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Prescribed Resistant Cultivars for Controlling Brown Stem Rot of Soybean and Managing Resistance Genes

BSR 301 is the first soybean cultivar with the resistance of PI 84.946-2 to brown stem rot (BSR). BSR 301 was and BSR 302 will be available for commercial production in Iowa in 1981 and 1982, respectively. These cultivars are prescribed for fields where 75% of the plants had BSR in any recent year. Why are the BSR-resistant soybeans being prescribed? Among the major considerations for using the term "prescribed" are to: 1) develop effective control methods for BSR, 2) diversify the genetic background of our major crops, and 3) introduce a practical method for managing resistance genes.

Symptoms and Signs of BSR

Allington and Chamberlain (2) first reported the BSR disease and named the pathogen *Cephalosporium gregatum* in 1948. In 1971, Gams (7) reclassified *C. gregatum* and named it *Phialophora gregata* (Allington & Chamberlain) W. Gams. Since BSR was reported, there have been many studies of the pathogen and of the disease incidence and losses it causes. Abel (1) provides a review of the brown stem rot literature.

Browning of the pith tissue is the principal identifying symptom of BSR (Fig. 1), and vascular tissues also are discolored. Because other pathogens can cause vascular tissue discoloration, uniform and continuous browning of the pith, particularly in the lower part of the stem, verifies the cause of the disease. Chlorosis and necrosis of interveinal tissues of leaves occur with BSR, but these symptoms also can be caused by other problems. Plants with BSR mature earlier than those without the disease, by as much as 10 days when BSR is severe (Fig. 2). Because prematurity is readily associated with other factors, it usually is not attributed to BSR. Yields are reduced significantly under optimum disease conditions, ie, adequate moisture for normal plant growth early and moisture deficiency late in the season.

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Recommendations and Controls

Allington and Chamberlain (2) recommended crop rotation to control BSR, based on field observations of disease occurrence in Illinois. BSR was found in fields where soybeans were grown frequently but not in fields where soybeans were rotated with other crops. A 4-year rotation with corn was subsequently recommended on the basis of experiments in Iowa. Corn grown for up to 5 years between soybean crops gave complete control of the disease (6).

Chamberlain and Bernard (5) first reported resistance to *P. gregata* in 1968 after many years of studying and working to develop the inheritance of resistance. How resistance is inherited remains unknown. In 1975, I reported on the problems involved in developing BSR-resistant soybeans (13).

Early in the 1970s, it was recommended that BSR-resistant soybeans then under development be released for commercial production because they outyielded commonly grown susceptible soybeans on infested land. The BSR-resistant soybeans were not released for numerous reasons. One reason was that data showing superior yield with the resistant cultivars generally were not obtained. Thus, the cooperative program between the U.S. Department of Agriculture and the Iowa Experiment Station subsequently emphasized extensive yield testing in infested land as well as further breeding and screening for resistance.

Examples of the BSR disease and yield findings for this period are data obtained at four locations in Iowa: west-central (Bagley), central (Huxley), south-central (Otley), and southeastern (Bloomfield) (Fig. 3). In combined demonstration and yield tests, growers were given seeds of resistant soybeans to alternately strip-plant side by side with their standard commercial BSR-susceptible soybeans. Although different resistant lines and commercial cultivars were tested and compared, each test pair was of comparable maturity. Brown stem rot occurred in all fields as expected, with the exception of those at Bagley, where disease severity was much lower than expected; this was thought to be the result of flooding. BSR-resistant soybeans had about half as much stem browning as susceptible soybeans at all locations, including Bagley.

Yields were higher with resistant than with susceptible soybeans at Huxley, Otley, and Bloomfield (Fig. 3); the susceptible soybean had higher yield at Bagley, where BSR was considerably less severe than at the other locations.

Even though rotation and resistant soybeans were known to be effective, the recommendations were neither adequate nor practical for BSR control or release of resistant soybeans. Changes and further research were necessary.

Current BSR Research

The current BSR project in Iowa continues to emphasize screening by yield-testing of resistant soybeans on infested land throughout the state. BSR 301 was released after it was shown to have a highly significant yield advantage in infested fields (14,16). BSR 301 and BSR 302 yielded more than susceptible current (Williams) and new (Oakland and Cumberland) cultivars of soybeans over wide areas in the southern sections of the state (Fig. 4) but still did not have a yield advantage in regional uniform tests. The resistant soybeans yielded one or two bushels below the highest-yielding BSR-susceptible soybeans. These differences, however, were not statistically significant. The BSR-resistant soybeans therefore were approved for release with the stipulation they be recommended specifically for BSR-problem fields.

Ten years ago it was my opinion that BSR-resistant soybeans were needed specifically for BSR-problem fields, not for general use over wide areas. I conducted an intensive BSR survey over limited areas in southeastern Iowa and identified fields with BSR for the purpose of possibly prescribing BSR-resistant soybeans and for obtaining further information on the need for BSR resistance. In a sense, the surveys were disappointing because practically all the fields I surveyed had BSR; thus, arguments for prescribing a resistant cultivar for the areas were inconsistent with the data of that time. However, the data confirmed earlier statewide surveys indicating a high disease incidence in southeastern Iowa. Data from other districts subsequently indicated the need for resistant soybeans in specific fields (13). BSR occurred in soybeans from 95% of the fields surveyed in northern Iowa in 1977, and more than 80% of the plants were infected in about 22% of the fields. BSR-resistant soybeans are prescribed for such fields if and when adapted resistant cultivars are developed.

Prescribing Resistant Cultivars

BSR 301 and BSR 302 soybean cultivars are prescribed for areas where maturity group III soybeans are adapted and for fields where more than 75% of plants have been infected in a recent year. Economic losses have been significant only when a high percentage of plants is infected (15). Because the pathogen is a soil invader and recent evidence indicates continued increase or spread of the pathogen, the problem is not expected to abate until some major change in cultural practice is introduced.

Fig. 1. (Left) Soybean stem infected with brown stem rot, with pith browning and, at lower section, vascular tissue discoloration. (Right) Healthy stem.

BSR-resistant soybeans are named for easy identification for intended use. BSR stands for brown stem resistance, 3 for maturity group III, and 01 for first of a series. BSR 302, the second resistant soybean for maturity group III, is more resistant than BSR 301 and has higher yield. Also, it is resistant to bacterial pustule caused by *Xanthomonas campestris* pv. *phaseoli* (Smith) Dye (syn. *X. phaseoli* (E.F. Smith) Dowson var. *sojensis* (Hedges) Starr and Burkholder).

Incidence of BSR can be determined by the soybean grower or crop production specialist for prescribing principally on the basis of the pith browning symptom. Although this symptom can be identified anytime late in the season, especially in September, traversing large acreages of the crop is difficult then. The stubble method is a simple way to examine a large field. After soybeans are harvested and before any tillage is performed, one can walk, run, or ride over large areas of fields to determine BSR incidence by examining cut ends of stubbles and determining the percentage of stubble with browning of the cut end. The cut end of a healthy stem is white. In my experience, fields with significant economic yield loss have few white stems, and I have not encountered any other disease that causes stem browning in a majority of the plants in a field. My group has effectively used the stubble method for many years to determine BSR incidence in a screening and testing field.

Fig. 2. (Left) Soybean cultivar susceptible to brown stem rot (Calland) matured 10 days earlier than (right) resistant cultivar (AP68-1016). Without brown stem rot, the cultivars mature at the same time.

Using PRC for Other Diseases

The prescribed resistant cultivars (PRC) method for BSR-resistant soybeans and disease control can be used for other plant diseases with control difficulties similar to those of BSR. For example, the current soybean cyst nematode (SCN) problem in Iowa and other areas can be controlled expediently by the PRC method. Although there is no current SCN-resistant cultivar for the area, usable resistant lines have been shown among breeders' populations (17). Unfortunately, these lines remain unreleased because they ranked low in yield in the regional tests. Breeders will continue efforts to improve the yield; in the meantime, the cyst nematode spreads unchallenged in the state and region.

The Iowa BSR program faced essentially the same problem 10 years ago. Useful BSR-resistant lines were identified in 1970, but it was not until 1981 that an agronomically improved and acceptable soybean could be made available after a concerted cooperative effort by scientists and support groups that emphasized research and development to meet the need. In the meantime, the BSR pathogen spread and in 1977 was found in 95% of the fields in northern Iowa.

Implementing the PRC concept and using soybeans shown to be superior on infested land could provide an effective and efficient control method for SCN. Hartwig (8) reported on breeding for resistance to SCN for the southern United States and provides additional evidence for plant disease problems resulting from unmanaged use of resistance.

The PRC method introduces and uses specific germ plasms and cultivars precisely, efficiently, and responsibly. The method should prevent, in some measure at least, plant disease cycles that result in feast and famine from crop and genetic uniformity. Much is known today of the consequences of genetic uniformity, and I think it irresponsible for scientists not to provide specific alternatives so that farmers also can change the ways of the past with new methods.

Management of Resistance Genes

Generally, the goal for developing new varieties and the principal criterion for releasing and producing them are superior yields over many locations and years. This practice is incompatible with the PRC concept. Other particular properties, such as disease resistance, may or may not be given equal importance, depending on the disease and the nature of resistance. For example, the wide use of specific resistance to Phytophthora rot of

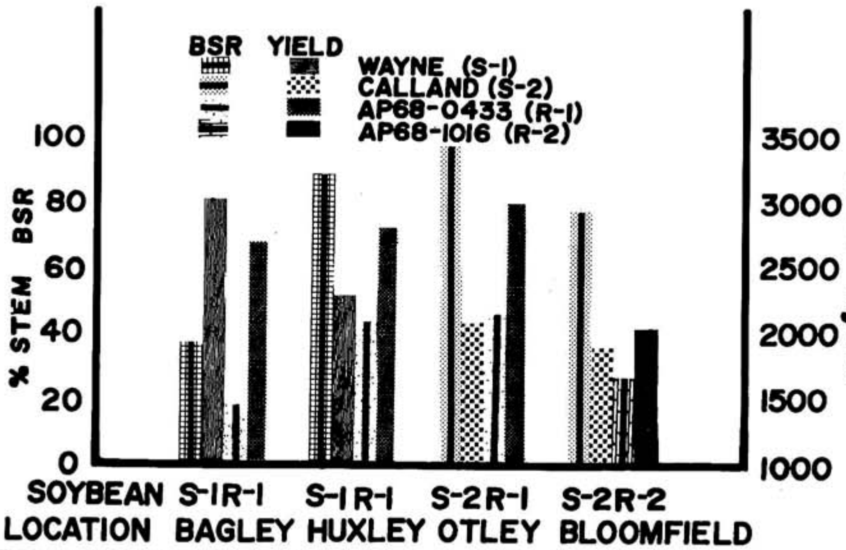

Fig. 3. Extent of stem browning with brown stem rot (BSR) and yield of susceptible and resistant soybeans at four locations in Iowa in 1973.

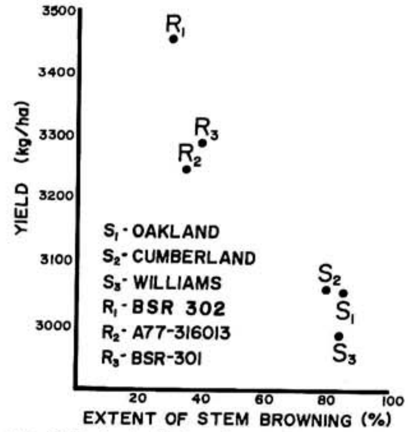

Fig. 4. Extent of stem browning and yield of susceptible and resistant soybeans in infested land in Iowa in 1978 and 1979.

soybeans in Iowa, where the disease is not as serious as in neighboring states, makes the crop more rather than less genetically uniform. In contrast, acceptance of BSR resistance has been slow considering that BSR is a widespread and serious disease problem. These contrasting and illogical practices for developing, releasing, and using resistance result in the production of superior and genetically uniform varieties over wide areas and create greater genetic uniformity. At the other extreme, some scientists think that improved resistance rather than improved quality or productivity should be the primary objective in breeding new varieties for pest resistance (11).

In addition to the philosophy of breeding primarily for higher yields or for disease resistance or other properties, there are proponents for using mixtures for diversity. Simmonds (12) reviewed the use of mixtures or blends, and others have utilized mixtures for various purposes and reasons. Notable among these is the development of different rust-resistant isogenic lines of small grains and their deployment as blends or multilines to control rust diseases. Although the multiline method for rust control in a particular field has been clearly demonstrated to be effective, the method has greater potential for control of the disease on a broader scope, such as along the so-called *Puccinia* path (4). For this to be effective, a system to manage the use of different resistance genes in multilines seems necessary. A recent example where such a system could have prevented a major plant disease epiphytotic is blue mold of tobacco; the pathogen seems to have spread from Cuba to Canada via the tobacco-producing states along the eastern seaboard of the United States (9,10).

Controlling plant diseases through the use of resistance is complicated. Knowledge gained from specific pest problems alone seems inadequate. Research, education, and organizations of broader scope are needed, something akin to the National Plant Health System proposed in 1977 by Browning to the United States Congress when he was invited to provide a field plant pathologist's view of IPM (3). Browning stated: "The cause of southern corn leaf blight (SCLB) in 1970 is commonly considered to have been *Helminthosporium maydis* race T, but this is not true. SCLB is a man-made disease; the real cause was excessive homogeneity of the nation's corn crop." And one of Browning's goals for remedy is indicated by the following: "The impetus for IPM (Integrated Pest Management) has been, primarily, to reduce pesticide usage through superior pest management and thereby protect the environment. This is a worthy goal for an IPM program but it is too narrow for the proposed National Plant Health System."

What Browning proposed may not be the only system to manage pests, pesticides, hosts, etc., but it is the only holistic scheme to provide resistance host gene management that I have seen. The PRC method is practical for BSR resistance gene management and disease control but inadequate for management of resistance against airborne and continental pathogens. Browning and others recognized this years ago.

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