

Technical Report No. 2
PRELIMINARY METHODOLOGY
AND RESULTS FOR ROOT BIOMASS
SAMPLING ON THE PAWNEE SITE

Prepared by Dale Bartos and Joseph Hughes

GRASSLANDS BIOME

U.S. International Biological Program

Investigators^{1/}:

Philip Sims	- Project leader
Joseph Hughes	- Computer programming
Steven Sargent	- Computer programming
Dale Bartos	- Field investigator
Daniel Uresk	- Field investigator
Donald Deines	- Root sampling and washing
Michael Yowell	- Root sampling and washing

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ABSTRACT

Biweekly sampling of root biomass, organic matter, and crown material was conducted at the Pawnee Site during the summer of 1969. The biomass data collected are presented here with means and standard deviations. These data will be utilized to determine future methods of sampling.

^{1/} Present address of the above: Range Science Department, Colorado State University, Fort Collins, Colorado.

INTRODUCTION

This report describes collection methods and enumerates data collected on root biomass at the Pawnee Site during the 1969 growing season. The primary objectives were to obtain estimates of the seasonal and depth variability of root biomass. This basic information will be used to develop sampling techniques for further studies.

DESCRIPTION OF STUDY AREA

The study area is located on the Pawnee Site, US-IBP Grassland Biome.^{2/} The plots are in Weld County, Colorado, 40 miles N.E. of Fort Collins in Section 15 and 23, Township 10N, Range 66W.

Study macroplots were located adjacent to the eight 0.5 ha micro-watersheds which are located on sandy-loam soils of the Ascalon Series.^{3/} The microwatersheds were selected to give two replicate samples of four different levels of cattle grazing intensities and are designated as 2 and 8, no grazing; 1 and 3 heavy; 4 and 5 light; and 6 and 7, moderate grazing. These treatments have been applied to the study areas since 1939.

OBJECTIVES OF SAMPLING

The main objectives of sampling were to determine total root biomass and its seasonal and depth variability. Total organic matter and crown

^{2/} The Pawnee Site is located on the Central Plains Experimental Range (Agricultural Research Service, USDA) and adjacent areas of the Pawnee National Grassland (Forest Service, USDA).

^{3/} Soil profiles were examined by James Crabb, Soil Conservation Service, USDA.

material was also collected as possible indicators of root biomass. This information will be utilized in determining future sampling procedures.

METHODS

Total root biomass was obtained by collecting soil cores using a hydraulic corer about every two weeks during the growing season of 1969.

Adjacent to each of the eight microwatersheds, macroplots with similar soil and vegetative characteristics were selected for sampling varying in size from 0.25 to 0.5 ha depending on the available area. Non-destructive sampling (estimation and dry-weight rank) was carried on within the area to determine total aboveground biomass.^{4/} Root samples were collected on four 0.25 m² plots, located at the ends of the macroplots which were clipped to determine herbage biomass.

The ranked-set method was utilized to determine the plots to be sampled for belowground biomass.^{5/} The two plots at either end of the macroplot were ranked as to high and low amounts of aboveground vegetation. If the high production plot was selected for sampling at one end, the low production plot was used on the opposite end.

The four clipped plots per macroplot were utilized to obtain all samples for total root biomass, organic matter, and crown biomass. Thus, the actual aboveground production was known for the area sampled.

^{4/} Aboveground biomass determinations were made by D. Uresk, Dept. of Range Science, Colorado State University.

^{5/} Halls, L. K. and T. R. Dell. 1966. Trial of ranked-set sampling for forage yields. *Forest Science* 12(1):22-26.

A typical macroplot is shown in Fig. 1 and the clipped plots were utilized as follows:

Organic matter - 1 core from plots 1, 2, 3, and 4

Crown biomass - 2 samples from plots 1, 2, 3, and 4

Root biomass - 2 cores from each of plots 1 and 4



Fig. 1. A typical macroplot showing the location of the four clipped plots.

Root biomass was sampled using a 7.62 cm diameter core to a depth of 40 cm and a 2.54 cm diameter core taken within the larger hole to a depth of 80 cm. These cores were divided into five sections as outlined in Fig. 2. These sections were then washed to extract the roots. Root washing was done the day after the sampling was completed so that washing could be completed while the cores were still near field moisture levels. Special dispersing agents were not necessary under these conditions. However, when the samples were left for a

period of time, they were then soaked in a solution of sodium pyrophosphate to aid in dispersing the soil. Even after careful washing a certain amount of soil remained on the roots. The roots were oven-dried at 105°C for 48 hr, weighed, and then ashed at 610°C for 8 hr. Root biomass was expressed as an ash-free value to correct for adhering soil particles and converted to grams per square meter.

The four organic matter samples per macroplot were taken using the 2.54 cm diameter, 80 cm core. This core was subdivided into sections in the same manner as the root sample cores (Fig. 2). A 1 cm horizontal section of soil was taken from the center of each subdivision, oven-dried at 105°C for 48 hr, weighed, ashed at 610°C for 8 hr, and reweighed. The remainder of the cores were combined by depth for each macroplot, washed and dried at 105°C for 48 hr and saved for future chemical analysis.

A 7.62 cm diameter sample was taken to obtain crown biomass. The crown material was the vegetation above the roots which was not removed by clipping the aboveground biomass. The crown material was removed, oven-dried at 105°C for 48 hr and ashed at 610°C. The cores used for root biomass were also utilized to obtain half of the crown material.

During the last sampling period detailed time measurements of the various sampling steps in Fig. 2 were recorded (Table 1). Values are given by depths for the various steps involved. Different time values for weighing and ashing the various depths are due to the volume of root biomass and the size of the crucible to accommodate it.

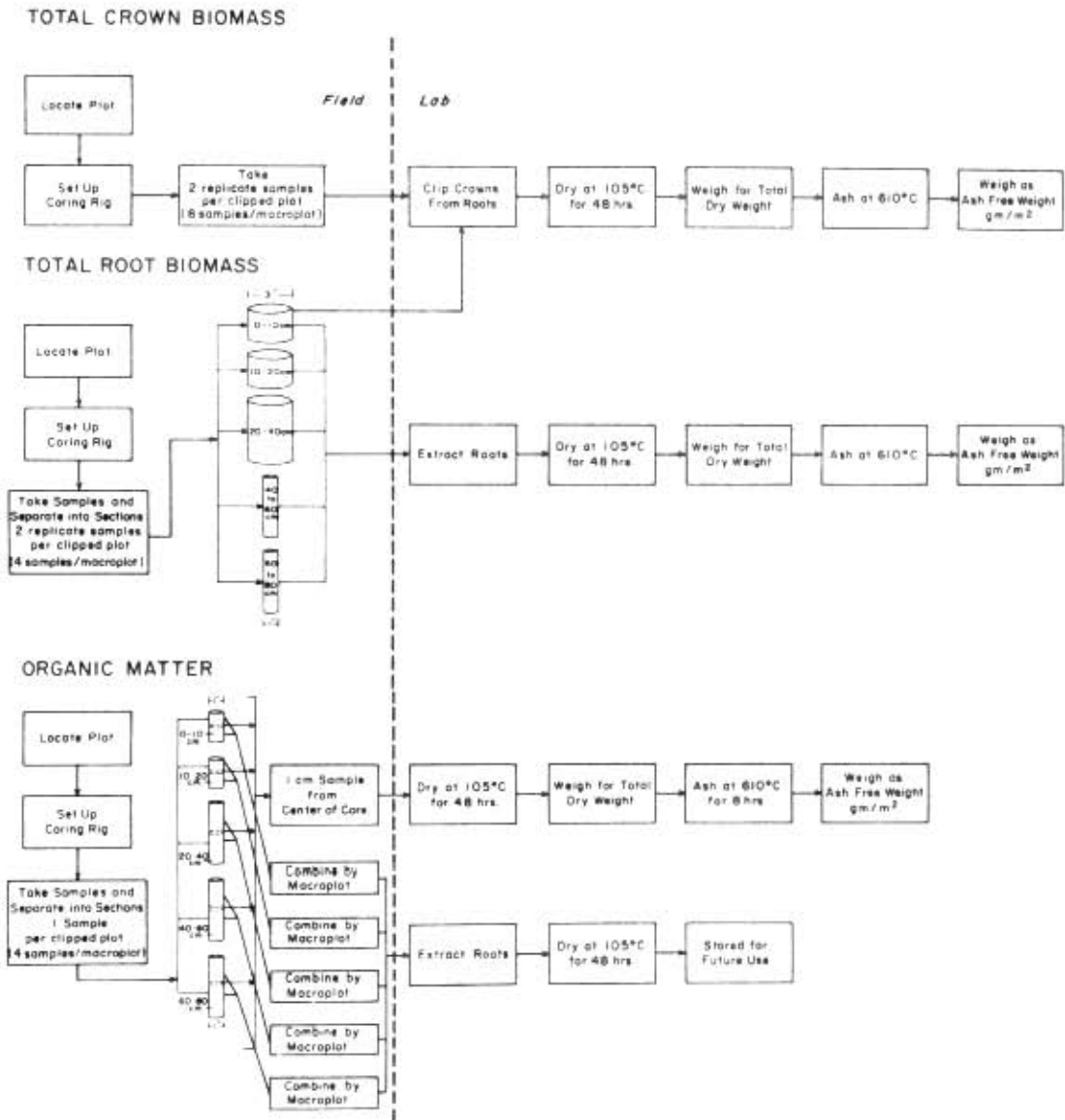


Fig. 2. Flow diagram of field and laboratory sampling procedures.

Table 1. Average time cost in man minutes for field and laboratory steps necessary to obtain one core sample. (Based upon times taken during the 9 September 1969 sampling period.)

FIELD						
Travel Between Plots	Anchoring Truck		Coring			
2.7 min	5.5 min		3.0 min			
LABORATORY						
Root level (cm)	0-10	10-20	20-40	40-60	60-80	Total
Washing (min)	18.5	20.3	22.7	14.2	11.5	87.2
Weighing and Handling (min)	2.9	2.4	2.4	1.7	1.7	11.1

PRELIMINARY RESULTS

Data from eight sample periods are available from the 1969 growing season. Uncorrected means and standard deviations calculated on total root biomass by depths, are given for each sampling date in Tables 2 through 9. The standard deviations presented are calculated as if the four corings from each macroplot were independently collected. This is incorrect. The standard deviations should be based upon the means of each pair of corings that were collected from each of the two sampling locations of each macroplot. The fluctuations that result from combining treatments by depths for all dates are given in Fig. 3 through 6.

Root samples were not classified as to plant species as was the aboveground biomass, but the major species were blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.), red threeawn (*Aristida longiseta*

Steud.), buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.), western wheatgrass (*Agropyron smithii* Rydb.), sun sedge (*Carex heliophila* Mackenz.), fringed sagewort (*Artemisia frigida* Willd.), scarlet gaura (*Gaura coccinea* Nutt. ex Pursh.), broom snakeweed (*Gutierrezia sarothrae* (Pursh.) Britt. & Rusby), evening-primrose (*Oenothera coronopifolia* Torr. & Gray), plains pricklypear (*Opuntia polyacantha* Haw.) scarlet globemallow (*Sphaeralcea coccinea* (Pursh.) Rydb.) and slimflower scurfpea (*Psoralea tenuiflora* Pursh.).

FUTURE ANALYSIS

The values for root biomass as presently recorded have an inherent error because a certain amount of the reported ash-weight value is due to the root ash. To correct this, a small number of samples will be washed with extreme care, examined under 10X magnification for attached soil particles, and then ashed to determine the necessary correction factor.

All possible correlations will be calculated among total root biomass, crown, organic matter and aboveground biomass. Both individual cores and means of the multiple cores within plots will be used for these analyses. If suitable root biomass correlations are found they will be combined with the time-cost values to determine the most efficient and valuable way to sample during the next growing season.

TABLE 2. WEIGHT OF ROOT MATERIAL COLLECTED ON 5/24/69 FROM FIVE SOIL DEPTHS OF FOUR CORINGS ADJACENT TO EACH OF EIGHT WATERSHEDS. (GM/M²)

WATERSHED	CORING	SOIL DEPTHS (CM BELOW GROUND LEVEL)					TOTAL 0-90
		0-10	10-20	20-40	40-60	60-90	
1	1	856.9	244.0	122.1	126.9	16.4	1366.5
1	2	535.4	186.1	136.9	67.7	17.2	943.5
1	3	664.6	147.8	116.4	87.4	43.2	1059.4
1	4	974.3	141.4	98.9	78.5	48.5	1241.7
MEAN +/- SD		732.8 162.3	179.8 47.1	118.6 15.7	90.1 25.8	31.5 16.9	1152.7 188.0
2	1	515.9	67.1	101.7	9.6	23.5	717.8
2	2	709.0	202.1	71.2	55.5	38.8	1076.4
2	3	610.1	146.6	87.3	52.4	12.0	908.4
2	4	870.5	107.7	94.0	48.4	26.3	1137.0
MEAN +/- SD		676.4 151.5	130.9 57.5	86.1 12.5	41.4 21.4	25.2 11.0	959.9 188.2
3	1	448.0	158.2	62.5	49.9	37.5	756.2
3	2	793.6	76.1	69.6	71.2	43.9	1054.5
3	3	511.2	195.1	132.1	15.0	27.6	881.1
3	4	922.0	142.2	99.5	47.6	8.1	1219.3
MEAN +/- SD		668.7 226.0	142.9 49.7	90.9 31.8	45.9 23.2	29.3 15.6	977.8 202.2
4	1	968.8	241.8	106.4	50.0	48.0	1415.0
4	2	622.9	124.7	120.3	42.0	31.5	941.5
4	3	290.6	144.0	123.0	68.8	22.9	649.3
4	4	340.3	156.3	139.0	50.4	30.9	716.9
MEAN +/- SD		555.7 311.9	166.7 51.8	122.2 13.4	52.8 11.3	33.3 10.5	930.7 346.2
5	1	577.0	46.3	166.8	37.8	31.6	859.5
5	2	433.6	105.7	74.4	37.9	33.5	685.1
5	3	623.0	226.3	121.4	11.5	94.6	1076.9
5	4	833.2	249.7	95.6	66.8	28.6	1274.0
MEAN +/- SD		616.7 165.3	157.0 97.1	114.5 30.8	38.5 22.6	47.1 31.8	973.9 256.4
6	1	346.6	185.6	123.7	240.9	41.3	938.1
6	2	692.1	203.7	76.5	117.5	27.6	1117.4
6	3	660.4	229.5	147.9	46.6	0.	1084.4
6	4	1044.8	268.0	221.2	41.2	0.	1575.3
MEAN +/- SD		686.0 285.6	221.7 35.7	142.3 60.4	111.6 93.0	17.2 20.7	1178.8 275.6
7	1	696.2	170.0	127.3	1.2	18.6	1013.2
7	2	335.1	126.3	118.6	40.0	20.2	640.2
7	3	384.8	164.3	145.6	51.6	26.7	773.3
7	4	510.5	109.6	22.7	92.0	46.0	782.7
MEAN +/- SD		481.7 160.9	142.6 29.4	103.5 55.1	46.2 37.4	27.9 12.6	801.8 155.0
8	1	403.0	112.8	111.0	110.2	89.1	826.1
8	2	422.6	171.3	157.0	30.1	44.7	825.8
8	3	636.7	227.7	136.6	122.0	86.0	1208.9
8	4	591.6	109.4	102.5	95.9	61.5	960.8
MEAN +/- SD		513.5 118.0	155.3 56.0	126.8 24.8	89.5 41.0	70.3 21.1	955.4 180.6

TABLE 3. WEIGHT OF ROOT MATERIAL COLLECTED ON 6/21/69 FROM FIVE SOIL DEPTHS OF FOUR CORINGS ADJACENT TO EACH OF EIGHT WATERSHEDS. (GM/M²)

WATERSHED	CORING	SOIL DEPTHS (CM BELOW GROUND LEVEL)					TOTAL	
		0-10	10-20	20-40	40-60	60-90	0-90	
1	1	897.2	231.7	108.8	65.8	21.9		1315.3
1	2	534.5	140.6	99.9	99.4	19.9		894.4
1	3	536.1	115.0	52.8	17.9	5.2		727.0
1	4	657.4	212.7	44.6	52.9	895.3		1052.9
MEAN +/- SD		655.8 165.9	175.0 56.0	76.5 32.5	59.0 33.7	233.1 454.9		1197.4 502.2
2	1	537.9	125.4	50.3	28.3	21.3		763.3
2	2	1127.0	169.3	50.4	49.7	20.7		1417.2
2	3	735.6	99.2	74.6	36.4	60.3		1006.2
2	4	1134.2	652.2	313.0	17.7	5.8		2122.9
MEAN +/- SD		885.7 296.3	261.5 262.1	122.1 127.8	33.0 13.5	27.0 23.3		1327.4 595.1
3	1	709.8	271.7	84.4	24.7	85.2		1175.8
3	2	590.6	109.2	65.5	29.1	41.4		835.9
3	3	493.6	189.8	57.6	74.7	26.1		841.9
3	4	584.7	106.2	193.2	19.4	18.7		922.3
MEAN +/- SD		594.7 88.7	169.2 78.3	100.2 63.0	37.0 25.5	42.9 29.7		944.0 159.5
4	1	992.0	114.2	68.6	14.1	9.1		1198.0
4	2	594.3	98.6	86.1	22.4	17.2		818.6
4	3	471.8	245.5	51.0	11.2	27.8		807.3
4	4	593.6	62.3	85.9	17.4	65.8		825.0
MEAN +/- SD		662.9 226.8	130.2 79.9	72.9 16.8	16.3 4.8	30.0 25.1		912.2 190.7
5	1	648.5	202.3	75.1	68.6	9.2		1003.6
5	2	409.4	183.2	139.8	37.5	9.8		779.7
5	3	673.4	219.6	74.2	12.3	11.3		989.8
5	4	447.7	142.5	78.9	74.4	28.0		771.5
MEAN +/- SD		544.7 135.5	186.6 32.8	92.0 31.9	48.2 28.9	14.6 9.0		886.1 127.8
6	1	843.9	147.0	36.4	12.5	21.9		1061.8
6	2	528.7	100.5	110.5	13.6	21.8		775.1
6	3	193.4	67.2	37.7	2.5	5.4		306.2
6	4	143.2	86.2	47.1	18.3	9.9		304.6
MEAN +/- SD		427.3 326.2	100.2 34.0	57.9 35.4	11.7 6.6	14.8 8.4		611.9 372.8
7	1	657.1	189.4	101.6	46.5	14.7		1009.3
7	2	1080.0	323.0	136.5	16.6	31.8		1587.9
7	3	524.4	135.4	64.3	7.4	38.0		769.4
7	4	570.3	129.8	77.4	24.1	48.9		850.5
MEAN +/- SD		708.0 254.1	194.4 89.9	95.0 31.7	23.6 16.7	33.4 14.3		1054.3 369.4
8	1	561.8	159.5	70.1	49.5	45.4		886.3
8	2	375.3	143.9	73.0	69.3	9.6		671.1
8	3	632.1	176.7	106.6	22.2	36.0		973.6
8	4	915.6	222.9	71.7	58.2	16.4		1284.8
MEAN +/- SD		621.2 224.2	175.7 34.2	80.4 17.5	49.8 20.1	26.8 16.7		954.0 254.6

TABLE 4. WEIGHT OF ROOT MATERIAL COLLECTED ON 7/2/69 FROM FIVE SOIL DEPTHS OF FOUR CORINGS ADJACENT TO EACH OF EIGHT WATERSHEDS. (GM./M²)

WATERSHED	CORING	SOIL DEPTHS (CM BELOW GROUND LEVEL)					TOTAL 0-80
		0-10	10-20	20-40	40-60	60-80	
1	1	486.3	1.4	63.4	39.4	24.6	615.1
1	2	221.7	103.7	51.6	78.6	32.2	487.9
1	3	675.9	206.9	111.2	64.4	37.9	1096.3
1	4	818.5	115.3	61.6	65.4	70.2	1130.9
MEAN +/- SD		550.6 258.0	106.8 84.1	72.0 26.7	62.0 16.4	41.2 20.1	832.5 329.0
2	1	1311.1	147.3	73.1	38.5	14.8	1584.8
2	2	555.8	115.6	46.3	16.9	27.2	561.8
2	3	371.3	152.8	37.9	27.1	19.2	608.4
2	4	921.8	84.7	53.1	22.3	38.5	1120.4
MEAN +/- SD		740.0 462.9	125.1 31.5	52.6 15.0	26.2 9.2	24.9 10.4	968.9 482.3
3	1	589.8	154.9	116.9	9.9	49.7	921.2
3	2	687.1	97.2	160.7	108.3	70.8	1124.2
3	3	377.7	106.5	87.6	88.7	28.9	689.4
3	4	764.3	155.7	91.8	27.3	27.5	1066.6
MEAN +/- SD		604.7 167.3	128.6 31.1	114.3 33.6	58.6 47.4	44.3 20.4	950.4 193.8
4	1	705.8	200.6	146.0	53.1	45.8	1151.3
4	2	892.8	203.5	112.4	49.6	391.6	1650.0
4	3	684.0	163.0	62.0	37.2	45.3	991.5
4	4	470.7	162.0	110.8	99.8	65.5	908.8
MEAN +/- SD		689.3 172.7	182.3 22.9	107.8 34.6	59.9 27.4	137.1 170.0	1175.4 332.0
5	1	583.9	158.9	75.9	29.5	10.9	859.1
5	2	902.5	231.7	70.0	37.6	18.6	1260.5
5	3	872.7	205.7	99.0	74.1	11.4	1262.9
5	4	505.8	123.0	68.5	32.4	34.5	764.2
MEAN +/- SD		716.2 200.8	179.8 48.4	78.4 14.1	43.4 20.7	18.9 11.0	1036.7 262.7
6	1	496.5	198.2	87.1	58.6	30.0	870.4
6	2	494.8	206.8	115.0	110.7	77.9	1005.3
6	3	854.7	144.3	106.7	54.9	11.1	1171.5
6	4	667.4	177.8	72.2	24.9	48.5	990.8
MEAN +/- SD		628.4 171.2	181.8 27.8	95.2 19.3	62.3 35.7	41.9 28.5	1009.5 123.8
7	1	396.5	227.1	101.7	79.1	45.2	849.6
7	2	680.3	200.2	94.2	59.5	17.9	1052.1
7	3	479.0	114.4	109.9	51.2	11.3	765.9
7	4	518.8	120.0	83.2	84.5	49.1	855.7
MEAN +/- SD		518.7 119.2	165.4 56.8	97.3 11.4	68.6 15.8	30.9 19.1	880.8 121.3
8	1	841.4	239.0	158.0	36.6	21.2	1296.2
8	2	419.7	176.7	109.2	49.4	60.9	816.0
8	3	770.2	235.7	98.9	44.3	45.7	1204.8
8	4	731.2	155.1	108.9	52.7	76.9	1164.7
MEAN +/- SD		690.6 186.3	226.6 52.9	118.8 26.6	45.8 7.0	51.2 23.7	1132.9 218.3

TABLE 5. WEIGHT OF ROOT MATERIAL COLLECTED ON 7/16/69 FROM FIVE SOIL DEPTHS OF FOUR CORINGS ADJACENT TO EACH OF EIGHT WATERSHEDS. (GM/M²)

WATERSHED	CORING	SOIL DEPTHS (CM BELOW GROUND LEVEL)					TOTAL	
		0-10	10-20	20-40	40-60	60-80	0-80	
1	1	536.8	172.6	72.2	5.2	3.8		788.6
1	2	614.1	175.8	47.2	64.0	42.5		943.6
1	3	406.0	104.1	52.0	15.5	5.0		578.6
1	4	659.9	187.2	86.5	8.0	4.9		926.6
MEAN +/- SD		549.2 105.0	159.9 37.7	64.5 18.5	22.2 28.2	13.6 19.3		809.5 168.8
2	1	516.3	84.2	70.5	28.8	23.4		725.1
2	2	455.7	142.1	92.8	25.0	25.5		739.1
2	3	952.1	178.1	81.0	47.8	23.2		1262.2
2	4	1139.3	151.6	152.6	54.6	21.7		1519.7
MEAN +/- SD		760.8 329.4	139.0 39.6	99.2 36.7	39.0 14.4	22.9 8.8		1061.0 395.5
3	1	253.4	88.4	74.4	87.0	39.3		542.5
3	2	501.6	164.9	65.9	42.9	33.7		809.0
3	3	478.6	124.1	115.9	51.6	56.4		826.6
3	4	353.2	114.5	69.7	63.3	52.5		653.1
MEAN +/- SD		396.7 115.7	123.0 31.7	81.5 23.2	61.2 19.1	45.5 10.7		707.8 135.0
4	1	709.6	167.2	80.4	32.7	10.6		1000.4
4	2	728.4	201.2	84.7	38.0	27.3		1079.6
4	3	454.1	261.5	54.9	29.8	11.1		811.4
4	4	353.3	92.7	84.0	12.4	24.3		566.7
MEAN +/- SD		561.3 186.8	180.6 70.4	76.0 14.2	28.2 11.1	18.3 8.8		864.5 228.2
5	1	518.2	234.8	78.7	20.3	11.9		863.9
5	2	686.0	298.3	132.1	52.6	7.0		1155.9
5	3	217.6	107.3	62.3	23.8	28.4		439.3
5	4	480.7	134.6	70.0	38.2	18.7		742.3
MEAN +/- SD		475.6 193.8	193.7 89.7	85.8 31.6	28.7 8.1	16.5 9.3		800.4 256.7
6	1	818.3	193.1	115.2	43.9	34.2		1204.7
6	2	649.3	171.2	142.9	22.7	48.6		1034.8
6	3	529.2	210.3	90.4	84.0	33.2		947.0
6	4	468.7	105.2	40.6	45.2	23.9		683.5
MEAN +/- SD		616.4 154.1	169.9 46.0	97.3 43.5	48.9 25.5	35.0 10.2		967.5 217.5
7	1	176.5	81.8	66.1	18.9	29.0		372.4
7	2	204.1	61.1	64.4	28.3	28.4		386.3
7	3	546.6	147.6	85.3	112.4	25.5		917.4
7	4	498.0	143.7	123.2	48.4	19.0		832.3
MEAN +/- SD		356.3 193.0	108.5 43.7	84.7 27.3	52.0 42.1	25.5 4.6		627.1 288.2
8	1	603.9	287.6	120.1	13.8	21.0		1046.3
8	2	658.2	201.0	119.0	89.4	28.5		1096.2
8	3	459.7	103.0	103.2	47.7	230.8		944.3
8	4	734.8	151.1	67.3	70.7	29.9		1053.8
MEAN +/- SD		614.1 116.1	185.7 78.9	102.4 24.6	55.4 37.5	77.6 102.2		1055.2 64.4

TABLE 6. WEIGHT OF ROOT MATERIAL COLLECTED ON 7/31/69 FROM FIVE SOIL DEPTHS OF FOUR CORINGS ADJACENT TO EACH OF EIGHT WATERSHEDS. (GM/M²)

WATERSHED	CORING	SOIL DEPTHS (CM BELOW GROUND LEVEL)										TOTAL 0-80	
		0-10		10-20		20-40		40-60		60-80			
1	1	317.6		130.4		5.2		82.4		49.1		584.7	
1	2	437.1		179.0		8.3		68.1		51.5		744.1	
1	3	545.5		96.8		57.7		95.5		15.1		608.4	
1	4	317.5		95.1		50.2		40.4		17.8		521.0	
MEAN +/- SD		353.9	56.8	125.4	59.3	30.4	27.4	71.5	23.6	33.4	19.6	614.5	93.9
2	1	337.6		77.0		41.9		36.2		36.4		529.1	
2	2	718.1		139.0		68.7		73.7		14.4		1014.0	
2	3	212.6		60.3		38.6		55.2		69.4		436.0	
2	4	808.8		110.3		77.3		16.1		22.0		1034.5	
MEAN +/- SD		519.3	288.9	96.7	35.1	56.6	19.5	45.5	24.8	35.5	24.3	753.4	315.2
3	1	442.3		86.6		54.7		28.7		51.1		663.5	
3	2	391.2		81.7		59.0		16.8		27.5		576.2	
3	3	148.1		95.1		48.1		5.1		16.5		312.8	
3	4	263.0		158.1		71.6		33.5		23.0		549.2	
MEAN +/- SD		311.1	132.3	105.4	35.6	58.3	9.9	21.0	12.7	29.5	15.1	525.4	149.8
4	1	396.8		120.0		113.7		84.6		79.6		794.6	
4	2	307.5		172.2		73.0		153.0		35.5		741.3	
4	3	618.7		233.0		86.2		42.0		29.2		1008.1	
4	4	405.6		133.3		60.3		82.9		57.7		739.8	
MEAN +/- SD		432.1	132.0	164.6	50.7	83.3	22.8	90.6	46.0	50.3	23.2	820.9	127.4
5	1	301.7		151.2		77.6		33.6		11.2		575.3	
5	2	303.7		123.2		64.8		29.8		23.9		545.4	
5	3	306.4		81.5		75.9		56.7		27.1		547.7	
5	4	319.8		132.6		71.0		58.9		57.8		640.1	
MEAN +/- SD		307.9	8.2	122.1	29.5	72.3	5.8	44.8	15.2	30.0	19.8	577.1	44.1
6	1	390.5		164.8		118.0		56.7		33.5		763.6	
6	2	565.9		149.1		102.9		50.0		0.		867.9	
6	3	289.5		174.6		73.1		54.3		32.7		624.1	
6	4	424.3		162.3		25.1		57.5		54.4		723.7	
MEAN +/- SD		417.6	114.3	162.7	10.5	79.8	40.9	54.6	3.4	30.1	22.5	744.8	100.9
7	1	321.7		104.0		59.0		51.8		16.1		552.6	
7	2	537.2		135.0		89.1		3.5		26.5		791.5	
7	3	852.3		171.7		76.9		21.7		21.5		1144.2	
7	4	663.2		157.0		92.1		22.2		16.1		950.6	
MEAN +/- SD		593.6	222.8	141.9	29.5	79.3	15.0	24.8	20.0	20.1	5.0	859.7	200.5
8	1	663.5		138.0		74.1		16.5		27.0		918.9	
8	2	374.1		151.5		82.0		51.8		14.1		633.6	
8	3	302.4		139.2		99.9		69.8		4.1		615.4	
8	4	609.7		156.2		82.4		33.5		25.3		997.1	
MEAN +/- SD		509.9	220.5	141.2	10.5	84.6	10.9	37.9	22.6	17.6	10.7	791.2	195.3

TABLE 7. WEIGHT OF ROOT MATERIAL COLLECTED ON 8/13/69 FROM FIVE SOIL DEPTHS OF FOUR CORINGS ADJACENT TO EACH OF EIGHT WATERSHEDS. (GM/M²)

WATERSHED	CORING	SOIL DEPTHS (CM BELOW GROUND LEVEL)					TOTAL 0-80
		0-10	10-20	20-40	40-60	60-80	
1	1	1112.0	167.8	286.0	261.4	27.5	1954.8
1	2	876.7	199.0	141.1	35.9	55.8	1286.5
1	3	578.0	111.4	61.2	155.2	14.2	920.1
1	4	476.6	138.6	96.4	141.4	0.	853.0
MEAN +/- SD		760.8 289.2	154.2 37.7	146.2 98.8	148.5 92.2	18.9 15.0	1228.6 458.9
2	1	442.6	122.7	88.2	49.5	34.1	737.1
2	2	540.6	128.7	68.3	17.8	14.2	769.6
2	3	475.6	164.9	63.7	66.4	67.0	837.7
2	4	574.8	174.2	81.4	54.1	41.8	926.4
MEAN +/- SD		508.4 60.2	147.6 25.7	75.4 11.3	46.9 20.7	39.3 21.8	817.7 85.7
3	1	459.4	162.6	61.2	78.8	79.5	841.7
3	2	485.8	169.3	50.5	27.5	62.0	795.1
3	3	398.9	96.2	87.5	42.8	12.4	637.9
3	4	561.6	125.4	57.2	70.2	78.5	892.9
MEAN +/- SD		476.4 67.4	158.4 34.1	64.1 16.2	54.8 23.8	58.1 31.5	791.9 110.2
4	1	376.0	136.5	74.1	35.4	49.1	671.2
4	2	295.0	105.7	91.4	35.7	11.2	539.0
4	3	600.5	112.6	97.5	38.5	55.1	904.1
4	4	596.4	105.8	40.0	61.5	9.9	613.6
MEAN +/- SD		417.0 129.9	115.2 14.6	75.7 25.8	42.8 12.5	31.3 24.1	682.0 157.7
5	1	742.0	255.4	91.9	33.4	27.0	1149.7
5	2	551.1	122.7	187.3	20.0	6.1	897.3
5	3	429.5	123.9	82.4	19.7	29.3	684.8
5	4	137.2	73.9	60.1	10.3	7.8	289.3
MEAN +/- SD		465.0 253.5	144.0 77.9	105.4 56.2	20.8 9.5	17.6 12.3	752.8 362.9
6	1	657.6	369.3	46.6	84.6	15.4	1173.5
6	2	621.2	96.0	110.5	99.5	29.6	956.7
6	3	295.0	129.1	73.1	46.7	49.2	593.1
6	4	212.5	183.6	97.1	23.2	31.2	547.6
MEAN +/- SD		446.6 225.7	194.5 122.0	81.8 28.1	63.5 34.9	31.4 13.9	817.7 299.6
7	1	489.8	184.9	47.1	24.0	22.8	768.6
7	2	458.1	121.8	61.8	31.9	16.7	690.1
7	3	551.6	128.1	53.2	25.9	21.2	779.9
7	4	595.2	158.7	74.3	34.0	34.2	896.5
MEAN +/- SD		523.7 61.5	148.4 29.2	59.1 11.8	28.9 4.8	23.7 7.5	783.8 85.1
8	1	381.3	125.4	29.1	37.1	34.4	607.3
8	2	476.3	107.7	74.6	52.0	25.2	735.7
8	3	472.7	182.0	59.7	32.1	51.7	798.2
8	4	837.5	148.1	59.2	53.9	11.8	1110.6
MEAN +/- SD		542.0 231.9	140.8 32.1	55.7 19.1	43.8 10.8	33.8 16.7	813.3 213.7

TABLE B. WEIGHT OF ROOT MATERIAL COLLECTED ON 8/27/69 FROM FIVE SOIL DEPTHS OF FOUR CORINGS ADJACENT TO EACH OF EIGHT WATERSHEDS. (GM/M²)

WATERSHED	CORING	SOIL DEPTHS (CM BELOW GROUND LEVEL)					TOTAL 0-80						
		0-10	10-20	20-40	40-60	60-80							
1	1	962.0	186.2	151.0	94.4	15.3	1408.9						
1	2	855.8	415.3	115.8	70.7	44.0	1501.6						
1	3	752.5	178.1	104.5	164.1	122.4	1321.6						
1	4	807.8	250.0	71.9	65.1	84.9	1279.7						
MEAN +/- SD		844.5	88.9	257.4	110.1	110.8	52.6	98.6	45.5	66.6	46.9	1578.0	98.4
2	1	353.5	125.0	49.8	18.5	20.2	564.7						
2	2	405.4	109.9	57.8	53.5	5.8	612.4						
2	3	570.0	188.8	82.9	43.2	18.2	903.0						
2	4	399.0	131.0	69.9	21.1	27.1	648.1						
MEAN +/- SD		431.9	94.9	138.2	54.9	65.1	14.4	29.1	11.5	17.8	8.9	682.1	151.2
3	1	637.4	203.8	182.6	98.7	79.7	1202.2						
3	2	476.7	180.4	125.3	104.4	116.6	1003.3						
3	3	660.9	105.8	130.0	18.6	63.3	978.6						
3	4	432.7	81.5	89.0	63.0	44.1	710.3						
MEAN +/- SD		551.9	114.1	142.9	58.5	131.7	58.5	71.2	39.5	75.9	30.8	973.6	202.1
4	1	484.4	161.3	129.3	27.3	4.4	806.8						
4	2	502.7	105.6	90.7	31.0	16.4	746.5						
4	3	688.5	169.0	106.7	26.1	15.3	1005.6						
4	4	634.1	168.7	75.4	40.4	53.8	972.4						
MEAN +/- SD		577.4	99.6	151.2	30.6	100.5	23.0	31.2	6.4	22.5	21.6	882.8	125.8
5	1	245.8	104.6	26.9	14.3	21.1	412.8						
5	2	659.5	146.9	117.1	45.0	33.8	1002.4						
5	3	1026.3	862.4	113.2	40.2	47.4	2089.4						
5	4	537.0	173.2	69.6	26.1	28.4	834.4						
MEAN +/- SD		617.2	523.5	321.8	361.5	81.7	42.4	31.4	13.9	32.7	11.1	1084.7	714.2
6	1	629.9	200.7	125.7	29.3	9.6	995.2						
6	2	493.0	232.7	140.7	27.2	89.2	982.9						
6	3	1231.3	160.4	97.9	32.1	15.0	1536.7						
6	4	1463.8	193.7	106.3	26.6	25.3	1815.7						
MEAN +/- SD		954.5	467.1	196.9	29.7	117.7	19.3	28.8	2.5	34.8	36.9	1332.6	412.8
7	1	287.1	125.2	91.5	12.7	47.0	563.5						
7	2	631.0	173.2	80.3	30.1	40.7	955.3						
7	3	459.5	185.5	123.7	48.1	10.3	827.0						
7	4	646.7	125.8	85.7	16.3	6.3	880.9						
MEAN +/- SD		506.1	168.8	152.4	31.5	95.3	19.5	26.8	16.0	26.1	20.7	906.7	170.4
8	1	400.8	123.3	878.5	5.7	20.5	1428.8						
8	2	715.7	167.8	981.6	4.1	34.2	1903.4						
8	3	695.0	160.4	76.6	136.3	61.3	1129.6						
8	4	647.7	217.7	49.9	119.1	37.0	1071.4						
MEAN +/- SD		614.8	145.5	167.3	38.8	496.7	502.3	66.3	71.3	39.3	17.0	1383.3	393.4

TABLE 9. WEIGHT OF ROOT MATERIAL COLLECTED ON 9/10/69 FROM FIVE SOIL DEPTHS OF FOUR CORINGS ADJACENT TO EACH OF EIGHT WATERSHEDS. (GM M²)

WATERSHED	CORING	SOIL DEPTHS (CM BELOW GROUND LEVEL)					TOTAL 0-80
		0-10	10-20	20-40	40-60	60-80	
1	1	731.6	231.7	100.3	105.7	25.4	1194.6
1	2	829.5	273.9	139.2	46.4	35.4	1325.2
1	3	437.1	266.1	74.7	36.1	76.9	890.9
1	4	594.6	175.0	61.2	29.5	5.1	655.4
MEAN +/- SD		595.4 217.8	236.7 45.0	93.9 34.3	54.4 34.9	35.7 30.2	1016.0 501.1
2	1	427.6	180.7	96.9	69.4	34.0	807.6
2	2	444.2	182.7	105.1	132.9	13.3	879.2
2	3	691.7	234.8	116.3	107.6	25.7	1176.0
2	4	650.6	159.2	89.9	67.3	100.6	1045.5
MEAN +/- SD		548.5 132.6	189.1 32.4	101.8 11.7	94.0 31.9	43.4 39.1	976.8 166.1
3	1	592.0	142.8	72.0	62.8	31.7	901.2
3	2	594.3	129.4	44.6	82.3	23.6	875.2
3	3	566.1	104.5	44.4	70.7	21.7	807.4
3	4	726.4	153.9	89.8	31.1	26.9	1028.2
MEAN +/- SD		619.7 72.3	132.4 21.3	62.7 22.3	61.7 21.9	26.0 4.4	902.5 92.6
4	1	706.5	183.3	89.6	39.5	30.0	1046.9
4	2	776.6	175.2	91.7	198.7	102.6	1344.9
4	3	476.1	146.1	78.9	31.3	11.7	744.1
4	4	553.6	189.8	93.5	18.7	8.2	863.8
MEAN +/- SD		628.2 137.7	173.6 19.3	88.2 6.5	71.8 85.0	38.1 44.0	999.9 261.5
5	1	710.8	216.4	138.8	22.3	49.7	1138.1
5	2	635.3	182.9	106.3	177.1	95.6	1197.2
5	3	786.4	242.7	97.0	50.3	45.8	1222.2
5	4	804.8	158.3	125.7	34.5	17.5	1140.8
MEAN +/- SD		734.3 77.5	200.1 37.1	117.0 18.9	71.1 71.6	52.2 32.3	1174.6 41.8
6	1	742.4	209.3	148.1	57.0	60.7	1217.5
6	2	307.6	134.3	76.8	34.8	13.2	566.8
6	3	644.5	260.2	152.9	139.8	26.6	1224.1
6	4	744.1	227.7	149.3	115.4	35.3	1271.8
MEAN +/- SD		609.6 206.7	207.9 53.4	131.8 36.7	86.8 49.0	34.0 20.0	1070.0 335.4
7	1	826.9	239.6	159.7	82.6	61.8	1370.6
7	2	303.0	146.6	71.4	75.3	23.3	709.6
7	3	308.2	143.5	133.9	49.6	22.4	737.7
7	4	713.4	223.9	88.2	51.2	39.1	1115.8
MEAN +/- SD		580.4 224.0	189.4 50.5	113.3 40.6	64.7 16.7	36.6 18.4	983.4 317.7
8	1	821.1	137.9	74.9	50.5	37.9	1122.3
8	2	361.2	189.7	95.4	46.8	22.7	715.7
8	3	506.3	179.9	107.9	63.5	60.4	918.0
8	4	884.5	132.0	89.2	79.3	20.1	1205.2
MEAN +/- SD		643.3 250.5	159.9 29.1	91.9 13.7	60.0 14.7	35.3 18.5	990.3 210.3

FIGURE 3. NO GRAZING. ROOT MATERIAL FROM FIVE SOIL DEPTHS FOR EIGHT SAMPLING DATES. (A=0-10CM,B=10-20CM,C=20-40CM,D=40-60CM,E=60-80CM)

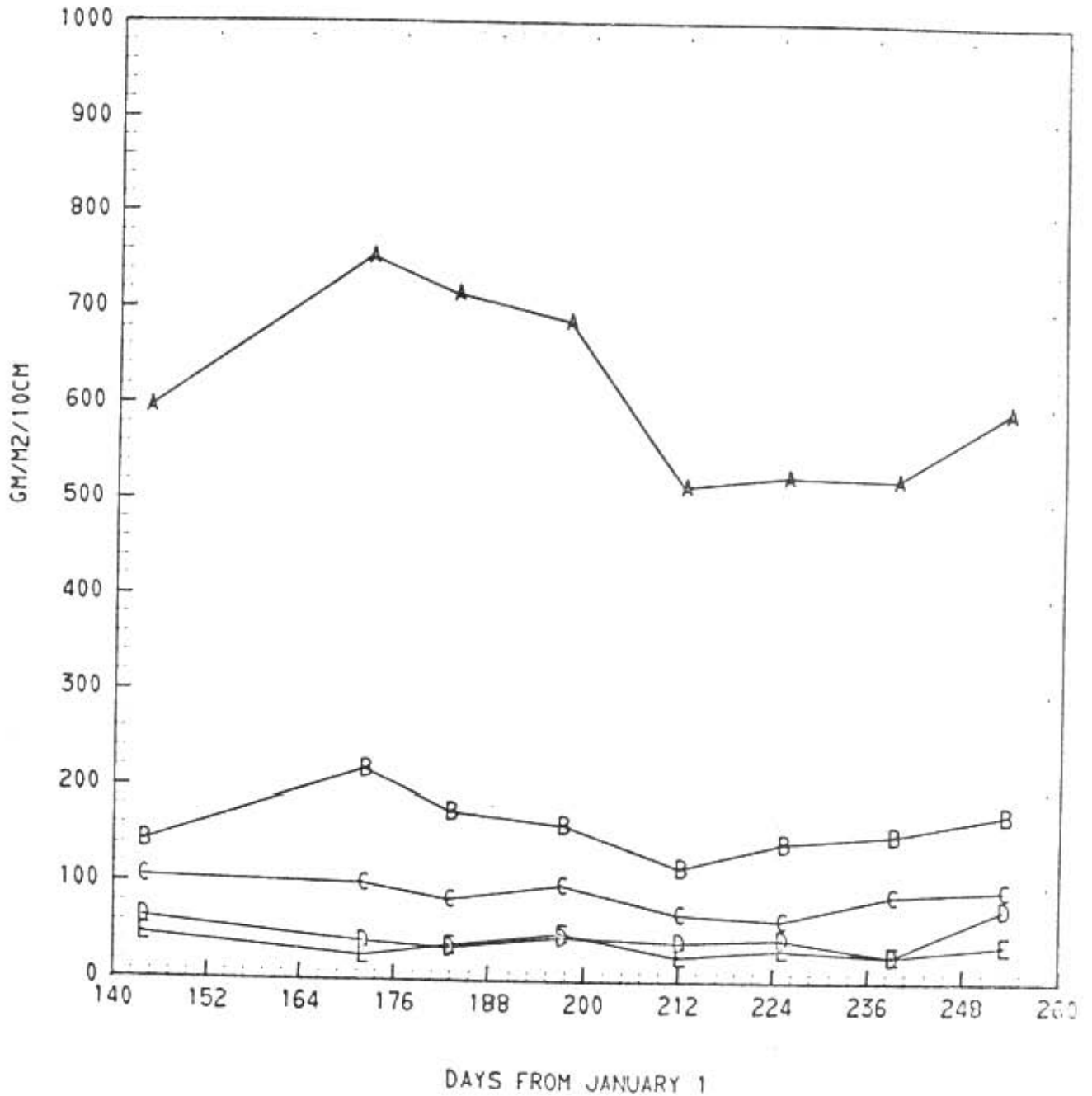


FIGURE 4. LIGHT GRAZING. ROOT MATERIAL FROM FIVE SOIL DEPTHS FOR EIGHT SAMPLING DATES. (A=0-10CM,B=10-20CM,C=20-40CM,D=40-60CM,E=60-80CM)

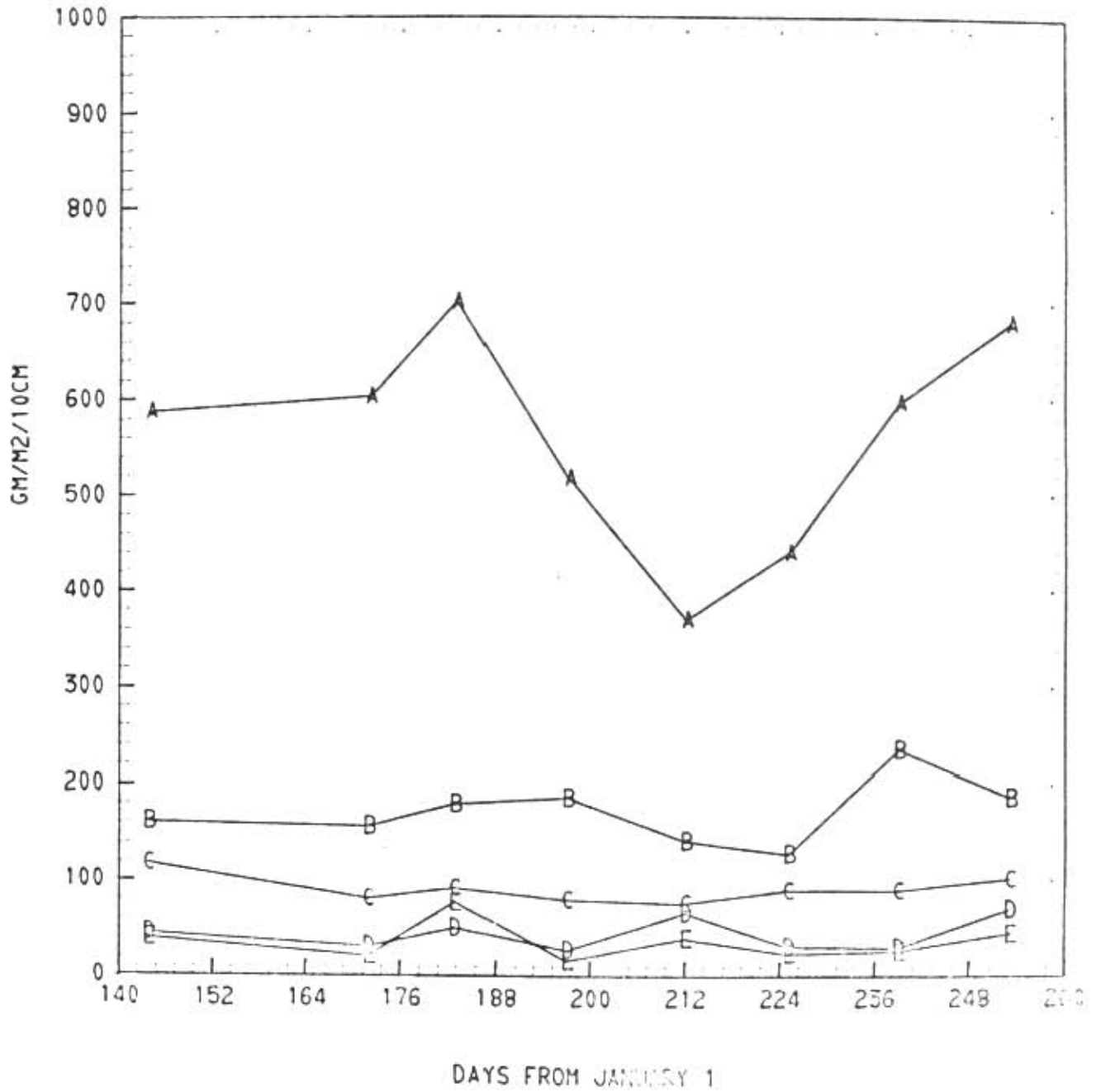


FIGURE 5. MODERATE GRAZING. ROOT MATERIAL FROM FIVE SOIL DEPTHS FOR EIGHT SAMPLING DATES. (A=0-10CM,B=10-20CM,C=20-40CM,D=40-60CM,E=60-80CM)

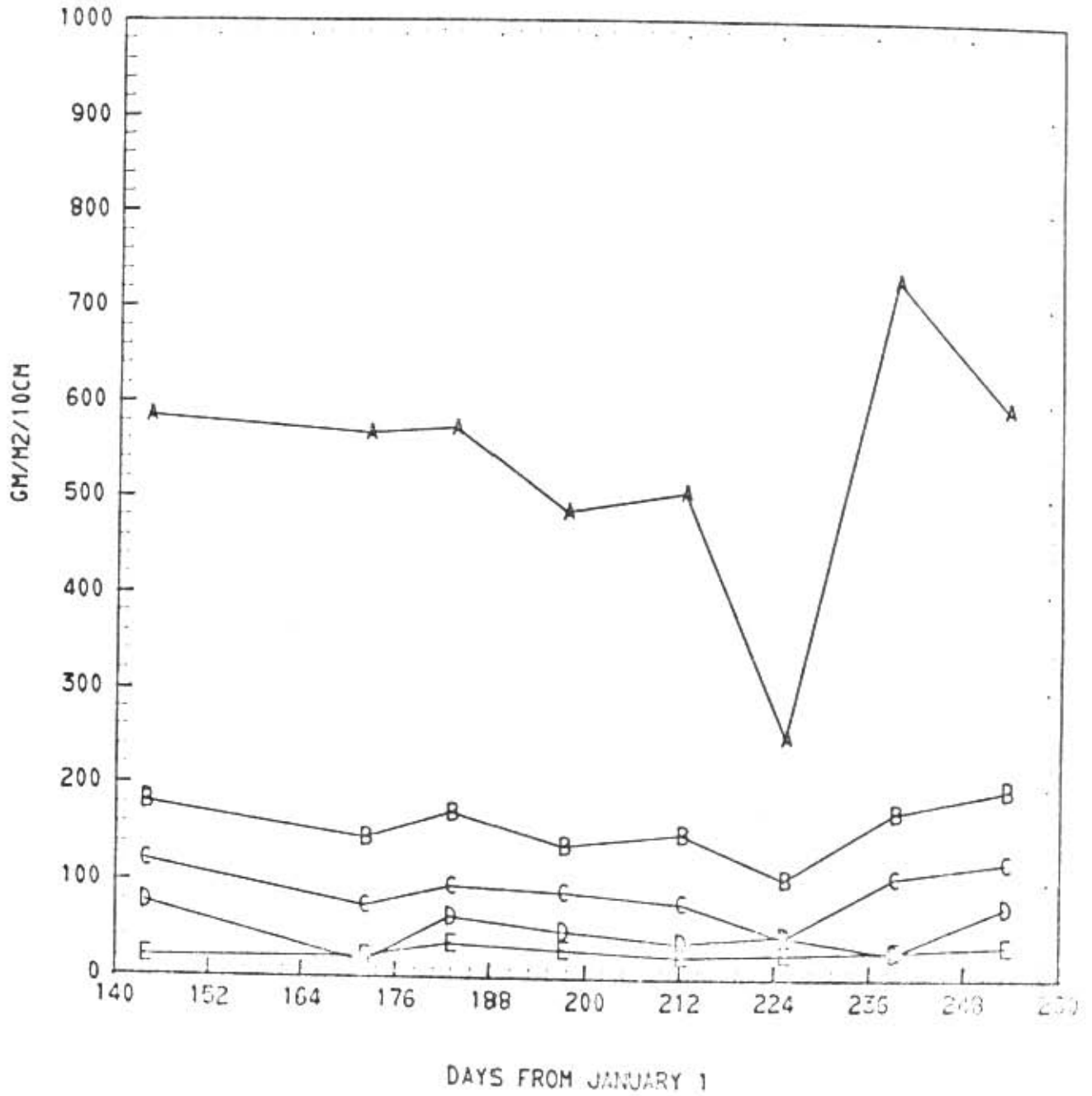


FIGURE 6. HEAVY GRAZING. ROOT MATERIAL FROM FIVE SOIL DEPTHS FOR EIGHT SAMPLING DATES. (A=0-10CM,B=10-20CM,C=20-40CM,D=40-60CM,E=60-80CM)

