Botanical Composition Changes in Annual Grassland as Affected by Fertilization and Grazing[1]

Milton B. Jones and Raymond A. Evans[2]

SYNOPSIS. Changes in botanical composition on the annual range type of California indicated significant fertilizer-grazing, fertilizer-year, and grazing-year interactions. Direct projection of botanical composition data from ungrazed fertilizer plots would not accurately predict changes resulting from the same fertilizer on grazed areas.

CHANGES in botanical composition on annual ranges in California have been observed and measured for a number of years. During the 1940's Conrad (4) observed that sulfur and phosphorus increased the yield of legumes and thereby substantially increased the succeeding crop of nonlegumes. Conrad's findings have been confirmed by Bently and Green (1) and Williams et al. (15). Hoaglund et al. (8) indicated that neither nitrogen nor phosphorus had any important effect on botanical composition where plots were clipped. However, these soils were not deficient in phosphorus. More recent fertilizer work on resident, annual ranges by Evans and Love (6) indicates that grasses such as soft chess *(Bromus mollis),* ripgut *(B. rigidus),* and wild oats (*Avena* spp.), and broadleaf filaree *(Erodium botrys)* increased with nitrogen especially in combination with phosphorus and sulfur.

The effects of livestock upon the botanical composition of California's annual rangeland have been observed by various workers. Love and Williams (12) and Jones and Love (10) pointed out that animals often are essential for reducing plant competition when seeding rangeland. Biswell (3) indicated that when heavy grazing is discontinued, a common pattern of change is from forbs to soft chess, to slender wild oats *(Avena barbata),* to ripgut. Studies by Bently and Talbot (2) indicated some increase in weedy species of low value under heavy grazing while light grazing maintained highest production of soft chess, filaree, and clovers. Laude et al. (11) found differences in behavior among annual species of grass in response to herbage removal. Heady and Torell (9) pointed out that animals selected plants and plant parts for their diet in a ratio which was different from that occurring in the pasture.

The above studies indicated that fertilization and grazing affect the botanical composition of annual grassland. The purpose of the present study was to investigate the effects of fertilization upon botanical composition when the rangeland was grazed and when protected from grazing.

PROCEDURE

The experiment was conducted at 2 locations, one on unimproved annual grassland (resident range) and the other on range seeded with a mixture of annual and perennial grasses and annual clovers. The experiments were located at the Hopland Field Station in north coastal California. The resident-range location was established at a 1500-foot elevation on Sutherlin soil (7). The reseeded-range location was at about 800-foot elevation on Laughlin soil (7). At both locations a split-plot design was used, with the main plots being grazed vs. ungrazed and the fertilizer treatments as the sub-plots. The fertilizer treatments at the resident-range location were: (a) none, (b) 100 pounds of nitrogen per acre, (c) 100 pounds of nitrogen with 200 pounds of phosphorus (P_2O_5) per acre, and (d) 200 pounds of phosphorus (P_2O_5) per acre. Each treatment was replicated 6 times. At the reseeded-range location the fertilizer treatments were: (a) 200 pounds of P_2O_5 per acre, (b) 50 pounds of nitrogen plus 200 pounds of P_2O_5 per acre, and (c) 200 pounds of nitrogen plus 200 pounds of P_2O_5 per acre. Each treatment was replicated 4 times. The resident-range plots received 3 annual applications of fertilizer in October 1956, 1957, and 1958, and the reseeded-range plots received 2 annual applications in October 1957 and 1958. Urea was used as the source of nitrogen at both sites. Treble superphosphate was the source of P_2O_5 on the resident-range plots and single superphosphate was used on the reseeded-range plots. There was an indication of a sulfur deficiency at the reseeded-range location only.[3]

In the fall of 1956 the area of the reseeded-range plots, which in previous years had been planted to sudangrass, was disked, rolled, and seeded to a mixture of sub clover *(Trifolium subterraneum),* crimson clover *(T. incarnatum),* rose clover *(T. hirtum),* hardinggrass *(Phalaris tuberosa),* and soft chess.

Both study sites were located in pastures to which sheep had intermittent free access. Most of the grazing occurred at both locations from October through May, during the growing season, with little grazing from June through September, during the dry dormant period of the year. Deer had free access to the grazed plots throughout the year at the resident-range location only. The ungrazed plots were mowed and raked in July of each year with a sickle-bar mower at a height of about 2 inches.

Botanical composition was determined by a modification of the step-point method as described by Evans and Love (5), when the vegetation was near maturity, but before seed shattering. In 1957, 50 points were taken in each plot at the resident-range location, and in 1958 and 1959, 25 points were taken in each plot at each location. Yield at both locations was estimated by hand-clipping 3 square-foot quadrats, and percentage of the ground covered by

[1] Contribution of the Department of Agronomy, University of California, Davis.

[2] Assistant Agronomist, University of California, Hopland Field Station, Hopland, and Range Conservationist, Crops Research Division, ARS, USDA, Reno, Nevada (formerly Assistant Specialist, University of California, Davis).

[3] Unpublished data. Milton B. Jones, Hopland Field Station.

living vegetation was estimated at 4 square-foot quadrats in each plot.

Each major species was considered separately for analysis of variance, as suggested by Snedecor (15) [$X = \sqrt{X + 0.5}$].

RESULTS AND DISCUSSION

At the resident-range location the dominant species were soft chess, slender wild oats, ripgut, broadleaf filaree, and various clovers *(Trifolium* spp. and *Medicago hispida)*. Percentages of species as they were affected by variables in the experiment are shown in table 1.

The percentage of soft chess at the resident-range location was increased by the combined application of nitrogen and phosphorus the first season, but showed little difference the second season on plots not grazed. In contrast, on the grazed plots, nitrogen alone and nitrogen with phosphorus produced a much higher percentage of soft chess than unfertilized, grazed plots. During the third year of the experiment, nitrogen and phosphorus reduced the percentage of soft chess, but the reduction was much greater where the plots were not grazed. Phosphorus alone produced no consistent change in the percentage of soft chess.

The percentage of slender wild oats on ungrazed plots was greater when these plots were fertilized with nitrogen alone or with nitrogen and phosphorus. On grazed plots the only effective treatment was nitrogen alone. Slender wild oats increased each year, but to a greater extent under protection, where this species tended to be dominant.

Phosphorus applied alone and with nitrogen increased the percentage of ripgut at the resident-range location. The increase was greater on ungrazed plots than on those grazed. Ripgut tended to increase each year and the rate of increase was greater on ungrazed and phosphorus-fertilized plots.

Table 1—Effect of grazing and fertilization, by year, upon the percent of different range species at the resident-range location. Each value is a mean of 6 replications.

Year	Ungrazed				Grazed			
	Fertilizer				Fertilizer			
	None	N	NP	P	None	N	NP	P
	Soft chess, % of stand							
1957	8	7	24	7	10	12	16	10
1958	30	46	31	33	33	50	63	33
1959	57	26	16	35	67	54	42	48
	Slender wild oats, % of stand							
1957	1	2	6	2	1	3	2	3
1958	5	27	28	11	1	11	5	3
1959	7	40	25	5	4	13	7	4
	Ripgut, % of stand							
1957	1	1	7	2	2	2	3	2
1958	3	1	20	7	1	1	7	5
1959	5	7	17	16	4	7	9	13
	Other grasses, % of stand							
1957	33	22	16	28	41	40	41	35
1958	44	4	3	37	63	29	10	53
1959	17	13	33	16	14	11	29	20
	Broadleaf filaree, % of stand							
1957	36	50	25	21	22	23	19	21
1958	5	18	2	0	0	5	1	0
1959	13	14	5	5	9	11	7	7
	Clovers, % of stand							
1957	3	0	2	18	4	0	1	8
1958	0	0	0	1	0	1	0	2
1959	1	0	2	21	1	1	0	5
	Other forbs, % of stand							
1957	18	18	20	22	20	20	18	21
1958	13	4	16	11	2	3	14	4
1959	0	0	2	2	1	3	6	3

	Main effects and interactions							
Species	N	P	N×P	G†	G×N	G×P	Year	G×Y
Soft chess	NS‡	NS	NS	**	*	NS	**	*
Slender wild oats	**	NS	NS	**	NS	NS	**	**
Ripgut	NS	**	NS	NS	NS	*	**	NS
Broadleaf filaree	**	**	**	**	NS	**	**	NS
Clovers	**	**	**	*	NS	*	**	NS

† G = grazing
‡ NS - Not significant, * - Significant at the 5% level, ** - Significant at the 1% level.

The percentage of broadleaf filaree was increased by nitrogen alone and decreased by nitrogen and phosphorus and phosphorus alone on ungrazed plots. Where plots were grazed the percentage of filaree was less than on ungrazed plots. Grazing appeared to equalize the change induced by fertilization. An exception appeared in 1958, the second year of the experiment, but the percentage of filaree on the grazed plots was so low that a good measure of change could not be made.

The percentage of resident clovers was decreased by nitrogen and increased by phosphorus. Grazing decreased the percentage of clovers, and the greatest reduction came where phosphorus was applied. This would be expected since very little clover was present in the plots not receiving phosphorus.

A small increase in the percent total ground cover resulted from the application of nitrogen and phosphorus and grazing reduced it at the resident-range location (table 2). Clippings taken from ungrazed plots indicated an increase in yield resulting from application of both nitrogen and phosphorus. Clippings taken from the grazed plots for estimation of the amount of forage left after grazing indicated that a significant increase in yield resulted from fertilization in 1958 only. Temperature and rainfall during 1957–58 were very favorable for growth of range plants, which resulted not only in higher production on the plots, but also in lighter grazing. During 1956–57 and 1958–59 the plots were grazed enough so that there was little difference in the amount of forage left on the plots after grazing. The different grazing intensities and differential utilization of the forage during each year of the experiment no doubt had an effect upon the botanical composition, as pointed out by Biswell (3) and Bently and Talbot (2). The season of use also would have an effect on the botanical composition (13).

At the reseeded-range location the dominant species were soft chess, ripgut, rose clover, sub clover, crimson clover, and hardinggrass. The percentages of ripgut and hardinggrass increased with nitrogen application (table 3). The increase of ripgut resulting from applied nitrogen was much greater on ungrazed plots than on grazed. Ripgut became the dominant species on ungrazed plots which were fertilized heavily with nitrogen and phosphorus. The percentage of soft chess increased with nitrogen on grazed plots but decreased on protected plots. At the end of the experiment, soft chess was the most abundant species on grazed plots fertilized heavily with nitrogen and phosphorus. Rose, sub, and crimson clovers decreased with added nitrogen.

Percentages of rose clover, sub clover, and soft chess were increased by grazing, and the percentages of ripgut

Table 2—Effect of grazing and fertilization upon percent ground cover and yield in May of three different years at the resident-range location. Each value is a mean of 6 replications.

Year	Ungrazed				Grazed			
	Fertilizer				Fertilizer			
	None	N	NP	P	None	N	NP	P
	Percent ground cover							
1957	83	86	92	82	45	50	54	58
1958	95	96	95	98	88	87	83	86
1959	97	99	100	99	83	79	86	94
	Yield in grams dry matter per square foot							
1957	21	37	48	25	17	18	20	17
1958	41	65	74	51	30	41	39	35
1959	37	47	62	46	25	25	28	34

Table 3—Effect of grazing and fertilization, by year, upon the percent of different range species at reseeded-range location. Each value is a mean of 4 replications.

Year	Ungrazed			Grazed		
	Fertilizer			Fertilizer		
	N_0 P_{200}	N_{50} P_{200}	N_{200} P_{200}	N_0 P_{200}	N_{50} P_{200}	N_{200} P_{200}
			Soft chess, % of stand			
1958	7	5	4	9	5	16
1959	33	45	17	22	29	40
			Ripgut, % of stand			
1958	13	29	32	4	11	11
1959	10	31	69	3	8	7
			Rose clover, % of stand			
1958	1	0	0	1	0	0
1959	7	0	0	20	10	5
			Sub clover, % of stand			
1958	26	32	23	70	69	66
1959	15	2	0	26	18	16
			Crimson clover, % of stand			
1958	49	25	25	11	11	4
1959	13	2	0	2	4	1
			Harding grass, % of stand			
1958	1	1	4	0	2	2
1959	7	11	12	1	3	7

Species	Main effects and interactions					
	N	G†	Year	N×G	N×Y	G×Y
Soft chess	NS‡	NS	**	**	NS	NS
Ripgut	**	**	NS	NS	NS	NS
Harding grass	*	NS	*	NS	NS	NS
Sub Clover	**	**	**	NS	NS	NS
Rose Clover	**	**	**	NS	**	**
Crimson clover	**	NS	**	**	NS	NS

† G = grazing
‡ NS - Not significant, * - Significant at the 5% level, ** - Significant at the 1% level

and crimson clover were decreased. Changes in the percentage of hardinggrass due to grazing were not significant.

The percentage of total ground cover was reduced slightly by grazing in 1959, but not in 1958 (table 4). Clippings in 1958 indicated no increase in yield from nitrogen applications on ungrazed plots, but in 1959 an increase in yield resulted from the application of nitrogen on the same plots. On the grazed plots, no significant differences resulted from applied nitrogen, either year, in terms of remaining forage after grazing.

At the 2 locations where the same species were involved similar trends were noted for a given treatment. In 1959 soft chess was the most abundant species on the grazed plots at both locations without regard to fertilizer treatments except where 200 pounds of P_2O_5 with no nitrogen was applied at the reseeded location. In this instance the percentage of sub clover was slightly higher. In the same year soft chess was the most abundant species on ungrazed plots at both locations where nitrogen was not applied. Slender wild oats was most abundant where nitrogen was added at the resident-range location. At the reseeded location, on plots where nitrogen was applied at the highest rate, ripgut was the most abundant species.

SUMMARY AND CONCLUSIONS

Changes in botanical composition resulting from applications of nitrogen and phosphorus, with and without sheep grazing, on the annual range type of California were studied at two locations. The first site was unimproved resident-range and the second had been seeded to sub, rose, and crimson clovers, hardinggrass, and soft chess.

The percentage of soft chess at the resident-range location was increased by nitrogen fertilization on grazed plots for 2 of 3 years but increased only the first year on ungrazed plots. Percentage of soft chess on the reseeded-range area was increased both years by nitrogen fertilization when grazed but decreased when protected.

Table 4—Effect of grazing and fertilization upon percent ground cover and yield in May of two different years at the reseeded-range location. Each value is a mean of 4 replications.

Year	Ungrazed			Grazed		
	Fertilizer			Fertilizer		
	N_0 P_{200}	N_{50} P_{200}	N_{200} P_{200}	N_0 P_{200}	N_{50} P_{200}	N_{200} P_{200}
			Percent ground cover			
1958	100	100	100	100	100	100
1959	100	100	100	90	94	96
			Yield in grams dry matter per square foot			
1958	136	150	148	58	56	55
1959	58	84	119	27	29	32

The percentage of ripgut on the resident-range site was increased by phosphorus fertilization, and this increase was less on grazed plots than on ungrazed. On the seeded site, where available phosphorus was adequate, ripgut was increased by nitrogen fertilization. Grazing reduced the percentage of ripgut at both locations.

Slender wild oats and broadleaf filaree, which were major components of the forage at the resident-range site only, were particularly responsive to nitrogen and both decreased in abundance when grazed. Little fertilizer effect could be measured in filaree on grazed plots.

In general, clovers were decreased by nitrogen fertilization, but subclover appeared to be an exception in 1958. Phosphorus increased the clovers. The percentage of clovers at the resident-range site and crimson clover at the seeded site decreased under grazing while rose and subclovers were increased by grazing.

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