WHITE MOLD OF PINTO BEANS:

Effects on Yield and Fungicidal Control

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Dry bean production in North Dakota began in 1963 and has developed into a 100,000 plus-acre crop. The white mold disease caused by Whetzelinia (Sclerotinia) sclerotiorum (Lib) Korf and Dumont is threatening production. Several farmers report that white mold has developed in their fields to the extent that they have had to limit bean acreage. Fortunately, these complaints are not as yet common. The disease has thus far been most severe in areas of North Dakota having the oldest history of pinto bean and sunflower production.

Once established in a field, white mold is difficult to control. Compact, durable sclerotia (Fig. 1) formed in and on plant tissue perpetuate the fungus by remaining viable in soil for several crop years. Cook et al. (3) showed that 75 per cent of the sclerotia recovered produced apothecia after three years burial in soil. The apothecia (Fig. 2) are tiny mushroom-like structures that form spores. Primarily, it is these spores that initiate the bean disease. The fungal spores must first colonize sluffed flowers or dried plant tissue (Fig. 3) to gain energy before initiating infection of leaf, stem or pod (1,3,9,10,11). Once the mold begins, any part of a plant or adjacent plant that contacts the fungus becomes rotted. Also, mold may start from germinating sclerotia on the soil surface (6,10,11), or dried infected plant tissue and molded organic matter may be blown to bean plants (9) to initiate the disease.

Present methods of control for white mold in pinto beans are crop rotation (3), at least a 30-inch row spacing (13), and, more recently, spraying benomyl at flowering (8). Pathologists and breeders have also suggested control by altering plant architecture (4), using a determinate or bush bean type (2,4,13), or employing genetic resistance (2,12). These latter three control methods need to be researched considerably more before they can be used.

Benomyl has been used with varying success for control of white mold. Timing of the application is important (8,9). Most efforts have employed ground sprayers. Aerial applications have only recently been used. Gabrielson et al. (5) successfully controlled **W. sclerotiorum** on cabbage by aerially applying 2 pounds benomyl in 10 gallons of water per acre.

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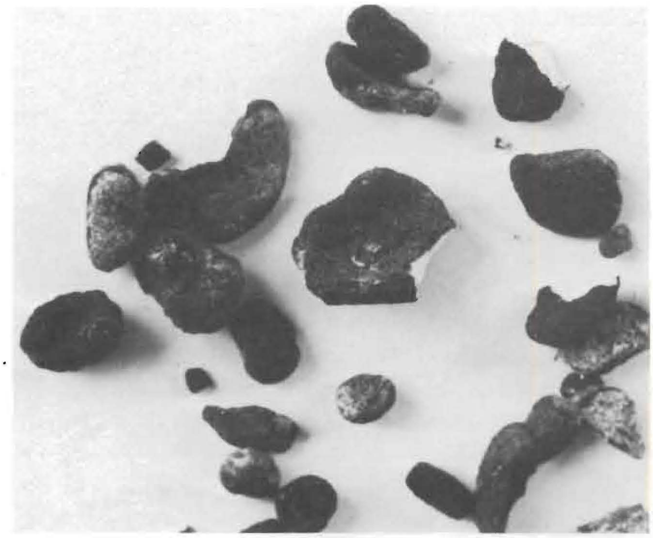

Figure 1. White mold sclerotia isolated from the soil.

Tests were made in 1974 to provide information on (1) the effects of white mold on bean production; (2) the use of the fungicide benomyl at different rates and application methods; (3) comparison of the disease on a bush vs. a vining type pinto bean; and (4) the sclerotial content of soil.

Materials and Methods

Plots were established in commercial fields of Pinto Idaho 111 beans in Pembina county, North Dakota. The cooperating farmer[1] exper-

[1] *Cooperating farmer was Richard Heuchert, St. Thomas, North Dakota.*

Table 1. Crop History and Per Cent of Diseased Plants for Two Fields That Had Severe White Mold in 1974.

Year	20 A Field	50 A Field
1974	Bean	Bean
1973	Grain	Grain
1972	Bean	½ Grain ½ Fallow
1971	Grain	½ Fallow ½ Grain
1970	Fallow	Bean
1969	Bean	Grain
1968	Grain	Bean
1967	Fallow	Grain
1966	—	Beets
Per Cent Diseased Plants, 1974	30.8	43.5

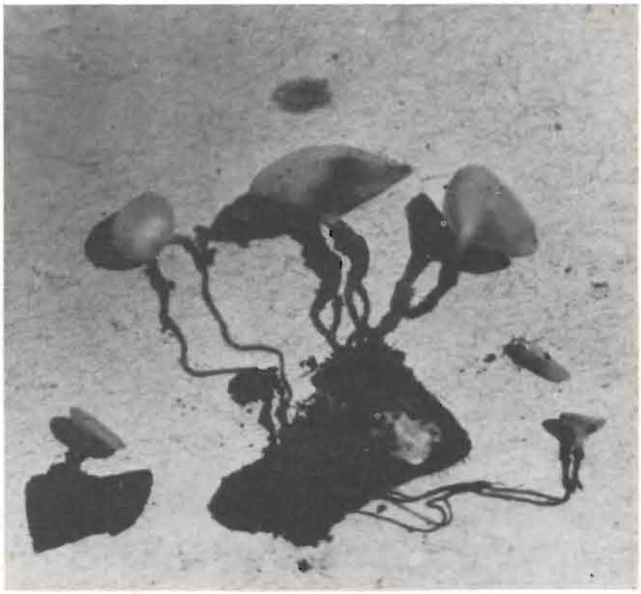

Figure 2. Apothecia are tiny, mushroom-like structures.

ienced severe white mold in past years and was anxious to participate in efforts to reduce disease losses, which in 1973 were about 30 per cent in fields adjacent to these 1974 plots (8).

Estimates of mold severity were made on two fields of I 111 composed of 20 and 50 acres planted June 3 (Table 1). Percentages of diseased plants were obtained by counting diseased plants and healthy plants in 10-foot rows from six random sites. The effects of white mold were evaluated by comparing number of pods, number of usable beans, and weight of usable beans from individual diseased plants and adjacent healthy plants from these same fields.

Fungicide plots were established in the 20-acre field situated south of an east-west multi-row shelterbelt. Benomyl 50W was applied with a hand sprayer at 1 pound per acre and $1\frac{3}{4}$ pounds per acre on July 13 or July 26, or on both dates. Single rows were treated in each of four replications and untreated rows served for comparisons.

Figure 3. White mold on dried leaf lodged in the bean plant canopy.

The 20-acre field of I 111 beans was also used to compare non-treated beans with those receiving a single airplane application of benomyl July 13, a double airplane application July 13 and July 28, or a ground spray application July 12. The dosage for aerial application was $1\frac{1}{2}$ pounds benomyl in 5 gallons of water per acre, plus 1 pint of spreader-sticker per 100 gallons. The ground spray was made with a modified 12-row cultivator (Fig. 4). Spray nozzles were positioned over each row. Twenty-four rows were treated with $1\frac{1}{2}$ pounds

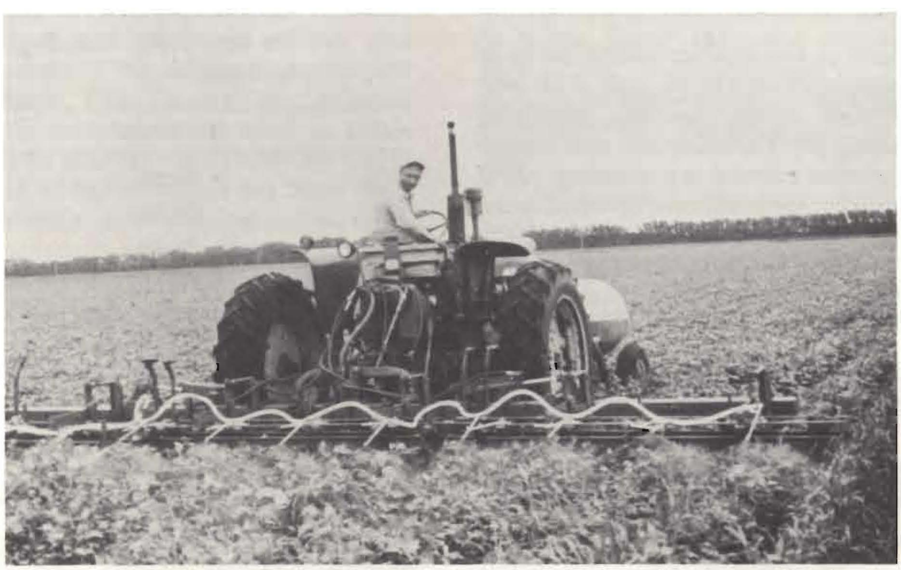

Figure 4. A 12-row cultivator rigged to spray benomyl during last cultivation on pinto beans.

benomyl in 100 gallons of water per acre at a pressure of 80 psi. A strip of 24 rows was left untreated.

Percentages of disease and yield were obtained for the small plot and large field fungicide trials. Data were obtained on the center 25 feet of each row in the small fungicide plots. The plants were pulled, left to dry five days, collected in grass-seed sacks, stored for several days, and then threshed. Beans were dried, sorted with a 10/64 mesh screen, and weighed.

An early frost necessitated using subplot data for the airplane or ground spray field trials rather than farmer-harvest yields. Samples were obtained by pulling plants in 10-foot rows in each of four random sites from each treatment. Plants were then handled as in small plot trials described above.

Variety reactions to white mold were evaluated during the growing season. Ouray, a bush-type pinto bean variety, was evaluated by planting several rows at the north end of the 20-acre field.

Soil samples for sclerotial analysis were collected in fall after harvest but before the fields were worked. Nine to 12 replicates of 6-inch square samples were dug with a trowel 0 to 2 and 2 to 4 inches deep at random in the 20-acre field or from areas of the 20 and 50-acre fields (Table 1) where severe mold occurred in irregular patches, "hotspots". Sclerotia were isolated by straining five, 67 g soil subsamples from each field sample through a 2.38 mm and a 0.85 mm sieve.

Results

White mold occurred in 2-week old seedlings of I 111 in 1974. Only scattered plants were affected. The young plants were killed and sclerotia developed readily within the stems. No apothecia were found in the fields at the time these seedlings became diseased, suggesting that the infection originated from mycelium of germinating sclerotia directly infecting young stems.

Apothecia did not appear nor did mold develop until after August 13, 71 days after planting. Apothecia abounded (Fig. 2) by August 27, by which time the disease had progressed severely throughout the area of the field where small fungicide plots were located.

Irregular-shaped patches of severely diseased plants occured in the commercial fields. These patches were in low-lying areas. Apothecia were observed in all parts of the fields, but appeared more abundantly in the patches.

The crop histories for the 20-acre and 50-acre fields are shown in Table 1. Thirty-one per cent (30.8 per cent) and 43.5 per cent of the plants in the 20-acre and 50-acre commercial fields, respectively, were diseased by September 6. The disease affected all factors which contribute to yield of beans. Pod and bean number and bean weight were reduced 24 per cent, 50 per cent and 56 per cent, respectively (Table 2).

Table 2. Effect of White Mold on Pod Number, Usable Beans, and Bean Weight for 10 Diseased and 10 Healthy Pinto Bean Plants.

	Healthy	Diseased	% Reduction
Number of pods	17.3	13.1	24.3
Number of usable beans	48.1	24.1	49.9
Number of usable beans per pod	2.78	1.84	33.8
Weight of usable beans (grams)	16.45	7.27	55.8
Weight per usable bean (grams)	0.342	0.301	12.0

Less disease developed in benomyl treated plots than in non-treated plots (Table 3). Plots receiving early and mid-bloom applications of either 1 pound or 1¾ pounds benomyl had significantly fewer diseased plants than non-treated plots. No significant differences existed between 1 pound and 1¾ pound rates of application. More disease occurred with only an early-bloom application than when plants received a mid-bloom or combination of early and mid-bloom sprays. Yield differences among treatments were similar to those for disease development although they were not significantly different. The quality of the beans in the plots was poor due to frost damage. The data suggest that although benomyl increased yields by reducing disease, the early frosts affected these beans more than non-treated beans.

Two airplane sprays were needed to provide disease control and yield benefit in the large field (Table 4). The early-bloom airplane spray alone was not effective. A single application by ground sprayer provided significant disease control and some yield increase.

Whetzelinia readily developed in individual Ouray plants, but its spread to adjacent plants was limited due to the upright nature of the variety. The disease spread readily through a row and

Table 3. Average Yield, Per Cent of Plants Diseased, and Per Cent Defects of Pinto Beans Treated with Benomyl to Control White Mold.[1]

Blossom Development When Benomyl Applied[2]	Rate Lb./100 g. Water	No. Appl.	Average Yield Cwt/A	Range Test[3]	Average Plants Diseased (%)	Range Test[3]	Average Defective Beans (%)	Range Test[3]
Early + Mid-bloom	1	2	26.80	n.s.	11.9	ab	25.8	n.s.
Mid-bloom	1	1	25.60	n.s.	37.0	abc	21.7	n.s.
Mid-bloom	1¾	1	24.97	n.s.	29.8	abc	21.7	n.s.
Early + Mid-bloom	1¾	2	24.88	n.s.	6.9	a	21.6	n.s.
Early-bloom	1¾	1	23.30	n.s.	36.0	abc	25.7	n.s.
Non-treated	—	—	21.55	n.s.	53.7	c	15.9	n.s.
Early-bloom	1	1	19.86	n.s.	61.5		19.8	n.s.

[1] *Readings are average of three replications.*
[2] *Benomyl applied July 12 early-bloom and July 26 mid-bloom.*
[3] *Level of significance is 95 out of 100; any two means followed by the same letter are not significantly different.*

from row-to-row of I 111. The variety, Ouray, did not perform well in other ways. The stems became brittle and broke near ground-level before maturity, and of equal importance was a Fusarium root and stem rot that killed many individual plants by July 23. The I 111 variety was not attacked by the **Fusarium** fungus.

Combined results of soil sampling for sclerotial content in two "hotspots" are presented in Table 5. Soil from the 0 to 2-inch depth yielded 18 sclerotia (Fig. 1) per pound of soil while the 2 to 4-inch depth gave eight sclerotia. Also, a greater share of the sclerotia from the 2 to 4-inch depth were small. Thirty-eight per cent of the sclerotia were isolated with a 2.38 mm sieve from the 0 to 2-inch depth soil, whereas 20 per cent were isolated from the 2 to 4-inch depth.

Analysis of 12 random sites in the 20-acre field revealed an average of 1.48 sclerotia per pound of soil at both the 0 to 2-inch and 2 to 4-inch depths.

Table 4. Average Yield and Per Cent of Plants Diseased of Pinto Beans Treated with Benomyl by Ground Spray and Airplane to Control White Mold.[1]

	Yield[2] Cwt/A	Range Test[3]	% Diseased Plants[2]	Range Test[3]
Airplane — Early bloom + Mid-bloom	22.12	n.s.	5.2	a
Ground sprayer — Early bloom	18.25	n.s.	6.1	ab
Non-treated	16.32	n.s.	30.8	c
Airplane — Early bloom	15.17	n.s.	34.0	c

[1] *Ground spray July 12, 1½ pounds benomyl in 100 gallons water per acre with 80 psi. Air spray July 13 and July 28 at 1½ pounds benomyl in 5 gallons water per acre plus 1 pint of spreader sticker per 100 gallons.*
[2] *Results are mean of four, 10 foot rows from predetermined sites in 20 acre field.*
[3] *Level of significance is 95 out of 100; any two means followed by the same letter are not significantly different.*

Discussion and Conclusions

White mold became important as a disease of beans after flowering began even though some seedlings were killed due to infection, undoubtedly from mycelium of germinating sclerotia. The occurrence of disease coincided with the appearance of apothecia. It is necessary to have saturated soil for sclerotia to absorb sufficient moisture to form apothecia (1). This explains why, in 1974, a year in which July was hot with infrequent rains, apothecia did not appear until August and were only numerous in low-lying areas of fields where sclerotia would become saturated. Mold may then develop differently in soils having different water holding capacities because of stringent water requirements for apothecial production.

Table 5. Average Number of Sclerotia Per Pound of Soil From Severely Molded Areas of Fields After Harvest.

	0 to 2 Inch Depth			2 to 4 Inch Depth		
	2.38 mm Sieve	0.85 mm Sieve	Total	2.38 mm Sieve	0.85 mm Sieve	Total
Average number of sclerotia per pound of soil	6.94	11.17	18.11	1.56	6.27	7.83
Per cent of total sclerotia	38.3	61.7		19.9	80.1	

Table 6. Yield Benefit of Pinto Beans Treated with Benomyl at Several Dates to Control White Mold.[1]

Blossom Development When 1¾ lb. Benomyl Applied	Application Date	Yield (cwt/A) 1-Appl.	2-Appl.	Non-Treated	Treatment Benefit (cwt/A)
Early	July 12	23.30	—	21.55	1.75
Mid	July 19	17.38	—	14.13	3.25
Mid	July 26	24.97	—	21.55	3.42
Late	August 10	15.94	—	14.13	1.81
Early + Mid	July 12 + July 26	—	24.88	21.55	3.33
Mid + Late	July 19 + August 10	—	19.37	14.13	5.24

[1] *Data are from spray plots of July 19 and August 10, 1973, and July 12 and July 26, 1974.*

The disease pressure was tremendous in the area of the field where the small plots were established. This probably influenced the benefit from benomyl and may have contributed to the variation within the treatments. Even so, the data supported the use of benomyl for mold control and were in general agreement with that reported in 1974 (8).

One application of benomyl gives control. A second application provides additional benefit. This is shown by the combined results obtained in 1973 and 1974, presented in Table 6. Applications made July 19 or July 26 (mid-bloom) gave about $3\frac{1}{3}$ cwt yield increase, while two applications were better, but not twice as good.

The 1974 data generally show that 1 pound of benomyl is equally as effective as $1\frac{3}{4}$ pounds whether applied once or twice. The best combination may be $1\frac{3}{4}$ pounds applied at early to mid-bloom and a second application of 1 pound at mid to late-bloom.

Employing the system of growth stage, blossom development and days after planting advanced by Lebaron (7), spray timing can be determined (Table 7). Based on the July 19 and July 26 spray dates it can be judged that the first application should be made about 45 days after planting. This is early to mid-bloom development and will be between July 4 and 21. The plants will have 8 to 10 nodes, the first blossoms may have sluffed, or there may be pods about one inch long at the first blossom position. The second application can be made 10 to 14 days later when the seeds are discernible in the pods. The first spray can be timed to go on at the last cultivation or shortly thereafter (Fig. 4). A ground sprayer can be used at this time. The second application usually requires the use of an airplane.

Table 7. Blossom and Plant Development of Pinto Beans as Related to Days After Planting and Approximate Dates in North Dakota.[1]

Blossom Development	Plant Description	Days After Planting[2]	Approximate Dates in North Dakota
Early	One blossom open at any node. Tendril begins to show.	40	July 1 - 15
Early	Pods ½ inch long at first blossom position. Eight to 10 nodes most plants. Blossom just sluffed.	43	July 4 - 18
Mid	Pods 1 inch long at first blossom position. Pods are showing at higher nodes when blossom sluffs. One-half bloom.	46	July 7 - 21
Mid	Pods 2 inches long at first blossom position.	50	July 11 - 25
Mid	Pods 3 plus inches long, seeds discernible by feel.	56	July 17 - 31
Late	Pods 4 to 5 inches long with spurs. Seeds at least ¼ inch in long axis.	60	July 21 - August 4

[1] *Information adapted from LeBaron (7).*
[2] *Normal date of planting is May 20 through June 5.*

Effects on yield reported here were averages of plants selected at random throughout the two fields. In some areas of the fields, plants were completely killed and yielded no beans. In others only limited effects were detected. The earlier an infection occurs, usually the more damaging is the disease. However, white mold will stop its growth in hot, dry weather. On the other hand, if the weather is warm and moisture falls periodically, mid-August infections become very damaging. This is one reason it is not reliable to spray for white mold according to weather data. The other is that the benomyl must be in the cast blossoms or injured plant organs before infection conditions are favorable. **Whetzelinia** requires a food source for energy before it causes an infection, and the cast blossoms or injured, dried plant tissue serve this need (1,3).

Cook et al. (3) showed that 75 per cent of the sclerotia recovered were viable after three years in soil. This suggests that the high population of sclerotia in the "hotspots" at the 0 to 2 and 2 to 4-inch soil depths, 18 and 8 sclerotia per pound of soil, respectively, makes these soils hazardous for many years for planting beans or other susceptible crops such as sunflowers.

The $1\frac{1}{2}$ sclerotia per pound of soil obtained at random in the field where 31 per cent of the plants (Table 1) contracted white mold agrees with results of Abawi and Grogan (1) who found 1.9 sclerotia per pound of soil in a 0 to 4-inch depth from non-plowed bean fields. This amount is sufficient to make the entire field risky for planting beans, at least within the next three years and probably longer. The risk, of course, coincides with moisture conditions that would saturate the sclerotia to generate apothecial production.

The cropping pattern for the 20-acre field presented in Table 2 contributed to the high level of sclerotia. The year 1972 was a "wet" year and white mold was obvious in the field (personal communication R. Heuchert). This moisture undoubtedly increased the numbers of sclerotia in the soil that initiated disease in 1974. On the other hand the 50-acre field which had 44 per cent diseased plants in 1974 (Table 1) was not planted to beans in 1972, and three years of grain or fallow separated the last two bean crops.

A search for satisfactory controls of the **Whetzelinia** disease should be implemented due to the facts that (1) sufficient sclerotia can be produced in a diseased bean field to render a rotation of less than three, and perhaps four years inadequate, (2) sunflowers is a susceptible crop of importance on many farms and has in some cases been grown in close sequence with dry beans, (3) some farmers, especially those growing sugarbeets, use 22-inch spaced planters for beans, (4) although benomyl has been found useful for preventing some of the **Whetzelinia** disease loss in dry beans, certain fungi, such as **Cercospora** attacking sugarbeets, have become tolerant to it, and (5) although it has been suggested, genetic resistance to **Whetzelinia** has not been found in commercial beans.

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