Effect of Sodium Bicarbonate and Oils on the Control of Powdery Mildew and Black Spot of Roses

R. K. HORST, Professor, S. O. KAWAMOTO, Research Support Specialist, and L. L. PORTER, Research Assistant, Department of Plant Pathology, Cornell University, Ithaca, NY 14853

ABSTRACT

Horst, R. K., Kawamoto, S. O., and Porter, L. L. 1992. Effect of sodium bicarbonate and oils on the control of powdery mildew and black spot of roses. Plant Dis. 76:247-251.

Powdery mildew, caused by *Sphaerotheca pannosa* var. *rosae*, and black spot, caused by *Diplocarpon rosae*, were significantly controlled by weekly sprays of 0.063 M aqueous solution of sodium bicarbonate plus 1.0% (v/v) Sunspray ultrafine spray oil on *Rosa* spp. Control of powdery mildew was evaluated on cultivars Bridal Pink, Gold Rush, Lavande, Prive, Samantha, Sonia, and Royalty in greenhouse experiments, and control of black spot was evaluated on cultivars Mr. Lincoln and Pascale in field experiments. The chemicals were eradicative when applied individually or in combination; however, for powdery mildew control, treatment in combination was better ($P = 0.0002$). These results indicate that sodium bicarbonate and oil appear to be effective biocompatible fungicides for control of powdery mildew and black spot of roses. Differences in response to powdery mildew among the cultivars ranged from complete resistance in Gold Rush to high susceptibility in Samantha.

Powdery mildew, caused by *Sphaerotheca pannosa* (Wallr.:Fr.) Lév. var. *rosae* Woronichin, is the most widely distributed and destructive disease of greenhouse-grown *Rosa* spp. in the world. Powdery mildew and black spot, caused by *Diplocarpon rosae* F. A. Wolf, are the most serious diseases of nursery- and garden-grown *Rosa* spp. Fungicide applications at 7-day intervals are the only means of control. At Cornell University, annual control of powdery mildew in cut rose production research has required up to 17 applications (5) at an annual cost per square foot of 43 to 97¢, excluding labor. Because the 1987 market value of cut rose crops grown on 3.6 million square meters of production space in the United States exceeded $180 million (1,19), the annual cost of fungicides for control of powdery mildew on production roses easily exceeds $3.6 million, or about 2% of the wholesale market value. This value does not include nursery- and garden-grown roses.

Moreover, present ecological concerns about frequent fungicide application are serious and include worker safety and reentry, contamination of greenhouse drainage water, consumer exposure to fungicide residues, and effects on crop photosynthesis and yield. Thus, "biocompatible" fungicides, which we define to be fungicides that exhibit low mammalian and environmental toxicities, were particularly interesting to us for the control of powdery mildew and black spot. Although the term "biorational" has been used to describe these types of chemicals, this term has been used previously to describe biological control microorganisms, such as parasites and pathogens of insects and weeds (11). Legitimate candidates were bicarbonates and horticultural oils, which have individually been demonstrated to show control activity against specific pathogenic fungi. Punja and Grogan (17) found that carbonate and bicarbonate salts of ammonium, potassium, sodium, and lithium were fungicidal to *Sclerotium rolfsii* Sacc., and Homma et al (9) found sodium bicarbonate to be inhibitive to powdery mildew on cucumber. Film-forming polymers have been shown to be inhibitive to powdery mildew on rose and several other diseases caused by fungi (6,7,21). The objective of our investigation was to determine the effectiveness of bicarbonates and horticultural oils, singly and in combination, in controlling powdery mildew and black spot on rose.

MATERIALS AND METHODS

Seven cultivars of rose were used in the powdery mildew experiments, including Bridal Pink, Gold Rush, Lavande, Prive, Samantha, Sonia, and Royalty. All plants received the same fertilizer treatment following Cornell Recommendations for Commercial Floriculture

Accepted for publication 23 August 1991 (submitted for electronic processing).

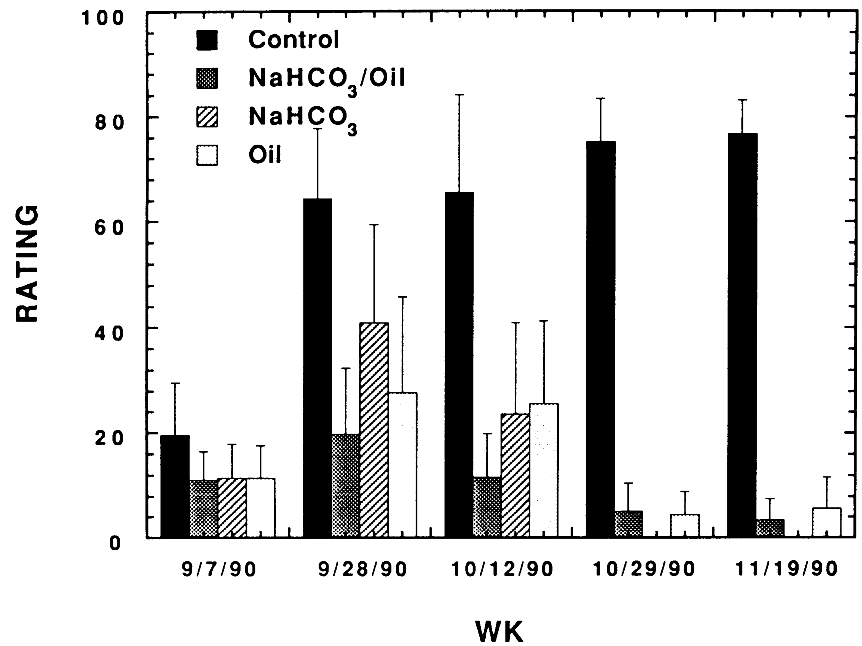

Fig. 1. Average combined disease severity ratings of powdery mildew on five rose cultivars (Bridal Pink, Lavande, Prive, Royalty, and Sonia) treated with $NaHCO_3$ and oil, alone and in combination. Lines on each bar represent standard deviations at each date.

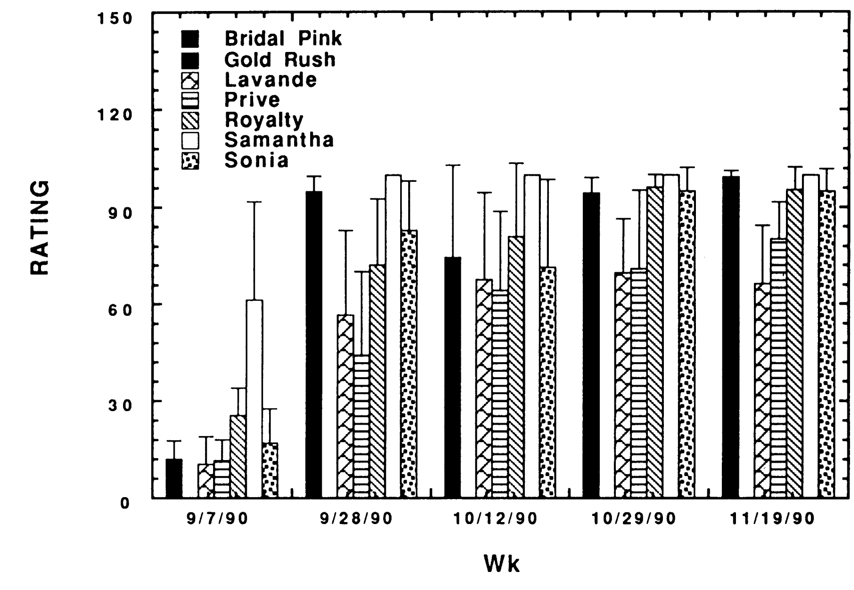

Fig. 2. Average disease severity ratings of powdery mildew on untreated rose cultivars Samantha, Bridal Pink, Sonia, Royalty, Lavande, Prive, and Gold Rush. Lines on each bar represent standard deviations at each date.

Table 1. Analysis of variance and planned orthogonal contrast analysis of $NaHCO_3$ and oil treatment effects, and treatment and cultivar interactions in severity of powdery mildew on rose cultivars Bridal Pink, Gold Rush, Lavande, Prive, Royalty, Samantha, and Sonia

Source	df	Sum of squares	Mean square	*F* value	*P* value
Treatment (T)[a]	3	44,003.62	14,667.87	130.13	0.0001
Cultivar (C)[a]	6	63,682.48	10,613.74	94.16	0.0001
T × C	18	3,585.11	199.17	1.76	0.10
$NaHCO_3$ vs. $NaHCO_3$/oil[b]	1	3,944.72	3,944.72	34.99	0.0002
Oil vs. $NaHCO_3$/oil[b]	1	1,955.80	1,955.80	17.35	0.0002
Error	24	2,705.21	112.71	...	...

[a] Analysis of variance using type III sum of squares of the SAS general linear procedure.
[b] Contrasts calculated using SAS general linear models procedure.

Crops (4). They were grown under glass and in a soil-based medium amended with perlite and peat moss. A randomized split-block design was used within each of four greenhouse concrete benches (19.8 × 1 m). Plants were spaced 30 cm on center. Each cultivar block contained 12 plants, and there were two blocks of each cultivar within each bench. An individual bench received one of the following four treatments: water, 0.063 M aqueous solution of sodium bicarbonate ($NaHCO_3$), 1.0% (v/v) Sunspray ultrafine spray oil, and 0.063 M $NaHCO_3$ plus 1% Sunspray ultrafine spray oil. Sprays were applied weekly between 13 September and 1 November 1990. Disease evaluations were made at approximately 14-day intervals beginning 7 September and ending 29 October 1990.

Another experiment was designed for the same greenhouse on two additional benches containing the cultivar Prive to compare 0.063 M $NaHCO_3$ plus 1.0% oil, 148 ml of propiconazole 14.3% EC (Banner) per 379 L of water, and water spray for their effectiveness in powdery mildew control during the same time period of the previously described experiment. Each treatment was applied weekly to two randomized split blocks containing 57 plants per block.

The disease rating system was modified from that described by Paulus and Nelson (15). Each plant was rated on a scale of 0–5 where 0 = no mildew lesions, 1 = 1–25, 2 = 26–50, 3 = 51–75, 4 = 76–90, and 5 = >90% total leaves per bush with lesions. Data were collected from 1,014 plants, and the means and standard deviations were calculated for each treatment and cultivar. Analyses were done by the general linear procedure of Statistical Analytical Systems, Cary, NC (18). Disease severity data were analyzed with a two-way analysis of variance (ANOVA) to identify main treatment effects and interactions. Planned orthogonal contrasts also were evaluated. Data were transformed into rating scale values as described by Little and Hills (13). These transformed rating scales were used to adjust treatment means and to ensure homogeneity of variance (8,12).

Cultivars Mr. Lincoln and Pascale were used in black spot experiments during the summers of 1988, 1989, and 1990 at Sonnenberg Gardens, Canandaigua, NY. Eighty-one plants of each cultivar were planted in separate ground beds. Treatments were as follows: no spray, 0.063 M $NaHCO_3$ plus 1.0% oil, 0.063 M $NaHCO_3$ plus 1.0% oil plus 0.6 ml of Tween 20 per 3.8 L of water, 1.0% oil, and 0.6 ml of Tween 20 per 3.8 L of water. Treatments were arranged in randomized blocks within each cultivar with two blocks of each treatment and one block with no treatment. Each block contained nine plants spaced 30 cm on center. The disease rating was the same as that used to evaluate powdery mildew.

RESULTS

Powdery mildew. Although treatments commenced 13 September 1990, the first disease evaluations were made 6 days earlier. It was obvious from data presented in Figure 1 that infection was established among plants before the initial spray applications. Disease ratings taken before treatment also provided a baseline for subsequent comparisons. There were no statistically significant differences among cultivars in disease ratings taken on 7 September 1990, except cultivar Gold Rush, which appeared to be totally resistant to *S. p. rosae* infections throughout the experiment (Fig. 2). The establishment of powdery mildew among roses included in this planting was anticipated because the existing environmental conditions in the greenhouse were especially conducive to powdery mildew epidemics (10,15,20), i.e., night/day temperatures and relative humidities were 16/27 C and 90–99%/40–70%, respectively. Disease ratings in the cultivar Samantha, sprayed with water only, reached 5 by 26 September and remained at that level for the duration of the experiment. Gold Rush had no visible mildew infections throughout the experiment. Because Samantha and Gold Rush represent the extremes in sensitivity to powdery mildew infections (Fig. 2), and because the standard deviations for the two cultivars skewed the evaluation of treatments in controlling the disease, mean differences and their standard deviations were evaluated on the remaining five cultivars, representing moderate to severe susceptibility to powdery mildew (Fig. 1). Highly significant ($P < 0.0001$) differences in treatment effects on disease severity were confirmed by ANOVA computations (Table 1). Planned orthogonal contrast computations to determine contrast differences revealed significant reductions in disease severity on plants treated with $NaHCO_3$ compared with $NaHCO_3$ plus oil ($P = 0.0002$) and on plants treated with $NaHCO_3$ plus oil compared with oil alone ($P = 0.0002$). The combination of $NaHCO_3$ plus oil significantly reduced powdery mildew incidence on all disease reading dates, and the amount of powdery mildew continued a linear reduction profile to the completion of the experiment (Fig. 3).

Oil alone significantly reduced infection on three out of the four reading dates; however, some variation was noted. For individual cultivars, $NaHCO_3$ and oil, alone and in combination, were effective in reducing infection from *S. p. rosae*, and this reduction was evident even on the highly susceptible cultivar Samantha (Fig. 3). Furthermore, $NaHCO_3$ plus oil was eradicative as shown by data presented in Figure 1 and by the disappearance of powdery mildew lesions from infected foliage as shown in Figure 4. Moreover, $NaHCO_3$ plus oil significantly reduced *S. p. rosae* infections on Prive on all reading dates in the experiment designed to compare its effectiveness with propiconazole (Fig. 5). Although propiconazole somewhat reduced disease severity, a significant reduction, as shown by mean standard deviation, was not found until the final readout date.

Differences among the untreated cultivars in their response to *S. p. rosae* are shown in Figure 2. As stated earlier, no powdery mildew lesions were found on Gold Rush during the 8-wk duration of

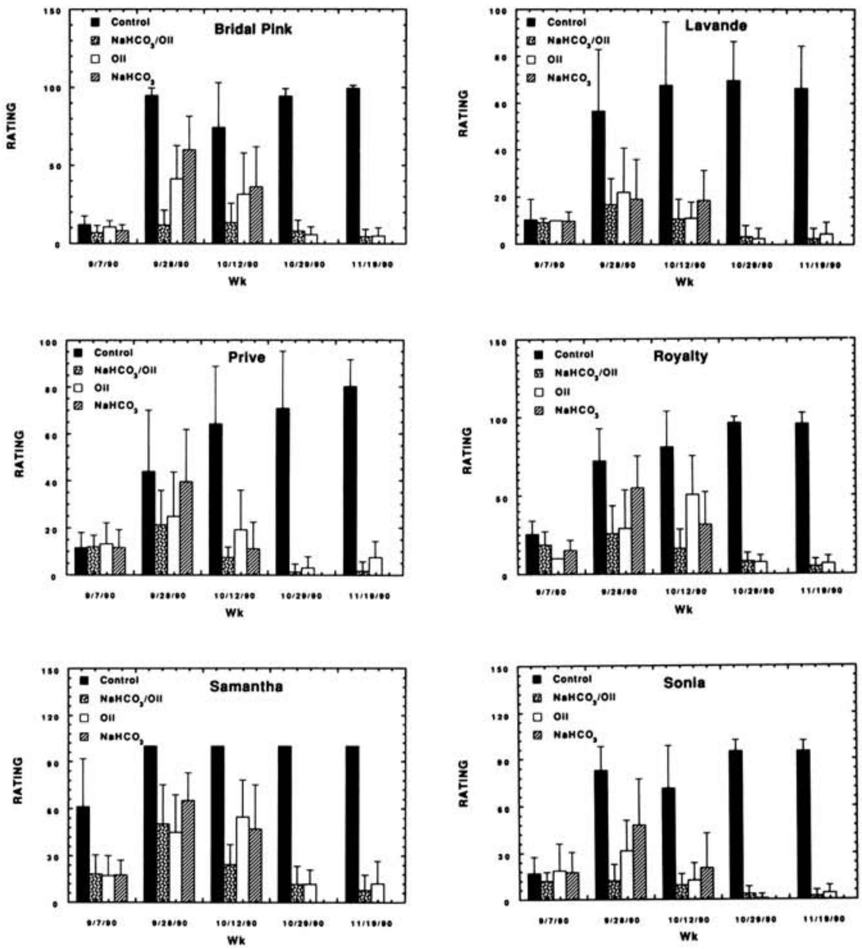

Fig. 3. Average disease severity ratings of powdery mildew on individual rose cultivars Bridal Pink, Lavande, Prive, Royalty, Samantha, and Sonia. Lines on each bar represent standard deviations at each date.

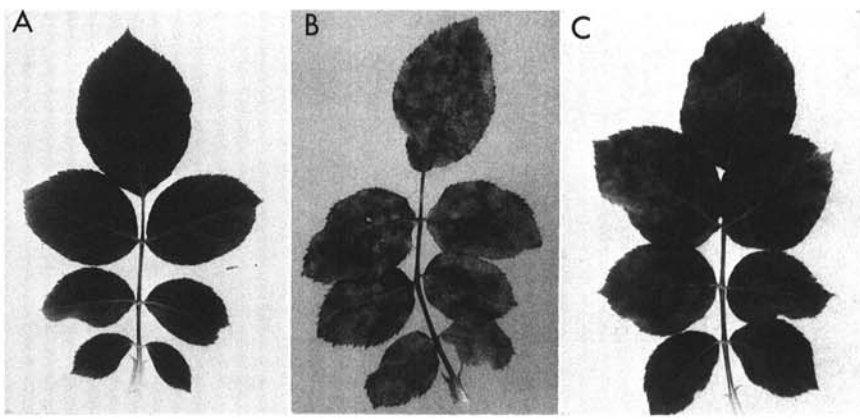

Fig. 4. Individual leaves of cultivar Samantha **(A)** treated with $NaHCO_3$ plus oil, which demonstrates protective properties on powdery mildew; **(B)** untreated with severe powdery mildew; and **(C)** treated with $NaHCO_3$ plus oil, which demonstrates the eradicative properties on powdery mildew.

the experiment, despite the high incidence of powdery mildew surrounding the randomly located blocks of Gold Rush throughout the greenhouse. Cultivar susceptibility could be arranged into four groups (Fig. 2) as follows: 1) Samantha—maximum disease ratings for entire experiment; 2) Sonia, Bridal Pink, and Royalty—moderate disease ratings during the initial 4 wk and near maximum disease ratings during the last 4 wk; 3) Prive and Lavande—moderate disease ratings during the 8-wk duration of the experiment; and 4) Gold Rush—0 disease ratings for entire experiment.

Black spot. Inoculum of *D. rosae* for this experiment was provided by severe black spot incidence in roses previously planted in the ground beds. Frequent rains during the summers provided the moisture required for natural infections. Applications of $NaHCO_3$ plus Tween 20 resulted in a reduction in disease severity for black spot during the summers of 1988, 1989, and 1990. Data for 1990 presented in Figure 6 showed that $NaHCO_3$ plus Tween 20 and $NaHCO_3$ plus Tween 20 plus oil reduced the incidence of black spot more than Tween 20 alone or Tween 20 plus oil. Mr. Lincoln was more susceptible to *D. rosae* than Pascale. A problem was encountered with spray runoff from rose foliage because of frequent rainfall.

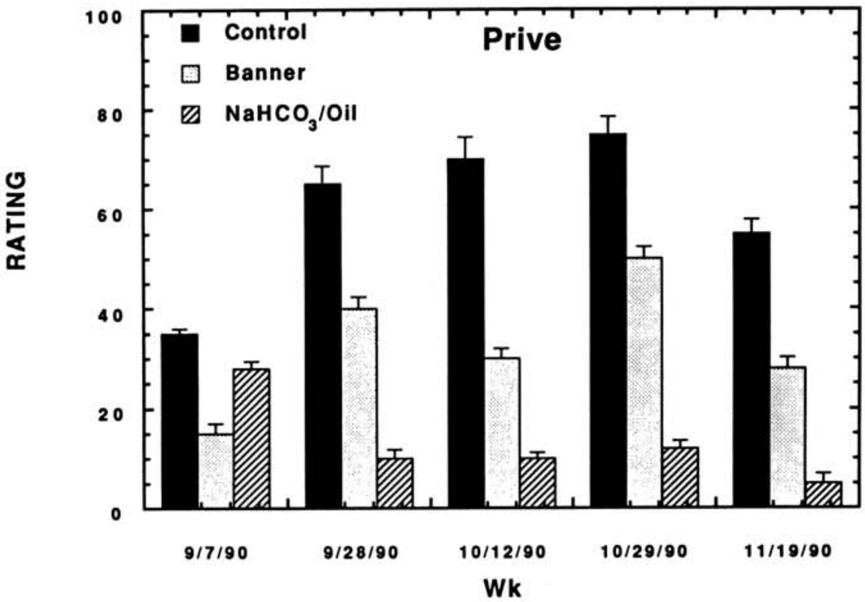

Fig. 5. Average disease severity ratings of powdery mildew on rose cultivar Prive treated with $NaHCO_3$ plus oil and with propiconazole. Lines on each bar represent standard deviations at each date.

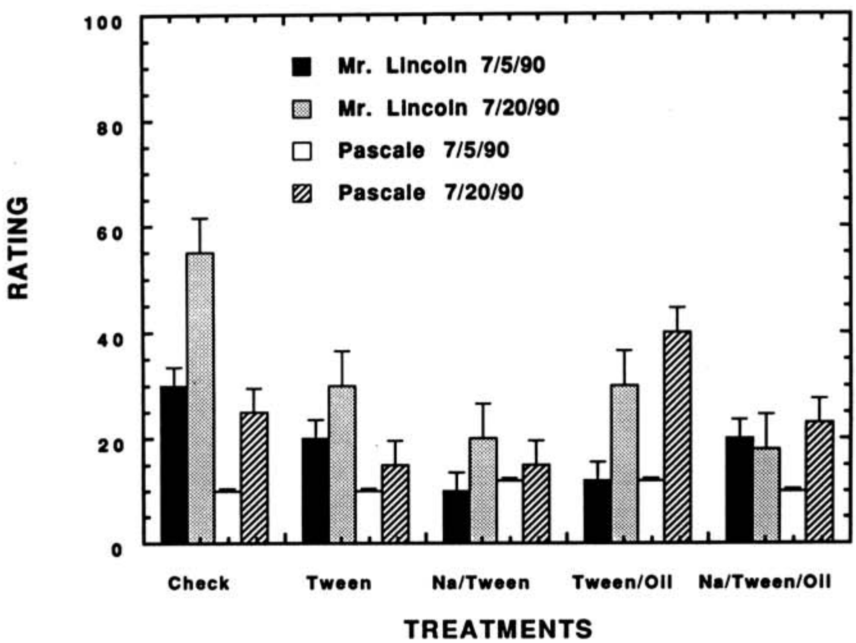

Fig. 6. Average black spot disease severity rating on rose cultivars Mr. Lincoln and Pascale treated with combinations of $NaHCO_3$ plus Tween, Tween plus oil, and $NaHCO_3$ plus Tween plus oil, and Tween alone.

DISCUSSION

$NaHCO_3$ and horticultural oils are effective biocompatible fungicides for control of powdery mildew and black spot on rose. Their effectiveness is quite good when applied singly but improved when used in combination. Their usefulness would be amplified if they were incorporated into production control programs in lieu of those fungicides that possess mammalian and environmental toxicity.

We postulate that the improved effectiveness of control with combinations of $NaHCO_3$ plus horticultural oils was attributable to fungicidal characteristics of bicarbonate ions (9,17), the fungicidal characteristics of oils (6,7,21), and spreader-sticker characteristics of oils that keep the bicarbonate ions on foliar surfaces. Hypotheses have been proposed for the inhibitory mechanisms for both bicarbonates and oils. Hydrogen ion concentration of bicarbonate salts has been shown to have a profound inhibitory influence on sclerotial germination of *S. rolfsii* (17) where pH 8.6 was fungicidal but pH 6.0 was not. Furthermore, Homma et al (9) found that $NaHCO_3$ inhibited conidial formation and germination. It is possible that the same fungicidal influence affected conidial germination of *S. p. rosae* in our investigations. Film-forming polymers may form a physical barrier on leaf surfaces against germ tube penetration by conidia of *S. p. rosae* (6,7,21).

Differences in susceptibility of rose cultivars to *S. p. rosae* were anticipated, but the spectrum of differences was not. The susceptibility of the cultivars affects the actual amount of control achieved by the $NaHCO_3$ and oil, although this effect diminishes with repeated applications of the chemical (Fig. 3). Because cultivar susceptibility could be arranged in groups and because the degree of susceptibility ranged from highly susceptible to completely resistant, a gene pool is available for developing resistant cultivars, and a cultivar pool is available for determining the mechanism(s) of resistance to powdery mildew. However, differences in cultivar susceptibility to *S. p. rosae* may be influenced by pathogenic variability of the pathogen as reported by Bender and Coyier (2,3).

Obviously, the mechanisms of fungicidal activity have not been conclusively established for bicarbonates and horticultural oils and is one of the objectives of further studies in our laboratory. Additional research is necessary to determine the minimal frequency of treatment, the effectiveness of other bicarbonate salts, and the effectiveness of other horticultural oils for control of powdery mildews. We know that the rates of $NaHCO_3$ and oil reported herein are critically important because our preliminary investigations reveal phytotoxicity to rose with rates >1.0% of both $NaHCO_3$ and oil. An important feature to recognize in frequency of treatment is that rose foliar tissues become more resistant to *S. p. rosae* infections as tissues age (14). Because flowers are continuously cut in cut rose production, young unsprayed foliar tissues are continuously available for infection.

ACKNOWLEDGMENTS

We thank De Vor Nurseries, Inc., Pleasanton, CA, and the Bear Creek Production Company (formerly Jackson and Perkins), Trustin, CA, for donating plants and Church and Dwight Co., Inc., Princeton, NJ, for financial support and supply of bicarbonates. We also thank Sun Refining and Marketing Co. for supplying Sunspray ultrafine spray oil, Ciba-Geigy Corporation for supplying Banner, H. W. Israel for invaluable advice and the suggestion of the term "biocompatible" to describe the chemicals used in these investigations, and both Sonnenberg Gardens, Canandaigua, NY, and Brigid Shipman and the members of Kenneth Post Laboratory, Department of Floriculture and Ornamental Horticulture, Cornell University, for invaluable help in these investigations.

LITERATURE CITED

1. Anonymous. 1989. Industry statistics from the USDA floriculture crops 1988 summary. Grower Talks 53(4):8-9.
2. Bender, C. L., and Coyier, D. L. 1984. Isolation and identification of races of *Sphaerotheca pannosa* var. *rosae*. Phytopathology 74:100-103.
3. Bender, C. L., and Coyier, D. L. 1986. Pathogenic variation in Oregon populations of *Sphaerotheca pannosa* var. *rosae*. Plant Dis. 70:383-385.
4. Cornell University. 1981. Cornell recommendations for commercial floriculture crops. Part I: Cultural practices and production programs. N.Y. State Coll. Agric. Life Sci. Cornell Univ.
5. Dreesen, D. R., and Walker, M. 1990. Investigations of environmental effects of pesticides and fertilizers used at Cornell University greenhouse facilities. N.Y. State Water Res. Inst. Cornell Univ.
6. Elad, Y., Ziv, O., Ayish, N., and Katan, J. 1989. The effect of film-forming polymers on powdery mildew of cucumber. Phytoparasitica 17:279-288.
7. Hagiladi, A., and Ziv, O. 1986. The use of antitranspirants for the control of powdery mildew of roses in the field. J. Environ. Hortic. 4:69-71.
8. Hills, F. J., Chiarappa, L., and Geng, S. 1980. Powdery mildew of sugar beet: Disease and crop loss assessment. Phytopathology 70:680-682.
9. Homma, Y., Arimoto, Y., and Misato, T. 1981. Effect of sodium bicarbonate on each growth stage of cucumber powdery mildew fungus (*Sphaerotheca fuliginea*) in its life cycle. J. Pestic. Sci. 6:201-209.
10. Horst, R. K. 1983. Compendium of Rose Diseases. American Phytopathological Society, St. Paul, MN. 50 pp.
11. Johnson, A. W., Young, J. R., Threadgill, E. D., Dowler, C. C., and Sumner, D. R. 1986. Chemigation for crop production management. Plant Dis. 70:998-1004.
12. Little, T. M. 1985. Analysis of percentage and rating scale data. HortScience 20:642-644.
13. Little, T. M., and Hills, F. J. 1978. Agricultural Experimentation: Design and Analysis. John Wiley & Sons, New York. 350 pp.
14. Nichols, L. P., and Nelson, P. E. 1987. Powdery mildew. Pages 289-296 in: Roses—A Manual on the Culture, Management, Diseases, and Insects of Greenhouse Roses. R. W. Langhans, ed. Roses, Inc., Haslett, MI.
15. Pady, S. M. 1972. Spore release in powdery mildews. Phytopathology 62:1099-1100.
16. Paulus, A. O., and Nelson, J. 1988. Controlling powdery mildew and rust in roses. Calif. Agric. 42:15.
17. Punja, Z. K., and Grogan, R. G. 1982. Effects of inorganic salts, carbonate-bicarbonate anions, ammonia, and the modifying influence of pH on sclerotial germination of *Sclerotium rolfsii*. Phytopathology 72:635-639.
18. SAS Institute, Inc. 1986. SAS for Linear Models: A Guide to the ANOVA and GLM Procedures. SAS Institute, Inc., Cary, NC. 231 pp.
19. U.S. Department of Commerce. 1989. 1987 Census of Agriculture. U.S. Dep. Commer., Washington DC.
20. Wheeler, B. E. J. 1978. Powdery mildew of ornamentals. Pages 411-455 in: The Powdery Mildews. D. M. Spencer, ed. Academic Press, London.
21. Ziv, O. 1983. Control of powdery mildew of roses with antitranspirant coating polymers. Hassadeh 53:1967-1969.