USDA Forest Service
Research Paper INT-199
February 1978

GROWTH AND NUTRITIONAL VALUE TO CATTLE OF GRASSES ON CHEATGRASS RANGE IN SOUTHERN IDAHO

R. B. Murray, H. F. Mayland,
and P. J. Van Soest

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401

THE AUTHORS

ROBERT B. MURRAY is Range Scientist for the Agricultural Research Service at the U.S. Sheep Experiment Station in Dubois, Idaho. His degrees are from the University of Montana: B.S. in range management and forestry (1954) and M.S. in range management and forestry (1961). He received his Ph.D. in plant ecology from Washington State University in 1975. He conducted research on cheatgrass ranges and pinyon-juniper woodlands for the Intermountain Station prior to his appointment to his present position.

HENRY F. MAYLAND is Supervisory Soil Scientist and Research Leader for the Agricultural Research Service, Kimberly, Idaho. He received his B.S. (1960) and M.S. (1961) degrees from the University of Wyoming and his Ph.D. (1965) in agricultural chemistry and soils from the University of Arizona. His principal research is concerned with mineral cycling in the soil-plant-animal system.

PETER J. VAN SOEST is Professor of Animal Nutrition at Cornell University, Ithaca, New York. He previously served as biochemist with the Agricultural Research Service (1957-1968). He received his B.S. (1951) and M.S. (1952) degrees from Washington State University and his Ph. D. (1955) in nutrition from the University of Wisconsin. His research is in ruminant digestion and metabolism; chemistry of fibrous feed and methods of analysis and forage chemistry.

ACKNOWLEDGMENTS

We thank the following for valuable technical and analytical assistance: Arlene Florence, Russell Rosenau, and Harold Waggoner, Research Technicians, Agricultural Research Service, Kimberly, Idaho; and Jim Robertson, Forage Analysis Laboratory, Cornell University, Ithaca, New York. Appreciation is also extended to others involved in this study including seasonal helpers, technicians from the Soil Conservation Service and Bureau of Land Management, and especially to the cooperating ranchers.

CONTENTS

APPENDIX:

RESEARCH SUMMARY

Seven grass species--desert wheatgrass (Agropyron desertorum), streambank wheatgrass (Agropyron riparium), cheatgrass (Bromus tectorum), basin wildrye (Elymus cinereus), Sandberg's bluegrass (Poa sandbergii), bottlebrush squirreltail (Sitanion hystrix), and needle-and-thread grass (Stipa comata)--were harvested to a 1/2-inch (1.2-cm) stubble height periodically between mid-March and December in most years from 1962 through 1968 at the Saylor Creek Experimental Range in southern Idaho. These samples were analyzed for N, P, S, Ca, Mg, K, Na, Zn, Mn, Cu, and Fe. Certain digestibility fractions (NDF, NDF-ash, DCW, DCW-ash free, and TDDM) were also determined on these samples. In addition, estimates of the soil chemical status, soil moisture contents over depth and time, forage yields, and moisture contents over time, effects of ammonium nitrate fertilization on forage yields and mineral composition, and animal grazing responses to cheatgrass range are included.

Trends in mineral concentration; mineral ratios Ca:P, K:(Ca + Mg), N:S, Zn:Ca, and Zn:Cu; and digestibility fractions were plotted over time in a series of graphs. When a significant r^2 value was determined for a given parameter and plant species through regression analysis, the equation and line describing the trend are given.

There was a distinct exponential decrease in plant tissue mineral concentration for each nutrient studied, except for Na, Mn, and Fe, which did not exhibit any trends in any species. In cheatgrass, Ca and Mg declined with plant maturity, but in the other species no trends could be detected. The Ca:P ratio increased exponentially, while the equivalents of K:(Ca + Mg) and N:S ratios decreased as plants matured. Ratios of Zn:Ca and Zn:Cu were unrelated to plant maturity. Total fiber (NDF) increased and tended to level as the forage matured. Digestibility, including cell wall digestibility (DCW), organic cell wall digestibility (DCW-ash free), and total dry matter digestibility (TDDM) decreased as plants matured. There were differences in the levels of these components between species, but the trends were as expected.

Organic N, K, Mn, and Fe concentrations were greater near the soil surface and decreased with depth in the soil. Although the organic N levels appeared adequate for these soils, results from a fertilization trial with N indicated that available N was limiting plant growth at least for the soil moisture conditions during the study period. Nitrogen levels in the seven species were inadequate after late June, and consideration should be given to crude protein supplementation of grazing animals.

Fertilization was shown to increase forage yields and N levels, but costs of fertilizing to increase crude protein concentration may be prohibitive compared to direct animal supplementation.

In spite of apparently adequate levels of K in the soil, plant K decreased rapidly with time and soon reached levels below those considered necessary for good nutrition in cattle. Manganese levels were adequate for animal nutrition through the season and showed no relationship to plant maturity. Iron levels were generally much higher than normally found in plant tissue. Measured Fe levels varied widely, probably because of soil contamination.

By the end of June, the level of plant P was below recommended allowances for cattle. Plant Zn levels were adequate for a brief period in the spring, and then declined to a level where supplementation has been shown to be beneficial for weight gains. Copper showed declining trends in five of seven plant species, but never declined below levels considered adequate.

Sulfur, as the sulfate ion, is readily leached in soils. We found that S was accumulating deep in the soil profile below the normal depth of plant roots. Levels of S in the plants declined rapidly between April and June. The N:S ratio also declined as plants matured and could reduce the protein conversion efficiency. However, cheatgrass, which comprises the bulk of the forage, maintained an N:S ratio considered adequate, but the low forage S in itself could be a problem.

Calcium and Mg are very abundant in Saylor Creek soils, and the levels found in plant tissues were considered adequate for cattle. Other factors, not considered here, may reduce Mg availability to ruminants particularly in the early spring, causing Mg deficiency. The amount of K in relation to Ca and Mg has been implicated in grass tetany problems. Basin wildrye and desert wheatgrass had equivalents of K:(Ca + Mg) ratios above 2.2 for portions of the spring period. On cheatgrass range, grass tetany is not likely to be a problem except where desert wheatgrass seedings are used in a management program. The Ca:P ratio increased as plants matured, and all species except desert wheatgrass and cheatgrass exceeded the recommended 7:1 level by late October.

Sodium was found in relatively large amounts in the soil below the normal rooting depth of our species. Plant tissue Na concentrations were variable with time, but were less than those considered adequate for cattle; however, normal management includes the provision of NaCl salt blocks.

No trends were found for the Zn:Ca and Zn:Cu ratios with plant maturity.

As indicated by TDDM measurements, most species were less than 60 percent digestible by September. Apparent dry matter digestibility or TDN was about 13 units lower. Comparative work with esophageal fistulated yearling cattle and lignin and chromic oxide techniques gave dry matter digestibilities of 65 percent in early September. These differences may reflect selective feeding on the part of the animals.

On cheatgrass range, fertilization with N increased yields and N contents, but had little effect on plant uptake of other minerals. Similar results were found on fertilized needle-and-thread grass range, but the increased yields were not economical. These results imply that fertilization on these two range types, under semiarid conditions, is not practical and that direct animal supplementation of needed nutrients could be practiced instead.

Cheatgrass range provided considerable forage that is nutritious in spring and early summer. Yearling cattle response to cheatgrass range under a variety of treatments has shown that this class of animals can make satisfactory weight gains without supplementation. However, it has been shown that these animals will perform somewhat better when protein and energy are added to their diets. Calves, in particular, are likely to benefit from Zn supplements, especially late in the season.

INTRODUCTION

Cheatgrass (*Bromus tectorum*)[1] range occurs widely in the Intermountain and Columbia basins and supports large numbers of livestock. This fall-germinating annual was introduced into North America from Europe about 1850 and spread rapidly across western rangelands until today it covers an estimated 60 million acres in the 11 western States (Hull 1965). In southern Idaho, cheatgrass is dominate on an estimated 6 to 7 million acres and is an important species on another 20 million acres.

Hull and Pechanec (1947) considered cheatgrass the most important forage plant in southern Idaho, and the associated species seasonally or periodically important. Grasses on these semiarid ranges are nutritious in the spring but mature rapidly, resulting in a forage quality decline. Murray and Klemmedson (1968) found that yearling cattle gains were greatest in the late spring when nutrient levels were still adequate and forage was abundant. Gains declined throughout the summer and fall as the forage cured and deteriorated.

Livestock performance is partially dependent upon adequate levels and favorable balances of nutrients in the forage consumed. Forage should contain at least the minimum balanced nutritional levels for maintenance and greater amounts for growth and gain. Since grass nutrient levels vary from one stage of development to another (Crampton and Jackson 1944; Cook and Harris 1950; Phillips and others 1954), the nutrient intake may be inadequate during part of the grazing season. An understanding of nutrient changes in range plants throughout the grazing season will give stockmen and managers information needed to develop supplementation programs, or to change management systems to enhance livestock performance.

The need to improve livestock performance on cheatgrass ranges prompted the research reported here. Our objectives were: (1) to determine the trends (over the April to November grazing season), and some of the causes of these trends in nutrient contents and digestibility fractions for seven grass species: desert wheatgrass (*Agropyron desertorum*), streambank wheatgrass (*Agropyron riparium*), cheatgrass (*Bromus tectorum*), basin wildrye (*Elymus cinereus*), Sandberg's bluegrass (*Poa sandbergii*), bottlebrush squirreltail (*Sitanion hystrix*), and needle-and-thread grass (*Stipa comata*); and (2) to develop equations which describe these trends and make it possible to predict dates of probable mineral deficiencies.

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[1] A list of species with complete scientific and common names is given in appendix I. Nomenclature follows Hitchcock and Cronquist (1973).

EXPERIMENTAL AREA

The Saylor Creek Experimental Range was formerly a joint facility of the Bureau of Land Management, U.S. Department of Interior, and the Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. All plant, soil, and animal weight gain data were collected at the Saylor Creek Experimental Range 9 miles (15 km) southwest of Glenns Ferry, Idaho. The experimental area occupies approximately 4,400 acres (1,780 ha) of rangeland at an elevation of 3,140 feet (957 m). Air temperature and precipitation data were obtained from the climatological station at Glenns Ferry at 2,600 feet (800 m) elevation.

The climate at the Saylor Creek Experimental Range is semiarid. Annual precipitation varies from about 5 inches (125 mm) to slightly under 19 inches (480 mm), based on long-term records from Glenns Ferry. Average monthly precipitation for 1961 through 1974 is shown in figure 1. Precipitation in 6 of these 14 years exceeded the 40-year, long-term average of 9.6 inches (240 mm).

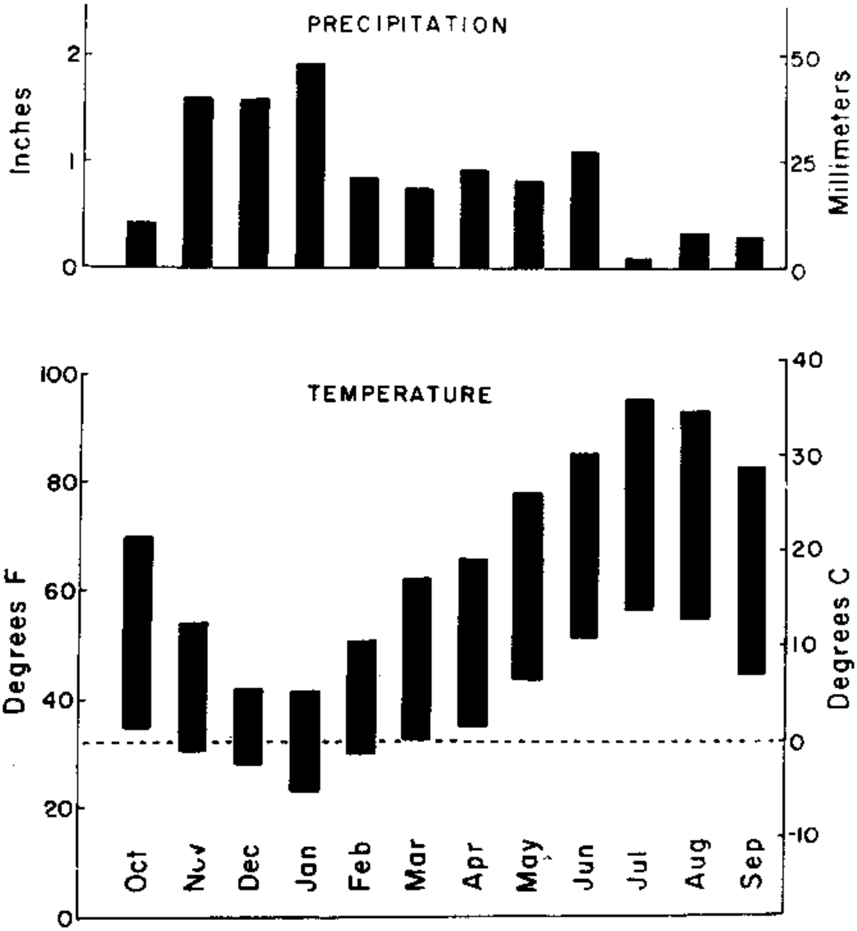

Figure 1.--Average monthly precipitation and the range between average maximum-minimum temperatures for Glenns Ferry, Idaho (1961 through 1974).

Low winter temperatures may reach -25° F (-32° C) and high summer temperatures frequently exceed 100° F (39° C). Average monthly maximum-minimum temperatures for 1961 through 1974 are depicted in figure 1.

Remnants of the original vegetation still present on some of the Saylor Creek Experimental Range indicate that the former vegetation for the area was a basin big sagebrush-needlegrass (*Artemisia tridentata* ssp. *tridentata-Stipa thurberiana*) type. Natural invasion of cheatgrass, fire, and subsequent heavy grazing of native species by cattle (primarily) and sheep have each played a role in altering this type drastically, leaving a range dominated by cheatgrass-bluegrass with varying amounts (depending upon locality) of bottlebrush squirreltail, streambank wheatgrass, basin wildrye, needle-and-thread grass, Russian thistle, tansy mustard, and other annual and perennial grasses and forbs. Fire has had a major impact on the vegetational succession observed on these ranges.

The experimental range has several acres of remnant sagebrush-grass range, which is in fair condition. Approximately 100 acres (40 ha) have burned and are now dominated by needle-and-thread grass. Interspersed in the cheatgrass and needle-and-thread grass range are clones of other species, including patches of streambank wheatgrass in the shallow swales, varying in size from a few plants to 0.05 acre (0.02 ha).

Percent composition of annual species vegetation at Saylor Creek varies considerably from year to year, and within years, depending on season, grazing intensity, and timing and amount of precipitation. Percent frequency was used to measure the change in species in two nongrazed cheatgrass community pastures in 1969 and 1973 (table 1). Cheatgrass increased, while the forbs, Russian thistle and tansy mustard, declined sharply, although the presence and frequency of the latter two are highly seasonal.

Cover, frequency, and standing crop for the needle-and-thread grass community and the adjacent sagebrush community were estimated in 1973. These values are given in table 2 for comparison with the cheatgrass type (table 1).

Table 1.--*Percent frequency of plant species found in the cheatgrass community at the Saylor Creek Experimental Range during 1969 and 1973*[1]

	1969	1973
GRASSES:		
Streambank wheatgrass	18.8	24.6
Cheatgrass	95.0	100.0
Sandberg's bluegrass	42.8	40.0
Bottlebrush squirreltail	.2	.0
FORBS:		
Sego lily	.2	.0
Tansy mustard	59.5	11.4
Prickly lettuce	.0	1.0
MacDougal lomatium	.2	.0
Longleaf phlox	1.0	1.2
Russian thistle	96.2	.0

[1] Based on 200 permanent plots (138 in^2, 890 cm^2) in each of two nongrazed pastures.

Table 2.--*Cover, frequency, and standing crop by species in needle-and-thread grass and in the sagebrush communities, Saylor Creek Experimental Range, 1973.*

	Grassland Community			Sagebrush Community		
	Cover	Frequency	Standing crop	Cover	Frequency	Standing crop
	Percent	*Percent*	*kg/ha*	*Percent*	*Percent*	*kg/ha*
SHRUBS:						
Basin big sagebrush						
Leaves						157
Flowers						8
Flower stalks						10
twigs <1 cm						248
Twigs >1 cm						2,304
Deadwood on plants						270
Litter						1517
				[1]28.4		[2]2,997
GRASSES:						
Cheatgrass	57.0	100	530	51.7	100	422
Indian ricegrass	[3]+	+	+			
Sandberg's bluegrass	17.8	72	144	6.8	49	47
Bottlebrush squirreltail	3.2	15	181	1.2	8	12
Needle-and-thread grass	15.6	53	270	10.0	43	255
Thurber's needle grass	.2	1	6	1.7	6	64
			1,131			802
FORBS:						
Low pussytoes				.5	20	11
Beckwith's milk vetch				4.9	11	1
Specklepod locoweed	+	+	+	1.5	3	16
Pursh locoweed	.5	2	+	+	+	+
Sego lily	+	+	+	+	+	+
Northwestern paintbrush				+	+	+
Tapertip hawksbeard	.5	2	10	.5	2	24
Western hawksbeard				+	+	+
Low fleabane				+	+	+
Oval-leaved buckwheat	+	+	+	+	+	+
MacDougal lomatium				1.2	18	4
Nineleaf lomatium				+	+	+
Hood's phlox	+	+	+	+	+	+
Longleaf phlox	1.0	10	12	4.2	44	54
			22			110
TOTAL STANDING CROP			1,153			3,915

[1] Line interception
[2] Does not include litter weight
[3] Present in macroplot

Table 3.--*Actual and predicted range forage production (95 percent cheatgrass). Yield data at Saylor Creek Experimental Range were taken about June 15 each year. Prediction equation based on the 1961 through 1968 data.*

Year[1]	Actual yield ± S$\bar{x}$		Predicted yield[2]
	Lb/acre	*kg/ha*	*kg/ha*
1961	239 ± 30	268 ± 34	266
1962	505 ± 31	566 ± 35	568
1963	654 ± 49	734 ± 55	728
1964	443 ± 65	497 ± 73	490
1965	491 ± 87	550 ± 98	551
1966	598 ± 110	670 ± 123	677
1967	204 ± 30	229 ± 34	239
1968	103 ± 15	115 ± 17	110
Mean	405	453	454
1975	545 ± 50	611 ± 56	-97
1976	924 ± 56	1,036 ± 63	250
Mean	734	824	

[1] For 1961 through 1968 the forage was harvested from a nongrazed pasture, while the harvests in 1975 and 1976 were from grazed pastures.

[2] Predicted yield = -1,656 + 7.5 (Apr. ppt.) + 80.9 (April mean temp.) - 28.1 (Feb. mean temp.) + 70.8 (May mean temp.) + 1.5 (May ppt.) where precipitation (ppt.) and temperature (temp.) are in millimeters and degrees Celsius, respectively.

Forage yield fluctuations on cheatgrass range are well known. Table 3 gives the forage production (mainly cheatgrass) for the years 1961 through 1968, taken from an area that was not grazed for the entire period. June 15 forage yields during that period were highly predictable using a stepwise multiple regression analysis. Fifty-two percent of the variation in yield was related to April precipitation and April temperature. Ninety-nine percent of the variation in yield was predicted by the equation:

$$\hat{Y} = -1656 + 7.5\ (\text{Apr. ppt.}) + 80.9\ (\text{Apr. mean temp.}) - 28.1$$

$$(\text{Feb. mean temp.}) + 70.8\ (\text{May mean temp.}) + 1.5\ (\text{May ppt.})$$

The $R^2 = 0.999$. Yield, precipitation, and temperature are in kilograms dry matter per hectare, millimeters, and degrees Celcius, respectively. Climatic data for Glenns Ferry, Idaho, were used in the regression analysis.

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Murray has observed that moderate grazing of cheatgrass range from year to year stimulates forage production when compared to nonuse. This is substantiated by the fact that the 1975 and 1976 yields from grazed pastures (table 3) were greater than those predicted by the equation. Nonuse for a long period in the absence of fire causes a litter buildup, which may interfere with cheatgrass germination and seedling establishment.

Soils at the experimental range were developed on gently, undulating topography, from Black Mesa gravels and aeolian sources (Malde and Powers 1962). The underlying rock is basalt and has not influenced soil development.

The soils are considered to be in the Minidoka silt loam series, a member of the coarse silty, mixed, mesic Xerollic Durorthid family. Appendix II gives descriptions of the soils for the needle-and-thread grass and sagebrush sites.

Throughout the range, some small areas termed "slick-spots" are present (Rasmussen and others 1972). These soils have a strongly developed B2 horizon that contains large amounts of exchangeable sodium. Weakly developed "slick-spots" are only noticeable during late May and June when cheatgrass is drying. Within these spots, cheatgrass will turn purple 2 to 3 weeks before the surrounding plants. Also, in many instances, cattle will graze the spot completely to the soil surface, while the surrounding grass appears little used. The reason for this grazing behavior is unknown; perhaps the stressed plants have a higher sugar and/or salt concentration than do plants on the adjacent soils.

METHODS AND PROCEDURES

Field Procedures

Forage phenology data were obtained from field observations made from 1962 through 1968. A variety of techniques, including line intercept, canopy coverage, and permanent circular plots, were used to determine species cover and frequency. Rectangular plots, 7.9 by 19.7 inches (20 by 50 cm), were clipped during the full flower stage to determine standing crops of grasses and forbs (fig. 2), while 236 by 394 inches (6 by 10 m) plots were used to determine the standing crop of basin big sagebrush.

A fertilizer trial, a minor part of the total study, was initiated to determine the effects of added N and P on forage dry matter yield, protein, and mineral concentrations. Cheatgrass plots were fertilized with 0, 40, 80, 120, 160, or 200 lb N per acre (1 lb/acre equivalent to 1.12 kg/ha). Needle-and-thread plots were fertilized with both N and P applied at 40, 80, or 120 lb N or P per acre in all combinations. The N as ammonium nitrate, and P as treble superphosphate, were applied in September 1964 with four replications. All fertilizers were surface-applied. The cheatgrass plots were harvested in mid-June 1965, the needle-and-thread plots were harvested in mid-June 1965 and 1966, and the forage was separated by species.

Figure 2.--Research technician clipping forage to determine productivity on cheatgrass range.

Forage dry matter production above 1/2-inch (1.3-cm) stubble height was determined by clipping 30 plots 20 inches (51 cm) by 15 feet (4.6 m) except in 1975 and 1976 when 200 randomly located 1-ft^2 (929-cm^2) plots were clipped. Plant material for chemical and forage quality characterization was harvested periodically (at 1/2-inch stubble height) from random clones in the same nongrazed pasture between mid-March and November during the 1962 through 1968 period. Plant material was ovendried 24 to 48 hours at 158° F (70° C) and ground to pass a 40-mesh screen. Forage moisture content was determined on some samples as the water lost by drying at 158° F (70° C) for 24 to 48 hours, divided by dry matter content.

Gravimetric soil moisture content was determined on triplicated soil core samples taken monthly from 1961 through 1968. Additional soil samples for chemical and bulk density analysis were taken from the side of soil pits dug in the cheatgrass, needle-and-thread grass, and sagebrush communities. Samples for chemical and textural analyses were air dried and passed through a 2-mm screen. Bulk density cores were ovendried for 24 hours at 220° F (105° C) and weighed. Soil descriptions follow the standard Soil Conservation Service procedures and terminology.

Forage Analyses

Total nitrogen (N), with the salicylic acid modification for N-N and N-O linkages, was determined by semi-microKjeldahl procedures. Nitric-perchloric acid (3:1) digestion of forage samples preceded analysis for phosphorus (P), sulfur (S), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), zinc (Zn), manganese (Mn), copper (Cu), and iron (Fe). Phosphorus was estimated colorimetrically following the ammonium molybdate-stannous chloride procedures. Sulfur content was determined by a modification of the turbidimetric procedure. All other elements were estimated by atomic absorption spectrophotometry. A standard plant sample that had been analyzed in several other laboratories was used as a check on procedures.

Forage samples were also analyzed for neutral-detergent fiber (NDF), NDF-ash, digestible cell wall (DCW), DCW-ash free, and true dry matter digestibility (TDDM) following the procedures specified by Goering and Van Soest (1970). Rumen fluid inoculum was obtained from a donor cow maintained on a timothy (*Phleum pratense*) grass-hay diet.

Soil Analyses

Soil organic N was determined on finely ground (100-mesh) soil by microKjeldahl procedures. Phosphorus was determined by extracting 5 g soil with 100 ml of sodium bicarbonate (pH 8.5), filtering, and using an ammonium molybdate-stannous chloride procedure to develop the blue color (Olsen and Dean 1965). Sulfate sulfur (SO_4-S) concentrations were obtained following the procedure outlined by Bardsley and Lancaster (1965).

Soluble and exchangeable sodium and potassium were extracted with 1 *N* ammonium acetate (pH 7.0 at a ratio of 5 g soil to 100 ml extracting solution). After shaking for 2 hours, the solution was filtered under suction and Na and K were determined by flame photometry.

Zinc, Mn, Cu, and Fe concentrations were determined by extracting 10 g soil with 20 ml diethylenetriamine pentaacetic acid (DTPA) extracting solution. The extracting solution contained 0.005 *M* DTPA, 0.01 *M* calcium chloride, and 0.1 *M* triethanolamine (TEA) adjusted to pH 7.30 with glacial acetic acid. After filtering, the extracts were analyzed by atomic absorption spectrophotometry (Lindsay and Norvell 1969; Follett and Lindsay 1970). Soil pH was determined on a 1:1 soil:distilled water paste, using a glass electrode.

Calcium carbonate equivalents were determined by acid neutralization (Allison and Moodie 1965). The soils were not analyzed for Ca and Mg, because of the high concentrations of calcium-magnesium carbonate in the profile which, upon extraction with ammonium acetate, yield erroneously high values (Heald 1965) although Mg content was determined on a 1 *N* ammonium acetate extract of the surface soil from the cheatgrass community.

Soil moisture content at the three-tenths and 15-bar tension was determined by pressure plate apparatus.

Statistical Analyses

Seasonal trends in soil water concentrations were calculated using a 2-factor Fourier analysis (Bliss 1958). Linear and curvilinear regression techniques were used to summarize forage water, forage mineral concentrations, and forage quality data. All forage mineral and nutritive quality data were fit to each of the following curve forms: $a + b/x$, ax^{bx}, $a + bx$, ae^{bx}, $x/(a + bx)$, $1/(a + bx)$ and $a + bx + cx^2$. The curve form selected was the one yielding the largest sum of r^2 values for the seven species tested.

Animal Weight-Gain Responses

Hereford and Angus beef cattle, or crosses of these breeds, were provided by local livestockmen. Yearling cattle weight-gain responses to various stocking intensities were determined by the "put-and-take" method. Other yearling and cow-calf weight-gain responses to season-long grazing of moderate intensity were also determined. Animals grazed within 0.6 mi (1 km) of water and were weighed at periodic intervals (generally 28 days) following an overnight shrink without feed or water.

RESULTS AND DISCUSSION

Soil Moisture

Monthly precipitation for 1961 through 1968 is shown in conjunction with soil moisture at Saylor Creek Experimental Range in the 0- to 12-inch (0- to 30-cm) and 12- to 24-inch (30- to 60-cm) depths (fig. 3).

Because most of the precipitation falls as snow or rain in winter and spring, plants generally mature by early to midsummer. Shallow-rooted plants, such as cheatgrass and bluegrass, mature before the deeper rooted species, which is reflected in forage moisture concentrations (table 4) and is related to the characteristic soil moisture patterns illustrated in figure 4. This analysis, representing 9 years of data, leads to highly predictable soil moisture values for the various soil depths and indicates a lag in soil moisture depletion with increasing depth during spring and summer months that explains the differential curing between shallow- and deep-rooted species.

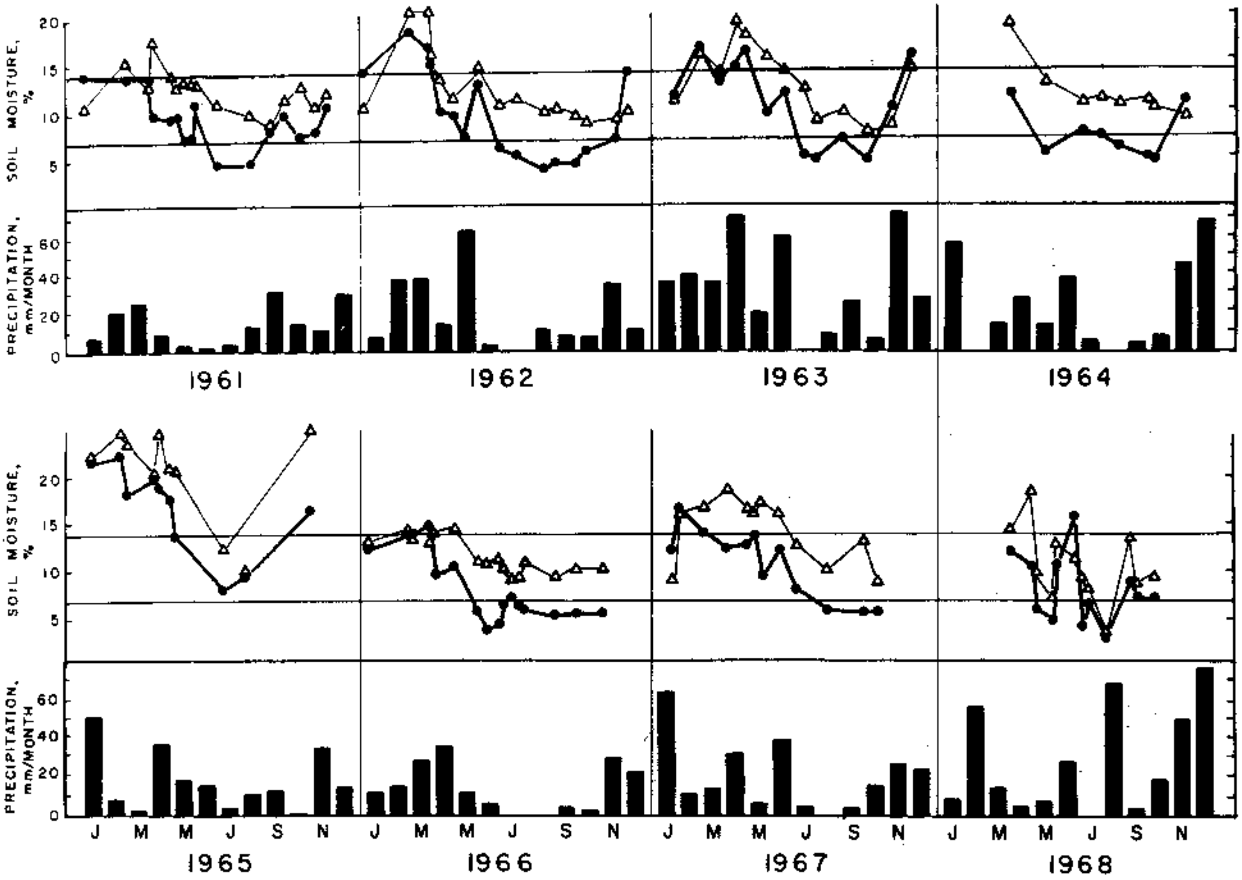
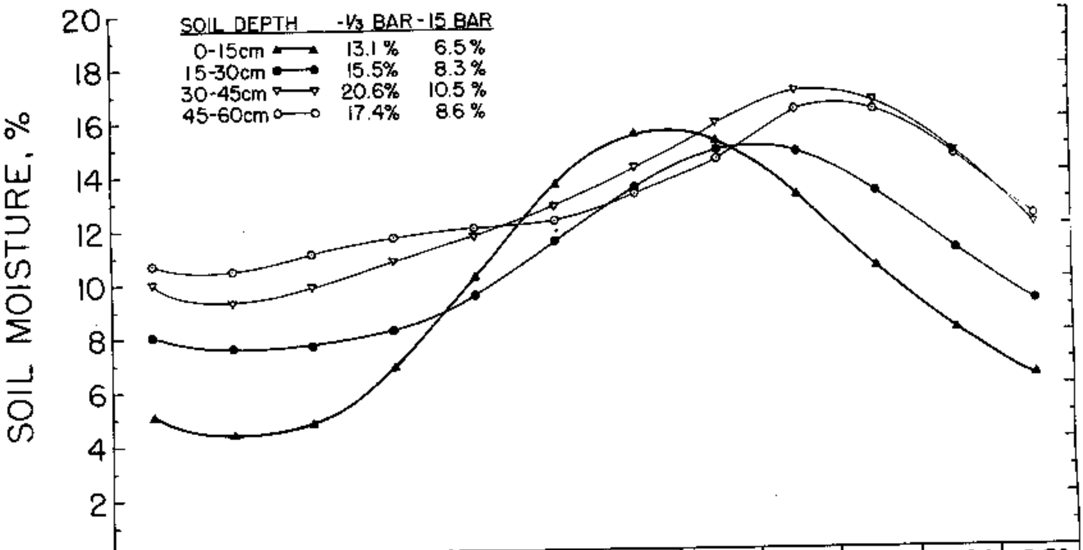


Figure 3.--Trends in soil moisture for the 0- to 12-inch (0- to 30-cm)•—• and 12- to 24-inch (30- to 60-cm)△—△ depths for the years 1961 through 1968 in relation to monthly precipitation. The -0.3 bar water content is 13.5 percent and the -15 bar water content is 7 percent (W/W).

Table 4.--*Regression of forage moisture content (Y = ((Wet Weight - dry weight)/dry weight) 100) against date (X) and correlation values for each of seven species collected on periodic dates for 5 years of a 7-year period and the predicted Ŷ values for each of four dates.*

Species	Regression-correlation	Collection date 4/15	5/15	6/15	7/15
		Predicted forage moisture, Ŷ			
Desert Wheatgrass	$Y = 380 - 1.51X$, $r^2 = 0.75$	220	175	128	83
Streambank wheatgrass	$Y = 317 - 1.23X$, $r^2 = .70$	187	150	112	75
Cheatgrass	$Y = 669 - 3.52X$, $r^2 = .85$	296	190	81	0
Basin wildrye	$Y = 524 - 2.13X$, $r^2 = .87$	298	234	168	104
Sandberg's bluegrass	$Y = 348 - 1.70X$, $r^2 = .72$	168	117	64	13
Bottlebrush squirreltail	$Y = 455 - 2.05X$, $r^2 = .82$	238	176	113	51
Needle-and-thread grass	$Y = 265 - 1.05X$, $r^2 = .61$	154	122	90	58



		JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
0-15cm	MEAN	4.74	4.28	5.33	6.42	10.06	13.82	15.48	14.97	13.13	10.70	7.84	6.79
	$S_{\bar{x}}$	0.63	0.73	1.05	1.08	1.06	0.85	1.10	0.80	0.68	0.93	1.05	1.17
15-30cm	MEAN	7.99	7.33	7.78	8.18	9.57	11.62	13.06	14.96	15.10	13.22	10.49	9.81
	$S_{\bar{x}}$	0.57	0.68	0.93	1.20	1.01	0.78	0.77	0.95	0.87	1.04	1.01	0.69
30-45cm	MEAN	10.12	9.58	10.42	10.72	11.51	12.39	13.92	16.54	17.33	17.07	13.82	12.02
	$S_{\bar{x}}$	0.76	0.53	0.75	1.38	1.29	1.06	1.17	1.14	0.96	0.82	0.99	0.76
45-60cm	MEAN	10.88	10.11	11.32	11.56	11.66	12.42	13.34	15.16	15.94	16.50	13.92	13.01
	$S_{\bar{x}}$	0.37	0.45	1.00	1.70	1.49	0.97	1.13	1.25	1.39	1.03	0.99	0.63
MONTH		JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN

Figure 4.--Trend in soil moisture at four depths at Saylor Creek Experimental Range. Mean monthly soil moisture percentage and standard error of the mean calculated from 9 years' data (1961 through 1969). The 1/3 and 15-atmosphere values for each depth given in table at top left. Data for soil moisture curves were calculated from 9 years' data using a two-factor Fourier analysis (Bliss 1958).

Soil Mineral Availability

Mineral composition of soil has an important bearing on soil fertility and plant chemical composition. Soils having a high proportion of minerals resistant to weathering, like granite quartz, are generally infertile. At Saylor Creek, the soils are derived from sedimentary and aeolian sources and are comparatively productive.

Plants with a wide and deep root distribution in the soil profile probably have a greater chance for ion uptake than those with narrow or shallow root distributions. Most roots were concentrated in the 0- to 16-inch (0- to 40-cm) zone in cheatgrass, needle-and-thread grass, and sagebrush-grass communities. In the first two communities, few roots were found below 16 inches (40 cm), but in the sagebrush-grass community roots were found in relatively greater abundance below 16 inches (40 cm).

Throughout the 32- to 55-inch (80- to 140-cm) zone at the needle-and-thread grass sites, decaying sagebrush roots were found upon fragments of caliche. Apparently, some sagebrush roots are unable to find their way through the caliche zone even during periods of high moisture.

Soil characteristics for the needle-and-thread grass, sagebrush-grass, and cheatgrass sites are given in table 5. Organic N, K, Mn, and Fe concentrations were greater near the surface and tended to decrease with depth. At the needle-and-thread grass site, the organic N increased in the 32- to 55-inch (80- to 140-cm) zone because of the decaying sagebrush roots. At the cheatgrass site, organic nitrogen began to increase at about 8 inches (20 cm). The levels of organic N were comparable to those found in a Minidoka silt loam soil from Canyon County, Idaho (Priest and others 1972).

Phosphorus, Zn, and Cu distributions were somewhat variable with depth, but tended to occur in higher concentrations near the surface. Both Na and sulfate-sulfur increased with depth. The higher concentrations of highly mobile Na and sulfate (1,050 and 916 ppm in the 32- to 55-inch (80- to 140-cm) zone) of the needle-and-thread grass site, compared to 450 and 136 ppm at the sagebrush site, might have resulted because deep-rooted sagebrush was removed in 1957 and these ions were leached from the upper profile and accumulated in the 32- to 35-inch (80- to 140-cm) zone of the grass site, but more likely represent some differences in soils between the two sites.

Follett and Lindsay (1970) found that the average DTPA-extractable Zn, Mn, and Fe contents from 37 Colorado soil profiles decreased with depth, while Cu remained relatively uniform with depth. They also found that the range varied from 0.13 to 14.2 ppm for Zn, 1.5 to 160 ppm for Fe, 0.6 to 39.5 ppm for Mn, and 0.14 to 3.68 ppm for Cu. Our values fell within these ranges, averaging toward the lower end of the range.

Some elements are readily leached from plant tissues (Mes 1954) which, with litter accumulation and decay, accounts for the high concentrations in the surface soil. Precipitation collected from under sagebrush plants contained more minerals than that collected from between sagebrush plants (Murray 1975). Part of the increase is probably due to the precipitation washing dust from the plant leaves.

Although plants use N in the ammonium and nitrate forms, little inorganic N can be detected in these soils during the growing season. Consequently, N is measured as organic N and the levels are assumed to indicate the potential availability of N. Stevenson and Wagner (1970) state that organic N consists mainly of (1) nitrogenous biochemicals synthesized biochemically by micro-organisms living on plant and animal residues, and (2) products formed by secondary synthesis reactions which bear no resemblance to any substances in plant and animal tissues (humic and fulvic acids). These products are eventually transformed into ammonium and nitrate--N. Moist Saylor Creek surface soils incubated for 10 weeks in the dark produced 16 ppm nitrate-N, and when alfalfa was added as an energy source to soil, it produced 58 ppm nitrate-N. Fertilization with N increases plant yields at Saylor Creek, thus indicating that N is limiting.

Table 5.--*Soil characteristics of the needle-and-thread grass, sagebrush-grass, and cheatgrass sites at the Saylor Creek Experimental Range (1972)*

NEEDLE-AND-THREAD GRASS SITE

NE.1/4, SE.1/4, sec. 17, T.6S., R.9E., Boise Meridian

Depth (cm)	pH	$CaCO_3$	N	K	P	SO_4-S	Na	Zn	Mn	Cu	Fe	Bulk density	15 Atm
		Percent			*Ppm*							*g/cm³*	*Percent*
0-10	8.2	3.8	0.106	0.040	2.8	3	12	0.9	7.6	1.2	5.3	1.32	7.7
10-20	8.3	8.5	.074	.028	2.2	T	12	1.0	6.1	1.2	5.3	1.43	8.3
20-30	8.4	15.5	.065	.022	2.3	T	14	.4	4.5	1.1	3.7	1.66	7.8
30-40	8.3	24.1	.066	.015	.9	T	19	.3	5.1	.9	3.5	1.70	8.4
40-80	8.6	43.4	.061	.009	1.5	7	132	.4	4.0	.5	2.6	1.68	9.5
80-140	8.3	36.0	.080	.020	3.0	916	1,050	.5	3.5	.4	2.0	1.64	

SAGEBRUSH-GRASS SITE

SE.1/4, NW.1/4, sec. 17, T.6S., R.9E., Boise, Meridian

Depth (cm)	pH	$CaCO_3$	N	K	P	SO_4-S	Na	Zn	Mn	Cu	Fe	Bulk density	15 Atm
		Percent			*Ppm*							*g/cm³*	*Percent*
0-10	7.9	3.0	0.089	0.051	4.8	5	8	1.1	13.9	1.1	12.0	1.33	7.3
10-20	8.2	9.0	.082	.044	2.3	T	10	.4	10.2	1.6	7.0	1.45	7.8
20-30	8.4	15.5	.044	.032	.6	T	8	.4	8.4	1.8	4.7	1.50	8.9
30-40	8.4	19.7	.070	.025	1.0	T	10	.4	6.5	.8	4.7	1.54	9.2
40-80	8.6	24.7	.039	.025	1.5	1	17	.4	4.9	1.0	4.5	1.82	7.4
80-140	8.8	57.3	.041	.030	2.4	136	450	.5	2.4	.5	2.7	1.71	10.9

CHEATGRASS SITE

Center NE.1/4, sec. 28, T.6S., R.9E., Boise Meridian

Depth (cm)	pH	Mg	N	K	Na	Sand	Silt	Clay	C.E.C.
		Percent			*Ppm*	*Percent*			*Meq./100 g*
0-5	7.6	0.030	0.093	0.055	18	42	44	14	11.6
5-10	7.8		.067			43	41	16	
10-15	7.9	.015	.066	.044	18	43	41	16	12.8
15-20	7.9		.068			43	41	16	
20-25	8.0	.018	.074	.035	21	44	39	17	10.1
25-30	8.0		.083			43	40	17	
30-36	8.1	.021	.090	.032	20	43	38	18	11.3
36-41	8.2		.088			43	38	18	
41-46	8.2	.022	.095	.022	23	48	38	14	10.7
46-51	8.3		.063			54	34	12	

McGeorge and others (1935) found that in calcareous soils P availability is governed by the carbon dioxide and pH of the soil. They show that P availability is reduced by the presence of calcium carbonate. Truog (1946) noted that between pH 6.5 and 7.5 conditions are most favorable for P availability; between pH 7.5 and 8.5 P availability is reduced; and at pH 8.5 and higher soluble sodium phosphate readily available for plant use would be formed. In the active rooting zone at Saylor Creek, pH values fall between 7.5 and 8.5, and thus P deficiencies could also limit plant growth.

Soil sulfur exists in both organic and inorganic forms. Tabatabai and Bremner (1972) discuss two forms of organic sulfur: (1) organic sulfates containing C-0-S linkages, and (2) S containing amino acids (methionine and cysteine). These forms are broken down to inorganic sulfates by micro-organisms, and it is in this form that plants take up S. The pH of the soil, except under very acid conditions, has little effect on S availability. However, the sulfate ion is mobile and readily leached as evidenced by the needle-and-thread grass site (table 5). It is not known whether the low concentration of S in the 4- to 16-inch (10- to 40-cm) zone is due to plant uptake, leaching, or differences in basic soil chemistry. Sulfate fertilization may be beneficial to plant growth, especially if N fertilization were practiced.

Generally, large quantities of K are found in soils, but most is in unavailable forms. However, the extractable K in Saylor Creek soils appears to be adequate.

Sodium is not known to be essential for plant growth except that certain saltbush species require it (Brownell 1965). Sodium levels in the Saylor Creek soils, within the rooting depth, are not sufficiently high to present a toxicity problem. Data in table 5 indicate that Na is readily transported to the lower depths. "Slick-spot" soils contain larger quantities of Na in the B horizon than normal soils. An examination of a well-developed "slick-spot" profile revealed that the A and B horizons contained 13 and 167 mg Na per 100 grams of soil, respectively. Such soils have only sparse vegetation.

Threshhold levels of extractable (with DTPA) trace minerals above which greater dry matter production will not result for many intensively managed crops on soils of the types at Saylor Creek can be tentatively considered as 1, 1, 5, and 5 ppm for Zn, Cu, Fe, and Mn, respectively. On this rangeland, soil water and perhaps N and S are limiting plant growth, and we would not expect forage growth response to trace mineral additions.

Zinc, Mn, Cu, and Fe availabilities are severely reduced at soil pH levels above 7.5 (Truog 1946). Peech (1941) found that at pH 9.0, nearly all the Zn is fixed. The uptake of Zn decreases with increasing Ca++ levels in soil (Epstein and Stout 1951). However, Wear (1956) has shown that uptake of Zn is controlled by pH and is not a calcium effect.

Zinc, Mn, Cu, and Fe concentrations were determined in alkali sacaton (*Sporobolus wrightii*) growing on sodic soils in Arizona (Bohn and Aba-Husayn 1971). They found that the Zn and Cu concentrations in the plants decreased as the pH of the soil changed from 7.5 to 9.5, but that the Mn and Fe contents increased. They suggested that this could be due to the reducing conditions resulting from low air and water permeability of these soils. Under our conditions at Saylor Creek, it is likely that the availability of these micronutrients is reduced by the higher pH.

Forage Yield and Mineral Content After Fertilization

The fertilization trial was initiated to determine the effects of added N (as NH_4NO_3) and P (as treble superphosphate) on yield and protein content of grasses within the cheatgrass and needle-and-thread grass communities. We later decided to analyze the same samples for additional nutrients (tables 6 and 7).

Table 6.--*Effects of different N (as NH_4NO_3) fertilization rates on yield and mineral concentrations or ratios of cheatgrass and tansy mustard. Fertilized in September 1964 and harvested in June 1965*

Fertilization rate (lb/ac	(kg/ha))	Yield		N	P	S	Ca	Mg	K	Na	Zn	Mn	Cu	N:S	K/(Ca+Mg)
		lb/ac	*(kg/ha)*	*Percent*						*Ppm*					
							CHEATGRASS								
0	(0)	670	(750)	0.45	0.062	0.040	0.280	0.078	0.40	143	18	61	6.1	11.2	0.50
40	(45)	1,228	(1,380)	.45	.062	.030	.315	.082	.40	275	16	64	4.1	15.0	.46
80	(90)	1,552	(1,740)	.60	.053	.035	.307	.077	.40	137	13	70	3.8	17.1	.47
120	(134)	1,667	(1,870)	.83	.075	.048	.408	.100	.45	141	16	78	4.4	17.3	.40
160	(179)	2,104	(2,360)	.78	.058	.040	.376	.082	.35	189	16	84	4.2	19.5	.35
200	(224)	2,269	(2,540)	.91	.070	.050	.446	.097	.57	208	15	64	3.8	18.2	.48
							TANSY MUSTARD								
0	(0)	252	(280)	1.28	.178	.325	.784	.201	1.05	92	16	20	3.6	3.9	.48
40	(45)	488	(550)	1.28	.191	.395	1.189	.359	1.10	86	15	12	3.3	3.2	.32
80	(90)	330	(370)	1.82	.150	.420	1.544	.390	1.15	62	15	24	3.7	4.3	.27
120	(134)	224	(250)	2.26	.182	.430	1.664	.462	1.18	73	18	26	4.8	5.3	.25
160	(179)	70	(80)	2.00	.137	.435	1.319	.384	1.02	82	16	16	2.7	4.6	.27
200	(224)	288	(320)	1.90	.130	.382	1.291	.340	1.02	164	14	16	2.1	5.0	.20

Table 7.--*Mineral composition of selected species in relation to nitrogen and phosphorus fertilization 1 and 2 years after application*[1]

	N	P	S	Ca	Mg	K	Na	Zn	Mn	Cu	N/S
	Percent						*Ppm*				
Desert wheatgrass (1965)											
Without fertilization	0.94	0.127	0.75	0.264	0.074	1.050	66.0	16.0	38.0	6.7	12.5
With fertilization	1.19	.131	.92	.288	.084	.972	65.0	14.8	44.4	7.8	13.0
S.E.m	.07	.003	.01	.010	.003	.086	3.0	.5	1.4	.3	.7
Desert wheatgrass (1966)											
Without fertilization	1.03	.112	.105	.444	.101	1.040	52.0	11.0	34.0	4.4	9.8
With fertilization	1.28	.121	.105	.459	.115	1.090	56.2	12.0	56.9	7.2	12.3
S.E.m	.05	.003	.004	.016	.003	.043	1.5	1.1	2.3	1.6	.6
Cheatgrass (1965)											
Without fertilization	.46	.068	.030	.337	.088	.350	85.0	19.0	81.0	7.7	15.3
With fertilization	.60	.064	.034	.340	.087	.353	119.0	15.2	84.2	7.4	17.6
S.E.m	.03	.004	.002	.007	.002	.013	10.0	.9	2.2	.3	.8
Sandberg's bluegrass (1965)											
Without fertilization	.92	.078	.072	.569	.121	.180	74.0	17.0	74.0	5.3	12.8
With fertilization	1.12	.082	.059	.531	.116	.217	74.8	17.4	66.3	5.7	19.1
S.E.m	.04	.002	.002	.010	.002	.006	2.6	.3	2.4	.1	.8
Sandberg's bluegrass (1966)											
Without fertilization	1.36	.108	.105	.658	.148	.380	69.0	12.0	67.0	6.1	13.0
With fertilization	1.43	.123	.110	.600	.143	.436	68.5	13.2	70.3	5.7	13.1
S.E.m	.04	.004	.003	.013	.002	.020	2.1	.3	1.9	.2	.3
Needle-and-thread grass (1965)											
Without fertilization	1.18	.140	.136	.684	.166	.920	65.0	16.0	33.0	5.8	8.7
With fertilization	1.48	.110	.109	.610	.162	1.048	71.8	15.2	51.6	6.1	13.6
S.E.m	.05	.003	.003	.025	.006	.022	4.0	.2	2.7	.1	.5
Needle-and-thread grass (1966)											
Without fertilization	1.80	.090	.114	.635	.162	.650	87.0	14.0	73.0	5.8	15.8
With fertilization	1.21	.099	.126	.632	.166	.698	74.6	12.6	79.3	5.5	9.6
S.E.m	.03	.002	.002	.005	.002	.027	.6	.3	1.5	.1	.3

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[1] Mineral concentrations in nonfertilized forage are compared to those in forage fertilized with 40, 80, or 120 lb/acre N in combination with 0, 40, 80, and 120 lb P/acre. Data within the 40 to 120 lb/acre N or P were not different from each other and were therefore combined and the standard error of the mean (S.E.m) calculated.

Fertilization with N increased cheatgrass dry matter yields from 670 to 2,270 lb per acre (750 to 2,540 kg/ha). Concurrent with a yield increase, the N concentration of the forage also increased from 0.45 to 0.91 percent. Higher N concentrations were found in tansy mustard plants at higher fertilization rates, but yields were erratic.

In cheatgrass, Ca was the only other nutrient that tended to increase with increasing levels of N application. The micronutrients were not influenced by added N. Nitrogen application caused the N:S ratio to become wider, which may reduce forage protein digestibility.

Nitrogen fertilization tended to increase S, Ca, and Mg concentrations in tansy mustard. The stimulation of cheatgrass and the weedy mustard species by N fertilization is caused by their early growth and utilization of available water and plant nutrients. These species would be expected over several seasons to gain a competitive advantage over any desirable perennials that might be present.

On the needle-and-thread grass range, both N and P were applied at rates of 40, 80, and 120 lb per acre (45, 90, and 134 kg/ha) in all combinations in September 1964; applications were replicated four times. The plots were harvested in June 1965 and June 1966 and species were separated. The results are given in table 7. The nonfertilized plots are shown in the table as "without fertilization" and constitute the composite of the four replications. The "with fertilization" data are the mean from all N and P plots without regard to level. The standard error of the mean (S.E.m) was computed from the latter data set and represents the chance of finding the true mean within the values given 67 percent of the time. If it is assumed that the "without fertilization" data have a similar standard error, then one can compare the effect of fertilization on the chemical composition. The data have been interpreted in this light, i.e., effects of at least 40 lb of N plus 0, 40, 80, or 120 lb of P per acre, compared to nonfertilized forage.

Fertilization increased the N content of desert wheatgrass, cheatgrass, bluegrass, and needle-and-thread grass in 1965, and of all species except needle-and-thread grass in 1966. From the original data, it appeared that P applications had little effect on increasing N content.

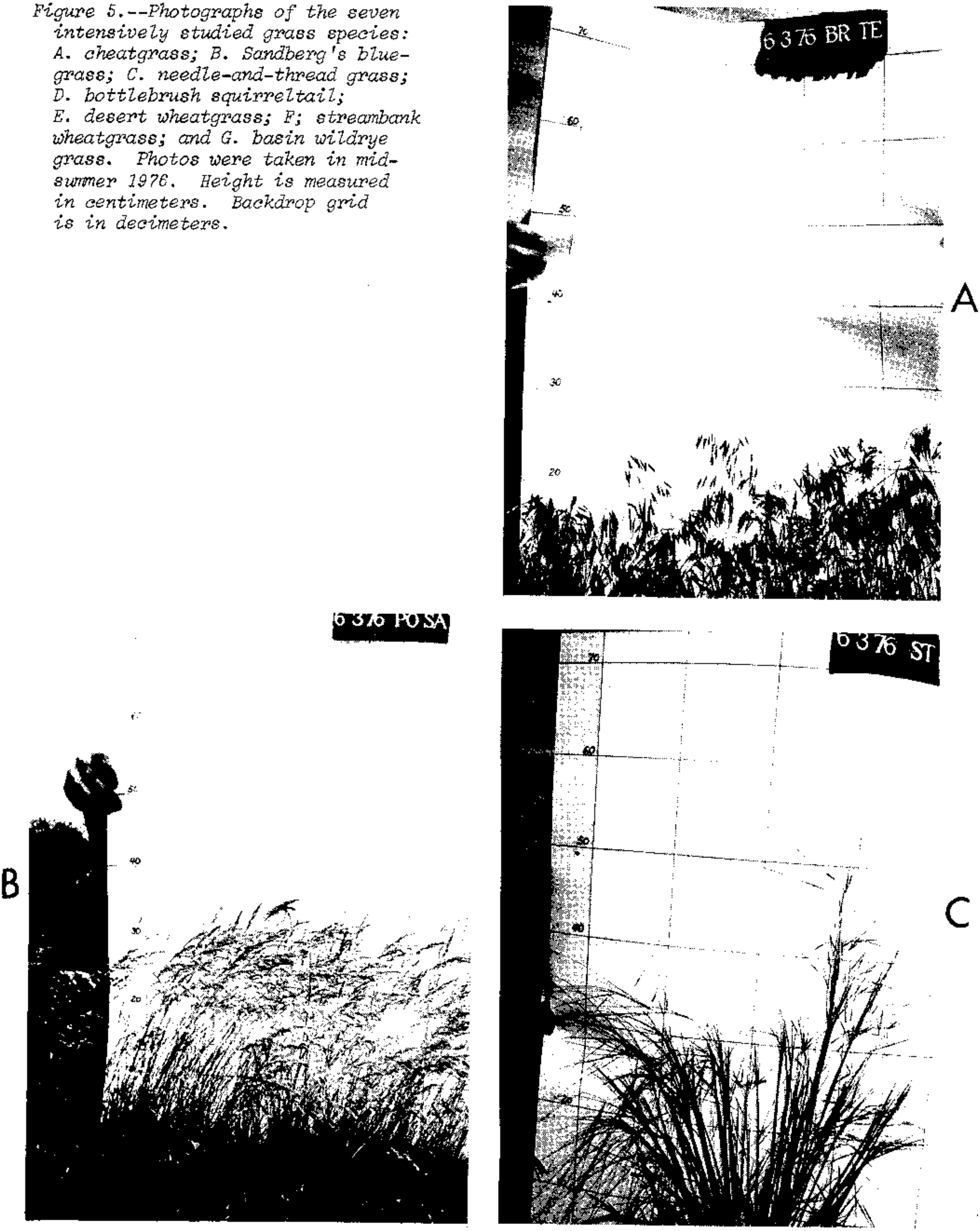
Fertilization did not greatly increase plant tissue levels of other nutrients, although there was a tendency for P to increase in some plants the second year following fertilization. It is possible that P was just becoming available. Phosphorus applications at higher N levels tended to increase the P content in bluegrass and wheatgrass in both 1965 and 1966, but not in cheatgrass nor needle-and-thread grass. Sulfur increased considerably in wheatgrass 1 year after fertilization, but no increase was detected in the second year. In cheatgrass, Na uptake increased in 1965. Manganese levels were higher in needle-and-thread grass in 1965 and in desert wheatgrass in 1966 due to fertilization. The erratic nature of these results indicates that fertilization with N and P cannot be relied upon to increase levels of nutrients other than N and possibly P.

Forage Nutritive Quality on Unfertilized Rangeland

Photographs of the seven grasses and the patterns of plant development for the seven grass species at Saylor Creek are shown in figures 5 and 6, respectively. The variations from year to year when the different stages occur explains some of the variations in chemical content. In addition, variations in chemical content also occur as the result of factors that influence availability and uptake.

We plotted mineral concentrations, digestibility components, and mineral ratios against dates in a series of graphs. When the respective r^2 value is significant, the equation for the least squares fit of the data is given.

Figure 5.--Photographs of the seven intensively studied grass species: A. cheatgrass; B. Sandberg's bluegrass; C. needle-and-thread grass; D. bottlebrush squirreltail; E. desert wheatgrass; F; streambank wheatgrass; and G. basin wildrye grass. Photos were taken in midsummer 1976. Height is measured in centimeters. Backdrop grid is in decimeters.



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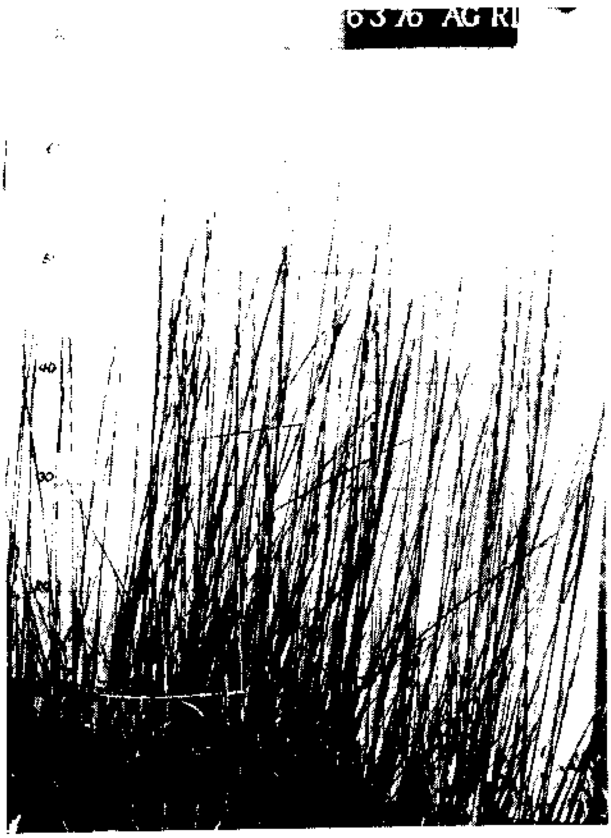

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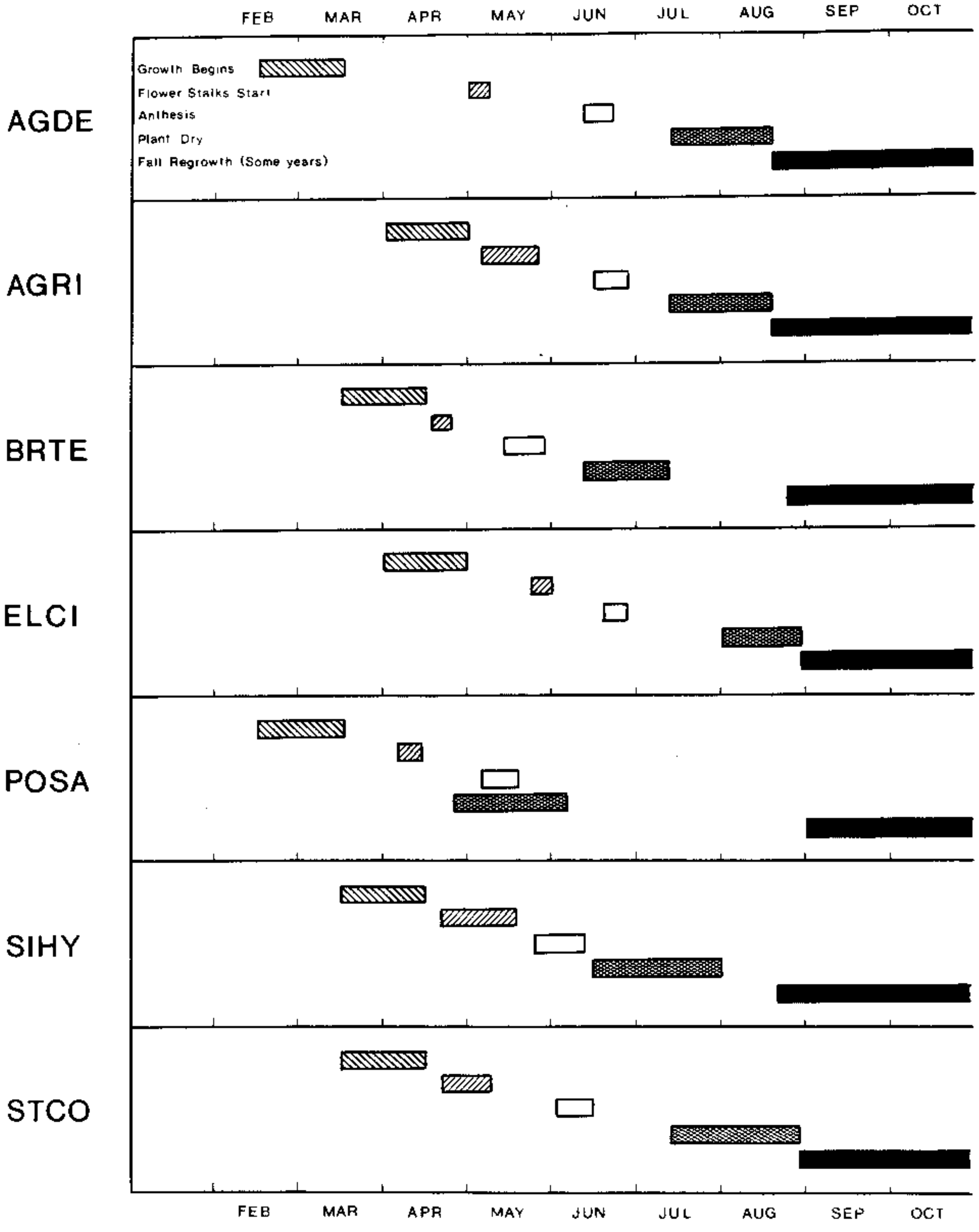

Figure 6.--Plant development of seven grass species. The beginning of the bar represents the earliest date and the end of the bar the latest date at which the stage occurred. (Data taken at Saylor Creek Experimental Range over the period 1960 to 1969).

Most of these figures show an exponential decay in mineral concentrations. This results because (1) plants tend to accumulate most of the minerals early in the season while subsequent dry matter accumulation is predominantly carbon compounds, and (2) there is a later loss of mineral-rich leaves and seed heads. Also, as the season advances, soil dries to greater depths and the moisture found at progressively lower depths is used to support top growth and root elongation, plant transpiration, and as a medium for soil mineral diffusion. The rate of mineral uptake may, as the season progresses, be reduced during soil drying because of reduced mineral diffusion rates to the roots and because mineral availability generally decreases with increasing soil depth (fig. 4, table 5).

Animal preference for various plant species is closely related to stage of plant development. Our observations of cattle grazing on cheatgrass range show a characteristic pattern. Very early in the spring when cheatgrass is short, cattle graze almost entirely upon the bluegrass and wheatgrass when these species are present. As cheatgrass becomes more available, the animals graze it heavily. Cattle tend to graze only the lower leaves of floral tillers. If the grazing pressure is sufficiently heavy, they eat the entire plant. Bluegrass is usually avoided when the plant is in anthesis. Although cheatgrass is utilized throughout the season from April through November, other plants are definitely preferred when cheatgrass has dried.

Early grazing and precipitation coming in late May and June favor the development of Russian thistle. Under these conditions, considerable thistle will be present on cheatgrass range. This species is heavily utilized throughout the summer and early fall before the plant becomes dry and spiny (fig. 7B). It provides a source of protein when other species are normally very low in protein.

Figure 7.--Forbs, such as goatsbeard (A) and especially Russian thistle (B), are consumed by the cattle up to the stage of maturity shown here. Both plants are about 20 inches (50 cm) in height.

B

Western hawksbeard and goats-beard are found in some years on this range, and the initial growth in the late spring and regrowth in late summer are readily eaten by cattle. Like Russian thistle, they are considered good forage, but contribute little to total dietary intake.

On cheatgrass range, generally two types of operations exist. The principal type on most of the range is a cow-calf system, but some operators run only yearlings. An abbreviated list of nutrient requirements is given in table 8, and nutrient concentrations are discussed in relation to animal requirements when known. Additional information on animal requirements will be found in the National Academy of Science publication (NAS-NRC 1976) from which table 8 data are taken. The following information considers total mineral analysis in the clipped forage and does not evaluate animal preference for given species or plant parts.

Nitrogen

Total N concentrations (fig. 8) in the seven grass species were greater than 3 percent (approx. 19 percent protein) in April, but declined rapidly, and by August all species contained less than 1 percent N (6.2 percent crude protein). Desert wheatgrass in one March sample had more than 4 percent N, as did cheatgrass in an April sample. However, cheatgrass, an annual, dries rapidly, and many of the samples taken after June 1 contained less than 1 percent N. In spite of the fact that leaves of Sandberg's bluegrass dry comparatively early, the N content remained higher than that of cheatgrass.

Lactating cows require at least 9.2 percent protein (1.47 percent N) in the daily ration to maintain body weight. Thus, a crude protein supplementation program should be considered for lactating cows grazing cheatgrass after mid-June. Growing steers

Table 8.--*Nutrient requirements for beef cattle (Abbreviated from NAS-NRC 1976)*

Body weight	Average daily gain	Daily dry matter/animal	Total protein	Digestible protein	Ca	P
kg			*Percent*			
GROWING STEERS						
200	0.00	3.5	8.5	4.8	0.18	0.18
	.50	5.8	9.9	6.0	.24	.22
	.70	5.7	10.8	6.8	.32	.28
400	.00	5.9	8.5	4.8	.18	.18
	1.00	9.4	5.7	5.7	.22	.21
GROWING HEIFERS						
200	.00	3.5	8.5	4.9	.18	.18
	.50	6.0	9.6	5.8	.23	.22
	.70	6.0	10.2	6.5	.30	.27
400	.00	5.9	8.5	4.8	.18	.18
	.50	8.5	8.8	5.1	.18	.18
	.70	8.7	9.0	5.3	.18	.18
DRY PREGNANT MATURE COWS						
400	.4	6.1-7.5	5.9	2.8	.18	.18
500	.4	7.2-8.6	5.9	2.8	.18	.18
600	.4	8.3-9.7	5.9	2.8	.18	.18
LACTATING COWS						
400	-	8.8	9.2	5.4	.28	.28
500	-	9.8	9.2	5.4	.28	.28

Estimated requirements for all animals:

Mg - 12 to 30 mg/kg of body wt/day
S - 0.1 percent of ration dry matter
Mn - 1 to 10 mg/kg of ration dry matter
Fe - 80 to 100 mg/kg of ration dry matter
Na - 0.05 percent of ration dry matter
K - 0.6-0.8 percent of ration dry matter
Zn - 20 to 30 mg/kg of ration dry matter
Cu - 4 mg/kg of ration dry matter when feed is low in Mo and sulfate

and heifers weighing 660 lb (300 kg) and gaining 2.0 lb per day (0.9 kg/day) require 10.0 percent protein (1.6 percent N) in the ration. The same animals, just to maintain their weight, require 8.6 percent protein (1.4 percent N) in the ration (NAS-NRC 1976). The N curves show that the maintenance level for growing steers and heifers is reached in June and July for most species, and after July N is deficient for maintaining yearlings and lactating cows.

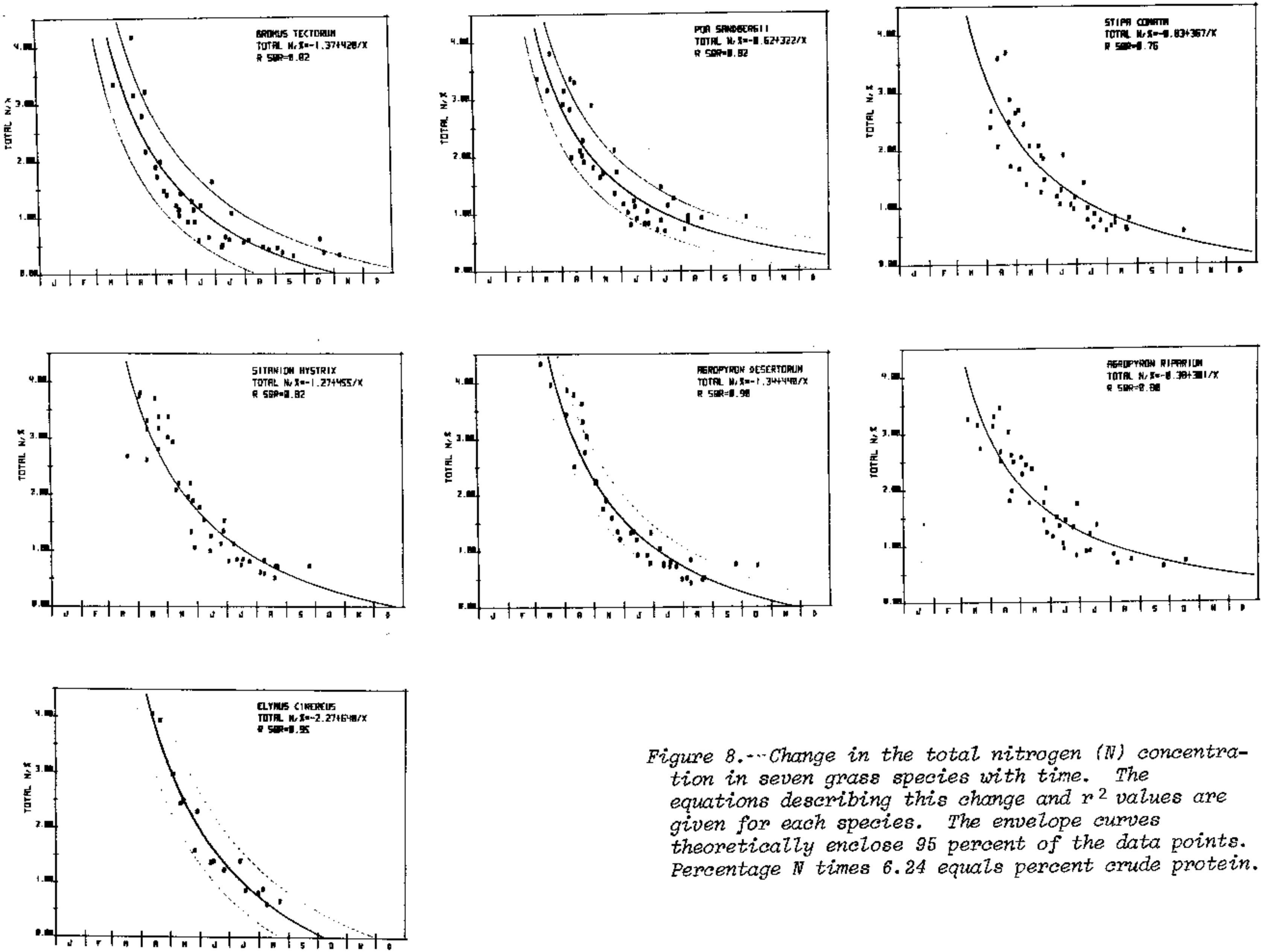

Figure 8.--Change in the total nitrogen (N) concentration in seven grass species with time. The equations describing this change and r^2 values are given for each species. The envelope curves theoretically enclose 95 percent of the data points. Percentage N times 6.24 equals percent crude protein.

Phosphorus

Total plant P (fig. 9) concentration trends follow a pattern very similar to total N, but values are lower by a factor of approximately 10. NAS-NRC lists a requirement of 0.18 percent P in the forage for maintenance of growing steers and heifers, and higher concentrations are needed if animals are fed to gain weight. The same concentration is required for dry pregnant cows, but cows with calves require forage containing 0.28 percent P.

In most species and in most years, the P values we found were below the recommended values by the end of June. Robertson and Torell (1958), in northeastern Nevada, found that cheatgrass, basin wildrye, Sandberg's bluegrass, and needle-and-thread grass had phosphorus contents of 0.27, 0.09, 0.11, and 0.17 percent in the mature stage, respectively. Other workers have also found similar low contents after maturity.

Calcium and Ca:P Ratio

A better measure of the P requirement is the Ca:P (percent/percent) ratio. The ratios should be 2:1 under normal circumstances, but can be as wide as 7:1 when sufficient vitamin D is present.

Calcium concentration values (fig. 10) for the seven species, when plotted over time, were extremely erratic except for cheatgrass. As a consequence, the Ca:P ratios were somewhat erratic, but did show an increase over time (fig. 11). Surprisingly, cheatgrass maintained a ratio of less than 7:1 through October. Desert wheatgrass maintained the lowest ratio of all species. The other species exceeded the 7:1 ratio before the end of the grazing season in October.

In a 112-day study on Saylor Creek range, yearling cattle supplemented with a trace mineral salt only versus trace mineral salt and monosodium phosphate at a ratio of 2:1 gained similarly, indicating phosphorus was not deficient (Olsen 1971). Lactating cows, on the other hand, have a higher P requirement and may respond to P supplementation.

Sulfur and N:S Ratio

The amount of S found in the seven grass species varied from approximately 0.25 to less than 0.05 percent (fig. 12). The level decreased rapidly from April through June. Cheatgrass was particularly low in S after reaching maturity, while needle-and-thread grass, streambank wheatgrass, and desert wheatgrass appeared to maintain levels near the required 0.1 percent S (NAS-NRC 1976).

Allaway (1969) states that the S requirement for ruminant animals is best expressed in terms of the N:S ratio of forage, and that the optimum should be 10:1 to 15:1. These ratios for the seven grass species are shown in figure 13.

The N:S ratios exhibited considerable scatter in cheatgrass, bluegrass, and wildrye. With the exception of bluegrass, there was a definite narrowing trend in the ratio as the season progressed. The individual N and S curves show that N levels continued to decrease while S levels tended to level; this has the effect of narrowing the ratio.

We assume that when the ratio is wider or narrower than given by Allaway (1969) the animal may have a reduced protein conversion efficiency and may also suffer nutritional problems. The data indicate that for some species (desert wheatgrass, needle-and-thread grass, and bottlebrush squirreltail) the N:S ratios are narrower than presumed adequate before the end of the grazing season. However, the bulk of the forage on the experimental range is cheatgrass, which has ratios within the desired range throughout the grazing season. Therefore, we conclude that on cheatgrass ranges, nutritional problems associated with N:S ratios are not serious, but the low levels of N and S by themselves are the biggest problem.

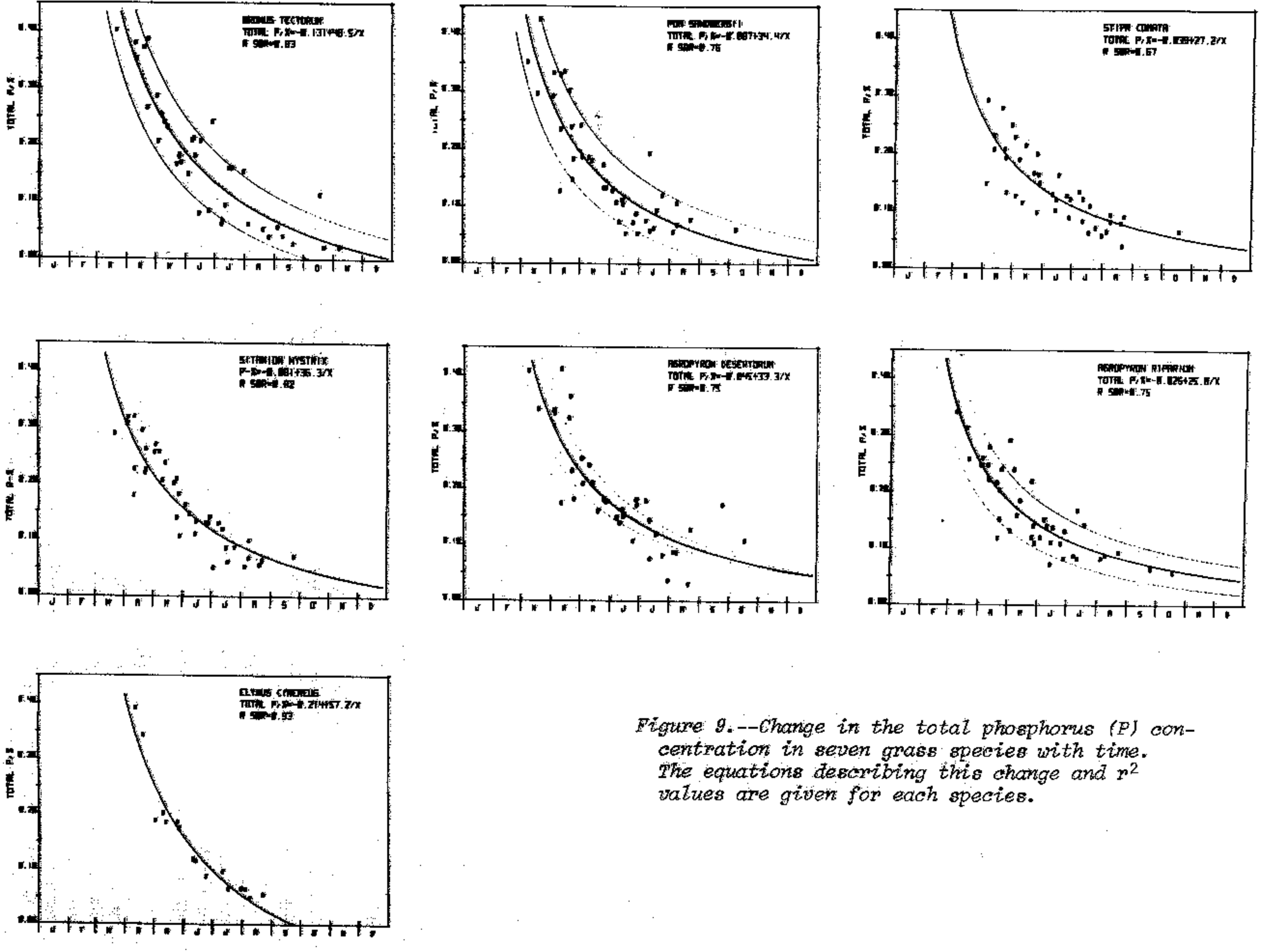

Figure 9.--Change in the total phosphorus (P) concentration in seven grass species with time. The equations describing this change and r^2 values are given for each species.

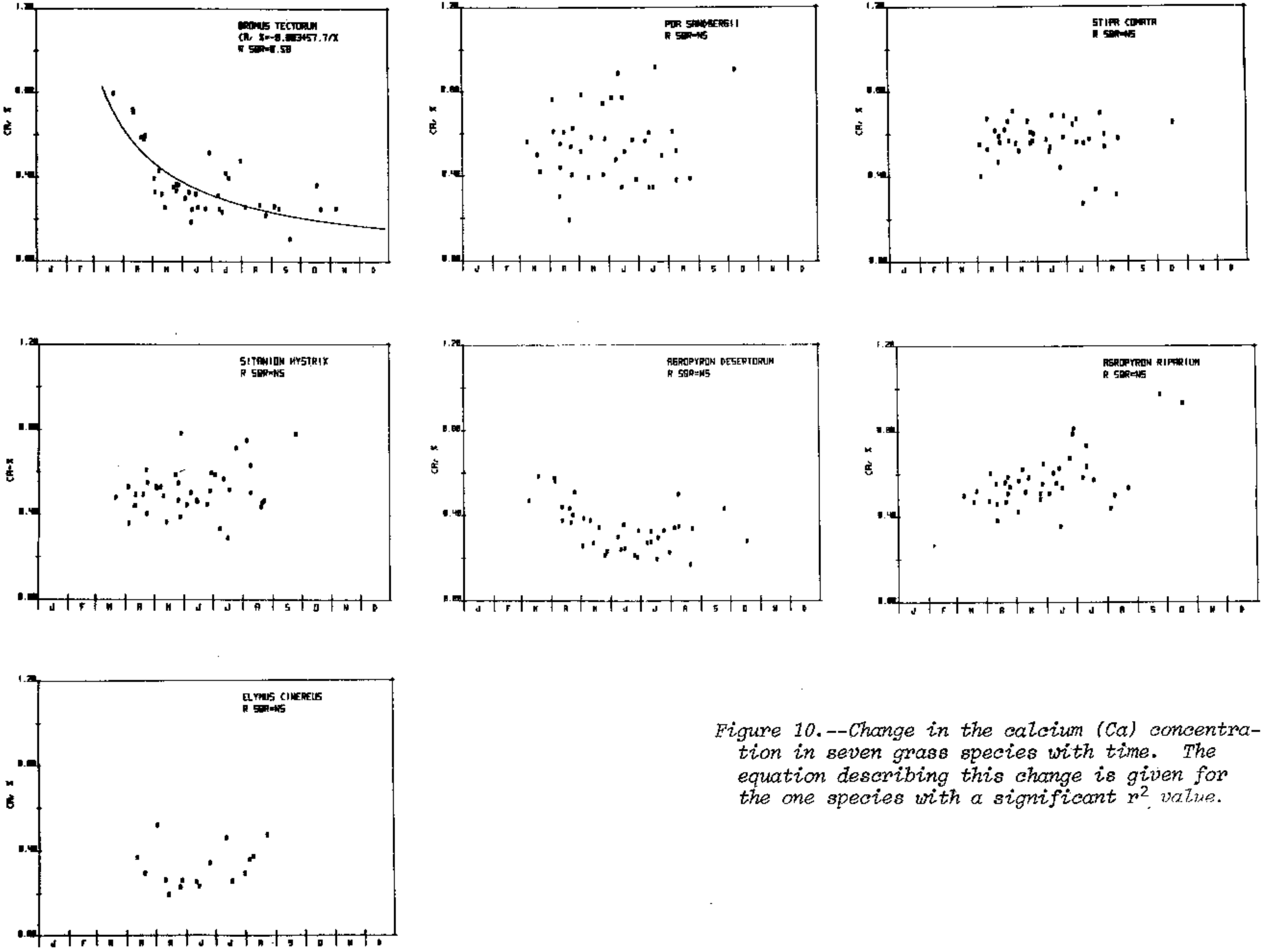

Figure 10.--Change in the calcium (Ca) concentration in seven grass species with time. The equation describing this change is given for the one species with a significant r^2 value.

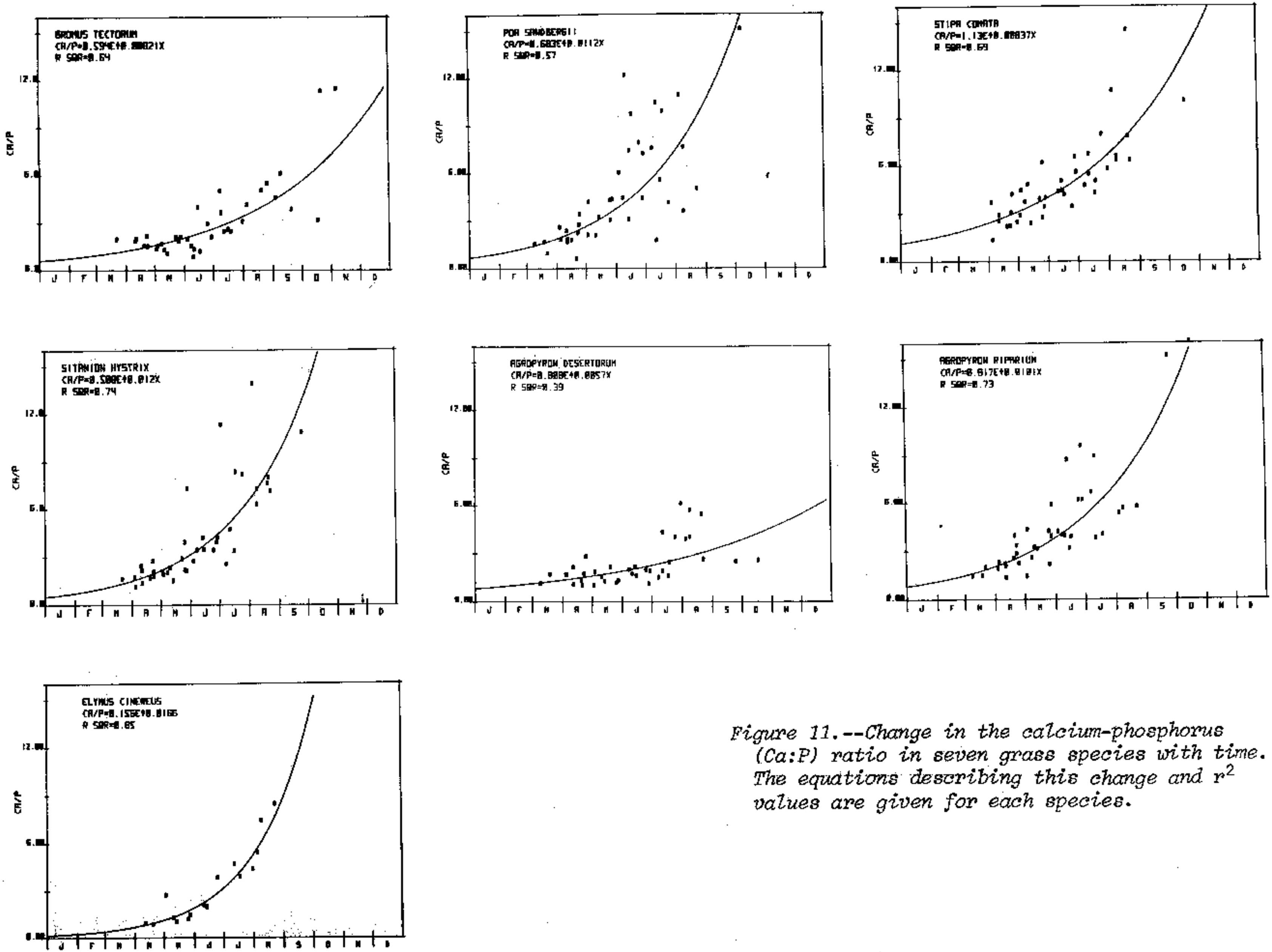

Figure 11.--Change in the calcium-phosphorus (Ca:P) ratio in seven grass species with time. The equations describing this change and r^2 values are given for each species.

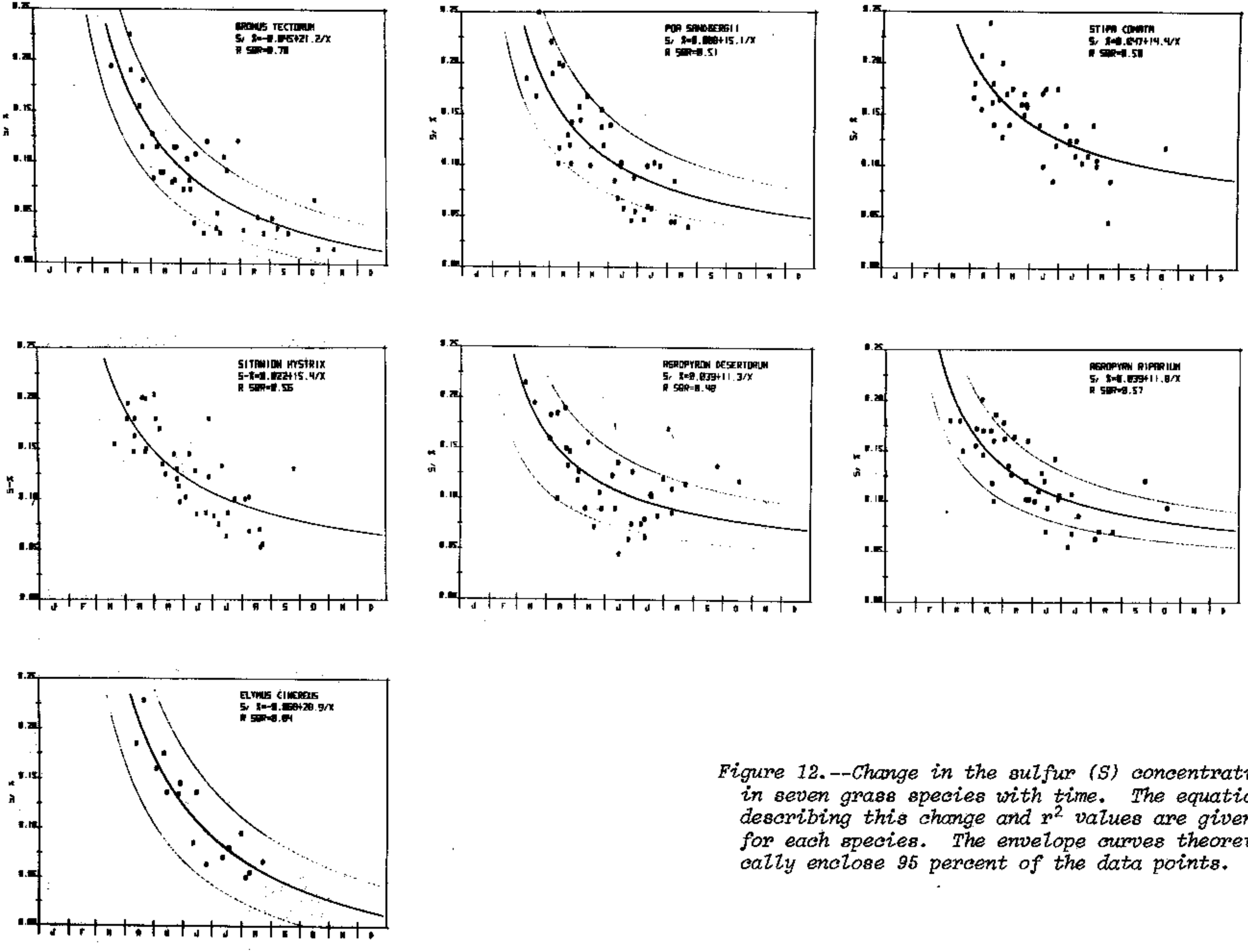

Figure 12.--Change in the sulfur (S) concentration in seven grass species with time. The equations describing this change and r^2 values are given for each species. The envelope curves theoretically enclose 95 percent of the data points.

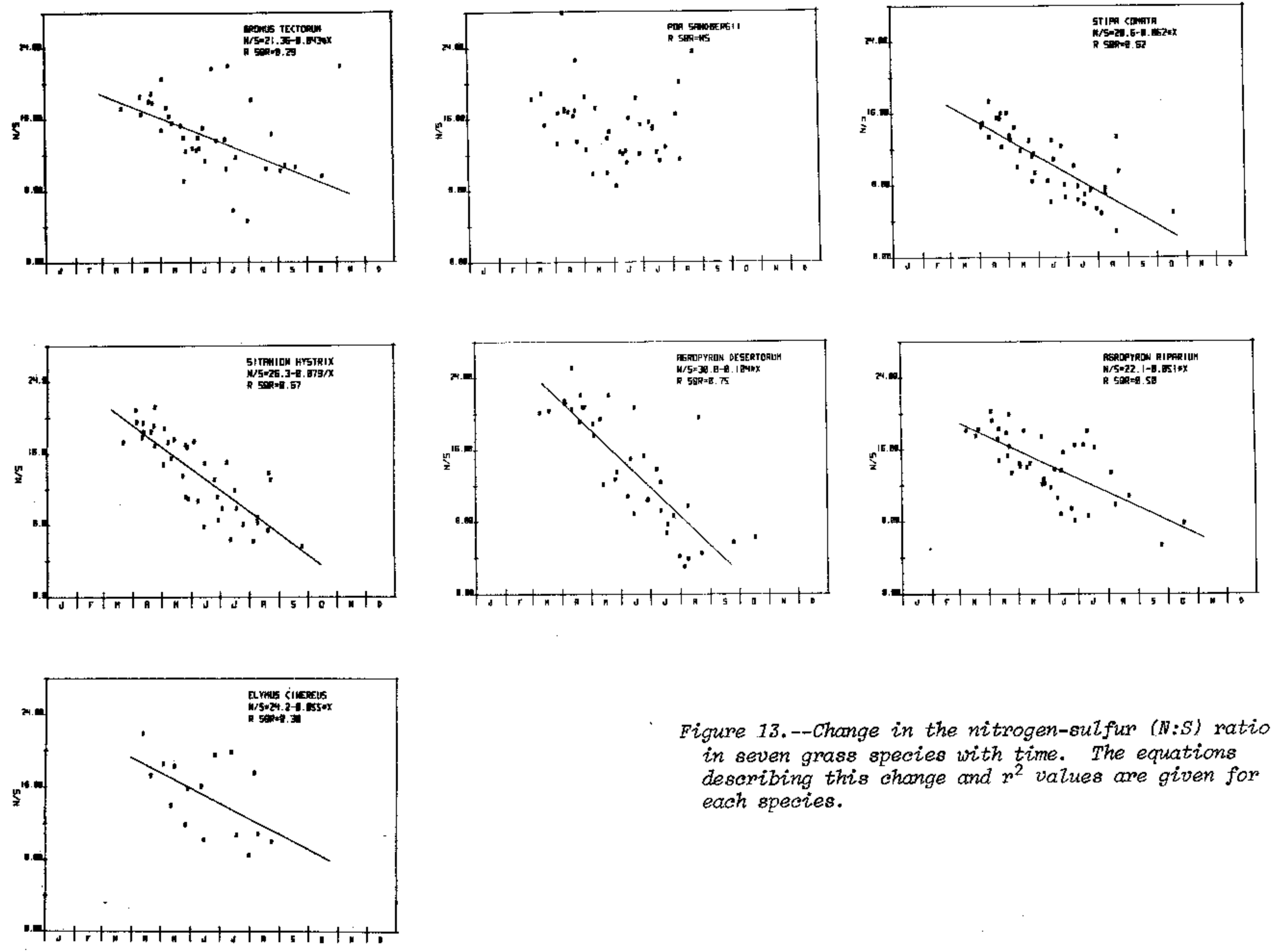

Figure 13.--Change in the nitrogen-sulfur (N:S) ratio in seven grass species with time. The equations describing this change and r^2 values are given for each species.

Potassium

The K concentrations (fig. 14) in the early spring varied considerably between species. Basin wildrye had values in excess of 4 percent K, while needle-and-thread grass had less than 2 percent K. The decrease in the K level is rapid, and by late July most species had values less than 1 percent K.

Lawton and Cook (1954), in their review of the role of potassium in plant nutrition, indicate that most common grasses contain between 0.8 and 1.5 percent K. Our values exceed this range during the early part of the season, decline to levels within the range, and later in some species fall to much lower levels. The high K values encountered in early spring undoubtedly contribute to the occurrence of grass tetany, especially in lactating cows, following turnout to spring range (Grunes and others 1970). Cattle, however, have not experienced tetany problems at Saylor Creek.

NAS-NRC (1976) states that the potassium requirements for beef cattle have not been critically measured, but indicates the optimum level for growing and finishing steers is between 0.6 and 0.8 percent K of the ration.

Our data strongly suggest that while some of these range grasses contain excessive K in early spring, K deficiencies could occur after July.

Magnesium

The Mg concentrations (fig. 15), like Ca, were extremely erratic. Only cheatgrass showed a decline in magnesium levels with advances in season. The majority of the forage samples had concentrations between 0.1 and 0.2 percent Mg.

Magnesium requirements of lactating beef cows have been determined as approximately 0.18 percent of dry matter (NAS-NRC 1976).

Allaway (1969) reported that in many cases of grass tetany, feeds have contained less than 0.2 percent Mg; the ratio K:(Ca + Mg), on an equivalence basis, has been wide; and concentrations of citric, aconitic, or both acids have been greater than 1 percent in the plants. Kemp and 't Hart (1957) explain that when the ratio is less than 2.2:1 there are few incidences of grass tetany. They indicate the cool weather in the spring decreases plant uptake of K, while the uptake of Ca and Mg remains constant, thus causing the ratio to narrow.

The K:(Ca + Mg) ratio, calculated on an equivalent basis, is shown in figure 16. Basin wildrye and desert wheatgrass are the two species that have ratios greater than 2.2:1. Wildrye exceeded the 2.2:1 value for much of the spring period, but the amount of this species on the range is small and thus should not present any nutritional problems. The general trend is a narrowing of the ratio with advance in season.

Sodium

No relation was found between Na concentration and date for any of the seven grass species (fig. 17).

Animal requirements are reported to be about 500 ppm Na (NAS-NRC 1976) which is greater than the levels found in these forages. Sodium chloride (NaCl), however, is generally provided for animals as a part of normal management operations.

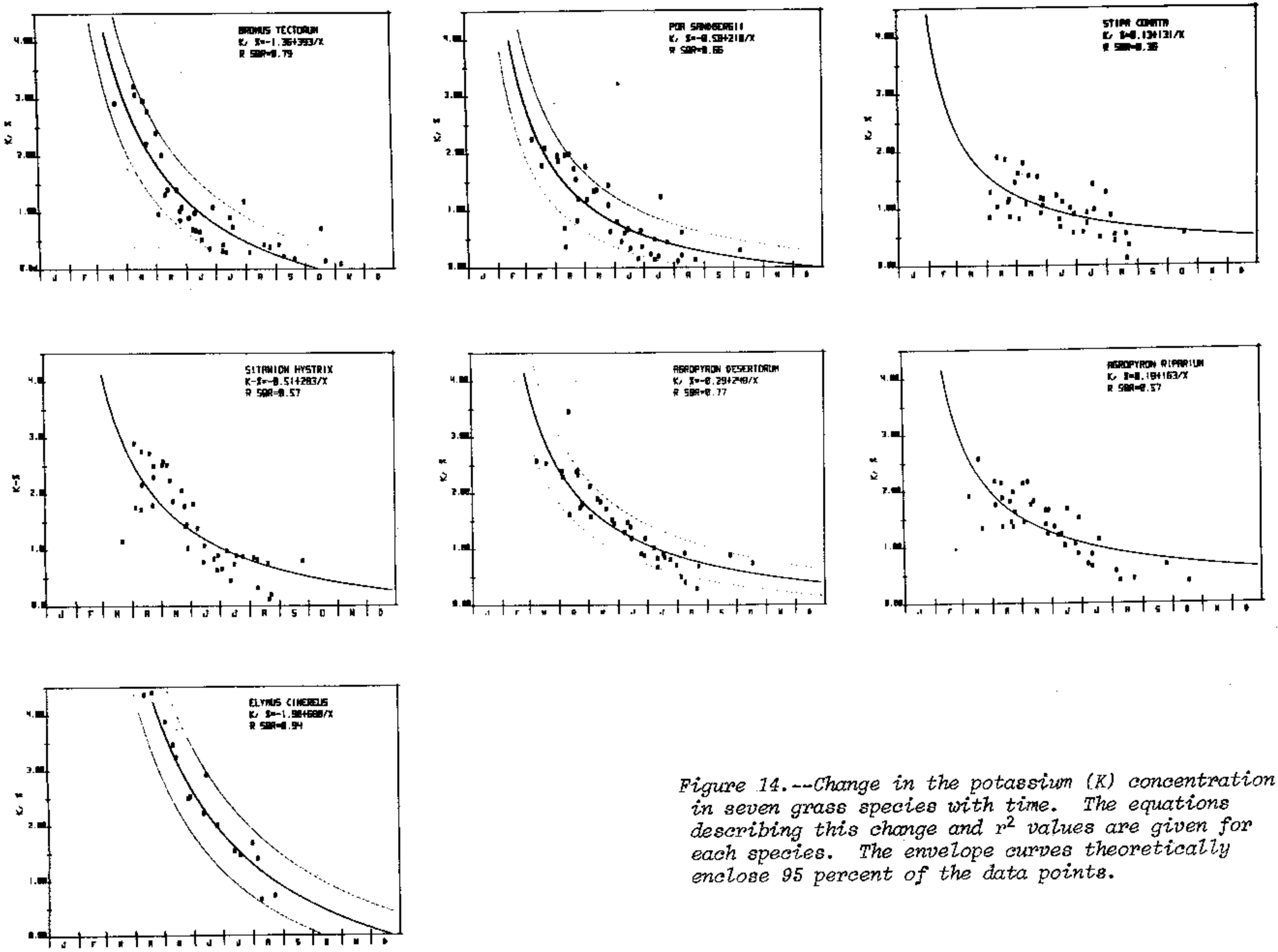

Figure 14.--Change in the potassium (K) concentration in seven grass species with time. The equations describing this change and r^2 values are given for each species. The envelope curves theoretically enclose 95 percent of the data points.

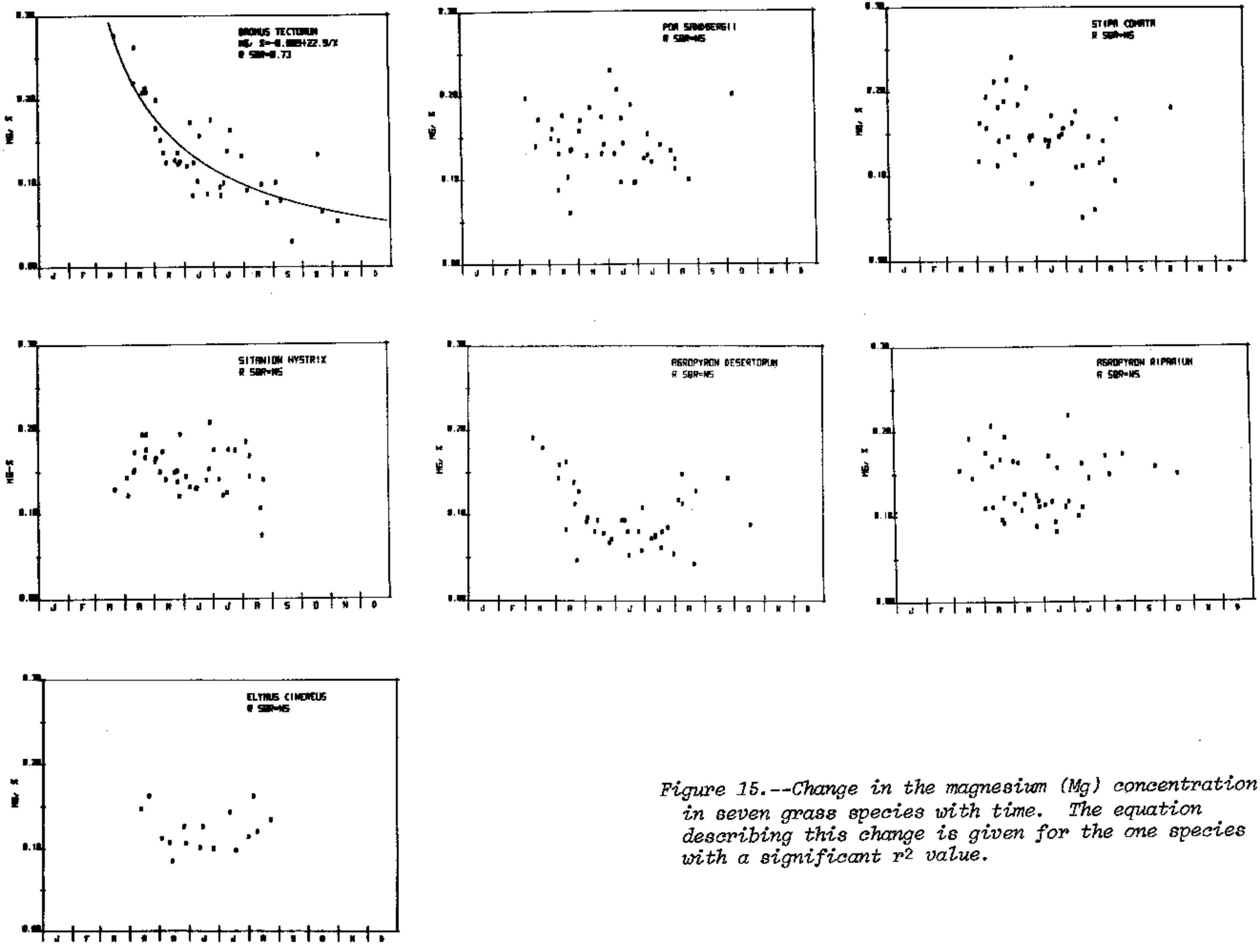

Figure 15.--Change in the magnesium (Mg) concentration in seven grass species with time. The equation describing this change is given for the one species with a significant r² value.

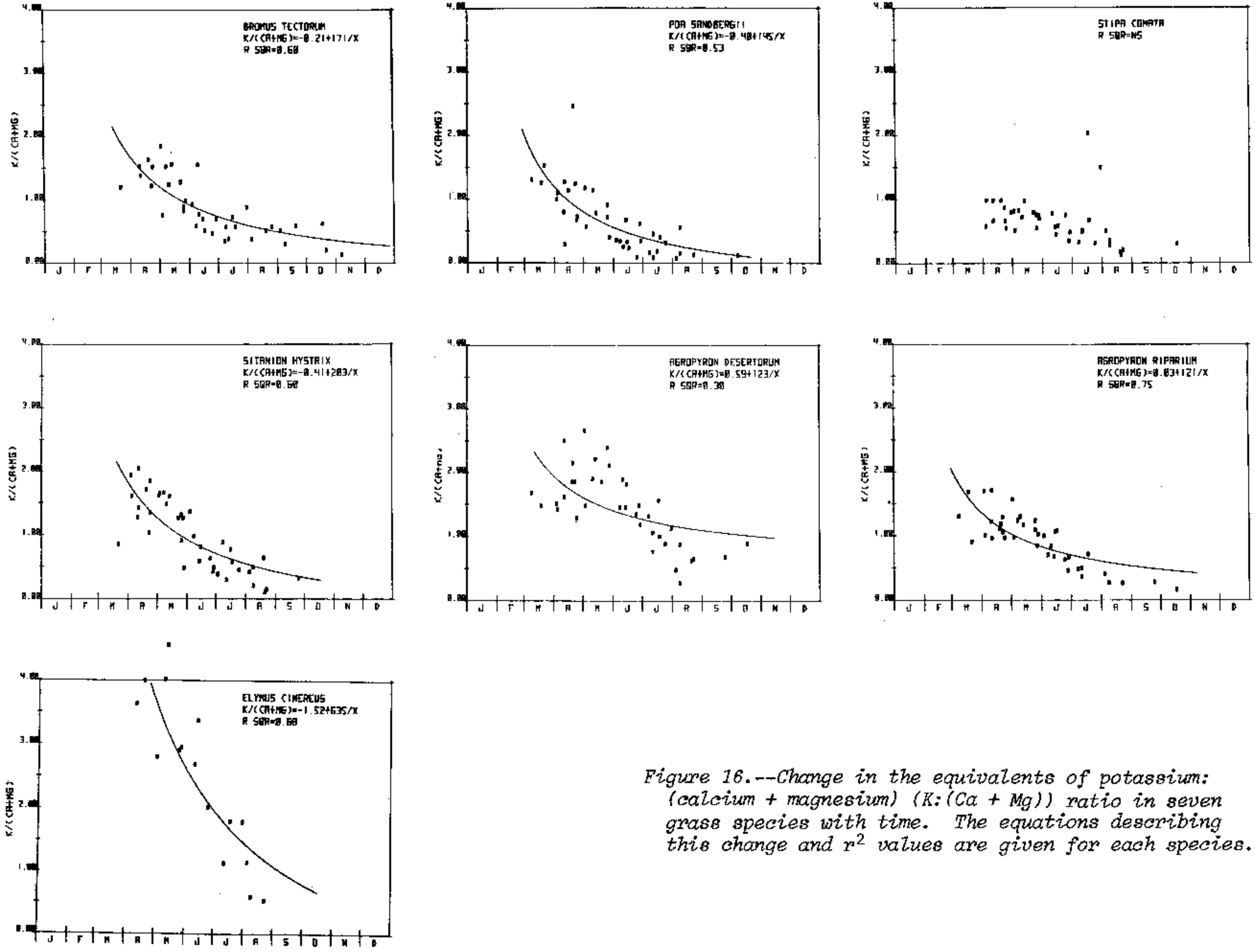

Figure 16.--Change in the equivalents of potassium: (calcium + magnesium) (K:(Ca + Mg)) ratio in seven grass species with time. The equations describing this change and r^2 values are given for each species.

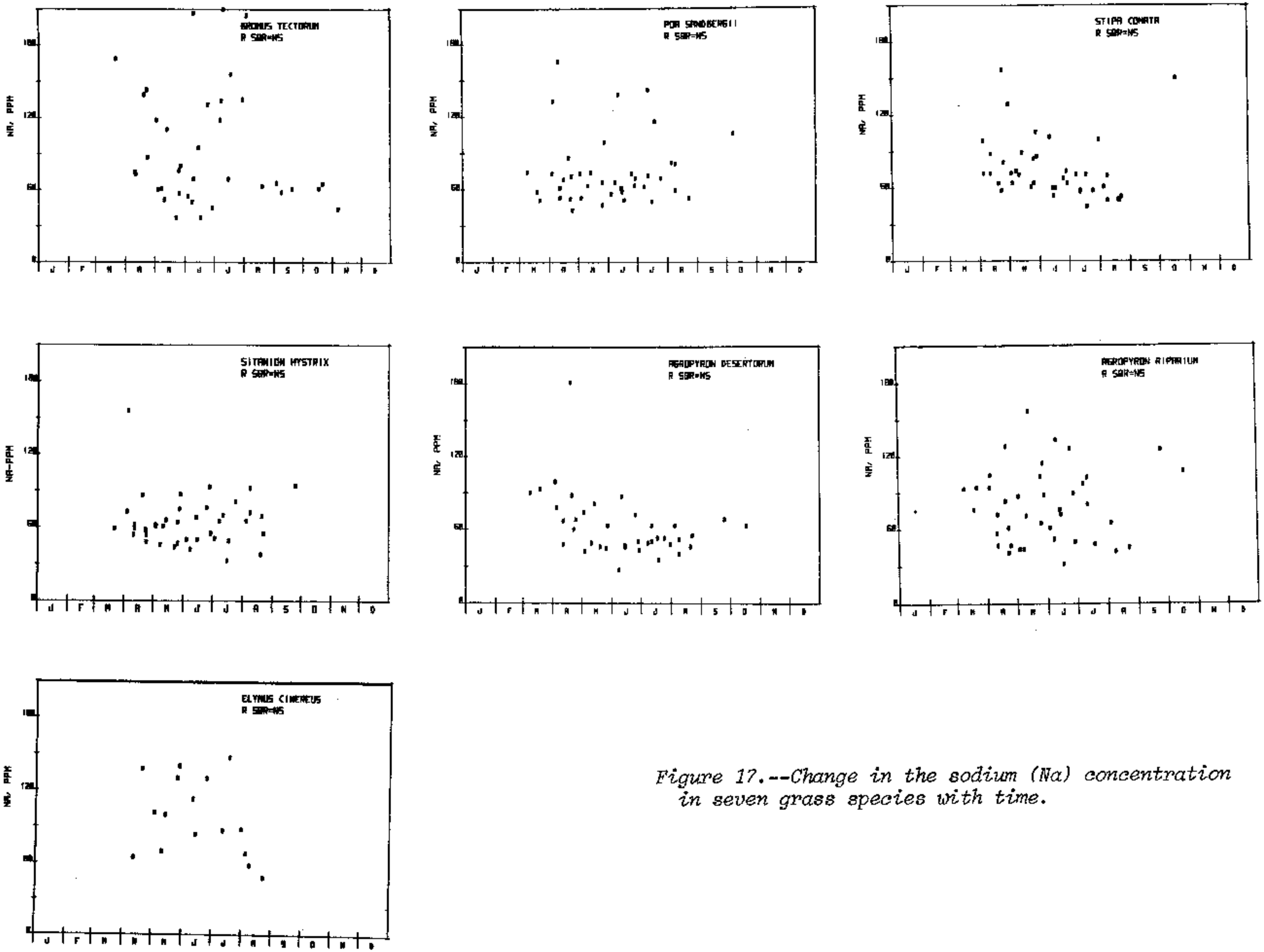

Figure 17.--Change in the sodium (Na) concentration in seven grass species with time.

Zinc

Decreasing trends in forage Zn concentration (fig. 18) are noted as the forage matures and concentrations are in the 20 to 30 ppm Zn (NRC-recommended levels) range for a brief period in early spring.

Mayland (1975) noted the trends of Zn, as reported here, were declining below adequate levels as forage matured; supplemental zinc was fed to cows and calves. Both the cows and calves showed increased weight gains due to the added zinc.

The Zn:Ca and Zn:Cu values are shown in figures 19 and 20, respectively. These ratios are of interest because these ions may compete for absorption sites in the animal. There do not appear to be any significant trends with date.

Manganese

Manganese concentrations (fig. 21) varied widely between species and dates. Basin wildrye contained the lowest Mn concentrations of the seven species analyzed.

Beef cattle requirements range from 1 to 10 ppm Mn in the forage (NAS-NRC 1976). The levels reported here are far in excess of the requirement, and thus Mn should not be deficient in cattle diets on cheatgrass range.

Copper

Copper levels (figure 22) exhibited downward trends with increased forage maturity in five of the seven species. Copper content in cheatgrass and streambank wheatgrass was not correlated with maturity.

NAS-NRC (1976) lists the Cu requirement for beef cattle at 4 ppm Cu in the ration dry matter. Only a few samples contained less than 4 ppm Cu, therefore Cu should not be deficient in the diet of animals grazing cheatgrass ranges. If molybdenum (Mo) values are high (>6 ppm), then dietary Cu values should be increased 2 to 3 times because of the depression in Cu absorption by Mo. The Mo values of a few random forage samples from this area indicated <3 ppm Mo. Therefore, Cu values in the forage grown on this range are considered adequate for beef cattle.

Iron

The concentrations of Fe (figure 23) in forage samples from Saylor Creek far exceeded the levels normally expected in plant tissue grown in dust-free environments. However, values of this magnitude are often encountered in range plants. The large values are attributed, in part, to soil contamination, which is verified by plotting the Fe concentration against the percent NDF-ash (insoluble silica and soil contamination). Although there is considerable scatter to the points, it is apparent that significant increases in Fe levels accompany increased NDF-ash. These plots are shown in figure 24.

Forage Quality Measures

Forage quality can be defined in many ways, but it usually is related to some animal response, such as feed intake, weight gain, or production of milk or wool (Dietz 1970). Nutritive composition and digestibility also provide measures of forage quality.

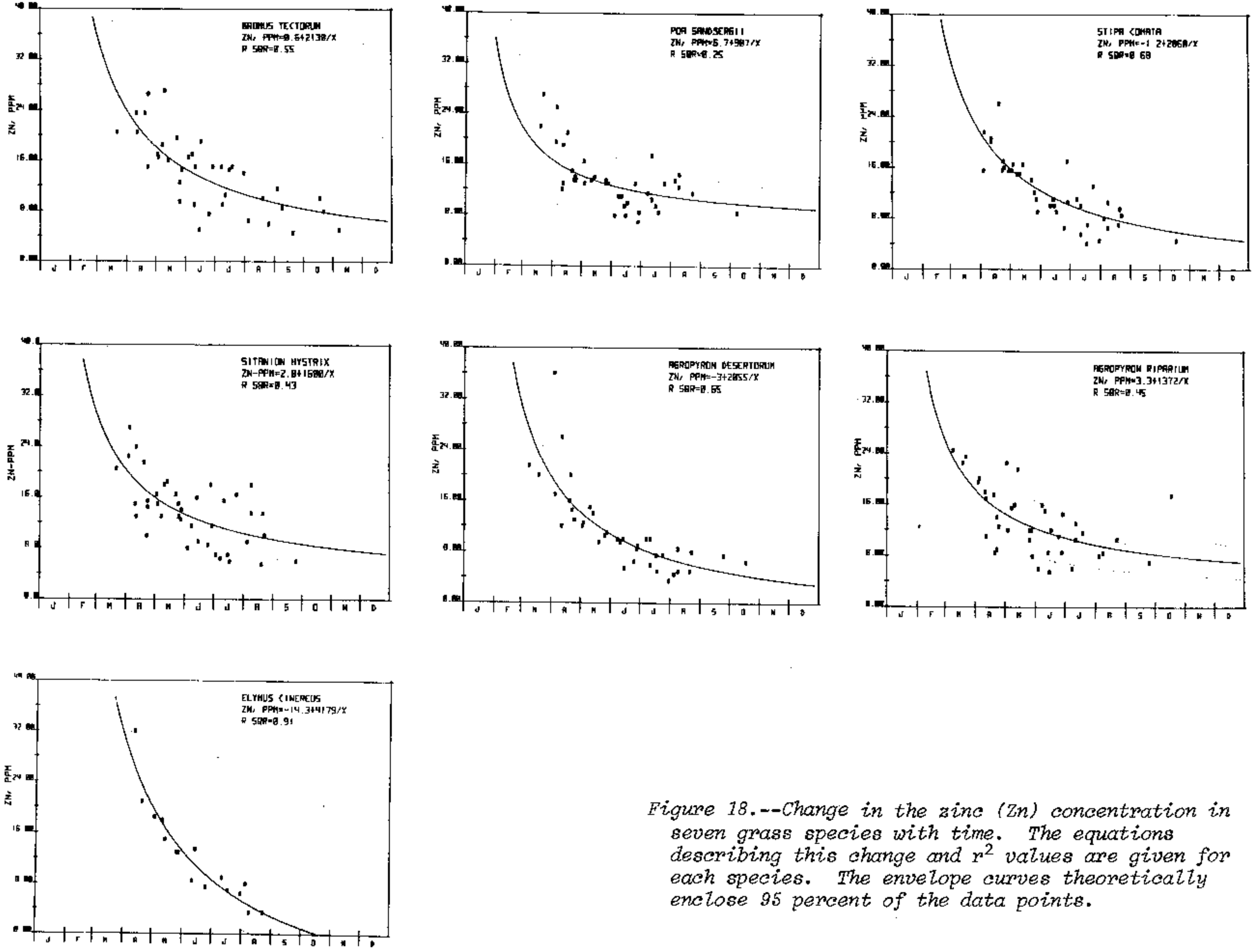

Figure 18.--Change in the zinc (Zn) concentration in seven grass species with time. The equations describing this change and r^2 values are given for each species. The envelope curves theoretically enclose 95 percent of the data points.

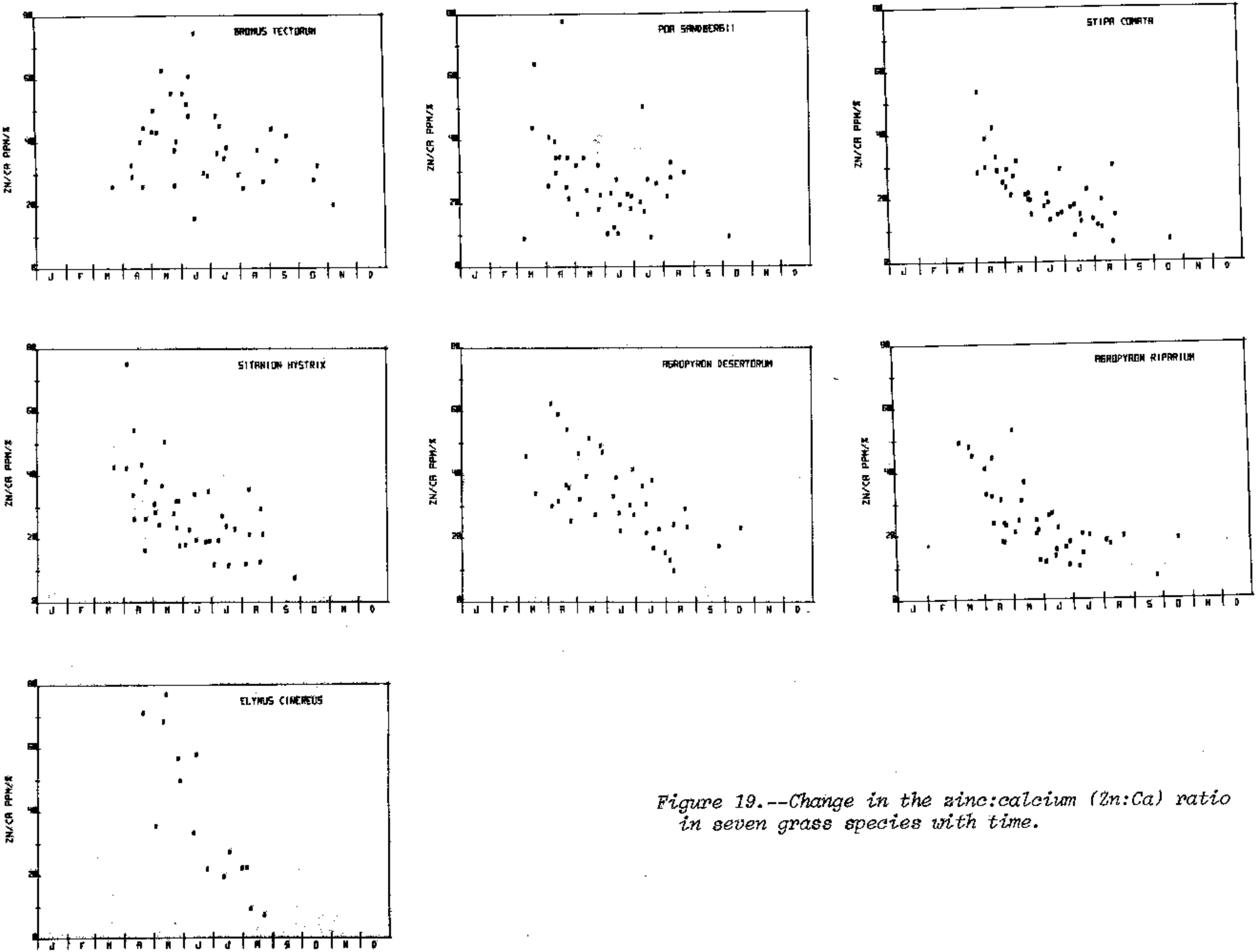

Figure 19.--Change in the zinc:calcium (Zn:Ca) ratio in seven grass species with time.

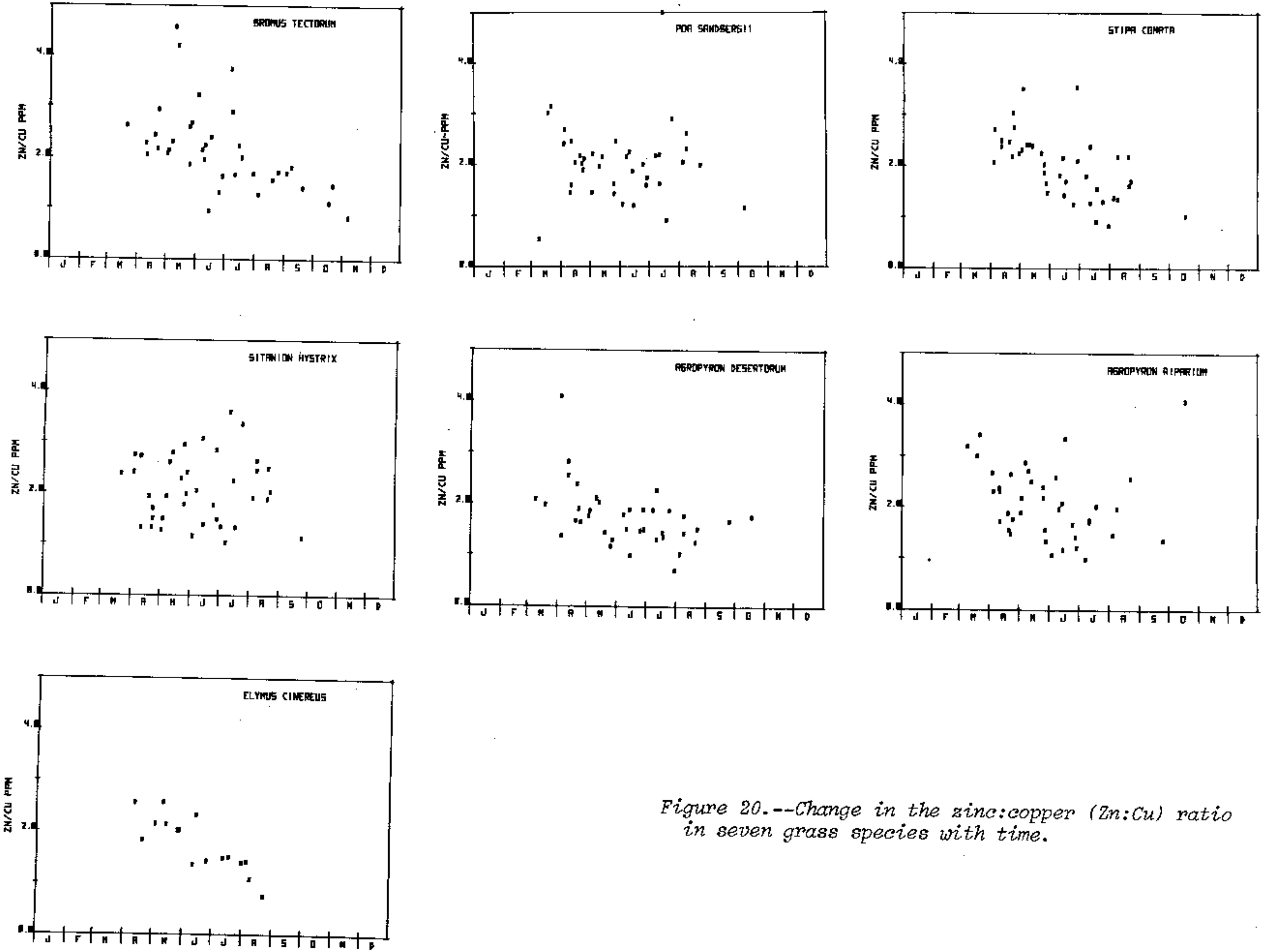

Figure 20.--Change in the zinc:copper (Zn:Cu) ratio in seven grass species with time.

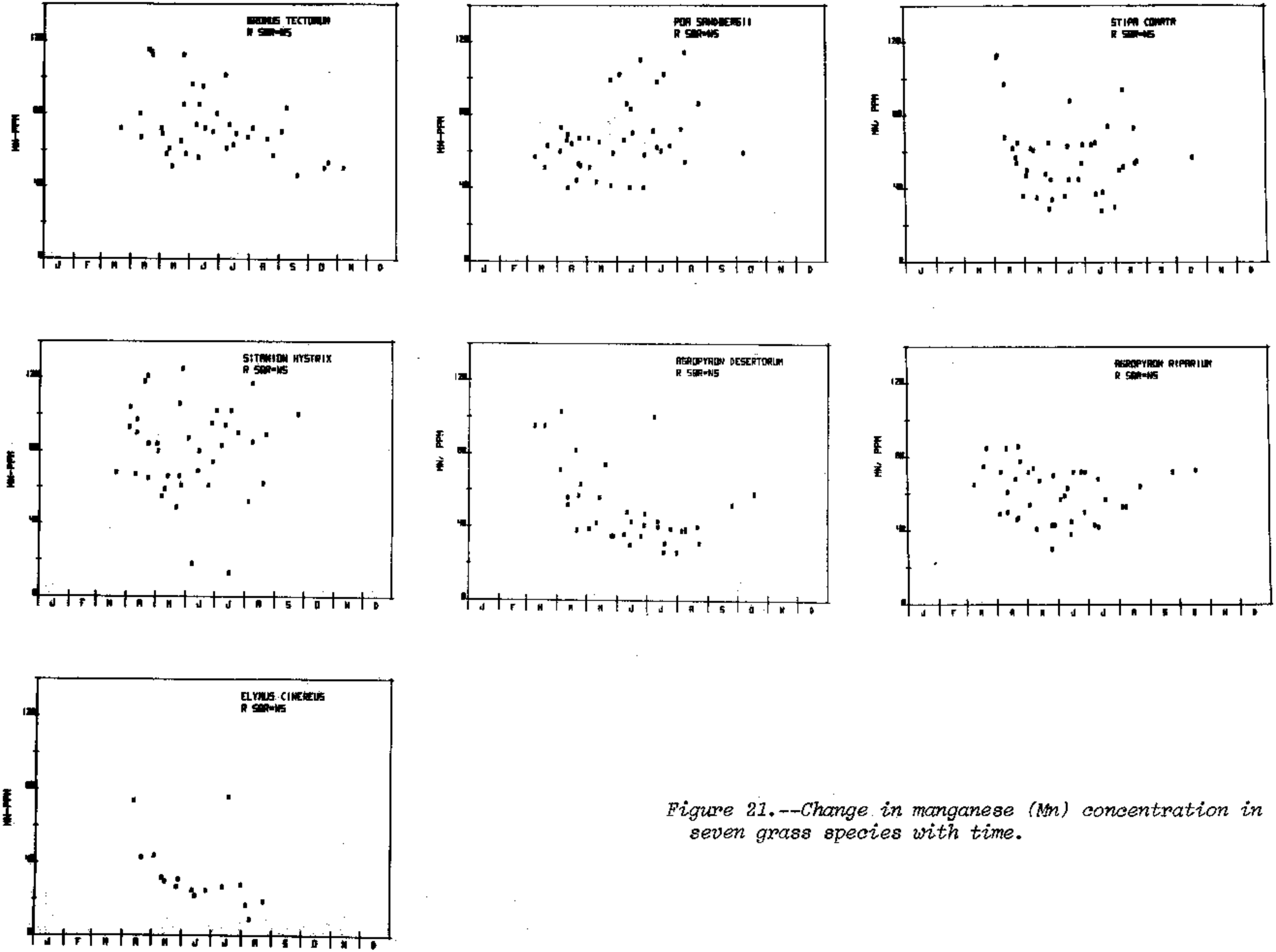

Figure 21.--Change in manganese (Mn) concentration in seven grass species with time.

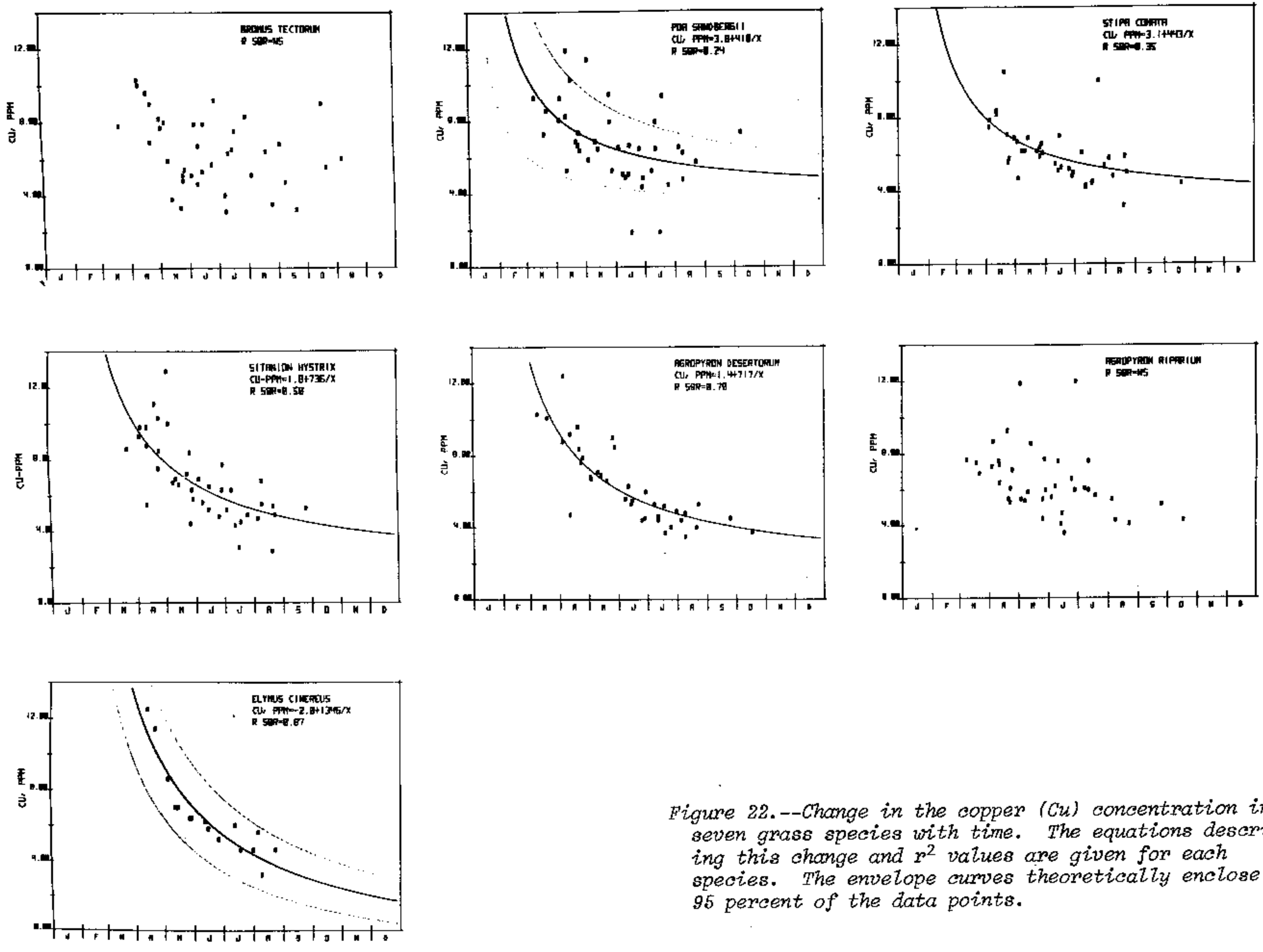

Figure 22.--Change in the copper (Cu) concentration in seven grass species with time. The equations describing this change and r^2 values are given for each species. The envelope curves theoretically enclose 95 percent of the data points.

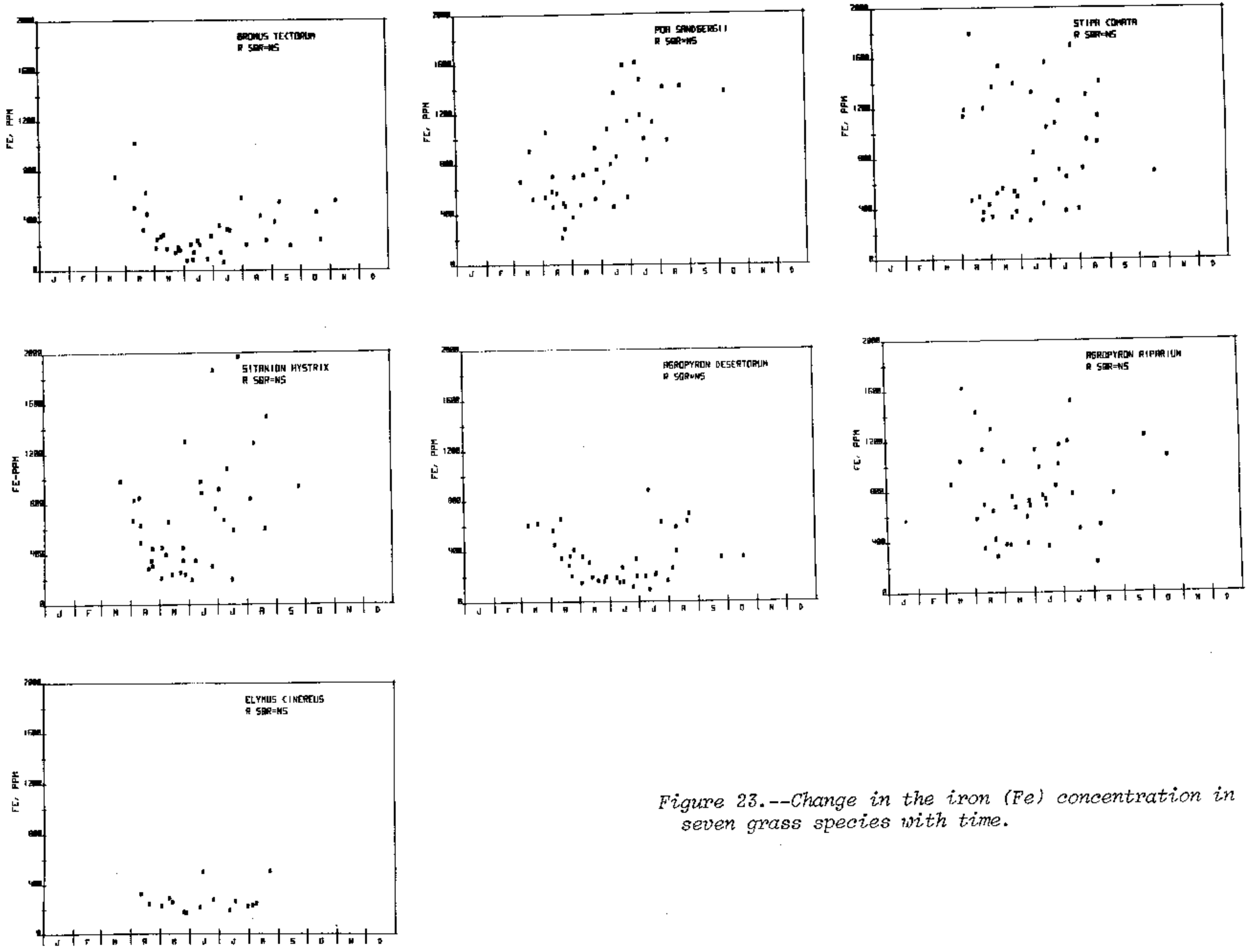

Figure 23.--Change in the iron (Fe) concentration in seven grass species with time.

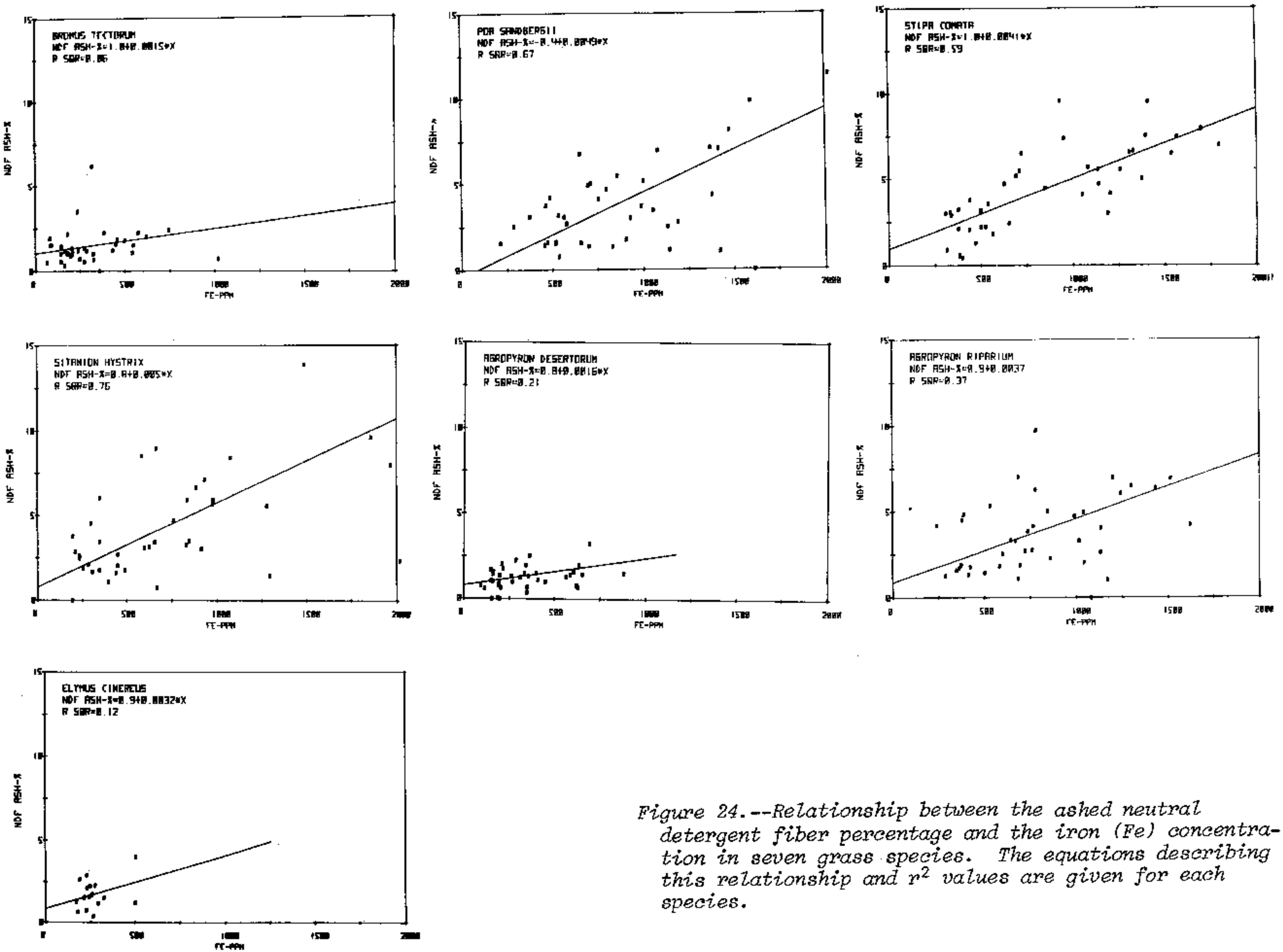

Figure 24.--Relationship between the ashed neutral detergent fiber percentage and the iron (Fe) concentration in seven grass species. The equations describing this relationship and r^2 values are given for each species.

A newer method, rapidly gaining favor, determines cell wall residues (total of lignin, cellulose, and hemicellulose) to replace the crude fiber analysis (Van Soest 1966). These residues are considered to be chemical components that cannot be completely digested. The cell wall constituents are separated into components that are: (1) insoluble in a neutral detergent solution (neutral detergent fiber, NDF), (2) soluble in an acid detergent solution (hemicellulose), and (3) insoluble in an acid detergent solution (acid detergent fiber, ADF, which includes cellulose, lignin, lignified nitrogen compounds, and silica). The cell contents are soluble in neutral detergent solution. The method separates the totally digestible from the partially digestible and indigestible components of forage.

The method of Van Soest in Goering and Van Soest (1970) leads to an estimate of the percent digestible dry matter. We present the data for NDF (a measure of the total fiber), NDF-ash (a measure of plant silica plus any soil contamination present), DCW (cell wall digestibility), DCW-ash free (organic cell wall digestibility, and TDDM (true dry matter digestibility corrected for ash).

The percent NDF (figure 25) in all species increases with plant maturity. The rate of increase between species is quite similar, but the initial and final percentages vary. Basin wildrye and needle-and-thread grass had the highest percentage of NDF in the early spring, and cheatgrass appeared to have the highest percentage at maturity.

The percent NDF-ash (figure 26) did not show any relationship with sampling date. The scatter of values indicates that some species--bluegrass, needle-and-thread grass, squirreltail, and streambank wheatgrass-accumulate more silica, collect more soil dust, or both, than the others. Soil contamination is important because animals may ingest considerable minerals. Mayland and others (1975) reported on the amount of soil ingested by cattle at the Saylor Creek Experimental Range. They found that from 0.1 to 1.5 kg, with a median of 0.5 kg, soil was ingested per animal-day on this cheatgrass range.

Cell wall content (fig. 27 and 28) decreased with increased maturity, while NDF increased in the forage. Cheatgrass digestibility (cell wall content) values were erratic and no trends with plant maturity can be shown, even though the NDF percentage was correlated with plant maturity. The rate of decrease in cell wall digestibility was greatest in basin wildrye, followed by desert wheatgrass, streambank wheatgrass, squirreltail, needle-and-thread grass, and bluegrass. The implications are that these species become increasingly indigestible with increasing maturity. By September, all species except cheatgrass and bluegrass were less than 50 percent digestible.

The estimated true dry matter digestibility (fig. 29) is a measure of the digestible cell contents and digestible lignified cell wall corrected for silica content. The NDF percentage subtracted from 100 gives the cellular content. The digestible cell wall percentage (100-NDF percentage) minus the silica correction gives the TDDM. Expected apparent dry matter digestibilities or total digestible nutrients (TDN) are about 13 units lower than TDDM due to the loss of metabolic matter in the feces.

The graphs show that the TDDM is greater than DCW. The TDDM follows patterns similar to DCW, and the rates of decrease are similar. Again, by September most species were less than 60 percent digestible. In another study, dry matter digestibilities of 72, 63, and 65 were determined for mid-July, mid-August, and early September, respectively, using esophageal fistulated yearling cattle and lignin and chromic oxide techniques (Olsen 1971). The higher digestion coefficient for mid-July may be attributed to considerable quantities of green Russian thistle being grazed during this period. The green thistle is readily eaten and is quite nutritious (table 9). The in vivo data also reflect animal preferences for forage species and plant parts, while our data are for total top growth.

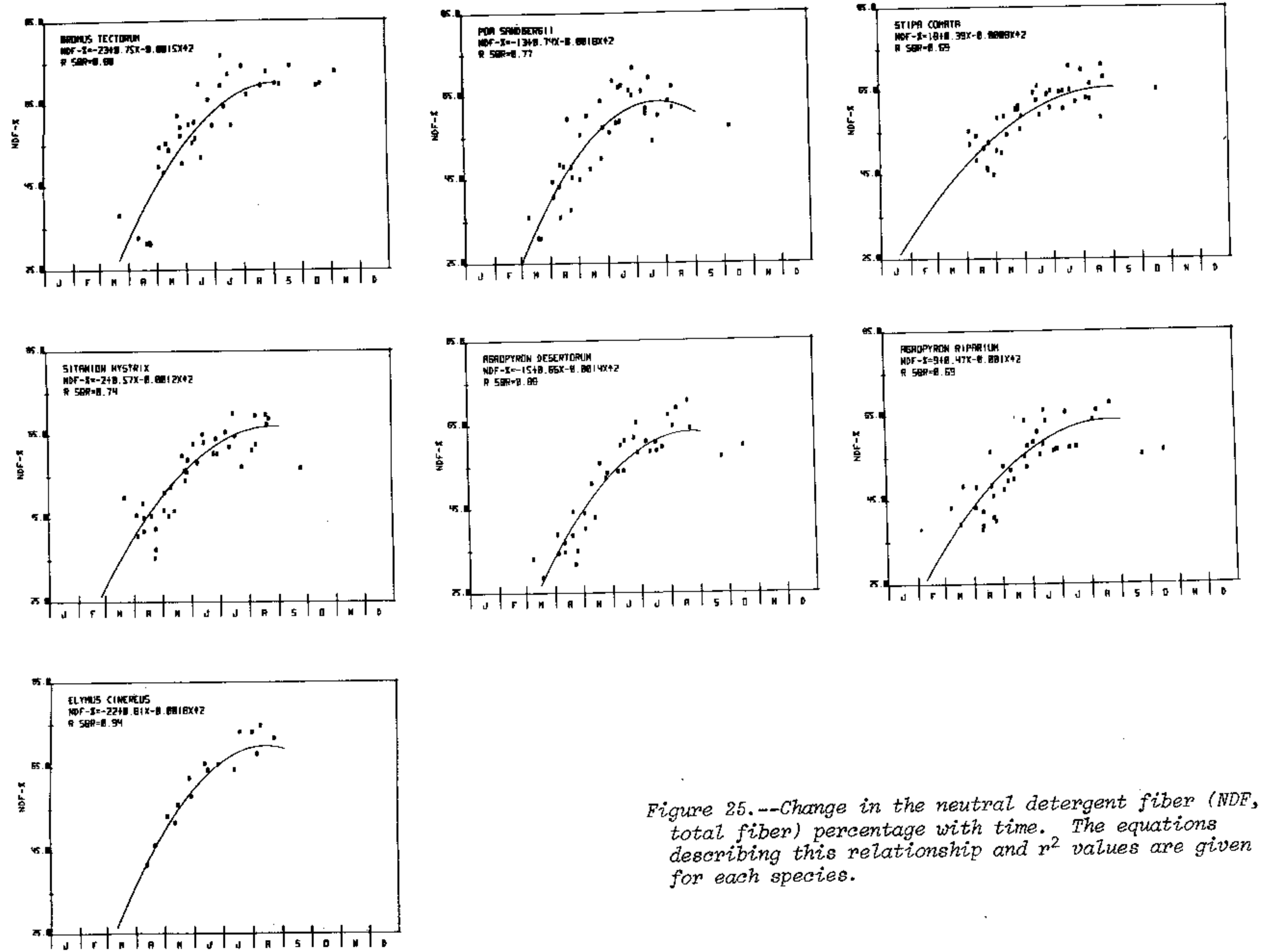

Figure 25.--Change in the neutral detergent fiber (NDF, total fiber) percentage with time. The equations describing this relationship and r^2 values are given for each species.

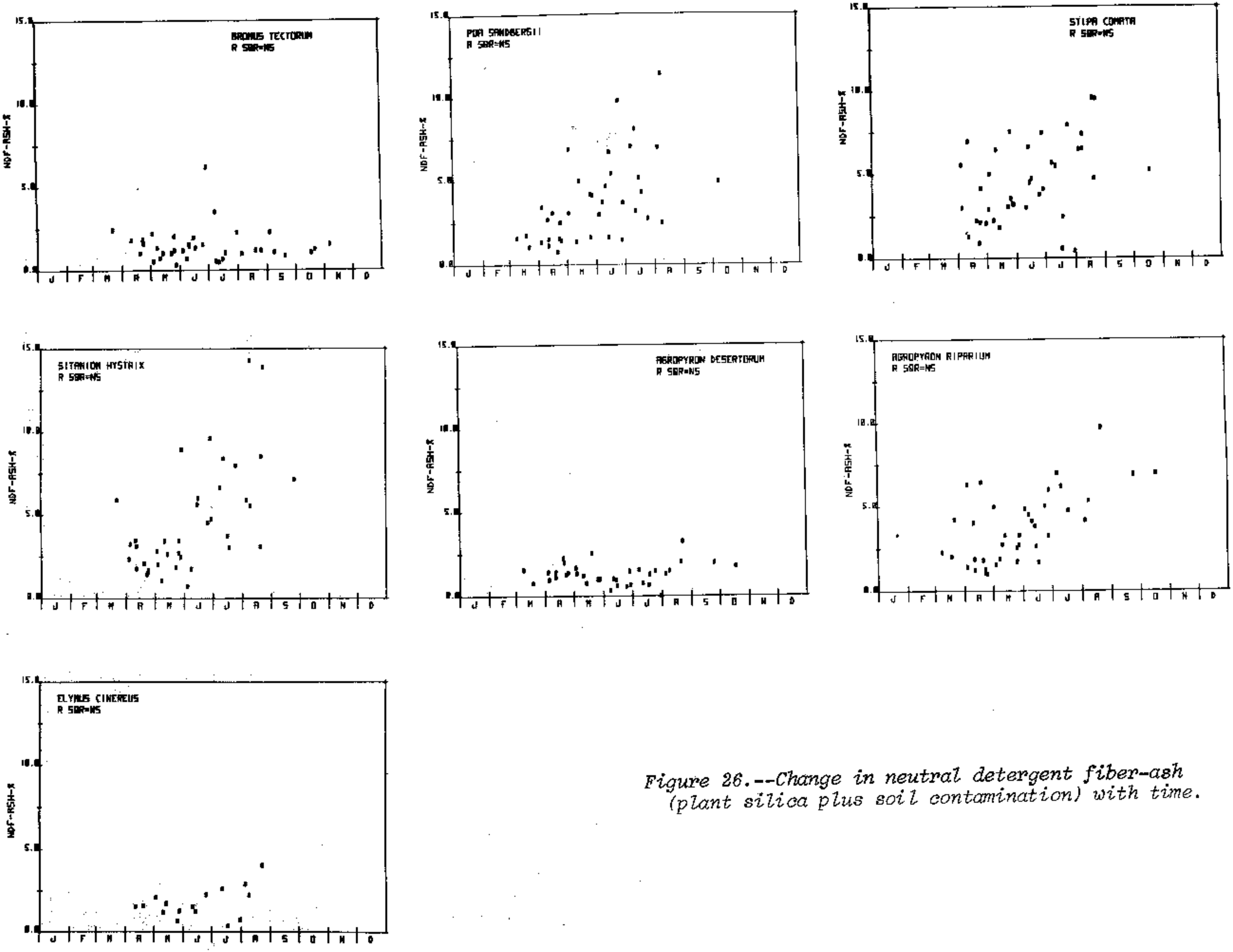

Figure 26.--Change in neutral detergent fiber-ash (plant silica plus soil contamination) with time.

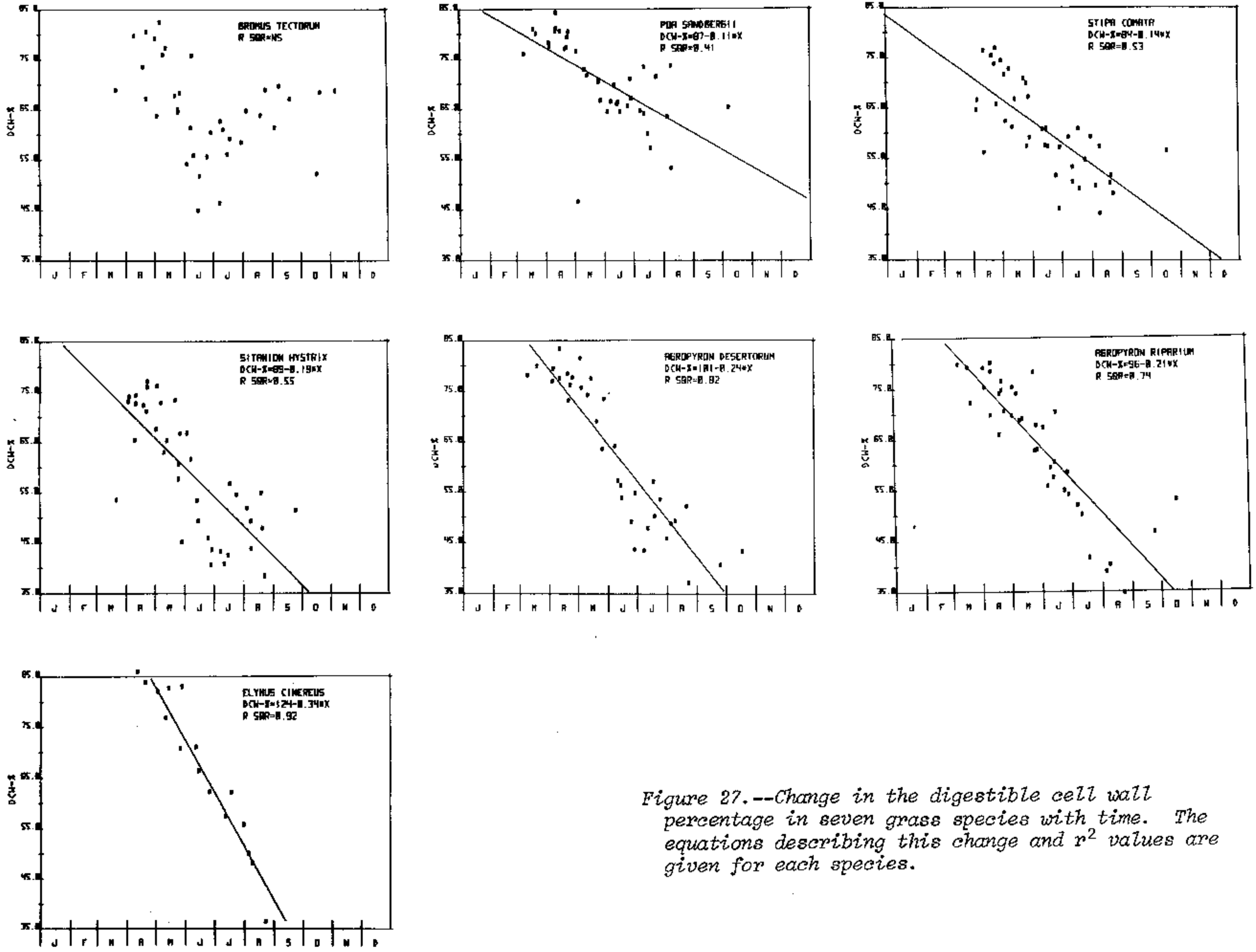

Figure 27.--Change in the digestible cell wall percentage in seven grass species with time. The equations describing this change and r^2 values are given for each species.

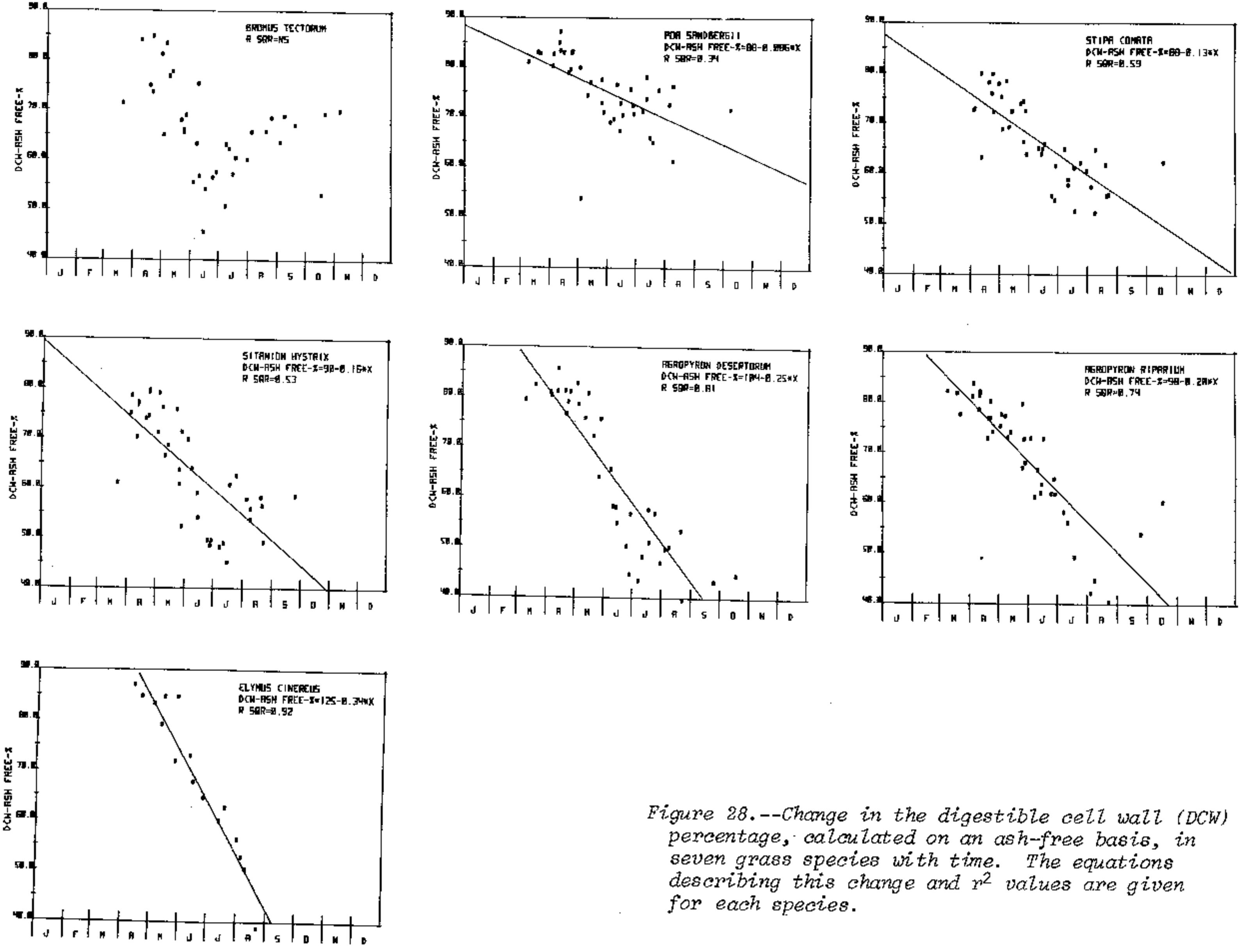

Figure 28.--Change in the digestible cell wall (DCW) percentage, calculated on an ash-free basis, in seven grass species with time. The equations describing this change and r² values are given for each species.

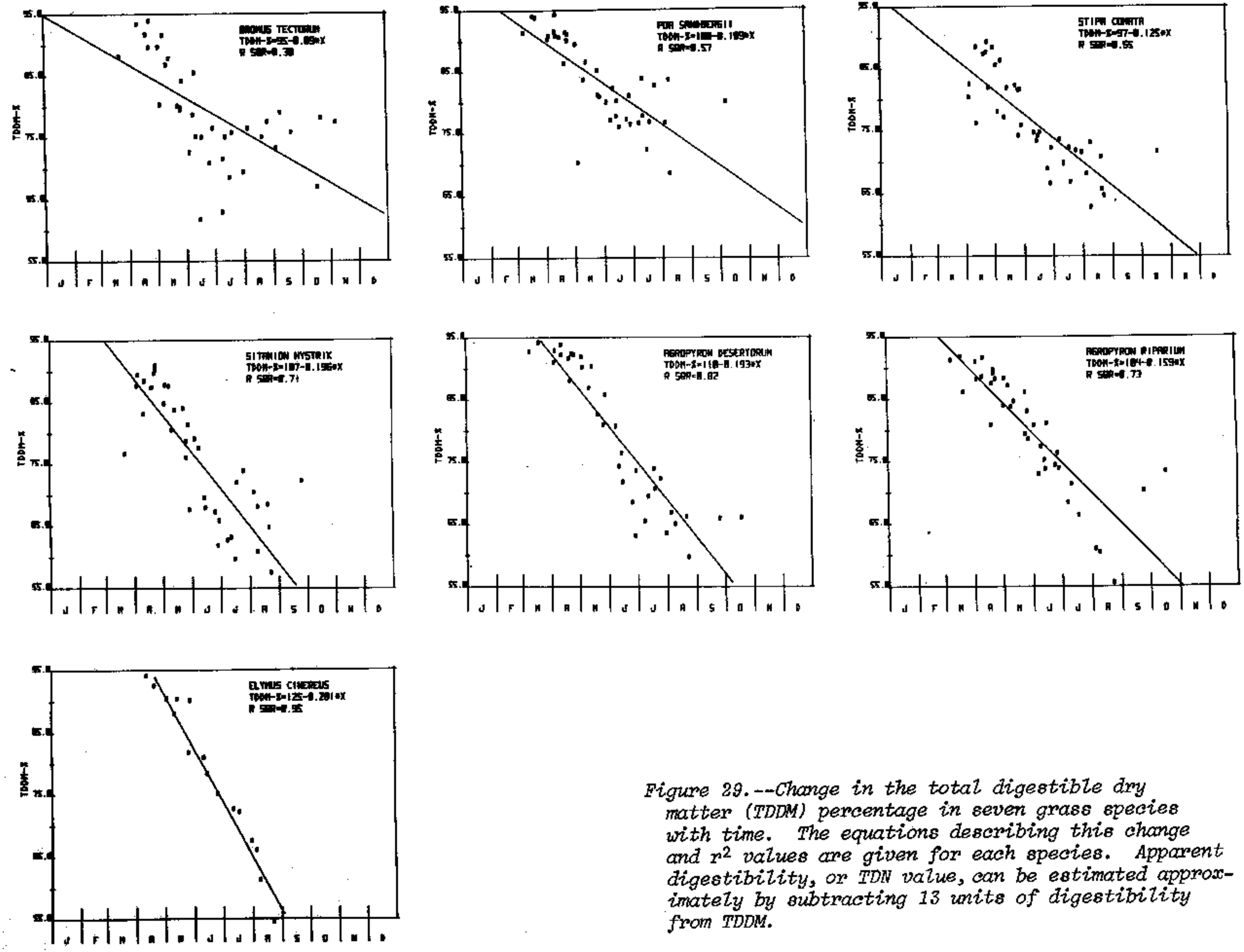

Figure 29.--Change in the total digestible dry matter (TDDM) percentage in seven grass species with time. The equations describing this change and r^2 values are given for each species. Apparent digestibility, or TDN value, can be estimated approximately by subtracting 13 units of digestibility from TDDM.

Table 9.--*Comparison of crude protein, calcium, and phosphorus concentrations in cheatgrass (Brte), Sandberg's bluegrass (Posa), and Russian thistle (Saka) on each of four harvest dates*[1]

Date	Crude Protein			Calcium			Phosphorus		
	Brte	Posa	Saka	Brte	Posa	Saka	Brte	Posa	Saka
	Percent								
7-3-69	2.5	2.9	18.4	0.34	0.24	2.2	0.04	0.04	0.28
8-2-69	3.0	2.1	16.7	.37	.14	2.0	.06	.03	.16
8-28-69	3.5	2.2	15.2	.28	.12	1.5	.05	.02	.17
10-3-69	2.8	2.1	7.0	.26	.11	1.3	.03	.02	.17

[1] From M.S. thesis, Olsen, T. E., Univ. Idaho 1971.

Animal Responses

Despite the many negative features of cheatgrass range, including early maturity, generally low yields, and high fire hazard, it serves as a valuable forage resource in the western United States. This was shown by Murray (1971) and Murray and Klemmedson (1968), who reported details of sheep and cattle grazing studies on the Saylor Creek Experimental Range.

Daily weight gains by yearling cattle stocked at several intensities during early spring, late spring, summer, and fall seasons, are given in figure 30. As in most grazing intensity studies, individual performance declined as stocking rate increased. On cheatgrass range, individual weight gains were most sensitive to changes in stocking rates in early and late spring, corresponding to the green feed period.

Yearling cattle weights over the entire grazing period are shown in figure 31. These data represent weight gains by cattle stocked at all experimental levels from 1961 through 1968. Differences in weight gain are attributed to differences in the quantity and quality of forage, stocking rates, and quality of cattle provided by the different ranchers.

Five years of weight gain data are shown in figure 32 for cows and calves. Cows in the 1974, 1975, and 1976 studies received supplemental crude protein, phosphorus, and sulfur during the mid-June to mid-October period; thus their performance would be better than that expected from unsupplemented animals. First-calf heifers (1972 and 1973) did not gain weight beyond the green feed period, nor did their calves do as well as did the animals in other years. Forage quality was not high enough for the pregnant and growing young animals. Also of importance is the decrease in rate of gain by calves after about October 1. Ranchers would be advised to place calves on higher quality feed at this time if rate of gain is to be continued.

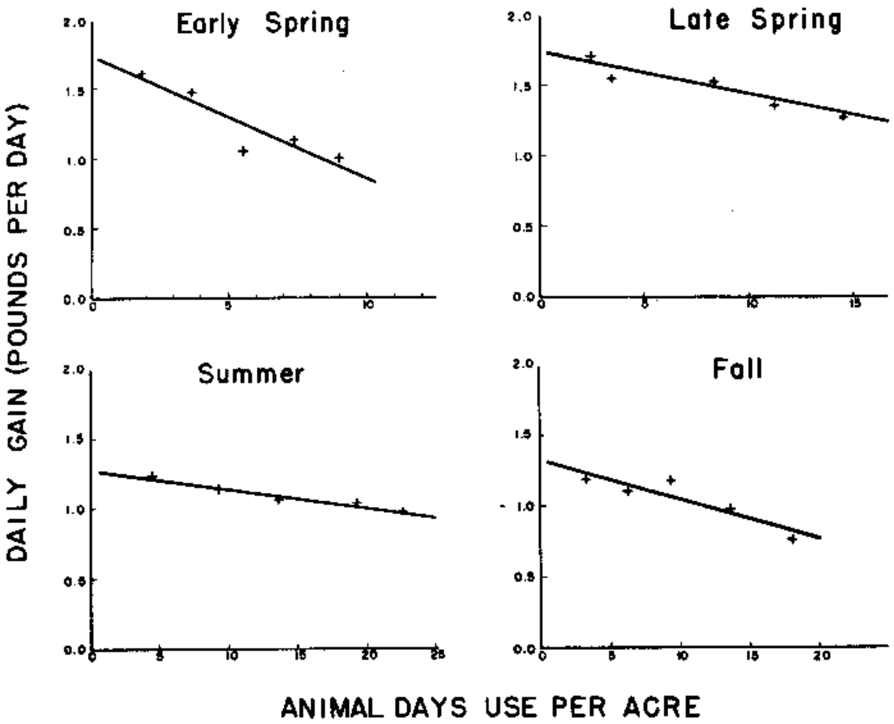

Figure 30.--Daily weight gains by yearling cattle at several stocking intensities on the Saylor Creek Experimental Range during early spring (April 1-May 5), late spring (May 6-June 9), summer (June 10-Sept. 1), and fall (Sept. 2-Oct. 27). These data are means of 5 years of study results (1964 through 1968). Note differences in the stocking rate scale.

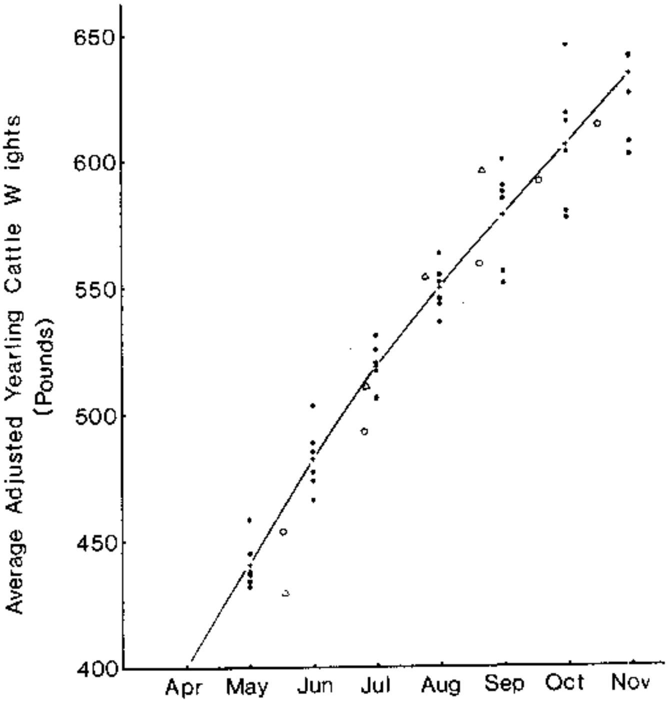

Figure 31.--Yearling cattle weights adjusted to a 400-pound weight over the period 1964 through 1968 at the Saylor Creek Experimental Range. Additional data represented by o *and* Δ *(1969 and 1970, respectively) are shown, but not included in the average response curve.*

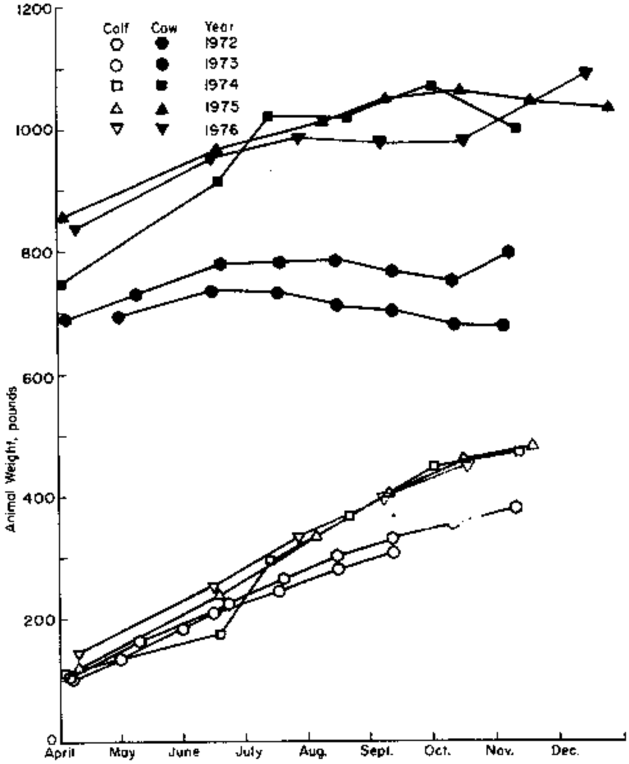

Figure 32.--Cow and calf weights for 5 years at the Saylor Creek Experimental Range. Animal ownership and age of cows varied. Cows in 1972 and 1973 were first-calf heifers. Means are for 100 to 120 animals each year. Note that cattle in 1974, 1975, and 1976 received supplemental crude protein, phosphorus and sulfur during the mid-June through mid-October period.

CONCLUSIONS AND RECOMMENDATIONS

In many areas of the semiarid West, the annual cheatgrass has replaced the longer lived grasses. Normally, cheatgrass germinates in the fall, overwinters, grows rapidly during the spring, and matures by mid-June. Forage quality declines as the forage matures. Consequently, cattle grazing on these ranges are consuming forage of poor quality over most of the grazing season (June to November). We have shown in this study that protein content and many minerals declined to levels below that recommended for optimum livestock performance.

On private cheatgrass range, cattle should be supplemented with both energy and crude protein as the forage matures (fig. 33). Supplementation, except for salting, is not allowed on public rangelands. Supplementing crude protein for economic production in growing animals has been shown to be impractical on desert wheatgrass beyond mid-August at Squaw Butte, south-central Oregon (Turner and Raleigh 1977). Beyond that point an increased supplement level inhibited forage intake. Therefore, both energy and crude protein should be added to cattle diets from mid-June to mid-August or longer if cattle are to continue to maintain good gains. Those interested in finishing animals on range should consult the paper by Turner and Raleigh (1977).

Figure 33.--Supplementing beef cattle diets with crude protein, P, S, and Zn on cheatgrass range.

Phosphorus levels decline rapidly and the Ca:P ratio escalates quickly in many plant species. However, in cheatgrass, which is predominant on many ranges, the P level is lower, but the Ca:P ratio is within the recommended allowance. Where needed, P can be added to the diet in salt blocks, however, satisfactory intake may not be achieved; so it is better to use other more palatable carriers such as molasses licks, cottonseed, or soybean meals.

Levels of all trace minerals, except Zn, are adequate for all classes of cattle. Supplemental Zn added to cow and calf diets at Saylor Creek Experimental Range resulted in better gains than those made by nonsupplemented animals. This suggests that Zn should be added to the diet when forage Zn levels drop below 10 ppm, which on cheatgrass range occurs usually by August 1. The supplemental Zn levels ought to provide 500 mg Zn per cow-day and can be provided in salt (Mayland, unpublished).

Calves, yearlings, and cows do well on cheatgrass range in the early spring to early summer period. First-calf heifers, which have not attained full growth, require better feed after this period. Nutritional intake is not sufficient to maintain the fetus, calf, and herself when the forage is dry. Calf gains are considerably reduced by October 1. First-calf heifers should be placed on better pasture by July, while calves of mature cows would benefit from better feed about mid-September (see also Turner and Raleigh 1977).

Increasing the stocking rate use decreases individual daily gains. The decline in daily gain is most rapid in the early spring when the forage contains high moisture and is not always abundant. To obtain maximum daily gains fewer animals should be grazed than when optimizing for gains per acre. Because of the extreme variability in cheatgrass yield between seasons and years, recommending grazing rates is impractical. However, removal of about 60 percent of the available forage will tend to optimize gains per acre.

The use of nitrogen fertilizers to increase yields and/or protein contents of forage on cheatgrass range is not economical. Although, in some years nitrogen additions increase yields up to 4 times those of nonfertilized range, the cost of the fertilizer is prohibitive. In most cases, direct supplementation of energy, protein, and minerals is more practical and cheaper than attempting to improve the forage through fertilization.

Predicting forage yields in advance of the grazing season is desirable. On many perennial grass ranges, this can be done using the accumulated precipitation over the previous winter (Sneva 1977). However, cheatgrass responds more to current precipitation and temperature. Our prediction equation reflects this fact, because April and May precipitation and temperature are included. Use of the equation allows one to estimate the quantity of the forage without extensive harvesting.

Adjusting animal numbers to properly utilize and optimize gains is not readily accomplished, because the rancher in a good year has too few animals while in a poor year he has too many. In those good years, cheatgrass range should be used to relieve pressure from other ranges in poor condition. When forage production is lower than needed on cheatgrass range, animals should be placed on other ranges.

Soil moisture fluctuates with time and depth. The nature of the time-depth curves suggests that deeper rooted plants would benefit from greater moisture lower in the profile that persists over a longer period.

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APPENDIX I

Species referred to in the text

Scientific Name	Common Name
SHRUBS:	
Artemisia tridentata ssp. *tridentata* Nutt.	Basin Big Sagebrush
GRASSES:	
Agropyron desertorum Fisch.	Desert Wheatgrass
Agropyron riparium Schribn. & Smith	Streambank Wheatgrass
Bromus tectorum L.	Cheatgrass, downy brome
Elymus cinereus Schribn. & Merr.	Basin Wildrye
Oryzopsis hymenoides (R & S) Ricker	Indian Ricegrass
Phleum pratense L.	Timothy
Poa sandbergii Vasey	Sandberg's Bluegrass
Sitanion hystrix (Nutt.) Smith	Bottlebrush Squirreltail
Sporobolus wrightii Munro	Alkali Sacaton
Stipa comata Trin. & Rupr.	Needle-and-Thread Grass
Stipa thurberiana Piper	Thurber's Needlegrass
FORBS:	
Antennaria dimorpha (Nutt.) T. & G.	Low Pussytoes
Astragalus beckwithii T. & G.	Beckwith's Milk Vetch
Astragalus lentiginosus Dougl.	Specklepod locoweed
Astragalus purshii Dougl.	Pursh Locoweed
Calochortus nuttallii T. & G.	Segolily, Mariposa Lily
Castilleja angustifolia (Nutt.) G. Don	Northwestern Paintbrush
Crepis acuminata Nutt.	Tapertip Hawksbeard
Crepis occidentalis Nutt.	Western Hawksbeard
Descurainia pinnata (Walt.) Britton	Tansy Mustard
Erigeron pumilus Nutt.	Low Fleabane
Eriogonum ovalifolium Nutt.	Oval-Leafed Buckwheat
Lactuca serriola L.	Prickly Lettuce
Lomatium foeniculaceum v. *macdouglii* (Coult. & Rose) Cronq.	Biscuit-Root, MacDougal Lomatium
Lomatium triternatum (Pursh) Coult. & Rose	Nineleaf Lomatium
Microsteris gracilis (Hook.) Greene	Microsteris
Phlox hoodii Rich.	Hood's Phlox
Phlox longifolia Nutt.	Longleaf Phlox
Salsola kali L. v. *tenuifolia* Tausch.	Russian Thistle, Tumbleweed
Sisymbrium altissimum L.	Tumblemustard
Tragopogon sp.	Goats-Beard, Salsify, Oyster Plant

APPENDIX II

Soil descriptions for the needle-and-thread grass and sagebrush sites at Saylor Creek Experimental Range

Needle-and-thread grass site
(NE¼, SE¼, Sec. 17, T.6S., R.9E.)

A11	0-5	Cm--Light brown gray (10 YR 6/2) dry, silt loam, dark gray brown (10 YR 4/2) moist; weak medium platy to weak fine granular; structure weakly coherent, very friable; slightly sticky, slightly plastic; plentiful medium roots; plentiful medium interstitial pores; very slightly effervescent; abrupt, smooth boundary.
A12	5-8	Cm--Light brown gray (10 YR 6/2) dry, silt loam, brown (10 YR 4/3) moist; moderate fine granular to moderate fine platy; structure weakly coherent, very friable, slightly sticky, slightly plastic; plentiful medium roots; plentiful medium tubular pores; slightly effervescent; abrupt, smooth boundary.
C1Ca	8-28	Cm--Light brown gray (10 YR 6/2) dry, silt loam, brown (10 YR 4/3) moist, weak, medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; abundant fine roots; plentiful medium tubular pores; strongly effervescent; clear, smooth boundary.
C2Ca	28-50	Cm--White (10 YR 8/2) dry, fine sandy loam, light brown gray (10 YR 6/2) moist; massive; structure weakly coherent, friable, slightly sticky, nonplastic; plentiful fine roots; plentiful medium tubular pores; violently effervescent; abrupt, smooth boundary.
C3Ca	50-64	Cm--White (10 YR 8/2) dry, fine sandy loam, light brown gray (10 YR 6/2) moist; massive; structure hard, friable, nonsticky, nonplastic; plentiful fine roots; plentiful medium tubular pores; violently effervescent; abrupt, smooth boundary.
IIC4Ca	64-78	Cm--White (10 YR 8/2) dry, sandy loam, light gray (10 YR 7/2) moist; weak coarse platy structure; very hard, very friable, nonsticky, nonplastic, plentiful fine roots; plentiful medium tubular pores; violently effervescent; clear, smooth boundary.
IIC5Casi	78-98	Cm--Pinkish white (7.5 YR 8/2) dry, moderately cemented hardpan, pinkish gray (7.5 YR 7/2) moist; weak coarse platy structure; extremely hard, extremely firm, nonsticky, nonplastic; few fine roots; plentiful medium tubular pores, clear, smooth boundary.
IIC6Casi	98-140	Cm--White (10 YR 8/2) dry, stony hardpan, light gray (10 YR 7/2) moist; weak coarse platy structure; extremely hard, extremely firm, nonsticky, nonplastic, few fine roots; clear, smooth boundary.

Sagebrush
(SE¼, NW¼, Sec. 17, T.6S., R.9E.)

A11	0-7	Cm--Brown (10 YR 5/3), dry silt loam, dark brown, (10 YR 3/3) moist; weak medium granular structure slightly hard, very friable, slightly sticky, slightly plastic; plentiful medium roots, plentiful medium pores, slightly effervescent; moderately alkaline (pH 8.0); abrupt, smooth boundary.
B2	7-13	Cm--Yellowish brown (10 YR 5/4) dry, silt loam, dark brown (10 YR 3/3) moist; weak, fine subangular blocky structure; slightly hard, very friable, slightly sticky, slightly plastic; plentiful medium roots; plentiful medium tubular pores; slightly effervescent; moderately alkaline (pH 8.0); abrupt, smooth boundary.
C1Ca	13-31	Cm--Pale brown (10 YR 6/3) dry, silt loam, brown (10 YR 4/3) moist; moderate, fine subangular blocky structure; slightly hard, friable, slightly sticky slightly plastic; plentiful medium roots; plentiful medium tubular pores; violently effervescent; moderately alkaline (pH 8.2); abrupt, smooth boundary.
C2Ca	31-41	Cm--Light gray (10 YR 7/2) dry, silt loam, gray brown (10 YR 5/2) moist; moderately medium platy structure; slightly hard, friable, slightly sticky, slightly plastic; plentiful medium roots; plentiful medium tubular pores; violently effervescent: moderately alkaline (pH 8.2); boundary not given.
C3Ca	41-63	Cm--Light gray (10 YR 7/2) dry, very fine sandy loam, gray brown (10 YR 5/2) moist; weak medium subangular blocky structure; hard, slightly firm; slightly sticky; slightly plastic; plentiful medium roots; plentiful medium tubular pores; violently effervescent; moderately alkaline (pH 8.2) abrupt, smooth boundary.
IIC4Ca	63-77	Cm--White (10 YR 8/2) dry, fine sandy loam, light brown gray (10 YR 6/2) moist; moderate, medium angular blocky structure; hard, firm; slightly sticky, nonplastic; plentiful fine roots; plentiful medium tubular pores; violently effervescent; moderately alkaline (pH 8.4); abrupt, wavy boundary.
IIIC5Casi	77-112	Cm--White (10 YR/8/2) dry, hardpan, very pale brown (10 YR 7/3) moist; moderate, medium platy structure; very hard, firm, nonsticky, nonplastic; plentiful fine roots; plentiful medium tubular pores; violently effervescent; strongly alkaline (pH 8.6); abrupt, wavy boundary.
IIIC6Camsi	112-128	Cm--White (10 YR 8/2) dry, indurated hardpan, very pale brown (10 YR 7/3) moist; strong, coarse platy structure; extremely hard, extremely firm, nonsticky, nonplastic; no roots; plentiful medium tubular pores; violently effervescent; strongly alkaline (pH 8.6); abrupt, wavy boundary.
IIIC7Casi	128-140	Cm--White (10 YR 8/2) dry, degraded hardpan, light gray (10 YR 7/2) moist; massive; structure very hard, nonfirm, nonsticky, nonplastic; no roots; abundant medium interstitial pores; violently effervescent; strongly alkaline (pH 8.6); boundary not given.

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