THE AMMONIFYING, NITRIFYING AND RESPIRATION POWER OF CERTAIN SOILS FOUND IN THREE HABITAT TYPES IN THE COLUMBIA BASIN RANGELANDS

by

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A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of

the requirements for the

degree of

MASTER OF SCIENCE

June 1961

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Date thesis is presented May 17, 1961

Typed by Elaine Anderson

ACKNOWLEDGEMENTS

The author has sincerely appreciated the opportunity to work with his Graduate Committee, Drs. W. B. Bollen, T. M. Ching, Charles E. Poulton, and C. T. Youngberg.

The writer acknowledges the financial support given to him by the Oregon Agriculture Experiment Station under Project 362.

Special gratitude is given to Dr. Charles E. Poulton, Major Professor, for guiding the field portion of this study, and for his acute criticisms in the preparation of this thesis.

Dr. W. B. Bollen's cooperation made this study possible. His guidance in the laboratory was both humbling and inspiring to the writer.

Finally, the author expresses gratitude to his very, very patient wife, Betty.

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INTRODUCTION

The purpose of this study was to determine the ammonifying, nitrifying and respiration capacities of certain soils found in selected habitat types in the Columbia Basin rangeland. Except for Daubenmire's work (10), which included nitrification experiments, similar studies have not been reported. Thus, the present investigation is considered to be an exploration into this area of investigation.

Daubenmire (9, p. 303) defines the habitat type as "The collective area which one association occupies or will come to occupy as succession advances, ...". The habitat types included in this study have been characterized and classified by Poulton (16). It was felt that the above mentioned determinations would constitute additional characterization. These measurements should also be an aid in evaluating the fertility status of the soils occurring in the habitat types. With a single exception, the sites chosen for study were considered to be supporting near-climax stands of vegetation. Poulton (Personal communication) defines climax as "The vegetation which reaches dynamic stability on the undulating uplands over normally developed soils

where only zonal climate and the existing flora limit the succession and ultimate nature of the equilibrium community". These relic sites constitute an index to which their deteriorated counterparts can be related. Ecologists, and rangeland managers as well, generally recognize the need for land management consistent with the natural potential of the land. An intimate and detailed knowledge of the few remaining relic areas which best represent pristine conditions is necessary to effectively evaluate the successional status and trend of present day rangelands.

It is well established (10, p. 32) that the population of vascular plants is altered with continued heavy grazing, and accelerated soil erosion often results. In contrast little is known about the effects of these edaphic-vegetative changes upon the ability of soil microorganisms to produce available plant nutrients. The question is then raised whether the fertility status of soil is materially affected by heavy grazing. Bollen (3, p. 1) defines soil fertility as, "....the ability of the soil to supply nutrients to plants; it is essentially the crop producing power of the soil under given climatic conditions. ....The function of soil microorganisms is to render potential fertility available". As a consequence of these considerations an example of one

habitat type known to have been continually overgrazed by domestic livestock was included in the study with the hope of obtaining an indication of the effect of overgrazing on microbiological activity.

DESCRIPTION OF THE STUDY AREAS

Two examples of each of the following habitat types were selected: 1. The Artemisia tridentata/Agropyron spicatum habitat type, 2. The Festuca idahoensis habitat type, 3. The Agropyron spicatum/Poa secunda habitat type. An additional, overgrazed example of the latter habitat type was included in the study. These selections provided a maximum range in ecological conditions to test the relationships between microbiological activity level and phanerogam vegetation and soils.

Location of the Habitat Types

The Artemisia tridentata/Agropyron spicatum habitat type: One example is located in Walla Walla County, Washington approximately two miles south of Wallula, Washington. The second example is about ten miles to the southwest on the north ridge above Juniper Canyon in Umatilla County, Oregon.

The Festuca idahoensis habitat type: Both examples are in Morrow County, Oregon. One is approximately twelve miles west of Nye Junction on the south side of state highway 74. The other site, also adjacent to highway 74, is about ten miles southwest of the first example in the Little Butter Creek drainage.

The Agropyron spicatum/Poa secunda habitat type: All three examples are in Morrow County, Oregon. One site is about one-half mile east of Heppner, Oregon on the western flank of a mountain locally known as "Heppner Hill". The two remaining sites, one in climax condition and the other heavily overgrazed, are adjacent to each other near Eightmile, Oregon and south of state highway 207.

The geographic location of each sampling area is shown in Figure 1.

Description of the Habitat Types

The writer has drawn upon his own field notes and the work of Poulton (16) for the following descriptions. Dr. Ellis G. Knox has given helpful suggestions for the identification of some soils encountered in this study.

I. The Artemisia tridentata/Agropyron spicatum habitat type: The soil collected from both sites belongs to the Ritzville series which is representative of the Brown great soil group. The soil of the Washington site is a silt loam while that of the Oregon example is a very fine sandy loam. The parent material is loess. The solum is approximately 50 to 60 inches thick. The Washington stand occurs on a southeast facing slope of about 10 percent. The topography of the Oregon site is more or less flat to gently undulating.

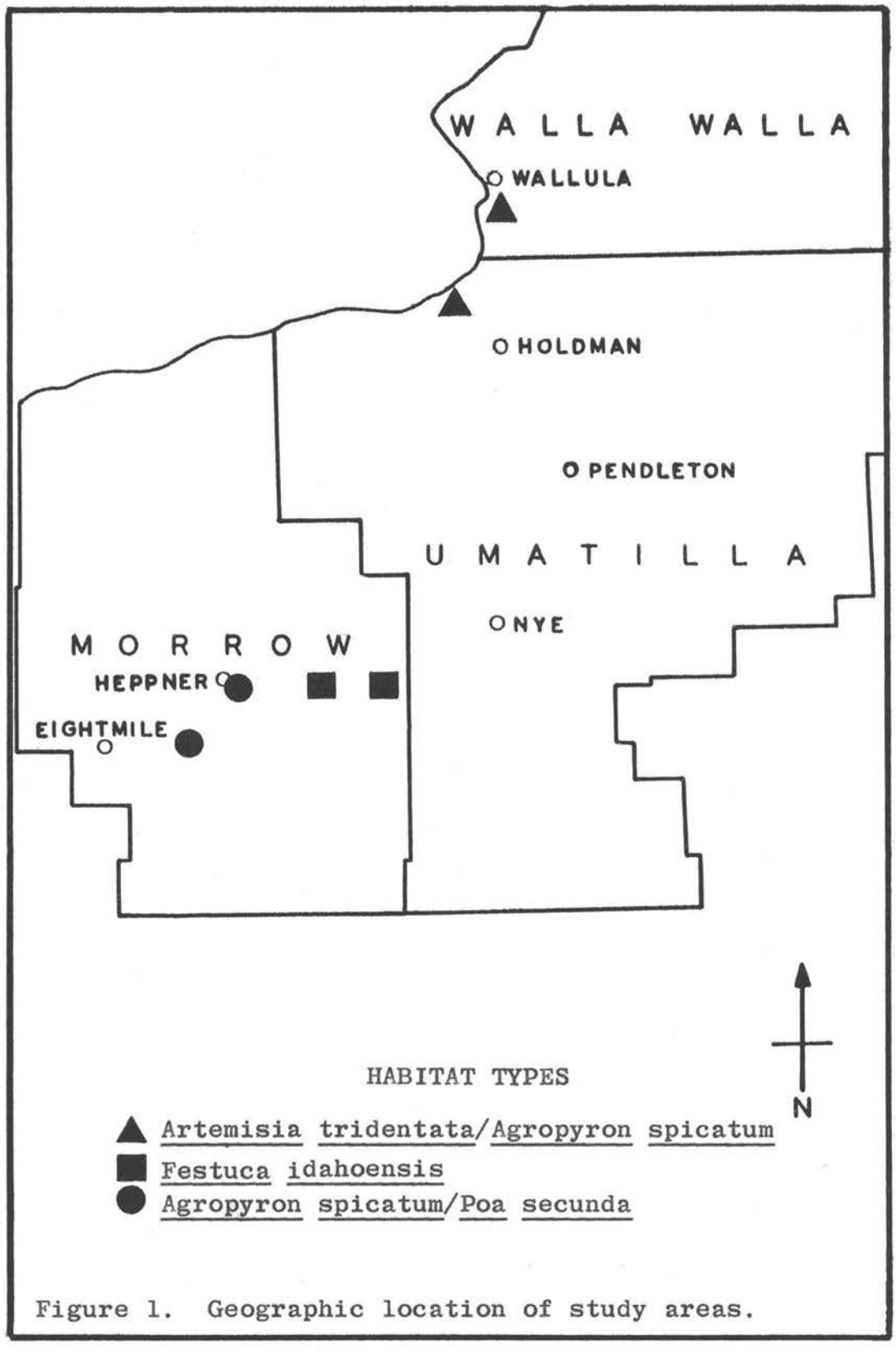

Figure 1. Geographic location of study areas.

Big sagebrush (Artemisia tridentata Nutt.) is the dominant shrub of this habitat type. Bluebunch wheatgrass (Agropyron spicatum (Pursh.) Schrib. & Smith) is the dominant grass. Distinct interspaces occur between the individual bunchgrass plants. These interspaces are dominated by Sandberg bluegrass (Poa secunda Presl.) and by various mosses and lichens. Agropyron spicatum covers about 55 percent of the area. Artemisia tridentata and epigeous cryptogams cover 14 and 10 percent of the ground respectively. Poa secunda has a mean cover value of 9 percent. Exposed soil (Resulting mostly from rodent activity) constitutes about 2 or 3 percent of the area.

This habitat type is considered to be the most xerophytic of those selected. It has the driest spring periods and the summers are the warmest. The July mean maximum temperature is 92°F. The January mean minimum is about 24°F. The mean annual precipitation, coming mostly in winter, is approximately 8.6 inches.

Figure 2 is a view of the general type. Figure 3 is a close-up of a typical interspace.

II. The Festuca idahoensis habitat type: The soil at the site twelve miles west of Nye is an uncorrelated series which might be considered similar to a maximal Morrow silt loam intergrading to the Waha silt loam.

Figure 2. A typical view of the Artemisia tridentata/Agropyron spicatum habitat type. The photograph was taken at the site two miles south of Wallula, Washington (4/30/60).

Figure 3. A close-up view of a representative interspace occurring in the site shown in Figure 2. The dominant grass is (Poa secunda) (4/30/60).

It appears to be a maximal Chestnut soil. The soil of the example twenty-two miles west of Nye is a Waha silt loam intergrading to the Morrow series. It represents a minimal Prairie soil. Because of the close relationship of these soils they will be referred to as the Waha series. The solum varies from about 20 to 30 inches in thickness. The parent material is basalt. Both examples occur on north facing slopes of about 5 percent.

Idaho fescue (Festuca idahoensis Elmer.) is the dominant species of the type. The interspaces occurring between the bunches of Festuca idahoensis are dominated by epigeous cryptogams and an annual fescue (Festuca pacifica Piper.). Festuca idahoensis, cryptogams and Festuca pacifica cover 52, 28 and 3 percent of the ground respectively. Less than 1 percent of the area is bare ground. Agropyron spicatum is also an important member of the community with a mean cover value of 11 percent.

This habitat type is considered to be the most mesophytic of those studies. The July mean maximum temperature is 85.8°F. The January mean minimum is 23.2°F. The mean annual precipitation is approximately 21.9 inches, much of it coming in the spring and fall.

Figure 4 is a general view representative of the sites studied.

III. The Agropyron spicatum/Poa secunda habitat

Figure 4. A general view of the Festuca idahoensis habitat type about twenty-two miles southwest of Nye, Oregon. At the center of the photograph note the interspace dominated by the annual fescue (Festuca pacifica). A branch of rabbitbrush (Chrysothamnus spp.) can be seen left of center (5/1/60).

type: The soils on "Heppner Hill" exist in a complex association. The soil sampled appears to be a Rock Creek-like soil, being very shallow and stony. It is a Lithosol-like soil, the solum ranging in thickness from 5 to 11 inches. Texturally, it is a very stony loam. The parent material is basalt. The site is on a northwest facing slope of approximately 15 percent. Agropyron spicatum has a cover value of only 23 percent. Epigeous cryptogams and Poa secunda have cover values of 6 and 16 percent respectively. About 7 percent of the area is bare ground.

The soil of the examples near Eightmile is a shallow phase of the Condon silt loam. It is a representative of the Chestnut great soil group. The solum of the near-climax site ranges in depth from about 15 to 19 inches. The parent material is loess admixed with basalt gravels. The heavily grazed site shows evidence of accelerated sheet erosion. A slight erosion pavement, and what appears to be frost heavage, are common. The soil here is shallower and more stony than that in the adjacent site. Both sites occupy positions just below and on the crest of a broad ridge. The slope varies from 0 to 5 percent and faces west.

The naturally occurring example near Eightmile is dominated by Agropyron spicatum which has a cover value

of about 46 percent. The interspaces are dominated by epigeous cryptogams and Poa secunda which have cover values of 51 and 29 percent respectively. Rabbitbrush (Chrysothamnus nauseosus (Pall.) Britt.) occurs as a rare component of pristine stands.

The vegetation of the overgrazed site varies from the adjacent near-climax stand in the following ways: 1. The stand of Agropyron spicatum is less dense and less vigorous. 2. Annuals are noticeably in greater numbers, particularly cheatgrass (Bromus tectorum L.). 3. Chrysothamnus nauseosus is common. 4. Plant cover is relatively sparse. A well constructed fence protects the near-climax site from livestock grazing.

The ungrazed examples of this habitat type are judged to be intermediate between the xerophytic Artemisia tridentata/Agropyron spicatum stands, and the more mesophytic, Festuca idahoensis sites. The July mean maximum temperature is 89°F. The January mean minimum temperature is 24°F which is the same as that for the Artemisia tridentata/Agropyron spicatum habitat type. The mean annual precipitation is approximately 14.5 inches.

Figure 5 is a typical view of the protected natural site near Eightmile. Figure 6 is the adjacent, heavily grazed, site.

Figure 5. A general view of the Agropyron spicatum/Poa secunda habitat type near Eightmile, Oregon. The site is in near pristine condition. Note the absence of rabbitbrush (Chrysothamnus spp.) (5/1/60).

Figure 6. A typical view of the deteriorated stand adjacent to that shown in Figure 5. Note the rabbitbrush (Chrysothamnus spp.) in the middle distance (5/1/60).

PROCEDURES AND METHODS

A preliminary study was conducted by the writer to compare the ammonifying and nitrifying capacities of two sets of soil samples taken from a rangeland soil in central Oregon. One set of samples was collected by first removing the aerial portions of individual bunchgrass plants, and then taking a core of soil and roots through the root zone to a depth of about seven inches. The second set was similarly obtained by sampling the interspaces between the individual bunchgrass plants. The results of the study indicate that the ammonifying and nitrifying capacities of the two sets of samples differ significantly; the respective processes being greater in the soil collected with bunchgrass roots. The numbers of bacteria and molds were approximated after incubating agar plates poured with soil dilutions. Counts were slightly higher in the bunchgrass soil, but not significantly so.

It was decided, based upon these preliminary results, that a similar sampling pattern would be employed in the present study. Plate counts were omitted as they generally require too numerous replications to have been practical in this study. Furthermore, biochemical investigations are regarded to be the most rewarding in soil microbiological studies. Although, when feasible these should

be supplemented with culture studies (19, p. 1).

Field Procedures

Field work commenced April 30, 1960 and continued through May 3, of the same year. The first two days were spent selecting examples of the three habitat types and taking photographs. Soil samples were collected the last two days.

Each example of the three habitat types selected was sampled in the following manner. Four individuals of the dominant bunchgrass species, having about equal basal areas, were selected. A square foot plot was then delineated about, and centered upon each plant. The boundaries were positioned to keep the number of other plants occurring within the plot to a minimum. The upper half-inch of soil and aerial vegetation was then removed from the plot. The perimeter of the cleared plot was incised to a depth of about seven inches or to underlying stones where shallow soil was encountered. By trenching along one margin of the plot it was possible to cut out a block of soil which, when handled carefully, could be removed intact. The block of soil thus removed was halved. Each half was considered to be a field sample. In a similar manner two field samples were obtained from each of four selected interspaces. The

plots in this case usually contained several species. Although, as mentioned earlier, the interspaces were usually dominated by a very few species. Thus one set of samples was representative of the soil-root complex of the dominant bunchgrass, and the other set represented the soil-root complex of those species occurring in the interspaces.

The field samples were placed in plastic bags, appropriately labelled, and sealed. They were then placed in an insulated, iced cooler carried in the vehicle used. The temperature in the cooler was maintained at or below 12°C. A total of 112 soil samples were collected and brought to the laboratory. Except for brief periods when soil was needed, the samples were kept in a cold room maintained at 5° ±2°C.

Laboratory Procedures and Techniques

Preparation of soil samples: The samples were weighed and screened through a 10-mesh screen. The intractable stones and roots were collected and weighed separately. The percent roots and stones was calculated for each sample on a water-free basis.

Percent moisture: Determinations were made on duplicate 100-gram portions of soil from each field sample. A rapid drying Moisture Teller instrument was

used for obtaining oven dry soil. In all analyses soil quantities were expressed on a water-free basis.

Moisture capacity: Duplicate determinations were made for each field sample. Calculations were based on the amount of water held against gravity. Soil placed in Gooch crucibles was allowed to absorb water from beneath until saturated, and then permitted to drain to a constant weight in a moisture saturated atmosphere.

pH: Duplicate determinations were made on each field sample. Determinations were made on 1:5 soil suspensions using 25 grams of soil in distilled water. After shaking the solutions approximately thirty seconds, the coarse particles were allowed to settle about one minute before making readings with a model 7664 Leeds and Northrup pH meter.

Ammonification: 100-gram portions of soil were prepared for incubation in the following manner. The weighed soil was mixed with 60-mesh Bacto-peptone equivalent to 1000 ppm of nitrogen. The soil was then added in about quarter portions to a pint milk bottle. Quarter portions of distilled water were carefully pipetted into the bottle after each soil addition to bring the soil to 50 percent of moisture capacity. Controls were similarly prepared by omitting the Bacto-peptone. One treated and one control bottle were prepared

for each field sample. The bottles with their contents were weighed, capped with lids punctured to permit air circulation, and placed in an incubation cabinet ($28^{\circ} \pm 1^{\circ}C$) for five to seven days. During incubation the bottles were checked for moisture loss. Moisture was restored to fifty percent of moisture capacity when loss exceeded three grams.

After incubation, duplicate 10-gram portions of soil from each bottle were distilled with phosphate buffer solution at pH 7.4 (18, pp. 187-188). Prior to distillation each portion was wrapped in weighing paper to ensure that the soil would be introduced directly to the bottom of the distillation flask. The distillates were collected in saturated boric acid solution. The ammonia was titrated directly with N/14 sulfuric acid using methyl red- bromcresol green mixed indicator (15, pp. 280-282). pH readings were made on 1:5 water suspensions of the remainder of soil in the milk bottles.

Nitrification: The preparation of the soil for incubation was similar to that just described, except ammonium sulfate was added instead of Bacto-peptone. Prior to moistening, the soil was mixed with calcium carbonate (5000 ppm rate) to reduce the acidifying tendency of the ammonium sulfate. The latter was added at a rate equivalent to 300 ppm of nitrogen with the

necessary amount of water to bring the soil to 50 percent of moisture capacity. Controls were also prepared in which only distilled water was added to the soil. Duplicate sets of treated and control soils were made up from each field sample. The soils were incubated for thirty days at 28° ±1°C. Moisture was replenished as necessary.

Solutions were prepared for nitrate and nitrite determinations in the following manner: 1:5 water suspensions of the incubated soils were made up in quart milk bottles. The bottles were capped and agitated on a mechanical shaker for ten minutes. Small aliquots of the solutions were taken for pH determinations. "Superfloc 16" or "Aerofloc 3171" flocculants (8) were then added at rates of 10 to 20 ppm to the remaining solutions which were agitated an additional two minutes. Clarification was usually instantaneous. The supernatants were decanted and filtered through Whatman No. 1 filter paper. Occasionally clarification was incomplete. In these instances addition of a little diatomaceous earth or additional shaking by hand were effective in completing the clarification.

Nitrates were determined by Harper's (11, pp. 180-183) phenoldisulphonic acid method with the above noted modification in the clarifying process. Nitrites were

determined by the standard American Public Health Association method (1, pp. 301-304). The nitrate and nitrite readings were made on a Klett-Summerson photoelectric instrument with use of appropriate filters.

Microkjeldahl nitrogen: A modified Association of Official Agricultural Chemists procedure (2, p. 643) was followed. A 0.1 gram sample was introduced into a 100 ml kjeldahl flask with about 0.1 teaspoon Hibbard's mixture, 2.5 mls concentrated sulfuric acid and a selenized granule. The mixture was digested for thirty minutes. The digest was cooled, diluted with fifteen ml of distilled water and transferred to a microkjeldahl distillation apparatus. About ten mls of concentrated sodium hydroxide was then added and the mixture distilled until fifteen mls passed over into five mls of a saturated solution of boric acid. The distillate was titrated with N/70 sulfuric acid using methyl red-bromcresol green mixed indicator.

Total carbon: The method used was designed by Dr. W. B. Bollen at Oregon State University. The technique is not published.

Total carbon was determined by combustion at 1400°C using a Lindberg, rapid combustion, tube furnace. An oxygen pressure system is used wherein, purified oxygen is delivered at 400 mls per minute to the furnace.

Inherent carbon dioxide and moisture in the oxygen supply are removed by passing the gas through towers of soda lime and sulfuric acid. Just prior to entering the combustion chamber, the purified oxygen is passed through mercury in an apparatus so designed, that in case of backfire during combustion, carbon dioxide will not be lost. The gas leaving the combustion chamber is filtered through glass wool from where it is passed into a catalyst furnace to convert any carbon monoxide to carbon dioxide. The gas is then dried by passing it through anhydrous barium perchlorate. Finally the carbon dioxide is absorbed in a cartridge of soda lime. The quantity of carbon dioxide released from combustion is directly proportional to the net increase in weight of the sorption cartridge.

Respiration: Respiration powers were determined for one interspace and one bunchgrass sample collected in each of the following examples of the habitat types. 1. The *Artemisia tridentata/Agropyron spicatum* example in Umatilla County, Oregon. 2. The *Festuca idahoensis* example about twenty-two miles west of Nye Junction. 3. The adjacent natural and overgrazed examples of the *Agropyron spicatum/Poa secunda* habitat type.

The roots obtained from the interspace samples within each example were composited, air dried, and ground to

60-mesh using a Weber pulverizing mill. Total carbon and microkjeldahl nitrogen were then determined for each set of composited roots. Bunchgrass roots were prepared and analyzed in a similar manner. Carbon determinations were made in triplicate. Nitrogen determinations were made in duplicate.

Soil for incubation in pint milk bottles was prepared in the usual manner with the following treatments. Duplicate, 100-gram portions of soil from each interspace and bunchgrass sample were mixed with their respective root material at rates equivalent to 2000 ppm carbon. The amount of ammonium nitrate necessary to adjust the C:N ratio of the roots to 20 was added with appropriate quantities of distilled water to attain 50 percent of moisture capacity. Duplicate controls were prepared in which only distilled water was added to the soil.

The prepared bottles were connected to a modified Potter and Snyder (17, pp. 76-95) respiration apparatus designed by Bollen (4, p. 359), and incubated at $28^{\circ} \pm 1^{\circ}C$. The soils were maintained at fifty percent of moisture capacity. Evolved carbon dioxide was absorbed in tubes containing N/1 sodium hydroxide. The tubes were replaced at the end of 22, 48, and 96 hours, and 8, 16, and 28 days. Carbon dioxide was determined by differential titration (7, p. 592) using a Beckman automatic

titrator.

Statistics: The paired observation design (13, pp. 96-98) was used in all experiments. Where appropriate the t-test was used to test the significance of sample means.

RESULTS

Percent roots: It can be seen from Table 1, based upon the unscreened weights of the field samples, that the mean percentages of the bunchgrass roots in the soils as sampled are higher than those for the respective interspace roots (Significant @ the 1% significance level). Ratios of bunchgrass to interspace roots were calculated (Table 1). The sites representative of the Artemisia tridentata/Agropyron spicatum habitat type have ratios of 4 and 2 with an average ratio of 3 which is intermediate between those of the other habitat types. The narrowest root ratio (1.7) was found in the Festuca idahoensis habitat type; the average ratio for the type being 2.2. The highest ratios, about 4, were found for the climax stands of Agropyron spicatum/Poa secunda habitat type; the overgrazed example having a ratio of approximately 3. Relative to the same habitat type, there is a greater concentration of roots in the interspace soil of the deteriorated site than in the analagous soil of the adjacent climax stand (Significant @ the 1% significance level).

Hydrogen ion concentration: The results for the pH determinations are shown in Appendix B. The Ritzville, Rock Creek and Condon series tend to be slightly basic.

Table 1

Percent by weight of air-dry roots per unscreened soil sample.

Habitat Types	Artemisia tridentata/ Agropyron spicatum				Festuca idahoensis				Agropyron spicatum/Poa secunda					
Soil Series	Ritzville				Waha				Rock Creek		Condon			
Locations	Wallula, Washington		Umatilla Co., Ore.		Nye, Ore. 12 mi.,W.		Nye, Ore. 22 mi., W.		"Heppner Hill"		Eightmile (Climax)		Eightmile (D)*	
Sample Designations[1]	B	I	B	I	B	I	B	I	B	I	B	I	B	I
	0.20	0.03	0.08	0.08	0.26	0.06	0.32	0.20	0.76	0.06	0.34	0.10	0.28	0.18
	.29	.03	.11	.08	.28	.06	.27	.17	.38	.09	.50	.11	.32	.14
	.10	.03	.10	.03	.30	.10	.17	.23	.54	.09	.26	.06	.80	.09
	.08	.03	.09	.09	.26	.07	.16	.15	.30	.14	.18	.09	.42	.08
	.19	.02	.11	.06	.32	.20	.36	.15	.58	.20	.23	.06	.58	.10
	.12	.03	.15	.03	.29	.14	.23	.09	--	.14	.29	.11	.42	.19
	.12	.05	.13	.05	.24	.11	.43	.16	.43	.13	.67	.08	.19	.13
	.14	.05	.10	.05	.22	.08	.38	.21	.24	.19	.47	.08	.20	.17
Mean Percentages[2]	.16	.04	.12	.06	.27	.10	.29	.17	.43	.10	.37	.09	.40	.14
Ratios	4		2		2.7		1.7		4.3		4.1		2.9	

[1] "B" and "I" designate bunchgrass and interspace samples respectively.

[2] The differences between the mean percentages within a location are highly significant @ the 1% significance level.

* (D) designates Deteriorated.

The Waha soil tends to be neutral.

Ammonification: As shown in Figure 7, except for the bunchgrass soil of the site 12 miles west of Nye, the range of ammonifying capacities is about 44 to 58 percent. The ammonifying capacity is essentially the same for the bunchgrass and the interspace soil within each example of the Artemisia tridentata/Agropyron spicatum habitat type on Ritzville soil. However, the soil at the Wallula location has a 6 to 10 percent greater capacity than the soil at the Umatilla location (Significant @ the 1% significance level).

The soils of the Rock Creek series have similar capacities of about 50 percent. On the other hand the bunchgrass soils of the Condon series have approximately a 6 to 7 percent higher capacity than the respective interspace soils (Significant @ the 5% significance level). The ammonifying capacity in the respective soils of the deteriorated site appears slightly lower than their counterparts in the adjacent climax community, but not significantly so (Not significant @ the 5% significance level).

In contrast to the situation in the Condon soils, the Waha series has a greater ammonifying capacity in its interspace soils. In the site twenty-two miles west of Nye, the interspace soil has a capacity of about 6 percent

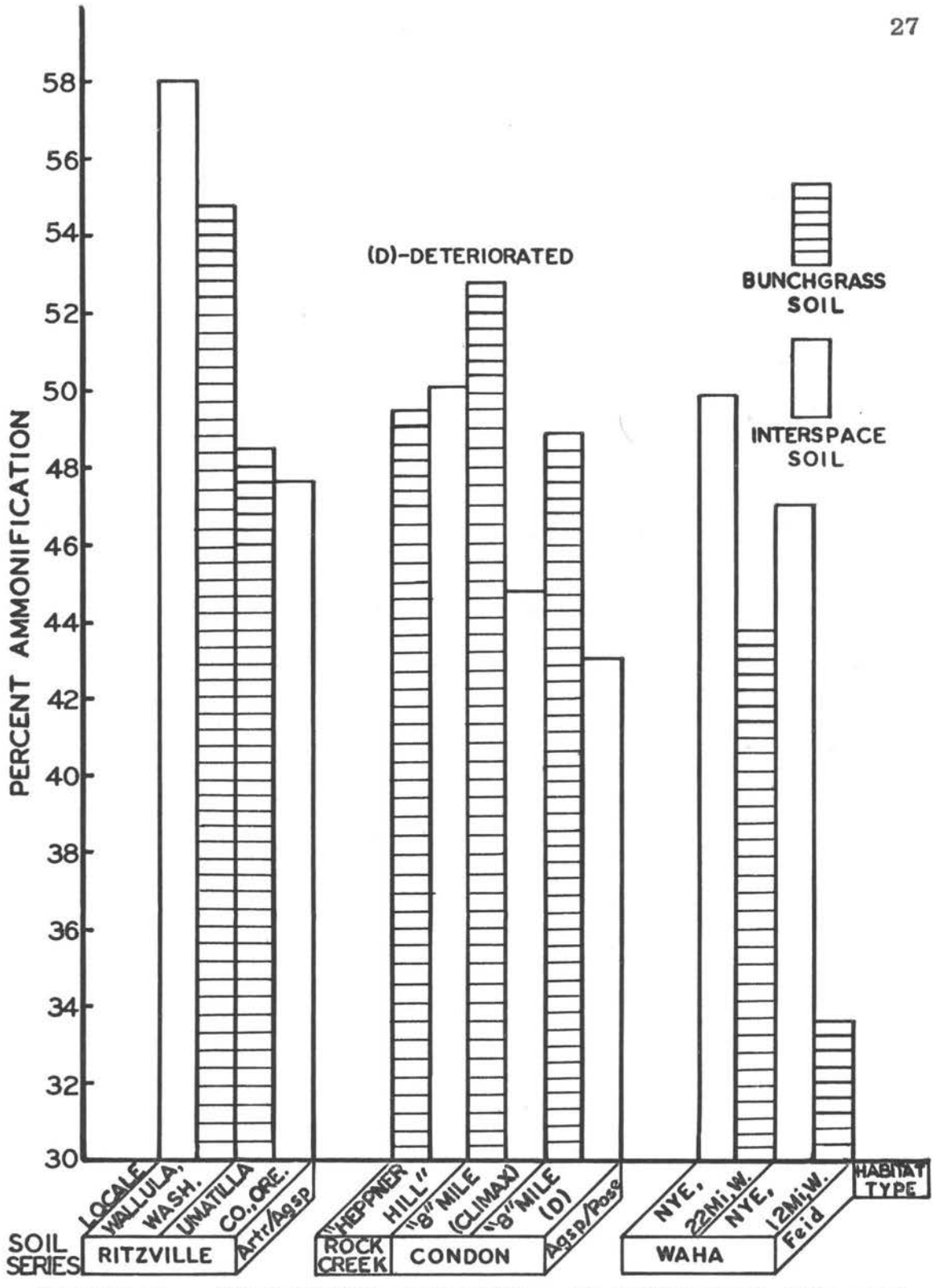

Figure 7. Ammonifying capacities of soils from selected habitat types. Habitat types: Artr/Agsp, Artemisia tridentata/Agropyron spicatum; Agsp/Pose, Agropyron spicatum/Poa secunda; Feid, Festuca idahoensis

greater than that of the bunchgrass soil (Significant @ the 1% significance level). The bunchgrass soil from the latter site has the lowest capacity of any of the soils investigated. A summary of results is given in Table 2.

Nitrification: The results of the nitrification experiment are shown in Figure 8. Except for the bunchgrass soil of the Eightmile climax site and the interspace soil from "Heppner Hill", the soils in the Agropyron spicatum/Poa secunda habitat type have similar nitrifying capacities of about 12 or 13 percent. The capacities of the exceptions are about 3 or 4 percent lower than their respective interspace and bunchgrass soils (Significant @ the 1% significant level). The capacity for the bunchgrass soil in the deteriorated site is about 5 percent greater than that of the analagous soil in the adjacent climax site (Significant @ the 1% significance level).

The nitrifying power or capacity is the same (6.7%) for the bunchgrass and interspace soils in the Wallula example of the Artemisia tridentata/Agropyron spicatum habitat type. However, in the Umatilla site nitrification was about 3 percent greater in the bunchgrass soil (Significant @ the 5% significance level). Furthermore, nitrification in both sets of soil from the Umatilla site was approximately 3 to 5 percent greater than the soil in

Table 2

Ammonification of peptone added at rate equivalent to 1000 ppm of nitrogen. Values[1] are given in ppm ammonia-nitrogen. The highest pH value obtained for each set of soils during incubation is also given.

Habitat Types	Artemisia tridentata/ Agropyron spicatum				Agropyron spicatum/Poa secunda						Festuca idahoensis			
Soil Series	Ritzville				Rock Creek		Condon				Waha			
Locations	Wallula, Washington		Umatilla Co., Ore.		"Heppner Hill"		Eightmile (Climax)		Eightmile (D)*		Nye, Ore. 22 mi., W.		Nye, Ore. 12 mi., W.	
Sample Designations[2]	B	I	B	I	B	I	B	I	B	I	B	I	B	I
	500	485	575	480	600	488	530	420	425	388	350	470	318	425
	635	655	415	520	473	478	503	433	415	413	495	548	313	485
	580	500	530	535	533	565	568	440	558	515	518	535	393	463
	630	695	515	540	528	638	603	490	538	445	490	590	408	513
	500	720	475	500	608	633	603	440	560	490	438	570	353	510
	570	575	495	530	505	578	540	550	533	470	485	497	308	548
	590	675	560	475	500	505	535	510	500	480	465	480	435	---
	570	580	525	505	510	455	578	488	555	553	493	520	445	508
Means	572	611	511	511	532	543	558	471	510	469	467	526	372	493
Means (-) Avg. of controls	548	580	485	477	495	501	528	448	489	430	438	499	336	470
pH	9.1	9.0	9.2	9.3	8.9	8.7	8.8	9.0	8.9	8.9	8.6	8.8	8.9	9.0

1 Values are means of duplicate determinations.

2 "B" and "I" designate bunchgrass and interspace soil respectively.

* (D) designates Deteriorated.

Percent ammonification= $100 \times \frac{\text{ppm ammonia nitrogen}}{1000}$

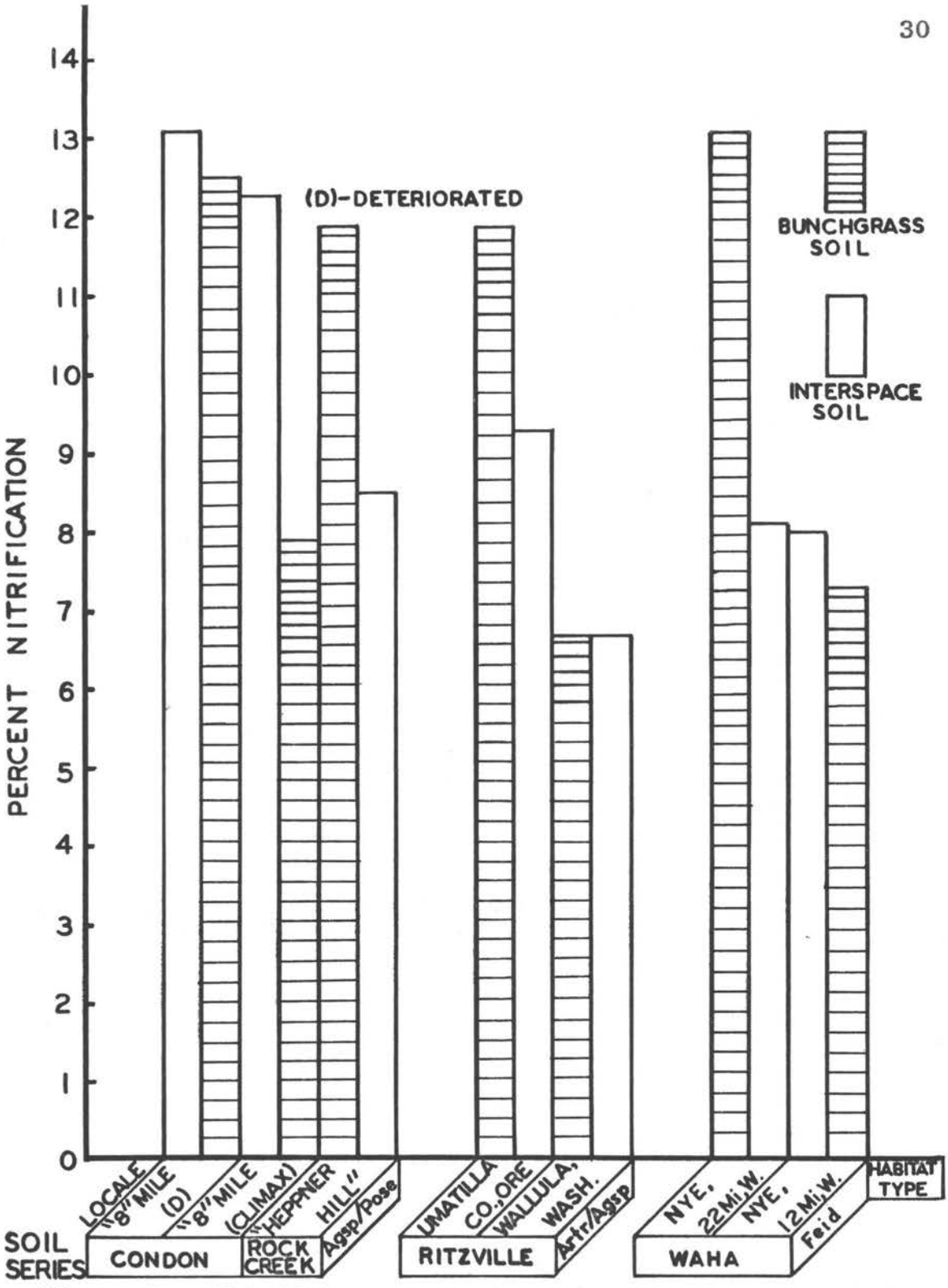

Figure 8. Nitrifying capacities of soils from selected habitat types. Habitat types: Agsp/Pose, Agropyron spicatum/Poa secunda; Artr/Agsp, Artemisia tridentata/Agropyron spicatum; Feid, Festuca idahoensis

the Wallula location (Significant @ the 5% significance level).

Except for the bunchgrass soil at the site twenty-two miles west of Nye, the soils of the Festuca idahoensis habitat type have similar nitrifying capacities of about 7 or 8 percent. The excepted bunchgrass soil has a capacity approximately 5 percent greater than the other soils (Significant @ the 1% significance level).

A summary of results is given in Table 3. It will be noted that in about 10 percent of the samples, significant amounts of nitrite nitrogen accumulated. Nitrite accumulation was highly variable ranging from 4 or 5 ppm to about 70 ppm in some of the Waha soil samples. There appears to be a greater tendency for nitrite accumulation in the soils from the Festuca idahoensis habitat type than in those soils from the other habitat types.

Carbon:Nitrogen ratios: The carbon and nitrogen analyses for the various roots are given in Table 4. The C:N ratios of the bunchgrass roots varied from 64 to 79. The ratios for the interspace roots were generally narrower, ranging from 43 to 68. However, the respective C:N ratios in the Festuca idahoensis habitat type are about the same; that is, 68 for the interspace roots and 71 for the bunchgrass roots.

Respiration: Figure 9 shows the results of the

Table 3

Nitrification of ammonium sulfate added at rate equivalent to 300 ppm of ammonia-nitrogen. Values[1] are given in ppm nitrate-nitrogen or nitrate-nitrogen plus nitrite-nitrogen.

Habitat Types	Agropyron spicatum/Poa secunda						Artemisia tridentata/ Agropyron spicatum				Festuca idahoensis			
Soil Series	Condon				Rock Creek		Ritzville				Waha			
Locations	Eightmile (D)*		Eightmile (Climax)		"Heppner Hill"		Umatilla Co., Ore.		Wallula Washington		Nye, Ore. 22 mi.,W.		Nye,Ore. 12 mi.,W.	
Sample Designations[2]	B	I	B	I	B	I	B	I	B	I	B	I	B	I
	47	48	44	43	48	30	56	28	#15	25	38	30	#10	#15
	44	54	43	31	41	28	24	27	30	27	36	26	#17	#29
	40	38	#19	42	35	31	#34	32	#10	# 9	#77	39	#26	#33
	42	43	#25	40	40	32	33	35	#19	#23	#73	36	#20	#24
	34	51	#12	48	#34	31	43	23	25	18	#38	#18	34	31
	43	50	#30	39	53	27	38	27	34	22	38	#15	30	32
	49	43	#27	40	50	30	39	36	#23	26	36	#27	31	#18
	41	47	#24	33	44	35	44	35	26	26	#34	34	29	#30
Means	42.5	46.8	28.0	39.5	43.1	30.5	38.99	30.4	22.8	22.0	45.6	28.3	24.6	26.5
Means (-) Avg. of controls	37.5	41.0	23.6	36.9	35.9	25.6	35.9	27.7	20.0	20.0	41.0	24.3	22.0	24.0
% Nitrification	12.5	13.1	7.9	12.3	11.9	8.5	11.9	9.3	6.7	6.7	13.1	8.1	7.3	8.0

1 Values are means of duplicate determinations.

2 "B" and "I" designate bunchgrass and interspace soil respectively.

* (D) designates Deteriorated.

\# Nitrate-nitrogen plus nitrite-nitrogen.

Percent nitrification = $100 \times \frac{\text{Nitrified ammonia (ppm)}}{300}$

Table 4

Analysis of roots for total carbon and total nitrogen.

Habitat Type	Sample*	Total Carbon %	Total Nitrogen %	C:N Ratio
Artr/Agsp	B	33.0	0.52	64
	I	38	.87	47
Feid	B	40	.48	71
	I	38	.56	68
Agsp/Pose (Climax)	B	38	.48	79
	I	23	.54	43
Agsp/Pose (Deteriorated)	B	38	.52	73
	I	32	.71	45

Artr/Agsp - Artemisia tridentata/Agropyron spicatum

Feid - Festuca idahoensis

Agsp/Pose - Agropyron spicatum/Poa secunda

* "B" and "I" designate bunchgrass and interspace roots respectively.

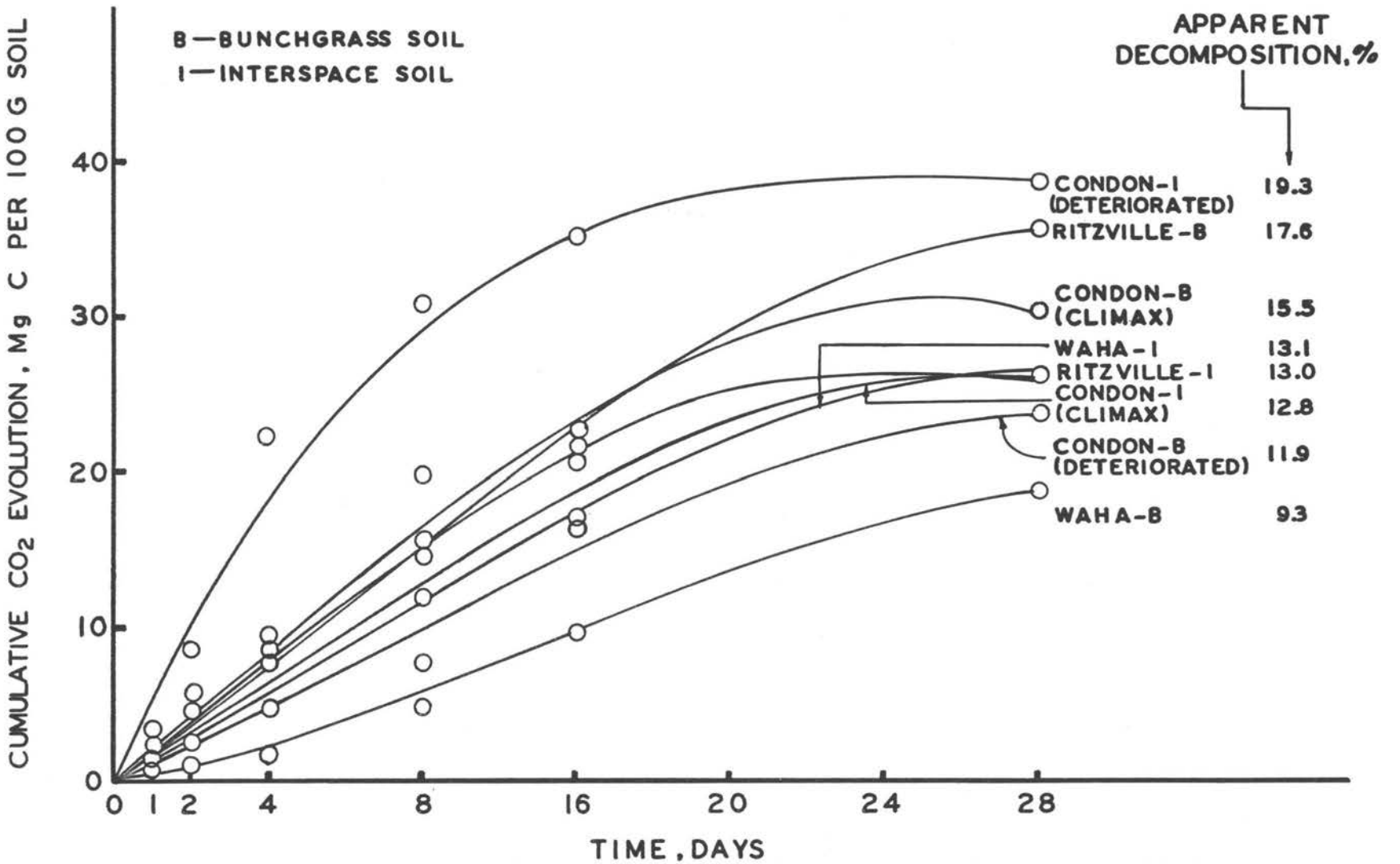

Figure 9. Capacity of different soils to decompose native roots added at 2000 ppm carbon with NH_4NO_3 to adjust C:N ratio to 20. Bunchgrass soil with bunchgrass roots; interspace soil with interspace roots. Values for soil only subtracted.

respiration experiment. The range of apparent decomposition of added native roots varies from 9.3 percent in the Waha bunchgrass soil to 19.3 percent in the Condon interspace soil of the deteriorated site. Apparent decomposition in the deteriorated interspace soil was about 7 percent greater than that in the bunchgrass soil of the same site, and 6 percent greater than in the interspace soil of the adjacent climax site. The bunchgrass soils of the overgrazed and protected sites gave decomposition values of 11.9 and 15.5 percent respectively.

The apparent decomposition in the bunchgrass soil of the Ritzville series was about 5 percent greater than that in the Ritzville interspace soil. The Waha interspace soil gave a decomposition value of about 4 percent greater than its associated bunchgrass soil.

DISCUSSION

Percent roots: In virgin sites one would expect a greater density of roots in the soil directly supporting Agropyron spicatum or Festuca idahoensis as opposed to the soil supporting interspace vegetation. The bunchgrass roots are relatively coarse and grow deeply and profusly. In contrast the fine roots of Poa secunda, a dominant of the interspaces, are concentrated in the upper two or three inches of soil (10, p. 33). The epigeous cryptogams, by virtue of their presence, tend to limit the space which may be occupied by rooting species. Festuca pacifica, an annual interspace dominant, is shallow rooting but forms a very dense mat of roots. It is likely this characteristic accounts for the relatively narrow root ratios in the Festuca idahoensis habitat type. Very few Festuca idahoensis roots were found in the interspace soil.

It was noted that there was a greater concentration of roots in the interspace soil of the deteriorated site than in the interspace soil of the adjacent climax stand (Table 1). This is consistant with the results obtained by Daubenmire (10, p. 34). These results seem attributable to the increase of annuals and Poa secunda since the Agropyron decreases under heavy grazing

pressure. Poa secunda although a perennial, tends to maintain itself or even increases under heavy cattle grazing which is practiced on this site (10, p. 33). An adequate explanation for the difference between the root ratios of the sites within the Artemisia tridentata/ Agropyron spicatum habitat type cannot be given at this time.

Hydrogen ion concentration: All the pH values obtained for the various soils (Appendix B) are well within the minimum (pH 4) and maximum (pH 10) cardinal values for general microbiological activity in soil (3, p. 6). Most of the pH values obtained indicate that the soils investigated have near optimum hydrogen ion concentration for microorganism activity and availability of plant nutrients (5, p. 405).

Ammonification: In general the results of the ammonification experiment were anomalous. In the Ritzville series there was a significant difference in ammonifying capacities between locations but not between bunchgrass and interspace soils. In the Condon series the bunchgrass soils have a greater capacity than the interspace soils. However, there was no significant difference in the capacities between locations. In the Rock Creek series the bunchgrass and interspace soils have essentially equal capacities which do not differ

significantly from the average capacity of the Condon soils. Finally, in the Waha series the interspace soils have significantly greater ammonifying capacities than the bunchgrass soils. The capacities are also significantly different between the two locations.

It would be presumptuous to maintain that the variations obtained here should be used as criteria for differentiating the soils among the various locations. It should be remembered that the soils were collected in the spring and thus the variations at best only reflect environmental conditions present at the time of sampling. As Waksman stated (20, p. 49) "The numbers of micro-organisms in the soil vary with the season of the year, being highest in spring and fall and lowest in summer and winter". It would seem, proper characterization of these soils based upon variation within habitat types would require data that represents seasonal changes as well as site and inherent soil variations.

It can be seen in Figure 7 that in general the ammonifying capacities range between about 40 and 60 percent. These results are typical of those obtained for many and varied ammonification experiments which commonly give ammonifying capacities ranging between the values just given (5, p. 11). That striking differences are uncommon is attributable to the fact that ammonification

can be effected by a great variety of microorganisms. Adequate explanations for the various significant differences found are not available at this time. It is unlikely that the slight changes in pH during incubation (Table 2) would materially affect microbial activity.

Nitrification: Again, results were generally irregular or anomalous. Several significant differences in nitrifying capacities were noted (Figure 8). These differences cannot be explained at this time. However, there appears to be a relationship between locations of the Ritzville soil with respect to ammonifying and nitrifying capacities (Figures 7 and 8). Ammonification was greater and nitrification was lower in the soils at the Wallula location than in the soils at the Umatilla location. Though this relationship cannot be currently explained, it suggests that whatever the causative factors may be, they are operating in both bunchgrass and interspace soils. It would appear that this relationship may be attributable to some inherent soil features other than the enrichment culture provided by the plant roots.

The soils used in this study gave comparatively low nitrifying capacities. A capacity of 80 percent, more or less, is considered to be good (5, p. 11). A low capacity is not necessarily a poor characteristic. It is well known that nitrate nitrogen can be readily leached

from the soil (3, p. 14). However, a good nitrifying capacity is generally indicative of a fertile soil (3, p. 14). In as much as nitrite nitrogen can be toxic (14, p. 452) and because it has been shown that it can accumulate in some of the soils studied here (Table 3), future investigations of its role in rangeland soils may be warranted. In view of the low nitrification values obtained, an investigation of the ability of important range plants to take up ammonium nitrogen may also be warranted.

Respiration: It should be pointed out that when a normal soil is treated in any manner to increase microbial activity the carbon dioxide evolution from the inherent organic matter in the soil is somewhat increased (5, p. 13). Therefore, the percent decomposition of the added roots, with or without ammonium nitrate, is regarded as apparent decomposition.

In general, results were anomalous (Figure 9) which is often the case when ammonium sulfate is added to the soil in respiration experiments (5, p. 13). The rate of carbon dioxide was distinctly greater in the interspace soil of the deteriorated site. This may be due to the introduction of organic matter and microorganisms from the feces of the domestic livestock. Although, if this is the case, it would seem a similar response should have

been obtained for the bunchgrass soil.

As previously noted the bunchgrass soil of the Waha series at the location 12 miles west of Nye has the lowest ammonifying capacity of the soils tested (Figure 7). This same soil also gave the lowest apparent decomposition (Figure 9) and one of the lowest nitrifying capacities (Figure 8). It appears that in this particular soil, microbiological acitivity may be affected by environmental factors intimately associated with the bunchgrass roots.

C:N ratios: In most cases the C:N ratios obtained for the respective roots (Table 4) indicate that in the natural environment, microbiological activity may differ more between bunchgrass and interspace soil than indicated in this study. The generally wider C:N ratios of the bunchgrass roots may indicate a greater conservation of nitrogen by microorganisms within the bunchgrass soil (14, p. 165). Such a difference would not be expected in the soils of the Waha series since the interspace and bunchgrass roots had similar C:N ratios.

SUMMARY AND CONCLUSIONS

An exploratory investigation was made to test the relationship between microbiological capacities, habitat types and soils representative of the Columbia Basin rangeland. Except for the selection of one deteriorated site the study areas were considered to be in near-climax condition.

Based upon the results of a preliminary study a soil sampling procedure was used wherein two sets of samples were obtained from each site. One set represented a soil-root complex of the dominant bunchgrass plant, the other set representing a soil-root complex of interspace vegetation.

The percentages of roots, moisture, moisture capacity and pH values were determined for each sample. C:N ratios were determined for selected bunchgrass and interspace roots. The ammonifying and nitrifying capacities were determined for the Ritzville, Waha, Rock Creek and Condon soil series. Except for the Rock Creek soil, respiration powers were determined for representative samples of each soil. These were based on the apparent decomposition of native roots added at a rate equivalent to 2000 ppm carbon with ammonium sulfate to adjust the C:N ratios of the roots to 20.

It was found that the concentration of roots was significantly greater in the bunchgrass soils than in the interspace soils. Ratios of bunchgrass to interspace roots were calculated. The narrowest ratio was found in the Festuca idahoensis habitat type. This was attributed to the tendency of Festuca pacifica to form a dense mat of roots in the interspaces. The greater concentration of roots found in the interspace soil of the deteriorated site appeared to be a result of the increase in annuals and Poa secunda, and a corresponding decrease in Agropyron spicatum under heavy cattle grazing. These results suggest that interspace and bunchgrass root concentrations and their ratios may be helpful in evaluating the condition and trend of rangelands.

The pH of the Ritzville, Rock Creek, and Condon series tended to be slightly basic. The Waha series tended to be neutral. In general pH values were near optimum for microbiological activity.

The ammonifying capacities of the soils tested were typical of those found for many soils. The nitrifying capacities were relatively low. The results obtained for these studies and the respiration experiment were generally anomalous. Although, relatively small but significant differences were found within and between the soils of the various habitat types, good explanations for

these differences are lacking at the present time.

In future work of this nature the intensity of field sampling could probably be reduced without seriously affecting results. However, samples should be taken in a manner to include various soil-root complexes. A comprehensive study would entail the testing of soils collected at seasonal intervals throughout the year. Culture studies (e.g., plate counts) should be included to elaborate possible variations in the population of microorganisms in time and space.

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APPENDIX

APPENDIX A

Soil Moisture Determinations*

I. *Artemisia tridentata/Agropyron spicatum* habitat type

A. Wallula, Washington (Ritzville silt loam)

Bunchgrass Soil		Interspace Soil	
% Moisture*	% Moisture Capacity*	% Moisture	% Moisture Capacity
3.7	45.1	4.7	39.2
6.8	50.9	7.8	42.0
4.8	42.1	1.2	32.2
5.5	41.8	2.8	36.3
8.1	42.3	8.6	40.9
8.3	41.7	7.4	41.3
8.7	41.7	6.6	42.6
8.2	42.2	7.2	41.7
Mean 7	44	6	40

B. Umatilla Co., Oregon (Ritzville very fine sandy loam)

Bunchgrass Soil		Interspace Soil	
% Moisture	% Moisture Capacity	% Moisture	% Moisture Capacity
10.6	56.0	8.7	47.7
8.3	52.1	8.1	49.5
8.8	52.2	9.1	47.2
7.8	48.2	8.9	51.8
8.1	52.3	10.0	46.2
9.1	52.4	3.2	41.7
9.4	52.4	9.1	48.4
7.8	50.2	8.6	48.4
Mean 8	51	8	48

* Values are averages of duplicate determination.

APPENDIX A (continued)

II. *Festuca idahoensis* habitat type

A. 12 Miles West; Nye, Oregon (Waha silt loam)

Bunchgrass Soil		Interspace Soil	
% Moisture	% Moisture Capacity	% Moisture	% Moisture Capacity
5.6	55.6	2.2	39.6
11.9	64.3	2.0	52.1
12.2	56.9	7.6	51.2
8.3	55.8	17.5	51.9
9.8	62.3	18.6	69.7
11.5	60.2	10.7	61.6
10.9	59.3	6.3	52.0
21.0	64.0	5.9	48.6
Mean 11	60	9	53

B. 22 Miles West; Nye, Oregon (Waha silt loam)

Bunchgrass Soil		Interspace Soil	
% Moisture	% Moisture Capacity	% Moisture	% Moisture Capacity
19.0	83.2	17.2	81.8
19.8	83.1	12.7	74.5
12.5	70.6	16.7	82.8
7.5	66.7	13.0	67.2
14.9	76.1	4.7	62.8
16.7	77.0	4.5	58.3
18.8	86.7	15.4	75.2
16.3	82.2	4.0	52.9
Mean 15	78	15	69

APPENDIX A (continued)

III. Agropyron spicatum/Poa secunda habitat type

A. "Heppner Hill" (Rock Creek very stony loam)

Bunchgrass Soil		Interspace Soil	
% Moisture	% Moisture Capacity	% Moisture	% Moisture Capacity
12.9	63.6	16.8	66.7
11.2	54.7	15.3	65.1
11.7	59.2	18.9	73.4
17.0	69.8	19.2	64.4
7.9	56.8	15.9	71.4
13.8	61.6	17.9	70.7
19.8	70.3	24.1	76.5
16.8	68.7	21.2	73.5
Mean 14	63	18	70

B. Eightmile (Condon silt loam)

Bunchgrass Soil		Interspace Soil	
% Moisture	% Moisture Capacity	% Moisture	% Moisture Capacity
18.3	65.4	20.2	63.1
20.5	61.2	21.7	68.0
17.8	58.4	20.5	70.9
13.0	56.2	18.9	60.7
15.6	62.2	20.6	73.4
12.2	55.2	22.1	73.6
18.2	53.7	20.0	50.2
13.8	44.8	19.6	49.3
Mean 16	57	21	64

C. Deteriorated (Condon silt loam)

Bunchgrass Soil		Interspace Soil	
% Moisture	% Moisture Capacity	% Moisture	% Moisture Capacity
9.5	56.5	12.2	56.3
10.1	55.0	10.0	49.3
10.1	59.9	10.1	45.2
14.5	64.3	10.7	48.8
11.0	52.2	9.2	46.9
13.0	62.0	10.0	53.3
12.6	60.9	10.0	49.9
14.8	69.1	11.5	53.2
Mean 12	60	10	50

APPENDIX B

Hydrogen ion determinations made on 1:5 soil suspensions.
Figures are averages of duplicate pH values determined.

Habitat Types	Artemisia tridentata/ Agropyron spicatum				Festuca idahoensis				Agropyron spicatum/Poa secunda					
Soil Series	Ritzville				Waha				Rock Creek		Condon			
Locations	Wallula Washington		Umatilla Co., Ore.		Nye, Ore. 12 mi., W.		Nye, Ore. 22 mi.,W.		"Heppner Hill"		Eightmile (Climax)		Eightmile (D)*	
Sample Designations[1]	B	I	B	I	B	I	B	I	B	I	B	I	B	I
	7.5	7.8	7.4	7.3	6.9	7.0	7.1	6.9	7.4	7.3	7.4	7.4	7.3	7.3
	7.4	7.2	7.5	7.0	6.8	7.0	6.6	6.9	7.3	7.5	7.5	7.4	7.3	7.3
	7.5	7.4	7.7	7.3	6.8	7.2	6.7	6.9	7.3	7.4	7.3	7.4	7.3	7.4
	7.5	7.4	7.7	7.5	6.8	7.4	6.8	6.8	7.5	7.4	7.4	7.4	7.3	7.5
	7.5	7.3	7.6	7.2	6.6	7.1	6.8	7.0	7.3	7.4	7.5	7.3	7.4	7.3
	7.4	7.4	7.6	7.3	6.8	7.0	6.9	6.9	6.8	7.4	7.2	7.3	7.3	7.4
	7.4	7.2	7.5	7.2	7.0	6.9	7.0	7.0	7.5	7.3	7.2	7.7	7.1	7.3
	7.2	7.2	7.5	7.1	7.0	7.0	6.8	6.9	7.6	7.6	7.1	7.6	7.2	7.3

[1] "B" and "I" designate bunchgrass and interspace samples respectively.

* (D) designates Deteriorated.

APPENDIX C

Cumulative totals of mgs of carbon evolved as carbon dioxide. Values are averages of duplicate determinations.

Soil	Days 1	2	4	8	16	28
	CO_2 Evolved, mgC/100 gms soil					
Ritzville						
Bunchgrass	6.6	8.8	15.6	23.9	35.6	54.1
Soil only	3.0	4.5	6.3	9.6	13.1	19.0
Interspace	5.7	10.0	17.2	26.4	35.6	47.5
Soil only	2.6	4.6	7.2	11.2	15.1	21.5
Waha						
Bunchgrass	2.8	5.5	8.3	13.6	22.0	39.2
Soil only	2.4	4.5	6.7	8.7	12.7	20.6
Interspace	3.3	7.2	11.6	18.2	26.3	40.9
Soil only	1.0	2.7	4.2	6.3	9.3	14.6
Condon (Climax)						
Bunchgrass	3.9	7.0	11.8	26.7	34.3	55.4
Soil only	2.5	4.6	7.3	6.8	12.9	25.3
Interspace	5.3	11.7	17.5	24.0	32.7	51.6
Soil only	3.2	6.0	8.8	12.5	16.4	26.0
Condon (Deteriorated)						
Bunchgrass	4.9	8.9	14.4	22.6	35.9	66.7
Soil only	2.6	6.2	9.8	14.8	21.8	43.0
Interspace	5.8	12.1	28.8	41.1	52.1	72.1
Soil only	2.0	3.7	6.7	10.4	17.0	33.6