Evaluation of Ammonium Bicarbonate for Control of Soilborne Peanut Pathogens

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ABSTRACT

Ammonium bicarbonate was evaluated for efficacy against southern stem rot and Sclerotinia blight of peanut in Georgia and Virginia, respectively. *In vitro* studies indicated the material provided little inhibition of mycelial growth by *Sclerotinia minor* and *Sclerotium rolfsii*, and negligible inhibition of mycelial growth of *Rhizoctonia solani* AG-4. However, ammonium bicarbonate did effectively inhibit formation of sclerotia by *S. rolfsii in vitro*. In the field, it was phytotoxic when applied as a granule or as a foliar spray and in general was not effective in controlling disease or increasing pod yield.

Key Words: Ammonium bicarbonate, *Sclerotium rolfsii*, Sclerotinia blight, Southern Stem Rot, *Sclerotinia minor*, PCNB, iprodione.

Nitrogenous fertilizers have been known for many years to suppress diseases caused by *Sclerotium rolfsii* Sacc. on various hosts including larkspur (12), sugarbeets (11), and bentgrass on golf greens (15). A review by Aycock (2) summarizes the early literature on this subject. Similar effects on other soilborne pathogens including *Phytophthora* (17) and *Verticillium dahliae* Kleb. (6) have been reported also. Mechanisms involved include direct toxic effects on sclerotia or mycelium of the pathogen, altered host susceptibility, or changing the composition of microflora in soil around sclerotia (1, 8, 14).

Peanut is a legume and thus able to obtain nitrogen from its symbiotic relationship with *Rhizobium*. In fact, well nodulated peanut roots can fix more than 200 kg of nitrogen per hectare (18). Numerous nitrogen fertilization studies on peanut throughout the world have shown the benefits of added nitrogen to be questionable, particularly on the alternate branched or virginia types (4). Nitrogenous fertilizers have therefore not been a major component of most peanut production programs. Little is known concerning their potential effects on peanut diseases, but greenhouse studies by Hudgins (9) indicated that N fertilization may influence the severity of southern stem rot. Results obtained in limited field testing on peanut have ranged from promising (7) to ineffective (5).

Soilborne pathogens cause severe economic losses to peanut growers. In the Virginia-North Carolina production area, the most destructive peanut disease is Sclerotinia blight, caused by *Sclerotinia minor* (Jagger) Kohn. Losses to farm income of $8.6 million have been reported in Virginia alone; fungicides are the best means of control but are not completely effective and are quite expensive (3). In the southeastern states, southern stem rot caused by *S. rolfsii* has historically been the predominant soilborne peanut disease. *Rhizoctonia solani Kühn*, the casual agent of Rhizoctonia limb rot, is rapidly becoming a major concern as well. Losses in Georgia were estimated by extension service specialists to be approximately $44 million in 1988.

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Ammonium bicarbonate was one of the nitrogenous compounds found to be inhibitory both *in vitro* and *in vivo* to *S. rolfsii* from bentgrass (14, 15, 16). It will also kill sclerotia of *S. minor* in lettuce fields when applied through sprinkler irrigation systems (C. L. Patterson, unpublished data). In a legislative climate in which we see few pesticides being labeled for crops, and increased cancellations of registered products, the use of a nonpesticide alternative would be important in production agriculture. Thus, this study was initiated to investigate the potential for using ammonium bicarbonate to control soilborne peanut pathogens. The sensitivity of *S. rolfsii*, *S. minor*, and *R. solani* AG-4 from peanut to ammonium bicarbonate was determined *in vitro*. The chemical was also applied in field trials to evaluate effects on disease incidence and pod yield.

Materials and Methods

In vitro **sensitivity.** Isolates of all three fungi were obtained from naturally infected peanut plants. The isolate of *S. minor* was from peanut cv. Florigiant in Virginia and the *S. rolfsii* and *R. solani* were from peanut cv. Florunner in Georgia. Inoculum of *S. rolfsii* consisted of moistened ryegrass seeds in 250-mL flasks autoclaved at 121 C for 20 min on two consecutive days prior to inoculation with the fungus. Flasks were inoculated with plugs from actively growing colonies on potato dextrose agar and incubated for 1 week at 27 C prior to use. Both *S. minor* and *R. solani* were grown on PDA and 5-mm-dia. plugs from actively growing cultures used as inoculum.

The fungitoxicants evaluated were PCNB (pentachloronitrobenzene) and ammonium bicarbonate (NH_4HCO_3) at 0.1, 1.0, 10.0, and 100 mg/L. Ammonium bicarbonate was also tested at a concentration of 500 mg/L. Water agar (1.5%) was amended with appropriate concentrations of the fungitoxicants after being cooled to 45 C. After through mixing, medium was dispensed into 10-cm petri plates and allowed to solidify. PCNB granules were ground with a mortar and pestle before being added to the medium. Ten replications of each level of fungitoxicant were tested per isolate. Plates were inoculated in the center with either an *S. rolfsii* infested rye seed or an inverted 5-mm-dia. plug from a PDA culture of either *R. solani* or *S. minor*. Plates for each treatment were placed in polyethylene bags and incubated at 27 C in an unlighted incubator. Radial growth was recorded after 72 h. Plates were then placed on laboratory benches at ambient temperature. After 21 days, the numbers of sclerotia and sclerotial initials formed on each plate inoculated with *S. minor* or *S. rolfsii* were recorded.

Levels of inhibition were plotted as a function of fungicide concentration, and linear regressions used to determine the effects of fungitoxicant concentration on mycelial growth and sclerotial formation. Dosages providing 50% inhibition (ED_{50} values) were calculated for comparison of treatments.

Field Tests. Tests to evaluate ammonium bicarbonate were conducted in Virginia in 1987 and Georgia in 1987 and 1989. The test area in Georgia was a Tifton loamy sand (pH 5.9) infested with *S. rolfsii* and in continuous peanut cultivation since 1981. Florunner peanuts (134.4 kg/ha) were planted 7 May 1987 or 16 May 1989 with aldicarb (2-methyl-2-(methylthio) propionaldenhyde 0-(methylcarbamoyl) oxime) (0.84 kg/ha) applied in the furrow. Peanuts were dug and inverted 17 Sept. 1987 and 4 Oct. 1989, respectively, and combined approximately one week later. Other management practices were as recommended by the Georgia Cooperative Extension Service (10). Plots were arranged in randomized complete blocks with four replications. Each plot consisted of two rows, 7.6 m-long and 0.7-m, apart.

The treatments with ammonium bicarbonate included: 56 or 112 kg/ha applied 60 and 90 days after planting, and 28 kg/ha applied 30, 60, 90, and 120 days after planting, each in a band 30-cm wide and centered over the row. In 1989, the 28 and 56 kg/ha rates were also evaluated when applied as a foliar spray (544 L/ha). Sprays were delivered utilizing a CO_2-pressurized backpack sprayer (310 kPa) with a single 8015 nozzle centered

over each row. PCNB was applied as Terraclor 10G (5.6 kg a.i./ha) 60 days after seeding in a 15-cm band. Control plots were not treated with fungicides other than chlorothalonil (tetrachloroisophtalonitrile) which was used on all plots at 1.2 kg/ha to control foliar diseases.

The test area in Virginia was a Dragston fine sandy loam (pH 6.2) infested with *S. minor*. The field site was planted to corn in 1986 and peanut in 1985. Peanut (cv. Florigiant) was planted 3 May with aldicarb (1.17 kg/ha) applied in furrow. Other management practices were as recommended by the Virginia cooperative Extension Service. Plots were arranged in randomized complete blocks with four replications. Fungicides for control of Sclerotinia blight were applied to the two center rows of four-row plots, each spaced 0.9 m apart and 12.2 m long. Application was via a CO_2-pressurized backpack sprayer having a single 8008 LP nozzle centered over each row to deliver 335 L of spray per hectare at 152 kPa. The ammonium bicarbonate was applied at the same rates and schedule as described for the granular treatments at the Georgia location, but was sprayed in solution rather than applied as a granular. Iprodione (3-(3,5-dichlorophenyl)-N-(1-methylethyl)-2,4-dioxo-1-imidazolidinecarboxamide) was sprayed three times as Rovral 50W (1.12 kg a.i./ha) tank mixed with Nu-Film 17 (0.58 L/ha) and PCNB was applied twice as Terraclor 10G (5.61 kg a.i./ha) in a 35.6-cm band over the row. Terraclor was used as a reference standard in both tests since it has a label for control of all three genera of fungi.

Disease loci for stem rot were determined at digging. A disease locus consisted of a 1-30 cm section of row infected with *S. rolfsii*. Disease loci for Sclerotinia blight were assessed three times during the growing season, the last being just prior to digging. After plots were harvested, peanuts were dried, weighed, and yields determined. Data were analyzed by analysis of variance and Duncan's multiple range test (SAS Institute, Cary, NC).

Results

Laboratory Tests. The mycelial growth of *S. minor* was the most sensitive of the three fungi to both fungitoxicants followed by *S. rolfsii* and *R. solani* AG-4, respectively. ED_{50} values for PCNB were 0.89, 2.96, and 6.91 mg/mL and for ammonium bicarbonate were 29.6, 60.2, and 649.4 µg/mL, respectively for *S. minor*, *S. rolfsii* and *R. solani* (Table 1). The highest rates of PCNB and ammonium bicarbonate (100 and 500 µg/mL, respectively) were totally inhibitory to *S. minor*. However, they provided only about 98 and 60-69% inhibition of *S. rolfsii* and *R. solani*, respectively.

Higher rates of both chemicals were needed to suppress formation of sclerotia by *S. minor* than to inhibit mycelial growth. ED_{50} values for sclerotial formation were 3.07 and 47.43 µg/mL for PCNB and ammonium bicarbonate, respectively. No sclerotia formed at concentrations of 10 and 500 µg/mL of PCNB and ammonium bicarbonate, respectively.

With *S. rolfsii*, the development of sclerotial initials and mature sclerotia was affected by lower concentrations of both chemicals than was mycelial growth. ED_{50} values for inhibiting development of sclerotial initials and mature sclerotia were 0.26 and 0.51 µg/mL for PCNB, and 0.13 and 2.64 µg/mL for NH_4HCO_3, respectively (Table 1). No sclerotia formed at concentrations of 100 µg/mL PCNB or 500 mg/mL ammonium bicarbonate.

Field Tests. Treatments with either iprodione or PCNB resulted in about 40% suppression of Sclerotinia blight at harvest and yield was increased 671 and 547 kg/ha, respectively (Table 2). Of the ammonium bicarbonate treatments, only the highest rate resulted in a reduction of Sclerotinia blight incidence. However, this treatment was also phytotoxic to the degree that considerable defoliation occurred and pod yields were decreased by 535 kg/ha as compared to nontreated controls. The lower rates of ammonium bicarbonate did not significantly alter either disease incidence or pod yield and caused some flecking of leaves but no defoliation.

Table 1. *In vitro* sensitivity of *S. minor*, *S. rolfsii*, and *R. solani* AG-4 to PCNB and NH_4HCO_3.

	Linear Regression	Correlation Coefficient	ED_{50}
PCNB			
Mycelial Growth			
S. minor	Y = 31.80X + 51.60	0.89	0.89
S. rolfsii	Y = 37.50X + 32.30	0.91	2.96
R. solani	Y = 23.84X + 29.98	0.96	6.91
Prod. of sclerotia			
S. minor	Y = 39.40X + 30.80	0.89	3.07
S. rolfsii	Y = 17.00X + 60.00	0.79	0.26
Prod. of sclerotia initials			
S. rolfsii	Y = 22.50X + 56.50	0.83	0.51
NH_4HCO_3			
Mycelial Growth			
S. minor	Y = 15.83X - 26.72	0.67	29.55
S. rolfsii	Y = 35.99X - 14.03	0.93	60.16
R. solani AG-4	Y = 32.88X - 42.47	0.81	649.38
Prod. of sclerotia			
S. minor	Y = 61.03X - 52.29	0.94	47.43
S. rolfsii	Y = 10.33X + 59.09	0.68	0.13
Prod. of sclerotia initials			
S. rolfsii	Y = 11.59X + 45.11	0.62	2.64

Table 2. Effects of fungicides on Sclerotinia blight of peanut cv. Florigiant 1987.

Trt., rate/ha and application date(s)	Disease Incidence[1] 26 Aug	28 Sep	13 Oct	Yield[2] (kg/ha)	Value[3] ($/ha)
NH_4HCO_3, 28 kg (17 Jun, 15 Jul, 13 Aug, 9 Sep)	0.3	10.5 AB	25.8 AB	5013 BC	3417 B
NH_4HCO_3, 56 kg (15 Jul, 13 Aug)	0.3	10.5 AB	30.3 A	4777 C	3262 B
NH_4HCO_3, 112 kg (20 Jul, 13 Aug)	0.0	8.8 AB	13.3 C	4230 D	2807 C
Iprodione, 1.12 kg + Nu-Film 17 0.58 L (31 Jul, 28 Aug, 25 Sep)	0.0	6.3 B	18.3 BC	5436 A	3714 A
PCNB, 5.61 kg (9 Jul, 19 Aug)	0.5	10.3 AB	17.0 BC	5312 AB	3672 A
Nontreated	0.3	12.5 A	29.5 A	4765 C	3247 B

[1] Disease incidence represents counts of infection centers in the two center rows of each plot. An infection center was a point of active growth by Sclerotinia minor.

[2] Yields are based on dried weight of peanuts with moisture content of 7%.

[3] Value determined from a 500 g composite sample from each treatment in accordance with Federal-State Inspection Service methods. Means in column with letter(s) in common are not significantly different according to Duncan's multiple range test (P = 0.05), and columns without letters have no significant differences.

Field tests for activity against *S. rolfsii* in 1987 indicated that this pathogen could be suppressed by the highest rate of ammonium bicarbonate (Table 3). This treatment resulted in a significant (P=0.10) yield increase of 772 kg/ha as compared to the nontreated plots. Performance was essentially equivalent to PCNB with respect to disease control and yield. The lower rates of ammonium bicarbonate did not significantly alter either disease incidence or yield.

In the 1989 test, none of the treatments including PCNB had an effect on disease incidence or pod yield (Table 3). Phytotoxicity ratings taken on 21 Sep. demonstrated that ammonium bicarbonate can burn peanut foliage when applied as a foliar spray or banded as a granule. At equivalent rates, foliar sprays were the most damaging, however. Peanut vine damage by *R. solani* ranged from 14 to 19% with no significant treatment differences.

There was no apparent nutritional response to ammonium bicarbonate either as greening of foliage or altered root nodulation. Application of excessive nitrogen to peanut can

Table 3. Effects of fungicides on disease incidence and pod yields of peanut cv. Florunner infested with *Sclerotium rolfsii*, 1987 and 1989.

Trt., rate/ha	Application Timing and Method	1987		1989		
		S. rolfsii incidence[1]	Yield (kg/ha)	S. rolfsii incidence	Phytotoxicity[2]	Yield (kg/ha)
NH_4HCO_3, 28 kg	30, 60, 90, 120 DAP[3] (granule, 30 cm band)	16.5 AB	2959	19.0	1.9 B	3252
NH_4HCO_3, 56 kg	60, 90 DAP (granule, 30 cm band)	17.5 A	2923	18.3	1.8 B	3692
NH_4HCO_3, 112 kg	60, 90 DAP (granule, 30 cm band)	12.3 B	3639	16.8	1.6 B	3017
NH_4HCO_3, 28 kg	30, 60, 90, 120 DAP (544 L/ha spray)	-[4]	-	16.3	1.0 C	3307
NH_4HCO_3, 56 kg	60, 90 DAP (544 L/ha spray)	-	-	22.3	2.5 A	3166
PCNB, 5.6 kg	60 DAP (granule, 15 cm band)	14.3 AB	3707	18.0	0.0 D	3491
Nontreated		16.5 AB	2867	16.5	0.0 D	3683

[1] Incidence equals number of loci consisting of 1-30 cm section of row with plants infected by S. rolfsii. Means in columns followed by same letters are not significantly different according to Duncan's multiple range test, P = 0.05. Columns with no letters had no significant differences.

[2] 0-3 scale where 0 = no phytotoxicity, 1 = some foliar burn, 2 = substantial foliar burn with holes in leaves, and 3 = severe foliar burn with some defoliation.

[3] DAP = days after planting. Peanut cv. Florunner was planted 7 May, 1987 or 16 May, 1989.

[4] Treatment not included in 1987.

interfere with nodulation (18), but this was not observed in our tests.

Discussion

In vitro studies provide a measure of direct toxic effects and our results indicate that ammonium bicarbonate provides a low level of inhibition of mycelial growth with the three pathogens in this study. This may have been related to the pH of the water agar (about 6) since the hydrogen ion concentration of agar medium has been shown to dramatically effect the toxicity of salts (14). Higher pH's were found to enhance toxicity of both ammonium and bicarbonate salts to sclerotia of *S. rolfsii* (14). Formation of sclerotia was the parameter most sensitive to ammonium bicarbonate in this study. With continued use, this perhaps could be a benefit in terms of reducing inoculum potential and survival of the fungus, but such an effect would be evident only after a period of years.

Field tests provide a measure of direct as well as indirect effects of test materials on disease development. Unfortunately, ammonium bicarbonate did not show promise in field tests for control of either southern stem rot or Sclerotinia blight, and additional ratings in the 1989 study indicated no effect on Rhizoctonia limb rot caused by *Rhizoctonia solani* anastomosis group 4. The 1987 test in Georgia demonstrated that high rates of ammonium bicarbonate tended to increase yield and reduce southern stem rot, but this was not seen in 1989. There was a significant amount of tomato spotted wilt virus in the 1989 tests which made rating difficult and was a confounding factor for both disease control and yield.

On the basis of previous research (11, 12, 15, C. L. Patterson, unpublished data), ammonium bicarbonate should have potential for control of both *S. minor* and *S. rolfsii*. Changes in formulation and/or application strategy could result in increased efficacy. For example, more frequent applications or higher spray volumes may ensure better distribution in the soil and reduce phytotoxicity. As mentioned previously (14), the toxicity of ammonium bicarbonate increases with higher pH's. Peanut field soils generally are more acidic, and the soil pH in these studies was approximately 6. Although it would not be practical to appreciably alter the pH of the soil, it may be beneficial to raise the pH of the spray solution.

The fact that peanut is normally self-sufficient for nitrogen may help explain the lack of a positive response in this study. Although the applied nitrogen did not have visible adverse effects on root nodulation, it also did not provide a nutritional benefit to the plant as it might to a nonlegume. A recent review by Punja (13) indicates that nearly all reports concerning the use of nitrogen containing compounds for *S. rolfsii* control also describe visible enhancement of crop growth and vigor. Evidence is also cited that healthy, vigorous crops are more resistant to infection by *S. rolfsii*, but the report is noticeably lacking in examples of successful control of this pathogen with nitrogenous compounds on a legume crop (13).

Current chemical controls for soilborne peanut pathogens are expensive and often provide only partial control. Control alternatives must be found due to the removal of pesticides from the marketplace and difficulties obtaining registrations for new materials. In this regulatory environment, an economical "nonpesticide" such as ammonium bicarbonate would be a welcome addition to our peanut disease control recommendations. However, further work is needed to make ammonium bicarbonate a viable option for disease control use on peanuts.

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