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NATURALIZATION AND HABITAT RELATIONSHIPS OF BITTER NIGHTSHADE (*SOLANUM DULCAMARA*) IN CENTRAL UTAH

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Abstract.— Ten plant communities containing bitter nightshade (*Solanum dulcamara*) were studied and the ecology and naturalizing relationships of bitter nightshade in central Utah area were investigated. Biotic and abiotic factors from each area were statistically analyzed. The data indicated that bitter nightshade was negatively correlated ($P < 0.01$) with perennial grass cover and positively correlated with tree overstory. Bitter nightshade reached its highest development in heavily shaded areas. No other habitat factors correlated with the presence of bitter nightshade. This lack of environmental constraints along with bitter nightshade's bright red fruits, which are readily consumed by birds, suggests possible reasons for the rapid and successful invasion of the plant into the Utah Lake area.

Bitter nightshade (*Solanum dulcamara* L.) is native to Europe, northern Africa, and eastern Asia (Crossley 1974) and was probably introduced into North America as a contaminant in crop seed used by early colonizers. Since its introduction to North America, bitter nightshade has become widespread and has invaded new areas with great success. The rapid spread of bitter nightshade may be attributed to its ornamental appeal and cultivation as an ornamental since 1561 (Crossley 1974). Also, bitter nightshade's red berries are eaten by both mammals and birds (Martin et al. 1961. Crossley (1974) writes, "The fresh berries are poisonous to most people and are fatal to rabbits, but some birds and wildlife eat them with impunity." Animals are probably the most effective method of dispersal for the plant's seeds in the wild.

Because it is an important source of aglycone solasodine, which is used in the production of steroid hormones, bitter nightshade has been intensively studied (Gatty-Kostyal et al. 1963, Gauhl 1975, Kuznetsoua and Khazanov 1973, Mathe 1974, Mathe and Mathe 1972, Mathe et al. 1975). Although several studies of bitter nightshade have focused on the environmental factors affecting the concentrations of alkaloids, few studies have been conducted concerning the naturalization and ecology of bitter nightshade. The few studies that have been conducted on bitter nightshade have been mainly in Hungary and Poland (Bernath and Tetenyu 1978, Clough et al. 1979, Gauhl 1975, Horvath et al. 1977, Nga et al. 1976). No reports are known from North America. Horvath et al. (1977) stated, "In spite of the fact that the natural occurrence of morphological and chemical taxons of this species have been analyzed in great detail, exact experiments to discover its relationship with the environment are hardly known."

The purpose of our study is to better understand the naturalization and ecology of bitter nightshade in central Utah.

Materials and Methods

Ten sites were selected depicting representative communities in central Utah in which bitter nightshade occurs (Fig. 1). At each site a 10 x 10 m study plot (0.01 ha) was established and 20 0.25 m^2 quadrats were placed at regular intervals across the plot. The study plots were delineated by a 40.0 m long cord with loops every 10 m for corners. The corners were secured by steel stakes. Variation in slope, drainage, erosion, and exposure were kept to a minimum. Density and frequency of all plant species encountered within the plots were determined from the quadrat data. Cover values were also estimated for each species as suggested by Daubenmire (1959).

Soils were sampled from the top 20 cm of the soil profile in each plot. Three samples

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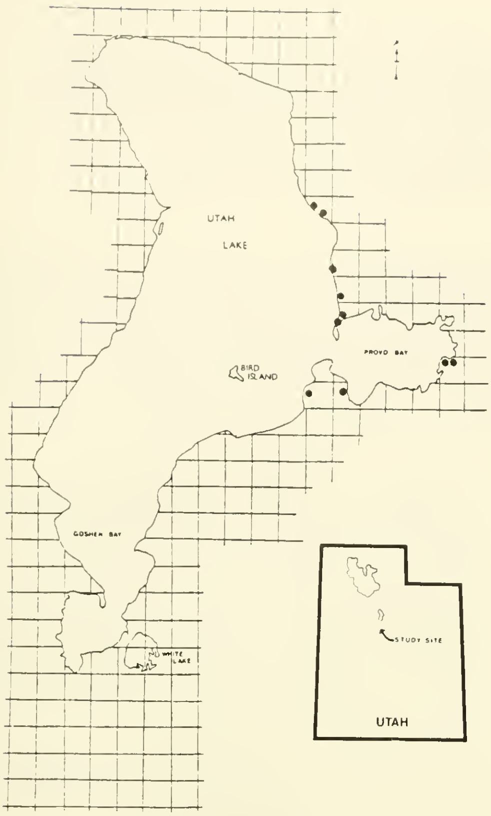

Fig. 1. Map showing the general locations of study sites in central Utah.

were taken from opposite corners and the center of each plot. Samples were pooled and analyzed for texture (Bouyoucos 1951), pH, soluble salts, and mineral content. The hydrogen ion concentration was measured with a glass electrode pH meter. Total soluble salts were determined with a Beckman electrical conductivity bridge. A paste consisting of a 1:1 g/v soil to water (distilled) mixture (Russel 1948) was used in determining pH and total soluble salts. Soil samples were also analyzed for total nitrogen (Brenner 1965), phosphorus (Olsen and Dean 1965), magnesium and calcium (Heald 1965), potassium and sodium (Pratt 1965a and Pratt 1965b), zinc, iron, copper, and manganese (Lindsay and Nowell 1969).

Cluster analysis (Sneath and Sokal 1969) was used to group the study sites which were similar with respect to species composition from the various microhabitats found within the community.

In addition to field studies, data were obtained from herbarium specimens obtained from seven college and university herbaria in Utah (Brigham Young University at Provo, University of Utah at Salt Lake City, Weber College at Ogden, Utah State University at Logan, College of Eastern Utah at Price, Dixie College at St. George, and Southern Utah State College at Cedar City). Data taken from the herbarium specimens included information on collection sites, habitat types, elevation, collection dates, and phenology. A dot map was constructed to show the distribution of bitter nightshade within the state of Utah.

The biotic and abiotic data were treated statistically by calculating the mean, standard deviation, and coefficient of variation for each factor. Simple correlation (Ott 1977) was used to determine significant relationships between percent cover of bitter nightshade and all other habitat factors. In addition, P x F (Presence x Frequency) (Anderson 1964, Curtis 1959) and Niche Breadth (Colwell and Futuyma 1971) indicies were computed for all species found in the study area to give an indication of that species importance in the community. A prevalent species list was then constructed (Warner and Harper 1972).

Results and Discussion

In a 1926 floral study of Utah Lake, bitter nightshade was not listed for any of the communities studied (Cottam 1926). However, our 1979 data shows that bitter nightshade makes up 37% of the average cover in the mixed deciduous woodlands around the lake (Fig. 1). Herbarium specimen data showed that 53% of the bitter nightshade specimens collected in the state were found at elevations between 4000 and 5000 feet with a total range in elevation from 4000 to 8000 feet. The distribution map (Fig. 2) for the state of Utah shows that the plant has spread mostly in the northern portion of the state, where the major wetlands of the region are also located. The plants collected in western Juab County and in Uintah County were located at the Fish Springs Bird Refuge and Ourey Wildlife Refuge, respectively (Fig. 2).

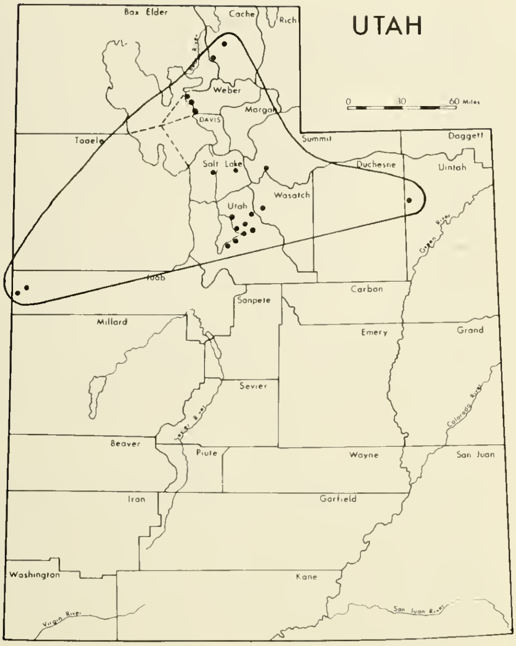

Fig. 2. Distribution of bitter nightshade in Utah based upon herbarium specimens.

Using cover data the average percent cover values for the major life forms of the communities invaded by bitter nightshade were tabulated (Table 1). As shown, total cover was very high with trees, perennial forbs and grasses making up over 90% of the ground cover. Of the 22% perennial forb cover, 89% is contributed by bitter nightshade.

Based upon a P x F Index, bitter nightshade ranked as the second most important species on the sites studied (Table 2). Bitter nightshade also had the greatest Niche Breadth of any species in the sampled community (Table 2). This would indicate that bitter nightshade is generally more adaptive than other species found growing with it.

Of the correlations between bitter nightshade cover and the biotic and abiotic factors, only the correlation between perennial grass cover and bitter nightshade cover was significant. The correlation of bitter nightshade cover to perennial grass cover gave an r value of -0.6518; the relationship was significant at the .05 level. A similar correlation between the most abundant perennial grass, quackgrass (*Agropyron repens* (L.) Beauv.), and bitter nightshade produced an r value of -0.8780, which is highly significant ($P < .001$) (Fig. 3). Quackgrass was found growing on sites that received a high incidence of sunlight, and bitter nightshade was found growing on the more shaded sites. Quackgrass apparently is more competitive than bitter nightshade on the sunny sites. It would appear that bitter nightshade is best adapted to shaded areas, although not entirely restricted to them, and quackgrass, which is less shade tolerant, does much better on the more sunny and open sites.

Most ecological studies of bitter nightshade focus on environmental factors affecting concentrations of alkaloids. Several studies deal with the effects of varying light quality and intensity on alkaloid production (Gauhl 1975, Kuznetsova 1971a, Kuznetsova 1971b, and Kuznetsova and Khagnov 1973). Gauhl (1975) for example, states that bitter nightshade exhibits great variation within the species for tolerance to varying light intensities. He also points out that plants selected from shaded habitats were damaged when exposed to high light intensities, but those selected from sunny habitats demonstrated an increase in photosynthesis and CO_2 uptake. Further, Clough

Table 1. Life forms within the mixed deciduous woodland communities heavily invaded by bitter nightshade in central Utah. Figures are in percentage cover.

Biotic factors	High	Low	Mean	Standard deviation	C.V.
Total cover	100.0	99.0	99.9	0.3	0.003
Trees	81.3	45.9	62.0	12.7	0.58
Perennial forbs	41.3	1.8	23.6	13.8	0.59
Annual forbs	19.0	1.0	6.2	6.2	1.00
Perennial grasses	39.9	0.2	8.1	13.9	1.72
Annual grasses	0.3	0.1	0.1	0.1	2.50
Shrubs	0.9	0.3	0.1	0.3	2.42
Diversity	7.7	2.3	4.9	2.1	0.42
Species/Stand	24.0	5.0	13.2	6.6	0.50

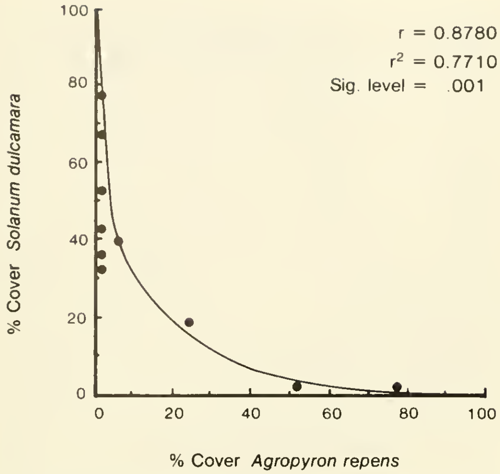

Fig. 3. Relationships existent between average percent cover of bitter nightshade and quackgrass.

et al. (1979) studied the growth performance and photosynthetic activity of bitter nightshade under a range of 12 environmental factors that simulated varying habitat conditions with respect to light intensity, moisture availability, and daily temperature amplitudes. They found no ecotypic differentiation with respect to the sun and shade environments from which the individuals were collected. All but one of the field-collected individuals was capable of successfully inhabiting a full range of light environments. We also found individuals of bitter nightshade inhabiting a full range of light environments, but it always contributed its greatest cover in the shaded areas.

Soil texture in the communities invaded by bitter nightshade (mixed deciduous woodlands) in central Utah were sandy clay loams. However, standard deviations for the percent sand, silt, and clay were highly variable, and therefore it was concluded that bitter nightshade is an opportunist that can grow and survive in a high diversity of soil textures (Table 3). Nga et al. (1976) also reported that microclimate played only a small role in the ability of bitter nightshade to inhabit a site. The soils also tended to be alkaline in nature and low in soluble salts and organic matter content (Table 3). Mineral content in the soils invaded were typical of the Utah Lake area. All measured minerals were found in sufficient quantities and were nonlimiting as far as the health and vigor of the vegetation was concerned (Table 4). Coefficients of variation (with exception of calcium) indicate a great deal of fluctuation in mineral concentrations across the sites studied.

Cluster analysis of the cover data (Fig. 4) revealed the following four groups: Group 1 consisting of sites 1, 6, 9, and 10; Group 2, sites 3 and 8; Group 3, sites 2 and 7; and Group 4, sites 4 and 5. The average percent cover of the major species found in the four groups was calculated and recorded (Table 5). As can be seen bitter nightshade is most abundant in Groups 1 and 2. These groups also have high corresponding tree cover. Groups 3 and 4 have the lowest percent of bitter nightshade and correspondingly less tree cover. It was assumed that the difference in relative cover of bitter nightshade in

Table 2. Prevalent species list for sites invaded by bitter nightshade in central Utah.

Species	P x F index	% Average frequency	% Average cover	Niche breadths
Salix amygdaloides	47.3	59.1	67.3	0.83
Solanum dulcamara	41.2	41.2	37.4	0.89
Atriplex triangularis	12.0	20.0	19.5	0.81
Populus deltoides	9.7	19.3	15.6	0.71
Agropyron repens	7.4	18.5	14.7	0.72
Conyza canadensis	3.3	6.5	12.5	0.56
Tamarix ramosissima	3.2	6.4	5.4	0.47
Salix fragilis	2.6	1.3	4.4	0.68
Cirsium arvense	2.3	4.5	3.9	0.74
Arctium minor	2.1	7.1	2.5	0.53
Xanthium strumarium	2.1	3.5	2.3	0.62
Polygonum coccineum	1.5	3.0	2.1	0.72
Lactuca serriola	1.3	4.4	1.8	0.67

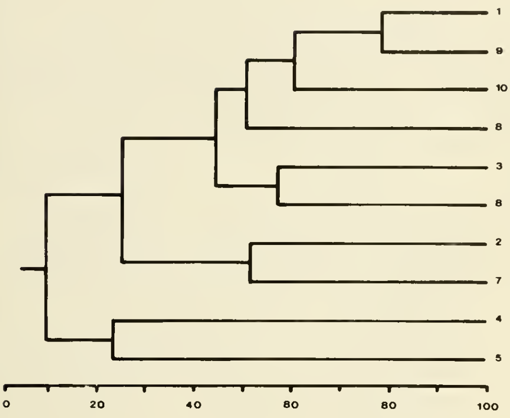

Fig. 4. Dendogram from cluster analysis showing the similarities among the 10 study sites.

Groups 1 and 2 when compared to Groups 3 and 4 was due to the high amount of tree cover and therefore less competition from perennial grass cover.

Areas of high bitter nightshade cover corresponded to areas of high overstory cover. Higher overstory generally indicates higher stem densities, and since bitter nightshade is a climbing vine, there is greater opportunity for bitter nightshade to use these stems for support. Conversely, high overstory values also indicate more shade and therefore less opportunity for the shade-intolerant grasses to compete. This should also help explain the negative relationships between the two plant types. Light intensity and extreme adaptability to varying environmental conditions seem to greatly influence the naturalization of bitter nightshade in the Utah Lake area. Light influence is also evident in the relationships represented by *Atriplex triangularis* (a shade-intolerant forb) since it increases in the understory as grass cover increases (Table 5).

We conclude that bitter nightshade naturalization is accelerated by the presence of favorable habitat (areas of high overstory cover and moist soil conditions) and a general lack of other biotic and abiotic constraints in areas of invasion. The only significant correlation of bitter nightshade cover was with perennial grasses, more specifically quackgrass. It is felt that the negative correlation between the two plants is best attributed to the fact that grasses are generally more drought tolerant and less shade tolerant than are forbs (Yake and Brotherson 1979). Also, the highly rhizomatous nature of quackgrass makes it very competitive once established.

Table 3. Measured soil factors of communities invaded by bitter nightshade along with their means, standard deviations, and coef. of variations.

Abiotic factors	High	Low	Mean	Standard deviation	C.V.
Sand	94.0	14.0	54.7	31.4	0.57
Silt	59.0	2.0	22.3	20.0	0.90
Clay	74.0	2.0	22.8	20.9	0.92
Fines (silt, clay)	86.0	4.0	45.1	31.7	0.70
Soluble salts (ppm)	3959.0	399.0	2240.0	1548.8	0.69
pH	8.5	7.5	8.0	0.4	0.04
Carbon	12.1	1.3	6.7	2.9	0.43

Table 4. Soil chemical factors from the communities invaded by bitter nightshade along with their means, standard deviations, and coefficients of variations.

Abiotic factors	High	Low	Mean	Standard deviation	C.V.
Phosphorous (ppm)	81.6	8.4	24.9	22.1	0.89
Nitrogen (ppm)	2480.0	190.0	1058.7	710.4	0.67
Calcium (ppm)	14800.0	4275.0	9852.5	2865.7	0.29
Magnesium (ppm)	2850.0	204.0	1038.9	826.2	0.80
Potassium (ppm)	270.0	39.0	166.7	144.0	0.86
Sodium (ppm)	1625.0	98.0	522.8	455.3	0.85
Iron (ppm)	210.0	7.6	80.6	65.1	0.81
Manganese (ppm)	13.2	2.3	7.9	4.0	0.50
Zinc (ppm)	76.8	0.9	14.0	22.7	1.62
Copper (ppm)	39.4	0.2	5.1	12.2	2.39

TABLE 5. Average cover by species within the four groups designated in the cluster analysis.

	Groups from cluster analysis			
	1	2	3	4
Acer negundo	0.0	0.0	0.4	0.0
Agropyron repens	19.6	0.0	49.8	28.4
Ambrosia artemisifolia	0.0	0.1	0.0	2.8
Arctium minus	0.0	1.6	0.1	25.2
Atriplex triangularis	0.1	0.5	22.7	39.1
Cardaria draba	0.0	0.0	1.4	1.3
Cirsium arvense	0.0	7.8	0.0	3.5
Convolvulus sepium	0.7	0.4	0.0	0.0
Conyza canadensis	0.0	17.4	4.0	0.4
Distichlis spicata var. *stricta*	0.0	0.0	9.0	0.0
Fraxinus pennsylvanica	0.0	0.0	0.0	7.9
Galium trifidum	0.0	0.0	1.3	0.0
Lactucca serriola	0.0	0.0	4.5	2.8
Lycopus lucidus	0.2	3.0	0.0	0.0
Mulhenbergia asperifolia	0.0	0.0	1.3	0.0
Nepeta cataria	0.0	0.0	0.0	1.3
Phalaris arundinacea	0.0	0.0	2.7	0.4
Polygonum coccineum	1.5	6.2	0.0	1.3
Populus deltiodes	7.3	43.2	4.5	35.2
Rumex sp.	1.2	0.0	0.0	0.0
Salix amygdaliodes	95.8	65.9	79.1	0.0
Salix exigua	0.0	0.0	0.4	1.4
Salix fagilis	0.0	0.0	0.0	73.6
Solanum dulcamara	35.5	45.4	10.9	20.8
Sonchus asper	0.0	0.0	0.0	4.7
Tamarix ramosissima	0.4	0.4	18.5	0.0
Urtica dioica	0.8	8.5	0.0	0.0
Xanthium strumarium	0.9	6.0	0.1	0.8

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