

## Resistance

### Resistance of Selected Potato Cultivars and Clones to Fusarium Dry Rot

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#### ABSTRACT

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A total of 13 white potato cultivars plus 247 breeding clones from the USDA Potato Breeding Program were screened for resistance to *Fusarium roseum* 'Sambucinum' from 1973 through 1977. Varying degrees of resistance were observed and one clone, B7200-33, appeared immune. In 1978, 30 clones from the USDA Breeding Program and 93 entries from

Sangerville Farm, Maine Department of Agriculture, were screened for resistance to *F. roseum* 'Sambucinum' and *F. solani* 'Coeruleum'; only B7200-33 was highly resistant to both *Fusarium* species. No correlation was found between amount of sprout growth and *Fusarium* resistance.

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*Fusarium* tuber rot of potato (caused by several *Fusarium* spp.) is one of the most economically important diseases of stored potatoes (9). The major species of the fusaria inducing this disease are: *F. roseum* Lk. ex. Fr. 'Avenaceum,' *F. roseum* 'Sambucinum,' and *F. solani* (Mart.) Appel. et Wr. 'Coeruleum' (3,4,24) of which *F. roseum* 'Sambucinum' and *F. solani* 'Coeruleum' are the most destructive. Exclusive of late blight (*Phytophthora infestans* (Mont.) deBy.), *Fusarium* spp. are the most important causes of tuber decay (6). Although rots caused by *Fusarium* seldom reach epidemic proportions, they are present wherever potatoes are grown and cause losses in the field, in storage, and in transit (2,4,9).

Losses from these rots can be held to a minimum by use of chemical control with thiabendazole, which is applied to the tubers at harvest or at preplanting (19). With the increasing pressure from society to reduce the use of pesticides, an appropriate area to be

studied for control of these rots is resistance. Many workers have searched, with varying degrees of success, for a source of resistance in potatoes (1,3,5,13-15,17,18,20,22,28,29). One of the major obstacles in studying resistance has been the lack of a reliable tuber inoculation method. Numerous inoculation methods, ranging from the use of a modified hypodermic needle to the use of three nails protruding through a board, have been devised and used by various workers (4,6-8,17,28,29).

The study of tuber reaction to inoculation with the pathogen generally determines the biochemical resistance only, and does not take into consideration wound type or rate of wound healing and how these factors may affect the pathogens. Wellving (28) studied the relationship between resistance and wounding and found that potato clones, when injured mechanically, had wide genotypical differences in ability to resist ingress and invasion by a parasite. This finding indicated that a study of both wound resistance and biochemical resistance to the pathogens should be included when studying resistance of the potato to *Fusarium* tuber rot.

In most potato resistance studies, only one *Fusarium* species has

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been used. Those potato cultivars listed as resistant are often found to be susceptible when tested with the other *Fusarium* species found in most potato soils (1,17,18,24). However, Ayers (3) studied cultivar resistance to the two most important tuber-rot-causing fusaria in Prince Edward Island, Canada—*F. solani* 'Coeruleum' and *F. roseum* 'Sambucinum.'

A review of the literature indicated that the majority of research concerning resistance to *Fusarium* in potatoes has been conducted in Europe. Stevenson (26) reported the new potato cultivars released from 1932–1947, and he did not mention resistance to *Fusarium*. Neither did Libby and Akeley (21) in their report on the cultivar testing and release program in Maine. In North America a majority of *Fusarium*-resistant cultivars have originated in Canada. Most of the cultivars reported to have *Fusarium* resistance are resistant to only one species (12,16,23,25,27). The cultivar Hunter is highly resistant to *F. roseum* 'Sambucinum,' but is highly susceptible to *F. solani* 'Coeruleum' (12); the same is true for the cultivar Belleisle (27). The release notice of cultivar Tobique stated that it is resistant to both *F. roseum* 'Sambucinum' and *F. solani* 'Coeruleum' (11).

The objectives of the work reported here were to determine whether any of the commonly grown potato cultivars are resistant to *Fusarium* and whether genes for resistance are present in clones from the USDA Potato Breeding Program.

## MATERIALS AND METHODS

In all testing before 1978, the test potatoes were supplied from the USDA Potato Breeding Program. In 1978, 93 entries in the potato project at Sangerville, Maine, and 30 clones from the USDA Potato Breeding Program were tested for resistance.

All testing was delayed until late November or early December to provide for the natural resistance observed in most potatoes at harvest (7). From 1974 to 1978, the test organism used was *F. roseum* 'Sambucinum.' *Fusarium solani* 'Coeruleum' was added in 1977.

Inocula of *Fusarium* spp. were prepared from 7-day-old cultures grown on potato-dextrose agar (PDA) in petri plates at 24 C. Conidia were washed from petri plates with glass-distilled water, passed through four layers of cheesecloth to remove mycelium, and

TABLE 1. Disease index of cultivars and clones of potato tubers inoculated at apical and stem ends with *Fusarium roseum* 'Sambucinum,' 1973–1974

| Cultivar or clone         | Inoculation site <sup>a</sup> | Mean area of tuber rot (mm <sup>2</sup> ) <sup>b</sup> |                |                |
|---------------------------|-------------------------------|--|----------------|----------------|
|                           |                               | Test 1<br>Oct.   | Test 2<br>Dec. | Test 3<br>Feb. |
| <b>Cultivar</b>           |                               |  |                |                |
| Superior                  | Apical end                    | 54.6   | 92.4           | 93.1           |
|                           | Stem end                      | 74.7   | 139.2          | 99.7           |
| Hudson                    | Apical end                    | 80.5   | 93.5           | 67.5           |
|                           | Stem end                      | 104.5  | 103.1          | 98.5           |
| <b>Clone</b>              |                               |  |                |                |
| B7141-1                   | Apical end                    | 87.6   | 171.7          | 160.0          |
|                           | Stem end                      | 104.5  | 283.6          | 258.0          |
| B7152-14                  | Apical end                    | 109.8  | 245.8          | 140.2          |
|                           | Stem end                      | 136.9  | 262.8          | 258.9          |
| B7148-1                   | Apical end                    | 362.9  | 696.5          | 913.2          |
|                           | Stem end                      | 365.7  | 699.1          | 772.4          |
| B6969-2                   | Apical end                    | 177.3  | 335.3          | 148.0          |
|                           | Stem end                      | 189.4  | 208.5          | 314.9          |
| B6987-57                  | Apical end                    | 74.5   | 68.8           | 135.8          |
|                           | Stem end                      | 51.1   | 50.6           | 195.5          |
| B6987-56                  | Apical end                    | 175.6  | 324.6          | 315.5          |
|                           | Stem end                      | 203.3  | 254.8          | 325.2          |
| Bayesian LSD <sup>c</sup> |                               | 39.4   | 51.2           | 74.6           |

<sup>a</sup>Ten tubers were inoculated at apical and stem ends with approximately 100 spores of *F. roseum* 'Sambucinum' per inoculation site.

<sup>b</sup>Mean area of rotted tissue at 10 inoculation sites.

<sup>c</sup>Significant mean differences determined according to Bayesian LSD,  $P = 0.05$ .

diluted with additional water to give a suspension of 50,000 propagules per milliliter.

The selection of a tuber inoculation method to be used throughout these studies was of great concern. After conducting numerous tests with the various methods reported, we selected a modification of the one developed by Boyd (6). This method required the use of a micrometer-type syringe, and we modified the needle so that all inoculations would be made 7 mm below the surface of the tuber.

For each test, we inoculated 10 tubers at one of two pairs of locations on each clone or cultivar to be tested to determine whether differences in susceptibility existed with regard to tuber anatomy. In 1973, the inoculations were at the apical and stem ends

TABLE 2. Tuber rot ratings of potato cultivars and clones inoculated with *Fusarium roseum* 'Sambucinum,' 1974

| Cultivar or clone | Tuber rot <sup>a,b</sup> | Clone     | Tuber rot <sup>a,b</sup> |
|-------------------|--------------------------|-----------|--------------------------|
| <b>Cultivar</b>   |                          |           |                          |
| Hudson            | 2.3                      | B7848-23  | 3.6                      |
| Russet Burbank    | 4.0                      | B7849-5   | 2.3                      |
| Superior          | 2.0                      | B7853-2   | 2.3                      |
|                   |                          | B7859-2   | 2.6                      |
| <b>Clone</b>      |                          |           |                          |
| BA6893-3          | 3.3                      | B7861-2   | 2.3                      |
| BA6893-4          | 3.6                      | B7863-2   | 2.6                      |
| BA68504-1         | 3.3                      | B7863-5   | 2.6                      |
| BA69433-3         | 3.6                      | B7863-6   | 3.6                      |
| B6987-57          | 1.6                      | B7866-3   | 2.3                      |
| B7157-9           | 3.0                      | B7871-5   | 4.0                      |
| B7188-2           | 3.0                      | B7872-7   | 2.0                      |
| B7196-74          | 3.0                      | B7872-7   | 2.0                      |
| B7583-6           | 2.0                      | B7888-7   | 3.6                      |
| B7583-19          | 2.3                      | B7888-8   | 3.6                      |
| B7587-5           | 3.3                      | B7888-9   | 3.0                      |
| B7607-3           | 2.0                      | B7897-3   | 4.0                      |
| B7637-7           | 3.6                      | B7901-3   | 3.0                      |
| B7637-9           | 4.0                      | B7901-5   | 3.6                      |
| B7644-1           | 3.3                      | B7903-1   | 3.0                      |
| B7645-5           | 2.0                      | B7905-2   | 3.0                      |
| B7645-12          | 3.0                      | B7901A-11 | 2.6                      |
| B7655-9           | 3.0                      | B7911-1   | 3.6                      |
| B7678-2           | 4.0                      | B7913-1   | 2.3                      |
| B7678-6           | 2.0                      | B7918-3   | 4.0                      |
| B7678-12          | 3.0                      | B7927-1   | 2.0                      |
| B7679-9           | 2.3                      | B7929-11  | 2.0                      |
| B7680-6           | 2.3                      | B7930-2   | 2.3                      |
| B7680-10          | 2.3                      | B7939-4   | 1.6                      |
| B7684-3           | 2.3                      | B7957-5   | 2.0                      |
| B7684-4           | 2.0                      | B7958-1   | 3.0                      |
| B7684-6           | 2.3                      | B7978-1   | 3.0                      |
| B7684-7           | 2.6                      | B7987-1   | 3.6                      |
| B7685-8           | 2.3                      | B8004-8   | 3.0                      |
| B7711-2           | 3.0                      | B8018-2   | 2.6                      |
| B7732-2           | 4.0                      | B8019-4   | 3.0                      |
| B7825-5           | 2.6                      | B8036-1   | 3.3                      |
| B7828-1           | 3.0                      | B8050-1   | 2.6                      |
| B7828-9           | 4.0                      | B8050-2   | 3.6                      |
| B7830-4           | 3.0                      | B8086-3   | 2.0                      |
| B7838-2           | 3.6                      | B8087-6   | 3.3                      |
| B7839-7           | 1.6                      | B8088-2   | 3.6                      |
| B7840-2           | 2.3                      | B8091-8   | 4.0                      |
| B7845-4           | 4.0                      | B8101-3   | 3.0                      |
| B7845-6           | 4.0                      | B8101-3   | 3.3                      |
| B7845-10          | 3.6                      | B8111A-5  | 2.3                      |
| B7845-17          | 3.3                      | B8123-3   | 1.6                      |
| B7845-19          | 3.0                      | B8125-5   | 3.6                      |
| B7845-29          | 3.0                      | B8140-5   | 3.3                      |
| B7848-2           | 3.0                      | B8145-1   | 3.3                      |
| B7848-16          | 2.6                      | B8148-4   | 2.6                      |
| B7848-19          | 2.6                      | B8151-1   | 2.3                      |
|                   |                          | B8154-9   | 2.3                      |

<sup>a</sup>Ten tubers were inoculated at two midlength points with 100 spores of *F. roseum* 'Sambucinum.'

<sup>b</sup>Ratings: 1.0 = no visible rot; and 4.0 = severe rot. A clone or cultivar with a rating of 1.6 or lower was considered to possess acceptable resistance.

of each tuber. In succeeding years, all inoculations were at two points on opposite sides and at the midlength of each tuber. An inoculation consisted of approximately 100 spores per site. After inoculation the tubers were placed in 4.5-kg (10-lb) potato sacks and randomly placed in a controlled-environment room maintained at 13 C and 95% relative humidity (RH). At the end of a 4-wk storage period, the tubers were rated for degree of decay, following the procedure described by Boyd (6). In 1978, the rating method was changed to that described by Wiersma (29) because it was easier to use and gave results similar to those with Boyd's method. The data from the 1974-1977 tests were transformed from Boyd's rating method to that of Wiersma for ease of comparison. The Wiersma rating system has a scale of 1-4 in which 1 = no penetration of the fungus into the flesh of the tuber; 2 = penetration of only a few millimeters and fungal growth restricted by severe

necrotic reactions; 3 = fairly deep penetration, but fungal growth finally restricted by a necrotic zone; and 4 = unrestricted growth of the fungus. In 1974 we determined that any clone or cultivar with a rating of 1.6 or lower possessed acceptable resistance. Because higher degrees of resistance were observed in more lines in 1975 than in 1974, we reduced the acceptable rating to 1.3 or lower. If any clones rated at 1.6 or lower in 1974 or at 1.3 or lower in 1975 had tubers with individual ratings of 3.0 or higher, then we considered the resistance of those clones to be unacceptable.

In 1973 three trials were conducted to determine whether the tests we were using were repeatable. We inoculated 10 tubers from each of two cultivars and six clones at monthly intervals for 7 mo, beginning 15 October 1973. Once the test was found to be reliable, we conducted only one test per year. Russet Burbank served as a standard because of its high degree of susceptibility.

TABLE 3. Tuber rot resistance and sprout growth ratings of potato cultivars and clones inoculated with *Fusarium roseum* 'Sambucinum,' 1975

| Cultivar or clone        | Tuber rot <sup>a,b</sup> | Sprout growth <sup>c</sup> | New clones (cont'd) | Tuber rot | Sprout growth |
|--------------------------|--------------------------|----------------------------|---------------------|-----------|---------------|
| Cultivar                 |                          |                            | B7610-1             | 2.3       | 4             |
| Abnaki                   | 2.3                      | 5                          | B7618-6             | 3.0       | 2             |
| Hudson                   | 1.6                      | 1                          | B7620-4             | 1.3       | 4             |
| Katahdin                 | 2.6                      | 3                          | B7620-7             | 2.0       | 3             |
| Kennebec                 | 2.3                      | 2                          | B7621-2             | 2.3       | 2             |
| La Chipper               | 2.3                      | 4                          | B7631-8             | 2.0       | 2             |
| Monona                   | 2.3                      | 2                          | B7636-15            | 3.6       | 4             |
| Norchip                  | 2.0                      | 2                          | B7650-9             | 2.0       | 4             |
| Norgold Russet           | 2.6                      | 4                          | B7668-2             | 1.6       | 4             |
| Russet Burbank           | 2.6                      | 2                          | B7680-2             | 1.3       | 3             |
| Superior                 | 2.0                      | 4                          | B7680-11            | 1.3       | 4             |
| Wauseon                  | 2.3                      | 2                          | B7680-12            | 2.0       | 3             |
|                          |                          |                            | B7763-3             | 4.0       | 3             |
| Previously tested clones |                          |                            | B7769-4             | 2.6       | 4             |
| B6969-2                  | 2.3                      | 2                          | B7802-2             | 1.6       | 2             |
| B7583-6                  | 2.0                      | 4                          | B7805-1             | 1.6       | 2             |
| B7607-3                  | 2.0                      | 5                          | B7828-3             | 3.0       | 4             |
| B7645-5                  | 2.0                      | 5                          | B7828-18            | 2.6       | 2             |
| B7684-4                  | 2.3                      | 1                          | B7832-2             | 2.0       | 4             |
| B7685-8                  | 2.0                      | 2                          | B7845-23            | 3.0       | 2             |
| B7828-9                  | 3.6                      | 4                          | B7858-5             | 1.6       | 2             |
| B7839-7                  | 1.3                      | 4                          | B7897-1             | 3.0       | 3             |
| B7861-2                  | 1.3                      | 1                          | B7902-2             | 2.3       | 2             |
| B7866-3                  | 2.0                      | 1                          | B7902-8             | 1.3       | 1             |
| B7929-11                 | 2.3                      | 3                          | B7910A-6            | 2.3       | 2             |
| B7939-4                  | 1.3                      | 4                          | B7914-2             | 2.0       | 2             |
| B7957-5                  | 1.3                      | 2                          | B7929-3             | 2.0       | 2             |
| B8086-3                  | 2.0                      | 3                          | B7929-5             | 2.3       | 4             |
| B8123-3                  | 2.0                      | 2                          | B8024-1             | 3.0       | 4             |
| B8154-9                  | 2.3                      | 1                          | B8073-3             | 2.0       | 3             |
|                          |                          |                            | B8086-3             | 2.0       | 3             |
| New clones               |                          |                            | B8123-12            | 2.0       | 2             |
| B6951-1                  | 3.0                      | 4                          | B8140-1             | 2.3       | 2             |
| B6955-14                 | 2.0                      | 4                          | B8181-3             | 3.0       | 4             |
| B6955-35                 | 2.0                      | 4                          | B8185-4             | 1.6       | 2             |
| B6987-2                  | 1.6                      | 4                          | B8185-6             | 2.3       | 1             |
| B6987-29                 | 2.6                      | 3                          | B8186-3             | 3.0       | 4             |
| B6987-43                 | 1.6                      | 4                          | B8206-2             | 1.3       | 4             |
| B7009-4                  | 2.6                      | 3                          | B8210-3             | 2.3       | 4             |
| B7127-1                  | 2.0                      | 2                          | B8218-4             | 2.6       | 2             |
| B7139-4                  | 2.3                      | 2                          | B8264-1             | 2.3       | 2             |
| B7151-4                  | 2.0                      | 2                          | B8280-8             | 1.3       | 5             |
| B7155-3                  | 2.3                      | 2                          | B8281-5             | 3.0       | 3             |
| B7164-25                 | 2.0                      | 5                          | B8302-1             | 1.3       | 4             |
| B7165-8                  | 2.6                      | 4                          | B8302-2             | 2.3       | 2             |
| B7167-2                  | 2.3                      | 3                          | B8302-5             | 2.0       | 2             |
| B7200-26                 | 2.3                      | 2                          | B8308-5             | 3.6       | 4             |
| B7516-1                  | 2.3                      | 2                          | B8316-3             | 3.0       | 4             |
| B7516-3                  | 2.6                      | 5                          | B8354-11            | 2.3       | 4             |
| B7615-6                  | 2.0                      | 2                          | B8357-1             | 2.3       | 1             |
| B7516-9                  | 2.3                      | 2                          | B8357-4             | 2.6       | 1             |
| B7573-3                  | 2.6                      | 4                          | B8359-2             | 2.0       | 2             |
| B7592-1                  | 2.0                      | 4                          | B8393-8             | 2.0       | 5             |
| B7608-2                  | 2.0                      | 2                          |                     |           |               |

<sup>a</sup> Ten tubers were inoculated at two midlength points with 100 spores of *F. roseum* 'Sambucinum.'

<sup>b</sup> Ratings: 1.0 = no visible rot; and 4.0 = severe rot. A clone or cultivar with a rating of 1.3 or lower was considered to possess acceptable resistance.

<sup>c</sup> Scores: 1 = no sprouting; 2 = pipping; 3 = 5-mm-long sprouts; 4 = 12-mm-long sprouts; and 5 = sprouts 30-mm or longer.

The 1974 test included 98 clones from the USDA Breeding Program and the cultivars Hudson, Russet Burbank, and Superior.

In the 1975 test, 11 cultivars, 16 clones that previously showed varying degrees of resistance, and 75 new clones were tested.

The 1976 test consisted of 10 cultivars, eight of which were

TABLE 4. Tuber rot resistance and sprout growth ratings of potato and clones inoculated with *F. roseum* 'Sambucinum,' 1976

| Cultivar or clone        | Tuber rot <sup>a,b</sup> | Sprout growth <sup>c</sup> |
|--------------------------|--------------------------|----------------------------|
| Cultivar                 |                          |                            |
| Atlantic                 | 3.6                      | 5                          |
| Cobbler                  | 2.3                      | 3                          |
| Hudson                   | 2.3                      | 2                          |
| Katahdin                 | 3.3                      | 2                          |
| Kennebec                 | 4.0                      | 2                          |
| Monona                   | 4.0                      | 4                          |
| Norchip                  | 2.3                      | 4                          |
| Norgold Russet           | 3.3                      | 5                          |
| Superior                 | 3.0                      | 5                          |
| Russet Burbank           | 3.0                      | 2                          |
| Previously tested clones |                          |                            |
| B6987-57                 | 1.6                      | 2                          |
| B7583-6                  | 2.0                      | 2                          |
| B7607-3                  | 1.6                      | 2                          |
| B7645-12                 | 3.0                      | 2                          |
| B7679-9                  | 2.3                      | 2                          |
| B7839-7                  | 2.3                      | 3                          |
| B7848-19                 | 1.3                      | 2                          |
| B7861-2                  | 2.0                      | 1                          |
| B7863-6                  | 4.0                      | 2                          |
| B7871-5                  | 3.3                      | 5                          |
| B7930-2                  | 2.6                      | 4                          |
| B7939-4                  | 1.6                      | 2                          |
| B7957-5                  | 2.0                      | 2                          |
| B8004-8                  | 3.6                      | 3                          |
| B8091-8                  | 4.0                      | 2                          |
| New clones               |                          |                            |
| B6987-131                | 3.0                      | 5                          |
| B6987-136                | 2.3                      | 5                          |
| B6987-145                | 2.6                      | 4                          |
| B6987-148                | 1.6                      | 5                          |
| B6987-162                | 2.3                      | 5                          |
| B6987-184                | 2.3                      | 5                          |
| B6987-224                | 2.3                      | 5                          |
| B7024-6                  | 2.0                      | 3                          |
| B7152-3                  | 3.0                      | 3                          |
| B7200-33                 | 1.3                      | 5                          |
| B7552-3                  | 3.6                      | 2                          |
| B7595-7                  | 1.6                      | 3                          |
| B7608-4                  | 2.3                      | 3                          |
| B7629-1                  | 4.0                      | 2                          |
| B7636-32                 | 3.0                      | 2                          |
| B7637-9                  | 3.6                      | 2                          |
| B7678-17                 | 4.0                      | 2                          |
| B7744-5                  | 3.3                      | 2                          |
| B7783-6                  | 1.3                      | 2                          |
| B7813-5                  | 2.6                      | 5                          |
| B7902-4                  | 3.0                      | 4                          |
| B8188-6                  | 3.3                      | 4                          |
| B8188-9                  | 4.0                      | 4                          |
| B8212-1                  | 4.0                      | 2                          |
| B8261-3                  | 3.3                      | 4                          |
| B8281-4                  | 2.0                      | 4                          |
| B8285-2                  | 4.0                      | 4                          |
| B8339-4                  | 2.3                      | 2                          |
| B8392-5                  | 3.6                      | 5                          |
| B8429-1                  | 3.0                      | 3                          |
| B8429-9                  | 2.0                      | 5                          |
| B8515-1                  | 3.0                      | 5                          |
| B8515-18                 | 3.6                      | 2                          |
| B8543-9                  | 2.6                      | 4                          |
| B8599-42                 | 3.6                      | 4                          |

<sup>a</sup> Ten tubers were inoculated at two midlength points with 100 spores of *F. roseum* 'Sambucinum.'

<sup>b</sup> Ratings: 1.0 = no visible rot; and 4.0 = severe rot. A clone or cultivar with a rating of 1.3 or lower was considered to possess acceptable resistance.

<sup>c</sup> Scores: 1 = no sprouting; 2 = pipping; 3 = 5-mm-long sprouts; 4 = 12-mm-long sprouts; and 5 = sprouts 30-mm or longer.

repeats, 15 repeat clones, and 35 new clones.

In 1977, Russet Burbank was the only variety tested because most of the test clones were of the russet type and comparisons with Russet Burbank were desired. We tested five clones that had been tested previously and 15 new clones.

The final year of this study, 1978, included tests on all 32 cultivars and 61 clones grown in the Sangerville project of the Maine State Department of Agriculture. Also tested were 30 clones from the USDA Breeding Program, of which nine were repeats. During 1978 all potatoes were tested for resistance to both *F. roseum* 'Sambucinum' and *F. solani* 'Coeruleum.' Clone B7200-33 became the standard because of its high degree of resistance to both species of *Fusarium*.

In the 1975 storage season we began to rate sprout growth to determine whether there was any correlation between sprout growth and *Fusarium* resistance. The sprout rating was on a 1-5 scale in which 1 = no sprouting; 2 = pipping; 3 = 5-mm-long sprouts; 4 = 12-mm-long sprouts; and 5 = sprouts of 30-mm length or longer.

## RESULTS

The 1973 test results indicated that the testing procedure was repeatable and that the inoculation sites were easy to evaluate. They also indicated that site of inoculation had little if any effect on degree of resistance, or susceptibility, of the cultivar or clone tested. All cultivars and clones tested followed the expected trend (7) in which disease susceptibility was generally lower at harvest than after potatoes had been stored (Table 1). None of the potatoes tested were immune, although the cultivars Superior and Hudson and clone B6987-57 had some degree of resistance. The results also indicated that tests of the resistance to *Fusarium* spp. should be conducted in late fall to reduce interference of natural low susceptibility observed at harvest.

Of the 98 clones and three cultivars tested in 1974, only clones B6987-57, B7839-7, B7939-4, and B8123-3 had an acceptable

TABLE 5. Tuber rot resistance and sprout growth ratings of potato clones inoculated with *Fusarium roseum* 'Sambucinum,' 1977

| Cultivar or clone        | Tuber rot <sup>a,b</sup> | Sprout growth <sup>c</sup> |
|--------------------------|--------------------------|----------------------------|
| Cultivar                 |                          |                            |
| Russet Burbank           | 3.3                      | 1                          |
| Previously tested clones |                          |                            |
| B6969-2                  | 1.6                      | 2                          |
| B6987-43                 | 2.0                      | 1                          |
| B7200-33 <sup>d</sup>    | 1.0                      | 5                          |
| B7783-6                  | 1.3                      | 5                          |
| B8429-9                  | 3.0                      | 5                          |
| New clones               |                          |                            |
| B7802-2                  | 1.6                      | 2                          |
| B8392-5                  | 3.3                      | 2                          |
| B8697-34                 | 1.6                      | 2                          |
| B8822-2                  | 2.3                      | 1                          |
| B8822-6                  | 1.3                      | 2                          |
| B8822-9                  | 2.0                      | 1                          |
| B8822-27                 | 3.0                      | 1                          |
| B8822-29                 | 2.0                      | 1                          |
| B8822-43                 | 2.0                      | 1                          |
| B8824-13                 | 1.3                      | 1                          |
| B8847-8                  | 1.3                      | 1                          |
| B8862-3                  | 3.0                      | 2                          |
| B8921-2                  | 3.0                      | 1                          |
| B8922-15                 | 1.3                      | 2                          |
| B8926-1                  | 3.0                      | 2                          |

<sup>a</sup> Ten tubers were inoculated at two midlength points with 100 spores of *F. roseum* 'Sambucinum.'

<sup>b</sup> Ratings: 1.0 = no visible rot; and 4.0 = severe rot. A clone with a rating of 1.3 or lower was considered to possess acceptable resistance.

<sup>c</sup> Scores: 1 = no sprouting; 2 = pipping; 3 = 5-mm-long sprouts; 4 = 12-mm-long sprouts; and 5 = sprouts 30-mm or longer.

<sup>d</sup> This clone was also rated 1.0 when inoculated with *F. solani* 'Coeruleum.'



degree of resistance to *F. roseum* 'Sambucinum' (Table 2).

None of the 11 cultivars tested in 1975 had an acceptable degree of resistance. Of the clones tested also in 1974, B7839-7, B7861-2, B7939-4 and B7957-5 had a high degree of resistance, whereas all others had very little (Table 3). Six new clones, B7680-2, B7680-11, B7902-8, B8206-2, B8280-8 and B8302-1 had an acceptable degree of resistance. Even though B7620-4 had a disease rating of 1.3 it did not have acceptable resistance because individual tubers had a rating of 3 or over. No correlation was found between sprouting index and resistance to *Fusarium*.

None of the 10 cultivars and only one clone used in previous tests, B7848-19, tested in 1976 had an acceptable level of resistance (Table 4). Of the 35 new clones tested only two, B7200-33 and B7783-6, had an acceptable level of resistance. Clone B7200-33 was almost symptomless, whereas clone B7783-6, even though given a rating of 1.3, exhibited some disease symptoms. B7200-33 was the first clone that exhibited the desired degree of resistance. Again, sprouting index did not correlate with disease resistance.

Russet Burbank had little or no resistance (Table 5) in the 1977 tests. Of the five repeat clones, B7200-33 had no disease symptoms and B7783-6 had few, whereas B8429-9 had little resistance. The other repeat clones tested in previous years had intermediate resistance and of the 15 new clones tested, four had high resistance.

Clone B7200-33 again had high resistance to *F. solani* 'Coeruleum.' No correlation was found between sprouting and disease resistance although all the new clones had lower sprout ratings than previously observed.

Of the nine clones tested again in 1978, B7200-33 was the only one that had a high degree of resistance to both species of fusaria (Table 6). None of the new clones tested had acceptable resistance. The results of the tests at Sangerville indicated that cultivars and clones may be resistant to one species of fusaria but not to another (Table 7). The cultivars found to be most resistant to both fusaria were Bison, Centennial Russet, and Shurchip. Clones with similar levels of resistance to both fusaria were B6969-2, B7583-1, B7802-2, B7859-2, B7863-5, AF197-7, BR7093-23, C7358-14A, C7358-26A, F69026, and 47156. Some clones or cultivars had a higher degree of resistance to one species of *Fusarium* than to the other; eg, Croatan, AF186-5, BR6863-5, and CD138-4R had more resistance to *F. roseum* 'Sambucinum' than to *F. solani* 'Coeruleum,' whereas Kennebec, Tobique, B7845-4, AF92-3, and AF238-21 had more resistance to *F. solani* 'Coeruleum' than to *F. roseum* 'Sambucinum.'

## DISCUSSION

The resistance tests reported herein indicated that inherent resistance to *F. solani* 'Coeruleum' and *F. roseum* 'Sambucinum' is genetically controlled.

The clone with the highest degree of resistance found was B7200-33. In most instances it was highly resistant to both species of *Fusarium*. This clone is golden-nematode resistant, had good processing qualities, is highly productive, and tubers are of an acceptable shape. The only reason this clone was not released as a variety is because of its low solids content (*unpublished*). This clone is being utilized as a parent in the USDA Potato Breeding Program to introduce resistance to *Fusarium* into future cultivars.

Lansade (18) found that most potatoes with *Fusarium* resistance tend to lose it as the storage period increases. However, clone B7200-33 does not appear to lose its resistance.

Corsini et al (10) studied the characterization of *Fusarium* resistance in potato breeding clones and found that a terpenoid, rishitin, was produced more rapidly in resistant clones than in nonresistant clones. They feel that resistance is determined by more than one factor. Wellving (28) agrees that more than one factor is responsible for resistance. He believes that there are biochemical (Biochem) and mechanical (Mech) factors for sensitivity to wounding and wound healing so that Resistant =  $R_{Mech} + R_{Biochem} + R_{Mech} \times R_{Biochem}$ . Boyd (8, and *personal communication*) also has

expressed similar feelings.

Results of Ayers' (3) work indicated, as did this study, that few cultivars or clones are highly resistant to both *F. roseum* 'Sambucinum' and *F. solani* 'Coeruleum.' Thus, if only one species of the pathogen is present in a location, some cultivars appear to be resistant, but, when planted in other locations, they may appear to be highly susceptible.

The work reported here is concerned with biochemical resistance only. However, if studies are undertaken to determine the degree of resistance to mechanical injury in the cultivars and clones that exhibit moderate degrees of biochemical resistance, one may identify more cultivars having both modes of resistance. Possibly a clone that is biochemically susceptible, but has a high degree of resistance to mechanical injury could exhibit a great degree of disease resistance. With a thorough knowledge of both biochemical resistance and resistance to mechanical injury in potato clones, one should be able to produce new varieties with very high degrees of resistance and, perhaps, immunity to this disease.

Research is presently being conducted to determine the mode of resistance in B7200-33. Early results indicate that a combination of both biochemical and morphological factors is involved.

With the continuing concern over the use of pesticides on food products and the high requirements for food in the world, breeding for resistance to this disease appears to be an excellent method by which we can reduce the use of pesticides and reduce losses of a food of importance to the world.

TABLE 6. Tuber rot resistance and sprouting ratings of potato clones inoculated with *Fusarium solani* 'Coeruleum' and *F. roseum* 'Sambucinum,' 1977

| Clone                    | Tuber rot <sup>a</sup>                       |   | Sprout growth <sup>c</sup> |
|--------------------------|--|---|----------------------------|
|                          | <i>F. solani</i> <sup>b</sup><br>'Coeruleum' | <i>F. roseum</i> <sup>b</sup><br>'Sambucinum' |                            |
| Previously tested clones |  |   |                            |
| B7200-33                 | 1.3  | 1.3   | 3                          |
| B7618-6                  | 3.3  | 3.6   | 3                          |
| B7863-5                  | 2.6  | 3.6   | 2                          |
| B7905-2                  | 3.3  | 3.6   | 3                          |
| B8101-3                  | 3.0  | 3.3   | 2                          |
| B8218-4                  | 3.0  | 3.6   | 3                          |
| B8281-5                  | 3.0  | 4.0   | 2                          |
| B8822-9                  | 4.0  | 3.3   | 3                          |
| B8822-43                 | 3.6  | 3.6   | 3                          |
| New clones               |  |   |                            |
| B8310-13                 | 3.3  | 3.6   | 3                          |
| B8375-7                  | 3.0  | 3.0   | 3                          |
| B8524-21                 | 3.0  | 2.6   | 3                          |
| B8525-18                 | 3.6  | 3.6   | 2                          |
| B8527-4                  | 3.6  | 3.6   | 3                          |
| B8528-3                  | 3.0  | 4.0   | 3                          |
| B8528-4                  | 3.0  | 3.6   | 3                          |
| B8530-4                  | 3.3  | 3.3   | 3                          |
| B8548-20                 | 3.0  | 3.6   | 3                          |
| B8615-2                  | 3.3  | 3.3   | 5                          |
| B8687-20                 | 3.0  | 4.0   | 1                          |
| B8761-2                  | 3.0  | 3.3   | 5                          |
| B8784-5                  | 3.0  | 2.6   | 3                          |
| B8799-8                  | 3.6  | 3.3   | 3                          |
| B8799-13                 | 3.0  | 3.0   | 3                          |
| B8824-7                  | 3.6  | 3.6   | 2                          |
| B8852-2                  | 2.3  | 4.0   | 3                          |
| B8908-3                  | 3.0  | 4.0   | 2                          |
| B8937-9                  | 2.6  | 3.3   | 3                          |
| B8947-3                  | 2.6  | 2.3   | 3                          |
| B8972-1                  | 3.6  | 2.6   | 3                          |

<sup>a</sup> Rating of 1.0 = no visible rot; and 4.0 = severe rot. A clone with a rating of 1.3 or lower was considered to possess acceptable resistance.

<sup>b</sup> Ten tubers were inoculated at two midlength points with 100 spores of the indicated test organism.

<sup>c</sup> Scores: 1 = no sprouting; 2 = pipping; 3 = 5-mm-long sprouts; 4 = 12-mm sprouts; and 5 = sprouts 30 mm or longer.

TABLE 7. Tuber rot resistance and sprouting ratings of cultivars and clones from the Sangerville, ME, project inoculated with *Fusarium solani* 'Coeruleum' and *F. roseum* 'Sambucinum,' 1978

| Cultivar or clone | Tuber rot <sup>a</sup>                    |  |                            | Clones (cont'd)    | Tuber rot <sup>a</sup>                    |  |                            |
|-------------------|---|--|----------------------------|--------------------|---|--|----------------------------|
|                   | <i>F. solani</i> <sup>b</sup> 'Coeruleum' | <i>F. roseum</i> <sup>b</sup> 'Sambucinum' | Sprout growth <sup>c</sup> |                    | <i>F. solani</i> <sup>b</sup> 'Coeruleum' | <i>F. roseum</i> <sup>b</sup> 'Sambucinum' | Sprout growth <sup>c</sup> |
| Cultivar          |   |  |                            | B8148-4            | 2.3                                       | 3.3  | 3                          |
| Alaska Red        | 3.3                                       | 3.6  | 2                          | AF24-33c           | 2.6                                       | 3.0  | 4                          |
| Atlantic          | 3.0                                       | 3.3  | 3                          | AF32-8             | 3.0                                       | 2.6  | 3                          |
| Bake King         | 3.0                                       | 3.3  | 2                          | AF84-4             | 3.0                                       | 3.6  | 3                          |
| Batoche           | 3.3                                       | 3.0  | 2                          | AF92-3             | 2.6                                       | 4.0  | 3                          |
| Belleisle         | 3.0                                       | 4.0  | 3                          | AF186-2            | 2.6                                       | 3.6  | 3                          |
| Belchip           | 3.6                                       | 3.0  | 2                          | AF186-5            | 4.0                                       | 2.6  | 3                          |
| BelRus            | 3.3                                       | 3.6  | 3                          | AF193-4            | 3.0                                       | 2.6  | 3                          |
| Bison             | 2.6                                       | 2.0  | 2                          | AF197-7            | 2.6                                       | 2.3  | 2                          |
| Bucksin           | 3.0                                       | 4.0  | 2                          | AF200-6            | 3.6                                       | 3.6  | 3                          |
| Butte             | 3.0                                       | 3.6  | 5                          | AF201-3            | 2.6                                       | 3.6  | 1                          |
| Campbell 11       | 3.0                                       | 3.3  | 3                          | AF205-9            | 3.0                                       | 3.3  | 3                          |
| Campbell 12       | 3.0                                       | 3.3  | 3                          | AF223-1            | 2.6                                       | 3.0  | 1                          |
| Campbell 13       | 3.0                                       | 2.6  | 3                          | AF238-21           | 2.3                                       | 4.0  | 3                          |
| Centennial Russet | 2.6                                       | 2.3  | 2                          | AK6-5              | 2.6                                       | 3.3  | 3                          |
| Croatan           | 3.3                                       | 1.3  | 4                          | AK24-3             | 3.0                                       | 3.0  | 2                          |
| Green Mountain    | 2.6                                       | 3.6  | 3                          | AK25               | 3.0                                       | 3.6  | 3                          |
| Hudson            | 3.0                                       | 2.6  | 1                          | AK28               | 3.0                                       | 2.6  | 3                          |
| Katahdin          | 2.6                                       | 3.0  | 2                          | AK37-19 (Denali)   | 2.6                                       | 3.0  | 3                          |
| Kennebec          | 2.0                                       | 3.6  | 2                          | BR5991-WL16        | 3.6                                       | 3.0  | 3                          |
| Monona            | 3.0                                       | 3.6  | 2                          | BR6863-5           | 3.0                                       | 1.6  | 5                          |
| Norgold-L         | 3.0                                       | 3.6  | 3                          | BR7088-18          | 3.0                                       | 3.0  | 3                          |
| Norland           | 3.0                                       | 3.0  | 3                          | BR7090-17          | 3.0                                       | 3.3  | 1                          |
| Oneida            | 3.6                                       | 3.3  | 2                          | BR7093-23          | 2.6                                       | 2.3  | 2                          |
| Peconic           | 3.0                                       | 3.0  | 2                          | C7232-4            | 3.0                                       | 3.0  | 5                          |
| Penn-71           | 3.0                                       | 4.0  | 2                          | C7236-2            | 3.0                                       | 2.3  | 2                          |
| Raritan           | 3.0                                       | 3.0  | 3                          | C7294-10           | 3.0                                       | 3.3  | 2                          |
| Russet Burbank    | 3.0                                       | 3.6  | 2                          | C72107-13A         | 3.3                                       | 3.0  | 3                          |
| Shurchip          | 2.6                                       | 2.3  | 3                          | C7356-13A          | 3.0                                       | 3.0  | 2                          |
| Snowchip          | 3.0                                       | 3.6  | 3                          | C7358-14A          | 2.6                                       | 2.6  | 3                          |
| Superior          | 3.0                                       | 3.0  | 3                          | C7358-26A          | 2.6                                       | 2.0  | 4                          |
| Superior-L        | 3.0                                       | 3.0  | 1                          | CA02-7             | 3.0                                       | 2.6  | 3                          |
| Tobique           | 2.6                                       | 4.0  | 1                          | CA55-24            | 3.6                                       | 3.0  | 2                          |
|                   |   |  |                            | CC26-1A            | 3.0                                       | 4.0  | 3                          |
| Clone             |   |  |                            | CD03-4             | 3.0                                       | 3.0  | 2                          |
| A68678-1          | 3.0                                       | 2.6  | 3                          | CD23-1             | 3.0                                       | 4.0  | 4                          |
| B6503-2           | 4.0                                       | 3.3  | 4                          | CD106-16           | 4.0                                       | 4.0  | 3                          |
| B6969-2           | 2.6                                       | 2.6  | 2                          | CD130-7R           | 3.0                                       | 2.6  | 3                          |
| B6987-184         | 3.3                                       | 3.3  | 3                          | CD138-4R           | 3.6                                       | 2.3  | 3                          |
| B7008-3           | 3.3                                       | 3.0  | 3                          | F67072 (Jemseg)    | 3.3                                       | 3.6  | 3                          |
| B7583-1           | 2.6                                       | 2.6  | 2                          | F67128             | 2.6                                       | 3.3  | 2                          |
| B7802-2           | 2.6                                       | 2.3  | 2                          | F68036             | 2.6                                       | 3.0  | 3                          |
| B7845-4           | 2.6                                       | 4.0  | 2                          | F69016             | 3.6                                       | 3.0  | 2                          |
| B7845-19          | 3.3                                       | 3.0  | 2                          | F69026             | 2.6                                       | 2.6  | 1                          |
| B7845-29          | 3.0                                       | 3.0  | 3                          | W524-5A            | 3.3                                       | 3.3  | 3                          |
| B7848-2           | 3.3                                       | 3.0  | 2                          | W564-3A            | 2.3                                       | 3.0  | 3                          |
| B7859-2           | 2.6                                       | 2.6  | 1                          | W718               | 3.3                                       | 3.0  | 2                          |
| B7863-5           | 2.6                                       | 2.6  | 2                          | 47156 (Delta Gold) | 2.6                                       | 2.6  | 1                          |

<sup>a</sup>Ratings: 1.0 = no visible rot; and 4.0 = severe rot. A clone or cultivar with a rating of 1.3 or lower was considered to possess acceptable resistance.

<sup>b</sup>Ten tubers were inoculated at two midlength points with 100 spores of the indicated test organism.

<sup>c</sup>Scores: 1 = no sprouting; 2 = pipping; 3 = 5-mm-long sprouts; 4 = 12-mm-long sprouts; and 5 = sprouts 30 mm or longer.

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