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Behavior of Winter Annuals as Influenced by Microtopography and Elevation[1]

Introduction

The herbage yield of winter annuals was measured throughout the spring growing season of 1969 on contrasting north- and south-facing slopes of artificially formed earth mounds in the semi-arid steppe region of south-central Washington (Rickard, Hinds, and Gilbert, 1971). Under the prevailing climatic regime the south-facing slopes produced a stand of winter annuals consisting mostly of cheatgrass, *Bromus tectorum*, that had fewer individuals per unit area but produced more biomass. The plants on the south-facing slope also matured earlier. South-facing slopes differed from north-facing in terms of microclimate by receiving more incoming solar radiation that produced higher soil temperatures and warmer air temperatures during daylight hours. The differences observed in plant yield were attributed to microclimatic differences because the mounds were constructed from a common soil substrate.

When locations are geographically close, increasing elevation provides a cooler climate even though incoming solar radiation is similar. This paper reports the results of observations on the behavior of winter annuals on two fields located at different elevations about four miles apart and compares the behavior with that of winter annuals growing on contrasting slopes of artificial earth mounds.

Description of the Fields

The two fields studied are situated on gently sloping terrain on the U.S. Atomic Energy Commission's Hanford Reservation in Benton County, Washington. Both were cultivated 28 years ago but have since been abandoned. During this period these fields have had only light grazing use during the early years, and there has been no grazing for several years prior to 1969. The low elevation field is small, approximately 10 acres, but the upper field is large, i.e., several hundred acres. The lower field was irrigated, but the details of its farming history are not known. The high elevation field was repeatedly cultivated for dryland wheat over a period of 20 to 30 years prior to abandonment in 1943.

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The soil of both fields is silt loam in texture and is free of stones at least in the upper meter of profile. The pH of the lower-field soil is characteristically higher than that of the upper field, but the upper-field soil is richer in available phosphorus and potassium (Table 1). These differences are statistically significant at the

TABLE 1. Chemical characteristics of the soil profile of abandoned fields.

Depth (dm)	pH	OM%	N%	P[1]	K[1]
			1700-feet elevation		
0-1	6.9	1.4	.08	49	1300
1-2	7.1	0.9	.06	29	1190
2-3	7.3	1.0	.06	22	1100
3-4	7.3	0.7	.06	19	980
5-6	7.4	0.9	.06	10	800
7-8	7.5	0.7	.05	10	700
9-10	7.7	0.5	.04	5	540
$\bar{X} \pm$ S.E.	7.3 ± .10	.87 ± .11	.06 ± .005	20.6 ± 5.7	944.3 ± 104.2
			600-feet elevation		
0-1	7.7	1.9	.10	18	1140
1-2	8.1	1.2	.08	3	680
2-3	8.1	0.6	.03	3	450
3-4	8.1	0.6	.03	1	450
5-6	8.2	0.5	.02	1	300
7-8	8.4	0.4	.03	1	260
9-10	8.4	0.5	.02	1	260
$\bar{X} \pm$ S.E.	8.1 ± .09	.81 ± .21	.04 ± .01	4 ± 2.4	505.7 ± 119.7

[1] Available phosphorus and potassium values are expressed as pounds per acre.

$\alpha = .01$ significance level using paired t tests (Snedecor and Cochran, 1967, p. 93). However, there were not significant differences between the fields in their organic-matter and total nitrogen contents, both of which were at low levels in the two fields. The climatic regimes of the fields are different with the upper field having cooler and more moist conditions (Hinds and Thorp, 1969).

The vegetation of both fields is presently dominated by winter annuals, especially cheatgrass and two annual crucifers: tansy mustard, *Descurainea pinnata,* and tumble-mustard, *Sisymbrium altissimum.* The upper field supports both of these and several perennial and biennial forbs, especially lanceleaf microseris, *Microseris lanciniata,* and yellow salsify, *Tragopogon dubius.* There are also a few scattered bunches of bluebunch wheatgrass, *Agropyron spicatum,* sandberg bluegrass, *Poa secunda,* squirrel tail, *Sitanion hystrix,* and *Lupinus* spp. The lower field had only one native perennial species within its boundaries, and this was *Poa secunda.*

Methods Employed

The harvest of winter annuals was done by hand-picking new growth from 1 x 1 foot (.093 m^2) quadrats. As the plants were plucked, a small part of the root system was usually attached, and this was discarded. The harvested material was oven-dried at 65°C for 48 hours. Harvests were conducted eight times on the low-elevation field and nine times on the high-elevation field from mid-March to late May, a time period that encompasses the most active part of the growing season for winter annuals.

Six to ten quadrats were harvested at each harvest date from a prearranged systematic sampling design. The density of plants was determined only on the final harvest which was judged to represent the peak herbage yield of the 1969 season.

Soil moisture was determined at decimeter depth increments at weekly intervals to a depth of 1 meter (depth of maximal moisture penetration) at the low-elevation field and to a depth of 1.5 meters at the high-elevation fields (Fig. 2). Two holes were bored in each field at each sampling time with a sand auger. The moisture content was determined gravimetrically by oven-drying at 105°C for 48 hours. Bulk density of the soil profiles was obtained by digging a soil pit and taking volume/weight samples from the sides of the pit. To estimate the amount of soil moisture available for plant use only, the moisture held at tensions less than —15 bars was considered as available.

Results and Discussion

The low-elevation field produced more herbage than the high-elevation field (Table 2). The difference of 14 grams per square foot was statistically significant at the $\alpha = .01$ level. In addition, the herbage yields on approximately equivalent harvest days were compared using t tests. All tests except 1 and 3 (see the last two columns of Table 2) were highly significant. Least squares linear fits were made to the herbage yield (Fig. 1). The relationship between herbage yield and time is apparently linear. The linear relationship between herbage yield and time on the old fields differed from the south and north slopes where the relationship is described better by exponential curves, particularly for the north slopes (Rickard, Hinds, and Gilbert, 1971). To determine if this apparent difference is real needs further study.

The density of cheatgrass on the average was greater on the high-elevation field than on the low-elevation field (Table 3). The difference of 208 plants per square foot was statistically significant at the $\alpha = .05$ level.

When the results of the observations made on the fields are compared with those of the earth mounds (Rickard, Hinds, and Gilbert, 1971), it is seen that the low-elevation field and the south-facing slopes, i.e. the more xeric habitats, produced

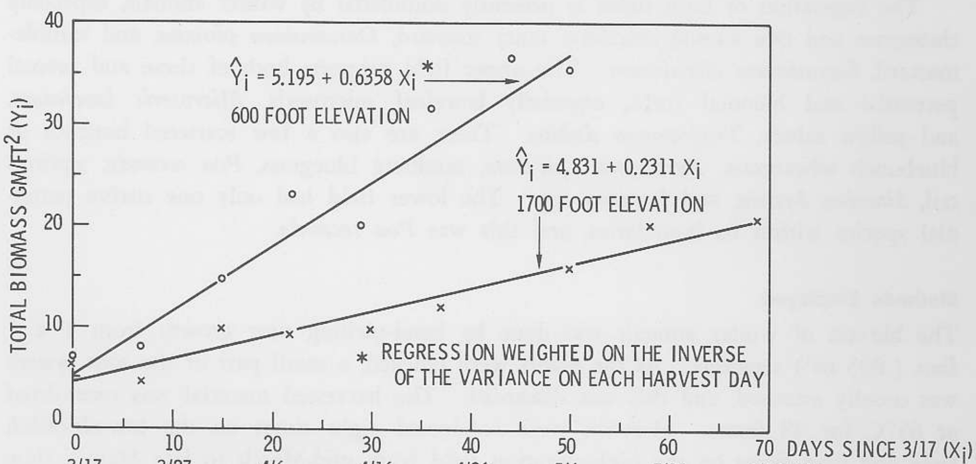

Figure 1. Least squares linear fit to herbage yields obtained on abandoned fields in the steppe region of south-central Washington.

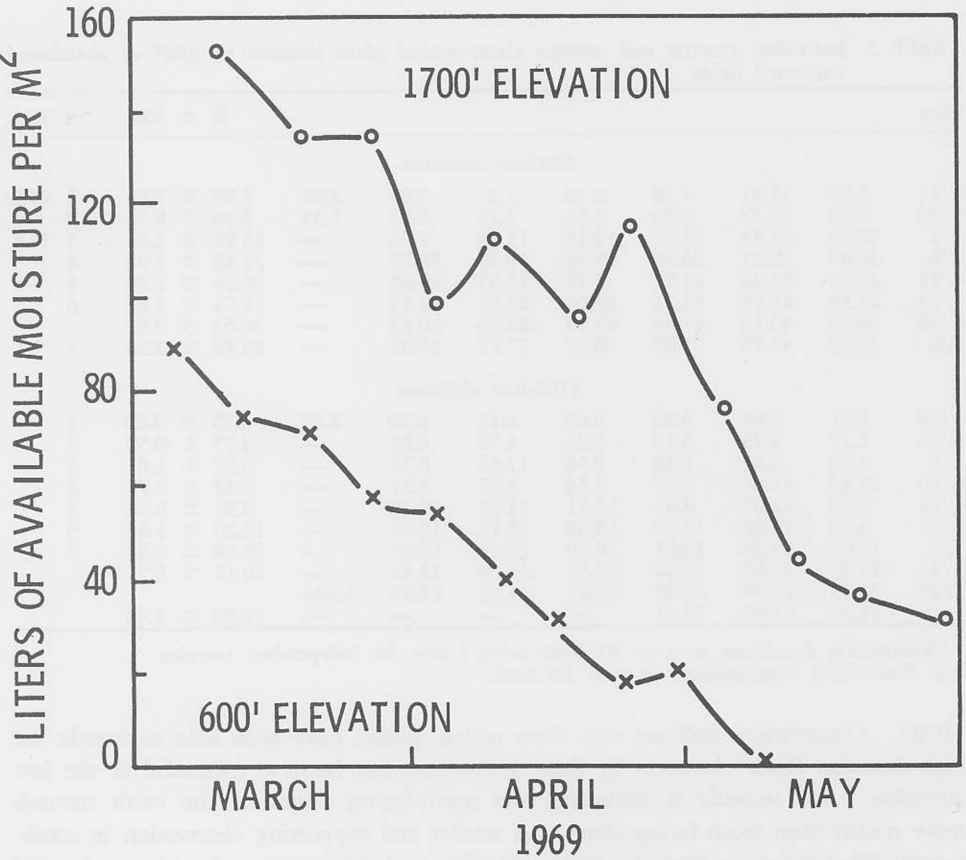

Figure 2. The decline of moisture in the soil profile of cheatgrass-dominated fields during the spring growing season of 1969.

more herbage over a shorter period of time with fewer plants. The more mesic habitats as represented by north-facing slopes and the high-elevation field produced stands that were more dense and matured later in the spring.

An indication of spring soil-moisture use by winter annuals on the high and low fields is illustrated in Figure 2. Clearly more moisture was available in the soil profile of the high-elevation field at the start of the spring growing season in early March. Soil moisture steadily declined on the low-elevation field until mid-May when no growth water remained.

Soil moisture was replenished periodically by spring precipitation at the high elevation although it also declined between March and May. By late May available moisture still persisted in the soil profile but only at depths one meter deep and below. Apparently deep moisture is not capable of sustaining growth of winter annuals, and these had matured and dried by late May. However, the leaves of *Microseris* and *Tragopogon* remained succulent although these plants had flowered and set seed. These data show that factors other than available soil moisture play important roles in determining herbage yields.

Under pristine conditions the vegetation of the more arid steppe region of southeastern Washington is dominated by shrubs, especially *Artemisia tridentata,* and perennial grasses, especially *Agropyron spicatum* and *Poa secunda* (Daubenmire,

TABLE 2. Individual quadrat and average above-ground plant biomass in g/ft² of abandoned cultivated fields.

Date								$\bar{X} \pm$ S.E.	t Test
				600-foot elevation					
3/17	6.33	11.51	7.76	8.12	7.27	5.00	2.96	7.00 ± 1.01	1 N.S.
3/24	5.79	10.72	9.58	8.78	5.29	9.01	7.55	8.10 ± 0.75	2 **
4/1	18.95	17.34	17.34	14.18	13.88	7.86	—	14.92 ± 1.62	3 N.S.
4/8	20.87	29.22	26.46	17.76	19.39	26.79	—	23.42 ± 1.90	4 **
4/15	22.45	17.86	23.92	9.71	23.35	23.65	—	20.16 ± 2.28	5 **
4/22	29.18	41.58	30.21	35.98	20.87	32.55	—	31.73 ± 2.84	6 **
4/30	20.45	49.16	47.45	43.94	27.93	30.73	—	36.61 ± 4.83	
5/6	29.95	42.75	37.05	40.07	37.17	25.93	—	35.49 ± 2.58	7 **
				1700-foot elevation					
3/19	3.81	5.84	6.02	8.60	6.18	6.50	8.89	6.55 ± 0.65	1
3/26	2.17	4.23	6.15	5.23	4.71	6.01	—	4.75 ± 0.59	2
4/3	8.10	8.82	6.26	8.96	17.63	9.77	—	9.92 ± 1.61	3
4/10	10.44	13.84	7.77	7.54	8.67	8.27	—	9.42 ± 0.97	4
4/18	7.52	12.07	8.43	11.11	11.28	9.15	—	9.93 ± 0.74	5
4/25	9.20	10.39	12.10	15.59	15.13	10.77	—	12.20 ± 1.07	6
5/8	14.69	15.26	16.61	16.19	16.44	16.07	—	15.88 ± 0.30	7
5/16	14.32	17.83	19.44	22.39	24.50	22.32	—	20.13 ± 1.51	
5/27	22.63	25.08	24.40	23.41	25.09	13.87	19.04		
	21.97	21.00	12.31	—	—	—	—	20.88 ± 1.43	

** Statistically significant at $\alpha = .01$ level using t tests for independent samples.
N.S. Statistically nonsignificant at $\alpha = .05$ level.

1970). Observations indicate that these native grasses have been able to invade the high-elevation field. Invasion by these grasses has not been so successful at the low elevation. *Poa secunda* is colonizing the north-facing slopes of the earth mounds more readily than south-facing slopes. A similar and supporting observation in southeastern Washington is given by Dillon (1967), and this suggests that the cooler and more moist sites are invaded more readily by native perennials than are the warmer and drier sites.

Estimates were not made of root biomass since it is impractical to separate the current year's root growth from older material as it exists in soil cores.

An extensive survey of above- and below-ground biomass of desert winter annuals in southern Nevada has been published by Beatley (1969). Herbage yield varied from site to site and from year to year within any particular plant association. The maximum biomass, 75.3 g/m² (above and below ground), occurred on a site previously disturbed by wildfire. Here most of the herbage was contributed by a single species of alien grass, *Bromus rubens.*

In southern Washington, the 1969 growing season was one of the most salubrious in many years. The herbage yield on the low-elevation field averaged 380 g/m²,

TABLE 3. The density of cheatgrass (plants/square foot) and associated forbs on abandoned fields.

											$X \pm$ S.E.
				600-foot elevation field							
Cheatgrass	275	225	310	240	128	95	--	--	--	--	212.17 ± 34.29
Tansy mustard	4	72	12	54	150	74	--	--	--	--	61.00 ± 21.53
				1700-foot elevation field							
Cheatgrass	400	878	215	450	449	378	383	497	324	225	419.90 ± 58.71
Perennial Forbs	0	0	5	1	5	1	5	6	3	6	3.2 ± .79

and the high-elevation field averaged 200 g of winter annuals per m^2 plus 25 g/m^2 of perennial forbs. The yield of winter annuals in the steppe region of Washington apparently exceeds that of the Mojave desert, at least during the most favorable years.

Productivity estimates in the steppe region of Washington are scarce in the published literature. Daubenmire (1970, p. 129) gives values for four stands of *Artemisia tridentata-Agropyron spicatum* association in pristine condition. These values range between 71.9 and 115 g/m^2. The average value for the four stands is 93.2 g/m^2. Clearly the herbage yield of winter annuals exceeds these values. However, estimates of productivity need to be made over a series of years that include unfavorable as well as favorable moisture conditions.

The production of dry matter over a 50-day spring growing period on the low-elevation field progressed at an average rate of 6.1 $g/m^2/day$. At the high-elevation field the average rate of increase amounted to only 2.4 $g/m^2/day$ calculated over a 63-day spring growing season. When calculated on the basis of $g/m^2/day$ over the entire year, the values are 1.05 and .62 at the low and high elevations, respectively. These values are indicative of the strong influence that relatively small increments of increasing elevation and associated changes in climate and soil can have on annual herbage yields in the steppe region of Washington.

Following soil disturbances that kill native plants, it can be expected that alien winter annuals will produce most of the herbage yield for a quarter of a century or more unless measures are taken to discourage winter annuals and purposefully introduce perennial grasses. The strong competition offered by cheatgrass is a factor to be considered when the seeding of native grasses on depleted range lands is a desired goal (Harris, 1967).

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