Some Characteristics of Soils and Associated Vegetation Infested with Halogeton[1]

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Among the important problems in the entry of an exotic plant into a new area, whether it be for economic use or as an undesirable migrant, are its adaptability and the range of its adaptability in its new environment. Equally important is the synecology of the plant: its relations with other introduced and endemic vegetation and its position in the plant community where its ability to persist and reproduce will ultimately be stabilized.

Principles and theories concerning the geographic distribution of plants have been advanced and investigated for many years (4, 10, 11, 14, 19). An effort has been made to bring these studies together by Cain (7) and a statement of factors in plant ecology reduced to a mathematical expression of relations has been proposed by Major (13).

Specific attempts have been made to relate distribution of vegetation to the effects of individual environmental factors. Likewise, the use of plant indicators as a guide to environmental characteristics of a given site has been investigated a number of times, and the status of the approach was evaluated by Sampson (20) in 1939.

Effects and limitations of the edaphic factor of environment were dealt with from a theoretical viewpoint by Mason (15, 16). Studies on the relations between vegetation and soil characteristics have been emphasized in the Western States because of the salinity and alkali problems which have occurred with utilization of arid lands. Kearney *et al.* (12) published the results of one such study in 1914. Among subsequent investigations are those of Shantz and Piemeisel in 1924 and 1940 (22, 23) and of Shantz in 1925 (21). More recent investigations have been made by Billings (1, 2, 3), Fireman and Hayward (8) and Gates *et al.* (10).

It has generally been found that the highest pH and salinity conditions occur in the "flats" occupied by greasewood (*Sarcobatus vermiculatus*) and Nuttal's saltbush (*Atriplex nuttallii*), and that the lowest pH and salinity are found in areas of big sagebrush (*Artemisia tridentata*). The pH and salt content of soils occupied by shadscale (*Atriplex confertifolia*) have generally been intermediate between those of big sagebrush and greasewood.

It was apparent in comparing results of the investigations previously mentioned that each species and association had a rather broad range of tolerance for variations in edaphic factors and that the soils were extremely variable and heterogeneous. The modification of edaphic factors by existing vegetation (17) and local climatic conditions may have been considerable. The extent of changes in soil characteristics which have accompanied the changes in vegetation in Utah and Nevada in the last century is not known. Changes were noted (18, 25) more than 50 years ago, however, and those changes have been in the direction of worthless perennials, annual grasses and forbs on the one hand and loss of topsoil and accelerated soil erosion on the other.

Among those weedy annual invaders has been one of conspicuous note, *Halogeton glomeratus*. Following discovery of its poisonous properties in 1942 (9), it received widespread and immediate attention as a result of some sensational losses of sheep ingesting lethal quantities. At present, halogeton infests in varying degrees an estimated 11 million acres in the states of California, Colorado, Idaho, Oregon, Montana, Nevada, Utah and Wyoming. The area of infestation still appears to be increasing.

A study of the soils occupied by halogeton and some aspects of the vegetation endemic to those soils in Nevada and on the perimeter of the infestation was begun in 1954 as a part of an ecological investigation of the plant. The data presented here are the results of a study dealing with soils in particular and the vegetation in general. The climatic requirements and responses of halogeton and its more detailed relations with the associated vegetation are still under investigation.

Methods and Materials

Nevada was arbitrarily divided into seven regions, and an effort was made to collect the same number of soil samples from each of six vegetation associ-

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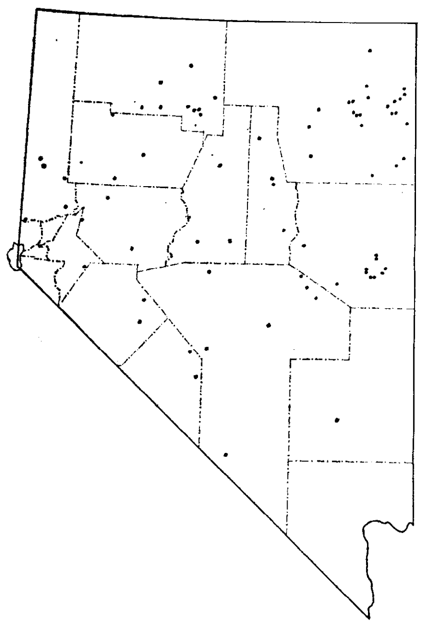

FIGURE 1. Sites in Nevada where soil samples and notes on vegetation were taken. Halogeton occurred or had occurred at all sites.

ations in each of the six regions where halogeton had been found. It had not been found in the seventh region, which included the southern desert shrub type of southern Nevada. In practice, the proposed procedure could not readily be followed since the native vegetation and halogeton were not uniformly distributed throughout the regions set up. The procedure was then modified to take samples of the soils where an important vegetation change occurred as well as from the vegetation associations ocurring in each region. A prerequisite of all sampling was that halogeton should occur on the sampling site.

It is characteristic of halogeton to occupy the soils of disturbed areas, as one would expect of a ruderal plant. These areas are amply provided by usual yearly "blading" of road shoulders and barrow pits by highway maintenance graders. These areas also occur in gravel pits, water courses and drainage ditches, and on stock trails and bed grounds. Spots of pronounced soil disturbance were avoided in this investigation, however, and samples were taken from adjacent sites.

The sampling sites in Nevada are shown in Figure 1. Areas of ecotones, and especially of alternes, are easily recognized by the clustered dots. In all sites sampled, halogeton occurred either as a general infestation or as an isolated spot. Vegetation associations or faciations arranged in order of the frequency of sampling were shadscale, sagebrush, greasewood, winterfat, juniper and Nuttall's saltbush. The area occupied by halogeton in 1957 included most of the Great Basin, in which the vegetation was predominantly of the Basin sagebrush formation.

The sampling was also done outside of Nevada in 1955 to the then existing perimeter of the area occupied by halogeton. This included most of Utah, western Colorado, the western part of Wyoming, the northern tip of the Bighorn Basin in southern Montana, the southern third of Idaho, the northeast corner of California east of the Sierra Nevada, and Oregon on the Nevada-Oregon boundary near Denio, Nevada.

On the northeastern edge of the perimeter in Montana, halogeton was found on a bed ground in a depleted stand of blue grama (*Bouteloua gracilis*). It was in a shadscale association in western Colorado on its eastern boundary and the same association had also been invaded on the southernmost extension of its area in southwest Utah. It was in both sagebrush and shadscale vegetation on its western edge. In the higher elevations, it entered into juniper-sagebrush associations. None was found in montane or sub-alpine vegetation.

Soil samples were taken at 0-6 inches and 6-18 inches, and the classification was made by screening out the gravel with a 1-mm. sieve. The texture of the remaining soil was then determined by the Bouyoucos hydrometer method (5). Electrical conductivity of the saturation extract (E.C.) was determined by use of a bridge (methods 3a and 4b of the U. S. Salinity Laboratory) (26), and pH on a soil suspension was determined by use of a glass electrode meter (method 21b). The soil was classified on the basis of mechanical separates according to the Soil Survey Manual classification (27). Range condition was expressed as an estimate of the amount of forage produced as compared with the maximum possible for the site (6) as follows: Excellent, 75-100 per cent; good, 50-75 per cent; fair, 25-50 per cent; and poor, 0-25 per cent. The degree of soil erosion was arbitrarily divided into four classes as follows:

- None: No evidence of soil movement away from or around crown of perennial vegetation. Litter essentially in place.
- Slight: Pedestal development clear, little evidence of active soil movement. Litter concentrated under plants.
- Moderate: Pronounced pedestal development, active rilling and cutting of soil surface, but no deep channels.
- Severe: Crown and roots of plants exposed. Pronounced rilling, cutting and channeling of soil surface.

Statistical comparison of conductivity of the saturation extracts of soils from all vegetation types at both levels was based on the logarithms of E.C. converted to ppm. pH comparisons were made by using the pH (logarithmic) values in the computations. Use of logarithms in the statistical analyses was based on

Table 1. Summary of chracteristics of soils in Nevada and on the perimeter of the area occupied by halogeton.

Type of vegetation	Depth (in.)	pH*	E.C. x 10^3*	Gravel (%)	Predominant soil type	Number of samples
Juniper	0- 6	8.1	0.8	36	Loam	4
	6-18	7.9	3.5	40	Loam	4
Sagebrush	0- 6	8.2	0.9	20	Loam	24
	6-18	8.1	1.6	29	Loam	24
Winterfat	0- 6	8.4	1.1	8	Loam	7
	6-18	8.4	2.4	9	Loam	7
Shadscale	0- 6	8.7	1.6	19	Sandy loam	35
	6-18	8.8	2.9	25	Sandy loam	35
Nuttall's	0- 6	8.6	2.8	5	Loam	3
saltbush	6-18	8.4	5.2	3	Loam	3
Greasewood	0- 6	9.3	5.6	7	Loam	10
	6-18	9.4	10.7	8	Sandy loam	10
No perennial	0- 6	8.3	1.2	2	Sandy loam	3
vegetation	6-18	8.6	1.2	1	Sandy loam	3
Average	0- 6	8.7	1.5	14	Loam	86
(or total)	6-18	8.8	2.5	16	Loam	86

* pH is based on an arithmetic mean and conductivity on a logarithmic mean.

recommendations of Snedecor (24) in order to satisfy requirements for a valid analysis of variance. A separate least significant difference was computed for each comparison.

Results and Discussion

It is to be noted in Table 1 that the numbers of samples in the various vegetation types differed, but the number of sites sampled in each vegetation type is similar in proportion to the relative sizes of the areas of the various vegetation types. The highest percentage of gravel in both of the sampling depths was in the juniper type, and the soil in general was in the classifications of loam and sandy loam.

Halogeton was not found on the sandiest class of soils, on which such species as Nevada dalea (*Dalea polyadenia*), hairy horsebrush (*Tetradymia comosa*), Indian ricegrass (*Oryzopsis hymenoides*), and desert evening primrose (*Oenothera caespitosa*) are found, although the opportunity for invasion was present in many cases. It might be assumed from this absence that halogeton required a soil of somewhat finer texture. A breakdown of the soils according to class showed a predominance of the medium-textured soils in the samples taken.

A tabulation of soil classification of sites occupied by halogeton (Table 2) indicated that sandy loam accounted for 32 and loam for 28 of the 86 observations (37 and 33 per cent, respectively), or taken as a group, loam and sandy loam accounted for 70 per cent of the total of the classes in the 0- to 6-inch depth. The same two classes included 49 (57 per cent) of the 86 observations in the 6- to 18-inch zone. Approximately 10 to 15 per cent of the sites had soils in the heavier clay loam to clay classes. However, since halogeton was found in soil classes ranging from loamy sand to clay in texture, it is assumed that it will grow in all these classes. The coarser soils appear to be more abundant in the Western States and this may partially account for the higher frequency of sandy loam and loam soils in sites supporting halogeton.

Table 2. The relative frequency of occurrence of various soil classes on sites occupied by halogeton.

Class	Depth (in.) 0-6	6-18
Sand	0	1
Loamy sand	7	8
Sandy loam	32	29
Loam	28	20
Sandy clay loam	6	10
Silt loam	5	6
Clay loam	6	7
Silty clay loam	0	2
Clay	2	3
Total	86	86

The distribution of pH (Figure 2) showed a definite mode—37 of the 86 observations in the 0- to 6-inch layer, with a similar distribution in the 6- to 18-inch zone—or 43 per cent, in the range of 8.2 to 8.5, corresponding roughly to the average pH of sagebrush and winterfat soils. This distribution class (8.2-8.5) together with the class immediately preceding (7.8-8.1) and the one following (8.6-8.9) roughly included the range of pH of soils in the sagebrush and shadscale associations. From this figure it would appear that halogeton had an optimum pH in the range of 7.8 to 8.9.

The conductivity of the saturation extract of the soils was generally below four millimhos or approximately in the range of juniper, sagebrush, winterfat, and shadscale in both depth zones (Figure 3). Examination of the summary tabulation (Table 1) shows that the predominant soil type under both sagebrush and winterfat was loam. Nuttall's saltbush and juniper were also growing on loam. It should be pointed out, however, that data were obtained on only three and four sites, respectively, for these two types of vegetation. The soils supporting juniper are probably best classified as gravelly loam. The shadscale complex ran to lighter textured soil, as did greasewood and the three areas of no perennial vegetation. The last category included an outwash fan, a railroad right-of-way, and a gypsum

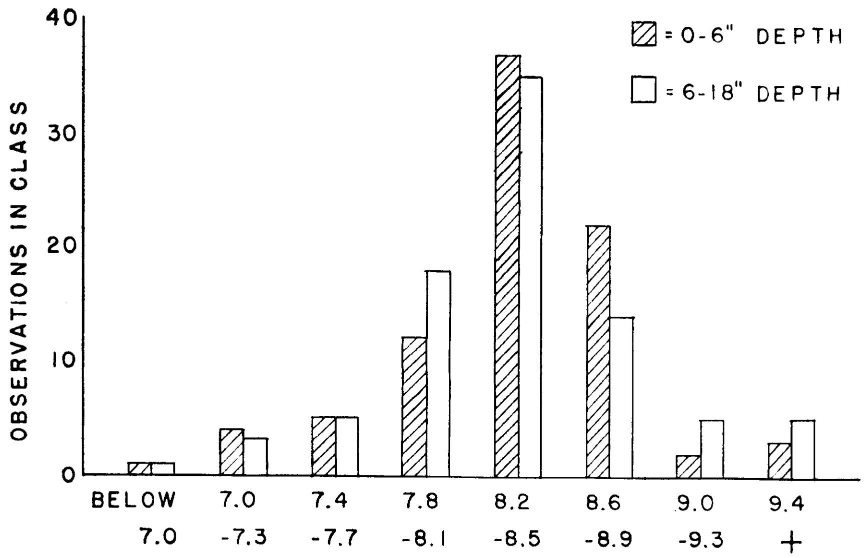

FIGURE 2. Distribution of pH of soils occupied by halogeton.

pit.

An examination of Table 3 indicates that in practically all cases where halogeton occurred, the perennial vegetation was not in vigorous condition and that on 70 per cent of the sites the condition was classified as fair or poor. The soil showed erosion from none to severe, and in 65 per cent of the observations it was either moderately or severely eroded. The halogeton plants were largest in shadscale and sagebrush, and the distribution of plants inclined more to specific spots than to a general distribution when a limited area was examined. It should be pointed out that occurrence of halogeton in vegetation classified as being in good or fair condition occurred most often in small areas of local disturbance. The exceptions to this were in winterfat, where a general infestation appeared to be the rule. This was true to a less extent in Nuttall's saltbush. However, the small number of areas of Nuttall's saltbush encountered in Nevada makes any general conclusion as to the competitive ability of that species questionable.

Statistical comparison of electrical conductivity and pH (Table 4) showed sagebrush soils to differ significantly and highly significantly from shadscale soils in the 0- to 6-inch depth and 6- to 18-inch depth, respectively, and significantly from Nuttall's saltbush soils in the 6- to 18-inch zone. In pH, the difference was significant between soils of shadscale and sagebrush at the 6- to 18-inch depth. Differences in soils for both electrical conductivity and pH were significant or highly significant under juniper, sagebrush, winterfat and shadscale, in both depths, when compared with greasewood. Nuttall's saltbush soils showed no significant difference from those of greasewood in either pH or conductivity. In comparison of the upper with the lower layer of soil in all vegetation types, there was a significant difference between the two only for the shadscale soils in conductivity. There was no significant difference in pH between the two zones.

It should be emphasized that the statistical interpretation of the data was based on only three sites in Nuttall's saltbush and a small number in both juniper and winterfat. If a larger number of samples had been taken in these three vegetation types, the difference probably would

Table 3. Condition of competitive vegetation, degree of soil erosion, and distribution and height of halogeton in each vegetation type sampled.

Type of vegetation	Condition of vegetation				Soil erosion				Halogeton			Total obser-vations per type
	Excel-lent	Good	Fair	Poor	None	Slight	Mod-erate	Severe	Height (in.)	Distribution General	Distribution Spot	
Juniper	0	2	1	1	1	1	0	2	7	1	3	4
Sagebrush	3	3	7	11	2	4	8	10	8*	9	15	24
Winterfat	1	0	4	2	2	1	3	1	4	6	1	7
Shadscale	4	7	16	8	6	6	12	11	8*	14	21	35
Nuttall's saltbush	2	0	0	1	3	0	0	0	6	1	2	3
Greasewood	0	3	3	4	2	1	3	4	6*	5	5	10
Total	10	15	31	27	16	13	26	28	—	36	47	83
Percentage of total observations per attribute	12	18	37	33	19	16	31	34	—	43	57	

* Live halogeton absent from one sampling area at time of sampling.

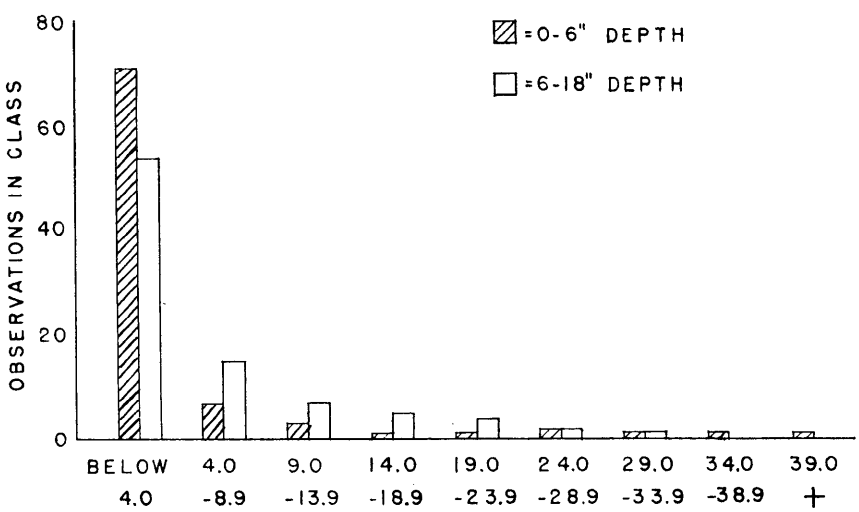

FIGURE 3. Distribution of electrical conductivity, expressed as millimhos (E.C. x 10^3), of soils occupied by halogeton.

have been significant or highly significant in comparison of E. C. in juniper and winterfat soils with those of Nuttall's saltbush.

An attempt to define an optimum pH or range of pH as well as an optimum concentration or range of tolerance of soluble salts as well as other soil characteristics by a habitat study method is complicated by factors other than the edaphic one. These are considered of primary importance in investigating ecological relations of annual plants in perennial vegetation. The first of these factors is the dependence upon sufficient seed in a given area during a particular growing season to insure a stand of an annual species, for the point inevitably arises in attempting to determine competitive relations as to whether the restriction or absence of an annual is a matter of competition or of inadequate seed dispersal when other conditions are favorable. A second factor is the amount and distribution of effective precipitation in that area during the given season. A third is the condition, density and type of competing vegetation, with its own particular seasonal demand for moisture. This last factor, together with the pH and soluble salt content, is directly related to precipitation and may be strongly modified by physiographic, biotic, and other climatic influences.

Summary and Conclusions

A sampling of Nevada soils during 1954 and 1955 on all major vegetation types infested with halogeton, together with additional sampling on the perimeter of the infestation in 1955, showed the plant to be practically confined at present to the northern desert shrub type. This does not, however, preclude its ability to grow in other formations under conditions favorable to its germination and development.

Halogeton was most often found on soils characterized by rather high pH, low salt concentrations, and medium texture and in the absence or reduced competition of other vegetation, particularly perennial shrubs.

The most frequent occurrence was on loams and sandy loams and in areas having big sage-

Table 4. Statistical comparison of pH and conductivity (E.C. x 10^3) of soils occupied by halogeton in different vegetation types.

Type of vegetation	Depth (in.)[1]	Mean pH[2]	Mean E.C.[2]	Sagebrush		Winterfat		Shadscale		Nuttall's saltbush		Grease-wood	
				pH	E.C.	pH	E.C.	pH	E.C.	pH	E.C.	pH	E.C.
Juniper	0- 6	8.0	2.7	0[3]	0	0	0	*	0	0	0	*	*
	6-18	7.9	3.1	0	0	0	0	**	0	0	0	**	*
Sagebrush	0- 6	8.0	2.7	—	—	0	0	0	*	0	0	**	**
	6-18	8.0	2.8	—	—	0	0	*	**	0	*	**	**
Winterfat	0- 6	8.4	2.8	—	—	—	—	0	0	0	0	0	**
	6-18	8.3	3.1	—	—	—	—	0	0	0	0	*	**
Shadscale	0- 6	8.6	3.0	—	—	—	—	—	—	0	0	0	**
	6-18	8.5	3.3	—	—	—	—	—	—	0	0	*	**
Nuttall's	0- 6	8.5	3.2	—	—	—	—	—	—	—	—	0	0
saltbush	6-18	8.4	3.5	—	—	—	—	—	—	—	—	0	0
Greasewood	0- 6	8.6	3.5	—	—	—	—	—	—	—	—	—	—
	6-18	9.9	3.8	—	—	—	—	—	—	—	—	—	—

[1]Comparisons for each depth were calculated separately.

[2]Means are logarithmic. Averages on Table 1 are logarithms of *arithmetic means* for pH and antilogarithms of *logarithmic means* for conductivity.

[3]0 Indicates no significant difference.

* Significant at 5% level

** Significant at 1% level

brush and shadscale vegetation. These vegetation types were found on soils further characterized by having electrical conductivities (E. C. x 10^3) of 0.9 and 1.6 and average pH values of 8.2 and 8.7 for big sagebrush and shadscale types, respectively, in the top 6 inches of soil. E.C. in the 6- to 18-inch zone for these types averaged 1.6 and 2.9 and pH 8.1 and 8.8 for big sagebrush and shadscale, respectively.

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Foresters Meet at Salt Lake City

"Multiple Use Forestry in the Changing West" is the theme of the 1958 annual meeting of the Society of American Foresters which is scheduled at Hotel Utah in Salt Lake City, September 29 through October 2. More than 850 persons are expected to attend.

Keynote speakers are: LEMUEL A. GARRISON, superintendent of Yellowstone National Park, Wyoming; DON E. CLARK, regional forester, U. S. Forest Service, Denver, Colorado; and FRED J. SANDOZ, Booth-Kelly Lumber Company, Springfield, Oregon. Principal speaker at the annual banquet will be TOM GILL, executive director of the Charles Lathrop Pack Forestry Foundation, Washington, D. C.

Over 70 papers are scheduled for presentation at the technical sessions. A field trip will be made to the Davis County Experimental Watershed in the Wasatch Mountains on October 2.

Co-chairmen of the meeting are REED W. BAILEY, director of the Intermountain Forest and Range Experiment Station, and FLOYD IVERSON, regional forester of the Intermountain Region, Ogden, Utah.