Technical Report No. 233

CARBON DIOXIDE EVOLUTION AND CELLULOSE, ROOT, AND LITTER DECOMPOSITION IN SOILS AT THE COTTONWOOD SITE, 1972

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GRASSLAND BIOME

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ABSTRACT

The rate of mineralization as measured by carbon dioxide evolution from soil and decomposition of litter from litter bags and cellulose from filter paper sheets was measured. Seasonal fluctuations are apparently related to temperature and soil water variations. We were not able, however, to show good correlation between soil water content, temperature, and decomposition rates. This may be from microecosystem variation and, therefore, may require more intensive sampling.

Both root and filter paper samples gained weight. This gain was from growth of roots and fungal mycelium into the samples.

Most of our methods of measuring decomposer activity in soil are very crude and need to be refined and/or replaced.

CARBON DIOXIDE MEASUREMENT

Introduction

Measurement of CO_2 released from the soil is generally the accepted measure of metabolic activity of soil microorganisms. It is also the most commonly used means of measuring the rate of "soil respiration." This respiration includes heterotrophic breakdown of organic matter by microbes as well as respiration by plant roots, nematodes, and other soil inhabitants. Eventually there will be a need to determine the role of each component of the population in total soil respiration. For now, the total soil respiration is sufficient to measure the activity and thus energy use of the decomposers in this ecosystem.

Materials and Methods

The most common method of measuring CO_2 evolution from the soil is absorption of the CO_2 in an excess of known strength alkali solution followed by back titration with a standard acid. The method is outlined by Coleman (1971).

Aluminum irrigation pipes, 10.16 cm in diameter and 27 cm in length, were driven into the soil to a depth of 17 cm. The 10 cm protruding above the ground formed a canopy in which vials of KOH could be placed for absorption of CO_2. The CO_2 canopies were emplaced on 8 April 1972. Emplaced were 24 canopies, 12 in the low range condition and 12 in the high range condition. The area inside the protruding aluminum containers was clipped of all photosynthetic material before the emplacement of the canopies as well as on sample dates before emplacement of the KOH for absorption of CO_2. A 20-dram plastic container containing 20 ml of 0.6 M CO_2-free KOH was placed in the canopy. The canopy was capped with plastic and covered with aluminum foil to shield from heat trapping. After a 24-hr period, the KOH vial was removed, capped, and taken back to the laboratory for titration. Four control samples of the same volume as the experimental samples were set up also--two for each condition. At the time of retrieval the temperature directly above 8 cm below ground level was recorded. Samples of the soil for percentage of water were also taken from both high and low range condition.

Results and Conclusions

All CO_2 is expressed as grams $CO_2 \times 24\ hr^{-1} \times m^{-2}$. Results of CO_2 investigations are depicted graphically.

Generally the low range condition produced more $CO_2 \times 24\ hr^{-1} \times m^{-2}$ than did the high range. This may be explained in terms of root biomass. The low range had considerably more root biomass than did the high range. In measuring the CO_2, the root respiration is also included; and, if there is a higher root biomass present in one condition than in the other, then the condition with more root biomass would presumably "respire" more and evolve more CO_2.

Fig. 1 depicts the results of CO_2 evolution. In both conditions there is a peak in CO_2 evolution occurring in May followed by a gradual decline. It has been suggested that perhaps the graph of CO_2 depicts the death of part of the ecosystem and is not quantitative for the actual production of CO_2. In emplacement of the cylinders into the ground, some roots were severed. Thus the production of CO_2 may come not so much from microbial activity on the natural mulch, but from the death and the resulting decomposition of the severed roots. Samples of root biomass will be taken from both inside and outside the cylinders as soon as possible. Comparisons will be made as to any differences in root mass from inside the canopy vs. root mass outside the canopy. The results will show if there was any difference in CO_2 production due to severed root decomposition

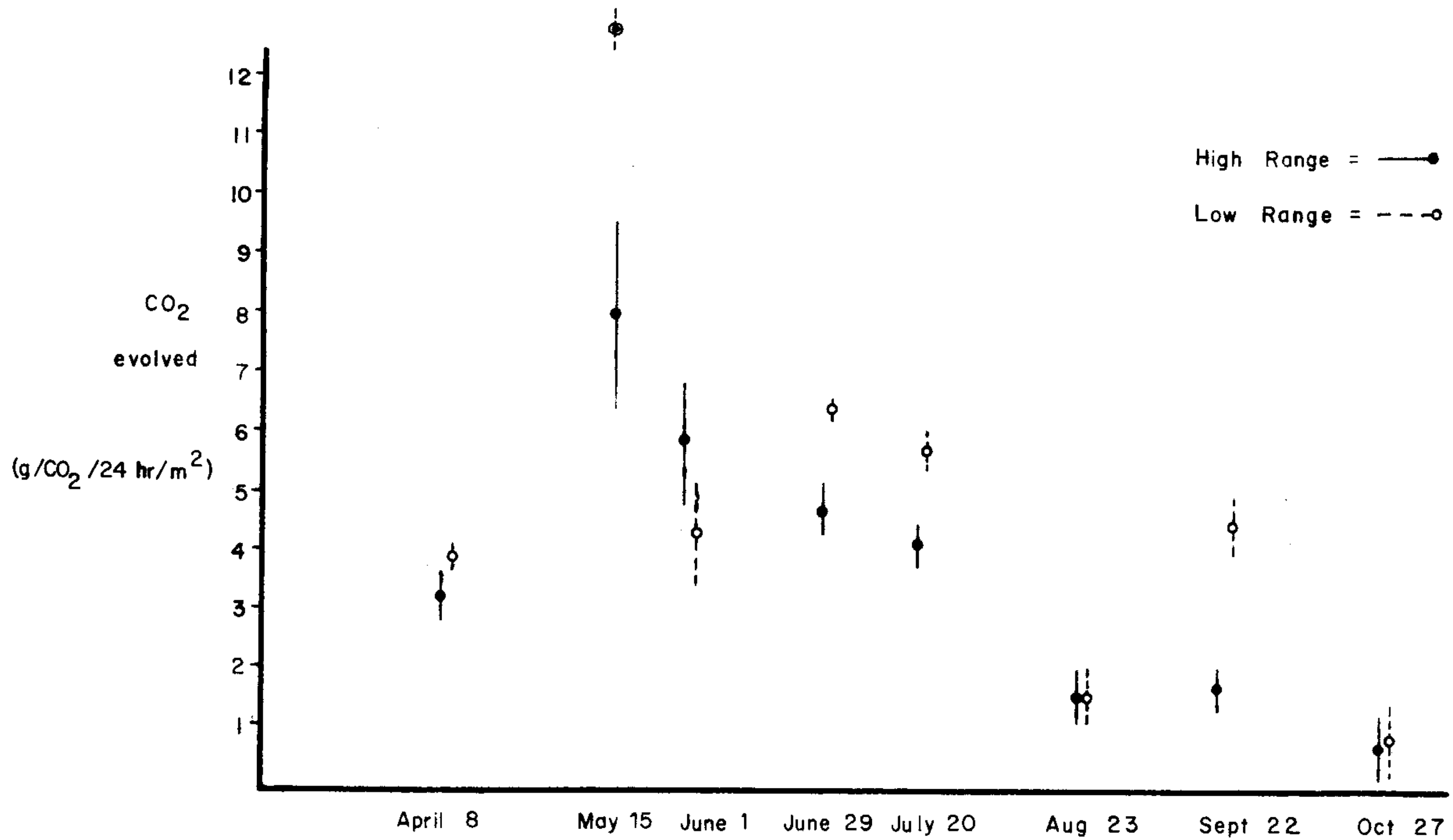

Fig. 1. CO_2 evolution from soil.

if the canopies were emplaced permanently in the soil or if they were emplaced before every CO_2 trial. Also, work is being done to detect if there is any difference in CO_2 evolution caused by removal of the photosynthetic material. It was suggested that if the photosynthetic material is removed before every CO_2 trial, then the natural condition of the site would be altered the same as that of a site which is exposed to heavy grazing. Results of the lab experiments should show if it is necessary to remove the photosynthetic material before the CO_2 collection or not.

Fig. 2 shows the percentage of soil water for the period that CO_2 evolution was measured. The graph for the high range corresponds roughly with the graph for the low range. Peaks of soil water occurred in May and June and again in August. There was no real basic correlation between rainfall and CO_2 production. However, rain presented a problem at Cottonwood, because a substantial rainfall filled the open cylinders with water. Evidently, because of the soil type, water would not drain from the canopies so the water had to be bailed out of the cylinder before CO_2 production could be sampled. This condition definitely would have a detrimental effect on CO_2 production and the CO_2 observed would not be quantitive.

Fig. 3 depicts the temperature of the soil at a depth of 8 cm for the sampling period. The temperature is quite similar in both conditions. The highest temperature occurred in late June and then tapered off for the remainder of the summer. While the CO_2 evolution reached its peak in mid-May, the temperature and soil water had not. A multiple regression was run using CO_2 production as the main variant and temperature, percentage of soil water, and time as the covariants. The regression coefficient was 0.42. Thus the relationship between temperature, percentage of soil water, and CO_2 evolution was weak under our conditions.

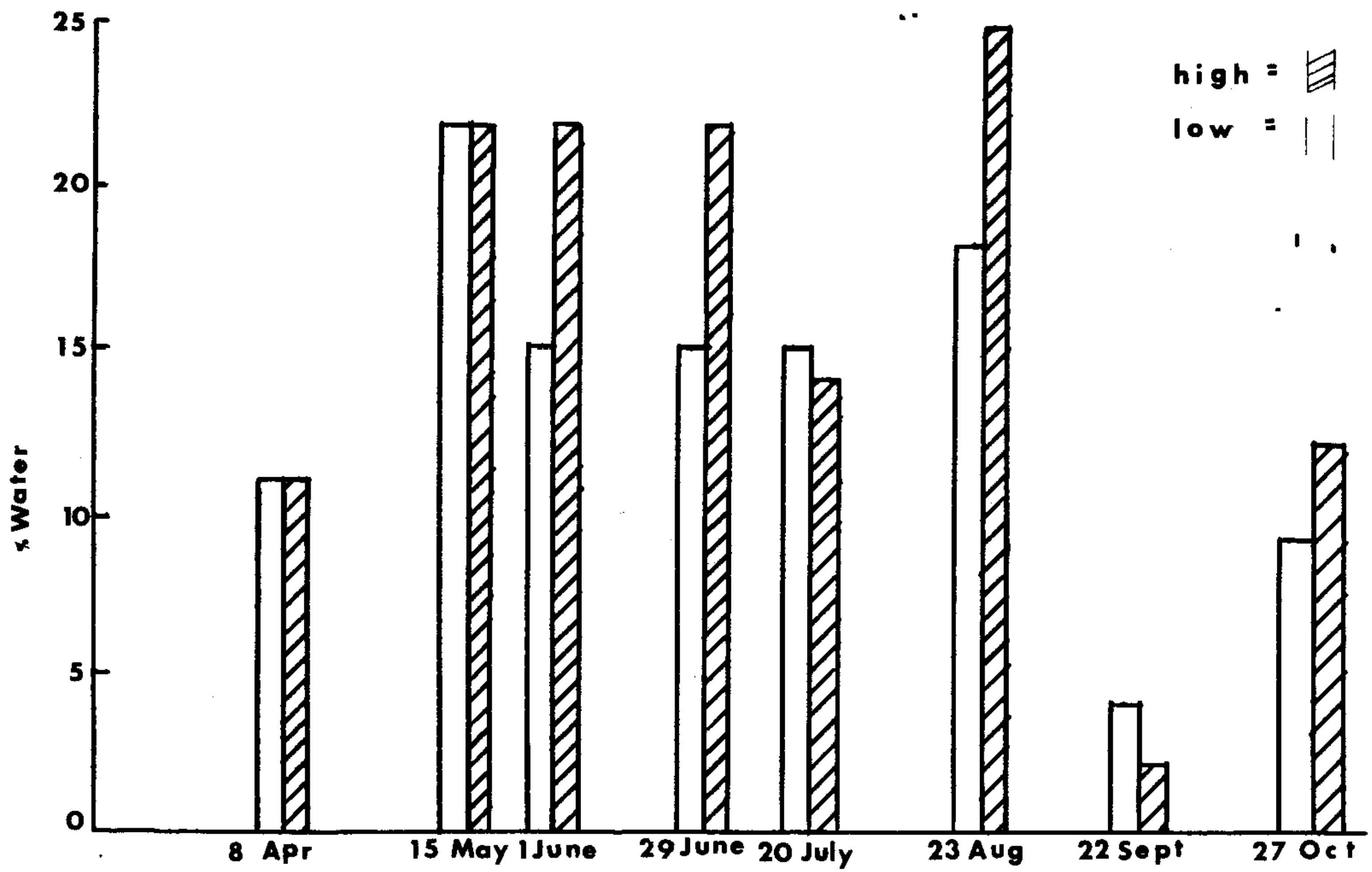

Fig. 2. Soil water content at sample dates.

Fig 3

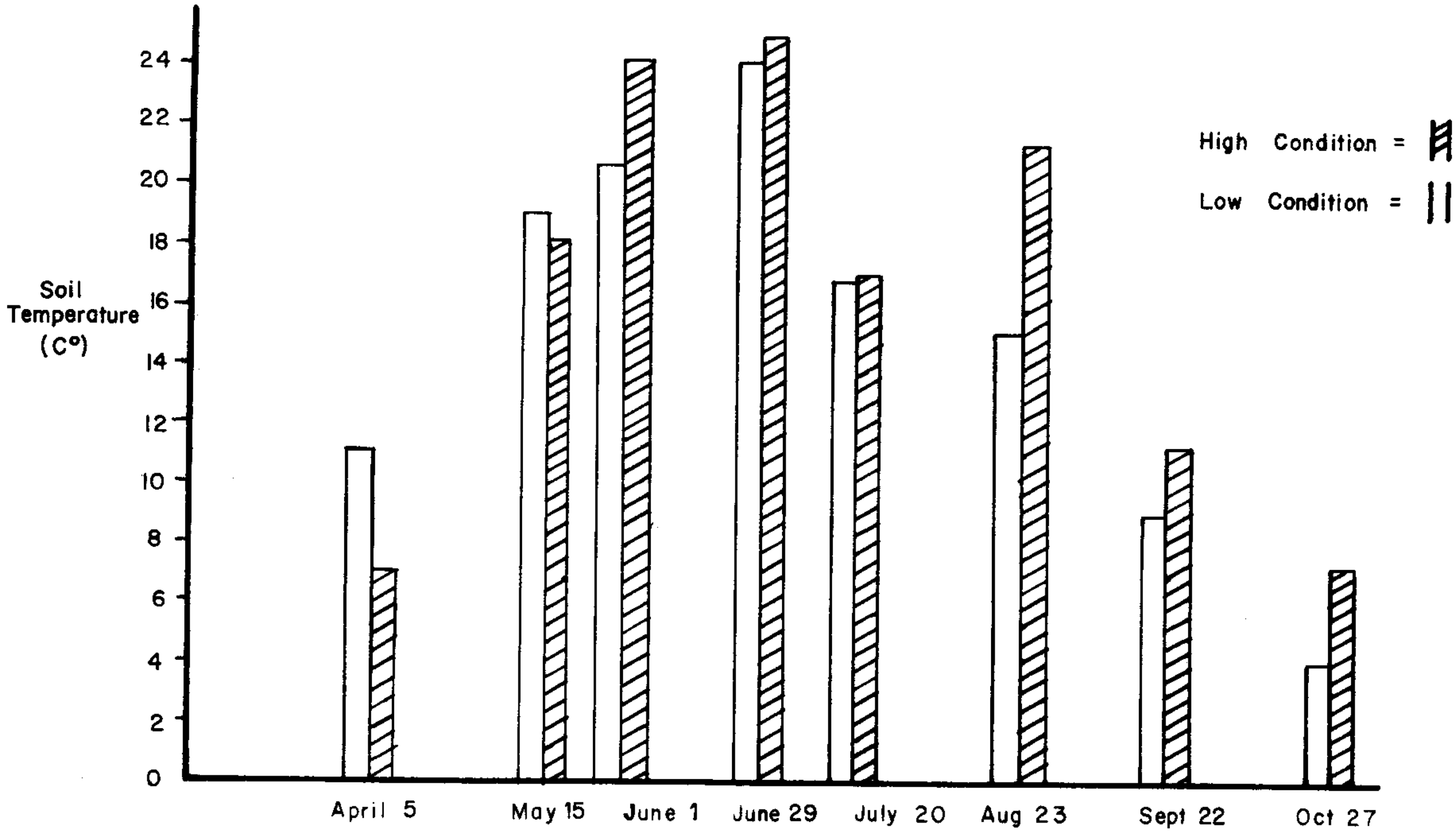

Fig. 3. Soil temperature at sample dates.

CELLULOSE, ROOT, AND LITTER DECOMPOSITION

Experimental procedure for 1972 was similar to sampling done at Cottonwood for 1971 (Pengra, 1972). Cellulose filter paper and standard litter representative of the condition were used as a method of determining rates of decomposition. This year the litter samples were composed of litter taken from the respective high and low conditions sites as sampled in September of 1970.

Materials and Methods

Representative samples of litter from both the high range and low range were sewn into bags of nylon net with a mesh size of 20 squares/cm^2.

The samples were collected in September of 1970 so the litter should be the same as that which was still on the plots. The nylon bags containing the litter were emplaced on 8 April 1972. Twenty bags each were placed below ground and above ground for each transect. There were three transects per replicate and two replicates per condition. There were two conditions --a high range and a low range. Also 20 nylon bags containing filter paper (Whatman No. 1) were placed below ground for each transect on 17 May to sample pure cellulose decomposition. Samples of roots were buried. Five bags were buried in the low range, and six in the high range.

On each sample date two bags of both above- and belowground litter and two bags of cellulose were pulled from each transect. Root samples were taken three times during summer.

All prepared bags were weighed and the weight of the nylon net was subtracted from this. Thus, for each bag, the weight of the litter on a dry basis was known before emplacement. Upon retrieval the bags were transported to the laboratory and decomposition of the litter was determined by weight loss.

Soil samples were taken from both the high range and the low range for determination of organic soil content. Organic content of the high range was found to be 20%, the low range 15%. Also samples were taken of the litter to determine the organic content of the material. For the high range where western wheatgrass (*Agropyron smithii* Rydb.) is the predominant grass, the percentage of organic matter of the litter was 90.6%. These correction factors were placed in the formula:

(mulch wt. upon retrieval) - [(soil ash wt.) + (organic material of the soil lost) - (% mineral content of mulch)] = (actual mulch weight).

The weight of the mulch upon emplacement minus the actual mulch weight will equal the amount of decomposition of that particular litter.

The procedure for determining decomposition of filter paper is basically the same as that for determining decomposition of mulch. However, filter paper is nearly 100% organic material; thus the mineral content of the filter paper can be disregarded.

Results and Conclusions

All decomposition is expressed in grams lost per gram of original material per sample date. Results are expressed graphically.

Fig. 4 shows the decomposition of aboveground mulch for the period 8 April to 27 October. The graph depicts a more or less linear relationship between percent decomposition and time. Several points show a decrease in percentage of decomposition from the sampling date preceding it. This can probably be explained as the result of a change in microclimate from site to site. The composition of litter samples may also vary in lignin content, etc. This would give a variability in decomposition. In many cases two samples would be pulled adjacent to each other.

Fig 4

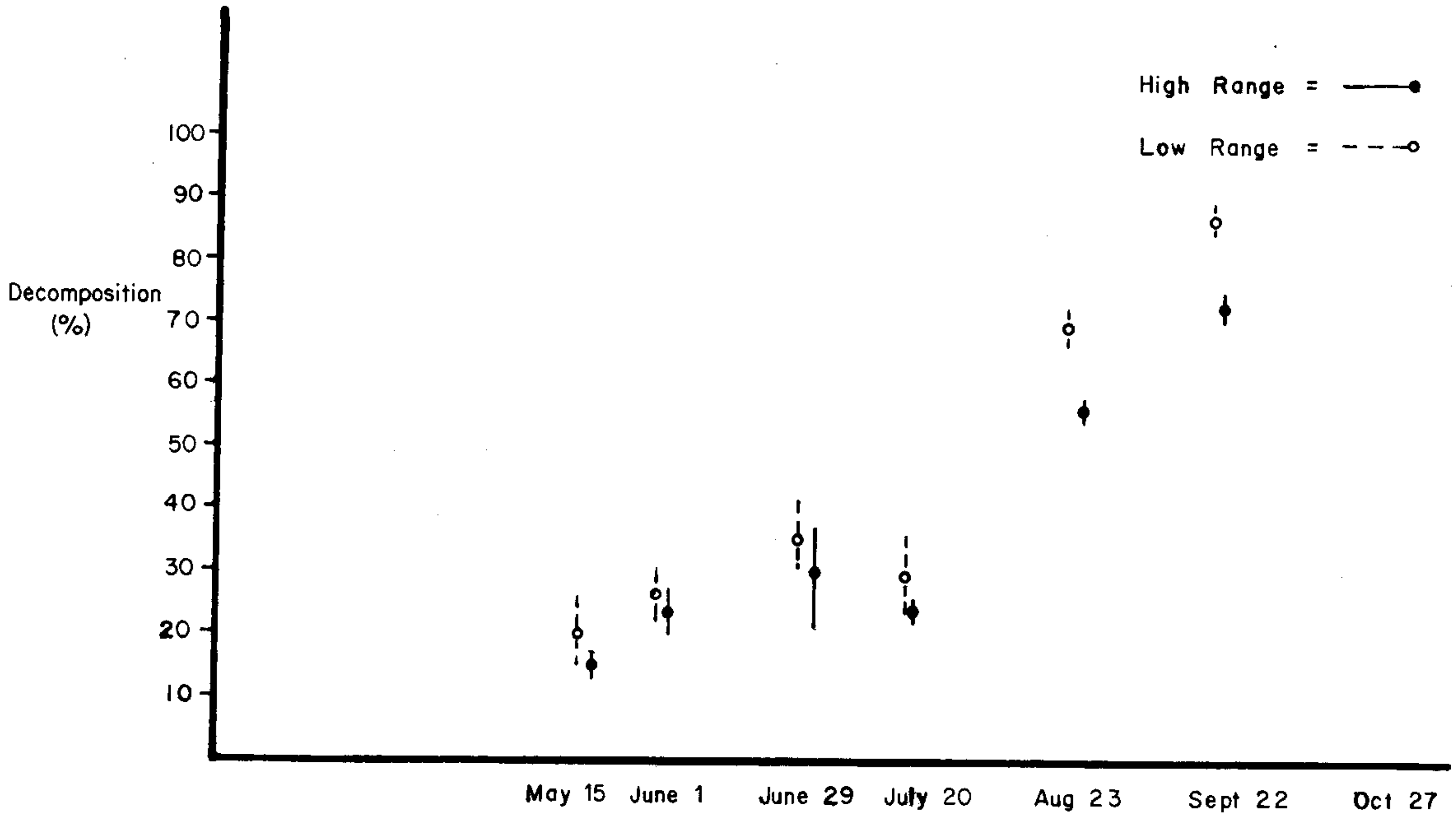

Fig. 4. Aboveground mulch decomposition.

One would show obvious decomposition, the other hardly any. The microclimate between the two probably has a great deal to do with these differences in decomposition, and it is definitely altered when the samples are emplaced in the soil.

Fig. 5 shows graphically the decomposition of belowground mulch. The difference in amount of decomposition of belowground mulch and aboveground mulch is not great.

For all decomposition rates for both high range and low range, the peak of decomposition seemed to occur between 20 July and 23 August. Comparing this with CO_2 production (Fig. 1), it is evident that where the peak of decomposition has occurred in July and August, the CO_2 production is declining to quite an extent. Both soil water and soil temperature are approximate to that of the date when CO_2 production reached its peak in May; yet, with temperature and soil water at an optimum and decomposition occurring at a maximum, CO_2 production tends to fall off. Perhaps this tells us that, indeed, we are measuring "the death of an ecosystem." However, the flooding of cylinders which occurred in mid-summer invalidating the CO_2 output data is an equally likely explanation.

As in previous years, cellulose decomposition was negative. In other words, in the period from 8 April to 27 October buried cellulose gained weight. In many cases the retrieved cellulose samples were covered with mycelium growth, yet the decomposition of that filter paper as measured by weight loss was not at all evident. Perhaps the mycelium is adding weight to the sample. There is also a question as to whether minerals may migrate to the filter paper from the soil. This would also cause the filter paper to gain weight.

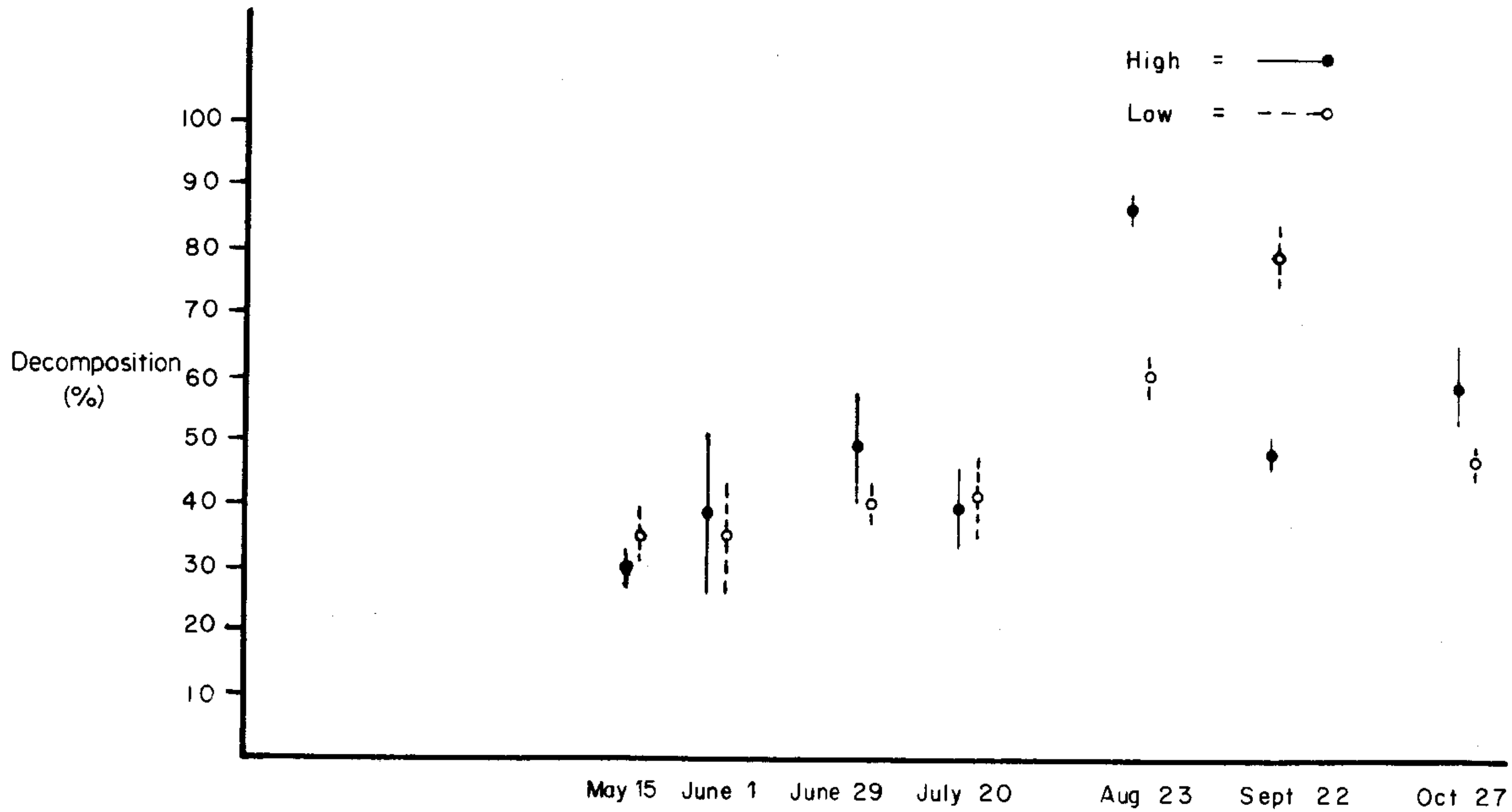

Fig. 5. Belowground mulch decomposition.

Fig. 6 depicts graphically the decomposition of roots. All the problems mentioned concerning decomposition of other material relate also to root decomposition.

If sampling is to be continued at Cottonwood the following recommendations are made: (i) cylinders for CO_2 measurement should be emplaced just prior to collection of CO_2; (ii) they should be emplaced 5 cm deep and moved to a new location each time; this should prevent measuring the decomposition of severed roots; (iii) the photosynthetic material should be clipped only enough to allow the KOH containing vial to be emplaced; this will prevent an "over-grazed" ecosystem microclimate; and (iv) only litter representative of the range condition of the treatment should be used for decomposition rate studies.

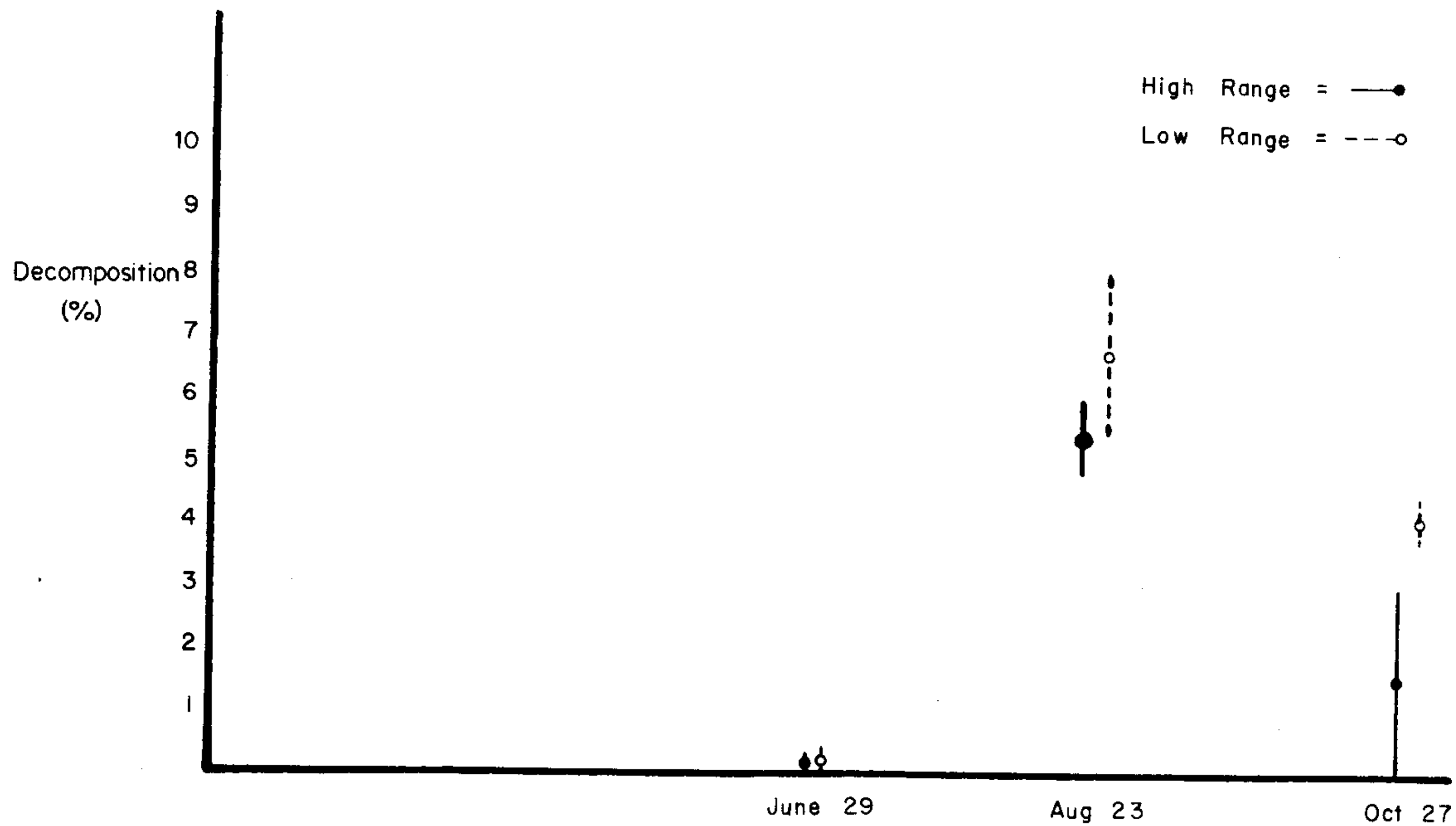

Fig. 6. Root decomposition at three sample dates.

LITERATURE CITED

Coleman, D. C. 1971. Measurement of "total soil respiration" at IBP Grassland Sites. U.S. IBP Grassland Biome. Colorado State Univ., Fort Collins. (Mimeo).

Pengra, R. M. 1972. Cellulose and litter decomposition and evolution of carbon dioxide from soils at the Cottonwood Site, 1971. U.S. IBP Grassland Biome Tech. Rep. No. 170. Colorado State Univ., Fort Collins. 20 p.

APPENDIX I

FIELD DATA

CO_2 Evolution Data

The data for the 1972 CO_2 evolution analyses at the Cottonwood Site were taken on form NREL-4E. The IBP designation for these data is A2U4044. Examples of the data and data form follow.

IBP

GRASSLAND BIOME

U.S. INTERNATIONAL BIOLOGICAL PROGRAM

FIELD DATA SHEET--MICROBIOLOGY - CO_2 EVOLUTION

Data Type	Site	Initials	Date			Treatment	Replicate	Cylinder Area	Soil Temperature	Soil Water	Experimental	Hours CO_2 Trapped	Molarity HCl	Mean of Blanks	ml HCl	B-E	Mg CO_2	Mg CO_2/24 hr	g CO_2/24 hr/m^2
			Day	Month	Year														
1-2	3-4	5-7	8-9	10-11	12-13	14	15	17-19	20-23	25-28	30	32-35	37-41	43-47	49-53	55-59	61-65	67-71	73-77
4E																			

Data Type
4E CO_2 evolution

Site
01 ALE
02 Bison
03 Bridger
04 Cottonwood
05 Dickinson
06 Hays
07 San Joaquin
08 Jornada
09 Osage
10 Pantex
11 Pawnee
12

Treatment
1 Ungrazed
2 Lightly grazed
3 Moderately grazed
4 Heavily grazed
5 Ungrazed current year only
A Diet light
B Diet moderate
C Diet heavy
D ESA - O
E ESA - W
F ESA - N
G ESA - WN

Experimental
1 Experimental cylinder
2 Blank cylinder

****EXAMPLE OF DATA****

1 2 3 4 5 6

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4E04VHL07047211	07807.5	15.6	1	24	.6	19.1	17.5	1.6
4E04VHL07047211	07807.5	15.6	1	24	.6	19.1	17.2	1.9
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Decomposition Data

The 1972 microbiology decomposition data were taken at the Cottonwood Site on form NREL-4D. The IBP designation for these data is A2U4004. Examples of the data and data form follow.

IBP

GRASSLAND BIOME

U.S. INTERNATIONAL BIOLOGICAL PROGRAM

FIELD DATA SHEET--MICROBIOLOGY - DECOMPOSITION

Data Type	Site	Initials	Date			Treatment	Replicate	Material	Percent O.M.	Location	Depth	Date Set Out			Number Days	Weight Original	Weight Retrieval	Weight Ignition	Soil Weight	Soil, Ignition
			Day	Month	Year							Day	Month	Year						
1-2	3-4	5-7	8-9	10-11	12-13	14	15	17	19-22	24	26-27	29-30	31-32	33-34	36-38	40-44	46-50	52-56	58-62	64-68
4D																				

Data Type
4D Microbiology - decomposition

Site
01 ALE
02 Bison
03 Bridger
04 Cottonwood
05 Dickinson
06 Hays
07 San Joaquin
08 Jornada
09 Osage
10 Pantex
11 Pawnee
12

Treatment
1 Ungrazed
2 Lightly grazed
3 Moderately grazed
4 Heavily grazed
5 Ungrazed current year only
6
7
8
9

Sample Material
1 Cellulose
2 Native litter
3 Native roots

Location
1 Aboveground
2 Belowground

EXAMPLE OF DATA

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