22 Multiflora Rose

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PEST STATUS OF WEED

Multiflora rose, *Rosa multiflora* Thunberg ex. Murray, is a non-indigenous rosaceous plant that is native to East Asia (Japan, Korea, and eastern China) (Fig. 1). It has been introduced into North America many times since the late 1700s as garden plants and as root stock for ornamental roses. Rehder (1936) found it listed in the second edition (1811) of the *Catalog of the Elgin Botanic Garden* in New York. Before its weedy characteristics were well understood, it was widely planted in the 1940s to 1960s in the eastern United States as a wildlife plant for erosion control and as a living fence. The hypanthia often are used for tea as a source of vitamin C. It has been declared a noxious weed in at least ten states (Amrine and Stasny, 1993).

Nature of Damage

Economic damage. Lost pasturage in many states, especially states with hilly terrain and pastures on steep slopes, has resulted in significant reduction in potential beef production. This thorned bramble now infests more than 45 million acres throughout the eastern United States (Underwood *et al.,* 1996). Chalamira and Lawrence (1984) reported that multiflora rose was the highest priority agricultural problem in West Virginia. Experimental multiflora control programs in West Virginia during 1980 and 1981 indicated that more than 36,500 hectares were heavily infested and that a ten-year eradication program using herbicides would cost more than $40 million (Williams and Hacker, 1982). Similar burdens and costs were reported from neighboring states; to date, multiflora has been declared a noxious weed in Illinois, Iowa, Kansas, Maryland, Missouri, Ohio, Pennsylvania, Virginia, Wisconsin, and West Virginia (Amrine and Stasny, 1993).

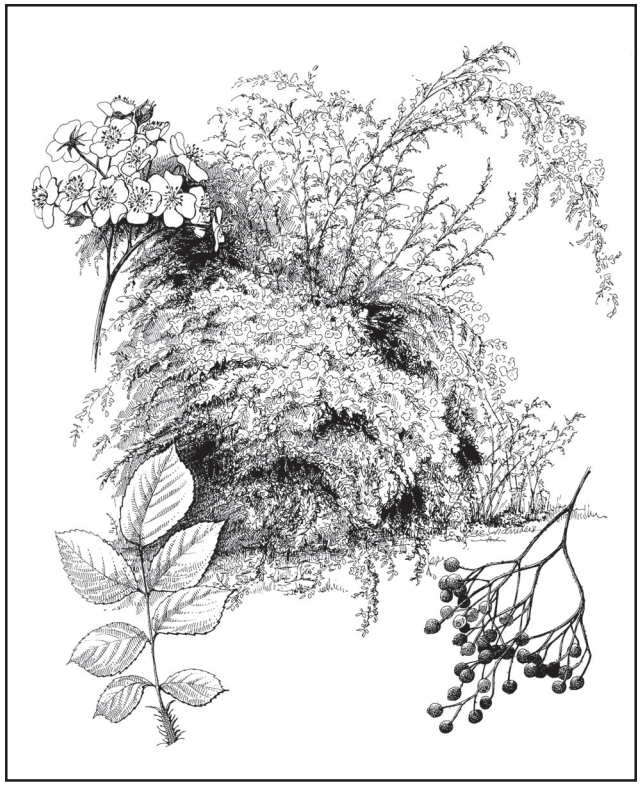

Figure 1. Multiflora rose. (Illustration by Rae Chambers, Pennsylvania State University.)

Ecological damage. Multiflora rose has invaded a large number of habitats, from hillside pastures, fence rows, right-of-ways, and roadsides to forest edges and the margins of swamps and marshes (Scott, 1965). A single, vigorous, mature plant can produce up to half a million achenes (seeds) annually. Where plants have become well established, a huge seed bank develops that can continue to produce seedlings for at least twenty years after removal of mature plants. Severe multiflora rose infestations have lowered land values for agriculture, forestry, and recreation (Underwood *et al.,* 1996). Since the 1960s, multiflora rose has become one of the most noxious weeds in the eastern United States. It is especially troublesome

in regions with steep slopes, which prevent access by tractors or mowers for cutting this weed. Multiflora rose forms dense, impenetrable thickets in many regions of the eastern United States. At least ten states have passed noxious weed laws against it, and it is illegal to plant it in many areas (Amrine and Stasny, 1993; Fawcett, 1980; Klimstra, 1956; Kriebel, 1987; Williams and Hacker, 1982; Underwood *et al.,* 1996). Many state publications and web sites list cultural and chemical methods for controlling multiflora rose, but biological control has been a neglected management option (Lingenfelter and Curran, 1995; Underwood and Stroube, 1986; Underwood *et al.,* 1996).

Extent of losses. In West Virginia, projected costs to farmers for controlling multiflora rose from 1981 to 1982 exceeded $40 million (Williams and Hacker, 1982); at today's rates, this cost would exceed $48 million. Similar costs accrue to most eastern states and control costs continue to rise as this noxious weed continues to spread.

Geographical Distribution

In eastern North America, multiflora rose is abundant from the Great Plains (where the species has been planted as wind breaks) to the east coast. It occurs from northern Texas, Arkansas, Mississippi, Alabama, and Georgia in the south, north to the New England coast, central New York, southern Michigan, Wisconsin, and Minnesota. It occurs only as plantings south of central Georgia, probably because of the lack of cold temperatures needed to stimulate seed germination. The plant's northern distribution is limited by its sensitivity to severe cold temperatures.

BACKGROUND INFORMATION ON PEST PLANT

Taxonomy

Multiflora rose is in the Subfamily Rosoïdeae, Tribe Roseae. *Rosa* is the only known genus in the tribe. The most closely related plants are members of the tribes Potentilleae (Sections Rubinae, Potentillinae, Dryadinae), Cercocarpaceae, Ulmariëae, and Sanguisorbeae. The most common genera that would be most closely related to *Rosa* are *Rubus, Potentilla, Fragaria, Geum, Dryas, Adenostema, Purshia, Cercocarpus, Alchemilla, Agrimonia,* and *Poterium.*

Multiflora rose was first described from Japan. It is a stout, thorny, diffusely branched, perennial shrub with numerous arching stems (canes) arising from the crown; plants may reach 3 m height and 6.5 m diameter. Twigs are reddish to green, 1.5 cm in diameter and armed with numerous, recurved thorns; thornless clones occur sparsely throughout the eastern United States. Leaves are odd-pinnately compound, 8 to 11cm long, divided into five to 11 sharply toothed, ovate to oblong leaflets. Basal petioles are 1.0 to1.3 cm long and have finely dissected, usually glandular stipules. Large clusters of showy, fragrant, white to pink 2.5 cm flowers occur in dense to sparse panicles that appear in late May or June. Panicles contain six to 100 (average of 63) hypanthia or hips that are glabrous to pubescent, develop during the summer, and become bright red by mid-September; hips contain an average of seven (one to 21) achenes. Hypanthia become soft after frost and eventually become leathery, remaining on the plant through the winter. Achenes are yellowish to tan, somewhat irregular in shape, about 2 to 4 mm long by 2 mm wide, and enclosed in sharp spicules. Winter-feeding birds often consume fruits by January. Seeds are attacked by the rose seed chalcid, *Megastigmus aculeatus* var. *nigroflavus* Hoffmeyer (Hymenoptera: Torymidae) in many areas (see below).

Biology

Each cane on a large plant may contain 40 to 50 pannicles. Each pannicle can contain as many as 100 hypanthia or hips (average of about 50) and each hip, an average of seven seeds (range of one to 22). Thus each large cane can potentially produce up to 17,500 seeds. Seeds remain viable for a number of years (Evans, 1983; Underwood *et al.,* 1996). We have found as many as 90% of the seed to be viable, in the absence of drought, stress, and seed chalcids. The abundant floral production of this plant may be the result of the plant's evolution in the presence of its seed predator, the multiflora rose seed chalcid, *Megastigmus aculeatus* var. *nigroflavus* Hoffmeyer (Hymenoptera: Torymidae). In Asia, the chalcid may infest 95% of the achenes or seeds (Weiss, 1917). The chalcid reproduces by parthenogenesis (female:male ratio is 200:1), possibly a mechanism to match the huge resource (Shaffer, 1987). Multiflora rose is moderately winter-hardy, tolerant to many North American insects and diseases, and grows rapidly into dense thorny thickets favorable for many species of

wildlife. Its abundant fruits are food to deer and birds. The flowers produce large amounts of golden, sweet-tasting pollen that can be harvested by fitting bee hives with pollen traps (Amrine unpublished). The plant has a vigorous root system capable of checking erosion, and if carefully planted and mechanically trimmed, multiflora rose can make living fences capable of restraining some species of livestock (Dugan, 1960). It is still planted as a living fence in southern Delaware to separate herds of horses. Because of these traits, multiflora rose was widely planted throughout the eastern United States from the 1930s until the 1960s as living fences, for erosion control, and to protect and feed native wildlife. In West Virginia, more than 14 million plants were planted in the 1940s to 1960s (Dugan, 1960), and in North Carolina, more than 20 million were planted (Nalepa, 1989). Only a few states (e.g., Kentucky) refused to promote this plant. Consequently, many areas of Kentucky are relatively free of the weed. Since the plant was distributed as rooted cuttings and not from seed, no seed chalcids were distributed.

Some early experiments were conducted to show that spread of multiflora seed by birds was minimal. However, the birds chosen were chickens, doves, pigeons, turkeys, and their relatives—all of which have gizzards containing stones that grind seeds. Songbirds were not tested as potential seed dispersers. Robins, mockingbirds, starlings, red-winged blackbirds, and other species feed heavily on multiflora rose hips in fall and winter, and, because of the numerous spicules in each hip, seeds pass rapidly through their digestive tracts and remain intact. Passage of seeds through digestive tracts of songbirds increases the germination rate, while bird feces provides fertilizer to seedlings (Lincoln, 1978; Scott, 1965).

Analysis of Related Plants in the Eastern United States

According to the *Synonymized Checklist of the Vascular Flora of the United States, Puerto Rico, and the Virgin Islands* and the Texas A&M University Bioinformatics Working Group on the Rosaceae (part of BONAP, theBiota of North America Program), there are 82 species or subspecies of roses that are either native to the eastern United States, have escaped from cultivation, or are grown in gardens. In addition, there are some 8,000 registered cultivars of roses, worldwide, with many new ones registered annually. The following is a list of roses occurring in this region:

1. ***Rosa acicularis* Lindl.** Cinnamomeae DC. Prickly rose. (native) Eurasia and North America, Zone 4.
2. ***Rosa acicularis* ssp. *acicularis*.** (native) Alaska, Eurasia, zone 4.
3. ***Rosa acicularis* ssp. *sayi* (Schwein.) W. H. Lewis.** (native) Alaska through Canada, south to West Virginia, Texas and New Mexico (mountains), Zone 5. Occasionally found at higher altitudes and farther north. Synonymy: *Rosa acicularis* var. *bourgeauiana* (Crépin) Crépin, *Rosa acicularis* var. *sayana* Erlanson, *Rosa bourgeauiana* Crépin, *Rosa collaris* Rydb., *Rosa engelmannii* S. Wats., *Rosa sayi* Schwein.
4. ***Rosa* x *alba* L. (pro sp.) [*arvensis* x *gallica*].** European hybrid. Zone 5, mountains and far north.
5. ***Rosa arkansana* Porter**. Cinnamomeae DC. (native). Prairie rose. New York to Alberta, south to Texas.
6. ***Rosa arkansana* var. *arkansana*** (native). Known locally as prairie rose. From Wisconsin and Minnesota to Colorado and Kansas; rocky slopes. Synonymy: *Rosa lunellii* Greene, *Rosa rydbergii* Greene.
7. ***Rosa arkansana* var. *suffulta* (Greene) Cockerell**.(native). Known locally as sunshine rose. New York west to Alberta, south to the District of Columbia, Indiana, Wisconsin, Missouri, Kansas, Texas, and New Mexico. Synonymy: *Rosa alcea* Greene, *Rosa conjuncta* Rydb., *Rosa pratincola* Greene, *Rosa suffulta* Greene, *Rosa suffulta* var. *relicta* (Erlanson) Deam.
8. ***Rosa banksiae* Aiton**. Non-indigenous rose from China, grown in Georgia. Apparently, it has not escaped.
9. ***Rosa blanda* Aiton**. Cinnamomeae DC. (native). Smooth rose. Newfoundland to Maryland and West Virginia, west to Kansas and Montana.
10. ***Rosa blanda* var. *blanda* Aiton.** (native). Distribution same. Synonymy: *Rosa blanda* var. *carpohispida* Schuette, *Rosa rousseauiorum* Boivin, *Rosa subblanda* Rydb., *Rosa williamsii* Fern.

11. *Rosa blanda* var. *glabra* Crépin. (native). Maine south to New York, west to Minnesota. Synonymy: *Rosa johannensis* Fern.

12. *Rosa blanda* var. *glandulosa* Schuette (native). Indiana.

13. *Rosa blanda* var. *hispida* Farw. (native). Maryland and Indiana.

14. *Rosa* x *borboniana* Desportes (pro sp.) [*chinensis* x *damascena*]. Bourbon rose. Non-indigenous hybrid. New York, South Carolina and Louisiana.

15. *Rosa bracteata* J. C. Wendl. Bracteatae Thory. Known as Chickasaw or Macartney rose. Non-indigenous rose from China. Found in Zone 7, in Texas, Louisiana, Georgia, and other southern states north to Virginia and Kentucky.

16. *Rosa canina* L. Caninae DC. Dog rose. Non-indigenous rose from Europe and West Asia; Maine south to Alabama, west to Arkansas, Kansas and Wisconsin; western distribution is Washington and Idaho to Utah and California, Zone 4. Present in the CalFlora Database (California distribution map). Synonymy: *Rosa canina* var. *dumetorum* Baker.

17. *Rosa carolina* L. Carolinae Crépin. (native). Carolina rose, pasture rose. Nova Scotia to Florida, west to Nebraska and Texas.

18. *Rosa carolina var. carolina* L. (native). Common in the east where it is known as the pasture rose. Synonymy: *Rosa carolina* var. *glandulosa* (Crépin) Farw., *Rosa carolina* var. *grandiflora* (Baker) Rehd., *Rosa carolina* var. *obovata* (Raf.) Deam, *Rosa serrulata* Raf., *Rosa subserrulata* Rydb., *Rosa texarkana* Rydb.

19. *Rosa carolina* var. *deamii* (Erlanson) Deam. (native). Indiana.

20. *Rosa carolina* var. *sabulosa* Erlanson. (native). Indiana.

21. *Rosa carolina* var. *setigera* Crépin. (native). New Hampshire, Vermont and Maine. Known locally as prairie rose, climbing rose.

22. *Rosa carolina* var. *villosa* (Best) Rehd. (native). Maine south to Georgia west to Minnesota and Texas. Synonymy: *Rosa carolina* var. *lyonii* (Pursh) Palmer and Steyermark, *Rosa lyonii* Pursh, *Rosa palmeri* Rydb.

23. *Rosa centifolia* L. Cabbage rose. Non-indigenous rose from Europe; grown by rosarians for attar of rose, an essential oil in the petals. New York and Connecticut south to New Jersey, west to Missouri and Wisconsin. Synonymy: *Rosa centifolia* var. *cristata* Prev., *Rosa centifolia* var. *muscosa* (Ait.) Ser.

24. *Rosa chinensis* Jacq. Chinese rose, pygmy rose, fairy rose. Non-indigenous rose from China, grown in Zone 7. Arkansas and Mississippi.

25. *Rosa cinnamomea* L. Cinnamomeae DC. Cinnamon rose. Non-indigenous rose from Eurasia; escaped in North America, Zone 5; Maine south to Virginia, northwest to Wisconsin.

26. ***Rosa x damascena* P. Mill. (*gallica* x *moschata*).** Damask rose. Introduced from Asia Minor; sporadic: New York, Michigan, Missouri and North Carolina. major source of attar of roses. Synonymy: *Rosa* x *bifera* (Poir.) Pers.

27. *Rosa* x *dulcissima* Lunell (pro sp.) (*blanda* x *woodsii*). Hybrid rose with native parents; Wisconsin and Iowa west to the Dakotas.

28. *Rosa dumetorum* Thuill. Corymb rose. Introduced from the Mediterranean region, Zone 6; Kentucky. Synonymy: *Rosa corymbifera* Borkh.

29. *Rosa eglanteria* L. Caninae DC.- Sweetbrier. Known locally as: sweetbrier. Naturalized from Europe into most of North America, Zone 6. Present in the CalFlora Database (California distribution map). Synonymy: *Rosa rubiginosa* L.

30. *Rosa foliolosa* Nutt. Ex. Torr. and Gray. (native). Known locally as leafy rose or white praire rose. Kansas and Arkansas to Texas, Zone 6. Synonymy: *Rosa ignota* Shinners.

31. *Rosa gallica* L. Gallincanae DC. French rose. Non-indigenous rose from Europe and west Asia; used to produce attar of roses. Naturalized in North America, Zone 6; Maine south to South Carolina west to Louisiana and Wisconsin.

32. *Rosa gallica* var. *gallica* L. Same distribution as *gallica*.

33. *Rosa gallica* var. *officinalis* Thory Missouri and Michigan.

34. *Rosa* x *harisonii* Rivers; also *Rosa* Harison's Yellow (*foetida* x *spinosissima*). A hybrid rose planted by the pioneers where they settled.

35. *Rosa* x *housei* Erlanson (pro sp.) (*acicularis* x *blanda*). A hybrid rose; New York, Michigan and Wisconsin.

36. *Rosa hugonis* Hemsl. Father Hugo's rose, golden rose of China. Non-indigenous rose from China. Cultivated in northeast North America.

37. *Rosa indica* L. Cyme rose. Non-indigenous rose from South Asia; escaped in Puerto Rico.

38. *Rosa laevigata* Michx. Cherokee rose. Non-indigenous rose from China; naturalized in southern United States, Zone 7; North Carolina south to Florida, west to Texas. State flower of Georgia. It has weedy propensities.

39. *Rosa majalis* J. Herrm. Double cinnamon rose. Non-indigenous rose from Europe. Southern New England west to Ohio and Wisconsin. Synonymy: *Rosa cinnamomea* sensu L. 1759, non 1753.

40. *Rosa manca* Greene. Mancos rose. Non-indigenous rose from Europe; Colorado, Utah and Arizona.

41. *Rosa micrantha* Borrer ex Sm. Caninae DC. Small-flower sweetbrier. Non-indigenous rose from Europe, naturalized in North America; most eastern states and the Pacific Northwest.

42. *Rosa moschata* J. Herrm. Musk rose. Non-indigenous rose from southern Europe, northern Africa and western Asia; naturalized in North America, Zone 7; Mississippi and Illinois.

43. *Rosa multiflora* Thunb. ex Murr. Synstylae DC. Multiflora rose, rambler rose. Non-indigenous rose from Japan, Korea and east China-All eastern states west to Texas, Nebraska and Minnesota; also in Washington and Oregon. Synonymy: *Rosa cathayensis* (Rehd. and Wilson) Bailey.

44. *Rosa nitida* Willd. Carolinae Crépin. (native). Shining rose. Newfoundland to Connecticut and Ohio, Zone 4.

45. *Rosa nutkana* K. Presl. (native). Nootka rose. Found from California to Alaska, northern Rocky Mountains.

46. *Rosa nutkana* var. *hispida* Fern. (native). Colorado north to Montana west to Nevada, Oregon and Washington. Synonymy: *Rosa anatonensis* St. John, *Rosa caeruleimontana* St. John, *Rosa jonesii* St. John, *Rosa macdougalii* Holz., *Rosa megalantha* G. N. Jones, *Rosa spaldingii* Crépin, *Rosa spaldingii* var. *alta* (Suksdorf) G. N. Jones, *Rosa spaldingii* var. *hispida* (Fern.) G. N. Jones, *Rosa spaldingii* var. *parkeri* (S. Wats.) St. John.

47. *Rosa nutkana* var. *muriculata* (Greene) G. N. Jones. (native); Washington, Oregon and California.

48. *Rosa nutkana* var. *nutkana* K. Presl. (native); Washington, Oregon, California, andWyoming. Synonymy: *Rosa durandii* Crépin

49. *Rosa nutkana* var. *setosa* G.N. Jones. (native); Washington and California.

50. *Rosa obtusiuscula* Rydberg. (native). Appalachian valley rose. Found in Tennessee.

51. *Rosa odorata* (Andr.) Sweet. Tea rose. Non-indigenous rose from China; one of the parents of tea roses. Found in Pennsylvania, Louisiana and Utah.

52. *Rosa* x *palustriformis* Rydb. (pro sp.) [*blanda* x *palustris*]. Hybrid rose with native parents; Maine to Wisconsin, south to Ohio.

53. *Rosa palustris* Marsh. Carolinae Crépin. (native) Swamp rose. A common native rose, found in marshy locations from Nova Scotia to Minnesota, south to Florida and Texas. Synonymy: *Rosa floridana* Rydb., *Rosa lancifolia* Small, *Rosa palustris* var. *dasistema* (Raf.) Palmer and Steyermark.

54. *Rosa* x *rehderiana* Blackb. [*chinensis* x *multiflora*]. Polyantha rose. A hybrid non-indigenous rose, similar to multiflora, but canes less than three feet, low and spreading. New York and Louisiana.

55. *Rosa rubrifolia* Vill. Red-leaf rose. Non-indigenous rose from central Europe; Zone 2; Illinois, Maine, Massachusetts, New York and South Carolina. Synonymy: *Rosa glauca* Pourret.

56. *Rosa* x *rudiuscula* Greene (pro sp.) (*arkansana* x *carolina*). Hybrid with native parents; Ohio to Oklahoma, north to Wisconsin.

57. *Rosa rugosa* Thunb. Cinnamomeae DC. Rugose rose. Non-indigenous rose from China and Japan; it has escaped along the northeast coast, especially in Maine and Long Island, New York. Commonly grown in gardens. Sometimes weedy.

58. *Rosa sempervirens* L. Evergreen rose. Non-indigenous rose from southern Europe, North Africa; Zone 7; escaped in Puerto Rico.

59. *Rosa serafinii* Viviani. Non-indigenous rose from the Mediterranean region; apparently has not escaped.

60. *Rosa setigera* Michaux. Synstylae DC. (native). Climbing rose, prairie rose. A common rose, found from Ontario to Kansas, south to Florida and Texas.

61. *Rosa setigera* var. *setigera* Michaux. (native). Synonymy: *Rosa setigera* var. *serena* Palmer and Steyermark. Same distribution as *setigera.*

62. *Rosa setigera* var. *tomentosa* Torr. and Gray. (native). Known locally in Texas as fuzzy rose. Same distribution as *setigera.*

63. *Rosa spinosissima* L. Pimpinellifoliae DC. Scotch rose. Non-indigenous rose from Europe; Found in Virginia and Tennessee west to Kansas, north to Wisconsin and Maine. Synonymy: *Rosa pimpinellifolia* L.

64. *Rosa spinosissima* var. *spithamea* S. Wats. Non-indigenous rose from Europe. Synonymy: *Rosa spithamea* var. *solitaria* Henderson

65. *Rosa stellata* Woot. (native). Desert rose. Found in New Mexico and southern Texas.

66. *Rosa stellata* ssp. *abyssa* A. Phillips. (native). Found in Arizona. Synonymy: *Rosa stellata* var. *abyssa* (A. Phillips) N. Holmgren

67. *Rosa stellata* ssp. *mirifica* (Greene) W. H. Lewis. (native). Known locally as desert rose; found in Texas and New Mexico.

68. *Rosa stellata* ssp. *mirifica* var. *erlansoniae* W. H. Lewis. (native). Found in Texas and New Mexico.

69. *Rosa stellata* ssp. *mirifica* var. *mirifica* (Greene) Cockerell. (native). Found in Texas and New Mexico. Synonymy: *Rosa mirifica* Greene.

70. *Rosa stellata* ssp. *stellata* Woot. (native). Found from Texas west to Arizona.

71. *Rosa tomentosa* Sm. Caninae DC. Whitewoolly rose. Non-indigenous rose from Europe and west Asia; apparently has not escaped. Synonymy: *Rosa tomentosa* var. *globulosa* Rouy.

72. *Rosa villosa* L. Apple rose. Non-indigenous rose from Europe and west Asia; apparently has not escaped. Fruit is eaten and used in drinks.

73. *Rosa virginiana* P. Mill. Caroninae Crépin. (native). Virginia rose. Newfoundland, south to upland Georgia, Alabama and Tennessee; west to Missouri and Illinois.

74. *Rosa virginiana* var. *lamprophylla* (Rydb.) Fern. (native). Found in Connecticut north to Maine.

75. *Rosa virginiana* var. *virginiana* P. Mill. (native). Same as *virginiana.*

76. *Rosa wichuraiana* Crépin. Synstylae DC. Memorial rose. Non-indigenous from east Asia; naturalized in North America, Zone 6, New York and Connecticut south to Florida and Mississippi west to Illinois.

77. *Rosa woodsii* Lindl. Cinnamomeae DC. (native). Wood's rose. A native rose found from western Ontario and Wisconsin to British Columbia, south to Nebraska, New Mexico, west Texas (mountains), and northern Mexico.

78. *Rosa woodsii* var. *glabrata* (Parish) Cole. (native). California. Synonymy: *Rosa mohavensis* Parish

79. *Rosa woodsii* var. *gratissima* (Greene) Cole. (native). California and Nevada. Synonymy: *Rosa gratissima* Greene

80. *Rosa woodsii* var. *ultramontana* (S. Wats.) Jepson. (native). Washington east to Montana south to New Mexico and California. Synonymy: *Rosa arizonica* Rydb., *Rosa arizonica* var. *granulifera* (Rydb.) Kearney and Peebles, *Rosa covillei* Greene, *Rosa lapwaiensis* St. John, *Rosa pecosensis* Cockerell, *Rosa ultramontana* (S. Wats.) Heller, *Rosa woodsii* ssp. *ultramontana* (S. Wats.) Taylor and MacBryde, *Rosa woodsii* var. *arizonica* (Rydb.) W. C. Martin and C. R. Hutchins, *Rosa woodsii* var. *granulifera* (Rydb.) W. C.Martin and C. R.Hutchins.

81. *Rosa woodsii* var. *woodsii* Lindl. (native). Montana south to New Mexico east to Texas and Wisconsin. Synonymy: *Rosa adenosepala* Woot. and Standl., *Rosa fendleri* Crépin, *Rosa hypoleuca* Woot. and Standl., *Rosa macounii* Greene, *Rosa neomexicana* Cockerell, *Rosa standleyi* Rydb., *Rosa terrens* Lunell, *Rosa woodsii* var. *adenosepala* (Woot. and Standl.) W. C. Martin and C. R. Hutchins, *Rosa woodsii* var. *fendleri* (Crépin) Rydb., *Rosa woodsii* var. *hypoleuca* (Woot. and Standl.) W. C. Martin and C. R. Hutchins, *Rosa woodsii* var. *macounii* (Greene) W. C. Martin and C. R. Hutchins.

82. *Rosa xanthina* Lindl. Hemsl. Non-indigenous rose from north China and Korea; Zone 6; South Carolina. Synonymy: *Rosa hugonis*

83. *Rosa yainacensis* Greene, (native). Cascade rose. Washington to California.

None of the above roses are known to be rare or endangered; many have ranges restricted to mountains, to the northern regions, to marshes, to deserts or to the west. Several introduced roses have become noxious weeds. The Macartney rose (*Rosa bracteata* Wendland) was imported into Texas from eastern Asia and has become a noxious weed along the Gulf Coast, infesting more than 500,000 acres of productive grasslands in 40 southeastern Texas counties (Scott, 1965). The Cherokee rose (*Rosa laevigata* Michaux), another introduced plant from China (however, the State Flower of Georgia), became a severe weed in the Black Belt region (several counties characterized by rich, dark soil) in central Alabama. Land covered by the weed in nine counties could have produced 1.5 million pounds of beef annually, if in productive pasture (Scott, 1965). *Rosa canina* L., a native of Europe and west Asia, has been introduced into most of the eastern United States; it is widely dispersed and occasionally found to be abundant, but has shown no weedy propensity in the east. The large hips of *R. canina* are valued by natural food enthusiasts. *Rosa eglanteria* L., another native of Europe has become widely dispersed in the United States; it is very weedy in New Zealand. *Rosa rugosa* Thunb., another non-indigenous rose from China, has been introduced throughout the eastern US; this species is commonly cultivated as an ornamental species rose; it has escaped and become abundant along the northeast coast, especially in Long Island, New York (Amrine, pers. observ., 2001) and Maine (Peck, 2001).

Common native roses in eastern North America include the prickly rose, *Rosa acicularis* Lindl. (in mountains and northern regions), the smooth rose (*Rosa blanda* Aiton), the prairie rose (*R. setigera*), the swamp rose (*Rosa palustris* Marsh), the Virginia rose (*R. virginiana*) and the pasture rose (*Rosa carolina* L.). None of these native roses have become weeds except in rare instances. Abundant natural controls and seed predators probably prevent them from becoming weeds. The introduced roses, *Rosa eglanteria* L., *R. canina*, and *R. rugosa*, all ornamental species, have escaped and are commonly found in many areas, but have not been observed to be significant weeds.

Related Species

Only the genus *Rosa* occurs in the tribe Roseae. The most closely related plants are members of the tribes Potentilleae (Sections Rubinae, Potentillinae, Dryadinae), Cercocarpaceae, Ulmariëae, and Sanguisorbeae. Thus, genera most closely related to *Rosa* are *Rubus* (blackberries, raspberries, brambles; probably more than 75 species occur in eastern North America), *Potentilla* (cinquefoil, 15 species), *Fragaria* (strawberries, five species), *Geum* (avens, 10 species), *Dryas* (mountain avens, two species in western North America), *Adenostema* (chamise, ribbonwood; two species in California), *Purshia* (antelope bush, two species in western North America), *Cercocarpus* (mountain mahogany, five species in western North America), *Alchemilla* (lady's mantle, parsley-piert; three to four naturalized species in eastern North America), *Agrimonia* (beggar-ticks, about 10 species in eastern North America), *Poterium* (burnet, one species naturalized in eastern North America) and *Filipendula* (meadowsweet, two or three native or naturalized species in eastern North America). Some of the *Rubus* are occasionally attacked by the rose stem girdler, *Agrilus aurichalceus aurichalceus* Redtenbacher; none of the other arthropods or diseases affecting multiflora rose, discussed herein, occur on any of these related plants.

HISTORY OF BIOLOGICAL CONTROL EFFORTS IN THE EASTERN UNITED STATES

Area of Origin of Weed

As mentioned above, *R. multiflora* originated in eastern Asia. It is native to Japan, Korea and northeast China and a wide variety of other deciduous-forest podzol areas of eastern Asia that are similar to those of the eastern United States (Good, 1964). It also occurs in similar areas of Europe.

Areas Surveyed for Natural Enemies and Natural Enemies Found

Hindal and Wong (1988) surveyed West Virginia for arthropods and diseases occuring on multiflora rose. They found several insects and diseases, of which the following were noted: the rose seed chalcid, *Megastigmus aculeatus* var. *nigroflavus* Hoffmeyer (Hymenoptera: Torymidae), introduced from Japan; a native raspberry cane borer, *Oberea bimaculata* Olivier (Coleoptera: Cerambycidae); a native tortricid hip borer, *Grapolita packerdi* Zeller (Lepidoptera: Tortricidae); a native powdery mildew (*Sphaerotheca* sp.); several native fungi that cause cankers (species of *Epicoccum, Leptosphaeria, Phoma,* and *Phomopsis*); and several introduced European stem gall forming species, from which bacteria were cultured that were similar to *Agrobacterium tumefasciens* (E. F. Sm. et Towns.) Conn. Of these, only the seed chalcid appeared to present any possibility of significant biological control. Mays and Kok (1988) found the seed chalcids in roses in Virginia, and Shaffer (1987) reported finding the seed chalcid in all counties of West Virginia that were surveyed as well as in Indiana, Kentucky, Maryland, Ohio, and Pennsylvania. To our knowledge, no surveys have been conducted for natural enemies of multiflora rose in eastern Asia. Consequently, surveys of natural enemies associated with this rose in its native range and compilation from the literature of its known natural enemies, both typical early steps of most plant biological control projects, have not been done.

Host Range Tests and Results

Results of host range tests for the eriophyid mite *Phyllocoptes fructiphilus* Keifer (vector of rose rosette disease [RRD]) and the rose rosette disease virus are given in Tables 1 through 3**.** Most native roses in the midatlantic region have been tested and can not be infected with RRD; all are excellent hosts for the mite. Most ornamental roses are capable of sustaining the mite and of being infected by RRD. Many cultivars are very susceptible to RRD and these are indicated in the tables in bold type. Only members of *Rosa* can be infected with RRD or serve as hosts for the mite. A large number of other rosaceous plants have been tested for RRD susceptibility and mite acceptance. All tests, including backgrafts to multiflora rose, have been negative. None of the other rosaceous plants support the mite. A number of grafted rosaceous plants have been grown at the West Virginia University Horticulture Farm since 1989; to date, none have shown any symptoms of RRD and backgrafts have been negative. The rose seed chalcid has only been found in seed from multiflora rose; apparently differences in the hips and/or times of flowering prevent the chalcid from successfully developing in seeds of other roses.

Releases Made

To our knowledge, no intentional releases were made of any of the insects, mites, or pathogens discussed in the following section; all are either native North American species or, as in the case of the rose stem girdler and the multiflora rose seed chalcid, were accidentally introduced. Rose rosette disease has been transmitted to target multiflora roses by grafting and by mite releases in Iowa and West Virginia (Amrine and Stasny, 1993; Epstein and Hill, 1994b, 1995b; Amrine *et al.,* 1995; Epstein, 1995; Epstein *et al.,* 1997). Because of the susceptibility of many ornamental roses to RRD and *P. fructiphilus* (Tables 1 and 3), this work has been opposed by the American Rose Society and by rosarians in general (Obrycki, 1995; Philley, 1995; Peck, 2001; Pagliai, pers. comm.). However, augmentation research has provided valuable information on the potential spread of RRD. Experi-

Table 1. Occurrence of Rose Rosette Disease in Species (italics) and Ornamental Roses (varieties in bold are very susceptible) (alphabetical by species or variety, *R.* ignored).

***Rosa* species or Cultivar**	**Citation**	**Location**	**Susceptible (S), Resistant (R) or Tolerant (T)**
Alba Maxima	**19**	**Manassas, Virginia**	**S**
American Pillar (Rambler)	**18**	**Alabama**	**S**
R. arkansana Porter = *suffulta* Greene	1, 7, 8, 9	Nebraska	T
R. banksiae Aiton	15	Georgia	S
Belle of Portugal (CL)	6	California	S
Bibi Mazoon (SH)	15	Tennessee	S
Black Jade (HT)	11	Missouri	S
Bonica	13, 17, 18	Iowa	R (mites)
Buff Beauty (hybrid musk)	**18**	**South Carolina**	**S**
Cara Mia (HT)	10	West Virginia	S
R. canina	1, 7, 8, 9, 10	Nebraska (1,7)	S
		Manitoba (1)	S
		California (8,9)	S
		Indiana (10)	S
Cherry Meidiland (SH)	15	Tennessee	S
Chicago Peace (HT)	11, 14	Missouri	S
Chrysler Imperial (HT)	11, 17	Missouri, Iowa	S
Climbers	7	Nebraska	S
Color Magic	13	Iowa	S
Comtessa de Cayla	15	Alabama	S
Constance Spry (climbing shr.)	**18**	**Georgia**	**S**
Crystalline (HT)	15	Tennessee	S
Double Delight (HT)	15	Tennessee	S
Dr. Huey (CL)	15	Tennessee	S
R. dumetorum Thuill (= *corymbifera* Borkh.)	7, 8, 9	Nebraska	S
R. eglanteria	1, 7, 8, 9	Nebraska	S
R. eglanteria stock w/ hybrids	1	Nebraska	S
English Perfume (HT)	15	Tennessee	S
Europeana (FL)	15	Tennessee	S

Table 1. Occurrence of Rose Rosette Disease in Species (italics) and Ornamental Roses (varieties in bold are very susceptible) (alphabetical by species or variety, *R.* ignored) (continued).

***Rosa* species or Cultivar**	**Citation**	**Location**	**Susceptible (S), Resistant (R) or Tolerant (T)**
Etna	**19**	**Manassas, Virginia**	**S**
First Prize (HT)	**15**	**Tennessee**	**S**
Florabundas	1, 15	Nebraska	S
Fourth of July	15	Georgia	S
Fragrant Cloud (HT)	11	Missouri	S
Francisco Juranville	15	Alabama	S
French Lace (G)	11, 14	Missouri	S
R. gallica L.	1	Nebraska	S
Garden Party (HT)	11, 14	Missouri	S
	15	Tennessee	S
Gertrude Jeckyl (SH)	**15**	**Tennessee**	**S**
Gold Medal (G)	11, 12, 14	Missouri	S
Graham Thomas (Engl. R.)	11, 14	Missouri	S
Grandifloras	1	Nebraska	S
Great Scott (HT)	18	West Virginia	S
Gros Choux d'Hollande	19	Manassas, Virginia	S
Henri Martin	19	Manassas, Virginia	S
R. hugonis Hemsl.	1, 7, 8, 9	Nebraska	S
		California	S
Hybrid Teas	1	Nebraska	S
Hybrid Musk	18	Georgia	S
Ipsilante-Gallica	15	Tennessee	S
Irresistable (M)	**15**	**Tennessee**	**S**
Jean Camiole (M)	1	Missouri	S
Jeanne LaJoie (C-MR)	18	West Virginia	S
Jennifer Heart (HT)	11	Missouri	S
Kathleen Harrop	19	Manassas, Virginia	S
Lady Banksia (species rose)	18	South Carolina	S
La Noblesse	19	Manassas, Virginia	S
Loving Touch (M)	11	Missouri	S
Lynn Anderson	15	Tennessee	S

Table 1. Occurrence of Rose Rosette Disease in Species (italics) and Ornamental Roses (varieties in bold are very susceptible) (alphabetical by species or variety, *R.* ignored) (continued).

***Rosa* species or Cultivar**	**Citation**	**Location**	**Susceptible (S), Resistant (R) or Tolerant (T)**
Maiden's Blush	**19**	**Manassas, Virginia**	**S**
Mme Alfred Carriere (noisette)	**18**	**Alabama**	**S**
Mary rose	15	Alabama	S
Mermaid	15	Alabama	S
Mons.Tillier	15	Texas	S
R. montezumae Hum. & Bonpl.	7,8	California	S
Mr. Lincoln (HT)	11,14	Missouri	S
R. multiflora Thunb.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 18	Arkansas (4)	S
		California (6,8,9)	S
		Georgia (18)	S
		Illinois (10)	**S**
		Indiana (10)	S
		Kentucky (10)	S
		Missouri (2,3)	S
		Nebraska (1,7)	S
		Oklahoma (2)	S
		Tennessee (15)	S
		Texas (15)	S
		West Virginia (10)	S
Napoleon	15	Alabama	S
New Dawn	15	Alabama	S
	19	Washington (D.C.)	S
***R. nutkana* Presl.**	**6**	**California**	**S**
R. odorata (Andr.) Sweet.	6	California	S
Old Blush Climber	15	Alabama	S
Old Fashioned Roses	7	Nebraska	S
Olympiad	14	California?	S

Table 1. Occurrence of Rose Rosette Disease in Species (italics) and Ornamental Roses (varieties in bold are very susceptible) (alphabetical by species or variety, *R.* ignored) (continued).

***Rosa* species or Cultivar**	**Citation**	**Location**	**Susceptible (S), Resistant (R) or Tolerant (T)**
Ornamental Roses	**2, 3, 4, 6, 15**	**Alabama (15)**	**S**
		Arkansas (4)	**S**
		California (6)	S
		Georgia (15)	S
		Kansas (2)	S
		Missouri (2, 3)	S
		Oklahoma (2)	S
		Tennessee	S
		Texas (15)	S
		Virginia (15)	S
Othello (Engl. Rose)	**11, 14**	**Missouri**	**S**
Peace	17	Iowa	S
Perfume Delight (HT)	15	Tennessee	S
Petite Orleanaise	19	Manassas, Virginia	S
Pink Peace (HT)	11, 14	Missouri	S
R. pisocarpa Gray	6	California	S
Properity	18	Georgia	S
Ragged Robin (China Rose)	6	California	S
Red Cascade (CM)	15	Georgia	S
Red Meidiland	13, 14	Missouri	S
Rina Hugo (HT)	15	Tennessee	S
Rose de Rescht (PT)	**15**	**Tennessee**	**S**
R. rubrifolia Vill.	6, 7, 8, 9	California (6-9)	S
		Wyoming (6)	S
Salet	19	Manassas, Virginia	S
Seven Sisters (hybrid multifl.)	15	Tennessee	S
Simply Irresistable (FL)	15	Tennessee	S
R. soulieana Crep.	1	Nebraska	S
R. spinosissima var. *altaica* (L.) Rehd.	1,8,9	Nebraska (1)	S
		California (8, 9)	S

Table 1. Occurrence of Rose Rosette Disease in Species (italics) and Ornamental Roses (varieties in bold are very susceptible) (alphabetical by species or variety, *R.* ignored) (continued).

***Rosa* species or Cultivar**	**Citation**	**Location**	**Susceptible (S), Resistant (R) or Tolerant (T)**
Starry Night (shrub rose)	**18**	**South Carolina**	**S**
Sun Flair (G)	**11,14**	**Missouri**	**S**
The Bishop	19	Manassas, Virginia	S
The Fairy (P)	15	Tennessee	S
The Squire (SH)	18	West Virginia	S
Turner's Crimson Rambler	15	Tennessee	S
Veteran's Honor (HT)	15	Tennessee	S
R. villosa L. (= R. *pomifera* J. Herrm.)	7, 8, 9	Nebraska (1, 7)	S
		California (8,9)	S
White Masterpiece (HT)	18	West Virginia	S
***R. wichurana* Crépin (RB)**	**15**	**Tennessee**	**S**
William Lobb	19	Manassas, Virginia	S
R. woodsii Lindl.	1,7,8,9	Nebraska (1, 7)	T
		California (8, 9)	S
R. woodsii var. *ultramontana* (Wats.) (= *R. gratissima* Greene)	5, 8, 9	California	S
Resistant Species, Varieties			
R. arkansana Porter	16	Iowa	R
R. blanda Aiton	16	Iowa	R
R. californica Cham. & Schon.	6	California	R
R. palustris Marsh.	10	West Virginia	R
R. setigera Michx.	10, 16	West Virg., Iowa	R
***R. spinosissima* L.**	**6, 7**	**Nebraska (7)**	**R**
		California (6)	R

Citations: 1) Allington *et al.*,1968, 2) Crowe, 1983, 3) Doudrick and Millikan, 1983, 4) Gergerich and Kim, 1983, 5) Keifer, 1966, 6) Thomas and Scott, 1953, 7) Viehmeyer, 1961, 8) Wagnon, 1966, 9) Wagnon, 1970, 10) Amrine *et al.*, 1995, 11) Finkes, 1991, 12) Worden, 1988, 13) Epstein and Hill, 1998, 14) Sauer, 2001, 15) Peck, 2001, 16) Epstein and Hill, 1994, 17) Epstein and Hill, 1999, , 18) Peck 2002, 19) Higgins 2001.

Abbreviations: CL = Large-flowered climber, CM = Climbing miniature, Engl. R. = English rose, FL = Floribunda, G = Grandiflora, HT = Hybrid Tea, M = Miniature, P = Pollyanna, PT = Portland rose, RB = Rambler, SH = Shrub; R = Resistant, S = Susceptible, T = Tolerant.

Table 2. List of Plants Tested for Susceptibility to Infection by Rose Rosette Disease.

Thomas & Scott, 1953	*Holodiscus discolor*	Cream Bush (grafting only)
	Fragaria chiloensis	Beach Strawberry
	Prunus ilicifolia	Holly-leaved Cherry
Doudrick, 1984	*Malus pumila*	Apple (grafting only)
	Prunus besseyi	Sandcherry
	P. persica atropurpurea	Peach
	P. serrulata	Japanese Cherry
	P. tomentosa	Nanking Cherry
	Pyrus communis	Pear
	Cydonia oblonga	Common Quince
	Gomphrena globosa	(Amaranthaceae)
	Vinca rosea	(Apocynaceae)
	Chenopodium quinoa	(Chenopodiaceae)
	Cucurbita pepo	(Cucurbitaceae)
	Cucuminus sativus	(Cucurbitaceae)
	Phaseolus vulgaris	(Leguminaceae)
	Vigna unguiculata	(Leguminaceae)
Amrine et al., 1990, 1995	*Malus x-domestica*	Apple
	P. persica atropurpurea	Peach
	Fragaria virginiana	Strawberry
(grafting and challenged with *P. fructiphilus* grown on RRD symptomatic *R. multiflora*)	*Rubus sp.*	Blackberry and Raspberry
	Sorbus americana	Mountain Ash
	Pyrus communis	Pear
	Prunus avium	Cherry
	Prunus communis	Plum
	Prunus serotina	Black Cherry
	Prunus armeniaca	Apricot

Results: NONE of the above plants were successfully infected with RRD; Amrine and Stasny (unpublished) showed that back grafts were negative.

Table 3. Rosaceous Pants Tested for host preference/acceptance by *Phyllocoptes fructiphilus* and *Phyllocoptes adalius*

Plant Species	Common Name	P. fructiphilus*	P. adalius*
COMMERCIAL FRUIT:			
Fragaria virginiana	**Strawberry**	**0**	**0**
Malus x-domestica	Apple	0	1
Prunus armeniaca	Apricot	0	1
P. avium	Cherry	1	1
P. domestica	Plum	0	0
P. persica	Peach	1	1
Pyrus communis	Pear	0	0
Rubus sp.	**Wild Blackberry**	**0**	**0**
Rubus sp.	Cultivated Blackberry	0	0
Rubus sp.	Wild Raspberry	0	0
ORNAMENTAL TREES:			
Prunus serotina	Black Cherry	0	1
Sorbus americana	Mountain Ash	0	1
SPECIES ROSES:			
Rosa bracteata	McCartney Rose	1	2
R. canina	Dog Rose	2	2
R. carolina	Pasture Rose	1	2
R. fendleri	Wild Rose-Midwest	2	2
R. multiflora	Multiflora Rose	2	2
R. palustris	**Swamp Rose**	**2**	**2**
R. setigera	Prairie Rose	2	2
R. woodsii	Mountain Rose	2	2
ORNAMENTAL ROSES:			
	'Cherish' (florabunda)	2	2
	'Climbing Blaze' (climbing rose)	2	2
	'Headliner' (hybrid tea)	2	2
	'Orange Sunblaze' (miniature)	2	2
	'Queen Elizabeth' (grandiflora)	2	2
	'Red Rascal' (shrub rose)	2	2

0- mites lived less than 3 days (unsuitable).
1- mites lived for a week without laying eggs (unsuitable).
2- mites laid eggs (suitable).

mental increase of the rose seed chalcid was successful in West Virginia; infestation increased in one season from 3.2 to 77.5% (see section on multifloral rose seed chalcid under Biology and Ecology of Key Natural Enemies).

BIOLOGY AND ECOLOGY OF KEY NATURAL ENEMIES

Four agents have been found in the United States that show potential for biological control of multiflora rose. These are a "virus" that causes rose rosette disease, an eriophyid mite (*P. fructiphilus*) that transmits this virus, a seed chalcid (*M. aculeatus* var. *nigroflavus*) that lays its eggs in rose hips and whose larvae feed on immature seeds, and a stem girdler (*Agrilus aurichalceus aurichalceus* Redtenbacher [Coleoptera: Buprestidae]) that kills multiflora rose canes.

Rose Rosette Disease and *Phyllocoptes fructiphilus* Keifer (Acari: Eriophyidae)

Rose rosette disease was first found in California, Wyoming, and Manitoba, Canada in 1941. It was found to occur on ornamental roses and on *Rosa woodsii* Lindl., the common rose in Rocky Mountain uplands and the western plains from Minnesota to British Columbia, south to California, Arizona, and Mexico (Liberty Hyde Bailey, 1976). Rose rosette disease produces symptoms in *R. woodsii* but does not kill the plant (Allington *et al.*, 1968). It was found in Nebraska in 1961 (Viehmeyer, 1961), in Kansas in 1976, in Missouri in 1978, and in Arkansas and Oklahoma in 1982 (Crowe, 1983). It was found in Kentucky and Indiana in 1986 (Hindal et al., 1988). Brown (1995) published a U.S. map showing RRD's known distribution as far east as Ohio, Pennsylvania, Tennessee, and West Virginia in 1994. This native pathogen has caused a fatal epidemic in *Rosa multiflora* from the Great Plains as far east as Berks County, Pennsylvania and Queen Annes County, Maryland, in the Delmarva peninsula (Fig. 2) (Amrine and Stasny, 1993; Epstein and Hill, 1995a, 1999).

Rose rosette disease is a mite-transmitted, graftable "virus" that produces fragments of double-stranded RNA in rose tissue (Frist, pers. comm.; Di *et al.,* 1990; Hill *et al.,* 1995). Various structures found in electron microscope micrographs have been tentatively identified as the agent (Gergerich and Kim, 1983), but none have been conclusively proven to be the agent. It has not yet been taxonomically characterized (Epstein and Hill, 1999). Symptoms of RRD in multiflora rose include red, purplish or dark green veinal pigmentation (Fig. 3); production of bright red lateral shoots (Fig. 4); enlarged stems and stipules; dense, yellowish, dwarfed foliage; and premature development of lateral buds producing many compact lateral branches forming "witches' brooms" (Figs. 5 and 6) (Amrine and Hindal, 1988; Epstein *et al,.* 1993; Epstein and Hill, 1999). Symptomatic canes are cold sensitive and usually die at temperatures below -10°C. Symptoms on ornamental roses include a yellow mosaic pattern on leaves, greatly increased thorniness of stems (Fig. 7), clumped and wrinkled foliage, and witches' brooms; however, the bright red lateral shoots and vein mosaic seen in multiflora rose do not usually occur except on a few varieties (Thomas and Scott, 1953; Allington *et al.,* 1968; Amrine and Hindal, 1988; Epstein *et al.,* 1993; Epstein and Hill, 1998, 1999,).

Rose rosette disease is transmitted by the eriophyid mite, *P. fructiphilus* (Figs. 8, 9, and 10), which develops in high numbers on shoots of RRD-infected multiflora roses and other rose species (Amrine *et al.*, 1988). *Phyllocoptes fructiphilus* was first described from *Rosa californica* Cham. et Schlechtend. in California by Keifer (1940). Since that date, it often has been found associated with RRD in roses throughout the United States (Amrine and Stasny, 1993; Epstein and Hill, 1994b; Epstein and Hill, 1995a, 1999; Amrine *et al.,* 1995; Amrine,1996). The mite often occurs in the absence of the virus, producing no visible symptoms on rose plants. It only develops on tender, rapidly growing tissue and is aerially disseminated (Zhao 2000). Doudrick (1984) and Doudrick et al. (1983) claimed that *Phyllocoptes fructiphilus* could not transmit RRD to multiflora roses. They conducted transmission tests by transferring mites from field collected symptomatic plants onto the foliage of greenhouse plants. Amrine *et al.* (1988) conducted transmission tests on large plants trimmed to the crown, transplanted to greenhouse mist beds and obtained 100% transmission in 17 days when mites were applied to the tips of new, rapidly growing shoots. These experiences show that transmission can be very difficult if mites are applied to older, slower growing plants; it also probably explains the slow rate of spread of RRD since 1989, since most of West Virginia has endured varying states of drought since that time. Return of moister conditions may result in more rapid spread of RRD.

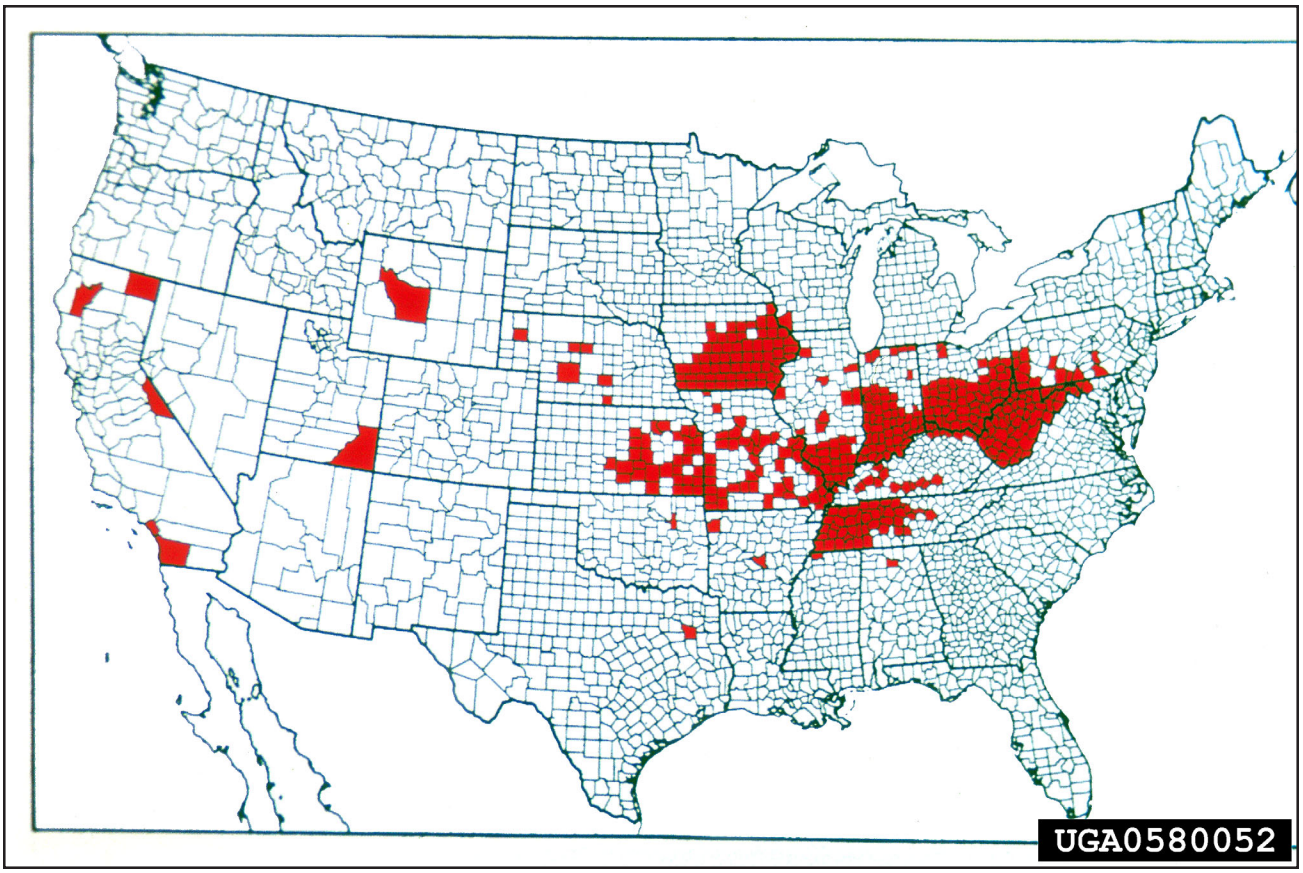

Figure 2. Map of the known distribution of Rose Rosette Disease in the USA; Virginia data from A. Boudoin (2002), J. Amrine, and A. Peck (2002); Maryland data from Tipping & Sindermann (2000), and J. Amrine; data for North Carolina, South Carolina and Georgia from A. Peck (2002).

Figure 3. Rose rosette; irregular reddening of leaf caused by RRD. (Photograph by Jim Amrine.)

Figure 4. Bright red RRD shoots emerging in the spring. (Photograph by Jim Amrine.)

Figure 5. Witches broom of RRD (yellow stems) on multiflora rose, heavily affected by powdery mildew. (Photograph by Jim Amrine.)

Figure 6. RRD-symptomatic inflorescence (red pannicle) on multiflora rose,accompanied by normal flowers on healthy foliage (a separate plant) (Photograph by Jim Amrine.)

Figure 7. Cara-Mia ornamental rose: diseased stem on left with an enlarged thorny stem; normal stem and flower on right (Photograph by Jim Amrine.)

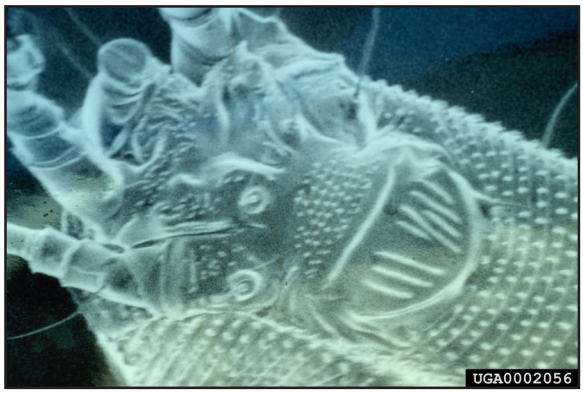

Figure 8. *Phyllocoptes fructiphilus,* ventral surface near head end as seen by the scanning electron microscope; the mite is about 50 microns wide at the genital coverflap. (Photograph by West Virginia University Anatomy Department.)

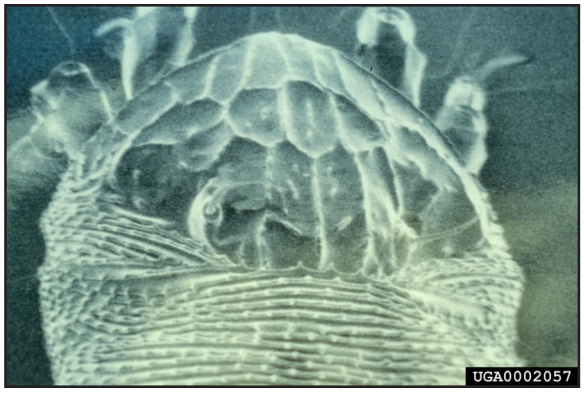

Figure 9. *Phyllocoptes fructiphilus,* dorsal shield of female showing the distinctive pattern that identifies this mite (SEM) (Photograph by West Virginia University Anatomy Department.)

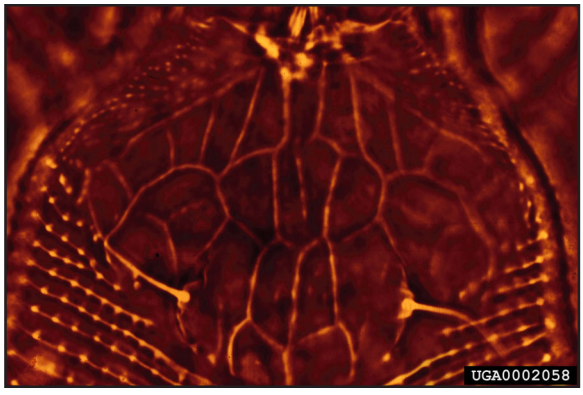

Figure 10. *Phyllocoptes fructiphilus,* dorsal shield of female as seen in the light microscope, using phase contrast microscopy. (Photograph by Jim Amrine.)

Phyllocoptes adalius Keifer is a mite very similar to *P. fructiphilus* and also occurs on many roses in the eastern United States; *P. adalius* occurs as a vagrant, usually on the underside of mature leaf blades of many species and varieties of roses. It has been thoroughly tested as a vector, but can not transmit RRD (Kharboutli, 1987; Kassar and Amrine, 1990; Amrine *et al.*, 1995). Rose rosette disease was first found in West Virginia in 1989, and spread throughout the state by 2000 (Brown and Amrine, unpub.). Several predators, a parasitic fungus, and drought appear to have affected field populations of *P. fructiphilus* in West Virginia and may have slowed the spread of RRD.

Rose rosette disease can also be transmitted by grafting, and experiments in Iowa have shown that this approach can be used to augment the virus in dense stands of multiflora rose (Epstein and Hill, 1994b; Epstein and Hill, 1995b, 1995d, 1998, 1999; Epstein *et al.,* 1997). Obrycki *et al.* (2001) are conducting new trials of RRD releases and augmentation in southern Iowa to reduce multiflora rose in pastureland. They indicate that releases will not be made in areas with ornamental roses. Much of this work has been opposed by the American Rose Society and by rosarians in general (Harwood, 1995; Obrycki, 1995; Philley, 1995; Peck, 2001; Sauer, 2001; Pagliai, pers. comm.). However, augmentation research by Epstein *et al.* has provided valuable information on the potential spread of RRD from multiflora to ornamental roses.

Mites overwinter as adult females on living, green rose tissue (Amrine and Hindal, 1988; Amrine *et al.,* 1995). In early spring, the mites move from wintering sites (clumps of overwintering foliage, loose bark on live stems, old or loose bud scales, etc.) onto developing shoots to lay eggs. A favorite oviposition site is between the stem and basal petiole of young leaves appressed to stems. Females live about 30 days and lay about one egg per day. Eggs hatch in three to four days and the development of each immature stage (protonymph and deutonymph) requires about two days (Kassar and Amrine, 1990; Kassar, 1992). Thus, in warm weather, one generation may be produced per week. Development is continuous throughout the season until weather turns cold in the fall and mites seek protective wintering sites on the plants. Overwintering mites will die if host canes die, as they require green stem or leaf tissue.

In May, 1987, Amrine *et al.* (1990) began a long-term study at Clifty Falls State Park in Madison, Indiana. The site was heavily infested with both healthy and RRD-symptomatic multiflora roses. A total of 180 multiflora rose plants were marked and visited monthly during the growing season for the next five years. The initial average density was 1,200 plants per acre and, at the beginning of the study, 30% of plants were symptomatic and 1% had been killed by RRD. The infection increased each year and leveled off to 94% by September 1991 with a mortality of 88%. The average longevity of infected plants was 22.4 months (range three to 48 months). Mite populations were 14 times larger on symptomatic plants compared to healthy plants in 1987 and 1988. Mite populations were low and sporadic in April and gradually increased to peak abundance by September in most years. At peak abundance, nearly all RRD-symptomatic plants (98%+) were infested with mites. The average number of mites per symptomatic shoot in September of each year (1987 to 90) was 112, 30, 112, and 6.6 respectively (mite density on healthy plants was usually below 10 per shoot). The low average number in 1988 (30) resulted from a severe drought that killed mites on desiccated foliage. The low fall density in 1990 (6.6) resulted from unusually cold weather in December 1989 (-31°C), which killed nearly all above ground RRD-symptomatic canes and thus killed most of the overwintering mites. By the end of the study (1994), 97% of the marked plants were dead or symptomatic and the density of live multiflora roses had dropped to about 800 per acre, many of which were new, small plants.

As of 2001, RRD was present in multiflora roses in all counties in West Virginia and was found as far east as Berks County, Pennyslvania, Queen Anne and Talbot Counties, Maryland and Manassas Battlefield, Virginia (Fig. 2**).** The disease is probably present in Delaware, New Jersey, New York, and other eastern states. It is likely that RRD will be present throughout the eastern United States within ten years. RRD will have a very significant effect on multiflora rose populations, potentially reducing numbers by 90% or more throughout the region. In each local area, the RRD epidemic is likely to continue until multiflora rose stands are killed. Young seedlings will then sprout and reach moderate size before RRD again reinfects the stand. In Madison, Indiana, for example, a survey in 1994 found that while more than 97% of

the original large plants had died of RRD, the infection rate of the abundant, newly sprouted plants was only 20 to 25%. The low percent infection rate reflects the slow build up of the infection in new plants. A visit to Clifty Falls State Park on 26 May 2002 revealed an estimated density of 200-400 multiflora roses per acre with an infestation of 60% RRD. Much of the original grassland has become early stage forest, which will shade future germinating seed and the resulting plants. As another example, RRD was first discovered in Monongalia County, West Virginia in 1989; as of July 2001, the average infection rate throughout the county was 10 to 20%. We expect to see infection rates equivalent to Madison, Indiana (30%) within five more years.

A serious limitation to the use of RRD as a biological control agent is its ability to infect ornamental roses. Many species and varieties of roses are susceptable to the vector and to RRD (Tables 1 and 3). However, other plants in the Rosaceae have been found to be immune to the RRD agent (Table 2). Rose breeders and gardeners throughout the eastern United States will need to reduce local stands of multiflora rose for a one or two mile radius in order to lower the risk of infestation by airborne mites, which transmit RRD. Thomas and Scott (1953), Allington *et al.* (1968), Amrine *et al.* (1995), and Epstein and Hill (1998, 1999) listed varieties and cultivars of ornamental roses that are particularly susceptible to RRD and its vector (also, see listings in bold type in Table 1). Avoiding planting of these varieties can help reduce injury to adjacent ornamental roses. Peck (2001) listed Cygon 2E (citing work by Dr. George Philley, Plant Pathologist, Texas A&M, Overton, Texas) as a treatment for protecting ornamental roses; other chemicals such as Avid (abamectin) may prove effective in controlling the mites. Thomas and Scott (1953), Allington *et al.* (1968), and Amrine *et al.* (1995) discussed varieties of roses resistant to RRD. This information can be used to incorporate resistance into new rose varieties.

Multiflora Rose Seed Chalcid, *Megastigmus aculeatus* var. *nigroflavus* Hoffmeyer (Hymenoptera: Torymidae)

The multiflora rose seed chalcid (*M. aculeatus* var. *nigroflavus*) is a light, yellowish-brown, small torymid (chalcidoid) wasp about 2 to 3 mm long (Fig. 11). It was reported in the United States from New Jersey in 1917, where it caused high mortality of multiflora rose seed imported from Japan for rootstock for ornamental roses (Weiss, 1917). Milliron (1949) reported that the rose seed chalcid was established in several mid-Atlantic states. Scott (1965) found large numbers of the rose seed chalcid at the Patuxent National Wildlife Refuge near Washington D.C. with infestation rates as high as 95%. Mays and Kok (1988) surveyed for the multiflora rose seed chalcid in Virginia in 1985 and 1986 and found average infestation rates of 26.5% (range of 2 to 59%) and 23.9% (range of 2 to 52%). Nalepa (1989) found the chalcid throughout North Carolina; with an average infestation rate of 63%. She also found two possible parasites of the seed chalcid in low numbers, *Eurytoma* sp. (Hymenoptera: Eurytomidae) (n=11) and *Eupelmus rosae* Ashmead (Hymenoptera: Eupelmidae) (n=4), out of 4,295 chalcids reared. Amrine and Stasny (1993) surveyed multiflora rose seed (Figs. 12 and 13) in West Virginia in 1984 and 1985 and found an average of 49.7% (range 0 to 100%) of viable seed infested with the chalcid. A survey of 16 sites from Maryland, Missouri, Oklahoma, Pennsylvania, Tennessee, Texas, and Virginia in 1984 to 1985 found an average infestation rate of 46.7 % (range of 0 to 95%).

The seed chalcid oviposits in the developing receptacle just after petal-fall in June (Fig. 14). Eggs hatch and larvae (Fig. 15) develop in the ovules beginning in mid-August, consuming and killing the seeds. Larvae mature in late September and enter diapause. In winter, larvae may die if exposed to temperatures below -20°C for 12 hours, and mortality reaches 20 to 80% if temperatures fall below -26°C for more than 24 hours. Seed chalcids in rose hips near the ground and in other protected sites survive low temperatures better than those in hips on exposed canes. Larvae in scattered seeds on the ground survive low winter temperatures if the ground is covered by snow. By late May, larvae transform to pupae. At about petal fall (early to mid-June in West Virginia), adult wasps chew their way out of the seed, emerge, mate and begin oviposition into immature rose hips. Most females are parthenogenic but will mate if males are available. The sex ratio was 0.5% males or about one male to 200 females.

Shaffer (1987) found that seed chalcids have limited ability to fly to newly established rose plantings. Most dispersal is by movement of infested seed by birds; seed chalcids rapidly pass the gut unharmed if

Figure 11. The multiflora rose seed chalcid, *Megastigmus aculeatus* var. *nigroflavus* Hoffmeyer; three females in a dissecting tray; the left female is about 2 mm long. (Photograph by Jim Amrine.)

Figure 12. Hypanthia or hips of multiflora rose. (Photograph by Jim Amrine.)

Figure 13. A dissected hip of multiflora rose: the *soft* fruit shell is on the right (typical of mid-November), five normal-sized seed are at the upper left, and three dwarf seed, representing unpollinated ovules at the lower left; note the abundant, sharply tapered fibers that are always present in the hip; they irritate the digestive tract of song birds, causing the seed to move quickly through the gut in just a few hours. (Photograph by Jim Amrine.)

Figure 14. Ovipositing female rose seed chalcid, inserting her ovipositor near the edge of the dried inflorescence. (Photograph by Jim Amrine.)

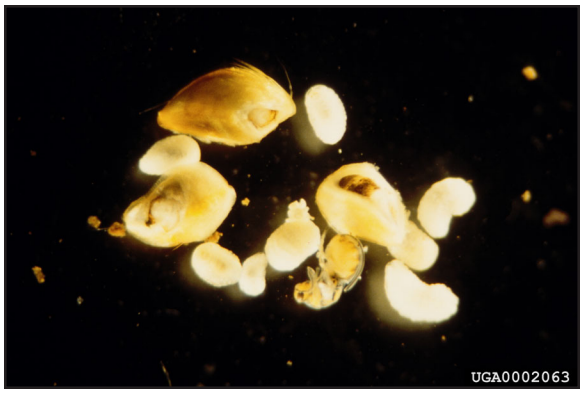

Figure 15. Dissected seeds showing larvae and a pupa of the chalcid that were inside (May). (Photograph by Jim Amrine.)

the seed are eaten by song birds such as robins and mockingbirds (Balduf, 1959; Lincoln, 1978; Nalepa, 1989, Amrine unpubl.). Multiflora roses planted in the eastern United States were set out as rooted cuttings, not planted from seeds. Thus chalcids were not disseminated when plants were initially established. Two or three decades are likely to be required, without active dissemination by humans, before the seed chalcid reaches all multiflora rose stands in the eastern United States.

Research suggests that the seed chalcid can quickly infest multiflora rose stands once it has reached them. For example, in 1988 two 30m rows of multiflora roses, each containing 50 plants, were set out as rooted cuttings in test plots in West Virginia. The plants first bloomed in 1989 and produced abundant seed in 1990 and 1991 (12 samples; 20 hips each produced an average of 125.3 seed per sample; 90.3% were viable). In November 1991, 3.2% (range of 0 to 14%) of seeds in the plot were infested with seed

chalcids. Multiflora roses growing within 500 m of the plot had an infestation rate of 74.1% (range of 64 to 79%). The seed chalcids likely had reached the new plantings in droppings of birds that fed on the hips produced in 1990. In fall 1991, numbers of seed chalcids in the plot were augmented by placing about 1,500 rose hips (average of seven seeds per hip), which had an infestation rate of 79%. In December 1992, the seed infestation rate in the plot reached 77.5% (20 samples; 20 hips each; range of 57 to 93%).

Suggestions that this seed chalcid will infest the seed of other roses seem unfounded. Torymid infestation of seeds of *R. setigera, R. palustris, R. carolina*, or *Rosa canina* L., in our study sites over the past 15 years have not been observed. Balduf (1959) reported rearing a dark form of *Megastigmus aculeatus* from *Rosa eglanteria* and *R. virginiana*; these were not reported to be *Megastigmus aculeatus* var. *nigroflavus* Hoffmeyer. Only *R. multiflora* seems to be susceptible, either because of timing of bloom (late May to early June for multifloras in West Virginia versus July for the others), or because the fruits of other roses are too large or thick for the chalcids' ovipositors to penetrate. Of 31 states in the eastern United States sampled by the author, the chalcid was found in all except Florida, Louisiana, Mississippi, Texas, and northern New England. It will continue to spread by feeding birds until all stands of multiflora roses are infested. Weiss's report (1917) about seed from Japan having 95% infestation indicates the probable potential for this seed chalcid to infest the seed of multiflora rose.

It is virtually certain that RRD will greatly reduce the density of multiflora rose. No multifloras have been found that are resistant to the disease (Amrine *et al.,* 1990, Amrine and Stasny,1993; Epstein and Hill, 1998). The reduced populations of multiflora rose remaining after the RRD epidemic are likely to be infested by the seed chalcid at the same rate (90 to 95%) as plants in Korea and Japan. Multiflora rose will then be another occasional plant in the environment, and not the noxious weed that it is today. We estimate that this scenario will transpire within the next three to five decades. Farmers and others wanting eradication of multiflora rose desire human intervention to increase the rate of spread of the disease, the mite and the torymid into uninfested areas. However, rosarians desire that all augmentation work with RRD and the mite cease.

Rose Stem Girdler, *Agrilus aurichalceus* Redtenbacher (Coleoptera: Buprestidae)

Synonyms for this species include *Agrilus viridis* L., *Agrilus viridis* var. *fagi* Ratz., *Agrilus communis* var. *rubicola* Abeille, *Agrilus rubicola* Abeille, and *Agrilus politus* Say. Many reports of this insect in *Rubus* (brambles) were made under the name *Agrilus ruficolis* (Fabricius), the red-necked cane borer, whose symptoms are nearly identical. The two beetles are distinctive and easily separated. This small brownish-golden, metallic buprestid beetle is about 5 to 9 mm long (Fig. 16). It is a non-indigenous species from Europe that has been established throughout eastern North America and is abundant at several sites in Delaware, Indiana, Maryland, Ohio, Pennsylvania, Virginia, and West Virginia. It caused a small degree of control of multiflora rose in Ohio and West Virginia (Amrine and Stasny, 1993). All plant tissue beyond the point where the stem is girdled was killed, including developing rose hips and seeds. Borers overwinter in the previous year's canes, pupate in April, and emerge as adults in May. Douglas and Cowles (2001) state that development may require two seasons, which is contrary to all other reports. Adults can be found on multiflora rose foliage in sunny mornings. Females oviposit on the bark of new canes in May and June. Larvae hatch and burrow under the bark, moving upward from the oviposition site (Fig. 17). The initial burrowing does not kill the cane but by late July the infested stems begin to wilt, and by August-September, canes beyond the girdle die and appear as brown "flags" on rose bushes (Figs. 18-19.)

The largest infestation we observed was a site with 20% of canes infested (Fayette County, Ohio, 1988). Large numbers of larvae were found to be parasitized; 22 parasitic wasps emerged from 45 canes held for the emergence of 23 beetles. These parasites were *Ptinobius magnificus* (Ashmead) (Pteromalidae)(determined by E. E. Grissell), *Eurytoma magdaldis* Ashmead (Eurytomidae) (new host record, determined by E. E. Grissell), *Leluthia astigma* (Ashmead) (Braconidae) (determined by P. M. Marsh), *Metapelma schwarzi* (Ashmead) (Eulophidae) (new host record, determined by M. E. Schauff), and *Tetrastichus agrili* Crawford (Eulophidae) (determined by M. E. Schauff). The last was most abundant. Because of relatively low inci-

Figure 16. The rose stem girdler, *Agrilus aurichalceus aurichalceus*; a mating pair on a multiflora rose leaflet (May); the male is the smaller, upper beetle. (Photograph by Jim Amrine.)

Figure 17. A girdled multiflora rose cane caused by the larva of the rose stem girdler (August); the oviposition site is at the right edge of the girdle; the cane will probably die distal to the girdle. (Photograph by Jim Amrine.)

Figure 18. A 'flag' or dead stem caused by the break of a cane at the girdle produced by the rose stem girdler (August) (Photograph by Jim Amrine.)

Figure 19. Close up of girdle and broken cane caused by the rose stem girldler. (photograph by Jim Amrine.)

dence and high parasitization, we believe that this insect will have only minor importance as a biological control agent of multiflora rose.

Amrine and Stasny (1993) found girdled rose stems on *Rosa multiflora* only. Douglas and Cowles (2001) report that it occurs on *R. rugosa* and *R. hugonis* in Connecticut. *Agrilus aurichalceus aurichalceus* often was found attacking canes of *Rubus* (blackberries, raspberries, brambles) (Hutson, 1932; Mundinger, 1941; Davis, 1963). Brussino and Scaramozzino (1982) reported it attacking *Rubus fruticosus* L., *Rubus caesius* L., and *Rosa idaeus* L. in Piedmont, Italy, where it also attacked *Rosa alpina* L., *R. canina*, *Rosa damascena* Mill., and *R. rugosa* . It has also been listed as attacking *Ribes, Grossularia, Crataegus*, and *Prunus* in North America and Europe (Garlick, 1940; Rejzek, 2001); however, these records are in error, and probably represent different species of *Agrilus* (Brussino and Scaramozzino, 1982).

EVALUATION OF PROJECT OUTCOMES

Establishment and Spread of Agents

All four agents have been well established in the eastern United States and should eventually be found in all dense stands of the weeds. Rose rosette disease and *Phyllocoptes fructiphilus* have been found as far east as Berks County, Pennsylvania, Queen Anne and Talbot Counties, Maryland, and Manassas Battlefield, Virginia. Careful surveys would probably find both agents as far east as New Jersey and southern New York. The rose seed chalcid has been found in 30 eastern states, and it probably is found in all regions where multiflora rose has become established. The rose stem girdler also is found in most areas of eastern North America and in Utah.

Suppression of Target Weed

Amrine *et al.* (1990) showed that RRD and *P. fructiphilus* have excellent potential to reduce multiflora rose. Rate of infection of 180 marked plants in Clifty Falls State Park increased from 30% in 1986 to 94% in 1990. Mortality of marked roses increased from 2% to 94% in the same period. However, germination by the vast seed burden replaces most roses killed by RRD. When seed chalcids significantly infest multiflora seed, then reduction will become apparent. This RRD epidemic has now reached equivalent levels in many parts of West Virginia, and it is expected that in the next decade, similar reduction of dense stands of multiflora rose will occur. The rate of infestation of the rose seed chalcid is increasing in all areas surveyed. In some areas of West Virginia, rates of seed infestation now exceed 80% (Amrine, unpub.).

Recovery of Native Plant Communities

In Clifty Falls State Park, multiflora rose was not replaced by native plant species, but by another invasive exotic plant, Japanese honeysuckle (*Lonicera japonica* Thunb.). This weed has covered nearly all of the old dead roses and has invaded nearly every part of the park (as of 1994). In many areas of West Virginia, multiflora rose has been replaced by the noxious weeds, Tatarian honeysuckle (*Lonicera tatarica* L.), autumn olive (*Elaeagnus umbellata* Thunb.), Japanese honeysuckle, and Japanese knotweed (*Polygonum cuspidatum* Siebold et Zucc.). If the alien invasive weeds can be controlled or eliminated, then native vegetation should recover.

Economic Benefits

Millions of dollars now spent annually by farmers in many eastern states to control multiflora rose will be saved when the plant is eventually controlled. In West Virginia, during 1980 and 1981, more than 36,500 hectares were heavily infested with multiflora and a ten-year eradication program using herbicides was estimated to cost more than $40 million (Williams and Hacker, 1982). The same or increased acreage is now infested, and allowing for inflation this cost has probably doubled. However, monetary savings will be slow to develop because of the slow natural spread of both the epidemic and biological control agents.

RECOMMENDATIONS FOR FUTURE WORK

Much work remains to be done to survey for the distribution and intensity of infection/infestation of RRD and *P. fructiphilus* in multiflora roses. The RRD epidemic in multiflora rose stands is expected to increase greatly over the next few decades. Studies and data are not available showing potential recovery of pastureland/farmland and savings involved; this work should be done in areas where significant mortality due to RRD has occurred (Missouri, Illinois, Indiana). Dense stands of multiflora rose will need to be controlled to prevent infection of ornamental roses with RRD. To quote R. Hartzler, "reduction of multiflora rose densities should be a common goal for rose growers and landowners" (Obrycki *et al.*, 2001). Horticulturalists need to breed RRD-tolerant or RRD-resistant roses (Zary, 1995). The rose seed chalcid, now found throughout the eastern United States, should be intentionally released in areas wherever infestation rates are below 50 to 60%. Risk to other rose species from this seed chalcid appears to be minimal, but host range studies should be conducted to confirm the chalcid¢s suspected high specificity. This insect's high potential to reduce seeding of multiflora rose justifies its increased distribution. Even if not deliberately spread, its range will increase by birds. Eventually, multiflora rose will be reduced to low levels, occurrence of RRD will become minimal, as in California, Wyoming and Utah, where it

originated, and problems for farmers and rosarians alike should be greatly reduced.

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I would like to dedicate this chapter to the memory of Professor Dale F. Hindal, West Virginia University Plant Pathologist, recently deceased. Our discussion of this possible research at a football brunch in 1985 began our work with multiflora rose, RRD, *Phyllocoptes fructiphilus*, and *Megastigmus nigroflavus.* His insights, humor, deep knowledge of plant pathology and entomology, and excellent teaching ability launched our adventures into this work. I also express my gratitude to the many acarologists, rosarians, plant pathologists, agronomists, and others who have shared important information regarding the mites, multiflora rose, the seed chalcid, the rose stem girdler and other arthropods discussed in this chapter. This work could not have been done without the expert assistance of my assistant, Terry Stasny. Much of our research was supported financially by the West Virginia Department of Agriculture; all of our research was conducted as part of Hatch Project 317, the Davis College of Agriculture, Forestry and Consumer Sciences, at West Virginia University.

REFERENCES

Allington, W. B., R. Staples, and G. Viehmeyer. 1968. Transmission of rose rosette virus by the eriophyid mite *Phyllocoptes fructiphilus*. *Journal of Economic Entomology* 61: 1137-1140.

Amrine, Jr., J. W., 1996. *Phyllocoptes fructiphilus* and biological control of multiflora rose, pp. 741-749. *In* Lindquist, E. E., M. W. Sabelis, and J. Bruin (eds.). *World Crop Pests, Vol. 6, Eriophyoid Mites: Their Biology, Natural enemies and Control.* Elsevier Science B.V., Amsterdam. The Netherlands.

Amrine, Jr., J. W. and D.F. Hindal. 1988. *Rose rosette: a fatal disease of multiflora rose*. Circular 147. West Virginia University. Agriculture and Forestry Experiment Station, Morgantown, West Virginia, USA.

Amrine, Jr., J. W. and T. A. Stasny. 1993. Biological control of multiflora rose, pp. 9-21. *In* McKnight, B. N. (ed.). *Biological Pollution.* Indiana Academy of Science, Indianapolis, Indiana, USA.

Amrine, Jr., J. W., D. F. Hindal, T. A. Stasny, R. L. Williams, and C. C. Coffman. 1988. Transmission of the rose rosette disease agent to *Rosa multiflora* Thunb. by *Phyllocoptes fructiphilus* Keifer (Acari:Eriophyidae). *Entomological News* 99(5): 239-252.

Amrine, Jr., J. W., D. F. Hindal, R. Williams, J. Appel, T. Stasny, and A. Kassar. 1990. Rose rosette as a biocontrol of multiflora rose. *Proceedings of the Southern Weed Science Society* 43: 316-319.

Amrine, Jr., J. W., A. Kassar, and T. Stasny. 1995. *Phyllocoptes fructiphilus* (Acari: Eriophyidae) the vector of rose rosette disease; taxonomy, biology and distribution, pp. 61-66. *In* Epstein, A.H. and J. H. Hill (eds.). *Proceedings, International Symposium: Rose Rosette and Other Eriophyid Mite-transmitted Disease Agents of Uncertain Etiology*. Iowa State University Press, Ames, Iowa, USA.

Balduf, W. V. 1959. Obligatory and facultative insects in rose hips. Their recognition and bionomics. *Illinois Biological Monograph* 16: 1-194.

Brown, T. 1994. United States distribution of rose rosette disease, pp. 53-56. *In* Epstein, A. and J. H. Hill (eds.). Proceedings of International Symposium "Rose Rosette and Other Eriophyid Mite-transmitted Plant Disease Agents of Uncertain Etiology," May 19-21, 1994. Iowa State University, Ames, Iowa, USA.

Brussino, G., and P. L. Scaramozzino. 1982. La presenza in Piemonte di Agrilus aurichalceus Redt. (Coleoptera Buprestidae) su lampone. *Informatore Fitopatologicao* 9-10 (1982): 55-58.

Chalamira, L. R. and L. D. Lawrence. 1984. *Agricultural research needs and priorities as perceived by West Virginia Vocational Agriculture Teachers and County agents.* West Virginia University Agricultural Experiment Station Miscellaneous Publication No. 11. Morgantown, West Virginia, USA.

Crowe, F. J. 1983. Witches' broom of rose: a new outbreak in several central states. *Plant Disease* 67: 544-546.

Davis, D. W. 1963. The control of the rose stem girdler on raspberries in Utah. *Journal of Economic Entomology* 56: 674-677.

Di, R., J. H. Hill, and A. H. Epstein. 1990. Disease-specific double-stranded RNA associated with the rose rosette disease of multiflora rose. *Plant Disease* 74: 56-58.

Doudrick, R. L. 1984. Etiological studies of rose rosette. M. S. thesis, University of Missouri, Columbus, Missouri, USA.

Doudrick, R. L. and D. F. Millikan. 1983. Some etiology and symptomological aspects of rose rosette. *Phytopathology* 73: 840, abstract.

Douglas , S. M. and R. S. Cowles (eds.). 2001. Plant Pest Handbook. Connecticut Agricultural Experiment Station, New Haven, Connecticut. http://www.caes.state.ct.us/PlantPestHandbookFiles/pphR/pphrose.htm (2001)

Dugan, R. F. 1960. *Multiflora rose in West Virginia*. West Virginia University Agriculture Experiment Station Miscellaneous Bulletin No. 447, Morgantown, West Virginia, USA.

Epstein, A. H. 1995. *Biological control of multiflora rose with rose rosette disease*. Pm-1615. Cooperative Extension Service, Iowa State University, Ames, Iowa, USA.

Epstein, A. H. and J. H. Hill. 1994a. Characteristics and control of rose rosette disease. *The American Rose Magazine* December issue, p. 22.

Epstein, A. H. and J. H. Hill. 1994b. Characterization of the rose rosette disease causal agent: potential for biological control of multiflora rose. *Leopold Center Progress Reports* 3: 33-36.

Epstein, A. H. and J. H. Hill. 1995a. Rose rosette disease - historical aspects and current status, pp. 47-51. *In* Epstein, A.H. and J. H. Hill (eds.). *Proceedings of the International Symposium: Rose Rosette and Other Eriophyid Mite-transmitted Disease Agents of Uncertain Etiology.* Iowa State University Press, Ames, Iowa, USA.

Epstein, A. H. and J. H. Hill. 1995b. Field augmentation of rose rosette disease: Results and risk assessment, pp. 71-73. *In* Epstein, A. H. and J. H. Hill (eds.). *Proceedings of the International Symposium: Rose Rosette and Other Eriophyid Mite-transmitted Disease Agents of Uncertain Etiology.* Iowa State University Press, Ames, Iowa, USA.

Epstein, A. H., and J. H. Hill. 1995c. Some physiological and structural changes observed in rose rosette infected plants, 67-69. *In* Epstein, A. H. and J. H. Hill (eds.). *Proceedings of the International Symposium: Rose Rosette and Other Eriophyid Mite-transmitted Disease Agents of Uncertain Etiology.* Iowa State University Press. Ames, Iowa, USA.

Epstein, A. H. and J. H. Hill. 1995d. The biology of rose rosette disease: A mite-associated disease of uncertain etiology. *Journal of Phytopathology* 143: 247-250.

Epstein, A. H. and J. H. Hill. 1997. Regional Research Project, S-268, Evaluation and Development of Plant Pathogens for Biological Control of Weeds, Annual Report. Auburn, Alabama, USA http://www.ag.auburn.edu/aaes/S268/s268rep_98.htm (2001).

Epstein, A. H. and J. H. Hill. 1998. Rose rosette disease. *The American Rose Magazine* February issue, pp 16-17.

Epstein, A. H. and J. H. Hill. 1999. Status of rose rosette disease as a biological control for multiflora rose. *Plant Disease* 83: 92-101.

Epstein, A. H., J. H. Hill, and J. J. Obrycki. 1993. *Rose rosette disease*. Iowa State University, University Extension Pamphlet PM-1532.

Epstein, A. H., J. H. Hill, and F. W. Nutter, Jr. 1997. Augmentation of rose rosette disease for the biocontrol of multiflora rose. *Weed Science* 45: 172-178.

Evans, J. E. 1983. A literature review of management practices for multiflora rose (*Rosa multiflora*). *Natural Areas Journal* 3: 6-15.

Fawcett, R. S. 1980. Today's weed—multiflora rose. *Weeds Today* 11: 22-23.

Garlick, W. G. 1940. Notes on the rose stem girdler, *Agrilus communis rubicola* AB. *The Canadian Entomologist* 72: 21-23.

Gergerich, R. C. And K. S. Kim. 1983. A description of the causal agent of rose rosette disease. *Arkansas Farm Research* 32: 7.

Good, R. 1964. *The Geography of the Flowering Plants,* 3rd ed. John Wiley and Sons, New York.

Harwood, C. 1995. Rose industry concerns regarding rose rosette disease. Pp. 79-80 *In*: Epstein, A., Hill, J. H. (eds.), Proc. Int. Symp. "Rose Rosette and Other Eriophyid Mite-transmitted Plant Disease Agents of Uncertain Etiology," May 19-21, Iowa State Univ., 82 pp.

Hill, J. H., A. H. Epstein, J. R. Seibel, and W. A. Miller. 1995. Causal agent of rose rosette disease, pp. 57-60. *In* Epstein, A.H. and J. H. Hill (eds.). *Proceedings of the International Symposium: Rose Rosette and Other Eriophyid Mite-transmitted Disease Agents of Uncertain Etiology.* Iowa State University Press, Ames, Iowa, USA.

Hindal, D. F., J. W. Amrine, R. L. Williams, and T. A. Stasny. 1988. Rose rosette disease on multiflora rose (*Rosa multiflora*) in Indiana and Kentucky. *Weed Technology* 2: 442-444.

Hindal, D. F. and S. M. Wong. 1988. Potential biocontrol of multiflora rose, *Rosa multiflora*. *Weed Technology* 2: 122-131.

Hutson, R. 1932. A new pest on raspberry. *Quarterly Bulletin of the Michigan Agricultural Experiment Station* 15(2): 68-70.

Kassar, A. 1992. A study of the biology of *Phyllocoptes fructiphilus* Keifer, and its ability to transmit rose rosette disease to multiflora rose, *Rosa multiflora* Thunb. Ph.D. dissertation, West Virginia University. Morgantown West Virginia, USA.

Kassar, A. and J. W. Amrine, Jr. 1990. Rearing and development of *Phyllocoptes fructiphilus*. *Entomological News* 101: 276-282.

Keifer, H. H. 1939. Eriophyid studies VII. *Bulletin of the California Department of Agriculture* 28:484-505.

Keifer, H. H. 1940. Eriophyid studies VIII. *Bulletin of the California Department of Agriculture* 29(1): 21-46.

Keifer H. H. 1966. Eriophyid studies B-21. Bureau of Entomology, California Department of Agriculture, Special Publication. Sacramento, California, USA.

Kharboutli, M. S. 1987. Eriophyid mites (Acari: Eriophyidae) on *Rosa multiflora* Thunb. in West Virginia and Rose Rosette Disease. M. S. thesis, West Virginia University, Morgantown, West Virginia, USA.

Klimstra, W. D. 1956. Problems in the use of multiflora rose. *Transactions of the Illinois Academy of Science* 48: 66-72.

Kriebel, R. C. 1987. *Plain ol' Charlie Deam: Pioneer Hoosier Botanist.* Purdue University Press, West Lafayette, Indiana, USA.

Liberty Hyde Bailey Hortorium. 1976. *Hortus Third, a Concise Dictionary of Plants Cultivated in the United States and Canada.* Macmillan Publishing Company, New York.

Lincoln, Jr., W. C. 1978. The effect of the digestive tract on the germination of multiflora rose seed. *Newsletter of the Association of Official Seed Analysts* 52(3): 23.

Lingenfelter, D. D. And W. S. Curran. 1995. *Multiflora rose management in grass pastures (an integrated approach)*. Agronomy Facts No. 46, Pennsylvania State College of Agricultural Sciences, Cooperative Extension. Pennsylvania State University, State College, Pennsylvania, USA.

Mays, W. T. and L.-K. Kok. 1988. Seed wasp on multiflora rose, *Rosa multiflora*, in Virginia. *Weed Technology* 2: 265-268.

Milliron, M. E. 1949. Taxonomic and biological investigations in the genus *Megastigmus. American Midland Naturalist* 41: 257-420.

Mundinger, F. G. 1941. Two buprestid cane-borers of brambles with experiments on control. *Journal of Economic Entomology* 34: 532-537.

Nalepa, C. A. 1989. Distribution of the rose seed chalcid *Megastimus aculeatus* var. *nigroflavus* Hoffmeyer (Hymenoptera: Torymidae) in North Carolina. *Journal of Entomological Science* 24: 413-416.

Obrycki, J. J. 1995. Conflicts of interest in weed biological control: lessons for Rose Rosette, pp. 75-76. *In* Epstein, A. H. and J. H. Hill (eds.). *Proceedings of the International Symposium: Rose Rosette and Other Eriophyid Mite-transmitted Disease Agents of Uncertain Etiology.* Iowa State University Press, Ames, Iowa, USA.

Obrycki, J. J., R. Hartzler, D. Frey, and S. Thompson. 2001. New project addresses multiflora rose infestations. ISU News Release, 5/9/01. Iowa State University, College of Agriculture, Ames, Iowa, USA.

Peck, A. 2001. Rose rosette: the early years. *Heritage Roses* 26(2): 5-7.

Peck, A., A. Boudoin, M. A. Hansen, J. W. Amrine. 1001. Recent spread of rose rosette disease in the southeastern U.S. Abstract of poster presentation.Annual Meeting, American Phytopathological Society, Williamsburg, VA, 13 March 2002 [in press].

Philley, G. L. 1995. Concerns of Extension. pp. 77-78. *In* Epstein, A. H. and J. H. Hill (eds.). *Proceedings of the International Symposium: Rose Rosette and Other Eriophyid Mite-transmitted Disease Agents of Uncertain Etiology.* Iowa State University Press, Ames, Iowa, USA.

Rehder, A. 1936. On the history of the introduction of woody plants into N. America. *National Horticultural Magazine* 15: 245-257.

Rejzek, Roman. 2001. Entomology. Prague, Czechoslovakia., *Agrilus aurichalceus aurichalceus* Redtenbacher, 1849: http://volny.cz/midge/buprcz/agaur.htm. (2001).

Sauer, R. 2001. Rose Rosette Disease Revisited. *Heritage Roses* 26(2):2-4 + map.

Scott, R. F. 1965. Problems of multiflora rose spread and control. *Transactions, 30th North American Wildlife and Natural Resources Conference* 30: 360-378.

Shaffer, D. F. 1987. A study of the biocontrol of *Rosa multiflora* Thunb. utilizing the rose-seed chalcid wasp *Megastigmus aculeatus* var. *nigroflavus* Hoffmeyer (Hymenoptera: Torymidae) in West Virginia. M. S. thesis, West Virginia University, Morgantown, West Virginia, USA.

Szafone, R. 1991. Vegetation management guidelines: multiflora rose (*Rosa multiflora* Thunb.). *Natural Areas Journal* 11: 215-216.

Thomas, E. A. and C. E. Scott. 1953. Rosette of rose. *Phytopathology* 43: 218-219.

Tipping, P. W., A. B. Sindermann. 2000. Disease Notes. Natural and augmented spread of rose rosette disease of multiflora rose in Maryland. *Plant Disease* 84 (11):1344.

Underwood, J. F., M. M. Loux, J. W. Amrine, Jr., and W. B. Bryan. 1996. *Multiflora rose control.* Ohio State University, Extension Bulletin No. 857. Columbus, Ohio, USA.

Underwood, J.F. and E.W. Stroube. 1986. *Multiflora rose control*. Ohio State University, Cooperative Extension Service Leaflet No. 303. Columbus, Ohio, USA.

Viehmeyer, G. 1961. A "new" disease of roses. *American Rose Annual* 46: 98-101.

Wagnon, H. K. 1966. Report of a new or unusual plant pathogen: Witches' Broom (Rosette of Rose). California Department of Agriculture, Plant Pathology A-66-11. Sacramento, California.

Wagnon, H. K. 1970. Report of new or unusual plant pathogen: Witches' Broom (Rosette of Rose). California Department of Agriculture, Plant Pathology A-66-11. Sacramento, California.

Weiss, H. B. 1917. *Megastigmus aculeatus* Swed., introduced into New Jersey from Japan. *Journal of Economic Entomology* 10: 448.

Williams, R. L. and J. D. Hacker. 1982. Control of multiflora rose in West Virginia. *Proceedings of the Northeast Weed Science Society* 36: 237.

Willis, J. C. 1985. *A Dictionary of the Flowering Plants and Ferns,* 8th ed. Cambridge University Press, Cambridge, United Kingdom.

Zary, K. W. 1995. Breeding for resistance to rose rosette. Pp. 81-82 *In:* Epstein, A., J. H. Hill (eds) Proc. Int. Symp. "Rose Rosette and Other Eriophyid Mite-transmitted Plant Disease Agents of Uncertain Etiology," May 19-21, Iowa State Univ., 82 pp.

Zhao, S. 2000. Study of dispersal and diversity of eriophyid mites (Acari: Eriophyoidea). Ph.D. dissertation, West Virginia University, Morgantown, West Virginia, USA.

SELECTED WEBSITES FOR MULTIFLORA ROSE

BONAP, Biota of North America Program, Texas A&M University Bioinformatics Working Group. Rosaceae: http://www.csdl.tamu.edu/FLORA/bonapfams/bonxxros.htm.

Calflora Database, Digital Library Project, University California Berkeley. http://elib.cs.berkeley.edu/calflora.

Douglas , S. M. and R. S. Cowles. (eds.). 2001. Plant Pest Handbook, Connecticut Agricultural Experiment Station, New Haven. http://www.caes.state.ct.us/PlantPestHandbookFiles/pphR/pphrose.htm.

Hortiplex. 2002. http://hortiplex.gardenweb.com/plants/

Illinois Department of Conservation, http://www.inhs.uiuc.edu/edu/VMG/mrose.html.

Invasive Plant Council of New York State, New York State Museum and the New York State Biodiversity Research Institute. http://www.nysm.nysed.gov/ipcnys/ipc_twentymf.html.

Lingenfelter, D. D. and W. S. Curran. 1995. Multiflora Rose Management in Grass Pastures (An Integrated Approach). Agronomy Facts 46, Cooperative Extension, Pennsylvania State University, State College, PA. Pennsylvania. http://pubs.cas.psu.edu/FreePubs/uc117.html. (2001)

Missouri Department of Conservation. http://www.conservation.state.mo.us/nathis/exotic/vegman/seventee.htm.

Nebraska. File G980: PLANT DISEASES, A-4, Ornamentals. http://www.ianr.unl.edu/pubs/PlantDisease/g980.htm

Peck, Anne. 2001. Rose Rosette, a web book. http://web.ntown.net/~apeck.

Roebuck, Field. 2001. Watch out for Rose Rosette. http://froebuck.home.texas.net/newpage2.htm.

Rejzek, Roman. 2001. Entomology. Prague, Czechoslovakia., *Agrilus aurichalceus aurichalceus* Redtenbacher, 1849: http://volny.cz/midge/buprcz/agaur.htm.

Synonymized Checklist of the Vascular Flora of the United States, Puerto Rico, and the Virgin Islands, 2001. http://www.csdl.tamu.edu/FLORA/b98/check98.htm.

Underwood, J. F., M. M. Loux, J. W. Amrine, Jr., and W. B.Bryan. 1996. Multiflora rose control. Ohio State University Extension Bulletin No. 857. http://www.ag.ohio-state.edu/~ohioline/b857/.

USDA, NRCS. 2001. The PLANTS Database, Version 3.1 (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Vascular Plant Image Gallery, Bioinformatics Working Group, Texas A & M University, College Station Texas.http://www.csdl.tamu.edu/FLORA/gallery.htm.

Virginia Native Plant Society. http://www.vnps.org/invasive/invmulti.htm.

Weeds Gone Wild, Alien Plant Invaders of Natural Areas, PCA Alien Plant Working Group, National Park Service, Washington, D.C. http://www.nps.gov/plants/alien/fact/romu1.htm.

Whitelaw, Mark. 2001. Landscape Consulting Services, Fort Worth, Texas. Rose Rosette Disease Confirmed in Texas? http://markw.com/rosette2.htm.

Wildflower Nirvana. http://www.wfnirvana.com/master.html; http://www.wfnirvana.com/prairie/rosacaro.html (*Rosa carolina*).

Wisconsin Department of Natural Resources: http://www.dnr.state.wi.us/org/land/er/invasive/factsheets/rose.htm.

West Virginia Extension Service, West Virginia University, Morgantown, West Virginia, Control of Autumn Olive, Multiflora Rose, and Tartarian Honeysuckle. http://www.caf.wvu.edu/~forage/5412.htm.