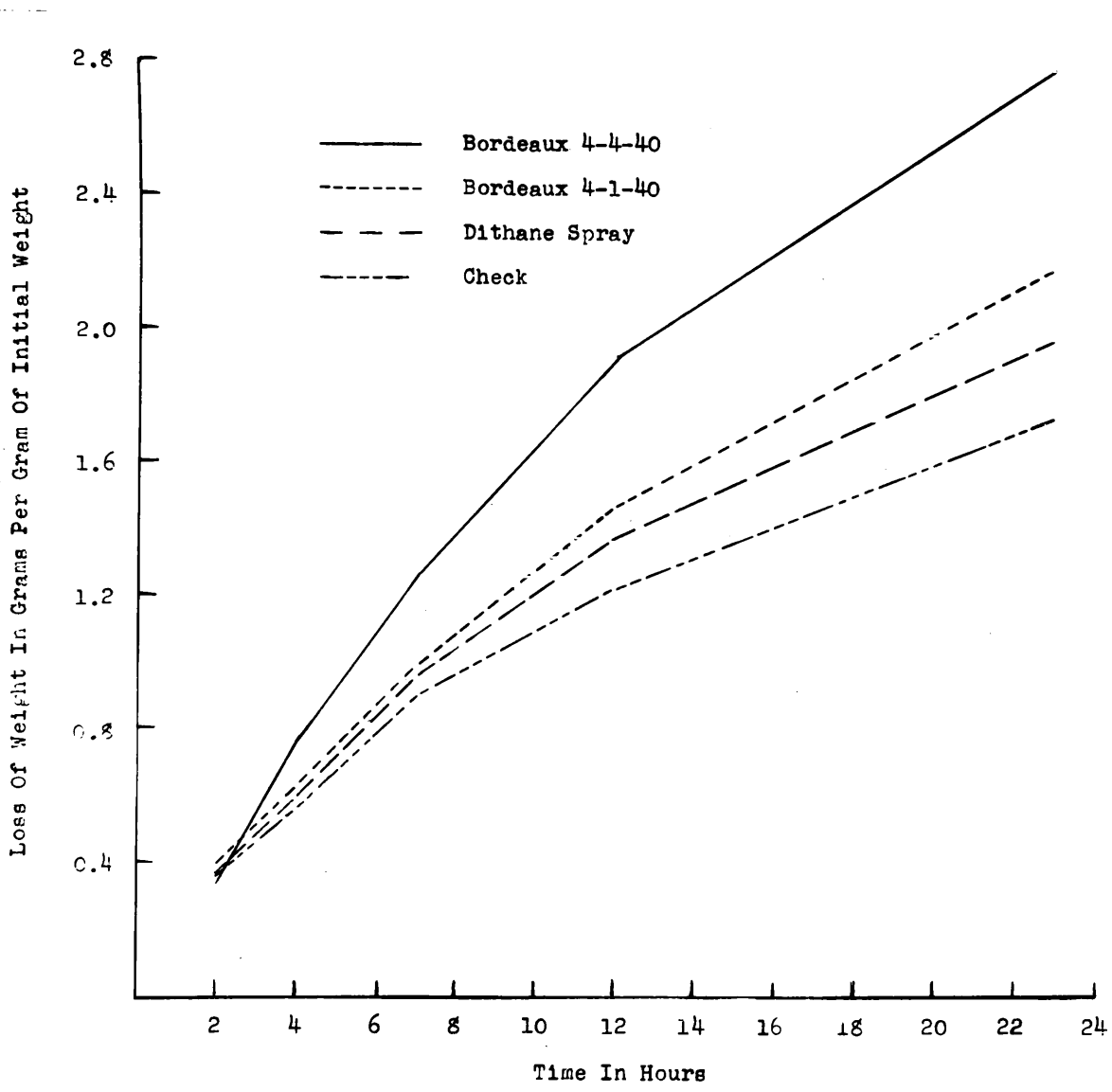
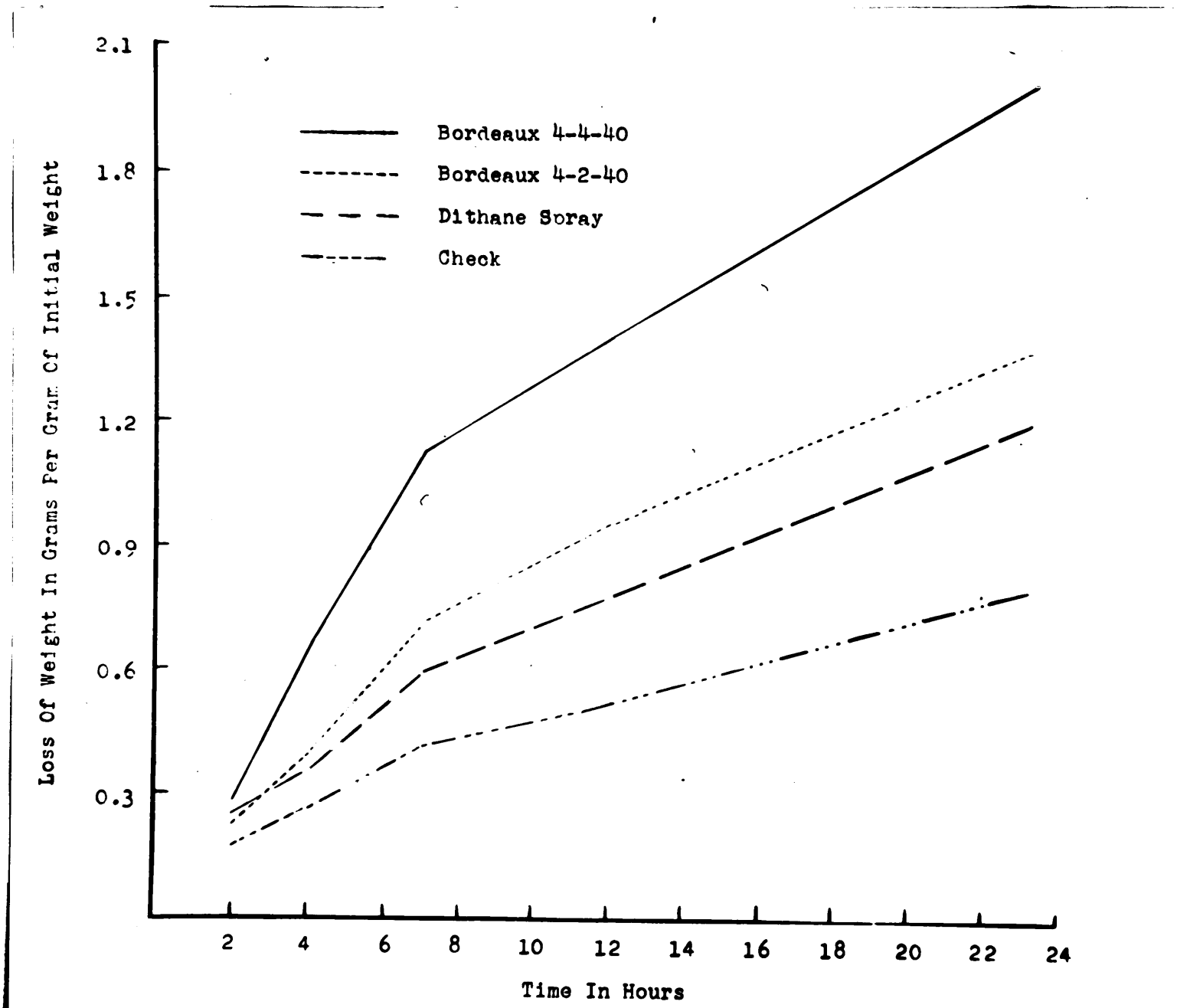


FIGURE IV

THE EFFECT OF BORDEAUX AND DITHANE SPRAYS ON THE CUTICULAR TRANSPIRATION OF TOMATO PLANTS



2-40 Bordeaux mixture. These results are in agreement with rsfall and Harrison (1939), who showed that cuticular anspiration increased markedly with an increase in the kalinity of the mixture.

DISCUSSION

The application of Dithane spray to plants that are not suffering from copper deficiency, and are free from insects and disease, has been found to result in higher yields than the application of Bordeaux mixture to such plants. This thesis has been concerned with an attempt to discover why, under these conditions, Dithane-sprayed plants outyield those sprayed with Bordeaux mixture.

In areas where insects are an important factor in causing a reduction in potato yields, Bordeaux mixture has been found to give higher yields than Dithane spray when both are used without an insecticide. It was thought that this might be due to the control of insects given by Bordeaux mixture, and in order to determine if this supposition was correct, experiments were conducted during 1947 and 1948 in which the effect of adding the insecticide D.D.T. to Bordeaux mixture and Dithane spray was observed. In the experiment conducted during 1947 Dithane treatments, with and without the insecticide D.D.T., and a Bordeaux treatment containing D.D.T. were used. Insects, however, caused little damage during 1947, and no information could be obtained on the effect of adding D.D.T. to Dithane spray, or on the comparative yields of Bordeaux mixture and Dithane spray when the insect factor was eliminated. In the experiment conducted with Irish Cobbler potatoes during 1948, Bordeaux

mixture and Dithane spray were both used with and without the insecticide D.D.T. The results show (see Table XIII) that the plots receiving Bordeaux mixture and Dithane spray without an insecticide gave about the same yield. As insects were abundant during 1948 this might be taken to indicate that Dithane spray gave about equal control of insects as Bordeaux mixture. However, if this were the case then it would be expected that the addition of the insecticide D.D.T. to Dithane spray would result in the same increase in yield as the addition of D.D.T. to Bordeaux mixture. The results show, however, that the addition of D.D.T. to Bordeaux mixture resulted in a small and non-significant increase in yield, while the addition of D.D.T. to Dithane spray resulted in a highly significant increase in yield. This indicates that Bordeaux mixture used alone gave almost complete control of insects while Dithane spray used alone did not. The fact that Bordeaux mixture did not give higher yields than Dithane spray when both were used without an insecticide was probably due to the toxic effect of Bordeaux mixture on the plant which balanced any increased yield that might have been obtained from the control of insects.

It has been observed by Wilson and Runnels (1935b) and Childers (1935) and others that Bordeaux mixture causes a retardation in the growth of plants. Table VI shows, however, that at all six sampling dates, extending over a

period beginning when tubers first formed (July 27th.) and continuing until they reached about maximum growth, (September 3rd.) the foliage-weight of the plants receiving Bordeaux-D.D.T. was not significantly less than the foliage-weight of plants receiving D.D.T. alone. On the last three sampling dates the foliage-weight of the plants receiving Dithane-D.D.T. was somewhat greater than that of the plants receiving Bordeaux-D.D.T. and D.D.T. alone. The increased foliage development resulting from the use of Dithane spray, although not mathematically significant, is in agreement with the observations of Heuberger and Manns (1945) who reported that plants receiving Dithane spray had a more vigorous vine growth than plants sprayed with Bordeaux mixture.

In the field experiment conducted during 1948 with Green Mountain potatoes, tuber samples were taken on eight occasions beginning when the tubers first formed (July 27th.) and continuing until they had attained about maximum size (October 6th.). All tubers obtained on the eight sampling dates were weighed individually and placed in one of five weight-ranges. The weight-ranges used were as follows: range one, 0-1.9 g.; range two, 2.0 g.-5.9 g.; range three, 6.0 g.-34.9 g.; range four, 35 g.-64.9 g.; range five, 65 g., and greater. This division of the tubers obtained at the various sampling dates into weight-ranges gave some evidence

of the comparative effect of Bordeaux-D.D.T., Dithane-D.D.T., and D.D.T. alone on the formation and growth of tubers. On the first three sampling dates no significant difference was found between the weight of tubers obtained from the three treatments. Table IV and V, however, show that the weight of tubers from the Bordeaux-D.D.T. treatment in range one and two on the first sampling date, in range three on the second sampling date, and in range four on the third sampling date, was somewhat less than the weight of tubers in the other two treatments. The weight of tubers in range five from the Bordeaux-D.D.T. treatment was significantly less than the weight of tubers in range five obtained from the other two treatments at the fourth sampling date. This agrees with the findings of Mader and Blodgett (1935a) and Fernow and Smith (1944), who stated that tuber development early in the season was most rapid on plants that were not sprayed with Bordeaux mixture. The weight of tubers obtained from the plants receiving Dithane-D.D.T. spray and D.D.T. alone were not appreciably different in any weight-range on the first four sampling dates. According to Mader and Blodgett (1935a), the weight of tubers from Bordeaux-sprayed plants gradually increased toward the end of the season, and finally gave the same yield as the unsprayed plants; however, there is no indication of this in the weight of tubers obtained on the fifth and sixth sampling dates.

On the seventh and eight sampling dates, the total weight of tubers obtained from the plants receiving D.D.T. alone was less than the total weight of tubers obtained from the other two treatments. The reduced tuber yield in the plots receiving D.D.T. alone was caused by a severe attack of late blight (Phytophthora infestans (Mont.) deBy.).The total yield of tubers on the last two sampling dates was significantly greater in the Dithane treatment than in the other two treatments. This was largely due to the greater weight of tubers in range five obtained from the plants receiving Dithane-D.D.T. spray. There is some indication, therefore, that Bordeaux mixture has a greater depressing effect upon the increase in the size of the tubers during both the early and late period of tuber formation than has Dithane spray.

Tables II and III show that the total number of tubers obtained from the plants in the Bordeaux-D.D.T., Dithane-D.D.T., and D.D.T. alone treatments increased up until the third and fourth sampling date, and then gradually decreased. At all sampling dates the total number of tubers from the plants receiving Dithane-D.D.T. was greater than the number obtained from the plants receiving Bordeaux-D.D.T. The total number of tubers from plants receiving D.D.T. alone was also greater at all sampling dates than the number obtained from the plants receiving Bordeaux mixture, except on the last two sampling dates when late

blight became severe in the D.D.T. plots. According to Mader and Blodgett (1935a), one of the important effects of spraying with Bordeaux mixture is that the sprayed plants develop a greater number of tubers. In this work, however, it has been found that up until the time late blight became serious, the plants receiving D.D.T. alone produced as many tubers as those receiving Bordeaux-D.D.T. Bordeaux mixture seemed to have some effect upon the early setting of tubers, as is shown by the smaller number of small tubers obtained on the first three sampling dates from plants receiving this treatment. On the fourth sampling date there were significantly more tubers in range five in the samples taken from the plants receiving Dithane-D.D.T., and D.D.T. alone. Throughout the remainder of the season plants receiving Dithane-D.D.T. produced more tubers in the largest weight range than did plants receiving Bordeaux-D.D.T. The higher yields obtained throughout the season from the plants receiving Dithane-D.D.T., therefore, would seem to be due to a greater production of tubers in the largest weight range.

In the field experiments conducted during 1948 with Green Mountain and Irish Cobbler potatoes, the final yield of plants treated with Dithane spray was found to be significantly greater than that of plants treated with Bordeaux mixture (see Tables XI and XIII). Horsfall and Turner

(1947) attribute the increase in yield resulting from the use of Dithane spray to the fact that Dithane spray contains less lime than Bordeaux mixture, and is therefore less toxic to the plant. The result of the field experiment conducted during 1947 (see Tables I and IX.) indicate, however, that the use of a Dithane spray containing an amount of lime equal to that found in Bordeaux mixture does not result in any effect on the formation of tubers throughout the season or on the final tuber yield. This indicates that, contrary to the opinion of Horsfall and Turner (1947), the increase in yield resulting from the use of Dithane spray is not due to the fact that Dithane spray contains less lime than Bordeaux mixture.

No evidence was found to indicate that either Bordeaux mixture or Dithane spray have an effect upon the maturing of the potato plant. The counts made of the percentage of plants in bloom throughout the season (see Tables VII and VIII.) show that all plants came into bloom about the same time after planting, and that the treatments had no effect upon the length of time the plants remained in bloom. It has been observed by Bonde and Snyder (1946) and others that Bordeaux mixture delays the maturing of potato plants, so that plants sprayed with Bordeaux mixture remain green after untreated plants or plants sprayed with Dithane spray have died. In the experiments conducted during

1947 and 1948, however, no evidence was found to indicate that either Bordeaux mixture or Dithane spray had any effect upon the length of time the plants remained green.

Studies were made to determine the effect of Bordeaux-D.D.T., Dithane-D.D.T., and D.D.T. alone on the manufacture and translocation of starch by determining the variation in the starch content of potato leaves taken over a period of twenty-four hours. Leaf samples were taken on two occasions, and the result of the analysis of these samples, as shown in Tables XV and XVI and graphically in Figures I and II, indicates that there was no difference in the variation in the starch content of the leaf samples taken from the three treatments. Southwick and Childers (1941) and others have observed that leaves treated with Bordeaux mixture retained starch long after it was absent from the untreated leaves, and Horsfall (1945) states that Ewert also observed that starch was retained longer in leaves treated with Bordeaux mixture. In the work reported here, however, no evidence was found to indicate that Bordeaux mixture has an effect upon the formation and translocation of starch.

The cuticular transpiration of tomato plants, two to four hours after treatment with Bordeaux 4-4-40, was found to be significantly greater than that of plants treated with Dithane spray. Bordeaux 4-1-40 and Bordeaux

4-2-40 were also found to cause a greater increase in cuticular transpiration than Dithane spray. The increase in cuticular transpiration resulting from the application of Bordeaux 4-1-40 and Bordeaux 4-2-40, however, was not as great as that caused by Bordeaux 4-4-40. Dithane spray was also found to increase cuticular transpiration, but not by as great an amount as any of the Bordeaux mixtures used.

The results show that, under the conditions of these experiments, the application of Dithane spray to plants that are free from insects and disease usually results in an increase in yield over plants treated with Bordeaux mixture. Little information was obtained to explain why plants treated with Dithane spray gave higher yields than plants sprayed with Bordeaux mixture. Some evidence was found to indicate that Bordeaux mixture causes a delay in the setting of tubers, and has a depressing effect upon the increase in the size of the tubers during the early and late period of tuber formation. No evidence was found to suggest, however, that the lime present in Bordeaux mixture causes a reduction in tuber formation or final yield, or that Dithane spray or Bordeaux mixture have any effect upon the formation and translocation of starch. Plants treated with Dithane spray were found to produce a greater foliage growth late in the season than Bordeaux treated plants, but no evidence was found to show that either

Bordeaux mixture or Dithane spray have any effect upon the length of time the plants remain green.

It should be noted that all the field experiments reported here were carried out at Charlottetown, Prince Edward Island, and that although the application of Bordeaux and Dithane spray was found to have certain effects upon the plant, these effects might be found to be different in areas where the climatic conditions are not the same. Different results might also be obtained in the Charlottetown area in seasons when the climatic conditions differ from those under which the experiments reported here were conducted.

The result of the experiments reported here only partly account for the increased yields resulting from the use of Dithane spray, and further investigations are necessary before a complete explanation can be given.

SUMMARY

(1) Studies were conducted to determine why the application of Dithane spray to potato plants that are grown in the absence of disease and insects results in a higher yield than when such plants are treated with Bordeaux mixture.

(2) It was found that Bordeaux mixture and Dithane spray gave about equal yields when they were used without an insecticide, and that the addition of D.D.T. to Dithane spray resulted in a highly significant increase in yield while the addition of D.D.T. to Bordeaux mixture resulted in a small and non-significant increase in yield. This was interpreted as indicating that Bordeaux mixture acts as an insecticide but, because of its toxic effect upon the plant, it does not give a higher yield than Dithane spray which has no insecticidal properties.

(3) Bordeaux mixture and Dithane spray were found to have no significant effect upon the weight of foliage produced by the potato. Towards the end of the season, however, the foliage weight of plants treated with Dithane spray was somewhat greater than that of plants treated with Bordeaux mixture.

(4) Some evidence was found to indicate that the reductior in yield resulting from the application of Bordeaux mixture

was due to its depressing effect upon the formation of tubers, and to the fact that fewer large tubers were produced.

(5) It was found that the increase in yield resulting from the use of Dithane spray was not due to the fact that it contained less lime than Bordeaux mixture.

(6) Bordeaux mixture and Dithane spray were found to have no effect on the rate of maturing of the plant or on the formation and translocation of starch.

(7) Bordeaux mixture of various lime concentrations was found to cause a greater increase in cuticular transpiration than Dithane spray.

(8) The differences found in the physiological effects of Bordeaux mixture and Dithane spray only partly explain why plants sprayed with Dithane spray give a higher yield than plants sprayed with Bordeaux mixture, and further work on the comparative physiological effect of the two fungicides is necessary.

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