Combinations of Specific Fungicides for Sugar Beet Seed Treatment

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Seedling diseases of sugar beets have assumed greater importance during recent years, especially in certain areas of the Sacramento and San Joaquin Valleys in California. This increase may be due in part to adverse weather conditions but also in part to changes in the sequence of crops and an increase in late plantings.

If a lower labor requirement is to be achieved during stand reduction a uniform, low density population of healthy seedlings is required, whether singling is accomplished by machine or by simplified hand labor operations. The achievement of uniform, low density seedling populations has been retarded in northern California by the fact that during 1956 and particularly during 1958 seedling diseases of sugar beets were extremely severe as indicated by the acreage abandoned or replanted (Table 1). To reduce the loss of crop and the costs incidental to replanting, growers in general have tended to increase seeding rates. In favorable years such as 1959 and in fields little affected by seedling disease high seeding rates have resulted in stands of high density leading to increased difficulty of machine thinning or increased hand thinning costs.

Table 1.—Replanted and Abandoned Acreage of Sugar Beets in Northern California because of Seedling Diseases, 1956-1958.[1]

	1956	1957	1958
		Acres	
Area surveyed	95,039	109,319	111,971
Abandoned because of seedling disease	3,019	1,677	7,837
Replanted because of seedling disease	4,540	4,507	11,112

[1] Compiled from data supplied by the agricultural staffs of Holly Sugar Corporation and Spreckels Sugar Company.

Because present seed treatment practices have not provided the protection required under conditions of severe infection, we have conducted extensive investigations under greenhouse house conditions to identify more efficient fungicides or more effective methods of seedling disease control.

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The problem is complicated by the fact that at least four different soil fungi cause seedling diseases of sugar beets in California. These organisms, *Pythium ultimum* Trow, *P. aphanidermatum* (Edson) Fitzp., *Rhizoctonia solani* Kuhn, and *Aphanomyces cochlioides* Drechs., differ in their abundance according to soil type, climatic conditions, season of planting, and previous cropping practices. Furthermore, these organisms usually occur in combinations rather than as simple infections by a single fungus.

As new fungicides have become available we have tested them in the laboratory and greenhouse against each of the seedling pathogens. From these trials we have identified a few fungicides that show high effectiveness against certain fungi but are, in some cases, so specific that they are not effective against others. With mixed fungus infections certain combination treatments appear especially promising.

Greenhouse trials from 1955 to 1957 showed that an experimental fungicide, Bayer 15080 (quinone oxime benzoyl hydrazone)[2] used as a seed treatment gave good protection of seedlings against *Pythium ultimum* but little or no protection against *Rhizoctonia solani*. Pentachloronitrobenzene (PCNB), on the other hand, protected seedlings against Rhizoctonia but not against Pythium. Neither fungicide, when used as a seed treatment, has proved effective against *Aphanomyces cochlioides*.

During the spring and summer of 1957 these two fungicides were evaluated alone and in combination in five field plantings in comparison with nontreated seed and with seed treated with Phygon (dichloronaphthoquinone or dichlone). These trials were located in northern California. The results are shown in Table 2.

In three of the five trials, Bayer 15080 resulted in significantly more seedlings than seed treated with Phygon. PCNB treated seed did not improve stands in any of the trials and in several cases the stands from combination treatments were reduced below those from Phygon or Bayer 15080 used alone. These results indicated that Rhizoctonia was of minor importance in these fields and also suggested that PCNB, at the rate used (4 oz. of 75% PCNB per 100 lb. seed), was slightly phytotoxic.

In March, 1957, Dexon (P-dimethylaminobenzenediazo sodium sulfonate, Bayer 22555) was offered by the manufacturer for testing as a soil fungicide. Greenhouse trials disclosed that this

[2] Frohberger, P. E. 1956. Untersuchungen uber die Wirkung von Chinonoximbenzoylhydrazon gegen Keimlingskrankheiten verschiedener Kulturpflanzen. Phytopathologische Zeitschrift 27:427-455. (English trans. Hofchen-Briefe IX:253-279.)

Table 2.—The Effect of Seed Treatment on Stands of Sugar Beets. Values are Seedlings per Ten Feet of Row. Results of 1957 Field Trials.

Seed Treatment[1] Material	Dosage Oz/100 Lb.	Trial Number 1	2	3	4	5	Avg. of 5 Trials
		Treatment means					
None		81	70	23	47	70	58
PCNB	4	78	83	18	57	59	59
Phygon XL	4	131	106	27	55	82	80
Phygon XL + PCNB	4 4	115	96	29	53	78	74
Bayer 15080	2	145	120	36	82	86	94
Bayer 15080 + PCNB	2 4	133	102	31	65	79	82
Sign. Diff. (19:1)		13	17	9	11	10	....
Interaction		n.s.	?	n.s.	?	n.s.	

[1] PCNB - 75% pentachloronitrobenzene (Terraclor); Phygon - 50% dichloronapthoquinone (dichlone); Bayer 15080 - 50% quinone oxime benzoyl hydrazone (Cerenox in Europe).

[2, 3] Indicates significant effects at the 5% and 1% levels, respectively.

material used as a seed treatment was extremely effective against *Pythium ultimum*, moderately effective against *P. aphanidermatum* and *Aphanomyces cochlioides*, but ineffective against *Rhizoctonia solani*. However, as a seed treatment Dexon proved to be more effective against *A. cochlioides* than any other fungicide tested although satisfactory protection was not obtained in severely infested heavy soils. Combination treatments of Dexon and PCNB were especially effective in soils containing both *R. solani* and *P. ultimum*.

In 1958, with the cooperation of beet sugar companies, farm advisors and growers, 19 field trials were completed in which standard commercial fungicides were compared with three candidate fungicides used alone and in combination. Twelve of these trials were located in northern California (trials 1 through 12, Tables 3 and 4). Seven were located in other states by the American Crystal Sugar Company as follows: two in Colorado (trials 13 and 14, Table 4), one in Iowa (trial 15, Table 4) and four in Minnesota (trials 16 through 19, Table 4). Individual plots were small consisting of two or four rows 50 feet long planted with a commercial seeder or, in trials 11 through 19, of 120 seeds dropped in 10 feet of row by a special plot planter.

Table 3.—The Effect of Seed Treatments on Stands of Sugar Beet Seedlings, 1958 Trials, With Phygon the Standard Fungicide. Values are Seedlings per Ten Feet of Row.

Seed Treatment[1]		Trial Number										Avg. of All Ten Trials	Avg. of Four Trials[3]
Materials	Oz. per 100 Lb.	1	2	3	4	5	6	7	8	9	10		
Treatment Means[2]													
None	—	74	55	46	20	45	81	38	47	26	55	49	50
PCNB	2	102	60	55	27	61	69	37	54	37	57	56	54
Phygon	6	101	80	44	42	89	85	52	64	41	85	68	74
Phygon + PCNB	6 + 2	94	75	47	41	85	82	31	54	52	88	65	70
B-15080	2	103	79	50	64	83	96	42	54	43	82	70	80
B-15080 + PCNB	2 + 2	117	67	46	66	92	86	43	66	49	101	73	78
Dexon	2	91	78	61	68	92	95	50	65	34	81	72	83
Dexon + PCNB	2 + 2	128	83	54	65	89	101	43	63	52	87	77	85
LSD (5%)		n.s.	18	n.s.	12	16	11	n.s.	8	n.s.	19	—	8
Average Effect of PCNB[4]													
Without PCNB		92	73	50	48	78	90	46	58	36	76	64	72
With PCNB		110	71	51	50	82	84	39	59	48	83	68	72
LSD (5%)		16	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	8	n.s.	n.s.	n.s.
Average Effect of Other Fungicides[4]													
None		88	57	51	24	53	75	38	50	32	56	52	52
Phygon		98	77	45	41	87	84	42	59	46	86	67	72
B-15080		110	73	48	65	87	91	42	60	46	92	71	79
Dexon		109	81	58	67	90	98	47	64	43	84	74	84
LSD (5%)		n.s.	13	n.s.	9	11	8	n.s.	6	12	13	—	5

[1] PCNB—75% pentachloronitrobenzene; Phygon—50% dichloronaphthoquinone; Bayer 15080—50% quinone oxime benzoyl hydrazone; Dexon (Bayer 22555)—85% P-dimethylaminobenzenediazo sodium sulfonate.

[2] Interaction of PCNB with non-treated seed and the other fungicides was not significant at the 5% level in any of the trials.

[3] Data for trials 2, 4, 5 and 6 were combined on the basis of having homogeneous error variances.

[4] Averages of all plots having seeds treated with the fungicide indicated.

Table 4.—The Effect of Seed Treatments on Stands of Sugar Beet Seedlings, 1958 Trials, with Captan as the Standard Fungicide. Values are Seedlings per Ten Feet of Row.

Seed Treatment[1]		Trial Number									
Materials	Oz. per 100 Lb.	11	12	13	14	15	16	17	18	19	Average of All Trials[3]
						Treatment Means[2]					
None	—	19	66	57	73	51	46	44	46	32	48
PCNB	2	19	65	63	76	50	48	51	42	42	50
Captan	10	35	71	116	97	60	60	49	62	60	67
Captan + PCNB	10 + 2	41	76	119	111	65	61	53	60	62	71
B-15080	2	50	97	118	94	59	52	63	44	57	70
B-15080 + PCNB	2 + 2	44	76	120	92	65	55	54	56	61	69
Dexon	2	45	69	128	105	67	63	56	55	70	73
Dexon + PCNB	2 + 2	40	94	140	108	71	57	60	62	66	77
LSD (5%)		11	17	12	12	11	11	10	12	13	4
						Average Effect of PCNB[4]					
Without PCNB		38	76	105	92	59	55	53	52	55	64
With PCNB		36	78	110	97	63	55	55	55	58	67
LSD (5%)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	2
						Average Effect of Other Fungicides[4]					
None		19	66	60	74	50	47	48	44	37	49
Captan		38	74	117	104	62	60	51	61	61	69
B-15080		47	87	119	93	62	53	59	50	59	69
Dexon		43	81	134	107	69	60	58	59	68	75
LSD (5%)		8	12	9	8	8	8	7	8	9	3

[1] Captan is 50% N-trichloromethylmercapto-4-cyclohexene-1, 2-dicarboximide. See footnote [1] Table 3 for chemical composition of other compounds.
[2] The interaction of PCNB with non-treated seed and the other compounds was not significant at the 5% level in any of the trials.
[3] All trials had similar error variances and were combined for analysis.
[4] Averages of all plots having seeds treated with the fungicide indicated.

Results, 1958 Trials

Comparisons with Phygon

The seedling counts from trials 1 through 10 in which Phygon was used as the standard seed treatment are presented in Table 3. There are wide differences in error variances and consequently all trials could not be combined in a single analysis. However, four of the trials, numbers 2, 4, 5, and 6, have homogeneous error variances and were combined for analysis following the method of Roessler and Leach[3] (last column, Table 3).

The results of the individual trials and the combined series show that PCNB used alone was not a satisfactory treatment. All other treatments definitely improved stands over those resulting from nontreated seed in most of the trials.

The average effect of PCNB indicates a significant improvement in only trials 1 and 9. The difference in trial 10 is nearly significant at the 5 percent level. Judging from greenhouse results we can assume that only in these trials was *Rhizoctonia solani* important in reducing seedling stand.

Considering the average effect of the other fungicides it is clear that treatment with Phygon significantly improved stands over nontreated seeds in seven of the ten trials. As in the 1957 trials, Bayer 15080 was equal to or more effective than Phygon. Dexon gave higher average stands than Phygon in eight of the ten trials and higher than Bayer 15080 in seven of the trials, although it did not differ significantly from Bayer 15080 in any of the individual trials. On the basis of the average of all of the trials, as well as with the homogeneous series, Dexon was significantly better than Phygon and appeared to give better protection than Bayer 15080 although the difference was just significant at the 5 percent level.

Comparisons with Captan

The results of the trials in which Captan was used as a standard fungicide are given in Table 4. Because of remarkable similarity of error variances it was possible to combine all nine trials in a single analysis. In this analysis, when the average of all plots in which seed was treated with PCNB is compared with the average of those where PCNB was not used a small but significant increase due to PCNB was observed. This effect could not be measured at the 5 percent level in any of the individual trials. This indicates that, while Rhizoctonia was not a major factor in any of these trials, this fungus did cause the loss of some

[3] Roessler, E. B., and L. D. Leach. 1944. Analysis of combined data for identical replicated experiments. Proc. Amer. Soc. Hort. Sci. 44: 323-328.

seedlings and that this effect could only be measured at the 5 percent level of significance by many replications.

A comparison of the average effects of the other fungicides for all the trials shows that all three materials improved emergence over that from nontreated seed. Captan and Bayer 15080 resulted in 41 percent more seedlings than was obtained from nontreated seed, while Dexon gave a 52 percent increase. The improvement in stand resulting from seed treated with Dexon compared to the other two materials is significant at the 1 percent level.

Field trials for 1959 were designed to compare Dexon and Phygon when each compound was used alone and in combination with PCNB. Plots of each trial consisted of four-row strips through a commercial field. Nontreated seed was not included because of the large size of the plots and the danger of stand deficiencies from nontreated seed. Seeds were planted with the seeder used by the grower. A randomized complete block design was used for each trial with six replications. Treatments were evaluated by counts of healthy seedlings soon after emergence and again just before thinning. Counts were made on ten feet of all four rows of each plot at two different locations in the field.

Results, 1959 Trials

The seedling stands resulting from the treatments in nine trials are given in Table 5.

Considering the individual trials, interactions significant at the 5 percent level occurred at two locations (trials 4 and 9). In both cases interaction was due to stand increases associated with the addition of PCNB to Dexon in contrast to no increase when PCNB was added to Phygon. The same tendency was noted in several of the 1958 trials (Table 3) but the apparent interaction was not significant at the 5 per cent level in any of the trials of that year.

There were significant effects of PCNB in two trials where interactions were not significant. In one (trial 3) PCNB improved stand; in the other it decreased stand (trial 7). In the latter trial there was a significant improvement due to Dexon; this effect also occurred in trial number 8.

On the basis of homogeneity of error variances, it was possible to combine the trials in two groups, one involving seven locations, the other, two. A summary of these analyses is given in the last two columns of Table 5.

The combined results from seven locations show a significant interaction of PCNB with Phygon and Dexon. PCNB combined

Table 5.—The Effect of Seed Treatment on Stands of Sugar Beet Seedlings, 1959 Trials. Values Are Seedlings per Ten Feet of Row Just Prior to Thinning.

Seed Treatment[1]		Trial Number									Avg. of Trials 1 to 7[2]	Avg. of Trials 8 and 9[2]
Materials	Oz. per 100 Lb.	1	2	3	4	5	6	7	8	9		
Treatment Means												
Phygon	6	66	73	78	134	72	80	115	124	155	89	138
Phygon + PCNB	6 + 2	63	72	86	130	65	78	104	116	158	86	135
Dexon	2	67	66	73	127	74	79	135	155	151	89	153
Dexon + PCNB	2 + 2	67	68	83	138	79	83	124	145	172	92	157
LSD (5%)		n.s.	n.s.	n.s.	10	15	n.s.	15	18	21	4	14
Interaction		n.s.	n.s.	n.s.	[4]	n.s.	n.s.	n.s.	n.s.	[4]	[4]	n.s.
Average Effect of PCNB[3]												
Without PCNB		67	69	75	131	73	80	125	140	153	89	146
with PCNB		65	70	84[4]	134	72	80	114[4]	131	165	89	146
Average Effect of Phygon and Dexon[3]												
Phygon		64	72	81	132	68	79	109	120	156	88	136
Dexon		67	67	79	132	76	81	129[5]	150[5]	161	91[4]	155[5]

[1] Dexon is 70% P-dimethylaminobenzenediazo sodium sulfonate. See footnote [1] Table 3 for chemical composition of other fungicides.
[2] Combined for analysis on the basis of similar error variances.
[3] Averages of all plots with seeds treated with the fungicides indicated.
[4, 5] Indicates significant effects at the 5% and 1% levels, respectively.

with Dexon tended to improve stand, but in combination with Phygon no improvement and possibly a reduction in stand was observed. When each was used alone, Dexon and Phygon produced equal results. Dexon in combination with PCNB resulted in a stand which was significantly greater than that resulting from the combination of Phygon and PCNB. In both combined series there was a significant over-all effect of improved stands with Dexon compared to Phygon.

Summary and Conclusions

During 1957-59 thirty-four field trials were conducted to evaluate pentachloronitrobenzene (PCNB), p-dimethylaminobenzenediazo sodium sulfonate (Dexon) and quinone oxime benzoyl hydrazone (Bayer 15080) as seed treatments used alone or in combinations. Fungicides in commercial use were included as standards.

Previous to and concurrent with the field trials numerous greenhouse trials were conducted to identify the effects of several organic compounds used as seed treatments for controlling seedling disease caused by specific pathogens. Results of the greenhouse trials are briefly iscussed.

The results of the field trials indicated that:

1. PCNB used alone had little or no advantage over non-treated seed.

2. PCNB added to Phygon did not increase and in certain instances decreased stands.

3. Dexon at a relatively low dosage rate was superior to Phygon and Captan at higher dosage rates.

4. On the average Dexon was superior to Bayer 15080.

5. The combination of Dexon and PCNB in some fields resulted in improved stands compared to stands from seed treated only with Dexon.

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