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Distribution and Balance of Biomass and Nutrients in Desert Shrub Ecosystem

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DISTRIBUTION AND BALANCE OF BIOMASS AND NUTRIENTS IN DESERT SHRUB ECOSYSTEMS

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ABSTRACT

During the third and final year of this study to measure distribution of biomass and nutrients in shrub ecosystems as a function of shrub age, season and environmental variables, nine shrub ecosystems each of mesquite (*Prosopis juliflora* var. *velutina*) and paloverde (*Cercidium floridum*) were sampled. Previously observed patterns of seasonal change in percentage nitrogen in annual plant parts of both species were more strongly manifested this third year, perhaps because of heavy fall and winter moisture. Although percentage nitrogen in mulch of the overstory species appears not to vary spatially under the shrub, nitrogen percentage of understory mulch and the absolute amount of nitrogen in mulch of both overstory and understory species does appear to vary spatially. This is reflected in strong spatial distribution patterns for soil nitrogen and, in turn, phytomass and amount of nitrogen in standing live and dead understory vegetation.

Soil under mesquite (*P. juliflora* var. *glanulosa*) sampled at the Jornada Experimental Range is higher in percentage nitrogen in the surface 5 cm and in the amount of nitrogen in the 0-60 cm depth than soil under mesquite (var. *velutina*) at Santa Rita. The influence of variety *glanulosa* at Jornada on nitrogen status of the soil appears large in terms of the phytomass of the shrubs, but of about the same magnitude as variety *velutina* at Santa Rita in terms of nitrogen status of soil beyond the shrub canopies.

Laboratory and data analyses will be completed within the next six to eight months and compiled in a Ph.D. dissertation. The major findings of this study will result from these analyses.

INTRODUCTION

Studies of the distribution of biomass and nutrients in shrub ecosystems of the Sonoran Desert were terminated in December, 1973, after three years of study. Mesquite (*Prosopis juliflora* var. *velutina*) has been sampled three times yearly for three years at a site on the Santa Rita Experimental Range; paloverde (*Cercidium floridum*) has been sampled for two years at the same site. For comparative purposes, mesquite (*P. juliflora* var. *glanulosa*) was sampled at the Jornada Experimental Range in New Mexico for one phenological date in 1972. A variety of other shrubs were sampled for nutrient content only at the Silverbell site west of Tucson in late 1973. Because of a heavy load of laboratory work, analyses will not be complete until early 1974 and data for sampling after May, 1974, are not reported herein. Hence, this is not a terminal report; rather, it brings up to date relationships developed earlier and presents some new information.

OBJECTIVES

The objectives of this study are to measure the distribution and balance of biomass and nutrients (carbon and nitrogen) in the regime of important desert shrub ecosystems, specifically mesquite (*Prosopis juliflora* var. *velutina*) and paloverde (*Cercidium floridum*).

Specific objectives are:

1. To determine the influence of shrub age on distribution of biomass, and on distribution and balance of nutrients in individual shrub ecosystems.
2. To measure seasonal changes in biomass, and in distribution and balance of nutrients in individual shrub ecosystems.
3. To determine the effect of macro-environmental factors (precipitation, temperature, radiation), which vary yearly, on increment of biomass and nutrient distribution.

METHODS

Size data of shrubs (DSCODE A3UKB01) were accumulated by measurements collected three times yearly on five randomly-selected shrubs of each species, representing the population of size classes available. Above-ground biomass of shrubs (A3UKB02) was determined through collections made three times yearly on five randomly-selected shrubs of each species, representing the population of size classes available. Weight was obtained to determine biomass/shrub. Samples were prepared for laboratory analysis.

Collections of root biomass associated with shrubs (A3UKB03) were made three times yearly from five randomly-selected shrubs of each species, representing the population of size classes available. Weight was taken to determine biomass/unit volume. Samples were prepared for laboratory analysis.

Collections of understory vegetation of shrubs (A3UKB04) were made three times yearly under five randomly-selected shrubs of each species, representing the population of size classes available. Standing dead and live material were separated and weighed to determine weight/unit area, then prepared for laboratory analysis.

Collections of mulch under shrubs were made three times yearly under five randomly-selected shrubs of each species (A3UKB05). Mulch of mesquite and other vegetation was separated and weighed to determine weight/unit area, then prepared for laboratory analysis.

Analyses for total nitrogen by the Kjeldahl method (Bremner, 1965) and for organic carbon by the dry combustion method (Allison, Bollen and Moodie, 1965) using a LECO high-frequency induction furnace, were run on above-ground biomass (A3UKB06), understory species (A3UKB07), mulch (A3UKB08), and soil (A3UKB09).

RESULTS AND DISCUSSION

The march of percentage N in plant parts of mesquite with time is shown in Figure 1 for seven sampling dates over three years. Each value for the first four dates is the mean of five samples; thereafter each value is the mean of three samples. Annual plant parts (flowers, fruits, leaves, and current branches) vary markedly in percentage N from one phenological period to the next; perennial plant parts are more stable but vary more than might be anticipated, particularly for dead wood and branches > 1 cm. Similar trends for paloverde (Figure 3) are also apparent. Although these data have not been related to climatological data as yet, it appears the high values of N in annual plant parts of mesquite and paloverde for May, 1973,might relate closely to the high precipitation received during the previous several months. Similar periods for 1971 and 1972 were extremely dry.

When data for the same phenological period each year are combined, annual trends in each plant part begin to appear for the two species (Figures 2 and 4). These trends appeared during the first year of study and have been maintained. Statistical analyses at the conclusion of the study should demonstrate which are real and which are due to random variation. We suspect trends for annual plant parts may prove significant and have biological meaning.

The march of nitrogen in any plant part from initiation of growth until it returns to the soil is probably uniquely characteristic for each plant part. This transition is characterized for leaves of mesquite and paloverde in Table 1 (N percentages for mulch are for all mulch, rather than leaves alone). It is interesting that percentage N of paloverde mulch is lower than that of mesquite even though the initial N percentage of paloverde leaves is higher. This could reflect the fact that paloverde leaves fall sooner than mesquite leaves, hence have been subject to decomposition for a longer period of time. Or, it may mean that the mulch of paloverde contains more woody material.

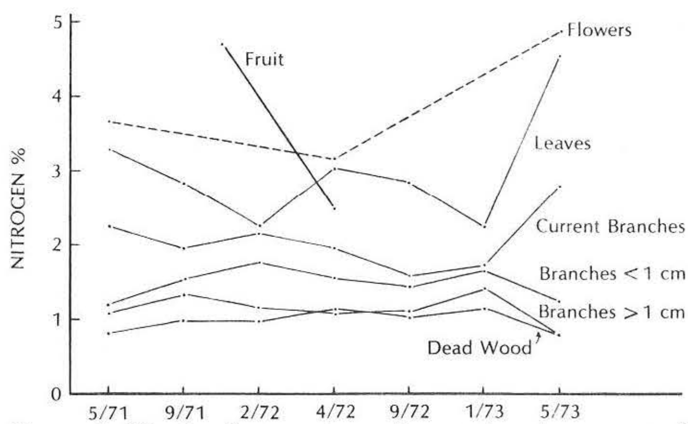

Figure 1. March of percentage nitrogen in plant parts of mesquite by sampling date (A3UKB06).

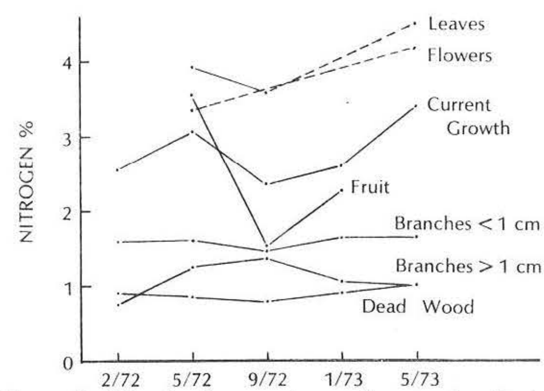

Figure 3. March of percentage nitrogen in plant parts of paloverde by sampling date (A3UKB06).

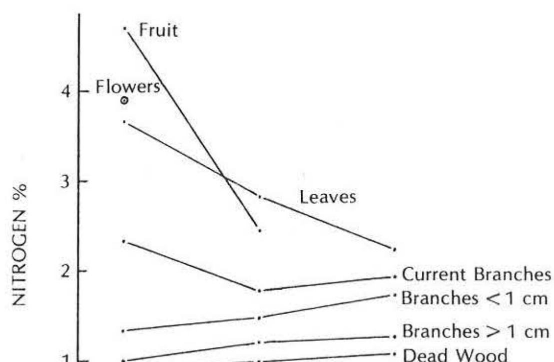

Figure 2. Average percentage nitrogen in plant parts of mesquite for three phenological periods (A3UKB06).

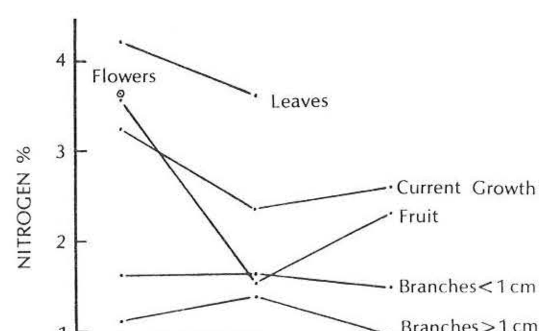

Figure 4. Average percentage nitrogen in plant parts of paloverde for 3 phenological periods.

Table 1. Status of ecosystem nitrogen over time from standing live vegetation (leaves) through decomposition to soil for mesquite and paloverde systems

Component	Percentage N	
	Mesquite	Paloverde
Leaves		
New	3.66	4.22
Mature	2.83	3.60
Old	2.24	--
Mulch	1.58	1.31
Soil		
0-5 cm	0.057	0.064
5-15 cm	0.039	0.038
15-30 cm	0.034	0.033
30-60 cm	0.027	0.029

Table 2. Percentage carbon in plant parts of mesquite by seasons (A3UKB06)

Plant Part	Sampling Date							
	5/71	9/71	2/72	4/72	9/72	1/73	5/73	Mean
Flowers	45.34	--	--	43.59	--	--	42.04	43.66
Fruit	--	--	--	43.18	43.58	--	--	43.38
Leaves	45.98	48.11	45.21	47.67	45.65	45.21	46.34	46.31
Current Growth	45.13	46.65	45.67	44.81	45.05	43.61	43.74	44.95
Branches < 1 cm	43.17	43.32	43.17	43.76	42.71	42.52	42.85	43.07
Branches > 1 cm	42.55	42.50	41.72	42.60	43.34	41.66	43.52	42.56
Dead Wood	42.92	42.83	41.40	42.01	41.34	40.91	42.15	41.94

Carbon is very stable in all plant parts (Table 2). Seasonal differences are small, and undoubtedly reflect random variation; they are not thought to be of biological significance. These C percentages are close to a nominal value of 45% reported by Olson (1970) for vegetal materials. Leaves appear to be higher (presumably significant) in C than woody tissues. Also average C percentage tends to decline with size and age of woody tissue. In contrast, needles of ponderosa pine are almost identical in C percentage to branches and boles (J. O. Klemmedson, unpublished data).

Carbon-nitrogen ratios by plant parts for both mesquite and paloverde are shown in Table 3. Because of the uniformity in C among plant parts, the C:N ratio is an inverse function of N content of these plant parts. The largest difference between species in C:N ratio is in leaves and current branches. The leaves of paloverde are significantly higher in N than those of mesquite, thus

Table 3. Average carbon-nitrogen ratios of mesquite and paloverde by plant parts (A3UKB06)

Plant Part	Mesquite	Paloverde
Flowers	13.2	13.7
Fruit	12.7	12.5
Leaves	16.7	10.9
Current Branches	22.3	17.0
Branches < 1 cm	29.1	25.4
Branches > 1 cm	36.9	40.4
Dead Wood	43.7	51.2

Table 4. Amounts of nitrogen and carbon in mulch under mesquite and paloverde canopies (A3UKB05, KB08)

Distance from stem to canopy edge	Nitrogen			Carbon		
	Overstory Shrub Mulch	Other Mulch	Total	Overstory Shrub Mulch	Other Mulch	Total
	g/m^2					
	Mesquite					
1/3	4.3	3.0	7.2	164	59	223
2/3	2.0	2.9	4.9	75	69	144
3/3	1.2	1.6	2.8	64	59	123
4/3	0.5	0.8	1.3	44	78	122
	Paloverde					
1/3	4.5	3.6	8.1	170	150	320
2/3	2.4	3.3	5.7	78	168	246
3/3	0.5	1.6	2.1	24	78	103
4/3	0.1	2.9	3.0	4	120	124

accounting for the lower C:N ratio in the former. It follows from the above that significant seasonal changes in C:N ratio may be expected in annual plant parts; specifically, the C:N ratio increases in leaves from growth initiation to maturity.

In the last report on this project (Klemmedson and Smith, 1973) we stated that canopy position apparently has no effect on percentage N of mulch from the shrub, but that mulch of understory species is higher in N near the shrub center and declines with distance away from the stem. That relationship appears to be holding. If absolute amounts of N and C in mulch are determined for various canopy positions (Table 4), it is apparent that greater amounts of N and C in mulch (both for the overstory shrub and understory species) are concentrated near the center of the canopy, and that these two elements diminish toward the edge. This effect appears more pronounced for mulch of the overstory shrub. Presumably this results in progressive build-up of soil N and C with age of the shrub. The reality of a shrub age-soil N relationship will be pursued when all laboratory analyses for the study are completed.

Percentage N in soil under paloverde appears slightly but inconsistently higher than that under mesquite at the Santa Rita site (Table 5). However, these differences may not be significant. Soil N is highly influenced by location under the shrubs and relates to distribution of mulch. This effect is shown graphically in Figure 5 where N is expressed as kg/m^2. These data express a somewhat different picture of soil N under the two trees, and probably reflect at least small differences in bulk density of the soils.

Data in Table 5 suggest that soil under mesquite at the Jornada site was distinctly higher in N than that under mesquite at Santa Rita, but only for the 0-5 cm level. Below that depth, differences are small and inconsistent. If we convert these data to absolute amounts of N (kg/m^2) an entirely different picture appears (Fig. 5). The two "mesquite soils" are similar in soil N at the center canopy

Table 5. Average percentage nitrogen† of soil as a function of soil depth and canopy position under mesquite and paloverde at Santa Rita and Jornada sites (A3UKB09)

Canopy Position	Depth cm	Percentage N		
		Santa Rita		Jornada
		Mesquite	Paloverde	Mesquite
0/3	0-5	.066	.070	.083
	5-15	.047	.038	.042
	15-30	.039	.035	.038
	30-60	.028	.031	.029
1/3	0-5	.054	.063	.090
	5-15	.037	.040	.040
	15-30	.033	.032	.034
	30-60	.027	.026	.028
2/3	0-5	.050	.060	.061
	5-15	.033	.035	.031
	15-30	.029	.032	.032
	30-60	.025	.030	.029
3/3	0-5	.040	.045	.045
	5-15	.031	.028	.028
	15-30	.030	.029	.032
	30-60	.024	.025	.026
4/3	0-5	.033	.036	.027
	5-15	.027	.027	.029
	15-30	.026	.027	.030
	30-60	.022	.025	.027

†Mean of 20 mesquite and 10 paloverde shrubs

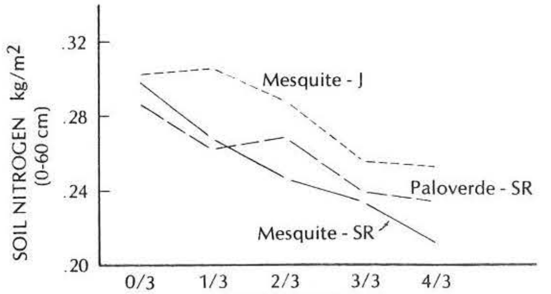

Figure 5. Amount of soil nitrogen ($kg/m^2/60$ cm depth) under mesquite at Santa Rita (SR) and Jornada (J) and under paloverde shrubs as a function of canopy position.

position but become dissimilar with distance away from the center of the shrub. These data will require more scrutiny, but soils at the Jornada site apparently have a higher bulk density. It is interesting to examine soil N status at these two sites in terms of the size and growth form of the shrubs. The *glanulosa* variety of mesquite at Jornada is small, squat and shrub-like, providing good protection and shade to the soil and averaging only 9.0 kg in above-ground phytomass. Mesquite and paloverde at Santa Rita are erect and tree-like. They averaged 88.9 and 87.6 kg of phytomass, respectively. Expressing the amount of soil N on a per kg of above-ground phytomass basis as follows,

	kg soil N/m^2/kg phytomass
Mesquite -- Santa Rita	2.9×10^{-3}
Paloverde -- Santa Rita	3.0×10^{-3}
Mesquite -- Jornada	33.2×10^{-3}

shows a contrasting distribution pattern for N in the mesquite ecosystems at the two sites. Presumably, these values reflect both the size of the shrub and the shrubs influence on accrual and maintenance of soil N. These relationships will be pursued in more detail in our final report.

In this study it is reasoned that N content of shrub components, the shrub's mulch and the soil under the shrub canopy are directly related to the shrub. Moreover, N content of understory species is related to the shrub, even if indirectly from its effect on soil under the shrub. This effect of mesquite and paloverde on percentage of N in standing live and dead components of understory species is shown in Table 6. However, data (although not analyzed statistically) suggest that N percentage of live understory plants beyond the canopy is higher than that under the canopy (compare mean of 1/3 to 3/3 positions with 4/3 position). This is the reverse of what might have been expected assuming higher soil N would lead to higher percentage N in herbage. Spatial differences in standing dead are small and difficult to speculate on.

Since phytomass of understory vegetation is spatially ordered with respect to shrub canopies (Table 7) with much larger phytomass at 1/3 and 2/3 positions than at canopy

Table 6. Average percentage nitrogen of standing live and dead understory vegetation under mesquite and paloverde canopies by canopy position (A3UKB07)

Distance from stem to canopy edge	Mesquite		Paloverde	
	Standing live	Standing dead	Standing live	Standing dead
	%			
1/3	1.26	1.04	1.17	0.88
2/3	1.24	0.99	1.14	0.78
3/3	1.14	0.94	1.19	0.68
4/3	1.38	0.87	1.57	0.74
Mean (1/3 to 3/3)	1.21	0.99	1.17	0.78

Table 7. Spatial distribution of standing-live phytomass plus dead understory vegetation under canopies of mesquite and paloverde (A3UKB04)

Distance from stem to canopy edge	Mesquite	Paloverde
	kg/m^2	
1/3	.325	.414
2/3	.173	.777
3/3	.158	.178
4/3	.065	.120

Table 8. Amounts of carbon and nitrogen, and carbon-nitrogen ratio for standing live and dead understory vegetation of mesquite and paloverde by canopy position (A3UKB07)

Distance from stem to canopy edge	Mesquite			Paloverde		
	N	C	C/N	N	C	C/N
	g/m^2			g/m^2		
1/3	3.01	113.7	37.8	1.97	76.5	38.8
2/3	1.36	57.6	42.4	2.74	155.2	56.6
3/3	0.74	28.7	38.8	1.33	79.1	59.5
4/3	0.50	19.9	39.8	1.05	77.0	73.3
Mean	1.41	54.9	39.7	1.77	96.9	57.0

edge and beyond, it follows from Table 6 that the amounts of N tied up in standing live and dead understory vegetation are also higher at these positions (Table 8). The distribution of carbon (Table 8) is, of course, similar to that of phytomass (Table 7). We have no explanation at present for the particular distribution patterns of phytomass, N and C at the 1/3 and 2/3 positions for mesquite and paloverde.

Carbon-nitrogen ratios for understory vegetation are comparable at the 1/3 canopy position for mesquite and paloverde but tend to be much higher under paloverde than mesquite at all other canopy positions. Arizona cottontop, a perennial grass, is commonly abundant under mesquite. The high C:N ratios for paloverde understory suggest that much of the understory beyond the 1/3 canopy position is shrubby in nature.

EXPECTATIONS

Plans for 1974 are to conclude the analyses of all data within the next six to eight months and compile it in the form of a Ph.D. dissertation. This dissertation and a final report abstracted from it will contain many of the more significant relationships we have been unable to produce to date because of incomplete data and the need for more exhaustive analysis.

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