D. M. Webster, J. D. Atkin, and J. E. Cross
Asgrow Seed Company, Twin Falls, ID, and Kalamazoo, MI

Bacterial Blights of Snap Beans and Their Control

Bacterial blights are some of the most persistent disease problems facing producers of snap beans (*Phaseolus vulgaris* L.). Any of three pathovars of bacteria can cause blight: *Pseudomonas syringae* pv. *phaseolicola* (PSP) causes halo blight, *P. syringae* pv. *syringae* (PSS) causes bacterial brown spot, and *Xanthomonas campestris* pv. *phaseoli* (XCP) causes common blight. Even though these three bacteria differ somewhat in geographic adaptation and symptoms induced (Fig. 1), they overlap enough to require laboratory isolation for positive identification. Under epidemic conditions these diseases can reduce yield, but losses are usually expressed as reduction in quality owing to pod lesions, which are classified as major defects by federal grading standards. Only 1% "serious blemishes" are allowed for grade A cut beans. Beans are graded substandard when 4% is exceeded. Such crops are often not even harvested.

Before 1960, bacterial blights were considered relatively minor disease problems on snap beans in the United States. The first major epidemic of halo blight in recent times occurred less than 20 years ago, and a second epidemic occurred 10 years later. Throughout this period the occurrence of blight has been of persistent concern. A review of the conditions that led to the increased importance of bacterial blights may contribute to more effective control.

The Modern Snap Bean Industry

Genetic uniformity of cultivars. As a garden vegetable, snap beans are a relatively recent development, having undergone a dramatic evolution since beans were introduced to Europeans by Columbus in 1493. Native Americans harvested beans for the dry seed and had little use for the pods as a green vegetable. Consequently, pods of types they used retained such wild-type characteristics as high fiber content and stringy sutures. Europeans tended to use green pods as a vegetable and began selecting types with less fiber in the pod wall. This selection has continued until the relatively tender-podded snap bean varieties became distinct from types used as shell beans or for dry seed (dry beans). The pedigrees of all modern snap beans in use in the United States trace to crossbreeding with two stringless cultivars: Keeney's Stringless Refugee Wax and Improved Black Wax. They represent an early step toward genetic uniformity among snap bean cultivars.

The cultivar Tendercrop was officially released in 1958 and soon became the foundation for a new class of snap beans. Although the success of the cultivar itself was limited by undesirable seed color, other characteristics made a tremendous impact on the industry. The plant was erect and easy to harvest with machines, the pods were of high quality and easy to process, and the yield potential was excellent. Plant breeders had used Tendercrop before its official release to bring these useful characteristics into new cultivars. Pedigrees of many currently successful cultivars indicate 50–75% of their genetic background is from Tendercrop; some early developments still in use are simply white- or buff-seeded selections from Tendercrop. Unfortunately, Tendercrop is also highly susceptible to the bacteria that induce halo blight and bacterial brown spot, and many of the cultivars developed from crosses with it appear equally susceptible.

The western seed industry. Before the 1920s, bean seed crops were grown in the eastern United States under conditions of high relative humidity and frequent rainfall. In this environment, diseases caused by a number of seedborne pathogens of beans can be severe. Anthracnose, caused by *Colletotrichum lindemuthianum* (Sacc. & Magn.) Scrib., was the most serious (19). Bacterial blights were also important. In high-rainfall environments, the bacteria that induce blight are readily disseminated by

Fig. 1. Symptoms of bean bacterial blight diseases: (A) Pod lesions characteristic of bacterial brown spot. (B) Foliar symptoms of bacterial brown spot. (C) Foliar and pod symptoms of halo blight. (D) Foliar symptoms of common blight.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

splashing rain and may be moved over distances by man or his machines or in aerosols. Bacteria may overwinter in infected bean crop refuse. Also, perennial alternate hosts may become infected or infested and serve as reservoirs of inoculum. Kudzu (*Pueraria thunbergiana* Sieb. & Zucc.), which became widely established in the Southeast after its introduction as a ground cover, is a host for PSP (19). Hairy vetch (*Vicia villosa* Roth), a common perennial weed, can harbor PSS (8). Regardless of the source, once a bean crop becomes infected in a humid climate, the seed produced are likely to be infected and serve as a source of inoculum for succeeding crops.

During the 1920s, a bean seed industry began to develop on irrigated desert land in Washington, Oregon, California, and Idaho. The total rainfall for these areas during the months of June, July, and August averages 3.8 cm or less and the relative humidity remains low. The move to the arid West came because of reliable, sanitary seed production. With surface irrigation there is relatively little free moisture on plant foliage; infrequent periods of free moisture that do occur rarely exceed 24 hours. As a result, seed produced in the West is free from *C. lindemuthianum*, and crops produced in the East from this seed seldom develop anthracnose. Likewise, the incidence of bacterial blight was greatly reduced, and for a period of over 30 years "western-grown seed" was considered the final answer to seedborne blight diseases (13). This system of seed production was so successful that some experts recommended infected seed lots be used as stock seed in the West to produce shipping lots for growers in the East. The assumption was that one more generation in the desert would eliminate the infection.

Snap bean production. As a commercial vegetable crop, snap beans are still grown mainly in high-rainfall areas. Before 1954, snap beans were hand-harvested from many small, isolated fields. The mechanical bean harvester, introduced in the middle 1950s, eliminated this system of snap bean production. Mechanical harvest was more efficient than hand harvest, but the equipment was expensive and could not be justified for small acreages. Growers who specialized in bean production began to produce a larger share of the total crop. These individuals realized maximum profit by increasing acreage; they tended to monocrop more often than smaller growers and they planted their beans in large, uniform blocks.

Bacterial Blight in the 1960s and Control Programs

From 1962 through 1967 the system for production of disease-free seed in the arid West appeared to have failed. Unfavorable weather was blamed for the relatively high incidence of halo blight in seed-producing areas during these years. Total rainfall, however, for June, July, and August in the bean seed-producing areas of Idaho was 1.3 cm below average in 1962 and only 4.3 cm above average during the wettest of these years. More likely, the high disease incidence resulted from a combination of genetic vulnerability, carelessness in introducing contaminated or infected seed, and enough wind and rain to spread bacteria over a wide area.

State of Idaho regulations. The high incidence of blight during those years led to a reevaluation of control programs. The state of Idaho, which produces approximately 80% of the snap bean seed produced in the United States, led the way in protecting this industry and in 1965 adopted the following rules:

1. Any seed imported into Idaho from west of the continental divide in the contiguous United States must have a clean phytosanitary history for three generations and must be found free from pathogens in laboratory tests administered by the Idaho Department of Agriculture. Seed with less than a 3-year phytosanitary history may be planted only with prior approval of the director of the Idaho Department of Agriculture.

2. Seed imported from east of the continental divide or from a foreign country must be grown on a state-approved trial ground of less than 2 acres per variety. If more than 1 lb of seed is to be planted, the seed lot must also pass an Idaho Department of Agriculture test for presence of bacterial pathogens.

3. Fields used to produce seed to be replanted in the state are inspected at least once during the growing season and once when the plants have been cut and raked into windrows before threshing. The advantage of windrow inspection is that the foliage is gone from the plants and pod infection is most visible at this time (Fig. 2). Seed fields for replanting that are grown under sprinkler irrigation are inspected twice during the growing season, and state-approved trial grounds are inspected four times during the growing season.

4. Idaho-produced seed must have been grown and inspected for two consecutive generations under surface irrigation before it can be reproduced under sprinkler irrigation in Idaho, if the seed crop is to be replanted in Idaho.

Further, the state enforces a zero tolerance for bacterial diseases found during the growing season and is authorized to destroy any crop in which blight is found at this stage. The state is also authorized to burn an area of 15 m around any infected area found during windrow inspection. Seed harvested from the remainder of a partially destroyed crop may not be replanted in Idaho.

In order to minimize the risk of losing a valuable bean seed crop, growers have organized insurance pools that, for a minimal cost, will return up to $300 an acre for a crop, or part of a crop, that is destroyed by the state. The availability of this coverage makes enforcement of regulations possible.

These regulations cover all classes of beans planted in Idaho except certain dry bean classes that have a degree of genetic resistance to the blight bacteria most often encountered in Idaho.

Voluntary programs adopted by seed companies. Certain seed companies involved in production of snap bean seed have adopted programs for blight control that go beyond the state regulations. Asgrow's approach has been one of recognition and prevention and applies to all western states where we produce seed. Emphasis has been on stock seed lots, which are to be planted for producing either additional stock seed or shipping lots that will be sold to producers of snap beans. This emphasis is justified in that one 5-ha field of a stock seed crop could be multiplied over two generations to well over 1.5 million kg of seed for shipment.

Our program begins with field personnel trained to recognize symptoms of bacterial blight. Both stock seed fields and shipping lot fields are inspected for genetic purity and symptoms of blight during the growing season. All fields are specifically inspected for bacterial blight after the plants have been cut and raked into windrows.

Seed production methods are designed to minimize the introduction of pathogenic bacteria into fields or seed lots. All personnel either disinfect their boots with a hypochlorite solution or change clothes between fields. Stock seed is never produced under sprinkler irrigation, and production of commercial seed for shipment under sprinkler irrigation is minimized. Infected areas found during windrow inspections are burned, but we are obliged to harvest any remaining seed. Pathogenic bacteria are generally present in culls from those crops, so they are milled last to minimize contamination of clean seed lots. The seed from fields with windrow infections is disposed of as dry edible beans. Finally, after being milled and tested, all stock seed is treated with streptomycin to reduce the level of possible surface contamination. All seed for shipment is also treated, unless it is to be sold in areas where streptomycin treatment is prohibited.

Detection of pathogenic bacteria in stock seed lots. An important step in the stock seed program is a test for seedborne pathogenic bacteria. Most seed testing procedures currently used by various state authorities involve samples of 2 or 3 kg of milled seed or less. This sample size may be adequate if the goal is to avoid disease incidence that is yield-limiting or harmful to the quality of the vegetable product. For seed production, larger samples must be tested because levels of primary infection actually encountered in the West are generally fewer than one infected plant per hectare. Also, testing gravity-culled seed (culls) from the mill line is preferable because the most severely infected seeds are shriveled or lightweight compared with normal, healthy seed.

The test procedure begins with collection of a 25-kg random sample(s) of culls as a lot is milled (Fig. 3A). The number of samples collected for a stock seed lot is determined by the size of the lot, with more samples for the larger lots. Each sample is placed in a plastic garbage bin and covered with water at 20 C. This "bean soup" is aerated (Fig. 3B), and after soak periods of 3 and 6 hours, liquid from the bin is sprayed onto seedlings of a highly susceptible Tendercrop-class cultivar (Fig. 3C). The young seedlings are wounded with sand from a modified paint sprayer just before this treatment. Eight pots of seedlings are used for each sample of culls. After 10 days' incubation under conditions favorable for symptom expression, the seedlings are inspected for blight (Fig. 3D).

The sensitivity of this procedure was tested on known infected seed diluted with culls that were apparently free from blight-causing bacteria. The infected seeds were quartered and mixed so as to average the seed-to-seed variation in the lower dilutions. The results indicate we are generally able to detect infection in mixtures of four quarters of infected seeds in 25 kg of culls for both PSS and PSP (Table 1). In these experiments, more lesions were usually observed from the 3-hour sample than from the 6-hour sample. This decline may indicate activity of antagonistic microorganisms, since pathogenic bacteria multiply rapidly in the "bean soup" after it has been autoclaved. The bacteria would not have reproduced to any extent after 3 hours, so infection on indicator plants is from bacterial cells originally in or on infected seed. When whole seeds were used, lesion counts were reduced to about 50% of that expected had the seeds been quartered. In routine tests, the procedure should reliably detect two to four severely infected seeds in a 25-kg sample.

Table 1. Sensitivity of soak test for *Pseudomonas syringae* pv. *syringae* (PSS) and *P. syringae* pv. *phaseolicola* (PSP)[a]

Bacterium	Number of infected seeds[b]	Total number of lesions on four pots of seedlings: 3-hr incubation	6-hr incubation
PSS	8	52	20
	4	38	7
	2	18	8
	1	10	7
	0	0	0
PSP	8	133	142
	8*[c]	25	34
	4	26	15
	4*	8	0
	2	1	0
	1	3	3
	0	0	0

[a] Severely infected seeds were added to 25 kg of uninfected culls, and liquid from the soak bin was sprayed onto indicator seedlings after incubation for 3 and 6 hours.
[b] Seeds were quartered and mixed to give effective number of infected seeds.
[c] * = Whole seeds were used.

Table 2. Results of 1977 field inspections and soak tests on seed culls and milled seed from infected or contaminated seed lots

Lot no.	Windrow inspection	Tests on seed culls[a]	Tests on milled seed
1	P[b]	1P	8P
2	P	1P	8P
3	P	1P	8P
4–21	P	P	...[c]
22	N	1P, 1N	...
23	N	3P, 1N	16N
24	N	2P	5P, 3N
25	N	1P, 1N	8N

[a] Samples from lots positive in windrow inspection and harvested after 15-m area around visibly infected portions of field had been burned.
[b] P = positive and N = negative for pathogenic bacteria.
[c] Not tested.

Success of control programs. State and seed industry programs had positive effects on control of bacterial pathogens. In 1965, the first year state regulations became effective, beans in 2,289 ha were found to be infected. By 1968, the number had declined to zero, and in 1969, a year favorable for disease, beans in only 15 ha, all tracing to the same 1967 seed lot, were found to be infected (1). The incidence of blight remained very low through 1976, and success during this period may have fostered complacency about the seriousness of bacterial blight.

The Need for Continued Caution

June of 1977 had below-normal precipitation, and the outlook for blight control appeared favorable. July and August had slightly above-average precipitation, which fell mostly as local thundershowers, but the season progressed well within the expected range of variation for weather. On 19 August, symptoms of halo blight were found in a planting of kidney beans. The planting, which was destroyed, was part of an area of infection occurring downwind of a field of improperly introduced beans later found to be infected. The actual origin of the epidemic that followed remains unproven, and more than one source may have been involved. During the latter part of August and September, one seed field after another was found to be infected and had to be plowed under. Many more were burned after the plants had been cut and raked into windrows. By the end of the season, over 500 ha of beans, with an estimated yield of 1 million kg of seed, had been destroyed by the state in an effort to stop the spread of disease. The seed from an additional 280 ha was not eligible for in-state planting. Of the total acreage destroyed, 90 ha, or 140,000 kg of seed, were grown for Asgrow. Based on 1977 soak tests, an additional 250,000 kg of seed were discarded from our inventory.

There was ample opportunity for evaluating the effectiveness of the soak test in 1977. The only bright spot that year was that the test proved to be very reliable (Table 2). Twenty-one lots were harvested from fields that had been partially destroyed to eliminate infection found during windrow inspection. Seed culls from all 21 gave positive test results. Eight 25-kg samples of milled seed from three of these lots were tested, and all 24 tests gave positive results. Four lots that had passed windrow inspection gave positive test results on culls, but for three of these lots, at least one test on culls was negative and 24 tests on milled seed were negative. The fourth lot, for which both cull tests had been positive, gave five positive and three negative tests on milled seed.

Results of 1977 indicate that windrow inspection is extremely useful but is not foolproof and is less sensitive than the soak test for detecting blight bacteria. Even the worst infections in the arid West are normally confined to scattered areas of a few plants, and the low numbers of diseased plants are missed when infection is light. Also, tests on milled seed are less likely to detect bacteria than tests on culls. But even the test on culls is not foolproof; if three infected lots gave one negative test, there undoubtedly have been some infected and/or contaminated lots that gave no positive test, especially when disease incidence was low.

In the summer of 1978, the incidence of blight in Idaho was sporadic and much reduced. A total of 65 ha of beans were either destroyed or rejected for in-state planting certificates. The dry weather that year was partly responsible for reduced infection, but efforts to control disease in 1977 also may have contributed. Perhaps the most positive aspect of 1978 was that the incidence of halo blight in the vegetable-producing areas of the East was not greatly above normal, indicating much better control than in the earlier epidemic. Although 1979 was again a year of sporadic thunderstorms and hail, the incidence of disease was negligible then and has remained so since.

At present it appears that state and voluntary control programs are useful and well worth the cost, but the incidence of disease in 1977 indicates the programs do not completely eliminate the problem. As a seed producer, Asgrow can do a good job of delivering sanitary seed, but it is impossible to be certain of complete freedom from blight bacteria. There is no guaranteed freedom from "blight years" in our seed production areas.

Fig. 2. After plants have been cut and raked into windrows (left), dried pods are inspected for symptoms of bacterial blight.

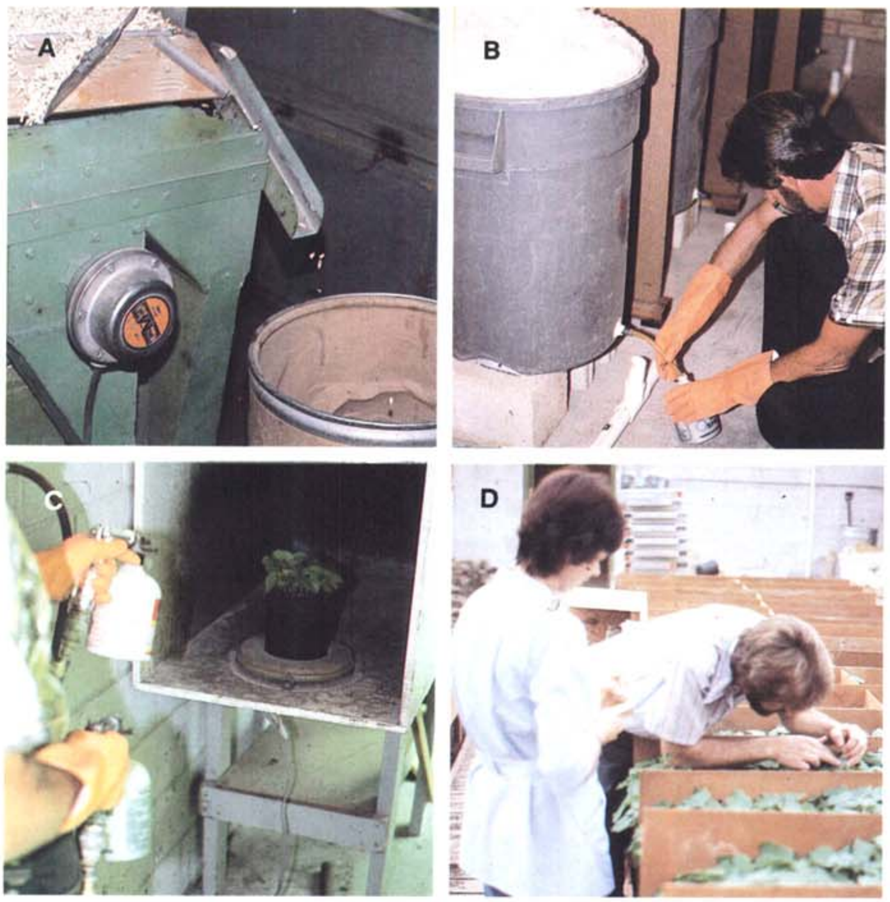

Fig. 3. Soak test for detecting seedborne bacterial blight pathogens: (A) Gravity separation of culls from normal seeds. (B) Collecting liquid sample from "bean soup." (C) Applying liquid to bean seedlings. (D) Inspecting seedlings for symptoms of bacterial blight.

Unanswered Questions

How do we account for the 30 years of relative freedom from blight before 1960? Undoubtedly part of the reason is because there was no systematic search for it as there is today in seed and commercial snap bean fields. Variations in weather contributed to recent outbreaks but cannot be solely responsible; rainfall was normal or below normal in several severe blight years and high in other years when no blight was recorded.

The increased use of sprinkler irrigation may be a contributing factor to recent outbreaks. Sprinkler systems are more efficient than surface irrigation in using labor and water resources and also help reduce soil erosion. Acreage under sprinkler irrigation has been expanding, often at the expense of land that is surface-irrigated, and it has become impossible to produce all the bean seed required without using fields that are sprinkler-irrigated. Unfortunately, one prominent negative feature of sprinkler irrigation systems is that they help spread foliar pathogens (9).

We may not be dealing with absolute elimination of the pathogen even in years when no blight is detected. Stock seed should be absolutely free from pathogenic bacteria, but such freedom may be rare (J. R. Venette, *personal communication*). Commercial shipping lots probably have a level below which seedborne infection becomes unimportant, or at least insignificant when compared with endemic or other local sources (16). Preventive measures greatly reduce the likelihood of infection in shipping lots, and we believe that careful windrow inspections will detect levels of disease severe enough to cause losses in snap bean production areas.

One aspect of seed transmission of bacteria that needs consideration is seed contamination as opposed to seed infection. Surface contamination of seeds by infected plant dust can lead to seedling infection for all three bacterial blight pathogens (9,18). Under natural conditions in the arid West, Guthrie (10) demonstrated that dilution of infected plant dust during normal thrashing operations would greatly reduce the probability of infection. His tests were on small samples of seed, however, and do not exclude contamination as a factor. If a serious problem, contamination would be difficult to control once introduced, as there is no way to sterilize an entire thrashing machine or mill line.

Our soak test should detect seed contamination, but we do not know to what degree of sensitivity. Likewise, the levels or variations in levels of contamination that occur naturally under field conditions in the arid West are unknown, as are the levels necessary for seedling infection. In Michigan (18), at least 10^3 viable bacteria per seed were necessary for seedling infection of a susceptible navy bean cultivar by XCP, and the levels of contamination varied considerably even within the same lot. Probabilities are involved in detection, and it may be that lower levels of contamination would be detectable in samples larger than the 400- to 800-seed samples observed. In experiments on infection of snap beans by PSP, a level that would give one infected plant in 10,000–16,000 was the limit for susceptible cultivars grown in conditions favorable for disease; above this limit, pod lesions in the vegetable crop could reach an unacceptable level (16). Whether the lower limit for one bacterial pathogen applies to others or how different levels of resistance affect threshholds is not known. Indications are that infection by bacteria in dust contamination is less likely to occur in moderately resistant cultivars (10).

Seed treatment with bactericides such as streptomycin reduces infection resulting from contamination but does not eliminate bacteria from natural openings or cracks in the seed coat (9). Because primary inoculum is a very important factor in the arid West, seed treatment would be of more use there than in areas where environment is more favorable for spread of secondary inoculum (11,15,16).

The soak test for detection of pathogenic bacteria on stock seed has proved its value on many occasions, but it is not perfect. We have presented examples where only one of two samples gave a positive test, and undoubtedly some contaminated or lightly infected lots give no positive results. One problem with the test is that the numbers of active bacteria often decline during the course of incubation. The sensitivity would be improved if the antagonistic factor were neutralized so that pathogenic bacteria could increase in number during the course of incubation before inoculation of indicator plants.

Improved Resistance as Part of the Answer

One important approach to improved control is the development of resistant cultivars. According to recent estimates, about 50% of snap bean cultivars currently grown in the United States are in the Tendercrop class (4), and cultivars in this group are generally very susceptible to bacterial blights. Furthermore, many cultivars in the important Blue Lake class have a high percentage of Tendercrop in their genetic background and are also very susceptible. These cultivars were selected for the desirable horticultural characteristics of Tendercrop and have become successful because of these characteristics.

Still, among all classes of snap bean cultivars there is substantial variation in susceptibility. Within the Blue Lake class are successful cultivars that appear to have a useful level of resistance. European cultivars, although generally small-podded, are usually less susceptible.

The genetic variation should be exploited, but there have been barriers to even consideration of the use of resistance. One argument is that cultivars with resistance would still harbor bacteria and therefore act as "Typhoid Marys." Bacterial infection in these cultivars would be undetected and they could serve as sources of bacteria for more susceptible cultivars. The biggest problem with this argument is that most of the beans grown in the arid West are dry bean cultivars that already are relatively resistant to the most common bacterial pathogen in that area, PSP. Therefore, development of resistance in snap beans would have relatively little effect on this inoculum source.

Moderately resistant bean cultivars may sustain populations of pathogenic bacteria approaching those of the more susceptible cultivars (3,5,7). These populations do not necessarily result in seed infection, however. In Michigan, seed infection of moderately resistant cultivars by XCP was detected only when plants were inoculated after pods had formed, not when plants were inoculated at flowering or earlier (2). In Nebraska, no seed infection was detected for moderately resistant cultivars even when pods were inoculated directly (6). In the arid West, moderately resistant cultivars in the Blue Lake class of snap beans have been grown for years, through the worst of the blight epidemic, with no visible infection and no evidence of seed contamination or infection in the soak test.

If resistance is part of the final answer, information on level of resistance necessary for effective control is badly needed. Resistance level varies widely even in commercially acceptable cultivars, but greater emphasis on this characteristic often comes at the expense of other characteristics critical for the success of a cultivar. The highest levels of resistance occur infrequently in a breeding program and are usually in horticulturally unacceptable genotypes. The objective becomes more complex for several reasons: Resistance against one species of bacterial pathogen may not be effective against another, virulence of pathogens differs (14,17), and reaction of different plant parts may vary (12,17). It seems likely, however, that intermediate resistance to several bacterial pathogens would be adequate to ensure reliable production of sanitary seed in the arid West, where conditions are generally unfavorable for disease.

The value of resistance is often not recognized in vegetable production areas. Growers in areas where diseases are endemic tend to treat all cultivars the same in their bactericidal spray programs. Also, horticultural characteristics are given more consideration by growers and processors than resistance is, especially if disease has not been severe for a few years. Again, information is needed on efficacy of different levels of resistance in controlling disease, alone and in combination with bactericide applications.

The Future?

Future success in control of bacterial blight will depend on a thorough understanding of the problem and conscientious application of control strategies. We need to know the influence of levels of resistance on seed transmission, disease incidence, and effectiveness of spray programs. Seed transmission is recognized as one source of primary infection, but the extent and relative importance of endemic inoculum from infection or epiphytic infestation of alternate hosts also must be assessed. Growers need to realize the importance of crop rotation to degrade infected refuse and the inherent danger in large open plantings of uniformly susceptible varieties. The extent and importance of contamination, as opposed to infection, in seed transmission of pathogenic bacteria need careful study.

Even with current limitations, a practical level of control is possible, given the combined concern and attention of all the parties involved in snap bean production.

Literature Cited

1. Butcher, C. L., Dean, L. L., and Guthrie, J. W. 1971. Halo blight incidence in Idaho bean seed crops during 1969. Plant Dis. Rep. 55:54-55.
2. Cafati, C. R., and Saettler, A. W. 1980. Transmission of *Xanthomonas phaseoli* in seed of resistant and susceptible *Phaseolus* genotypes. Phytopathology 70:638-640.
3. Cafati, C. R., and Saettler, A. W. 1980. Effect of host on multiplication and distribution of bean common blight bacteria. Phytopathology 70:675-679.
4. Committee on Genetic Vulnerability of Major Crops, National Research Council. 1972. Genetic Vulnerability of Major Crops. National Academy of Sciences, Washington, DC. 307 pp.
5. Coyne, D. P., and Schuster, M. L. 1973. Genetic control of reaction to common blight bacterium in bean (*Phaseolus vulgaris*) as influenced by plant age and bacterial multiplication. J. Am. Soc. Hortic. Sci. 98:94-99.
6. Coyne, D. P., Schuster, M. L., and Magnuson, S. 1976. Effect of tolerant and susceptible dry bean germplasm on seed transmission of *Xanthomonas phaseoli*. Annu. Rep. Bean Improv. Coop. 19:20.
7. Daub, M. E., and Hagedorn, D. J. 1981. Epiphytic populations of *Pseudomonas syringae* on susceptible and resistant bean lines. Phytopathology 71:547-550.
8. Ercolani, G. L., Hagedorn, D. J., Kelman, A., and Rand, R. E. 1974. Epiphytic survival of *Pseudomonas syringae* on hairy vetch in relation to epidemiology of bacterial brown spot of bean in Wisconsin. Phytopathology 64:1330-1337.
9. Grogan, R. G., and Kimble, K. A. 1967. The role of seed contamination in the transmission of *Pseudomonas phaseolicola* in *Phaseolus vulgaris*. Phytopathology 57:28-31.
10. Guthrie, J. W. 1970. Factors influencing halo blight transmission from externally contaminated *Phaseolus* seed. Phytopathology 60:371-372.
11. Hagedorn, D. J. 1967. Streptomycin seed treatment for the control of bean halo blight. Plant Dis. Rep. 51:544-548.
12. Hill, K., Coyne, D. P., and Schuster, M. L. 1972. Leaf, pod, and systemic chlorosis reactions in *Phaseolus vulgaris* to halo blight control by different genes. J. Am. Soc. Hortic. Sci. 97:494-498.
13. Natti, J. J. 1967. Fighting halo blight of beans. Pages 20-23 in: Libby's Contract Crops.
14. Patel, P. N., and Walker, J. C. 1965. Resistance in *Phaseolus* to halo blight. Phytopathology 55:889-894.
15. Taylor, J. D., and Dudley, C. L. 1977. Seed treatment for the control of halo blight of beans (*Pseudomonas phaseolicola*). Ann. Appl. Biol. 85:223-232.
16. Taylor, J. D., Phelps, K., and Dudley, C. L. 1979. Epidemiology and strategy for the control of halo blight of beans. Ann. Appl. Biol. 93:167-172.
17. Valladeres-Sanchez, N. E., Coyne, D. P., and Schuster, M. L. 1979. Differential reaction of leaves and pods of *Phaseolus* germplasm to strains of *Xanthomonas phaseoli* and transgressive segregation for tolerance from crosses of susceptible germplasm. J. Am. Soc. Hortic. Sci. 104:648-654.
18. Weller, D. M., and Saettler, A. W. 1980. Evaluation of seed-borne *Xanthomonas phaseoli* and *X. phaseoli* var. *fuscans* as primary inocula in bean blights. Phytopathology 70:148-152.
19. Zaumeyer, W. J., and Thomas, H. R. 1957. A monographic study of bean diseases and methods for their control. U.S. Dep. Agric. Tech. Bull. 868. 255 pp.

D. M. Webster

Dr. Webster has been a research plant scientist with Asgrow Seed Company in Twin Falls, Idaho, since 1978, the year he received his Ph.D. from the University of Wisconsin, Madison. His research responsibilities include cultivar development and control of seedborne pathogens of beans and peas. Special research interests are the use and incorporation of resistance for disease control.

J. D. Atkin

Dr. Atkin is Worldwide Pea and Bean Project Leader and manager of Asgrow Seed Company's Western Breeding Station. He obtained a B.S. degree from Utah State University and M.S. and Ph.D. degrees from the University of California at Davis. He served as assistant, then associate professor at New York Agricultural Experiment Station, Geneva, New York, from 1953 to 1964. He was director of research for Keystone Seed Company from 1964 to 1970 and has been with Asgrow since 1970.

J. E. Cross

Dr. Cross is manager of Vegetable Technical Services for Asgrow Seed Company in Kalamazoo, Michigan. He received a Ph.D. degree in plant pathology from the University of Minnesota in 1965 and joined Asgrow Seed Company in 1966. He worked as a vegetable breeder in California, then became manager of Quality Assurance before assuming his current responsibilities.