Reprinted from the *Soil Science Society of America Journal*
Volume 48, no. 3, May–June 1984
677 South Segoe Rd., Madison, WI 53711 USA

# Soil Chemical Patterns under Eastern Oregon Plant Communities Dominated by Big Sagebrush

PAUL S. DOESCHER, RICHARD F. MILLER, AND ALMA H. WINWARD

# Soil Chemical Patterns under Eastern Oregon Plant Communities Dominated by Big Sagebrush[1]

Paul S. Doescher, Richard F. Miller, and Alma H. Winward[2]

## ABSTRACT

**The objectives of this study were (i) to examine soil nutrient patterning in eastern Oregon plant communities dominated by subspecies of *Artemisia tridentata* Nutt., and (ii) to compare soil nutrient levels between adjacent sites characterized by contrasting amounts of sagebrush and perennial grasses. Horizontal and vertical soil chemical patterns were evident on all sites. Surface concentrations of nutrients were greatest under shrubs in comparison to interspace and grass influenced soils. Values of total N, organic matter, K, and P tended to decrease with depth, while Mg concentrations generally increased in lower soil horizons. Soil pH was generally lower in upper soil horizons. Soil chemical differences between shrub, interspace and bunchgrass influenced soils became less distinct with increased soil depth. Differences in soil chemical levels between sites with a high proportion of perennial grasses to shrubs and sites with a low proportion of perennial grasses to shrubs were noted. However, no consistent patterns were evident.**

***Additional Index Words:* soil nutrients, nutrient patterns, *Artemisia tridenta* Nutt.**

Doescher, P. S., R. F. Miller, and A. H. Winward. 1984. Soil chemical patterns under eastern Oregon plant communities dominated by big sagebrush. Soil Sci. Soc. Am. J. 48:659–663.

---

In semiarid rangelands, modification of soils by vegetation have resulted in distinct plant-induced soil chemical patterns. Numerous studies have shown this to be a common occurrence in shrub dominated ecosystems (Fireman and Hayward, 1952; Rickard and Keogh, 1968; Sharma and Tongway, 1973; Charley and West, 1975). Accumulations and decomposition of above and below ground litter have increased nutrient levels under shrubs as compared to adjacent bare soil zones (Bjerregard, 1971). Increased surface concentrations of total N, organic P, organic S, monovalent and divalent cations and organic C generally occur beneath shrub canopies (Fireman and Hayward, 1952; Tiedemann and Klemmedson, 1973; Charley and West, 1975). Changes in soil pH have been shown to be a function of the vegetation present on a site. Increased pH levels generally exist under halophytic shrub species when compared to adjacent bare soil areas (Sharma and Tongway, 1973), but tend to be lower than surrounding soils for xerophytic shrub communities on saline sites (Charley and West, 1975). The net effects of these changes in the soil nutrient capital in semiarid shrublands has been the partitioning of soil chemicals in a horizontal and vertical fashion.

Although a few studies have documented soil chemical patterns in big sagebrush (*Artemisia tridentata* Nutt.) communities (Fireman and Hayward, 1952; Charley and West, 1975; Fairchild and Brotherson, 1980), a comprehensive evaluation of sites differentiated by subspecies of big sagebrush has not been performed. Further, studies have not included comparisons of the perennial herbaceous component in the evaluation of soil nutrient patterns nor examined differences between sagebrush sites with a high proportion of grasses compared to those with a denuded understory. The importance of examining soil nutrient patterns for sagebrush grassland ecosystems are as follows: First, since rooting depth, litter quality, and plant phenology differ for species within a community, an evaluation of soil nutrient patterns may provide an increased understanding of structural and functional relationships in big sagebrush plant communities. Second, a comparison of these patterns for sites with a large proportion of high seral grasses vs. sites with a decreased understory may indicate shifts in soil fertility which have resulted from retrogression or improvement. These changes may perpetuate big sagebrush on sites in poor range condition.

The primary objectives of this research were: (i) to examine soil chemical patterning in eastern Oregon plant communities dominated by subspecies of big sagebrush, and (ii) to compare soil chemical levels between sites characterized by contrasting amounts of shrubs and perennial grasses.

---

[1] This research was a cooperative effort and jointly supported by the USDA, Agricultural Research Service, Eastern Oregon Agric. Res. Center, Squaw Butte Station, and Dep. of Rangeland Resources, Oregon State Univ. Agric. Exp. Stn. Tech. Paper no. 7132, Oregon Agric. Exp. Stn. Received 28 Mar. 1983. Approved 6 Dec. 1983.

[2] Assistant Professor, Dep. of Rangeland Resources, Oregon State Univ., Corvallis, OR 97331, Associate Professor, Eastern Oregon Agric. Res. Cent., Squaw Butte Station, Star Rt. 1-4.51 Hwy. 205, Burns, OR 97720, and Regional Forest Ecologist, Regional Office, U.S. Forest Service, Fed. Office Building, 324-25th St., Ogden, UT 84401, respectively. Reprint requests should be sent to Dr. Doescher.

## STUDY AREA

Sample areas were selected by locating adjacent, mature stands of vegetation which had contrasting amounts of sagebrush to perennial grasses. These stands of vegetation were assumed to represent previously similar plant communities which, through different land use practices, had developed divergent stands of vegetation. Sites were of similar topography and parent materials. Within each plant community, one had a high proportion of perennial grasses to shrubs and the other stand had a low proportion of perennial grasses to shrubs. These will be referred to in this discussion as high grass–low shrub (HGLS) and low grass–high shrub (LGHS) sites of a particular plant community.

The following procedures, modified from Poulton and Tisdale (1961), were used to describe the species present within HGLS and LGHS sites. At each site, a circular marcoplot with a 25-m radius was located to be representative of the plant species present within the stands. Through the center of each plot, a randomly located baseline was established. Three 30-m by 1-cm transects at distances of 8 and 16 m on one side of the plot center and 8 m on the other side of the plot center were established perpendicular to the baseline. Along each transect at 3-m intervals, frequency of all plant species present was determined utilizing a 30-cm by 60-cm sampling frame. Thirty samples at each site were recorded. Shrub and perennial grass cover using a line-intercept approach was also determined along the three 30-m transects.

Plant communities were named on the basis of the subspecies of big sagebrush and characteristic perennial grasses present within the HGLS site. The following plant communities were studied: *Artemisia tridentata* ssp. *vaseyana/Festuca idahoensis-Agropyron spicatum* (ARTRV/FEID-AGSP), *Artemisia tridentata* ssp. *tridentata/Elymus cinereus* (ARTRT/ELCI) and *Artemisia tridentata* ssp. *wyomingensis/Stipa thurberiana* (ARTRW/STTH). The ARTRT/ELCI and ARTRW/STTH plant communities have been described as habitat types (Winward, 1970; Hironaka, 1979) and the ARTRV/FEID-AGSP plant community has been recognized as a distinctly different plant community by Sheehy (1975). The ARTRV/FEID-AGSP plant community was located near Baker, OR. Both the ARTRT/ELCI and ARTRW/STTH plant communities were studied at the Squaw Butte Exp. Stn. west of Burns, OR. At each plant community, a fence line separated HGLS and LGHS sites.

For the ARTRV/FEID-AGSP plant community, the HGLS site had a history of fall sheep grazing, while the LGHS site had been consistently grazed spring and summer by cattle. Dominant high seral grass species in the HGLS site were *Festuca idahoensis* and *Agropyron spicatum*, with *Poa sandbergii* the most common understory perennial grass present on the LGHS site. The HGLS ARTRW/STTH and ARTRT/ELCI sites were located in areas excluded from grazing the past 40 years, while both LGHS sites are used as spring and summer range by cattle. *Elymus cinereus* was the dominant high seral understory grass species present on the HGLS ARTRT/ELCI site. *Sitanion hystrix* and *Stipa thurberiana* were most prevalent in the understory of the LGHS site. Vegetation of the HGLS ARTRW/STTH site was characterized by an understory dominance of *Sitanion hystrix, Poa sandbergii* and *Stipa thurberiana*. *Sitanion hystrix* was the dominant perennial grass species present in the adjacent LGHS site.

At each study site, soil characteristics were noted. Vegetative and soils information in each of the three plant communities is given in Table 1.

## MATERIALS AND METHODS

For each plant community, the vegetation-soil resource was stratified into the following functional groups: under-shrub canopy (S), bare soil interspace (I), and under-grass crown area (G). At each study site, 10 mature big sagebrush plants were randomly located and served as collection areas for the S soil samples. These 10 sagebrush plants were also used as reference points for the selection of an equal number of I and G sampling areas. Interspace soils adjacent to the selected sagebrush plants were sampled for assessment of nutrient levels. The immediate area around the selected sagebrush plant frequently was void of a perennial bunchgrass individual not influenced by the sagebrush canopy. When this occurred, the nearest plant or plants which provided sufficient soils material for evaluation were selected for sampling. When two grass species were selected for assessment within a site, the 10 samples for the G functional group were evenly split between the two species. These samples were then collectively analyzed. *Agropyron spicatum* and *Festuca idahoensis* were sampled in the HGLS site of the ARTRV/FEID-AGSP plant community, while *Poa sandbergii* was assessed on the adjacent LGHS site. For the ARTRT/ELCI plant community, *Elymus cinereus* was evaluated on the HGLS site and *Stipa thurberiana* and *Sitanion hystrix* sampled on the LGHS site. Grass species sampled in the HGLS site of the ARTRW/STTH plant community included *Stipa thurberiana* and *Sitanion hystrix*, while *Sitanion hystrix* was the only species assessed on the adjacent LGHS site.

Soils were sampled at three depths. At the ARTRV/FEID-AGSP and ARTRW/STTH plant communities, depths of 0 to 10 cm, 10 to 20 cm, and 20 cm down to a restrictive horizon were assessed. Soils on the ARTRT/ELCI plant community were deeper and samples were taken from depths of 0 to 10 cm, 10 to 25 cm, and 25 cm to restrictive horizon. Approximately 0.5 kg of soils was collected from each of these depths. Under all surface conditions, superficial organic debris was removed prior to sampling. Following recommendations of Charley and West (1975), the zone of maximum surface accumulation of sagebrush litter under the shrub canopy was used as the site for vertical soil sampling. Excavation of soils under bunchgrass plants was made directly under the crown area.

Sampling the ARTRV/FEID-AGSP and ARTRT/ELCI plant communities was performed during August 1980. The ARTRW/STTH plant community was sampled during August 1981. Within HGLS and LGHS sites at each plant community 180 soil samples were collected. Obvious root material and organic debris were removed prior to chemical analysis.

Soils analysis was performed at the Oregon State University Soil Testing Laboratory. The following evaluations were performed: total N was determined using the Kjeldahl method as outlined by Bremner and Edwards (1965); organic matter was estimated utilizing the wet oxidation-titration method of Walkley and Black (1934); assessment of

**Table 1—Vegetation and soil characteristics of the study areas.**

| Plant communities | Elevation (m) | Site location | Shrub cover % HGLS | Shrub cover % LGHS | Grass cover % HGLS | Grass cover % LGHS | Soil classification | Soil texture of surface horizon |
|---|---|---|---|---|---|---|---|---|
| ARTRV/FEID-AGSP | 1066 | NE¼NE¼S24 T7SR41E | 9.5 | 19.1 | 17.5 | 3.6 | Typic Haploxerolls | Loam |
| ARTRT/ELCI | 1372 | SE¼SW¼S24 T24SR25E | 20.0 | 26.0 | 27.5 | 8.2 | Xerollic Durorthids | Sandy loam |
| ARTRW/STTH | 1372 | SW¼NE¼S35 T24SR25E | 15.3 | 21.3 | 21.3 | 2.3 | Xerollic Durorthids | Sandy loam |

**Table 2—Soil chemical characteristics in an ARTRV/FEID-AGSP plant community between shrub (S), interspace (I), and grass (G) soil zones, at 3 depths for high grass-low shrub (HGLS) and low grass-high shrub (LGHS) sites.**

| Chemical characteristic | 0–10 cm | | | 10–20 cm | | | > 20 cm | | |
|---|---|---|---|---|---|---|---|---|---|
| | S | I | G | S | I | G | S | I | G |
| | | | | | HGLS | | | | |
| Total N (% D.W.) | 0.13abA* | 0.12aD | 0.16bG | 0.11aAB | 0.11aD | 0.10aH | 0.10aB | 0.10aD | 0.09aH |
| Organic matter (% D.W.) | 4.45aA | 3.11dB | 4.73aG | 2.69aB | 2.56aD | 2.84aH | 2.22aB | 2.23aD | 2.39aH |
| P mg $kg^{-1}$ | 29.00aA | 21.30bD | 24.30abG | 24.00aA | 12.90bE | 19.70abG | 11.70aB | 9.30aE | 10.90aH |
| K mg $kg^{-1}$ | 739.90aA | 501.90bD | 927.50aG | 530.60aA | 414.20aDE | 577.30aH | 363.10aB | 347.90aE | 410.20aI |
| Ca (cmol($p^+$)$kg^{-1}$) | 13.01aA | 12.31aD | 12.35aG | 13.13aA | 14.06aDE | 13.88aH | 15.51aB | 15.79aE | 15.30aI |
| Mg (cmol($p^+$)$kg^{-1}$) | 4.67aA | 4.06aD | 4.21aG | 4.73aB | 4.83aDE | 4.52aGH | 5.53aB | 5.77aE | 5.20aH |
| pH | 6.47aA | 6.34aD | 6.54aG | 6.59aA | 6.56aDE | 6.68aGH | 6.68aA | 6.71aE | 6.79aH |
| | | | | | LGHS | | | | |
| Total N (% D.W.) | 0.21aA | 0.13bD | 0.15bG | 0.09aB | 0.12bD | 0.10aH | 0.13aB | 0.09bE | 0.09bH |
| Organic matter (% D.W.) | 4.86aA | 3.47bD | 3.70abG | 2.27aB | 3.20bD | 2.42aH | 3.41aC | 2.24bE | 2.18bH |
| P mg $kg^{-1}$ | 42.80aA | 25.70bD | 22.80bG | 14.20aB | 22.20bD | 15.50aH | 23.60aC | 11.70bE | 10.40bI |
| K mg $kg^{-1}$ | 956.00aA | 511.80bD | 592.80bG | 421.50aB | 449.80aDE | 465.90aH | 565.40aB | 409.30bE | 358.40bI |
| Ca (cmol($p^+$)$kg^{-1}$) | 14.60aA | 12.23bD | 12.59bG | 13.00aB | 12.95abD | 12.03bG | 11.91aB | 13.13bD | 12.52abG |
| Mg (cmol($p^+$)$kg^{-1}$) | 4.87aA | 4.27bD | 4.33abG | 4.58aA | 4.30aD | 4.37aG | 3.95aB | 4.67bD | 4.70bG |
| pH | 6.68aA | 6.41bD | 6.52abG | 6.62aA | 6.51abD | 6.46bGH | 6.56aA | 6.63aD | 6.56aH |

* Similar lower case letters indicate nonsignificant differences ($\alpha = 0.05$) at a particular soil depth and condition class for comparison of S, I, and G soil chemical values. Similar capital letters denote nonsignificant differences holding S, I, and BG soil zones and condition class constant, but comparing differences with depth.

extractable P was conducted using the procedure of Olsen and Dean (1965). A modification of the technique outlined by Pratt (1965) was used to assess extractable K. Instead of a multiple extraction of soil by extractant a single equilibration of the sample was used. Calcium and Magnesium levels were determined using an ammonium acetate method (Peech et al., 1947, p. 25). Soil pH was measured by utilizing a 1:2 soil/solution ratio and glass electrode pH (Jackson, 1958, p. 151–154).

Analysis of variance with a completely randomized design and Tukey's w-procedure were used to test differences ($\alpha = 0.05$) between functional groups at a given soil horizon and between soil horizons under a given functional group. A student t-test was utilized to assess differences ($\alpha = 0.05$) between adjacent HGLS vs. LGHS plant communities (Steel and Torrie, 1980). Owing to differences in year sampled, parent material, and geographic location, statistical analyses of soil chemical characteristics between plant communities were not performed.

## RESULTS

### Horizontal and Vertical Changes

The presence of shrubs significantly affected the horizontal distribution of soil chemicals. Generally, surface concentrations were significantly greater under shrubs than adjacent interspace areas. This relationship was particularly evident for both HGLS and LGHS sites of the ARTRT/ELCI and ARTRW/STTH plant communities, and the LGHS site of the ARTRV/FEID-AGSP plant community (Tables 2, 3 and 4).

Accumulations of certain soil chemicals were significantly greater in surface soils under the shrub canopy than soils influenced by grasses. This relationship was evident for (i) total N, P, K, and Ca in the LGHS site of the ARTRV/FEID-AGSP plant community (Table 2), (ii) total N, organic matter and P in the HGLS site and P, K, Ca, and Mg in the LGHS site of

**Table 3—Soil chemical characteristics in an ARTRT/ELCI plant community between shrub (S), interspace (I), and grass (G) soil zones, at 3 depths for high grass-low shrub (HGLS) and low grass-high shrub (LGHS) sites.**

| Chemical characteristics | 0–10 cm | | | 10–25 cm | | | > 25 cm | | |
|---|---|---|---|---|---|---|---|---|---|
| | S | I | G | S | I | G | S | I | G |
| | | | | | HGLS | | | | |
| Total N (% D.W.) | 0.23aA* | 0.14bD | 0.15bG | 0.10aB | 0.08bE | 0.09bH | 0.07aB | 0.07aE | 0.07aH |
| Organic matter (% D.W.) | 4.96aA | 2.59bD | 3.24bG | 1.86aB | 1.51aE | 1.62aH | 1.00aB | 1.14aE | 1.12aH |
| P mg $kg^{-1}$ | 57.40aA | 37.90bD | 32.10bG | 28.00aB | 20.60abE | 18.60bH | 7.90aC | 4.80bF | 5.20abI |
| K mg $kg^{-1}$ | 1622.20aA | 961.20bD | 1556.60aG | 1414.50aA | 1110.40bD | 1145.50abH | 1059.70aB | 986.20aD | 938.90aH |
| Ca (cmol($p^+$)$kg^{-1}$ | 10.65aA | 9.26bD | 9.33abG | 9.31aB | 9.60aD | 9.55aG | 9.24aB | 9.78aD | 9.58aG |
| Mg (cmol($p^+$)$kg^{-1}$ | 5.12aA | 4.62aD | 4.70aG | 5.05aA | 5.41bE | 5.37bH | 6.32aB | 6.60aF | 6.58aI |
| pH | 6.50aA | 6.60abD | 6.70bG | 7.09aB | 6.86bE | 7.12aH | 7.25aB | 7.22aF | 7.29aH |
| | | | | | LGHS | | | | |
| Total N (% D.W.) | 0.13aA | 0.08bD | 0.12aG | 0.06aB | 0.05aE | 0.06aH | 0.05aB | 0.05aE | 0.05aH |
| Organic matter (% D.W.) | 2.85aA | 1.44bD | 2.29aG | 1.08aB | 0.94aE | 1.05aH | 0.84aB | 0.68abE | 0.63bI |
| P mg $kg^{-1}$ | 42.80aA | 25.48bD | 21.90bG | 17.40aB | 13.00aE | 13.70aH | 6.10aC | 5.90aF | 5.00aI |
| K mg $kg^{-1}$ | 1316.00aA | 731.30bD | 869.50bG | 996.50aAB | 729.90bD | 825.20abG | 615.00aB | 568.00aD | 555.80aH |
| Ca (cmol($p^+$)$kg^{-1}$ | 8.91aA | 7.98bD | 7.96bG | 8.95aA | 8.68aDE | 8.77aG | 9.68abA | 9.02aE | 10.20bH |
| Mg (cmol($p^+$)$kg^{-1}$) | 4.27aA | 3.80bD | 4.10bG | 4.67aA | 4.65aE | 4.91aH | 5.65aB | 5.71abF | 6.15bI |
| pH | 6.93aA | 6.60bD | 6.60bG | 7.27aB | 7.05aE | 7.18aH | 7.19aB | 7.31aF | 7.33aH |

* Similar lower case letters indicate nonsignificant differences ($\alpha = 0.05$) at a particular soil depth and condition class for comparison of S, I, and G soil chemical values. Similar capital letters denote nonsignificant differences holding S, I, and BG soil zones and condition class constant, but comparing differences with depth.

**Table 4—Soil chemical characteristics in an ARTRW/STTH plant community between shrub (S), interspace (I), and grass (G) soil zones, at 3 depths for high grass-low shrub (HGLS) and low grass-high shrub (LGHS) sites.**

| Chemical characteristics | 0–10 cm | | | 10–20 cm | | | > 20 cm | | |
|---|---|---|---|---|---|---|---|---|---|
| | S | I | G | S | I | G | S | I | G |
| | | | | HGLS | | | | | |
| Total N (% D.W.) | 0.16aA* | 0.08bD | 0.10bG | 0.08aB | 0.06bDE | 0.06bH | 0.04aC | 0.04aE | 0.04aI |
| Organic matter (% D.W.) | 3.84aA | 1.60bD | 2.21bG | 1.87aB | 1.12bE | 1.24bH | 0.81aC | 0.72aF | 0.61aI |
| P mg kg$^{-1}$ | 45.80aA | 20.90bD | 23.60bG | 22.70aB | 10.60bE | 10.20bH | 6.10aC | 4.10aF | 4.30aI |
| K mg kg$^{-1}$ | 1263.60aA | 546.50bD | 593.10bG | 1032.50aA | 599.60bD | 553.20bH | 478.20aB | 515.30aD | 452.80aH |
| Ca (cmol(p$^+$)kg$^{-1}$) | 8.16aA | 6.67bD | 6.84bG | 7.78aA | 7.65aE | 7.71aG | 8.07aA | 8.49abE | 8.90bH |
| Mg (cmol(p$^+$)kg$^{-1}$) | 3.91aA | 3.51aD | 3.61aG | 4.23aA | 4.94bE | 4.63abH | 5.68aB | 6.40bF | 6.00abI |
| pH | 7.03aA | 6.85bD | 6.82abG | 7.44aB | 7.36aE | 7.31aH | 7.48aB | 7.66aF | 7.60aI |
| | | | | LGHS | | | | | |
| Total N (% D.W.) | 0.19aA | 0.12bD | 0.12bG | 0.09aA | 0.09aDE | 0.08aH | 0.07aB | 0.07aE | 0.07aH |
| Organic matter (% D.W.) | 4.06aA | 2.17bD | 2.51bG | 1.53aB | 1.51aDE | 1.34aH | 1.11aB | 1.05aE | 0.92aH |
| P mg kg$^{-1}$ | 19.80aA | 24.60aD | 32.00aG | 18.80aA | 13.20abE | 12.20bH | 5.90aB | 4.30aF | 4.80aI |
| K mg kg$^{-1}$ | 1681.10aA | 741.50bD | 1001.70bG | 965.00aB | 651.00bD | 627.10bH | 443.30aC | 388.40aE | 389.00aI |
| Ca (cmol(p$^+$)kg$^{-1}$) | 10.28aA | 9.12aD | 9.17aG | 9.81aA | 9.55aD | 9.75aG | 9.99aA | 9.75aD | 9.68aG |
| Mg (cmol(p$^+$)kg$^{-1}$ | 4.89aA | 4.55bD | 4.88aG | 5.60aB | 5.65aE | 6.01aH | 6.19aC | 6.10aF | 6.13aH |
| pH | 7.00aA | 6.80aD | 6.94aG | 7.21aA | 7.04bE | 7.23aH | 7.18abA | 7.31bE | 7.53bI |

* Similar lower case letters indicate nonsignificant differences ($\alpha = 0.05$) at a particular soil depth and condition class for comparison of S, I, and G soil chemical values. Similar capital letters denote nonsignificant differences holding S, I, and BG soil zones and condition class constant, but comparing differences with depth.

the ARTRT/ELCI plant community (Table 3), and (iii) total N, organic matter, and K within the LGHS site, plus P and Ca in the HGLS site of the ARTRW/STTH plant community (Table 4). Soil chemical concentrations between I and G influenced soils were often not significantly different.

Other patterns in the spatial distribution of soil chemicals indicated in Table 2, 3, and 4 included:

1) Less distinct soil chemical differences between S, I, and G functional groups as soil depth increased.
2) Decreased levels of total N, organic matter, K, and P as soil depth increased, for all functional groups,
3) Generally lower soil pH levels in the upper horizons than the lower horizons regardless of functional group, although no significant change with depth was detected for shrub influenced soils on the ARTRV/FEID-AGSP community,
4) Greater concentrations of Mg in the lower soil horizons, across functional groups, especially on the ARTRT/ELCI and ARTRW/STTH plant communities,
5) Either no change or an increased Ca concentration as depth increased for the I and G functional groups.

### HGLS vs. LGHS Comparisons

Surface concentrations of total N, organic matter, P, K, Ca, and Mg with respect to plant community for HGLS vs. LGHS sites are presented in Tables 2, 3, and 4. Surface pH values did not significantly differ between adjacent sites except for S influenced soils on the ARTRT/ELCI plant community. There, soil pH was significantly greater on the LGHS site than the HGLS site.

Although differences between absolute levels of soil nutrients between HGLS and LGHS sites were indicated in some instances, generalized trends across the three plant communities were not evident. The HGLS site of the ARTRT/ELCI plant community had significantly greater concentrations of soil chemicals for all functional groups in comparison to the LGHS plant community except for P under shrubs and total N under grasses.

Surface values of K, Ca, and Mg for the ARTRW/STTH plant community were significantly higher within the LGHS site than the HGLS site for all functional groups. However, no significant differences in total N for S and G influenced soils and organic matter for all functional groups were noted between the HGLS and LGHS sites. Phosphorus concentrations in the HGLS site were significantly greater under shrubs but significantly less under grasses in comparison to values in the LGHS site.

For the ARTRV/FEID-AGSP plant community, surface concentrations under S influenced soils of total N, P, K, and Ca were significantly greater on the LGHS site in comparison to the HGLS site. The only soil chemicals judged significantly different in the G functional group were organic matter and K. Interspace soils did not significantly differ in surface nutrient levels across the three functional groups.

## DISCUSSION

The examination of soil nutrient patterns for sagebrush/grassland ecosystems provides insights into the functional and structural relationships that exist on these sites. Results of this research support other finding that accumulations of soil chemicals under shrubs concentrate the nutrient capital of these soils (Tiedemann and Klemmedson, 1973; Charley and West, 1975). This may be an important adaptation by arid land shrubs which enable them to better cope with a moisture limited environment. During relatively brief periods of adequate soil moisture, optimization of uptake by having an available source of nutrients in close proximity to the plant would seemingly enhance growth. These nutrient accumulations may improve the competitiveness and perpetuation of shrubs in semiarid ecosystems.

Perennial grasses do not exhibit similar surface accumulations of soil nutrients as compared to shrubs. One explanation may relate to differences in rooting characteristics between shrubs and perennial grasses. Grasses, such as those examined in this research, exhibit root systems which are fibrous in nature and extend in a vertical fashion below the crown of the plant. This is in contrast to sagebrush root systems which have been shown to consist of a well-developed lateral and vertical root network (Sturges, 1977). The net effect of a limited root system for grasses may be a relatively small volume of soil available for nutrient extraction. Sagebrush with an extensive root network appears better adapted to remove soil nutrients from adjacent interspace areas and deeper in the soil profile.

An interesting result of this research was the high surface accumulations of K under sagebrush plants at all locations and under grasses in the good condition ARTRT/ELCI and ARTRV/FEID-AGSP plant communities. Potassium is generally considered one of the most mobile ions in leaves and is rapidly leached during decomposition (Mack, 1977). The reason K is accumulated in upper soil horizons is not entirely clear. The enhancement may be related to the volume of soil available to the plant for root exploration, and the subsequent uptake of K in excess of the plants' needs. The big sagebrush individuals and understory perennial grasses accumulating K in the surface soil on the various sites appeared to be larger and deeper rooted than those which did not show this effect.

Potassium enrichment of upper soil horizons may confer an ecological advantage with regard to nitrogen metabolism. Potassium recirculation in the plant may be an important factor in facilitating the uptake and distribution of $NO_3^-$-N (BenZioni et al., 1971; Armstrong and Kirkby, 1979). Because $NO_3^-$-N tends to be the dominant form of available N in the upper soil layers for semiarid shrublands (Charley and West, 1977) and plant roots generally fully occupy these soil horizons (Sturges, 1977; Cline et al., 1977), enhanced levels of soil K may promote rapid absorption and internal translocation of $NO_3^-$-N during relatively brief periods of active surface mineralization. Thus, mineral nutrition of the plant may be improved, and growth accelerated when soil moisture is available.

As range condition declines, the composition and percentage of the various functional groups apparently shift in relation to one another. Our findings indicated an increase in shrub cover and a decrease in bunchgrass cover going from HGLS to LGHS site within each plant community (Table 1). Although coverage of interspace areas was not recorded, the percentage of bare ground was noticeably greater in the LGHS sites. The proportion of land area occupied by S and I zones appears to increase at the expense of the G component. This change represents a structural rearrangement of the soil nutrient capital. Although no consistent increase or decrease in soil nutrient levels within functional groups was noted as range condition declined, one might expect the soil chemical resource to become more strongly differentiated into zones of surface nutrient accumulations. This would result from an increased prevalence of the shrub component. How this change influences mineral cycling dynamics of sagebrush/grassland ecosystems requires further research.

## ACKNOWLEDGMENTS

The authors thank S. M. Doescher for technical assistance during the collection of research data and W. C. Krueger for constructive review of this manuscript.

## REFERENCES

1. Armstrong, M.J., and E.A. Kirkby. 1979. Estimation of potassium recirculation in tomato plants by comparison of the rates of potassium and calcium accumulation in the tops with their fluxes in the xylem stream. Plant Physiol. 63:1143–1148.
2. BenZioni, A., Y. Vaaidia, and S.H. Lips. 1971. Nitrate uptake by roots as regulated by nitrase reduction products in the shoot. Physiol. Plant. 24:288–290.
3. Bjerregard, R.S. 1971. The nitrogen budget of two salt desert shrub plant communities of western Utah. Ph.D. Diss. Utah State University. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 33(B):3037B).
4. Bremner, J.M., and A.P. Edwards. 1965. Determination and isotope-ratio analysis of different forms of nitrogen in soils. Soil Sci. Soc. Am. Proc. 29:504–507.
5. Charley, J.L., and N.E. West. 1975. Plant induced soil chemical patterns in some desert shrub-dominated ecosystems in Utah. J. Ecol. 63:945–964.
6. Charley, J.L., and N.E. West. 1977. Micro-patterns of nitrogen mineralization activity in soils of some shrub-dominated ecosystems of Utah. Soil Biol. Biochem. 9:357–366.
7. Cline, J.F., D.W. Ursk, and W.H. Rickard. 1977. Comparison of soil water used by a sagebrush-bunchgrass and cheatgrass community. J. Range Manage. 199–201.
8. Fairchild, J.A., and J.D. Brotherson. 1980. Microhabitat relationships of six major shrubs in Navajo National Monument, Arizona. J. Range Manage. 33:150–156.
9. Fireman, M., and F.E. Hayward. 1952. Indicator significance of some shrubs in the Escalante Desert, Utah. Bot. Gaz. 114:143–155.
10. Hironaka, M. 1979. Basic synecological relationships of the Columbia River sagebrush type. p. 27–32. *In* The sagebrush ecosystem—a symposium. April 1978. Utah State Univ., Logan.
11. Jackson, M.L. 1958. Soil chemical analysis. Prentice-Hall, Englewood Cliffs, N.J.
12. Mack, R.N. 1977. Mineral return via the litter of *Artemisia tridentata* Am. Midl. Nat. 97:189–197.
13. Olsen, S.R., and L.A. Dean. 1965. Phosphorous. *In* C.A. Black et al. (ed.) Methods of soil analysis, part 2. Agronomy 9:1035–1048. Am. Soc. of Agron., Madison, WI.
14. Peech, M.L., T. Alexander, L.A. Dean, and F.F. Reed. 1947. Methods of soil analysis for fertility investigations. USDA Circ. 757. U.S. Government Printing Office, Washington, DC.
15. Poulton, C.E., and E.W. Tisdale. 1961. A quantitative method for the description and classification of range vegetation. J. Range Manage. 14:13–21.
16. Pratt, P.G. 1965. Potassium. *In* C.A. Black et al. (ed.) Methods of soil analysis, part 2. Agronomy 9:1022–1030. Am. Soc. of Agron., Madison, WI.
17. Rickard, W.H., and R.F. Keogh. 1968. Soil-plant relationships of two desert steppe shrubs. Plant Soil 29:205–213.
18. Sharma, M.L., and D.J. Tongway. 1973. Plant induced soil salinity patterns in two saltbush (*Atriplex* spp.) communities. J. Range Manage. 26:121–125.
19. Sheehy, D. 1975. Relative palatability of seven *Artemisia* taxa to mule deer and sheep. M.S. Thesis. Oregon State Univ., Corvallis.
20. Steel, R.G.D., and J.H. Torrie. 1960. Principles and procedures of statistics, 2nd ed. McGraw-Hill Book Co., Inc., New York.
21. Sturges, D.L. 1977. Soil water withdrawal and root characteristics of big sagebrush. Am. Midl. Nat. 98:257–274.
22. Tiedemann, A.R., and J.O. Klemmedson. 1973. Effect of mesquite on physical and chemical properties of the soil. J. Range Manage. 26:27–29.
23. Walkley, A., and I.A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 37:29–38.
24. Winward, A.H. 1970. Taxonomic and ecological relationships of the big sagebrush complex in Idaho. Ph.D. Diss. Univ. of Idaho, Moscow. Univ. Microfilms, Ann Arbor, MI (Diss. Abstr. 31(B):3791B-3792B).