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DECOMPOSITION OF ORGANIC MATERIALS IN GRASSLAND SOIL.

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ABSTRACT

Burial and retrieval of cellulose filter paper or of herbage materials, in conjunction with gravimetry and ignition, has been found an operationally simple procedure for studying microbial responses to the field environment. It has been observed that decomposition at the Pawnee Grassland Site occurs during bursts of microbial activity elicited by favorable conditions of moisture and temperature. During the growing season, decomposition of organic material occurred in a stepwise pattern, with intense activity following seasonal precipitation and plateaus of zero or negligible activity during seasonal droughts. No soil decomposer activity was observed during the winter months.

Data were also accumulated concerning both the suceptibility of the herbage of different plant species to decomposition and the changes in susceptibility within a given species during the course of the growing season. Grasses were distinctly more resistant to decomposition than were annual forbs. For individual species of either grasses or forbs, early season herbage collections were more susceptible to decomposition than were late season collections. Some good correlations have been observed concerning the fate of herbage materials in soil microbial systems in comparison with their fate in herbivore microbial systems.

INTRODUCTION

It is now quite generally recognized that soil organisms are responsible for one-half or more of the total annual energy flow derived from the photosynthetic productivity of plants. It is also true that the microbes constitute by far the largest biomass component, other than the primary vegetation, in a grassland ecosystem. How the microbial component operates in conjunction with other biome components is poorly understood. Perhaps the most important beneficial activity of the soil microflora is its role in the degradation of organic compounds and in the recycling of mineral nutrients needed by the growing plant.

Intensive studies have been made for controlling and achieving an understanding of decay processes having immediate economic impact, such as those involving the successful handling of foods and fibers. Equally intensive studies have not in general been made for the organic litter being returned directly to field and stream by plants and animals, where microbes operate as slaves of the environment rather than as slaves of man-made technologies.

Objectives of the current work were to measure rates of decomposition both of filter paper cellulose and of herbage materials, to determine the impact on such rates of ambient moisture and temperature, and to compare the fate of herbage materials in soil microbial and in herbivore microbial systems. Further objectives of the work have been to correlate the decomposition data obtained with other on-going research at the Pawnee Site and to accumulate data on microbial processes that hopefully can be used in the formulation of mathematical models of the grassland system.

EXPERIMENTAL

<u>Experiment I</u>: An exploratory experiment was conducted in the laboratory to determine the feasibility of a nylon-net, soil burial procedure for measuring decomposition of cellulose. Flat sheets (11 x 14 cm) of Whatman No. 1 filter paper were individually encased in nylon net whose mesh openings were 3 mm in diameter. The encased cellulose was buried horizontally at a depth of 3 cm in Ascalon sandy loam (0 to 10 cm, screened and mixed) collected from the Pawnee Site. Prior to burial, filter papers, in lots of nine each, were given one of the following treatments: (a) no treatment; (b) KH_2PO_4 and $MgSO_4$ in aqueous solution added to filter paper at a rate to provide one part each of P and S to 100 parts of filter paper carbon; (c) urea added at a rate of 10 parts N to 100 parts of filter paper carbon; and (d) the preceding two treatments in combination.

Incubations were at 25° C with soil moisture at 75 percent of moisture-holding capacity. Filter paper retrievals were made in triplicate after 2, 4, and 6 weeks. After oven-drying for 48 hours at 65° C, papers were weighed, ignited at 700° C for 2 hours, and the mineral residues remaining were weighed. W_r, the weight of filter paper recovered following soil exposure, was calculated as follows: $W_r = W_1 - W_2 - W_3$, with W_1 being the weight of oven-dry recovered filter paper and adhering soil, W_2 the weight of mineral residue after ignition of the W_1 sample, and W_3, the weight correction for the soil organic matter in the soil adhering to the recovered or W_1 filter paper. As the Ascalon soil employed had 3% organic matter, and as the filter paper itself was essentially ash-free, W_3 was routinely calculated as 0.03 of W_2.

The data accumulated are summarized in Table 1. The technique was found to be feasible in that it was responsive both to length of incubation and to the treatment variables. The data show that the rate of cellulose decomposition was accelerated, in Ascalon soil in the laboratory, in the presence of added N. Added P, S, and K, without added N, differed only slightly from the untreated control. In the presence of added N, there did appear to be a significant response to added P, S, and K.

Experiment II: Decomposition of buried filter paper cellulose was studied at the Pawnee Site during the period of October 1, 1969 to September 29, 1970. Burials were made on five dates; namely, Oct. 1, Nov. 21, and Dec. 4, 1969, and Feb. 23 and May 26, 1970. Data are given in five sub-units according to date of burial, e.g., IIa for the October 1 burials, and so on.

For IIa, there were 48 individual plots, each a square meter in size, and each given a nylon-net encased rectangle of filter paper, as specified in Experiment I, excepting that the nylon net employed for the field work had mesh openings of 0.3 cm instead of 3 cm. The field site employed was in the S½ of the E½ of Section 15, medium intensity grazing, Ascalon soil. Cellulose retrievals were made in triplicate on 16 dates of sampling as listed in Table 2. That table shows the occurrence of some microbial activity and cellulose loss in October, essentially zero loss and activity during November, December, and January; an accelerating rate of loss during February, March and April; and peak loss during May to about mid-June. Seasonal drought during June was reflected in a near cessation of decomposition, followed by resumption of decomposition following seasonal showers during July.

In part IIb, nine burials were made on Nov. 2, 1969, and retrievals were in triplicate after 32, 82, and 172 days. Cellulose loss (Table 3) was at the zero level during the period Nov. 2 to Jan. 23, and at a rate of roughly 4 percent per month for the following 3 months. The data are in good agreement with those of part IIa.

In part IIc, 26 burials were made on Dec. 4, 1969. As a treatment variable, 13 of the burials were given treatment (a) and 13, treatment (d), as described in Experiment I above. Retrievals were made in triplicate on Jan. 23, Apr. 10, and Apr. 24, and in duplicate on May 26 and June 9. The loss data tabulated in Table 4 show that there was an acceleration of cellulose loss during late winter and early spring from filter papers treated with N, P, S, and K.

In part IId, 48 filter papers were buried at a soil depth of 5 cm, 9 papers at 15 cm, and 9 at 25 cm. The deep burials were made as follows: sod rectangle cut and moved to one side; soil from 5 to 10 cm depth removed to container A; from 10 to 20 cm to container B; from 20 to 30 cm to container C; soil in each container pulverized and mixed by hand. Using C container soil, filter paper burial made at 25 cm, and similarly, B soil and A soil were used for the 15-cm and the 5-cm burials. Replacement of the top sod mat completed the deep burial procedure. Table 5 summarizes the cellulose loss observations obtained on assorted sampling dates during the eight months following the initial burials.

In part IIe, 21 filter paper burials were made at the 5-cm soil depth on May 26, 1970. Table 6 summarizes the cellulose loss observations obtained on assorted sampling dates during the following four months.

In part IIf, 32 filter paper burials were made at the 5 cm-soil depth on May 19, 1970. Four replicate burials were made for each of eight treatment conditions; each treatment was sampled in duplicate after 31 and 45 days of field exposure. The eight treatments employed are listed in Table 7. The mineral amendments, whether made singly or in combination, were made at the following rates: nitrogen, 10 parts per 100 parts of filter paper carbon; phosphorus, 1 part per 100 parts of filter paper carbon; sulfur, same as phosphorus. Table 7 summarizes the cellulose loss observations after 31 and 45 days of field exposure.

<u>Experiment III</u>: The plant material used in this study was "Harris grass"; it has been keyed as material 2 (cellulose filter paper being material 1) on the raw data sheets. Material 2 was assembled by John O. Harris, Kansas State University, Manhattan, for distribution to several workers in the comprehensive network in early 1970. The general idea was to find out whether or not workers at different locations could observe either uniform decomposition rates or else rates that were largely unique for their location, and if so, could the individualistic rates be linked to differing techniques of exposure, to differing microclimates (temperature, moisture), or to differing soil environments (soil pH, texture, fertility). As a group effort, this study was meant to be exploratory, and no detailed experimental plan was drawn up for general use.

Only limited work was done with the "Harris grass" at the Pawnee Site. Twenty-one nylon-bagged samples, each containing 2 grams of the plant material, were buried at a depth of 5 cm on May 19, 1970. Retrievals were made in triplicate on seven different sampling dates. Decomposition losses observed are summarized in Table 8.

Some additional observations were made in the laboratory. It was found that the "grass" material, using the same coarse chopping as was employed for the field burials and which provided grass segments ranging from 5 to 20 mm in length, showed a cold-water soluble fraction of 10.5%, a hot-water soluble fraction of 15.5%, and a hot 3% HCl soluble fraction of 22.0%. Also, the grass showed a decomposition loss of 51% when buried in laboratory soil and incubated for 14 days under optimal moisture and temperature conditions. Inspection of Table 8 will show that it took 133 days of field exposure at the Pawnee site in order to obtain this same amount of loss by decomposition.

Experiment IV: This experiment involved decomposition studies of 93 "Hansen" plant samples (keyed collectively as material 3) in Pawnee field burials and in laboratory soil burial experiments. This work was carried out in cooperation with Richard Hansen and Dennis Pendleton, and it is being reported upon separately in a technical report entitled, "The Degradation of Plant Materials in Soil Microbial and in Herbivore Microbial Environments," by D. F. Pendleton, R. M. Hansen, and F. E. Clark.

Inasmuch as this writer (F.E.C.) has compiled the raw data sheets for the decomposition studies carried out in the soil microbial environments, and inasmuch as that data is being filed in the Pawnee data bank, it seems desirable to include here an identification table for the plant samples employed in order to insure that any individual interested in the soil phases of the work will have access to the appropriate sheets in the data bank. Table 9 constitutes such an identification table.

In closing the data presentation part of this report, some reference should be made to the data sheets that have been compiled in the course of this past year's work. Such sheets are being filed in the central data bank for the Pawnee Site. To exemplify the type of data on file, one specific sheet (sheet No. 6) is shown in facsimile as Table 10. Given in Table 11 is a key showing data sheet numbers grouped according to the experimental write-ups summarized in the preceding pages of this report.

GENERAL DISCUSSION

What have the Pawnee cellulose burials told us? More than a year ago this writer took the position that making plate counts of bacteria and fungi or making other determinations involving primarily laboratory manipulations of disturbed and transported soil were of little value in pinpointing what was actually happening in the field. I suggested using cellulose-nylon net burials as an alternative and exploratory approach. During the past year, my suggested procedure has been variously assailed as faulty because it involves some very slight disturbance of field soil, or because it measures decomposition of a material (pure cellulose) that does not occur as such in the field, or because it measures decomposition below ground but not above ground where the epigeal plant litter occurs.

At the risk of belaboring the obvious, let me say here that I at no time implied that measuring cellulose losses was a means of measuring plant litter losses. In using pure cellulose, I was not especially concerned with the actual rate of cellulose decomposition *per se*, but rather, I was concerned with finding out when and to what extent the soil microflora was showing activity under field conditions. For that specific purpose, the cellulose procedure has been reasonably satisfactory. Perhaps what it has told us is no more than what could have been predicted from the literature, but certainly it has told us far more than innumerable plate counts could have done. The cellulose loss data show that there is no soil microbial activity at the Pawnee site during the winter months when the ground is frozen.

There is accelerating activity as the soil warms up in the spring. The summer and fall seasons are characterized by steps or spurts of activity coinciding with periods of favorable soil moisture immediately following precipitation events.

The cellulose burials at Pawnee have yielded the general orientation that was desired, and I see no value in making any more cellulose burials at that site. Perhaps some above-ground exposures of cellulose paper at Pawnee would be worthwhile. Cellulose loss data, to the extent that it is not already being gathered, could also be desirable for the comprehensive network sites to the extent necessary to provide information at those sites comparable to what has been gathered for the Pawnee site. It might also be desirable to know whether or not distinctly different microfloras exist at the several different sites, including both the intensive and the comprehensive.

Much the same can be said for burials of plant materials. What must be kept in mind in the course of burial studies with plant litter, regardless of whether such litter is mixed freely with the soil or is nylon-bagged, is that just as with pure cellulose, one is measuring the suitability of the ambient environment for microbial activity and also the rate of loss of an introduced and artificial component. One is not measuring the rate of loss of the soil organic matter or the below-ground root material as it occurs in the field. Those who think otherwise had best confine their efforts solely to smoking grass.

The data compiled on the comparative decomposability of different plant species and of individual species at differing stages of plant maturity are of interest primarily because they show such good correlation with the comparative digestability of the same plant materials as measured in the fistulated rumen studies. Apparently, the same components, and rough ly the same fractional part of the total herbage material, are destroyed in soil microbial systems as are destroyed in herbivore microbial systems. This raises the intriguing question of does it really make much difference, insofar as the residual debris is concerned, whether the herbage is or is not consumed by either large or small mammals. Perhaps we now need to give some study to that portion of the litter that goes phlatt, phlatt, phlatt as it hits the ground. In short, we need to recognize a dropping dead compartment as well as a standing dead compartment when we concern ourselves with grassland litter.

In closing, let me again reiterate my opinion that simple substrate measurements, that is, measuring gains or losses of specific components or of specific materials, can give much meaningful information on soil microbial processes involving both rate and time factors. Ecologists have traditionally been concerned with population numbers and with biomass. Microbial ecologists, in their zeal for elaborate measurements and expensive instrumentations, ofttimes appear to be more dedicated to biomasochism than to biomass.

Table 1. The extent of cellulose decomposition at 2, 4, and 6 weeks as observed in unamended and amended Ascalon soil.

Soil treatment	Percentage of added cellulose lost after:		
	2 wks	4 wks	6 wks
None	26.2[1/]	52.5	89.7
P, S, K added	24.6	50.8	85.6
N added	55.1	70.2	93.9
N, P, S, K added	74.4	81.0	94.6

[1/] Values given are the averages for the three replicates. The raw data has been submitted to the data bank; statistical analysis of that data has not as yet been undertaken.

Table 2. Cellulose retrieval dates and losses measured for filter papers buried 5 cm deep at the Pawnee Site on October 1, 1969.

Dates of retrieval of buried filter papers	Days of exposure in field soil	Loss of initially added cellulose, %
Nov. 2, 1969	32	3.3
Nov. 21	51	3.8
Dec. 4	64	3.3
Jan. 2, 1970	93	4.4
Jan. 23	114	4.3
Feb. 23	145	9.7
Mar. 28	178	14.9
Apr. 10	191	15.9
Apr. 24	205	19.9
May 19	230	37.4
May 31	242	51.3
June 9	251	59.8
June 16	258	71.3
June 26	268	73.8
July 7	279	74.6
July 28	300	84.6

Table 3. Cellulose retrieval dates and losses measured for filter papers buried November 2, 1969.

Dates of retrieval of buried filter papers	Days of exposure in field soil	Loss of initially added cellulose, %
Dec. 4, 1969	32	0
Jan. 23, 1970	82	0
Apr. 24, 1970	172	12.3

Table 4. Cellulose retrieval dates and losses measured for filter papers buried December 4, 1969

Dates of retrieval of buried papers	Days of exposure in field soil	Loss of added cellulose, %	
		Control	N,P,S,K added
Jan 23, 1970	50	0.3	0.3
Apr. 10	126	5.4	25.7
Apr. 24	140	11.3	33.6
May 26	173	30.4	80.0
June 9	187	52.3	85.4

Table 5. Cellulose retrieval dates and losses measured for filter papers given soil burial on February 23, 1970.

Date of retrieval of buried papers	Days of exposure in field soil	Losses of cellulose, in %:		
		at 5 cm	at 15 cm	at 25 cm
Mar. 28, 1970	33	1.3		
Apr. 10	46	1.6		
Apr. 24	60	4.6		
May 19	85	30.2	27.9	26.9
May 31	97	27.7		
June 9	106	33.8		
June 16	113	30.5	39.0	65.6
June 26	123	34.9		
July 7	134	47.2	55.4	62.3
July 28	155	63.9		
Aug. 6	164	67.9		
Aug. 21	179	72.6		
Sept. 29	218	66.2		

Table 6. Cellulose retrieval dates and losses measured for filter paper given soil burial on May 26, 1970.

Dates of retrieval of buried papers	Days of exposure in field soil	Losses of cellulose, %
June 16, 1970	21	11.0
June 26	31	14.5
July 7	42	25.1
July 28	63	43.3
Aug. 6	72	59.1
Aug. 21	87	59.9
Sept. 29	126	58.7

Table 7. Losses of cellulose from filter papers given mineral fertilizer treatments at time of burial on May 19, 1970.

Treatment employed	% loss after 31 days (retrievals on June 26)	% loss after 45 days (retrievals on July 10)
none	14.1	13.8
P, S	18.3	20.8
N	49.2	53.4
N, P, S	68.6	69.1
S	17.0	18.5
P	14.6	14.8
N, S	50.6	53.5
N, P	51.6	55.4

Table 8. Decomposition losses of "Harris grass" at the Pawnee Site.

Dates of sample retrievals	Number of days of soil burial	Loss of plant material during soil burial, %
May 31, 1970	12	25.7
June 9, 1970	21	33.3
June 16	28	34.5
July 7	49	40.7
July 28	70	47.0
Aug. 21	94	49.2
Sept. 29	133	51.5

Table 9. Key to identification numbers of "Hansen" plant samples. These numbers identify the specific plant samples for which data are recorded on data sheets 27-42, inclusive, Pawnee data bank.

Date of sample harvest	*Bouteloua curtipendula*	*Bouteloua gracilis*	*Buchloe dactyloides*	*Sporobolus cryptandrus*	*Kochia scoparia*	*Chenopodium album*	*Salsola kali*	*Aristida longiseta*	*Helianthus annuus*	*Agropyron smithii*
<u>1967</u>										
May 19	1	14	27	40	53	--	--	86	--	97
June 13	2	15	28	41	54	66	77	87	--	98
July 7	3	16	29	42	55	67	78	--	89	--
July 20	4	17	30	43	56	68	79	88	90	99
Sept 12	5	18	31	44	57	69	--			
Oct. 4	6	19	32	45	58	70	--			
<u>1968</u>										
June 21	7	20	33	46	59	--	80			
July 5	8	21	34	47	60	71	--			
July 17	9	22	35	48	61	72	81			
Aug. 12	10	23	36	49	62	73	82			
Sept. 3	11	24	37	50	63	74	83			
Sept. 16	12	25	38	51	64	75	84			
Oct. 30	13	26	39	52	65	76	85			

Table 10. Data sheet No. 6, exemplifying type of data on file. This particular sheet shows the raw data for cellulose retrievals made in triplicate on four separate dates, representing 114, 145, 178, and 191 days of soil exposure.

1-2	3-4	5-7	8	9	10	11-12	13-15	16-17	18-19	20-21	22-23	24-25	26-27	28-30	31	32-33	34-37	38-41	42-45	46-49	50-53	54-57	58-61					
Data type	Site	Initials	Treatment	Material	Conditions	Depth-Cm.	Soil O.M.%	Burial: Day	Mo.	Yr.	Recovery: Day	Mo.	Yr.	Days buried	Replicate	Retr.-Ign. days	Original Wt.	OD Recovery	Wt. after Ign.	Loss on Ign.	Soil O.M. Corr.	Net recovery	% Recovery			Mean recovery	S.D.	
40	11	FEC	3	1		05	3.0	01	10	69																		
1Q, 4Q, 7Q Soil not frozen but temperature at 7 cm reads zero. 0-7 cm 2.69% moisture 7-14 cm 6.45% moisture											23	01	70	114	1	3	1.30	1.95	0.70	1.25	0.02	1.23	94.6					
															2	3	1.30	1.45	0.19	1.26	0.01	1.25	96.2			95.7		
															3	4	1.30	1.44	0.18	1.26	0.01	1.25	96.2					
4B, 7H, 7N Temperature 5° at 5 cm, 3.5° at 15 cm, and 3° at 25 cm. Moisture 2% to 5%.											23	02	70	145	1	4	1.30	1.42	0.27	1.15	0.01	1.14	87.7					
															2	4	1.30	1.39	0.18	1.21	0.01	1.20	92.3			90.3		
															3	37	1.30	1.26	0.08	1.18	0.00	1.18	90.8					
7B, 4G, 4M Some frost crystals at 5 cm. at 10 cm, temp 0-5° 2-7 cm, 13.4% soil moisture											28	03	70	178	1	02	1.30	1.76	0.62	1.14	0.02	1.12	86.1					
															2	02	1.30	1.66	0.53	1.13	0.02	1.11	85.3			85.1		
															3	02	1.30	1.60	0.50	1.10	0.01	1.09	83.8					
7E, 1G, 4L Temperature at 5 cm = 4° Moisture in range of 10-12%											10	04	70	191	1	03	1.30	1.81	0.74	1.07	0.02	1.05	80.8					
															2	03	1.30	1.58	0.47	1.11	0.01	1.08	83.1			82.1		
															3	03	1.30	2.25	1.15	1.10	0.03	1.07	82.3					

Table 11. Key to data sheets showing their relationship to Experiments I - IV as described in this technical report.

Data sheet numbers	Associated Experiment		Brief title for the associated experiment
1 - 4 incl.	Experiment	I	Cellulose burials in laboratory soil.
5 - 8	Experiment	IIa	Cellulose at Pawnee Site, burials made Oct. 1, 1969.
9	Experiment	IIb	Ditto, burials made Nov. 2, 1969.
10-11	"	IIc	Ditto, burials made Dec. 4, 1969.
12-17	"	IId	Ditto, burials made Feb. 23, 1970.
18-19	"	IIe	Ditto, burials made May 26, 1970.
20-23	"	IIf	Ditto, burials made May 19, 1970.
24-26	"	III	"Harris" grass samples.
27-42	"	IV	"Hansen" plant samples.