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EXPERIMENTS WITH POTATOES

I. DUSTING VS. SPRAYING

F. C. STEWART AND P. J. PARROTT

II. ROW COMPETITION AND BORDER EFFECT

F. C. STEWART

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I. DUSTING VS. SPRAYING

F. C. STEWART AND P. J. PARROTT

SUMMARY

Each summer during the past four years an experiment has been made to determine how the efficiency of the Sanders' copper-lime dust compares with that of liquid bordeaux mixture for the control of the insect and fungous enemies of potato foliage.

Both the dust and the spray were applied very thoroly—the dust by means of hand dusters, the spray with an orchard power sprayer.

In each of the four experiments the spray gave much the better results, as shown both by the appearance of the foliage and by the yield of marketable tubers. Both early blight and late blight were controlled fairly well by dusting but considerably better by spraying. For the control of tipburn or hopperburn (caused by leafhoppers), the dust proved almost valueless, while the spray showed high efficiency. Since neither flea beetles nor Colorado potato beetles were important factors in any of the experiments, no data on the control of these insects were obtained.

Notwithstanding the lesser efficiency of the dust its use may be advisable under certain conditions, for example, where water is difficult to obtain and in small fields where it is necessary to use hand machines.

INTRODUCTION

In America, liquid bordeaux mixture first came into use as a fungicide for potatoes about 1890 (1).[1] Enterprising manufacturers were quick to see the commercial possibilities of substitutes which could be applied in the form of dust. During the past 30 years a great many kinds of such mixtures have been put upon the market under various proprietary names. Certain of these, possessing some merit and being well advertised, have held their place upon the market in spite of the adverse reports upon them by the agricultural experiment stations. As long ago as 1896 Professor L. R. Jones (3) reported the results of a carefully conducted field test at the Vermont

[1]Figures in parenthesis refer to Literature Cited, page 28.

Experiment Station in which several forms of bordeaux mixture, including two proprietary powder forms, were used on potatoes. The conclusion from the results of the test was stated as follows: "When these powders were applied dry even in most liberal amounts they gave so little protection that their substitution for the ordinary or wet mixture is not to be recommended under any circumstances." Subsequently, similar reports were made by various other experimenters until it was considered to have been definitely established that, as a fungicide for use on potatoes, the home-made liquid bordeaux mixture is superior to any dust mixture.

Then came the so-called Sanders' copper-lime dust. This originated with Messrs. G. E. Sanders and A. Kelsall (8, 9) who were, at that time, connected with the Canadian Department of Agriculture, Entomological Branch, Annapolis Royal, Nova Scotia. The Sanders' copper-lime dust is a mixture of hydrated lime and finely ground partially dehydrated copper sulfate. When calcium arsenate is added for the control of chewing insects, the mixture is known as Sanders' copper-arsenic dust. It goes, also, by other names. According to Mr. Sanders (7), the copper-arsenic dust was first used on potatoes in 1918 at Truro, N. S., and Frederickton, N. B. In 1919 and 1920 additional experiments were made with it at Strathroy, Ont., Annapolis Royal and Church Point, N. S., and Frederickton, N. B. In these eight Canadian experiments the dusted potatoes outyielded the sprayed potatoes by an average of 26.31 bushels per acre.

At the annual meeting of the New York State Potato Association held at Ithaca, N. Y., in February, 1921, Professor H. H. Whetzel (10) of the New York State College of Agriculture reported briefly the results of six potato spraying and dusting experiments in five widely separated localities in New York during the season of 1920. In four of the six experiments the treatment with Sanders' copper-lime dust gave a larger yield than that obtained by spraying with bordeaux mixture.

The remarkable showing made by the Sanders' dust in these experiments attracted the attention of potato growers everywhere and gave a great impetus to the sale of the dust and potato dusting machinery. Soon there began to come to this Station a considerable demand for information concerning the relative merits of dusting and spraying for potatoes.

Altho the history of experimentation with such dusts was opposed to the idea that this new Sanders' dust would prove to be a fit sub-

stitute for liquid bordeaux mixture, the question could not, under the circumstances, be disposed of in that way. New materials and improved methods have frequently overturned supposedly established principles. On the other hand, the writers were unwilling to accept, as a final answer to the question, the results of the experiments reported by Sanders and Whetzel. Such being the situation it seemed necessary to obtain more experimental evidence.

EXPERIMENTS AT GENEVA

Each summer during the past four years the writers have conducted on the Station farm an experiment in which the Sanders' dust and liquid bordeaux mixture have been used on potatoes in such a way as to show their relative efficiency in disease and insect control.

In each of these experiments a small field of potatoes has been divided into plats, some of which were dusted, others sprayed, and others left untreated (except for "bugs") as checks. The dust has been applied with hand dusters of four different kinds. The spray has been applied by means of an orchard sprayer and under a pressure of about 200 pounds per square inch. A long line of hose was used to carry the nozzles wherever needed, making it unnecessary to drive the heavy sprayer thru the potato field. In all cases, the dust was applied when the air was quiet and several of the applications were made while the foliage was wet with dew. All of the spraying was done on dry foliage. Both the dusting and the spraying were done very thoroly. The potatoes used in the experiments were of the variety Enormous No. 9.

THE EXPERIMENT IN 1920

In this experiment there were 21 rows each 125 feet long. As the potatoes had not been planted for experimental purposes, the seed pieces were not accurately spaced in the rows but were supposed to be 15 inches apart. They were planted on May 24. The stand obtained was good but not perfect.

On account of dry weather and the absence of Colorado potato beetles and flea beetles there seemed to be no need for either dusting or spraying until late in July. This was fortunate because it proved impossible to get ready for the experiment earlier.

The Sanders' copper-calcium-arsenate dust used in the experiment was purchased of the Riches-Piver Co., 30 Church St., New York

City. According to the label on the container, it analyzed 5 per cent copper (as metal), 5 per cent tri-calcium arsenate, and 90 per cent inert ingredients. It was applied with a Leggett Champion No. 2 hand duster. The bordeaux mixture used contained 6 pounds of copper sulfate, and about 10 pounds of lime to each 50 gallons. Commencing July 30, four applications of dust and spray were made at intervals of two weeks. The dust was applied while the foliage was dry and when there was little or no wind. To insure thoroness the rows were dusted twice over each time using from 130 to 155 pounds of dust per acre in each of the four applications.

The plan of the experiment was as follows:

Row 1. Discard.

Rows 2, 3, and 4 (Plat 1). Sprayed four times with bordeaux mixture.

Row 5. Discard.

Rows 6, 7, and 8 (Plat 2). Dusted four times with Sanders' copper-arsenic dust.

Row 9. Discard.

Rows 10, 11, and 12 (Plat 3). Check, no treatment.

Row 13. Discard.

Rows 14, 15, and 16 (Plat 4). Sprayed four times with bordeaux mixture.

Row 17. Discard.

Rows 18, 19, and 20 (Plat 5). Dusted four times with Sanders' copper-arsenic dust.

Row 21. Discard.

Notes of September 9.—On the check rows there is considerable early blight (*Alternaria solani*) and a considerable number of yellow lower leaves. On dusted rows there is less early blight and fewer yellow leaves. On sprayed rows there is still less of both. The difference between dusted and sprayed rows is not marked, but plainly in favor of the latter.

Notes of September 15.—The check rows now show, also, a little late blight (*Phytophthora infestans*) and there are traces of it on the dusted rows, but none on the sprayed rows. The dusted rows appear better than the check, but not as good as the sprayed rows. However, the contrast is not marked in either case. So far, there has been no tipburn or hopperburn of any consequence on any of the plats.

Notes of September 28.—The three check rows are nearly dead—only a little green foliage is to be seen here and there. Both strips

of dusted rows are markedly superior to the check, but have considerable dead and yellow foliage. The early blight is now much in evidence and seems to be largely responsible for the deterioration of dusted plants. The sprayed rows are nearly perfect in foliage. They show no early blight, no late blight, and no yellow leaves. The sprayed rows are decidedly superior to the dusted rows. It now appears improbable that late blight has been an important factor in the dying of the foliage on any of the plats. There is none to be seen anywhere.

Notes of October 7.—Last night there was a light frost which will terminate the growing season for the potatoes in this experiment. When the frost came the sprayed plants still held approximately 50 per cent of their foliage, while of the dusted plants there were only 5 or 6 on each plat which showed any green leaves. The sprayed plants lived several days longer than the dusted plants and their foliage was in distinctly better condition than that of the dusted plants for some time previous.

Yields.—The potatoes were dug on October 20 with a double-mold-board plow. The yield of each plat of three rows was taken separately, the tubers being divided into two classes, sound and rotten, without regard to size. The yield by plats is shown in Table 1. and the yield per acre for the three kinds of treatment in Table 2.

TABLE 1.—YIELD BY PLATS IN THE 1920 EXPERIMENT ON DUSTING VS. SPRAYING FOR POTATOES.

PLAT 1, ROWS 2, 3, AND 4, SPRAYED		PLAT 2, ROWS 6, 7, AND 8, DUSTED		PLAT 3, ROWS 10, 11, AND 12, CHECK		PLAT 4, ROWS 14, 15, AND 16, SPRAYED		PLAT 5, ROWS 18, 19, AND 20, DUSTED	
Sound	Rotten	Sound	Rotten	Sound	Rotten	Sound	Rotten	Sound	Rotten
Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
569	2	518	15	383	71	589	2	473	11

TABLE 2.—YIELD PER ACRE IN THE 1920 EXPERIMENT ON DUSTING VS. SPRAYING FOR POTATOES.*

SPRAYED, PLATS 1 AND 4		DUSTED, PLATS 2 AND 5		CHECK, PLAT 3		DIFFERENCE IN YIELD OF SOUND TUBERS		
Sound	Rotten	Sound	Rotten	Sound	Rotten	Sprayed over check	Dusted over check	Sprayed over dusted
Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
373.1	1.3	319.3	8.3	246.9	45.8	126.2	72.4	53.8

*Calculated from data in Table 1.

Comments on the results.—The principal cause of the premature dying of the leaves in this experiment was the early blight. The differences in the condition of the foliage on the different plats were due, chiefly, to differences in the control of early blight. It was controlled fairly well by dusting, but spraying controlled it perfectly. The evidence furnished by the total yields, likewise, indicates the superiority of the spray over the dust treatment for the control of foliage diseases. As a preventive of late blight rot, the dust proved highly efficient, tho not quite the equal of the spray. Altho there had been very little late blight on the foliage, a large amount of rot was found on the check at digging time. This was due to the frequent heavy rains occurring during the latter part of September and forepart of October as the plants were maturing.

It is the opinion of the writers that, as a measure of the relative efficiency of the dust and the spray, the condition of the foliage on the different plats is much more reliable than the yields in this experiment. Because of the manner of planting, the imperfect stand, and, particularly, the method of harvesting, the yields are unreliable. However, as the yields and the foliage symptoms are in harmony, there can be no harm in reporting them, if it is understood that they may not be entirely dependable.

THE EXPERIMENT IN 1921

In 1921 the plan of the experiment was improved somewhat. There were 15 plats each containing three rows each 125 feet long. Between each plat and the adjoining one on either side there were two untreated discard or buffer rows. The total number of rows included in the experiment was 77. Five of the three-row plats were sprayed four times at intervals of two weeks with bordeaux mixture of the 6–10–50 formula; five were dusted four times on the same dates with Sanders' copper-calcium-arsenate dust; and the other five were left untreated for checks. Both the spray and the dust were applied very thoroly in the same manner as in 1920. The time of planting was a week later than in 1920, but this year care was taken to space the seed pieces accurately in the row, insuring the same number of plants per row. A perfect stand was obtained by filling vacant spaces with transplants of the same age and variety.

The summer was dry and hot. The total rainfall for July, August, and September was only 5.43 inches. In each of these three months it was less than half the rainfall for the corresponding month in 1920. Under such weather conditions late blight and rot were, as might be

expected, entirely lacking. Neither was there any early blight nor flea-beetle injury of any consequence. But leafhoppers appeared early and became abundant with the result that plants on the check plats suffered severely from hopperburn and died prematurely. Thruout the season the condition of the plants on the dusted plats was but little better than that of plants on the check plats, but plants on the sprayed plats suffered only slightly from hopperburn. Their greener foliage caused the sprayed plats to contrast strongly with the others. Judging from the appearance of the foliage, the spraying had been highly beneficial in prolonging the life of the plants, while the dusting had had little influence in preventing injury by the leafhoppers.

At harvest time the middle row of each plat was dug with a double-mold-board plow and the potatoes weighed without sorting. The mean yield of the check plats was at the rate of 149.9 bushels, of the dusted plats 169.4 bushels, and of the sprayed plats 193.6 bushels per acre. Because of the manner in which they were taken the yields should be regarded as merely indicative of the general trend of the results rather than as measuring the relative efficiency of dust and spray.

THE EXPERIMENT IN 1922

In 1922 the experiment included 30 three-row plats, ten of which were dusted, ten sprayed, and the remaining ten left untreated for checks. The rows were 3 feet apart, 146 feet long, and each contained 117 plants 15 inches apart. The area of each row was 0.01 acre and the area of each plat 0.03 acre. Between the plats there were blank spaces 6 feet wide. This arrangement greatly facilitated the handling of the long hose used in spraying. The soil was a rather heavy clay loam. It was plowed in the fall and again the following spring.

About a month before planting the seed tubers were given the corrosive sublimate treatment for scab and Rhizoctonia. Planting was done by hand on May 25. The seed pieces were laid in furrows (opened with a plow) and accurately spaced with the aid of ruled rods. The rows ran crosswise the direction in which the land had been plowed and a light application of stable manure had been spread. No commercial fertilizer was used.

The plants came up well and more evenly than is usual. On the whole 90 rows, containing a total of 10,530 plants, there were but 97 misses. Hence, there was, originally, a stand of 99.08 per cent. There seemed to have been no injury by Rhizoctonia. On June 23

and 24, when the plants were 3 to 7 inches high, the 97 vacancies were filled with transplants of the same age and from the same lot of seed. The soil being moist no water was used in transplanting. Every one of the 97 transplants lived and made a satisfactory growth. Nevertheless, an absolutely perfect stand was not obtained. Five or six weak plants ultimately died.

There being an abundance of rain during the latter part of June the plants grew rapidly. On July 4 they stood about 12 inches high. Counts made at this time to determine the percentage of the plants which were affected with leafroll disclosed 40 affected plants in the first ten plats which contained a total of 3,510 plants. Accordingly, 1.14 per cent of the plants were affected with leafroll. In a second inspection of the same ten plats made on July 12 the same number of leafroll plants was found. Since the conditions seemed favorable for the expression of leafroll symptoms, it is believed that these determinations of the percentage of leafroll were quite accurate.

It was the plan this year to apply the dust and the spray in such quantities that equal amounts of copper would be used. As it was planned, also, to prepare the copper-lime dust at the Station in accordance with the recommendations of Mr. Sanders, it became necessary to inquire into the chemistry of his "monohydrated copper sulphate" (7, pp. 11–12). Some of the Station chemists who were interviewed upon the subject disclaimed any knowledge of such a chemical compound. The matter was then referred to Mr. Sanders who wrote as follows, "As you know, crystal copper sulphate contains approximately 40 per cent water or 5 molecules of water in the crystal. We can drive off 4 molecules of water quite easily but the fifth requires a very much higher temperature. We, therefore, only drive off 4 molecules of water or 32 per cent of the crystal by weight. This gives us a monohydrated copper sulphate which contains approximately 35 per cent of metallic copper whereas the crystals contain approximately 25 per cent of metallic copper. I hope that this information will satisfy your chemists. They, of course, know that the formula for crystal copper sulphate is Cu SO_4–5 H_20. We dehydrate this down to Cu SO_4–H_20."[2]

With this information it was readily determined, by means of a little calculation, that the amount of metallic copper in one pound of Sanders' "monohydrated copper sulphate" is equivalent to that in

[2]Letter of June 28, 1922.

1.4 pounds of ordinary copper sulfate crystals. Accordingly, our dust and spray mixtures were prepared on this basis.

Six applications of dust and spray were made on the following dates: July 5 and 6, July 20, August 3, 17, and 31, and September 9.

The dust used in the first two applications was prepared at the Station by the following formula:

"Dehydrated" or "monohydrated" copper sulfate[3]	20 pounds
Calcium arsenate	10 "
Hydrated lime	65 "
"Kayso" (calcium caseinate)	5 "
Total	100 "

It was finely ground and thoroly mixed in a ball mill.

Altho the home-made dust thus prepared appeared as good as the commercial Sanders' dust, it was deemed expedient, after the second application, to abandon the original plan and use commercial dust in the later applications. Upon the advice of Mr. Sanders the last four applications were made with the "B-16", "Blight Special," or "25–75 copper lime dust" of the Dosch Chemical Co., Louisville, Ky. This was kindly furnished, without charge, by the manufacturers. It is said to contain the following ingredients:

"Monohydrated" copper sulfate	25 per cent
Hydrated lime	70 " "
Sticker	5 " "

In all six applications the dust was applied with a "Niagara Blower Dust Gun." Each row was gone over twice from opposite sides and in opposite directions.

The bordeaux mixture used in the first two applications contained 3 pounds of copper sulfate, about 10 pounds of stone lime, and 2.5 pounds of dry arsenate of lead in each 50 gallons. That used in the last four applications contained about 5 pounds of copper sulfate and about 10 pounds of lime in each 50 gallons.

At the time of the first two applications of dust and spray the check plats were treated with arsenate of lead in water—2.5 pounds of dry arsenate of lead in 50 gallons of water. In the last four applications nothing was put on the checks and poison was omitted from both the dust and the spray.

Some difficulty was had in applying the exact quantities of dust and spray desired. The results obtained were only approximate, as will

[3]Purchased of the Riches-Piver Co., 30 Church St., New York City.

be seen from the detailed accounts of the several applications which follow.

First application—July 5 and 6.—At this time the plants were about a foot high and growing rapidly. Colorado potato beetles were scarce. The dusted plats were treated on July 5 and the sprayed plats and checks on July 6. The dust was applied at the rate of 1 pound per plat, or 33.3 pounds per acre. The foliage was dry and there was a light breeze which caused the dust to drift some. The ten sprayed plats received 50 gallons of 3–10–50 bordeaux which is at the rate of 167 gallons per acre. The quantity of copper per acre applied in the dust was approximately 2.3 pounds and in the spray 2.5 pounds.

Second application—July 20.—This time the dust was applied between 5:30 and 7:00 A. M., while the foliage was wet with a heavy dew and the air almost perfectly quiet. The conditions for dusting were ideal. At each passage the plants were enveloped in a dense cloud of dust. The quantity of dust and of spray used was the same as in the first application. Owing to frequent rains the plants were still growing rapidly, but were not yet in bloom. There were no signs of insect injury or of blight.

Appearance of leafhoppers and hopperburn.—Traces of tipburn or hopperburn were observed on July 24. On July 31 there were a considerable number of leafhoppers and a little hopperburn on all of the plats. However, the injury was so slight the casual observer would not have noticed anything wrong with the plants.

Third application—August 3.—The dusting was done between 6:00 and 7:30 A. M., while the air was quiet and the foliage wet with dew. Commencing with this application, the 25–75 copper-lime dust was used and as the quantity was increased to 1.5 pounds per plat or 50 pounds per acre the quantity of copper applied was increased to 4.4 pounds per acre.

The quantity of bordeaux used this time was 167 gallons per acre, the same as in the two previous applications, but since its composition was now 5–10–50 the amount of copper applied was about 4.2 pounds per acre. Owing to engine trouble which caused considerable variation in pressure, the spraying this time was not well done. Also, a light shower came before the plats last sprayed were thoroly dry. Altogether, the spray was at a slight disadvantage in this application.

Fourth application—August 17.—In this application, the dust was applied early in the morning on partly dry foliage at the rate of 70.8

pounds (equivalent to 6.2 pounds of copper) per acre, while the spray was applied at the rate of 220 gallons (equivalent to 5.5 pounds of copper) per acre.

Fifth application—August 31.—Again, the dust was applied on partly dry foliage. This time 66.7 pounds of dust, carrying 5.8 pounds of copper, and 227 gallons of bordeaux, carrying 5.7 pounds of copper, were the quantities applied per acre.

On August 24, halfway between the fourth and fifth applications, there was a deluge. Five inches of water fell during a period of nine hours. The experiment field was flooded. It appears that this rain was largely responsible for the severe attack of late blight which ravaged the field a few days later. The total rainfall during the month of August was 9.14 inches.

Sixth application—September 9.—This application was made five days ahead of schedule time because of the heavy infestation of late blight and the prospect of more rain. Dust and spray were applied in the same quantities as in the fifth application. The dusting was finished before the dew was all off in the morning. A light breeze was blowing part of the time, but it did not interfere to any great extent. In the spraying the sprayed plat of Series X (Plat No. 28) did not receive fair treatment. The supply of bordeaux became nearly exhausted and the pressure ran low, making it impossible to do a good job of spraying.

Effect on the foliage.—Observations made the day previous to the last application showed the condition of the plants to be as follows: On some of the check plats there was still a little green foliage and the stems of most of the plants were still succulent. All check plats should be considered as having finished their growth on this date. The foliage conditions on the ten check plats were fairly uniform. There had been some hopperburn and a little flea-beetle injury but no early blight. The principal cause of the death of the plants was late blight, which developed very rapidly after the heavy rain of August 24. On August 26 there was not much late blight in evidence and the contrast between treated plats and checks was slight. A week later the superior condition of the treated plats was quite plain. On September 8 plants on the sprayed plats (except those near the south end of the field) were still in nearly full foliage. Plats at the south end of the field already showed some browning, due in part to hopperburn and in part to late blight. All sprayed plats showed a little hopperburn, but in no case as much as the corresponding check. The dusted

plats were all browner than the sprayed plats, but in most cases their condition was considerably better than that of the corresponding check. However, at the south end of the field the dusted plats were not much superior to their checks. All dusted plats were considerably affected by late blight, while the sprayed plats showed only traces of the disease.

On September 13 an estimate was made of the percentage of green foliage on each of the 30 plats. On sprayed plats the plants still held from 40 to 80 per cent of their foliage. Dusted plats in the first six series showed 20 to 25 per cent of green foliage, but in the last (south) four series the dusted plants were all dead. Also, all check plants were devoid of green foliage.

On September 19 only a few plants on any of the dusted plats had any green foliage. Growth on the dusted plats is to be considered as finished on this date. Sprayed plants still retained from 15 to 35 per cent of their foliage.

Judged by the condition of the foliage on the different plats in this experiment the copper-lime dust clearly has some merit but is not the equal of liquid bordeaux mixture.

Yields.—Digging was postponed until the plants on the sprayed plats had been dead for several days. On dusted plats the plants had been dead somewhat longer and on check plats still longer. The digging was done by hand. Much care was taken to secure all of the tubers and to make a complete and accurate record of them.

The tubers were first sorted into two classes according to their weight: (1) Those weighing 2 ounces or more, and (2) those weighing less than 2 ounces. The tubers of each class were then divided into "sound" and "rotten" and the number and weight of each kind recorded. A separate record was kept of the tubers from each row. All of the counting, sorting, and weighing were done by the senior author.

A complete record of each of the 90 rows in the experiment is given in Table 4. The yield by plats is given in Table 5. Table 6 shows the mean yield per plat and Table 7 the mean yield per acre of sprayed, dusted, and check plats.

Discussion of results.—From Table 5 it will be seen that in nine of the ten series the yield of marketable tubers (that is, tubers over 2 ounces in weight) was considerably increased both by dusting and by spraying, and that the advantage was with the spraying in every case. In the tenth series, on the contrary, dusting produced only a

TABLE 4.—YIELD BY ROWS IN THE EXPERIMENT OF 1922 ON DUSTING VS. SPRAYING OF POTATOES.

SERIES	TREATMENT	ROW*	TUBERS OVER 2 OZ. IN WEIGHT				TUBERS UNDER 2 OZ. IN WEIGHT				TOTAL YIELD PER ROW	
			Sound		Rotten		Sound		Rotten			
			No.	Weight†	No.	Weight	No.	Weight	No.	Weight	No.	Weight†
				Lbs.		*Lbs. Oz.*		*Lbs. Oz.*		*Lbs. Oz.*		*Lbs.*
I	Spray	1	474	194.0	12	4 11	36	2 0	3	0 4	525	200.9
		2	487	179.5	14	4 13	65	4 5	0	0 0	566	188.6
		3	474	181.0	20	7 1	54	3 14	0	0 0	548	191.9
	Dust	1	451	164.5	11	4 4	39	2 10	0	0 0	501	171.4
		2	477	163.0	7	2 4	71	5 6	1	0 1	556	170.7
		3	481	162.0	9	4 5	44	3 7	0	0 0	534	169.7
	Check	1	481	153.0	13	3 12	67	5 10	0	0 0	561	162.4
		2	515	151.5	9	2 2	105	8 3	2	0 3	631	162.0
		3	510	153.5	15	5 0	67	5 12	0	0 0	592	164.2
II	Spray	1	491	190.5	32	12 8	53	3 14	3	0 3	579	207.1
		2	529	178.5	20	6 7	56	4 7	3	0 3	608	189.6
		3	503	186.5	15	4 10	53	4 1	2	0 3	573	195.4
	Dust	1	464	158.0	9	2 11	51	3 10	0	0 0	524	164.3
		2	463	151.5	8	3 2	83	6 9	0	0 0	554	161.2
		3	483	160.5	9	3 13	56	4 4	1	0 1	549	168.6
	Check	1	467	145.5	17	5 6	77	6 0	1	0 1	562	156.9
		2	445	139.5	12	3 7	78	5 14	4	0 5	539	149.1
		3	463	148.0	21	7 7	63	4 13	6	0 8	553	160.7
III	Spray	1	448	178.0	37	15 15	31	2 8	0	0 0	516	196.4
		2	456	174.5	22	8 5	54	4 2	0	0 0	532	186.9
		3	478	177.5	11	4 8	45	3 1	1	0 1	535	185.1
	Dust	1	423	144.5	14	5 3	53	3 14	2	0 2	492	153.7
		2	451	153.5	8	1 11	69	5 10	0	0 0	528	160.8
		3	475	163.5	15	4 12	76	6 4	1	0 1	567	174.6
	Check	1	461	141.5	15	5 0	56	4 6	0	0 0	532	150.9
		2	449	133.0	18	5 13	93	6 8	1	0 1	561	145.4
		3	454	137.5	22	7 5	71	6 0	2	0 3	549	151.0
IV	Spray	1	501	180.0	25	9 5	53	3 10	1	0 1	580	196.0
		2	459	165.0	33	11 12	61	4 11	1	0 1	554	181.5
		3	493	177.5	23	8 13	56	4 4	2	0 3	574	190.7
	Dust	1	429	153.5	10	4 6	48	3 14	0	0 0	487	161.7
		2	481	166.0	5	1 6	66	5 6	1	0 2	553	172.9
		3	477	177.5	14	5 2	46	3 7	2	0 3	539	186.2
	Check	1	423	136.5	10	3 8	52	3 12	2	0 2	487	143.9
		2	399	121.5	21	6 2	76	5 8	1	0 1	497	133.2
		3	460	147.5	17	5 0	63	4 15	0	0 0	540	157.4

*Rows 3 by 146 feet; area 0.01 acre.

†In Columns 5 and 13 the ounces have been expressed in decimal parts of a pound to facilitate the calculation of the probability of the means.

TABLE 4.—CONTINUED.

Series	Treatment	Row*	Tubers over 2 oz. in weight				Tubers under 2 oz. in weight				Total yield per row	
			Sound		Rotten		Sound		Rotten			
			No.	Weight†	No.	Weight	No.	Weight	No.	Weight	No.	Weight†
				Lbs.		*Lbs. Oz.*		*Lbs. Oz.*		*Lbs. Oz.*		*Lbs.*
V	Spray	1	454	166.5	17	7 3	53	4 2	6	0 5	530	178.1
		2	452	157.5	23	6 14	67	4 15	3	0 4	545	169.6
		3	446	165.5	34	14 9	53	4 2	6	0 7	539	184.6
	Dust	1	481	156.5	16	4 12	68	6 3	4	0 3	569	167.6
		2	418	130.0	17	5 1	57	7 12	8	0 10	500	143.4
		3	499	161.0	13	3 15	72	5 14	4	0 4	588	171.7
	Check	1	450	131.5	17	5 2	84	5 7	3	0 3	554	142.2
		2	394	107.5	19	5 7	130	9 9	5	0 7	548	122.9
		3	452	130.0	26	8 1	90	5 7	7	0 11	575	144.2
VI	Spray	1	507	185.0	28	9 13	77	5 13	1	0 1	613	200.7
		2	520	171.0	27	9 14	95	8 0	7	0 11	649	189.6
		3	562	190.5	41	15 2	71	5 5	5	0 5	679	211.2
	Dust	1	507	157.0	16	4 12	114	8 5	4	0 6	641	170.4
		2	512	161.5	16	5 8	124	8 7	4	0 4	656	175.7
		3	523	166.5	15	5 9	119	7 15	2	0 3	659	180.2
	Check	1	445	130.0	21	6 4	116	8 2	5	0 6	587	144.7
		2	455	133.0	29	8 0	84	6 2	8	0 10	576	147.7
		3	483	144.0	43	14 0	101	7 14	5	0 8	632	166.4
VII	Spray	1	520	171.0	45	16 3	112	7 6	8	0 12	685	195.3
		2	533	172.0	45	14 7	134	9 1	19	0 9	731	196.1
		3	530	178.0	35	12 12	128	9 1	7	0 8	700	200.3
	Dust	1	479	151.0	44	13 13	140	9 5	1	0 1	664	174.2
		2	505	156.5	30	8 7	122	8 12	8	0 11	665	174.4
		3	530	162.0	40	14 7	108	7 1	2	0 3	680	183.7
	Check	1	427	148.5	23	6 0	103	6 6	4	0 5	557	161.2
		2	443	134.5	38	11 4	120	8 0	10	0 12	611	154.5
		3	477	142.5	40	11 11	129	8 11	5	0 6	651	163.2
VIII	Spray	1	522	175.0	48	17 11	118	8 3	21	1 8	709	202.4
		2	497	156.5	47	16 2	129	9 4	19	1 6	692	183.2
		3	530	172.5	40	13 8	126	8 11	14	0 14	710	195.6
	Dust	1	475	142.5	29	9 5	103	7 14	5	0 6	612	160.1
		2	499	139.5	20	5 13	124	8 11	7	0 8	650	154.5
		3	486	147.0	31	9 5	134	9 6	6	0 7	657	166.1
	Check	1	454	131.0	16	4 1	110	7 12	7	0 10	587	143.4
		2	481	130.5	22	6 10	149	10 3	14	0 14	666	148.2
		3	480	137.5	37	10 4	142	9 11	4	0 6	663	157.8

*Rows 3 by 146 feet; area 0.01 acre.

†In Columns 5 and 13 the ounces have been expressed in decimal parts of a pound to facilitate the calculation of the probability of the means.

TABLE 4.—CONCLUDED.

Series	Treatment	Row*	Tubers over 2 oz. in weight				Tubers under 2 oz. in weight				Total yield per row	
			Sound		Rotten		Sound		Rotten			
			No.	Weight†	No.	Weight	No.	Weight	No.	Weight	No.	Weight†
				Lbs.		*Lbs. Oz.*		*Lbs. Oz.*		*Lb. Oz.*		*Lbs.*
IX	Spray	1	507	167.0	47	14 8	110	9 3	13	10 2	677	192.8
		2	460	150.0	68	21 14	125	9 2	22	1 9	675	182.6
		3	520	166.0	58	18 8	98	8 5	25	1 13	701	194.6
	Dust	1	492	141.5	16	4 6	105	7 13	6	0 7	619	154.1
		2	481	135.0	14	4 6	127	9 2	2	0 3	624	148.7
		3	468	136.0	20	5 3	145	9 7	13	1 0	646	151.6
	Check	1	426	102.0	17	4 0	135	10 10	6	0 6	584	117.0
		2	411	107.5	16	3 14	130	9 11	7	0 8	564	121.6
		3	411	108.5	19	4 12	151	12 0	10	0 14	591	126.1
X	Spray	1	453	122.0	34	9 13	155	11 6	22	1 9	664	144.7
		2	457	128.5	36	9 15	118	8 15	10	1 0	621	148.4
		3	484	132.0	20	7 2	128	9 8	12	1 1	644	149.7
	Dust	1	455	123.5	20	4 12	127	9 11	3	0 5	605	138.2
		2	427	131.0	7	1 13	166	13 5	1	0 1	601	146.2
		3	464	134.0	11	3 8	144	10 9	4	0 10	623	148.7
	Check	1	451	128.0	31	9 2	142	10 4	9	0 10	633	148.0
		2	464	123.0	16	3 14	140	11 0	6	0 8	626	138.4
		3	479	131.5	11	2 13	168	12 12	5	0 6	663	147.4

*Rows 3 by 146 feet; area 0.01 acre.
†In Columns 5 and 13 the ounces have been expressed in decimal parts of a pound to facilitate the calculation of the probability of the means.

small gain and spraying none at all. The irregular results in the tenth series appear to be due in part to poor application of materials, especially of the spray, and in part to the August flood which injured this series some because it was on rather low ground.

From Tables 6 and 7 it will be seen that the average increase in yield of marketable tubers was at the rate of 54.05 pounds per plat or 30 bushels per acre for dusting and 108.25 pounds per plat or 60.1 bushels per acre for spraying.[4] The percentage of increase was 13.5

[4]Acting upon the advice of Dr. H. H. Love, Professor of Plant Breeding in Cornell University, the writers have made use of Student's method (*Biometrika*, **6**, *1-25. 1908*) for calculating the probable errors of the mean yields in this experiment and also in the experiment of 1923. In a recent paper by Love and Brunson (*Jour. Amer. Soc. Agron.*, **16**, *60-68. 1924*) it is pointed out that for observations which naturally arrange themselves in pairs (like the yields of the plats in this experiment) Student's method is a better method than either that of Bessel or Peter for determining the probability of the difference. Applying Student's method to Table 5, it is found that the odds are 10,000 to 1 that dusting is better than no treatment, infinite that spraying is better than no treatment, and infinite that spraying is better than dusting. The writers are under obligation to Dr. Love for assistance in checking their computations of these odds.

TABLE 5.—YIELD BY PLATS IN THE EXPERIMENT OF 1922 ON DUSTING VS. SPRAYING OF POTATOES.

SERIES	PLAT*	TUBERS OVER 2 OUNCES IN WEIGHT				TUBERS UNDER 2 OUNCES IN WEIGHT				TOTAL	
		Sound		Rotten		Sound		Rotten			
		No.	Wgt.†	No.	Wgt.	No.	Wgt.	No.	Wgt.	No.	Wgt.†
			Lbs.		*Lbs.Oz.*		*Lbs.Oz.*		*Lbs.Oz.*		*Lbs.*
I	Sprayed	1,435	554.5	46	16 9	155	10 3	3	0 4	1,639	581.8
	Dusted	1,409	489.5	27	10 13	154	11 7	1	0 1	1,591	511.6
	Check	1,506	458.0	37	10 14	239	19 9	2	0 3	1,784	488.0
II	Sprayed	1,523	555.5	67	23 9	162	12 6	8	0 9	1,760	592.1
	Dusted	1,410	470.0	26	9 10	190	14 7	1	0 1	1,627	494.8
	Check	1,375	433.0	50	16 4	218	16 11	11	0 14	1,654	466.5
III	Sprayed	1,382	530.0	70	28 12	130	9 11	1	0 1	1,583	568.1
	Dusted	1,349	461.5	37	11 10	198	15 12	3	0 3	1,587	489.2
	Check	1,364	412.0	55	18 2	220	16 14	3	0 4	1,642	447.2
IV	Sprayed	1,453	525.5	81	29 14	170	12 9	4	0 5	1,708	568.9
	Dusted	1,387	497.0	29	10 14	160	12 11	3	0 5	1,579	520.5
	Check	1,282	405.5	48	14 10	191	14 3	3	0 3	1,524	434.3
V	Sprayed	1,352	489.5	74	28 10	173	13 3	15	1 0	1,614	532.1
	Dusted	1,398	447.5	46	13 12	197	19 13	16	1 1	1,657	482.4
	Check	1,296	369.0	62	18 10	304	20 7	15	1 5	1,677	409.5
VI	Sprayed	1,589	546.5	96	34 13	243	19 2	13	1 1	1,941	601.3
	Dusted	1,542	485.0	47	15 13	357	24 11	10	0 13	1,956	526.9
	Check	1,385	407.0	93	28 4	301	22 2	18	1 8	1,795	458.7
VII	Sprayed	1,583	521.0	125	43 6	374	25 8	34	1 13	2,116	591.2
	Dusted	1,514	469.5	114	36 11	370	25 2	11	0 15	2,009	532.9
	Check	1,347	425.5	101	28 15	352	23 1	19	1 7	1,819	478.2
VIII	Sprayed	1,549	504.0	135	47 5	373	26 2	54	3 12	2,111	581.7
	Dusted	1,460	429.0	80	24 7	361	25 15	18	1 5	1,919	480.4
	Check	1,415	399.0	75	20 15	401	27 10	25	1 14	1,916	449.0
IX	Sprayed	1,487	483.0	173	54 14	333	26 10	60	4 8	2,053	569.4
	Dusted	1,441	412.5	50	13 15	377	26 6	21	1 10	1,889	454.7
	Check	1,248	318.0	52	12 10	416	32 5	23	1 12	1,739	364.8
X	Sprayed	1,394	382.5	90	26 14	401	29 13	44	3 10	1,929	442.1
	Dusted	1,346	388.5	38	10 1	437	33 9	8	1 0	1,829	433.8
	Check	1,394	382.5	58	15 13	450	34 0	20	1 8	1,922	433.8

*Each plat contained three rows 3 by 146 feet and had an area of 0.03 acres. Cultivated blank spaces 6 feet wide between plats.

†In Columns 4 and 12 the ounces have been expressed in decimal parts of a pound to facilitate the calculation of the probability of the means.

per cent for dusting and 27 per cent for spraying. In other words, the benefit from spraying was almost exactly double that from dusting.

The results of the experiment, as shown by the yields, are what

TABLE 6.—MEAN YIELD PER PLAT IN EXPERIMENT OF 1922 ON DUSTING VS. SPRAYING OF POTATOES.

TREATMENT	TUBERS OVER 2 OUNCES IN WEIGHT				TUBERS UNDER 2 OUNCES IN WEIGHT				MEAN TOTAL YIELD	
	Sound		Rotten		Sound		Rotten			
	No.	Wgt.	No.	Wgt.	No.	Wgt.	No.	Wgt.	No.	Wgt.
		Lbs.		*Lbs.*		*Lbs.*		*Lbs.*		*Lbs.*
Sprayed	1,474.7	509.20	95.7	33.46	251.4	18.52	23.6	1.70	1,845.4	562.88
Dusted	1,425.6	455.00	49.4	15.76	280.1	20.98	9.2	0.74	1,764.3	492.48
Check	1,361.0	400.95	63.1	18.51	309.2	22.69	13.9	1.08	1,747.2	443.23

TABLE 7.—MEAN YIELD PER ACRE IN EXPERIMENT OF 1922 ON DUSTING VS. SPRAYING OF POTATOES.

TREATMENT	TUBERS OVER 2 OUNCES IN WEIGHT				TUBERS UNDER 2 OUNCES IN WEIGHT				MEAN TOTAL YIELD	
	Sound		Rotten		Sound		Rotten			
	No.	Bu.	No.	Bu.	No.	Bu.	No.	Bu.	No.	Bu.
Sprayed	4,915.7	282.9	3,190	18.6	8,380	10.3	787	0.9	61,514	312.7
Dusted	4,752.0	252.8	1,647	8.7	9,337	11.7	307	0.4	58,811	273.6
Check	4,536.7	222.8	2,103	10.3	10,307	12.6	463	0.6	58,240	246.3

might be expected from the appearance of the foliage of the plants during the latter part of the growing season.

It is interesting to observe that the loss from rot was greater on the sprayed plats than on either dusted or check plats. A study of Table 5 will show that this was true of every series. The average loss from rot (including tubers of all sizes) was at the rate of 19.5 bushels per acre for sprayed plats, 9.1 bushels per acre for dusted plats, and 10.9 bushels per acre for check plats.

It may be suspected that this paradoxical result with rot was due to the early decay and disappearance of affected tubers on the check and dusted plats where the plants had died prematurely. However, we are confident that such was not the case. There was no evidence that any considerable number of tubers had been lost thru complete decay. A few tubers were so much decayed that their weight could not be determined accurately. In such cases the weights were estimated.

The probable explanation is that the tubers on the sprayed plats were exposed to rot infection for a considerably longer period of time, due to the longer life of the plants on these plats; and that the most

favorable conditions for infection occurred late in the season when there were left but few living blight spores on the dusted and check plats to cause infection.

Heavier loss from rot on sprayed plants than on unsprayed plants is not uncommon in potato spraying experiments; but in all cases of this kind coming under our observation there has been, also, a larger yield of marketable tubers from the sprayed plants resulting from their prolonged growth period.

THE EXPERIMENT IN 1923

In 1923 the experiment was conducted on the same piece of land and the plats laid out on the same plan as in 1922.

The land was given a light application of stable manure after which it was plowed in the fall of 1922 and again in the spring of 1923, both times crosswise the direction of planting. It was thoroly fitted and quite mellow at planting time. The date of planting was May 28. The furrows for planting were opened with a shovel plow. The seed pieces were accurately spaced 15 inches apart in the furrow and covered by means of the shovel plow. No commercial fertilizer was used. The potatoes were of the variety Enormous No. 9 and of the same strain as those used in previous experiments. They were not disinfected. The rate of planting was about 20 bushels per acre. As in 1922, there were 30 three-row plats with blank spaces 6 feet wide between plats. The rows were 146 feet long and 3 feet apart.

When the plants came up there was from 93 to 95 per cent of a full stand. During the early stages of growth the plants were uneven in size owing, in part, to the occurrence of a considerable number of slender-stemmed, small, weak plants. Upon investigation it was found that the cause of this condition was a premature decay of the seed pieces.

Between July 2 and 5 the places of the missing plants in the first 21 plats were filled with transplants as in 1922. Owing to the large number of missing and weak plants on the remaining nine plats it was considered impracticable to put them into fit condition for use in measuring results by means of yield. Hence, no attempt was made to complete the stand on these plats and no record of their yield was made at digging time.

This season the method of treatment was changed somewhat. The results of the experiments in the previous three years having convinced the writers that the dust is not as efficient as the spray

when the same number of applications of dust and spray are made, it was planned this year to apply the dust every week and the spray once in two weeks. By this arrangement ten of the plats were dusted ten times, ten plats were sprayed five times, and the remaining ten plats left untreated (except for "bugs") as checks. The dates of dusting were July 7, 13, 21, 27, August 3, 9, 17, 24, 31, and September 8. The dates of spraying were July 7, 20, August 3, 17, and 31.

The dust used in the first four applications was the "B-14" dust manufactured by the Dosch Chemical Co., Louisville, Ky. It is said to contain 20 per cent "monohydrated" copper sulfate, 25 per cent calcium arsenate, and 55 per cent hydrated lime. In the last six applications the "B-16" dust of the Dosch Chemical Co. was used. This is said to contain 25 per cent "monohydrated" copper sulfate and 75 per cent hydrated lime.

In the first seven applications the dust was applied by means of a hand duster manufactured by the A. I. Root Co., Medina, Ohio. The last three applications were made with the American Beauty Dust Sprayer manufactured by the California Sprayer Co., 6001 Pasadena Ave., Los Angeles, Calif.

All of the dust applications were made early in the morning while the air was quiet and the foliage wet with dew. Contrary to our previous practise, the plants were dusted but once over at each application. The quantity of dust applied varied, in different applications, from 20 to 46.7 pounds per acre, the average being 35.25 pounds per acre. The total amount of copper applied in ten dustings was at the rate of 28.5 pounds per acre.

The composition of the bordeaux mixture was the same as that used in 1922, namely, in the first two applications the 3–10–50 formula with 2.5 pounds of dry arsenate of lead in each 50 gallons, and in the last three applications the 5–10–50 formula without poison. The bordeaux was applied with the same sprayer and in the same manner as in previous experiments at the rate of about 200 gallons per acre in each of the five applications. The total amount of copper applied in five sprayings was at the rate of 21.3 pounds per acre.

The ten check plats were treated twice (on July 7 and 20) with dry arsenate of lead in water (2.5 pounds to 50 gallons) applied with the power sprayer at the rate of about 200 gallons per acre.

The results as indicated by the condition of the foliage.—By July 30 leafhoppers were present in moderate numbers and there were already some indications of hopperburn, but as yet there was no appre-

ciable difference in the amount of it on plats under the different kinds of treatment. Neither Colorado beetles nor flea beetles were factors of importance at any time.

On September 7 plants on the check plats showed a moderate amount of injury by typical hopperburn. The browning of the leaf tips was abundant and quite conspicuous. However, only a few leafhoppers were to be seen at this time. There was no early blight and no late blight. Dusted plats and sprayed plats both showed somewhat less hopperburn than the check plats but the contrast was not marked. The sprayed plats were in slightly better condition than the dusted plats.

Up to October 3 there had been no killing frost. By this time it was plain that both the dusting and the spraying had been beneficial; also, that sprayed plants were greener than dusted plants. A careful estimate was made of the percentage of green foliage remaining on the plants of each plat with the following result:

On check plats, 10 to 20 per cent.

On dusted plats, 55 to 65 per cent.

On sprayed plats, 75 to 85 per cent.

These differences were fairly constant thruout the experiment. The slightly superior condition of the foliage on sprayed plats over that of plants on dusted plats appears to have been due to the better protection against hopperburn afforded by the spray. A moderate amount of hopperburn was the only foliage trouble involved in this experiment. A few aphids were found all thru the field during the latter part of July, but they did not multiply sufficiently to cause appreciable damage.

Yields.—The crop was harvested during the last ten days of October. The first 21 plats were dug by hand and carefully sorted and weighed, but no record was made of the yield on the remaining nine plats. As in 1922, the tubers from each row were sorted into two grades, according as they weighed more or less than 2 ounces, and those of each grade counted and weighed. There being no rotten tubers this year no sorting for rot was necessary. A few tubers weighed over 12 ounces each and so were above marketable size, but as their number was small it was considered unnecessary to make a separate record of them.

The yield by rows is given in Table 8 and the yield by plats in Table 9, while Table 10 shows the mean yield per plat and Table 11 the mean yield per acre under the three kinds of treatment.

The results as shown by the yields.—Both in number of tubers and in weight of tubers the crop of 1923 was considerably smaller than that of 1922. Also, the yields this year were not as regular and consistent as in 1922. There was a notable irregularity in Series I where neither the sprayed plat nor the dusted plat yielded as much as the check. (See Table 9.) However, in every one of the seven series the sprayed plat outyielded the dusted plat, both in marketable tubers and in total yield.

The average increase in yield of marketable tubers was at the rate of 13.83 pounds per plat or 7.6 bushels per acre for dusting, and 55.16 pounds per plat or 30.6 bushels per acre for spraying. These yields are consistent with the foliage indications, but when the probability of the difference is calculated by Student's method it is found that the odds are only 2.8 to 1 that the apparent gain from dusting was not due to chance. On the other hand, the odds are 56 to 1 that spraying was beneficial and 1,428 to 1 that spraying was better than dusting.[5] Altho statistical analysis of the yields gives no assurance that dusting was of any benefit in this experiment, the writers are of the opinion that there was actually some benefit. In short, the foliage indications are more reliable than the yields.

[5]Dr. H. H. Love has kindly checked our calculations.

TABLE 8.—YIELD BY ROWS IN THE EXPERIMENT OF 1923 ON DUSTING VS. SPRAYING OF POTATOES.

SERIES	TREATMENT	ROW*	TUBERS OVER 2 OUNCES IN WEIGHT		TUBERS UNDER 2 OUNCES IN WEIGHT		TOTAL YIELD PER ROW	
			Number	Weight†	Number	Weight	Number	Weight†
				Lbs.		*Lbs. Oz.*		*Lbs.*
I	Dust	1	255	59.5	228	14 3	483	73.7
		2	218	48.5	240	16 8	458	65.0
		3	266	58.5	245	15 6	511	73.9
	Spray	1	293	69.5	278	17 6	571	86.9
		2	306	82.4	171	10 3	477	92.6
		3	318	85.0	195	13 5	513	98.3
	Check	1	326	84.7	216	13 2	542	97.9
		2	340	86.4	218	14 10	558	101.1
		3	302	75.0	188	12 12	490	87.7
II	Spray	1	331	90.5	200	11 11	531	102.2
		2	323	91.6	191	12 12	514	104.3
		3	330	86.5	152	10 10	482	97.1
	Dust	1	265	70.0	195	12 10	460	82.6
		2	310	77.0	164	11 6	474	88.4
		3	315	81.0	184	13 1	499	94.1
	Check	1	291	73.0	188	12 8	479	85.5
		2	303	79.9	191	13 13	494	93.7
		3	321	81.5	187	12 5	508	93.8
III	Spray	1	344	96.9	180	11 8	524	108.4
		2	380	107.0	178	11 11	558	118.7
		3	364	103.0	117	7 14	481	110.9
	Dust	1	341	94.0	161	11 5	502	105.3
		2	358	94.3	183	11 14	541	106.2
		3	336	92.0	173	10 10	509	102.6
	Check	1	337	86.0	197	13 1	534	99.1
		2	342	88.0	202	12 15	544	100.9
		3	316	82.0	180	13 6	496	95.4
IV	Spray	1	372	108.0	147	10 3	519	118.2
		2	359	111.5	150	9 6	509	120.9
		3	368	102.0	187	12 2	555	114.1
	Dust	1	345	91.5	202	14 7	547	105.9
		2	368	103.5	166	11 3	534	114.7
		3	366	104.0	143	11 6	509	115.4
	Check	1	394	107.0	157	10 3	551	117.2
		2	347	94.0	181	13 2	528	107.1
		3	394	110.0	132	9 2	526	119.1

*Rows 3 by 146 feet, area 0.01 acre.

†In Columns 5 and 9 the ounces have been expressed in decimal parts of a pound to facilitate the calculation of the probability of the means.

TABLE 8.—CONCLUDED.

Series	Treatment	Row*	Tubers over 2 ounces in weight		Tubers under 2 ounces in weight			Total yield per row	
			Number	Weight†	Number	Weight		Number	Weight†
				Lbs.		*Lbs.*	*Oz.*		*Lbs.*
V	Spray	1	383	129.4	133	9	0	516	138.4
		2	447	133.6	140	9	2	587	142.7
		3	378	123.6	149	9	7	527	133.0
	Dust	1	327	109.3	116	8	12	443	118.1
		2	367	109.0	188	13	8	555	122.5
		3	352	104.2	141	9	14	493	114.1
	Check	1	304	81.5	154	11	2	458	92.6
		2	306	76.5	195	13	10	501	90.1
		3	308	76.7	194	15	0	502	91.8
VI	Spray	1	337	96.2	174	11	5	511	107.5
		2	392	118.0	184	10	15	576	128.9
		3	373	111.1	159	10	11	532	121.7
	Dust	1	359	96.7	193	12	15	552	109.7
		2	351	94.0	177	12	4	528	106.2
		3	361	92.7	187	12	7	548	105.2
	Check	1	322	80.0	228	14	10	550	94.6
		2	278	72.0	234	13	11	512	85.7
		3	330	82.0	229	14	7	559	96.4
VII	Spray	1	330	93.6	199	13	6	529	107.0
		2	366	101.5	169	11	0	535	112.5
		3	358	97.5	182	12	7	540	109.9
	Dust	1	356	90.5	212	13	15	568	104.4
		2	336	82.5	243	17	6	579	99.9
		3	334	96.0	211	13	13	545	109.8
	Check	1	324	79.0	201	15	3	525	94.2
		2	304	73.9	202	12	14	506	86.7
		3	338	83.0	225	15	5	563	98.3

*Rows 3 by 146 feet, area 0.01 acre.
†In Columns 5 and 9 the ounces have been expressed in decimal parts of a pound to facilitate the calculation of the probability of the means.

TABLE 9.—YIELD BY PLATS IN THE EXPERIMENT OF 1923 ON DUSTING VS. SPRAYING OF POTATOES.

SERIES	PLAT*	TUBERS OVER 2 OUNCES IN WEIGHT		TUBERS UNDER 2 OUNCES IN WEIGHT		TOTAL	
		Number	Weight†	Number	Weight	Number	Weight†
			Lbs.		*Lbs. Oz.*		*Lbs.*
I	Dusted	739	166.5	713	46 1	1,452	212.6
	Sprayed	917	236.9	644	40 14	1,561	277.7
	Check	968	246.2	622	40 8	1,590	286.7
II	Sprayed	984	268.6	543	35 1	1,527	303.6
	Dusted	890	228.0	543	37 1	1,433	265.1
	Check	915	234.4	566	38 10	1,481	273.0
III	Sprayed	1,088	306.9	475	31 1	1,563	338.0
	Dusted	1,035	280.3	517	33 13	1,552	314.1
	Check	995	256.0	579	39 6	1,574	295.4
IV	Sprayed	1,099	321.5	484	31 11	1,583	353.2
	Dusted	1,079	299.0	511	37 0	1,590	336.0
	Check	1,135	311.0	470	32 7	1,605	343.4
V	Sprayed	1,208	386.6	422	27 9	1,630	414.2
	Dusted	1,046	322.6	445	32 2	1,491	354.9
	Check	918	234.7	543	39 12	1,461	274.6
VI	Sprayed	1,102	325.2	517	32 15	1,619	358.2
	Dusted	1,071	283.6	557	37 10	1,628	321.2
	Check	930	234.0	691	42 12	1,621	276.7
VII	Sprayed	1,054	292.6	550	36 13	1,604	329.4
	Dusted	1,026	269.0	666	45 2	1,692	314.1
	Check	966	235.9	628	43 6	1,594	279.2

*Each plat contained three rows 3 by 146 feet and had an area of 0.03 acre. Cultivated blank spaces 6 feet wide between plats. By accident the relative position of the dusted and sprayed plats in Series I was different than that in the remainder of the experiment.

†In Columns 4 and 8 the ounces have been expressed in decimal parts of a pound to facilitate the calculation of the probability of the means.

TABLE 10.—MEAN YIELD PER PLAT IN EXPERIMENT OF 1923 ON DUSTING VS. SPRAYING OF POTATOES.

TREATMENT	TUBERS OVER 2 OZ. IN WEIGHT		TUBERS UNDER 2 OZ. IN WEIGHT		MEAN TOTAL YIELD	
	Number	Weight	Number	Weight	Number	Weight
		Lbs.		*Lbs.*		*Lbs.*
Sprayed	1,064.6	305.48	519.3	33.71	1,583.9	339.2
Dusted	983.7	264.13	564.6	38.40	1,548.3	302.5
Check	875.3	250.33	585.6	39.54	1,560.9	289.9

TABLE 11.—MEAN YIELD PER ACRE IN EXPERIMENT OF 1923 ON DUSTING VS. SPRAYING OF POTATOES.

TREATMENT	TUBERS OVER 2 OZ. IN WEIGHT		TUBERS UNDER 2 OZ. IN WEIGHT		MEAN TOTAL YIELD	
	Number	Bushels	Number	Bushels	Number	Bushels
Sprayed	35,487	169.7	17,310	18.7	52,797	188.4
Dusted	32,790	146.7	18,820	21.3	51,610	168.0
Check	32,510	139.1	19,520	21.9	52,030	161.0

CONCLUSIONS

In all four seasons' experiments the condition of the foliage indicated plainly that better protection had been afforded by the spray than by the dust. Likewise, in all four seasons the differences in yield were decidedly in favor of the spray. Fairly severe attacks of three of the principal foliage troubles—early blight, late blight, and hopperburn—were involved in the experiments. No one of the three was controlled in a satisfactory manner by the dust, even tho the quantity of dust used was considerably greater than that recommended by advocates of the dust method. Even when the dust was used twice as often as the spray it did not equal the spray in efficiency.

It may be argued that the test was unfair in that the work of hand dusters was compared with that of a power sprayer. Some persons who examined the experiments remarked that the dust was unevenly distributed. This is admitted, but the plants were completely and thoroly covered with the dust nevertheless. It was the excessive amount of dust on the upper leaves which attracted attention. The large quantities of dust used made it possible to waste a part of it in this manner and yet cover the plants thoroly. Also, it should be considered that most of the dust applications were made in the early morning under the most favorable conditions. It seems improbable that the poor showing made by the dust was due to uneven or improper application.

Our observations on these experiments lead us to conclude that, under parallel conditions, the bordeaux spray is considerably more efficient than the Sanders' copper-lime dust in the control of potato pests, particularly the leafhopper. This conclusion is in harmony with the results of experiments recently reported by Hartwell (2) of Rhode Island, Kotila and Coons (4) of Michigan, Parks and Clayton (6) of Ohio, and Leach (5) of Minnesota.

In the evaluation of the results of dusting and spraying experiments

with potatoes it should be borne in mind that yields, unless carefully checked, may be very misleading.

Because the dust is less efficient than the spray it does not follow, necessarily, that the dust has no place in potato culture. Altho the writers have had little experience with power dusters in potato fields, they can readily believe that it may be easier for the average potato grower to dust than to spray, especially where water is not readily obtainable. Hence, some growers may prefer dusting to spraying even tho the increase in yield from dusting does not equal that from spraying. Those who seek maximum yields and have good facilities for spraying certainly should spray. Probably, the maximum net profit, also, will be obtained, in most cases, by spraying rather than by dusting.

The dust method will probably find its greatest usefulness in the hands of growers having a small acreage of potatoes—one acre or less. Of necessity, such growers must use some kind of hand outfit, if any, and hand sprayers are very unsatisfactory. The trouble and expense of keeping them in working order, coupled with the bother of preparing the bordeaux mixture, practically eliminates hand sprayers from potato fields. But hand dusters are less expensive and get out of order less easily. Also, the dust may be purchased and kept on hand ready for use as needed.

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II. ROW COMPETITION AND "BORDER EFFECT"

F. C. STEWART

SUMMARY

The three-row plats used in the dusting and spraying experiments in 1922 and 1923 have been utilized in a study of row competition and "border effect." By comparing the yields of the middle rows with those of the outside rows, it is shown that in the wet season of 1922 the latter definitely outyielded the former; while in the dry season of 1923 there was only an insignificant difference in favor of the middle rows. Furthermore, in 1922 the south outside rows outyielded the north outside rows, owing, it is believed, to the better illumination of the former.

The conclusion reached is that weather conditions have an important relation to row competition and border effect in potato plats.

INTRODUCTION

In some kinds of field experiments with potatoes it is important to know how the yield of a row of plants is affected by adjacent rows. Is there such a thing as row competition in potato fields? If so, to what extent is the yield affected?

B. A. Brown,[1] who has studied the yields in potato experiments conducted during six seasons at the Agricultural Experiment Station at Storrs, Connecticut, concludes that with conditions such as were had in those experiments yields are not influenced by competition between single-row plats. However, it is usually assumed by experimenters that outside or border rows are not strictly comparable with interior rows and that plat experiments should be so planned as to eliminate what is known as "border effect."

DATA FURNISHED BY THE SPRAYING AND DUSTING EXPERIMENTS

It occurred to the writer that the plats of potatoes used for the dusting and spraying experiments in 1922 and 1923, as described in the first part of this bulletin, might be made to serve the additional purpose of furnishing data on row competition and border effect. With this in mind the yield of each row was taken separately so that

[1]Plat competition with potatoes. *Jour. Amer. Soc. Agron.*, **14**, *257–258. 1922.*

the yield of the middle or interior row might be compared with that of the two outside rows of each plat.

It was the writer's plan to compare the yield of the middle row with the mean yield of the two outside rows in each plat, but Dr. H. H. Love, whose advice was sought, suggested that a better method would be to compare the yield of the middle row with that of the two outside rows separately and calculate the odds of the mean difference, in each of the two series, by Student's method. Accordingly, this was done. To facilitate the comparison Tables 1 and 2 have been prepared.

TABLE 1.—ROW COMPETITION IN POTATOES: YIELDS OF MIDDLE AND OUTSIDE ROWS COMPARED IN DUSTING AND SPRAYING EXPERIMENT OF 1922.

SERIES	PLAT*	TREATMENT	ROW†	TOTAL YIELD‡	DIFFERENCE—YIELD OF ROW 1 LESS YIELD OF ROW 2	DIFFERENCE—YIELD OF ROW 3 LESS YIELD OF ROW 2
				Lbs.	*Lbs.*	*Lbs.*
			1	200.9	+12.3	
	1	Sprayed	2	188.6		
			3	191.9		+3.3
			1	171.4	+ 0.7	
I	2	Dusted	2	170.7		
			3	169.7		— 1.0
			1	162.4	+ 0.4	
	3	Check	2	162.0		
			3	164.2		+ 2.2
			1	207.1	+17.5	
	4	Sprayed	2	189.6		
			3	195.4		+ 5.8
			1	164.3	+ 3.1	
II	5	Dusted	2	161.2		
			3	168.6		+ 7.4
			1	156.9	+ 7.8	
	6	Check	2	149.1		
			3	160.7		+11.6

*Cultivated blank spaces 6 feet wide between plats.
†Rows 146 feet long and 3 feet apart. Plants 15 inches apart in the row.
‡Copied from last column of Table 4 of first section of this bulletin.

TABLE 1.—CONTINUED.

SERIES	PLAT*	TREATMENT	ROW†	TOTAL YIELD‡	DIFFERENCE—YIELD OF ROW 1 LESS YIELD OF ROW 2	DIFFERENCE—YIELD OF ROW 3 LESS YIELD OF ROW 2
				Lbs.	*Lbs.*	*Lbs.*
III	7	Sprayed	1	196.4	+ 9.5	
			2	186.9		
			3	185.1		— 1.8
	8	Dusted	1	153.7	— 7.1	
			2	160.8		
			3	174.6		+13.8
	9	Check	1	150.9	+ 5.5	
			2	145.4		
			3	151.0		+ 5.6
IV	10	Sprayed	1	196.0	+14.5	
			2	181.5		
			3	190.7		+ 9.2
	11	Dusted	1	161.7	—11.2	
			2	172.9		
			3	186.2		+13.3
	12	Check	1	143.9	+10.7	
			2	133.2		
			3	157.4		+24.2
V	13	Sprayed	1	178.1	+ 8.5	
			2	169.6		
			3	184.6		+15.0
	14	Dusted	1	167.6	+24.2	
			2	143.4		
			3	171.7		+27.7
	15	Check	1	142.2	+19.3	
			2	122.9		
			3	144.2		+21.3
VI	16	Sprayed	1	200.7	+11.1	
			2	189.6		
			3	211.2		+21.6
	17	Dusted	1	170.4	— 5.3	
			2	175.7		
			3	180.2		+ 4.5
	18	Check	1	144.7	— 3.0	
			2	147.7		
			3	166.4		+18.7

*Cultivated blank spaces 6 feet wide between plats.
†Rows 146 feet long and 3 feet apart. Plants 15 inches apart in the row.
‡Copied from last column of Table 4 of first section of this bulletin.

TABLE 1.—CONCLUDED.

SERIES	PLAT*	TREATMENT	ROWS†	TOTAL YIELD‡	DIFFERENCE—YIELD OF ROW 1 LESS YIELD OF ROW 2	DIFFERENCE—YIELD OF ROW 3 LESS YIELD OF ROW 2
				Lbs.	*Lbs.*	*Lbs.*
			1	195.3	— 0.8	
	19	Sprayed	2	196.1		
			3	200.3		+ 4.2
			1	174.2	— 0.2	
VII	20	Dusted	2	174.4		
			3	183.7		+ 9.3
			1	161.2	+ 6.7	
	21	Check	2	154.5		
			3	163.2		+ 8.7
			1	202.4	+19.2	
	22	Sprayed	2	183.2		
			3	195.6		+12.4
			1	160.1	+ 5.6	
VIII	23	Dusted	2	154.5		
			3	166.1		+11.6
			1	143.4	— 4.8	
	24	Check	2	148.2		
			3	157.8		+ 9.6
			1	192.8	+10.2	
	25	Sprayed	2	182.6		
			3	194.6		+12.0
			1	154.1	+ 5.4	
IX	26	Dusted	2	148.7		
			3	151.6		+ 2.9
			1	117.0	— 4.6	
	27	Check	2	121.6		
			3	126.1		+ 4.5
			1	144.7	— 3.7	
	28	Sprayed	2	148.4		
			3	149.7		+ 1.3
			1	138.2	— 8.0	
X	29	Dusted	2	146.2		
			3	148.7		+ 2.5
			1	148.0	+ 9.6	
	30	Check	2	138.4		
			3	147.4		+ 9.0
		Mean			+5.1	+9.68
		Odds§			399 to 1	∝

*Cultivated blank spaces 6 feet wide between plats.
†Rows 146 feet long and 3 feet apart. Plants 15 inches apart in the row.
‡Copied from last column of Table 4 of first section of this bulletin.
§Calculated by the method of Student (*Biometrika*, 6, *Part* 1, 1-25. 1908).

TABLE 2.—ROW COMPETITION IN POTATOES: YIELDS OF MIDDLE AND OUTSIDE ROWS IN DUSTING AND SPRAYING EXPERIMENT OF 1923.

SERIES	PLAT*	TREATMENT	ROW†	TOTAL YIELD‡	DIFFERENCE—YIELD OF ROW 1 LESS YIELD OF ROW 2	DIFFERENCE—YIELD OF ROW 3 LESS YIELD OF ROW 2
				Lbs.	*Lbs.*	*Lbs.*
	1	Dusted	1	73.7	+ 8.7	
			2	65.0		
			3	73.9		+ 8.9
I	2	Sprayed	1	86.9	— 5.7	
			2	92.6		
			3	98.3		+ 5.7
	3	Check	1	97.9	— 3.2	
			2	101.1		
			3	87.7		—13.4
	4	Sprayed	1	102.2	— 2.1	
			2	104.3		
			3	97.1		— 7.2
II	5	Dusted	1	82.6	— 5.8	
			2	88.4		
			3	94.1		+ 5.7
	6	Check	1	85.5	— 8.2	
			2	93.7		
			3	93.8		+ 0.1
	7	Sprayed	1	108.4	—10.3	
			2	118.7		
			3	110.9		— 7.8
III	8	Dusted	1	105.3	— 0.9	
			2	106.2		
			3	102.6		— 3.6
	9	Check	1	99.1	— 1.8	
			2	100.9		
			3	95.4		— 5.5
	10	Sprayed	1	118.2	— 2.7	
			2	120.9		
			3	114.1		— 6.8
IV	11	Dusted	1	105.9	— 8.8	
			2	114.7		
			3	115.4		+ 0.7
	12	Check	1	117.2	+10.1	
			2	107.1		
			3	119.1		+12.0

*Cultivated blank spaces 6 feet wide between plats.
†Rows 146 feet long and 3 feet apart. Plants 15 inches apart in the row.
‡Copied from Table 8 of first section of this bulletin.

TABLE 2.—CONCLUDED.

SERIES	PLAT*	TREATMENT	ROW†	TOTAL YIELD‡	DIFFERENCE—YIELD OF ROW 1 LESS YIELD OF ROW 2	DIFFERENCE—YIELD OF ROW 3 LESS YIELD OF ROW 2
				Lbs	*Lbs.*	*Lbs.*
V	13	Sprayed	1	138.4	— 4.3	
			2	142.7		
			3	133.0		— 9.7
	14	Dusted	1	118.1	— 4.4	
			2	122.5		
			3	114.1		— 8.4
	15	Check	1	92.6	+ 2.5	
			2	90.1		
			3	91.8		+ 1.7
VI	16	Sprayed	1	107.5	—21.4	
			2	128.9		
			3	121.7		— 7.2
	17	Dusted	1	109.7	+ 3.5	
			2	106.2		
			3	105.2		— 1.0
	18	Check	1	94.6	+ 8.9	
			2	85.7		
			3	96.4		+10.7
VII	19	Sprayed	1	107.0	— 5.5	
			2	112.5		
			3	109.9		— 2.6
	20	Dusted	1	104.4	+ 4.5	
			2	99.9		
			3	109.8		+ 9.9
	21	Check	1	94.2	+ 7.5	
			2	86.7		
			3	98.3		+11.6
		Mean			—1.88	—0.3
		Odds§			6.15 to 1	0.0

*Cultivated blank spaces 6 feet wide between plats.
†Rows 146 feet long and 3 feet apart. Plants 15 inches apart in the row.
‡Copied from Table 8 of first section of this bulletin.
§Calculated by the method of Student (*Biometrika*, 6, *Part* 1, 1-25. 1908).

DISCUSSION OF RESULTS

The outstanding feature of the tables is that they show a positive difference in yield in favor of the outside rows in 1922 but none in 1923. Probably, this result finds its explanation in the difference in weather conditions in the two seasons, 1922 being a wet season and 1923 a dry one. Other conditions were practically parallel in the two seasons. Doubtless there are several other factors which might enter into the problem, such as the character and fertility of the soil, distance between rows, thickness of planting, variety, and method of cultivation, but all of these were the same for the two seasons.

It is also noteworthy that in 1922 the mean yield of the No. 3 rows was 4.6 pounds greater than that of the No. 1 rows. Calculation (by Student's method) of the probability of this mean difference shows it to be significant, the odds being 195 to 1. Since the rows ran east and west and were numbered from north to south, the No. 1 row was on the north side and the No. 3 row on the south side of the plat in each case. A row on the south side of a plat would be more exposed to the sun than one on the north side. Probably, their better illumination would be an advantage to the No. 3 rows if there was an abundance of rain and the temperature moderate as in 1922, and this may account for the larger yield of the No. 3 rows that year. On the other hand, in a dry season like that of 1923 increased exposure to the sun would be a disadvantage. There is no evidence that the larger yield of the No. 3 row was due to increasing fertility of the soil from north to south.

From these experiments it appears that the outside rows of a potato plat may have a positive advantage in some seasons and not in others. Also, when the plats run east and west the south outside row may or may not have an advantage over the north outside row, depending on the character of the season.