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A SAGEBRUSH WILT DISEASE OF UNKNOWN CAUSE

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Abstract.— A sagebrush wilt disease is causing severe damage to Forest Service uniform shrub garden plantings in Utah. Plants within most species of the section Tridentatae express disease symptoms and may die within several months. Varying degrees of susceptibility are evident within and between species. Modification of the soil environment through past agricultural use may dispose these wildland shrubs to associated potentially pathogenic fungi.

A sagebrush (*Artemisia* L.) disease of unknown cause is severely damaging USDA-Forest Service uniform shrub garden plantings at the Utah State University Snow Field Station at Ephraim, Utah. Although the disease is not known to occur in the wildland situation, it is important from at least two aspects. First, it renders growing and maintaining the uniform shrub gardens almost impossible. Second, decimation of selected population accessions greatly depletes the genetic base. Evaluation and selection of plants for desirable characteristics such as productivity, nutritional value, drought tolerance, winter hardiness, disease resistance, and so forth are thus on a less firm basis. Assemblage of plant materials in uniform plantings is the initial step in the Forest Service's wildland shrub improvement program. The program is a cooperative effort of the USDA-Forest Service, Utah State Division of Wildlife Resources, and Utah State University.

Artemisia is a major component of the vast western United States shrublands (Beetle 1960, McArthur and Plummer 1978). Among the members of this aggressive, diverse, and adaptable genus are species useful for restoring depleted ranges and disturbed landscapes (McArthur et al. 1974, Monsen 1975), for providing nutritious and palatable browse on western big game and livestock ranges (Plummer et al. 1968, Welch and McArthur 1979), and for habitat of numerous other forms of wildlife (McKell et al. 1972).

Materials and Methods

Assemblage of plants at the Snow Field Station began in the late 1960s and has continued to the present. The *Artemisia* selections were collected primarily from the Great Basin. Others were obtained from surrounding areas in Arizona, Colorado, Idaho, Utah, and Wyoming. Accession sources for the same species or subspecies, with few exceptions, were from different origins in each of the different years of planting. All entries of the same year were placed in the same section of the garden with those of subsequent years in adjoining sections. Entries were made as young wildling transplants. After initial watering to encourage establishment, no supplementary water was given. The plantings were cultivated to control weeds.

The number of plants established following transplant was determined at the end of the first season. Thereafter annual observations were made on plant development. The number of plants within each accession was highly variable because of transplant loss and the number available at the collection sites. Observations on disease development were not begun until 1974. The accession entries made from 1968 through 1971 appeared to be the most comparable and were selected for a disease survey in the fall of 1978. The number of plants surviving without advanced wilt symptoms was determined for each accession.

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The range in percentage survival was calculated from individual accessions within years and the mean percentage from a total of all accessions within species for each year. The total percentage survival representing accession totals for all years was totaled for each species. The more or less miscellaneous array of differing sources and numbers within and between species each year allowed only a general statistical comparison.

Results

Observations revealed the following general pattern of disease development. First symptoms of the disease usually occurred in late fall or early spring as wilted leaves and shoot tips (Fig. 1). By midsummer, portions (Fig. 2A) or entire plants (Fig. 2B) collapsed and died. The disease occurred in young well-established plants during their first season of growth and in plants one or more years old. In one planting, there was a high incidence of wilt and death of plants during the second season that subsided but continued to occur at a reduced rate in following years. Plants died out in patches (Fig. 3A), but more commonly there was a scattered pattern of dying (Fig. 3B).

Fig. 1. Wilt disease symptoms on *Artemisia tridentata*. Note wilted leaves and shoot tips (arrow).

A pronounced bluish green vascular discoloration, symptomatic of a *Verticillium*-induced disease of woody plants (Bedwell and Childs 1938, Caroselli 1957), was associated with some dying plants; however, the discoloration also occurred with non-wilted plants. Portions of the root systems of some wilt-diseased plants were necrotic, but death of plants did not seem to be associated with earlier advanced root rot or decay. It was not obvious where and how the disease was initiated in the plants. Usually, for example, when half the crown wilted and died, the corresponding portion of the root system was also found dead. Death from a vascular wilt pathogen rather than from winter injury appeared more probable because of the lack of a marked increase in rate or intensity of kill immediately following colder and drier winters and the typical wilt disease symptoms expressed by some plants during the first season planted.

All members of the section Tridentatae (see taxonomy in Beetle 1960, Beetle and Young 1965) exhibited symptoms except *A. pygmaea*, *A. longiloba*, *A. rigida*, and *A. spinescens* (Table 1). The latter three species were represented by only a few plants and therefore were not listed in Table 1. Species representing other sections of *Artemisia* did not express wilt symptoms and, except for *A. filifolia*, which was represented by only a small number of plants, survived to a relatively high degree compared to the Tridentatae in general. *Artemisia ludoviciana* and especially *A. abrotanum* seem to have suffered the least loss. Within the remaining Tridentatae, survival appeared to be the highest with *A. arbuscula* and *A. nova*, intermediate with *A. tridentata*, and lower with *A. bigelovii*, *A. cana*, and *A. tripartita*; the most severely affected was *A. rothrockii*. Within *A. tridentata*, which is of special interest to the project, ssp. *tridentata* (valley or basin big sagebrush) appeared to be somewhat less affected than ssp. *vaseyana* (mountain big sagebrush). The other subspecies, *wyomingensis* (Wyoming big sagebrush), probably cannot

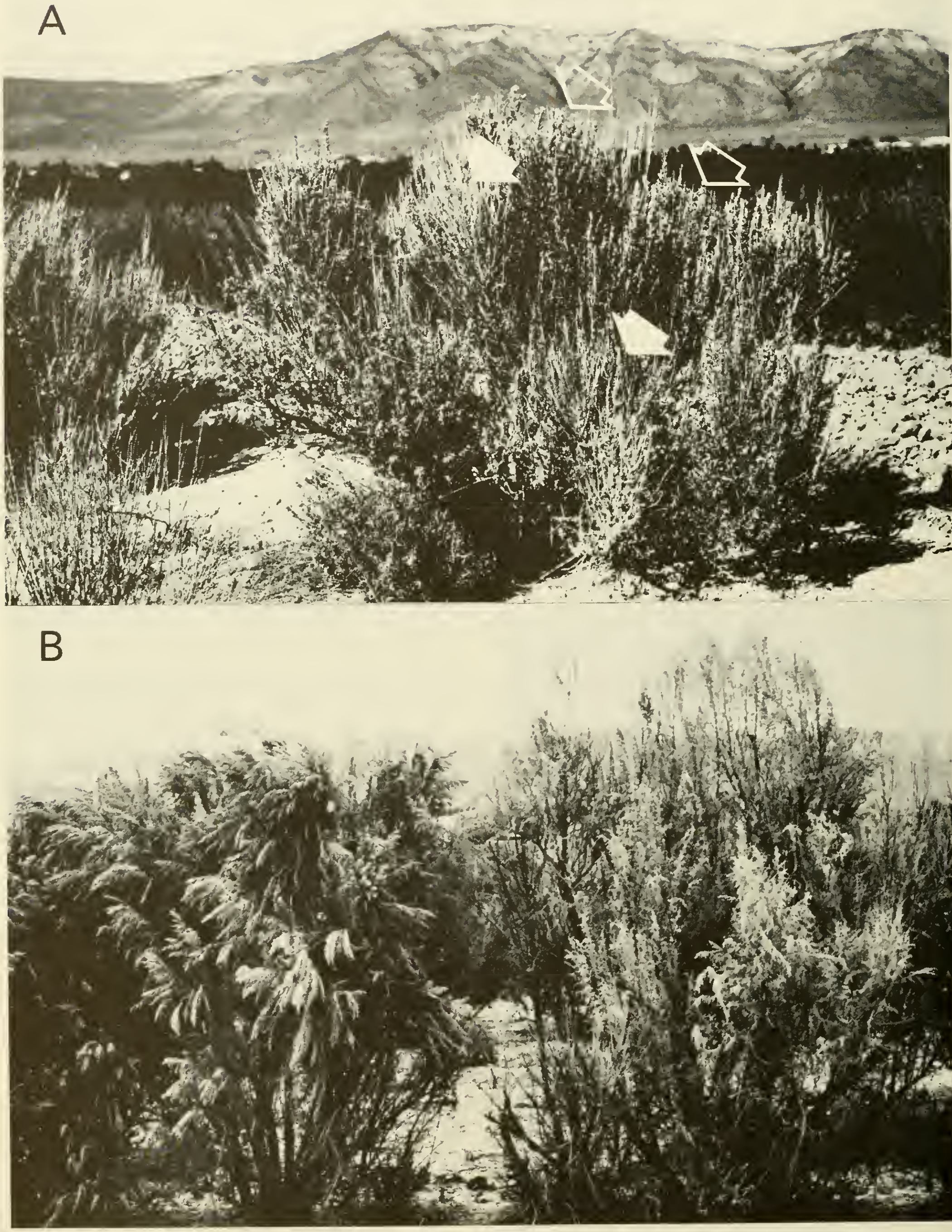

Fig. 2. Pattern of dying from wilt disease in individual plants. A, Partial death of A. *tridentata* ssp. *vaseyana*, Spring City, Utah, source. Open arrows mark living portions, closed arrows mark dead portions of plant. B, Death of entire plant on right occurred by midsummer. Dove Creek, Colorado, source of A. *tridentata* ssp. *tridentata*. Plants are about 2.5 m tall. Drooping appearance of plant on left is from heavy floral heads.

Fig. 3. Pattern of dying from wilt disease in shrub garden plantings. A, A patch of dying plants. Photo taken during third season of planting, Snow Field Station. B, Scattered death of plants of various accessions. Photo was taken during fourth season of planting, Snow Field Station.

be compared reliably because of the small number of plants. Accessions within most species appeared to vary markedly in survival rates (see "percent survival" ranges, Table 1), and there tended to be a continuous death with time (see survival amounts of plants established, 1969–1972, Table 1).

The annual loss of *A. tridentata* was followed in another planting established in 1975 in a different area of the Snow Field Station. Plants grew vigorously throughout the observation period. Starting from one-year-old seedling transplants, at the end of the first season ssp. *tridentata* averaged 55 cm (Dove Creek source 60 cm) and ssp. *wyomingensis* and ssp. *vaseyana* 34 cm in height. Readings were made each fall through 1978 on the number of plants expressing wilt symptoms and dying from the disease. The results are summarized in Table 2. Loss of plants through midsummer of the first season was attributed to transplant injury. September through November, plants began developing wilt symptoms, and most of these died early in spring 1976. After the second season, little additional death of the *A. tridentata* ssp. *tridentata* accessions occurred. With the other subspecies additional deaths occurred but in somewhat lesser amounts each year. By the end of the 1978 season only 58.8 percent of the three *A. tridentata* ssp. *vaseyana* accessions survived. Survival in *A. tridentata* ssp. *wyomingensis* and *A. tridentata* ssp. *tridentata* was 75.3 percent and 90.1 percent, respectively.

Discussion

Wilt disease symptoms were associated with most of the severe loss of plants recorded in Table 1. This loss cannot be attributed entirely to the disease since observations of the disease were not documented during early years of the plantings. In some accessions, especially with larger plant species, the spacing turned out to be too close and competition for water, light, and nutrients likely contributed directly to their death.

In its virgin state, the Snow Field Station area was a big sagebrush (*Artemisia tridentata*), black greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.), and bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn.

TABLE 1. Loss of *Artemisia* plants at the Ephraim shrub garden.

Artemisia species	Year established	No. of accessions	Number established	No. without wilt in 1978	Range and mean[a] survival (%)
SECTION TRIDENTATAE					
A. arbuscula Nutt.	1969	4	50	2	0.0 (4.0) 9.1
	1970	1	106	15	(14.2)
	1971	2	87	9	8.8 (10.3) 11.9
	1972	3	165	161	62.5 (97.6) 100.0
			408	187	45.8
A. bigelovii Gray	1970	5	203	9	0.0 (4.4) 7.7
	1971	4	54	2	0.0 (3.7) 18.2
	1972	4	82	29	0.0 (35.4) 52.8
			339	40	11.8
A. cana Pursh	1969	2	4	0	(0.0)
	1970	1	34	5	(14.7)
	1971	3	138	15	5.5 (10.9) 19.1
	1972	1	20	0	(0.0)
			196	20	10.2
A. nova Nelson	1969	6	120	16	0.0 (13.3) 37.5
	1970	4	76	19	15.2 (25.0) 28.6
	1971	9	171	100	0.0 (58.5) 100.0
	1972	4	238	121	0.0 (50.8) 80.8
			605	256	42.3
A. pygmaea Gray	1969	1	46	0	(0.0)
	1970	1	36	6	(16.7)
			82	6	7.3

[a]The three figures represent the range and mean (center) percentage survival of the individual accessions for each year. The "total" percentage survival is of the total number of plants for all years sampled.

Table 1 continued.

Artemisia species	Year established	No. of accessions	Number established	No. without wilt in 1978	Range and mean[a] survival (%)
A. *rothrockii* Gray	1969	2	196	12	1.5 (6.1) 15.9
			196	12	6.1
A. *tridentata* Nutt. ssp. *tridentata*	1969	13	283	35	0.0 (12.4) 53.3
	1970	3	50	11	0.0 (22.0) 25.6
	1971	9	352	155	0.0 (44.0) 64.0
	1972	2	17	2	0.0 (11.8) 20.0
			702	203	28.9
A. *tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle	1969	1	18	0	(0.0)
	1970	3	146	39	3.6 (26.7) 36.8
	1971	13	420	54	0.0 (12.9) 28.6
	1972	15	992	324	8.3 (32.7) 80.7
			1576	417	26.5
A. *tridentata* Nutt. ssp. *wyomingensis* Beetle & Young	1969	3	27	1	0.0 (3.7) 20.0
	1970	2	51	1	0.0 (2.0) 2.0
	1971	4	66	17	0.0 (25.8) 39.5
	1972	2	16	11	0.0 (68.8) 73.3
			160	30	18.8
A. *tripartita* Rydb.	1969	2	55	5	7.3 (9.1) 14.3
	1972	2	23	5	0.0 (21.7) 31.3
			78	10	12.8
OTHER SECTIONS					
A. *abrotanum* (Bess) Rydb.	1972	1	161	154	(95.7)
			161	154	95.7
A. *filifolia* Torr.	1971	2	9	1	0.0 (11.1) 16.7
	1972	1	8	3	(37.5)
			17	4	23.5
A. *frigida* Willd.	1969	1	6	0	(0.0)
	1970	2	73	6	3.2 (8.2) 36.4
	1971	4	128	80	0.0 (62.5) 89.9
	1972	1	32	17	(53.1)
			239	103	43.1
A. *ludoviciana* Nutt.	1970	2	64	31	44.4 (48.4) 51.4
	1971	2	49	48	83.3 (98.0) 100.0
			113	79	69.9

and Smith) site. The soil is a heavy alluvial clay derived from limestone parent material. Although the physical and mineral nutrient characteristics have probably been altered to some extent by agricultural use, these factors do not appear to be a major or direct cause of the disease. The majority of plant accessions in the gardens were made as wildling transplants and, after establishment, their growth in general was vigorous to exceptional.

Artemisia spp. are known to form vesicular-arbuscular mycorrhizal associations (Williams and Aldon 1976, Williams et al. 1974) and may also form ectomycorrhizae. Interference with or lack of their formation in the uniform shrub gardens could lead to a nutritional deficiency from lack of prôper nutrient adsorption (Voigt 1969). Some soil factors thought to influence formation of mycorrhizae include temperature, moisture, aeration, pH, organic and inorganic nutrients, fungal and plant exudates, and the rhizosphere biota (Slankis 1974). How the past agriculture may have altered these factors rela tive to *Artemisia* mycorrhizae is unknown.

TABLE 2. Death of *Artemisia tridentata* subspecies from the sagebrush wilt disease[a].

Subspecies	Accession source	No. planted spring 1975	No. surviving[b] 1975	1976	1977	1978	Survival[c] (%)
A. tridentata tridentata	Dove Creek, Colorado	100	87	82	80	78	89.7
A. tridentata tridentata	Bonanza, Utah	25	24	24	22	22	91.7
A. tridentata wyomingensis	Trough Springs, Nevada	75	73	68	60	55	75.3
A. tridentata vaseyana	Excel Canyon, Utah	132	131	84	80	79	60.3
A. tridentata vaseyana	South of Brigham Canyon, Utah	100	100	80	75	68	68.0
A. tridentata vaseyana	Hobble Creek, Utah	100	99	79	66	47	47.5

[a]Planting located at Snow Field Station.
[b]Number of plants surviving in the fall of each year.
[c]Percentage survival is of those plants surviving transplant in fall 1975.

The presence of mycorrhizae on sagebrush in the shrub gardens has not been determined, but growth of affected sagebrush was vigorous on the site prior to the disease, indicating a mycorrhizal presence or adequate nutrition in its absence. Even though nutrition and other growth factors appear to be adequate, lack of mycorrhizal formation may dispose the plants to disease through the lack of protection it may provide against pathogenic microorganisms (Zak 1964).

Sagebrush has a loose exfoliating outer bark, and older stems split easily, commonly separating at annual growth junctures. Sagebrush also has a low branching habit, with main branches commonly originating just above the root-stem transition zone. The lower branches split readily, adaxially, from the main stem. The bases of some lower branches die, apparently from shade suppression, and their decay extends to the heart of the main stem. These characteristics possibly dispose the plant to pathogens. During approximately 100 years of agricultural use, which was primarily for forage and grain crop production, the composition of soil microorganisms has undoubtedly changed and is artificial to the native *Artemisia* rhizosphere. Any soil-borne plant pathogens and resulting diseases confronting *Artemisia* in the plantings could very well be artifacts of the previous agriculture.

Exploratory isolation trials have yielded a multitude of microorganisms, including bacteria, fungi, and nematodes. Because surface sterilants do not contact saprophytic-type organisms within outer bark and other dead tissue, distinction of parasitic pathogens and saprophytes is confused during isolation attempts. Fungal species of the genus *Fusarium* and a verticillate *Gliocladium* were commonly isolated from living root and stem segments of diseased plants. *Sclerotinia* and *Rhizoctonia* were occasionally isolated from the upper root zone and the latter also was isolated from higher in the stems. Many soil-borne saprophytes and important parasitic plant pathogens exist within these genera (Walker 1969). Species of ordinarily saprophytic fungi such as *Alternaria*, *Ulocladium*, and *Cylindrocarpon* were commonly encountered. Isolation and inoculation studies are being made in an effort to establish the cause of the disease.

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