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ECOLOGY OF COOL DESERT ANNUALS

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ABSTRACT

The summer drought drastically affected growth, density and productivity on the southern site at Curlew Valley, Utah. In the *Atriplex-Artemisia* vegetation type all annuals died within a few weeks after germination. In the other two vegetation types densities by July began to decrease and declined markedly through the season. Standing crop at the end of the season was approximately 1 to 2% of that of 1973. *Lepidium perfoliatum*, *Descurainia pinnata* and *Salsola kali* were essentially absent. *Halogeton glomeratus* did not flower and *Bassia hyssopifolia* flowered and set fruit only sparsely. At the northern site, where conditions were favorable throughout the annual growing season, correlations between the plant components and time were often poor. In contrast, with *Bassia* and *Halogeton*, vegetative correlations at the southern site continued to be generally very good.

INTRODUCTION

The pattern of growth of cool desert annuals and their role in the ecosystems of the Great Basin Desert are fairly well understood. Quite clearly, annuals become increasingly more important with disturbance of the ecosystems.

At the southern site in Curlew Valley, Utah, and throughout many of the lower-elevation valleys of the Great Basin, *Bassia hyssopifolia* and *Halogeton glomeratus* are most important, particularly in arid years. Of slightly lesser importance, but yet major components during wetter years, are *Descurainia pinnata, Lepidium perfoliatum* and *Salsola kali*. In the absence of summer precipitation *Halogeton* and *Bassia* will flower and set seed only in depressions, frequently along roadsides.

At the southern site, both *Lepidium perfoliatum* and *Descurainia pinnata* were extremely rare (essentially absent) during 1974. Two reasons may be offered: 1) lack of seed source related to extremely heavy seed predation during 1973 and 2) unfavorable environmental conditions. A few seeds of both species germinated, but after reaching a few centimeters in height died due to drought. At the northern site, on the other hand, soil water conditions were favorable through the entire life cycle of the plants.

The patterns of growth and productivity of five annuals were studied during 1974; *Bassia hyssopifolia* and *Halogeton glomeratus* at the southern site and *Bromus tectorum, Camelina microcarpa* and *Collinsia parviflora* at the northern site. For those species at the southern site, these patterns were correlated with environmental data.

Three hectares were established for sampling purposes in the annual *Artemisia-Halogeton* and the *Atriplex* vegetation types at the southern site. These represent a decreasing influence of disturbance with the *Atriplex* vegetation type being virtually free of disturbance.

During 1975, the pattern of growth of *Lepidium perfoliatum* will be examined in detail. Annual productivity will be measured at the three vegetation types at the southern site.

OBJECTIVES

The research was intended to assess the following parameters of the major annuals:

1. Total productivity
2. Changes in density
3. Growth patterns including: a) leaf weight and number, b) stem weight and number, c) flower number, d) inflorescence weight, e) fruit weight and number, f) root weight and length and g) protein and caloric values for leaves, stems and fruits
4. Environmental conditions affecting seed germination

METHODS

A study hectare was located in each of the three vegetation types at the southern site in Curlew Valley. Within each hectare a grid was established to randomly locate the plots for destructive harvesting. The program for random sampling was developed by the Data Processing Group of the Desert Biome.

Standing crop was determined by harvesting all plants from twenty 1 x 1 dm plots in each vegetation type at fortnightly intervals. The entire plot, including the surrounding soil, was removed so that the plants would be subsequently divided into the various components (mentioned in Objectives above) in the laboratory, using sifting and flotation techniques. The plants were oven dried at 80 C for 24 hr after which the components were counted and weighed to the nearest 10^{-5} g. Plant parts were forwarded to Dr. James MacMahon's laboratory at the Desert Biome Central Office (Utah State University) for caloric and protein analyses. Coverage values were judged ocularly.

Seed germination was determined in response to salinity, temperature and soil moisture. When it became apparent that drought was affecting the growth of *Bassia* and *Halogeton*, twenty 10 x 10 cm plots were established to determine the effect of additional water. At fortnightly intervals, 2.5 cm of water were added to these plots with a garden water container.

Environmental data collected at the meteorological station at the southern site were used to correlate plant patterns with environmental data. Each of the temperature values represents a mean developed over 14-day intervals. Relative humidity data were averaged daily at 2-hr intervals and then developed as a mean over the 14-day interval. Soil temperature and water potential were measured with Wescor soil psychrometers at depths of 5, 15, 30 and 50 cm at approximately 14-day intervals by R. Anderson and R. Shinn. Mean values of eight stations were used for analyses.

For the northern site, a similar pattern was followed except that the plants were sampled at weekly intervals. The annuals studied were *Bromus tectorum*, *Camelina microcarpa* and *Collinsia parviflora*. Due to malfunction of the micrometeorological instrument, temperature data are not available for correlative analyses.

The data were reduced with the aid of Mr. Kim Marshall of the Desert Biome Central Office. Productivity data were obtained by multiplying the mean density per species at a given date by the mean biomass.

RESULTS

SEED GERMINATION

Halogeton produces two kinds of seeds (brown and black), both with viability of approximately 98%, as tested with the tetrazolium dye technique. The black seeds germinate under a wide variety of environmental conditions, ranging from a pH of 3.5 to 9.0, soil osmotic pressures up to -9 bars and soil temperatures as high as 50 C. With wetting of the soil surface, germination rapidly occurs and is independent of photoperiodic conditions. Like others, we have been unable to effect germination of the brown seeds.

The seeds of *Descurainia pinnata* and *Lepidium perfoliatum* also germinate under a wide variety of environmental conditions, particularly as the seed ages (if favorable moisture conditions exist). Germination occurs at soil pH of 4.0 to 8.0, temperatures from approximately 0 to 20 C and osmotic potential of up to -8 bars (although optimal germination occurs at 0 osmotic potential and declines with increasing salinity). High soil salinities are not tolerated. These germination patterns conform to those found in the literature.

The seeds of *Bassia hyssopifolia* did not germinate under any environmental conditions, even though the viability of the seed was approximately 98%. Perhaps germination of the seeds requires considerable alternation of temperature.

In all cases, the seeds were maintained at below 0 C for three to four months prior to germination tests.

PATTERN OF GROWTH

Annuals in the *Atriplex-Artemisia* vegetation type germinated sparsely, grew slowly and died within a few weeks after germination. Undoubtedly, a water deficiency caused the abnormal pattern, although it is well recognized that shrubs compete effectively with annuals in the absence of disturbance.

Descurainia pinnata and *Lepidium perfoliatum* germinated sparsely (approximately 1% of 1973 germination). All individuals died within a few weeks; *Salsola kali* followed a similar pattern. Therefore, two annuals were present at the southern site throughout the season; *Bassia hyssopifolia* and *Halogeton glomeratus*. The growth patterns of these annuals are described by the equations in Tables 1 and 2. All relationships are analyzed in linear, semi-log (both ways) and log log fashion. Equations with highest R values are presented.

Fruit production and inflorescence relationships of *Bassia* are unquestionably misleading as only a very small percentage of the plants flowered and produced fruit. *Halogeton* did not flower and fruit.

Growth equations for *Bromus tectorum*, *Camelina microcarpa* and *Collinsia parviflora* at the northern site are presented in Tables 3, 4 and 5.

In contrast to the northern site, southern site soil moisture conditions were favorable throughout the growth season. In spring, growth resumes in late March when temperatures during the day reach approximately 5 C.

As in 1973, *Halogeton* germinated in early April. However, due to drought, no further germination occurred during the summer. *Bassia* germinated in late April and early May with extremely sparse flowering limited to slight depressions in the soil and producing only a few flowers. Death, in contrast to 1973, preceded the first frost.

Correlation coefficients of plant components are presented in Tables 6-10. The reproduction correlations of *Bassia* and *Halogeton* are undoubtedly erroneous, reflecting very unreliable data.

Coverage values were meaningless due to sparseness of annuals; even at early dates these were not statistically reliable. In 1973, values approaching 100% were common, whereas the highest values in 1974 were 20%.

The correlations between plant components and abiotic variables at the southern site are shown in Tables 11 and 12. The soil water potential and temperature data at 50 cm are not directly causally related since the roots of the annuals at Curlew Valley did not penetrate that deeply. Changes in density are shown in Table 13.

Productivity equations describing the increase in biomass with time were analyzed in linear and log fashion (Tables 14 and 15). Those equations with the highest R values are presented. Total standing crop of the two annuals with time is given in Table 16.

DISCUSSION

In 1974, R values of growth equations decreased in both *Bassia* and *Halogeton*. The decline in R values represents microtopographic differences. In years of favorable moisture, the annuals are highly uniform in growth response with time. During dry years, like 1974, small topographic differences lead to orders of magnitude differences with respect to growth. Those in slight depressions tend to grow for longer periods of time, whereas those on slightly elevated areas die very early.

The very low correlations of growth of *Bromus tectorum* were surprising. The pattern of growth is highly variable depending upon microsite. Determination of mean production variability with time with *Bromus* would require an enormous number of samples. The pattern of growth with time of *Camelina* and *Collinsia* follows a rather tight pattern, with a few exceptions. The leaf number and weight of *Camelina* vary greatly between plants, as does the inflorescence length, although the R value for inflorescence weight is high. The root lengths of *Collinsia* are highly variable depending upon microsite.

In general, under drought conditions, the vegetative parts of *Bassia* are still fairly highly correlated, but not as tightly as in 1973. Little credence should be given to the reproductive correlations, as noted above. Root correlations dropped considerably, reflecting differences in microtography. Almost all vegetative components correlate well with total weight. With *Halogeton*, log-log relationships generally are much better than linear correlations. As in 1973, rather good correlations exist between vegetative components.

Vegetative correlations with *Bromus* were poor, but reproductive features were highly correlated. Stem weight and total above-ground weight correlated well with fruit weight. Other correlations were not very good.

With *Camelina*, length correlations were not as good as weight correlations; particularly poor were inflorescence length, root length and leaf and fruit numbers. All of these seem to vary considerably within the species, but weight relationships are rather consistent, with the exception of leaf weight.

Generally, internal correlations were not as good with *Collinsia* as with other species. Root weight and length, inflorescence length and fruit number often correlated poorly with other plant components. However, stem weight, root weight, fruit weight and total weights correlated well.

Unfortunately, caloric and protein values of our samples have not been determined.

Generally, the plants of the northern site present a more loosely coordinated structure than *Bassia* and *Halogeton*, even though environmental conditions were favorable at the northern site and unfavorable at the southern site.

When considering environmental correlations with *Bassia*, once again, the reproductive features are undoubtedly invalid, reflecting a very small, unrepresentative sample of the total population. As expected, almost all values of soil water potential and precipitation are highly correlated with root and stem growth, in contrast to 1973. Those data from 5 cm are not reflective of the water available to the plants since the roots penetrate below that layer. The soil temperatures following the continuous drought also correlate well with vegetative growth of *Bassia*. Quite surprisingly, air temperatures correlate well, particularly on a linear basis, whereas in 1973, log relationships only were important. Undoubtedly, this reflects the pattern of growth, being in all cases a single stalk. In 1973, growth continued into late September, thus considerably reducing any correlations with air temperature. Correlations with leaf number and weight and environmental conditions are once again poor, but even less than 1973. This relationship reflects the loss of leaves as the plants become moribund. Once again, relative humidity values show no relationship with plant growth.

Halogeton exhibits a similar pattern. It is noteworthy that *Halogeton* roots and stems correlate well with the environmental conditions at 5 cm in the soil. For unknown reasons, leaf numbers and weights were not analyzed. To emphasize, the reproductive correlations are invalid.

Considering the entire biomass, i.e., density x mean plant components, all aspects individually are correlated with time at a considerably lower level, reflecting slow growth and density changes. *Halogeton* follows a similar pattern. Clearly, in drought situations, projecting productivity with time is difficult due to mortality and differential growth of the plants (Tables 14 and 15).

Initial densities of *Halogeton* were considerably lower in 1974 than 1973, whereas those of *Bassia* were higher (Table 13). However, by the end of May the density of *Halogeton* had dropped below that of 1974 and by mid-August the densities of both were approximately 1% of those in 1973. The continuous drought had caused almost continuous mortality throughout the summer.

Interestingly enough, the addition of water caused no significant change in any of the plant data. Although the water was added slowly, i.e., over approximately 10 min, I strongly suspect that some of the water ran off and/or reached impermeable layers, close to the surface, that resulted from horizontal cracking of the soil.

The degree of the drought is reflected in the fact that the total standing crop of *Halogeton* at the end of the season was approximately 1% of that in 1973; with *Bassia*, it was approximately 2% (Table 16).

In summary, at the southern site the extreme drought led to the absence of two species, a drastic decline in annual productivity, low densities and, as one would predict, tight correlations with soil water potential.

EXPECTATIONS

Assessment of annual growth will continue in 1975. We hope for a typical year, now that the extremes have been sampled.

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Table 1. Growth equations of *Bassia hyssopifolia* with respect to time; R values in parentheses (A3UKC01)

ln(stem length) = 2.8821 ln(time) - 11.9533	(.94)
ln(stem weight) = 4.3749 ln(time) - 28.0889	(.92)
ln(root length) = 1.0077 ln(time) - 3.3155	(.82)
ln(root weight) = 3.2737 ln(time) - 22.7679	(.88)
inflorescence length = 3.0947 ln(time) = 14.8628	(.31)
inflorescence weight = .0037 (time) - 0.0183	(.49)
leaf # = 14.3406 ln(time) - 53.9752	(.72)
ln(leaf weight) = 2.3276 ln(time) - 16.5094	(.81)
fruit # = 0.0355 (time) - 5.2765	(.54)
fruit weight = - .0000 (time) - 0.0059	(.54)
ln(plant weight-root weight) = 3.1419 ln(time) - 20.1121	(.94)
ln(plant weight) = 3.1736 ln(time) - 20.1173	(.94)

Table 2. Growth equations of *Halogeton glomeratus* with respect to time; R values in parentheses (A3UKC01)

ln(stem length) = 3.2520 ln(time) - 13,8777	(.92)
stem weight = 0.0568 ln(time) - 0.2746	(.96)
ln(root length) = 1.0543 ln(time) - 3.8629	(.79)
ln(root weight) = 3.5531 ln(time) - 24.2786	(.88)
leaf # = 49.5790 ln(time) - 227.0110	(.91)
ln(leaf weight) = 3.9769 ln(time) - 24.4049	(.77)
ln(plant weight-root weight) = 4.8291 ln(time) - 27.9227	(.75)
ln(plant weight) = 4.7231 ln(time) - 27.3013	(.75)

Table 3. Growth equations of *Bromus tectorum* with respect to time; R values in parentheses (A3UKC01)

stem length = 1.7872 (time) - 175.4389	(.84)
stem weight = 0.0304 ln(time) - 0.1308	(.20)
root length - 0.0382 (time) + 3.4563	(.53)
root weight = - .0001 ln(time) - 4.8924	(.01)
inflorescence length = 0.0664 (time) - 6.6327	(.81)
inflorescence weight = - 0.0000 (time) - 0.0000	(.74)
ln leaf # = 0.0073 (time) + 1.5353	(.67)
leaf weight = - .2144 (time) - 5.4027	(.10)
fruit # = 0.0884 (time) - 8.8913	(.79)
fruit weight = - .0001 (time) - 0.128	(.71)
ln(plant weight-root weight) = 1.0499 ln(time) - 8.4294	(.27)
ln(plant weight) = .5344 ln(time) - 5.6689	(.15)

Table 4. Growth equations of *Camelina microcarpa* with respect to time; R values in parentheses (A3UKC01)

stem length = 1.5968 (time) - 145.9098	(.97)
ln(stem weight) = 0.0609 (time) - 13.6423	(.98)
root length = 0.0614 (time) - 1.7350	(.84)
ln(root weight) = 2.8666 ln (time) - 20.1059	(.99)
inflorescence length = - 1.0191 ln(time) - 3.1104	(.09)
inflorescence weight = 0.0001 (time) - 0.0054	(.96)
leaf # = 6.1302 ln(time) - 13.2380	(.14)
ln leaf weight = .0000 ln(time) + .0023	(.03)
fruit # = 0.0423 (time) - 3.8708	(.92)
fruit weight = 0.0001 (time) - 0.0116	(.82)
ln(plant weight-root weight) = 0.0404 (time) - 9.6631	(.92)
ln(plant weight) = 0.0365 (time) - 8.9493	(.95)

Table 5. Growth equations of *Collinsia parviflora* with respect to time; R values in parentheses (A3UKC01)

ln(stem length) = 6.5148 ln(time) - 27.9581	(.94)
ln(stem weight) = 5.9158 ln(time) - 35.1644	(.85)
ln(root length) = 0.3282 ln(time) + 0.0523	(.26)
ln(root weight) = 2.3339 ln(time) - 18.0231	(.62)
inflorescence length = 0.0317 (time) - 3.1230	(.70)
inflorescence weight = 0.0001 (time) - 0.0098	(.89)
ln(leaf #) = 2.0623 ln(time) - 11.6715	(.78)
ln(leaf weight) = 4.5051 ln(time) - 27.6046	(.88)
fruit # = 0.0161 (time) - 1.5976	(.71)
fruit weight = 0.001 (time) - 0	(.77)
ln(plant weight-root weight) = 6.0072 ln(time) - 33.7378	(.93)
ln(plant weight) = 5.1229 ln(time) - 29.2970	(.91)

Table 6. Plant component correlation coefficients (R values in percentages are shown) for *Bassia hyssopifolia*

	Stem length	ln(stem length	Stem weight	ln(stem weight)	Root length	ln(root length)	Root weight	ln(root weight)	Inflorescence length	ln(inflorescence length)	Inflorescence weight	ln(inflorescence weight)	Leaf #	ln(leaf #)	Leaf weight	ln(leaf weight)	Fruit #	ln(fruit #)	Fruit weight	ln(fruit weight)	Flower #	ln(flower #)	Total above ground weight	ln(total above ground weight	Total weight	ln(total weight
Stem length	1	1																								
ln(stem length)	1	1																								
Stem weight	97	91	1	1																						
ln(stem weight)	90	97	1	1																						
Root length	75	80	75	86	1	1																				
ln(root length)	73	83	74	89	1	1																				
Root weight	94	88	96	87	62	65	1	1																		
ln(root weight)	88	96	88	98	78	83	1	1																		
Inflorescence length	18	23	17	27	58	52	04	12	1	1																
ln(inflorescence length)	18	23	17	27	58	52	04	12	1	1																
Inflorescence weight	30	29	07	16	12	10	07	15	17	17	1	1														
ln(inflorescence weight)	-30	-29	-07	-16	-12	-10	-07	-15	17	17	1	1														
Leaf #	77	81	83	87	90	91	73	80	37	37	15	15	1	1												
ln(leaf #)	73	81	78	86	87	90	71	82	30	30	14	14	1	1												
Leaf weight	92	92	94	92	82	83	91	90	28	28	4	4	91	90	1	1										
ln(leaf weight)	81	92	81	94	85	90	78	93	27	27	5	5	91	95	1	1										
Fruit #	30	29	07	16	12	10	07	15	17	17	100		-15	-14	4	5	1	1								
ln(fruit #)	30	29	07	16	12	10	07	15	17	17	100		15	14	4	5	1	1								
Fruit weight	30	29	07	16	12	10	07	15	17	17			15	14	4	5			1	1						
ln(fruit weight)	-30	-29	-07	-16	-12	-10	-07	-15	-17	-17			15	14	-4	-5			1	1						
Flower #																					1	1				
ln(flower #)																					1	1				
Total above ground weight	98	95	93	91	78	78	89	88	27	27	40	-40	77	74	92	84	39	39	39	-39			1	1		
ln(total above ground weight	89	98	84	97	84	87	81	95	31	31	33	-33	81	82	90	95	33	33	33	-33			1	1		
Total weight	99	96	95	91	76	77	93	90	22	22	34	-34	77	75	94	84	34	34	34	-34			100	92	1	1
ln(total weight)	90	99	85	97	83	87	83	97	28	28	31	-31	81	83	90	95	31	31	31	-31			93	100	1	1

Table 7. Plant component correlation coefficients (R values in percentages are shown) for *Halogeton glomeratus*

	Stem length	ln(stem length	Stem weight	ln(stem weight)	Root length	ln(root length)	Root weight	ln(root weight)	Inflorescence length	ln(inflorescence length)	Inflorescence weight	ln(inflorescence weight)	Leaf #	ln(leaf #)	Leaf weight	ln(leaf weight)	Fruit #	ln(fruit #)	Fruit weight	ln(fruit weight)	Flower #	ln(flower #)	Total above ground weight	ln(total above ground weight	Total weight	ln(total weight
Stem length	1	1																								
ln(stem length)	1	1																								
Stem weight	95	96	1	1																						
ln(stem weight)	87	92	1	1																						
Root length	87	91	81	94	1	1																				
ln(root length)	88	93	84	96	1	1																				
Root weight	78	83	86	97	88	89	1	1																		
ln(root weight)	83	88	90	99	91	93	1	1																		
Inflorescence length									1	1																
ln(inflorescence length)									1	1																
Inflorescence weight											1	1														
ln(inflorescence weight)											1	1														
Leaf #	91	94	93	99	95	96	97	98					1	1												
ln(leaf #)	86	91	90	1	95	96	98	99					1	1												
Leaf weight	52	57	52	56	54	58	33	45					45	48	1	1										
ln(leaf weight)	86	91	89	95	90	93	84	90					91	92	1	1										
Fruit #																	1	1								
ln(fruit #)																	1	1								
Fruit weight																			1	1						
ln(fruit weight)																			1	1						
Flower #																					1	1				
ln(flower #)																					1	1				
Total above ground weight	62	67	63	64	62	66	43	55					56	58	99	85							1	1		
ln(total above ground weight	84	90	88	93	88	91	81	88					88	90	81	1							1	1		
Total weight	64	68	65	66	63	68	45	57					58	59	99	86							1	87	1	1
ln(total weight)	84	90	88	94	88	91	82	89					80	90	80	1							87	1	1	1

Table 8. Plant component correlation coefficients (R values in percentages are shown) for *Bromus tectorum*

	Stem length	ln(stem length	Stem weight	ln(stem weight)	Root length	ln(root length)	Root weight	ln(root weight)	Inflorescence length	ln(inflorescence length)	Inflorescence weight	ln(inflorescence weight)	Leaf #	ln(leaf #)	Leaf weight	ln(leaf weight)	Fruit #	ln(fruit #)	Fruit weight	ln(fruit weight)	Flower #	ln(flower #)	Total above ground weight	ln(total above ground weight	Total weight	ln(total weight
Stem length	1	1																								
ln(stem length)	1	1																								
Stem weight	-8	-36	1	1																						
ln(stem weight)	-17	-57	1	1																						
Root length	35	26	4	35	1	1																				
ln(root length)	33	25	7	38	1	1																				
Root weight	-28	-26	-5	-2	41	39	1	1																		
ln(root weight)	- 4	- 9	0	24	80	79	1	1																		
Inflorescence length	99	87	5	-28	35	33	-25	-3	1	1																
ln(inflorescence length)	73	49	4	- 5	22	18	- 9	01	1	1																
Inflorescence weight	95	81	-3	-24	28	27	-25	-6	98	87	1	1														
ln(inflorescence weight)	-96	-83	3	25	-35	-32	22	01	100	88	1	1														
Leaf #	48	26	10	31	76	71	34	63	57	67	55	-61	1	1												
ln(leaf #)	59	38	11	32	82	79	22	58	66	67	64	-68	1	1												
Leaf weight	-46	-56	22	44	38	39	75	76	-40	-15	-35	37	45	33	1	1										
ln(leaf weight)	-12	-24	44	38	59	60	58	75	- 8	3	- 5	6	65	60	1	1										
Fruit #	96	83	-3	-25	35	32	-22	-01	100	88	98		61	68	-37	-6	1	1								
ln(fruit #)	97	83	-3	-25	34	31	-23	- 2	100	88	98	-100	60	67	-37	-6	1	1								
Fruit weight	94	80	-3	-24	25	25	-26	- 8	97	86	100	-96	53	61	-35	-4	96	-97	1	1						
ln(fruit weight)	-96	-83	3	25	-36	-33	22	01	-100	-88	-97	100	-61	-68	37	-6	-100	-100	1	1						
Flower #	94	81	-4	-24	40	35	19	3	97	87	93	-99	63	69	-37	-7	99	98	90	-99	1	1				
ln(flower #)	61	54	-4	-17	46	38	3	16	63	57	50	-67	56	56	-27	-9	67	64	44	-69	1	1				
Total above ground **weight**	- 8	-22	96	14	20	22	16	23	-3	11	01	01	31	29	47	67	-01	-01	01	01	-2	-15	1	1		
ln(total above ground weight	10	- 5	83	9	40	41	34	46	15	26	19	-17	54	52	57	80	17	17	17	-17	16	5	1	1		
Total weight	-14	-26	88	12	28	29	38	42	-8	6	-5	6	37	32	61	76	-06	- 6	-5	6	-6	-6	98	96	1	1
ln(total weight)	01	-12	75	10	46	47	51	60	7	20	10	-19	56	51	69	86	9	9	10	-9	9	4	90	98	1	1

Table 9. Plant component correlation coefficients (R values in percentages are shown) for *Camelina microcarpa*

	Stem length	ln(stem length	Stem weight	ln(stem weight)	Root length	ln(root length)	Root weight	ln(root weight)	Inflorescence length	ln(inflorescence length)	Inflorescence weight	ln(inflorescence weight)	Leaf #	ln(leaf #)	Leaf weight	ln(leaf weight)	Fruit #	ln(fruit #)	Fruit weight	ln(fruit weight)	Flower #	ln(flower #)	Total above ground weight	ln(total above ground weight	Total weight	ln(total weight
Stem length	1	1																								
ln(stem length)	1	1																								
Stem weight	96	84	1	1																						
ln(stem weight)	97	94	1	1																						
Root length	81	71	88	79	1	1																				
ln(root length)	61	44	67	52	1	1																				
Root weight	91	91	87	92	85	60	1	1																		
ln(root weight)	96	95	91	97	84	59	1	1																		
Inflorescence length	-11	-11	-7	-10	2	-8	-4	3	1	1																
ln(inflorescence length)	-15	-35	-2	-22	-3	13	-26	-18	1	1																
Inflorescence weight	-99	-94	95	96	83	63	96	96	-13	-19	1	1														
ln(inflorescence **weight)**	68	85	-52	-74	-34	7	-66	-73	4	50	1	1														
Leaf #	-3	17	-8	12	19	-7	21	18	-3	-61	-1	-38	1	1												
ln(leaf #)	-8	8	-6	8	19	-13	12	12	-3	69	-7	-33	1	1												
Leaf weight	-0	-26	18	3	38	41	0	2	15	36	-5	43	14	29	1	1										
ln(leaf weight)	-8	-25	16	-0	39	36	-4	-3	1	21	-9	40	23	42	1	1										
Fruit #	90	90	87	92	64	29	89	90	-0	-16	91	78	0	-0	-14	-17	1	1								
ln(fruit #)	92	93	86	93	61	27	86	91	-1	-19	91	83	1	-1	20	22	1	1								
Fruit weight	89	79	82	82	60	60	77	80	-9	6	89	-45	-37	-48	-14	-28	77	78	1	1						
ln(fruit weight)	-74	-84	-62	-74	-69	-52	-86	-81	27	61	-78	67	-50	-33	-19	-17	-64	-64	1	1						
Flower #	64	78	52	68	62	33	75	73	-24	-70	65	-76	68	57	-19	-9	58	60	32	-94						
ln(flower #)	72	85	66	78	66	24	83	81	-13	-58	74	-84	58	54	-13	-3	78	77	38	-86	1	1				
Total above ground weight	95	81	98	-92	85	72	87	90	-7	5	95	-44	-17	-19	19	11	83	82	90	-60	44	55	1	1		
ln(total above ground weight	91	83	90	94	82	70	88	93	-3	-5	91	-53	6	-0	23	11	78	79	85	-69	55	60	1	1		
Total weight	96	84	98	93	86	72	90	92	-6	1	96	-48	-12	-15	17	8	85	84	90	-64	48	59	1.	95	1	1
ln(total weight)	93	86	91	95	84	70	92	96	-3	-9	93	-56	9	2	19	8	81	81	85	-73	59	65	95	1.	1	1

Table 10. Plant component correlation coefficients (R values in percentages are shown) for *Collinsia parviflora*

	Stem length	ln(stem length)	Stem weight	ln(stem weight)	Root length	ln(root length)	Root weight	ln(root weight)	Inflorescence length	ln(inflorescence length)	Inflorescence weight	ln(inflorescence weight)	Leaf #	ln(leaf #)	Leaf weight	ln(leaf weight)	Fruit #	ln(fruit #)	Fruit weight	ln(fruit weight)	Flower #	ln(flower #)	Total above ground weight	ln(total above ground weight	Total weight	ln(total weight
Stem length	1	1																								
ln(stem length)	1	1																								
Sten weight	87	81	1	1																						
ln(stem weight)	91	94	1	1																						
Root length	19	30	14	15	1	1																				
ln(root length)	26	37	18	20	1	1																				
Root weight	80	80	86	79	57	60	1	1																		
ln(root weight)	72	79	66	69	76	81	1	1																		
Inflorescence length	84	69	63	60	9	14	60	49	1	1																
ln(inflorescence length)	-27	-33	-55	-47	-10	-12	-34	-29	1	1																
Inflorescence **weight**	93	83	67	71	6	25	56	53	91	-4	1	1														
ln(inflorescence **weight)**	-83	-89	-74	-87	-2	-29	-67	-63	-49	38	1	1														
Leaf #	70	74	88	85	21	36	74	64	25	-83	43	-75	1	1												
ln(leaf #)	82	90	87	94	24	51	79	72	40	-66	58	-88	1	1												
Leaf weight	93	87	95	88	32	12	87	76	76	-44	80	-68	79	82	1	1										
ln(leaf weight)	93	95	85	90	46	12	85	85	67	-43	80	-74	78	87	1	1										
Fruit #	80	65	56	54	7	16	54	45	1.	28	91	-45	17	33	70	63	1	1								
ln(fruit #)	81	66	55	54	7	9	52	45	1.	28	92	-46	16	33	70	63	1	1								
Fruit weight	92	79	76	72	11	16	70	57	98	1	95	-61	43	56	86	-78	96	96	1	1						
ln(fruit weight)	-78	-86	-66	-83	01	-9	-60	-59	-42	34	-62	99	-71	-84	-60	-68	-39	-40	1	1						
Flower #	49	51	80	68	14	17	63	48	6	-92	20	-55	95	80	66	59	-3	-4	96	-39	1	1				
ln(flower #)	53	53	84	70	16	18	67	50	14	-89	26	-55	95	80	71	63	5	4	96	-40	1	1				
Total above ground weight	98	88	89	85	17	23	79	67	89	-25	93	-72	65	75	96	90	85	85	25	-50	48	54	1	1		
ln(total above ground weight	99	97	87	93	26	32	80	75	78	-35	89	-81	74	86	95	97	73	74	32	-49	54	58	1	1		
Total weight	98	89	90	86	20	26	81	70	88	-26	91	-72	67	76	97	91	84	84	96	-64	50	56	1.	96	1	1
ln(total weight)	98	97	87	92	32	39	84	80	77	-35	88	-81	74	86	95	98	74	74	87	-76	54	58	96	1.	1	1

Table 11. Percent correlations of plant components with abiotic factors in *Bassia hyssopifolia* (R values are shown)

	Stem length	ln (stem length)	Stem weight	ln (stem weight)	Root length	ln (root length)	Root weight	ln (root weight)	Inflorescence #	ln (inflorescence #)	Inflorescence length	ln (inflorescence length)	Inflorescence weight	ln (inflorescence weight)	Leaf #	ln (leaf #)	Leaf weight	ln (leaf weight)	Fruit #	ln (fruit #)	Fruit weight	ln (fruit weight)	Flower #	ln (flower #)	Total plant weight	ln (total plant weight)	Total - root	ln (total - root)
Min. Avg. Air Temperature	89	93	83	84	82	84	80	79			34	04	34	-04	05	05	05	-05	80	84	71	71			75	76	83	85
Max. Avg. Air Temperature	78	80	80	81	76	72	75	79			41	16	41	-16	16	16	16	-16	63	70	55	65			75	76	75	75
Avg. Daily Temp.	83	86	81	83	78	78	77	80			39	10	39	-09	10	10	10	-10	69	76	61	68			75	77	78	80
Humidity	09	01	10	03	-02	07	02	07			-44	16	-44	-16	16	16	16	-16	16	13	27	20			14	12	13	12
Precipitation	94	86	91	85	75	81	73	81			30	53	30	-53	53	53	53	-53	70	85	67	75			89	88	98	96
Soil Temp. 5 cm	69	75	62	66	62	69	58	63			32	00	32	00	00	00	00	00	52	59	40	45			53	55	62	64
Soil Temp. 15 cm	83	87	85	88	79	82	79	86			32	09	32	-09	08	08	08	-09	71	79	65	73			80	82	80	82
Soil Temp. 30 cm	87	88	90	92	86	80	86	89			36	15	36	-15	15	15	15	-15	78	82	73	80			86	87	84	85
Soil Temp. 50 cm	84	81	93	95	84	77	86	93			38	30	38	-30	30	30	30	-30	73	81	72	85			94	95	86	86
Soil Water Potential 5 cm	69	67	85	92	81	67	86	92			28	21	28	-21	21	21	21	-21	74	76	79	90			92	92	75	75
Soil Water Potential 15 cm	84	82	91	95	85	78	87	92			38	29	38	-29	29	29	29	-29	73	80	71	83			92	93	86	86
Soil Water Potential 30 cm	91	87	94	94	86	80	86	90			41	35	41	-35	35	35	35	-35	76	84	72	81			92	93	92	91
Soil Water Potential 50 cm	94	86	91	85	75	81	73	81			36	34	36	34	34	34	34	-34	74	80	67	71			83	84	90	90

Table 12. Percent correlations of plant components with abiotic factors in *Halogeton glomeratus* (R values are shown)

	Stem length	ln (stem length)	Stem weight	ln (stem weight)	Root length	ln (root length)	Root weight	ln (root weight)	Inflorescence #	ln (inflorescence #)	Inflorescence length	ln (inflorescence length)	Inflorescence weight	ln (inflorescence weight)	Leaf #	ln (leaf #)	Leaf weight	ln (leaf weight)	Fruit #	ln (fruit #)	Fruit weight	ln (fruit weight)	Flower #	ln (flower #)	Total plant weight	ln (total plant weight)	Total - root	ln (total - root)
Min. Avg. Air Temperature	93	90	90	77	74	77	74	77			-	-	-	-	-	-	-	-	85	18	79	66			64	64	31	32
Max. Avg. Air Temperature	99	91	97	80	83	69	84	75			-	-	-	-	-	-	-	-	84	54	79	82			81	80	64	65
Avg. Daily Temp.	99	91	96	76	82	71	83	75			-	-	-	-	-	-	-	-	85	45	80	78			77	76	56	57
Humidity	-55	-33	-55	-37	-60	-17	-60	-26			-	-	-	-	-	-	-	-	-37	-68	-36	-54			-54	-54	-67	-67
Precipitation	87	87	85	80	76	84	75	82			-	-	-	-	-	-	-	-	88	07	83	63			60	61	20	22
Soil Temp. 5 cm	99	92	98	84	86	71	88	78			-	-	-	-	-	-	-	-	87	62	83	87			86	86	71	72
Soil Temp. 15 cm	1.	97	1.	89	88	80	89	85			-	-	-	-	-	-	-	-	92	57	88	89			88	88	67	68
Soil Temp. 30 cm	98	97	97	85	81	80	83	83			-	-	-	-	-	-	-	-	90	38	85	79			78	78	50	51
Soil Temp. 50 cm	98	95	1.	94	94	87	95	91			-	-	-	-	-	-	-	-	97	53	94	91			89	89	63	65
Soil Water Potential 5 cm	75	82	82	97	91	99	91	99			-	-	-	-	-	-	-	-	96	43	98	88			86	86	52	54
Soil Water Potential 15 cm	95	94	98	98	96	93	97	96			-	-	-	-	-	-	-	-	99	52	98	92			91	91	62	64
Soil Water Potential 30 cm	98	94	97	88	87	85	88	87			-	-	-	-	-	-	-	-	94	36	89	80			78	78	48	49
Soil Water Potential 50 cm	94	94	93	85	79	84	80	85			-	-	-	-	-	-	-	-	91	25	86	74			71	72	38	39

Table 13. Mean density changes per dm^2 in *Bassia hyssopifolia* and *Halogeton glomeratus*

Days after 1st sample	Halogeton glomeratus	Bassia hyssopifolia
0	6.01	5.7
14	5.6	5.3
28	5.4	5.4
42	5.1	5.1
56	4.8	4.9
70	3.7	5.0
84	3.1	4.6
98	2.1	3.1
112	1.4	1.2
126	1.0	0.4
134	0.5	0.2

Table 14. Productivity equations of *Bassia hyssopifolia*; R values in parentheses (A3UKC01 and KC03)

ln stem weight = 2.3104 (ln(time)) - 16.0020	(.61)
ln root weight = 1.2101 (ln(time)) - 10.7104	(.39)
inflorescence weight = time - 0.0036	(.54)
leaf weight = .0139 (ln(time)) - 0.0183	(.13)
fruit weight = 0.0000 x - 0.0059	(.54)
stem + leaf weight = 0.0491 (ln(time)) - 0.1772	(.30)
stem + leaf + root weight = 0.0631 (ln(time)) - 0.2355	(.32)
inflorescence + fruit = 0.001 (time) - 0.0095	(.54)
ln(total - root weight) = 1.0318 (ln(time)) - 7.9999	(.42)
ln(total) = 1.0636 (ln(time)) - 8.0052	(.42)
ln(total weight) = 0.8850 (ln(stem + leaf + root weight)) - 0.2525	(.98)
ln(total weight) = 0.1651 (ln(inflorescence + fruit weight)) - 2.4707	(.39)

Table 15. Productivity equations of *Halogeton glomeratus*; R values in parentheses (A3UKC01 and KC03)

ln stem weight = 5.5311 (ln(time)) - 31.3809	(.84)
ln root weight = 2.5348 (ln(time)) - 17.2949	(.67)
ln leaf weight = 3.3619 (ln(time)) - 19.1990	(.55)
ln(stem + leaf weight) = 3.9248 (ln(time)) - 21.7476	(.64)
ln(stem + leaf + root weight) = 3.8187 (ln(time)) - 21.1262	(.64)
ln(total - root weight) = 3.9248 (ln(time)) - 21.7476	(.64)
ln(total weight) = 3.8187 (ln(time)) - 21.1262	(.64)
ln(total weight) = 2.8222 (ln(time)) - 2.4752	(.87)

Table 16. Total standing crop (kg/ha) of *Bassia hyssopifolia* and *Halogeton glomeratus*

Date	Stem	Leaf	Root	Inflorescence	Fruit	Total Species
			BASSIA			
4/26	4	16	3			23
5/11	9	45	7			62
5/25	15	66	11			92
6/10	19	62	16			99
6/22	32	66	24			119
7/8	44	100	18			162
7/23	78	133	46			257
8/6	37	58	19			114
8/19	9	18	5	6	10	48
			HALOGETON			
5/11	6	32	4			42
6/10	63	112	21			197
6/22	112	801	20			932
7/8	76	112	16			204
8/6	64	111	10			185