DOSAGE RATES AND APPLICATION METHODS WITH PCNB FOR CONTROL OF POTATO SCAB AND RHIZOCTONIA[1]

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Pentachloronitrobenzene (PCNB) has been shown to have great promise as a soil fungicide against certain plant pathogens. It is evidently quite selective in action, being particularly effective against *Rhizoctonia solani* Kuhn. (1,2,3,6,7). Its effectiveness against the potato scab organism *Streptomyces scabies* as previously reported is somewhat variable (3,4,5). The experiments reported here were conducted to obtain detailed information on dosage required for scab and rhizoctonia control; to measure toxicity to potatoes and duration of fungicidal effectiveness; and to test practical methods of application and mixing.

MATERIALS AND METHODS

PCNB was furnished as a 75 per cent wettable powder by the Olin Mathieson Chemical Corporation who market this material under the trade name Terraclor. All dosages referred to in this paper are in terms of active ingredient.

The field experiments were conducted in the lower Yakima Valley on Ritzville or Sagemoor fine sandy loam. These soils contain less than 2 per cent organic matter and have a cation exchange capacity of approximately 12 m.e. per 100 grams. The fields selected had been cropped numerous times to potatoes and contained a heavy uniform natural infestation of the pathogens being studied. The soil pH ranged betweeen 6.5 and 7.4, which is well within the tolerance for scab incidence.

The PCNB was mixed with fine sand in such proportions that it could be broadcast by hand on the surface of the plots in an accurate manner. It was found that if the sand were slightly damp when mixed with PCNB an even distribution without loss from dust drift could be obtained. Usually about 5 pounds of mix were used for a plot of 500 square feet. For experimental work this method is more dependable than using spreading machines.

In treatments where the material was incorporated by rotary tillage a Howard Rotovator was used. Discing was done with a heavy off-set disc.

Potatoes were planted with 2- or 4-row planting equipment and handled during the growing season in the usual commercial manner .All plots were 4 rows wide and sections of the two middle rows were taken at harvest time for yield, grade, and disease records. Samples were taken from the plots during the growing season to obtain some of the data.

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1954 Experiments

A preliminary field test was conducted in 1954 on Ritzville fine sandy loam to find the range of dosage of PCNB needed for scab control. For this purpose, rates of 0, 50, 100, and 150 pounds per acre were applied by rotary tillage to a depth of 6 inches on plots 10′ x 50′ in size with three replications. The effect of these treatments on yield and scab of White Rose potatoes is shown in table 1.

Scab control was very striking even with the 50 pound per acre treatment in which 73 per cent of the tubers were marketable compared to 14 per cent in the check. The plots of higher rates were essentially scab-free. The yield data reflect phytotoxicity which was expressed as delayed emergence and stunted growth, particularly at the higher PCNB rates.

These plots were replanted with potatoes in the spring of 1955 to measure the residual effects of PCNB both in scab control and plant injury. Yield and scab records for 1955 are given in table 2. Residual scab control, although significant, was much less than the year before. Confirmation of this was found in observing a replanting of an area in a commercial field where PCNB has been used successfully for scab control in 1954 at the rate of approximately 90 pounds per acre. The potatoes in 1955 were almost as scabby as in the untreated area. The plant injury effect in 1955 from the residual PCNB, as shown in yield reduction in table 2, is surprising in view of the decreased disease control. In 1954 the total yields were lower, even in check plots, but there was evident stunting in the residue plots all season, which was distinct enough to distinguish the different rates in each replicate. Since there is no published record of this occurring in other cases with PCNB, it may be related to the particular soils used in this study. The fact that the yield reduction from the 50-pound residual was very slight, may indicate that this effect is not a serious problem at rates likely to be used.

1955 Experiments

Using the results of 1954 as a guide, a more extensive experiment was conducted in a scab-contaminated commercial field in 1955 using rates of 0, 20, 40, 60, and 80 pounds per acre of PCNB.[3] All plots were 100′ long and 10′ wide on Ritzville fine sandy loam. Four methods of application were tried in an effort to find possibilities for reducing the dosage per acre and eliminating plant injury. These methods were as follows:

1. *Rotary tillage.* The PCNB was broadcast on the surface of the ground after discing and light harrowing. This material was then worked into the soil by two passes with a rotovator operating at 6″ depth.

2. *Discing.* PCNB was worked into the soil by 3 passes with an offset disc operated in the same direction each time. The depth of discing was approximately 6 inches. In commercial practices a better mix might be obtained by cross discing, a method that could not be followed on the long narrow plots.

[3]These experiments were conducted in cooperation with the firm of Balcom and Moe, on their potato crop.

TABLE 1.—*Effect of preplating treatment of soil with PCNB on yield of White Rose potatoes — 1954.*

Rate of PCNB	Total Yield	Yield in Grades on Scab Basis[1]		
		No. 1	No. 2	Culls
Lbs./Acre		Tons/Acre	Tons/Acre	Tons/Acre
0	15.0	2.0	11.2	1.8
50	12.0	9.0	3.0	0.0
100	11.6	11.4	.2	0.0
150	11.1	10.5	.6	0.0

[1]Grading System: No. 1: less than 5 per cent of surface area scabbed.
No. 2: between 5 and 25 per cent of surface area scabbed.
Culls: more than 25 per cent of surface area scabbed.

TABLE 2.—*Residual effect of previous-year soil application of PCNB on yield and scab in White Rose potatoes.*

Rate of PCNB Applied in 1954	Total Yield 1955	Yield in Grades on Scab Basis[1]		
		No. 1	No. 2	Culls
Lbs./Acre	Tons/Acre	Tons/Acre	Tons/Acre	Tons/Acre
0	10.4	.7	4.3	5.4
50	9.3	1.8	4.6	2.9
100	7.2	1.6	3.1	2.5
150	6.2	2.1	2.5	1.6

[1]Grading System: See table 1.

3. *Harrowing.* Broadcast application of PCNB on prepared ground was followed by a single harrowing to a depth of approximately 3 inches with a "finger weeder." In this treatment the final hill of potatoes was built from treated soil, but the seed piece and root zone were in untreated soil.

4. *Row Application.* In an attempt to simulate application and mixing in a band, the potatoes were planted first but not covered except by an inch of loose soil. PCNB was then applied in a strip 15" wide (½ row width) over the row. A finger weeder was used to fill the furrow level after which the row was hilled by hilling discs. The rates of PCNB used were ½ the amount used for the broadcast treatments.

All treatments and planting were done during a three-day period from April 13-15. Because of a possibility that the usual band placement of fertilizer might interfere with the performance of the fungicide the fertilizer was broadcast and disced in before planting. This proved to be somewhat unsatisfactory because the plants showed nitrogen deficiency before the end of the season, which resulted in lower-than-normal yields.

Records were made during the growing season on rate of emergence, total top growth and rhizoctonia stem damage. It will be seen in table 3 that PCNB when rototilled or disced had a definite delaying effect on early growth. There were no specific symptoms of injury other than slow sprouting. By harvest time this slow start had been overcome and final yield was not affected.

TABLE 3.—*Effect of PCNB soil treatments on emergence and early growth of White Rose potatoes as measured by dry weight of plants 45 days after planting.*

Rate of PCNB	Dry Wt. of Plants from a 10-plant Sample — Grams per Stem			
	Rototilled	Disced	Harrowed	Stripped
Lbs./Acre	Gms.	Gms.	Gms	Gms.
0	1.21	1.08	.90	.79
20	.78	1.10	.76	.92
40	.70	.93	1.08	.86
60	.85	.85	.80	.80
80	.49	.70	.95	.73

The data on rhizoctonia were recorded twice during the growing season for stem and stolon damage and at harvest for tuber sclerotia. These results are shown in table 4. The lowest rate of 20 pounds PCNB per acre, when either disced or rototilled, gave striking control of stem lesions. In the case of rotary tillage the incidence of infected stems was reduced from 84 per cent to 7 per cent by the 20-pound rate. The decreased effectiveness of discing (21 per cent infected stems at the 20-pound rate) was probably caused by less effective mixing.

TABLE 4.—*Effect of rate and method of application of PCNB on rhizoctonia control in White Rose potatoes.*

Rate of PCNB	Application Method	Rhizoctonia Infected Stems		Stolons per Stem Girdled	Tubers Marred by Sclerotia
		May 31	July 18		
Lbs./Acre		Per cent	Per cent	No.	Per cent
0	Rotary tillage	40.1	84.1	1.5	5.4
20	" "	6.1	6.6	.05	4.7
40	" "	2.7	0	0	1.4
60	" "	.9	2.7	0	0
80	" "	1.9	1.9	0	.2
0	Disced	25.2	81.9	2.3	4.2
20	"	4.0	21.0	.1	5.0
40	"	4.3	0	0	1.8
60	"	1.0	0	0	.4
80	"	0	6.0	.3	0
0	Harrowed	37.4	58.5	1.3	3.3
20	"	22.0	33.0	2.1	2.4
40	"	20.1	59.4	1.1	2.3
60	"	18.9	52.5	1.0	.9
80	"	19.0	27.5	.6	1.7
0	Stripped	49.6	49.0	1.3	2.7
10	"	30.2	50.0	.6	.9
20	"	14.4	30.7	.6	2.6
30	"	26.9	25.0	.2	1.4
40	"	19.1	39.0	.3	2.6

Tuber rhizoctonia expressed as the percentage of tubers thrown out of U. S. No. 1 grade because of sclerotia on the surface was also controlled by PCNB but in both the rotary tilling and discing treatments 40 pounds per acre were required.

The two harrowed treatments were not effective in rhizoctonia control indicating that the mixing methods used did not place the fungicide deep enough to protect the stems for their entire underground length.

The yield of tubers in this experiment is included in table 5. Some explanation is needed for the lack of yield increase that might be expected from the degree of control of rhizoctonia stem and stolon damage. Growing conditions seem to determine whether or not early season rhizoctonia is damaging. In the check plots with 80 per cent of the stems infected, severe damage could have occurred if the weather had remained cool. However, during late May and June growth was rapid. The rhizoctonia lesions remained superficial and very little complete girdling occurred. In the case of girdled stolons they were replaced by a later set that escaped infection. If this experiment had been conducted during a cool season, there would, undoubtedly, have been serious yield reductions from rhizoctonia damage.

TABLE 5.—*Effect of rate and method of application of PCNB on scab control in White Rose potatoes—1955.*

Rate of PCNB	Application Method	Scab Index	No. 1 Potatoes		Total Yield
			Scab Basis[1] Only	U. S. Grade	
Lbs./Acre			Per cent	Per cent	Tons/Acre
0	Rotary tillage	14.2	24.9	10.2	10.3
20	" "	10.1	45.5	11.3	9.2
40	" "	5.6	61.0	23.5	9.6
60	" "	.8	92.8	47.7	10.2
80	" "	.9	93.8	52.8	8.7
0	Discing	14.2	28.2	4.7	10.2
20	"	2.7	86.8	41.5	11.0
40	"	3.6	82.2	30.1	9.3
60	"	.9	95.6	54.8	9.3
80	"	1.7	87.9	49.0	9.6
0	Harrowing	6.6	53.7	8.8	10.4
20	"	4.3	70.4	24.1	10.3
40	"	4.3	75.3	27.2	9.8
60	"	3.6	80.8	32.9	9.8
80	"	8.1	61.1	15.6	10.0
0	Stripped[2]	17.7	17.0	.9	10.8
10	"	6.5	59.8	16.4	10.3
20	"	2.8	82.3	27.1	10.3
30	"	5.7	62.5	22.0	9.8
40	"	5.5	64.4	24.0	10.7

[1]Includes all tubers with less than 5 per cent of the surface scabbed regardless of other defects.

[2]Note dosage per acre in all strip applications is ½ that of the other treatments.

The effect of the rates and application methods on control of scab are reported in a number of ways in table 5. For purposes of close comparisons the scab indices are the most precise because the tubers from each plot were carefully graded into seven scab classes from which the average index is calculated. Maximum benefits were reached at the 60-pound rate for both rotary tillage and discing. Results at lower rates are somewhat variable. If the 20-pound-disced treatment is considered out of line, then it would appear that satisfactory scab control can be obtained in this type of soil at 40 to 60 pounds PCNB per acre.

Results with the harrowed and stripped treatments were variable but there are suggestions of effective scab control in the strip application. Undoubtedly it is simply a matter of getting the material mixed in the soil at the right location.

Further data on rhizoctonia control with PCNB were obtained by a supplemental experiment on late potatoes at another location. In this case PCNB was applied prior to planting by broadcasting and discing at rates of 0, 5, 10, 20 and 40 pounds per acre. Plots were 10′ wide by 100′ long. Russet Burbank potatoes were used in this test. The results are summarized in table 6. Even 5 pounds per acre of PCNB greatly reduced the stem canker stage of rhizoctonia. As in the previously described experiment, the incidence of tuber sclerotia was not reduced by rates below 40 pounds.

TABLE 6.—*Effect of rate of PCNB on rhizoctonia control in Russet Burbank potatoes, 1955.*

Rate of PCNB	Stems Infected by Rhizoctonia	Tubers Marred by Sclerotia
Lb./Acre	Per cent	Per cent
0	66.1	14.3
5	18.5	13.2
10	19.3	11.8
20	1.8	9.7
40	1.0	5.5

DISCUSSION

PCNB is shown in these experiments to be a highly effective soil fungicide for rhizoctonia control in potatoes under certain conditions. It can be disced into the soil before planting at rates of 10-20 pounds active ingredient per acre and, if thoroughly incorporated in the soil, should give almost complete control in this type of soil. The same conclusions are justified for scab control except that three times as much fungicide per acre is required.

Only rotary tillage and discing were satisfactory methods of mixing PCNB in the soil for control of these potato diseases. The failure of harrowing as a mixing method is believed to be due to the immobility of PCNB in soil. With this treatment the harvested potatoes showed great variation in the amount of scab. When a few hills were harvested by hand it was noted that the upper tubers in the hills were scab-free, whereas the

lower tubers were scabby. A similar situation occurred in the strip-application treatment. It is concluded that PCNB must be mixed into the soil at least as deep as the seed piece to protect most of the tubers. Consequently the fungicide will have to be applied at or before planting.

A rate of 50 pounds per acre is roughly equivalent to a concentration of 25 parts per million in the top 6 inches of soil. Since PCNB does not move appreciably in the soil and since protection from the two pathogens involved is needed only in the stem, stolon and tuber zone, it is evident that confining applications to this zone would require considerably less material per acre than broadcast treatment.

Until machinery is devised that will do this type of mixing, the use of discing is recommended. Any slight advantage from rotary tillage would not outweigh the cost and time required for this operation.

These experiments were conducted with irrigation on fine sandy loam low in organic matter. In each case the land had produced potatoes the previous year so that there was very little undecomposed plant residue in the soil at time of treatment. These features are emphasized because they indicate a limitation to the use of this fungicide. For example, a commercial trial of PCNB was made by a grower in 1956 using PCNB at both 20 and 40 pounds per acre. Several fields were treated but in each case either a green manure crop of winter cereal was plowed in before treatment or it was made on plowed grain stubble. Under these conditions no significant reduction in rhizoctonia damage or scab incidence could be seen, nor was there any improvement in yield of marketable potatoes. It is believed that the plant residue and cloddy structure interferred with mixing the fungicide by discing to the point that control was not achieved at the relatively low rates used.

The results here reported not only demonstrated the ability of PCNB to control scab and rhizoctonia in potatoes but also point out the practical problems relative to distributing the material throughout the soil mass. This problem is one that will be common to all attempts to use insoluble, non-volatile fungicides in soil. Its solution will depend upon the improvement of mixing machinery and methods of application. Even so, the practicality of using such materials will be limited by clods, plant residue and basically by the limits to which we should go in destroying soil structure in order to add the fungicide.

Summary

Pentachloronitrobenzene (PCNB) controlled potato scab in fine sandy loam of the Yakima Valley when applied at the rate of 50 pounds per acre broadcast before planting and mixed by discing or rotary tillage. Mixing with a harrow in the top 2 inches of soil was ineffective even when 80 pounds per acre were used. Control was also unsatisfactory when the material was applied after shallow planting followed by harrowing and hilling.

The stem-canker stage of rhizoctonia was controlled similarly with PCNB at the rate of 10 to 20 pounds per acre. Tuber sclerotia, however, were not controlled until rates of 40 to 50 pounds per acre were used. At these rates there was no reduction in total yield of tubers but some

delay in emergence resulted. Limited data indicate only slight residual disease control in the second year.

These results were obtained with irrigation on fine sandy loam low in organic matter but at very high levels of infestation of the pathogens. Observations indicate that undecomposed plant residue in the soil may interfere with mixing and thus seriously reduce the effectiveness of treatment.

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