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COMPARATIVE INVESTIGATIONS IN THE

U.S. IBP GRASSLAND BIOME: DECOMPOSITION SECTION[1]

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GRASSLAND BIOME

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TABLE OF CONTENTS

ABSTRACT

Litter decomposition and total soil respiration were studied on several U. S. IBP Grassland Biome sites in 1970 and 1971. This report presents data on decomposition activity of buried substrates and total CO_2 mineralization and examines key abiotic variables, i.e., soil water percentage and soil temperature as they influence decomposition.

Various linear regression models explained as much as 75% of the total variability in decomposition, the higher values being associated with soil respiration activities at the ALE and Osage Sites. The need for C/N ratios and year-round measurements is emphasized, so that key chemical and historical aspects of decomposition can be included for greater understanding and predictability of grassland decomposition and nutrient cycling.

INTRODUCTION

The previous two papers have been concerned principally with a wide range of different biomass estimates, whereas this subsystem is treated as more of a process or decomposition rather than a decomposer subsystem. Thus, we can estimate microbial biomass by a number of techniques, obtaining values ranging from 500 to 1000 kg/ha, and then are unable to make valid conclusions from this due to an inability to differentiate living and dead cells. It is much more productive to concentrate on certain key process functions. Using a subsystem model (Fig. 1), the key inputs are indicated as a litter component, animal feces and residues, and dead roots. These are processed by the microbiota with a resulting output of CO_2. The humic compound box includes all soil organic matter or several thousands of kilograms per hectare just in the 0- to 15-cm depth. For our purposes, we are treating it as essentially a black box with a uniform flow rate into and out of it, because we are more concerned with the inputs of the more labile compounds over the time span of 1 to 2 years with which we are dealing. The key driving variables indicated in the control box on the right-hand side are soil water and temperature. Also important are the available nitrogen and the decomposability index, but I will reserve comments on those for a later time. The main emphases in this paper will be on litter decomposition and total soil respiration in the sense of Macfadyen (1970).
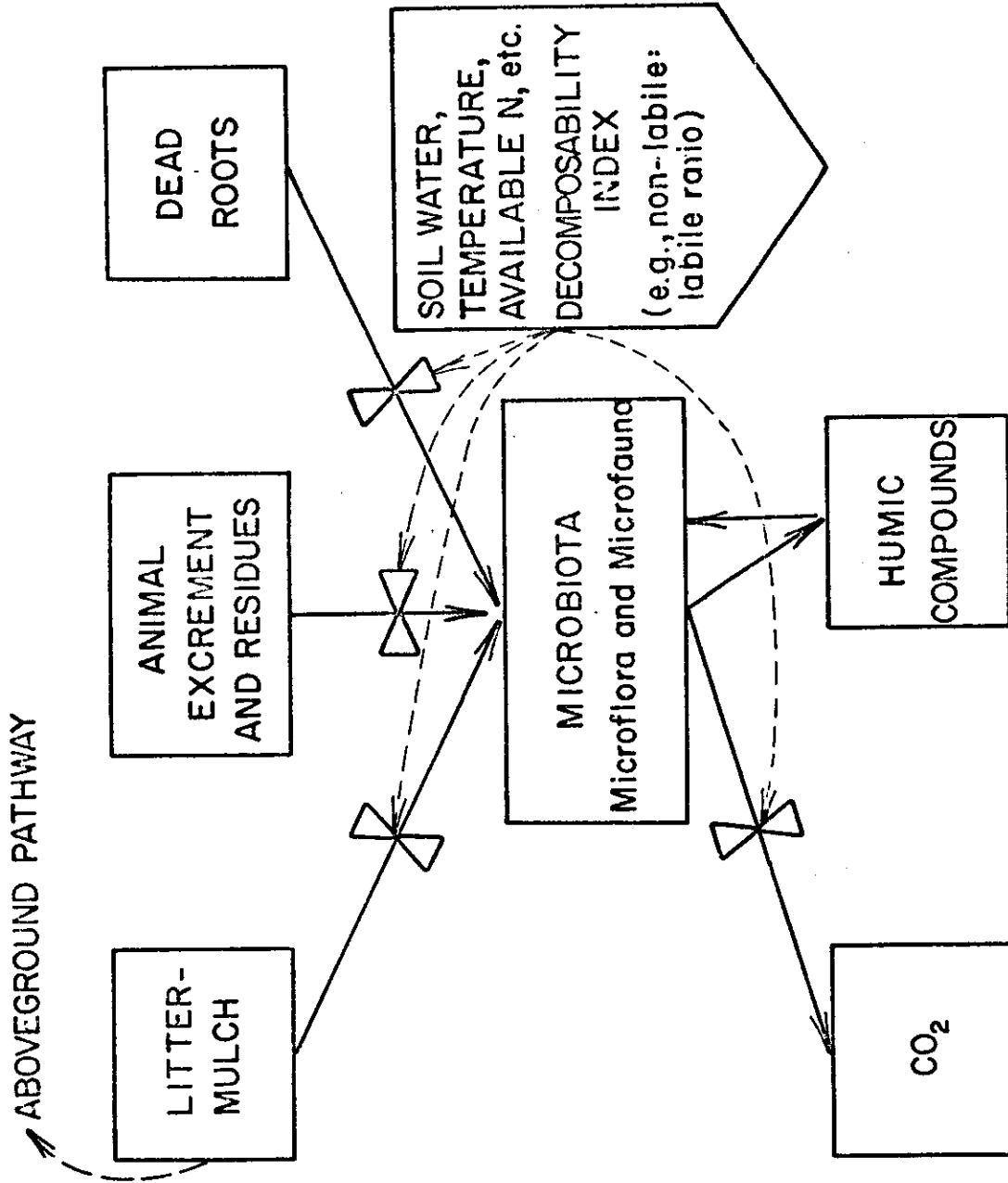
Fig. 1.   Decomposer subsystem belowground model.

PROCEDURES

Various litter types were set out, either cellulose filter paper or a standard litter (*Andropogon gerardi*) obtained from Dr. J. O. Harris of Kansas State University, either on the soil surface or 5 cm belowground in nylon mesh bags of 1 to 2 mm. A series of calculations of percent loss per month on an ash free basis were made for litter decomposition at several sites. A somewhat mesic site (Cottonwood) and the dry Pacific northwest bunchgrass site (ALE) are compared in Fig. 2. ALE, with its very early growing season, had a marked spurt of decomposition activity from the end of March through April and then a lower rate from May through July. The activity at Cottonwood, in contrast, was almost 18% in early summer, dropping down steadily to almost zero at the end of September. The prevailing moisture conditions on a site are very important as shown in Fig. 3 where standard litter or cellulose at Osage decomposed at a quite rapid rate. Interestingly, the cellulose disappeared at a markedly faster rate, approximately 33% per month from April through June, whereas the standard bluestem litter decomposed at around half that, about 13 or 14% per month.

The time of burial is also very important as shown by the Pawnee litter decomposition data. Thus, those litter bag samples which had been buried later in the season, i.e., late May in contrast to late April, decomposed at a faster rate. In general, the cellulose at Pawnee decayed at a slower rate than did the standard litter which would seem to indicate that the lack of available nitrogen led to a lower loss rate in contrast to the situation at the Osage Site.

There is a very marked contrast at the Jornada Site where burials were made in June and September 1970 and mid-April and early August 1971. There
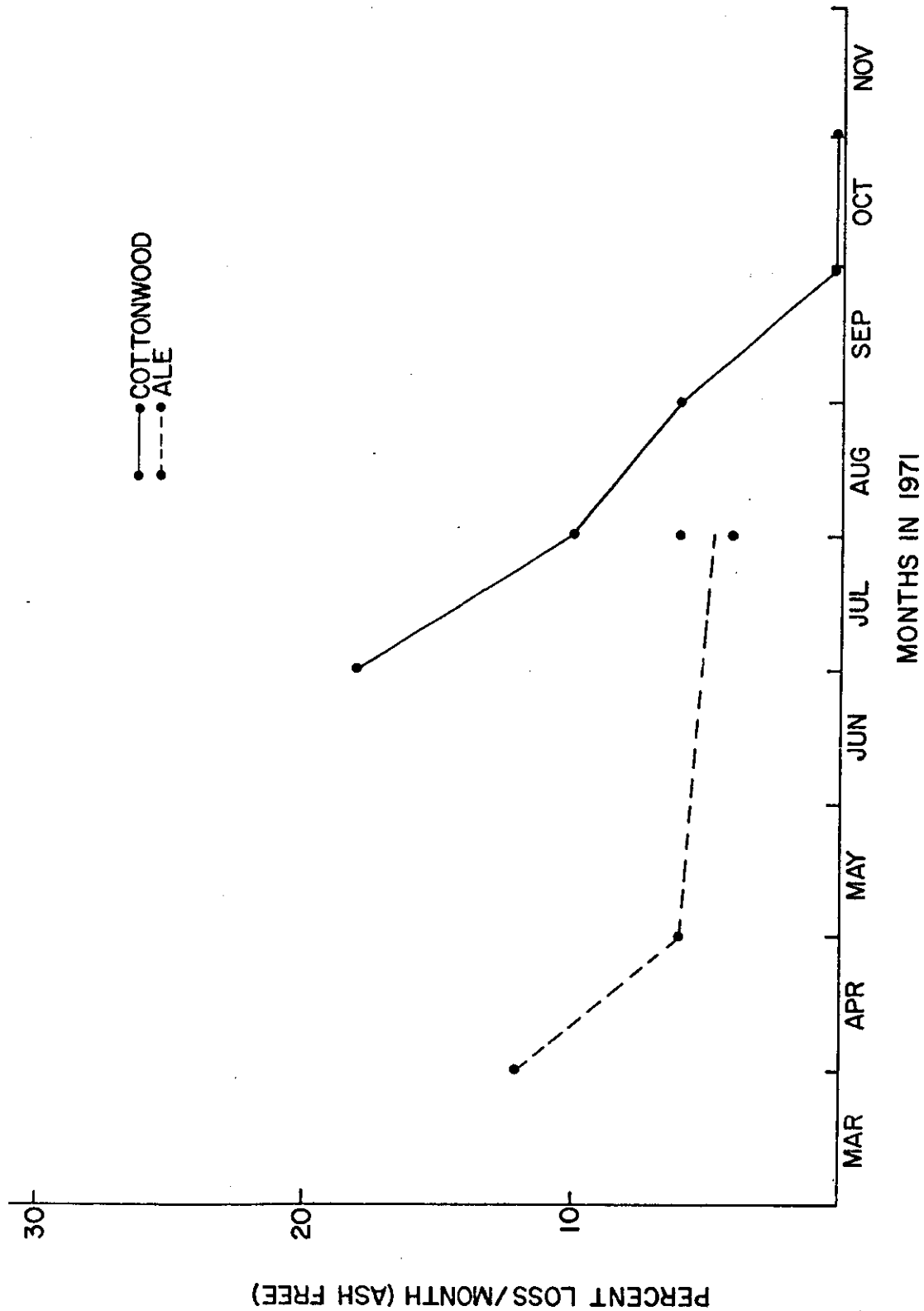
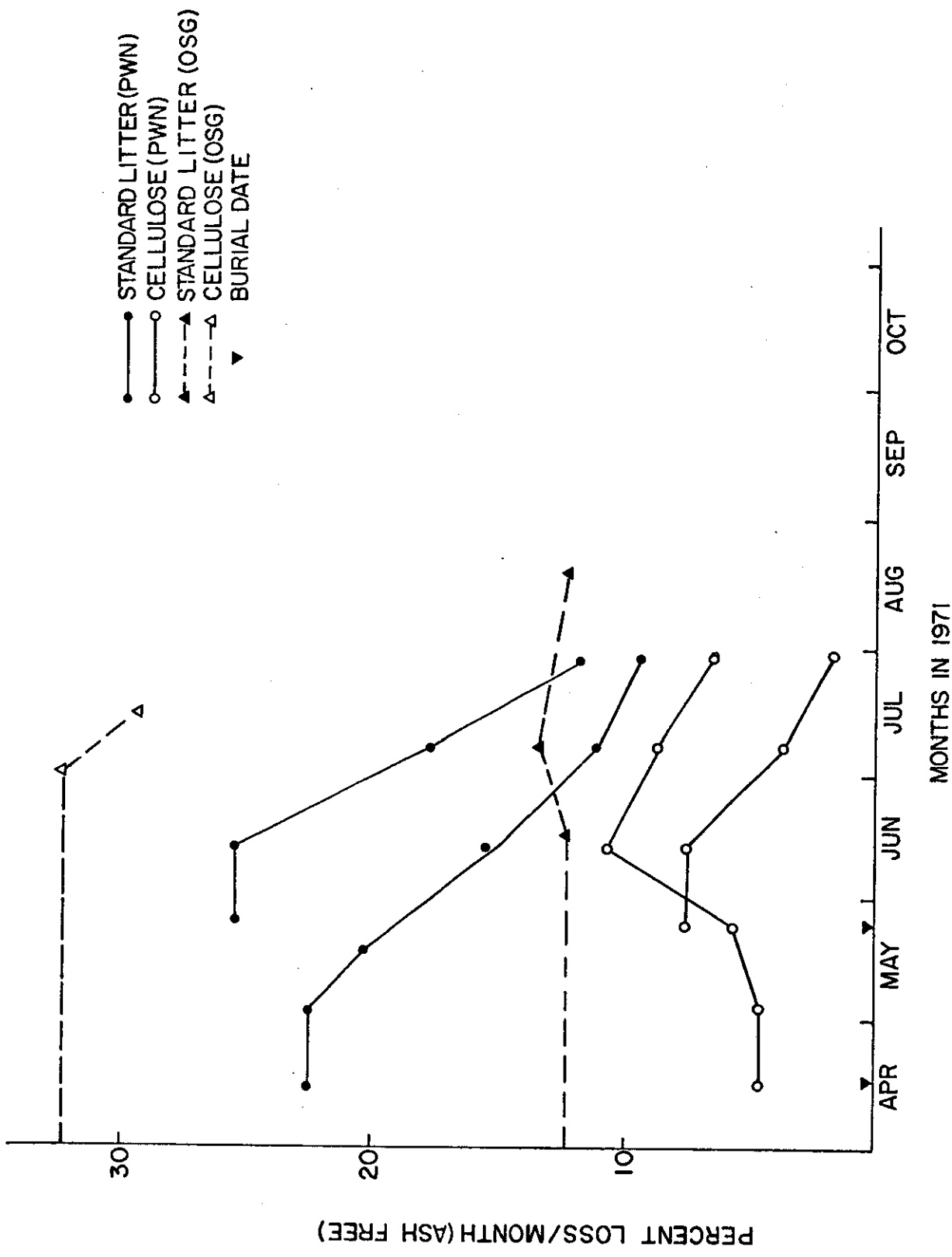Fig. 2. Decomposition of standard litter at the Cottonwood and ALE Sites.

Fig. 3. Decomposition of standard litter and cellulose at the Pawnee (PWN) and Osage (OSG) sites.

was an essentially uniform loss rate at about 10% per month from June through August and then a more rapid loss corresponding with the quite heavy late summer showers (Fig. 4). However, from December on through late summer of 1971, there was essentially no loss whatever and then suddenly a 35% loss occurred in only 21 days at the time of late summer showers. Obviously, in this situation, intraseasonal dynamics are quite marked.

In an attempt to measure the effects of soil temperature or water on decomposition rates, simple linear regressions were calculated on some of the 1971 Pawnee data. Using data from early April to the end of July 1971, loss rate of cellulose or litter was plotted against increasing soil temperature or soil water (Fig. 5 through 8). In all cases the points plotted represent means of triplicate determinations. For both cellulose and standard litter the r was negative (-.505 for cellulose and -.649 for the standard litter). In contrast, the effect of increasing soil water was reflected with an increasing weight loss. Here $r = .474$ for cellulose and .800 for standard litter. A multiple stepwise regression model was also used on these data, and because of the opposite trends of soil water and temperature there was very little improvement in the R^2 value.

Another major area of research in the decomposition subsystem is total soil respiration, in which the evolved carbon dioxide is absorbed in dilute alkali (ca. 0.6 M NaOH) and then the excess is titrated with standardized hydrochloric acid in the laboratory. The measurements are made in 8 to 10 samples per replicate and 2 replicates per treatment on both the grazed and ungrazed sites. For 1971 a complete series of data were obtained only on Osage, ALE, and Pawnee, and my comments are restricted solely to those. Because there are varying amounts of litter and roots in the grazed and
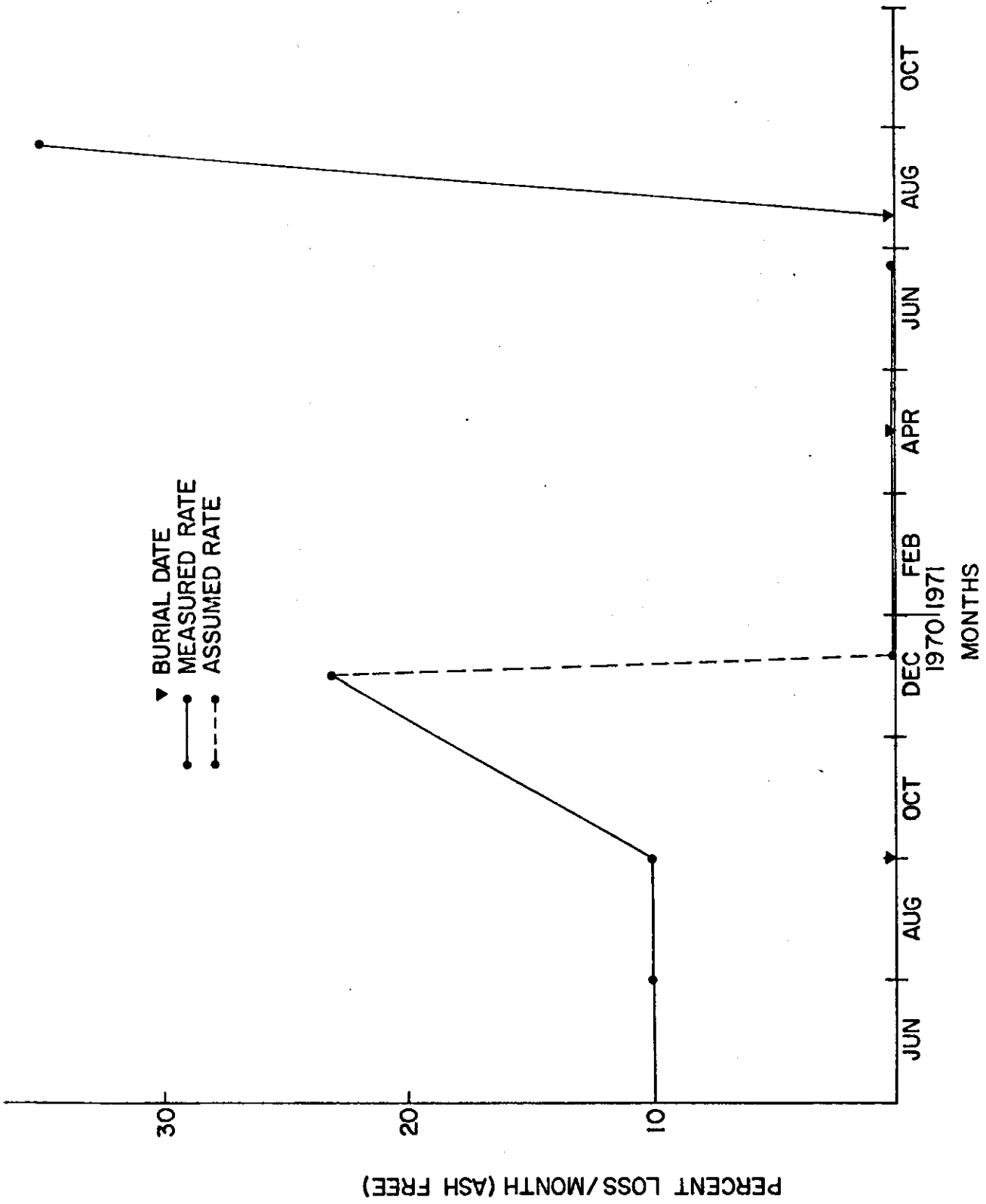
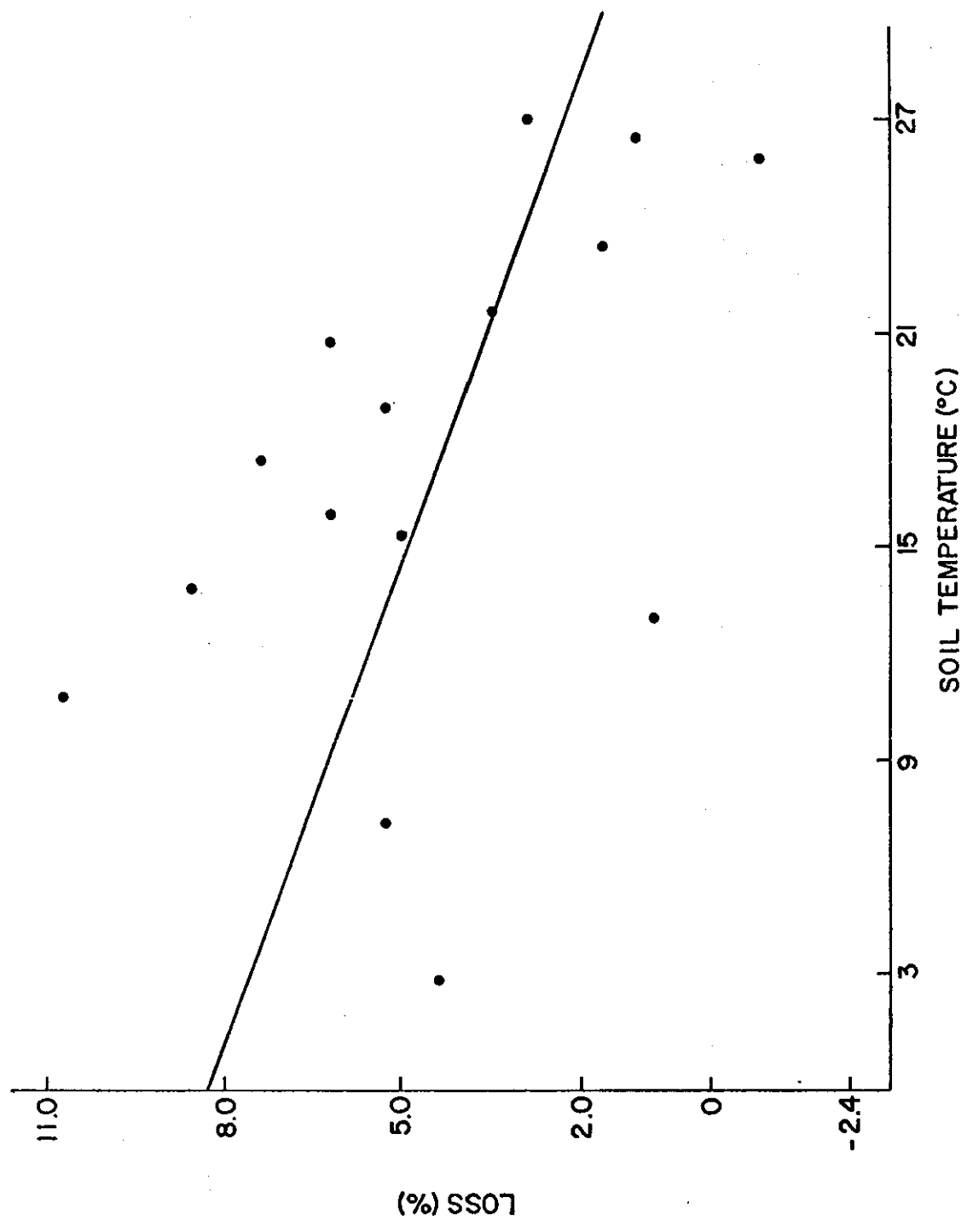Fig. 4.   Decomposition of standard litter at the Jornada Site, 1970 and 1971.

Fig. 5. Pawnee (1971) cellulose weight loss; y = 8.5605 - .2212x, r = -.505, N = 15.

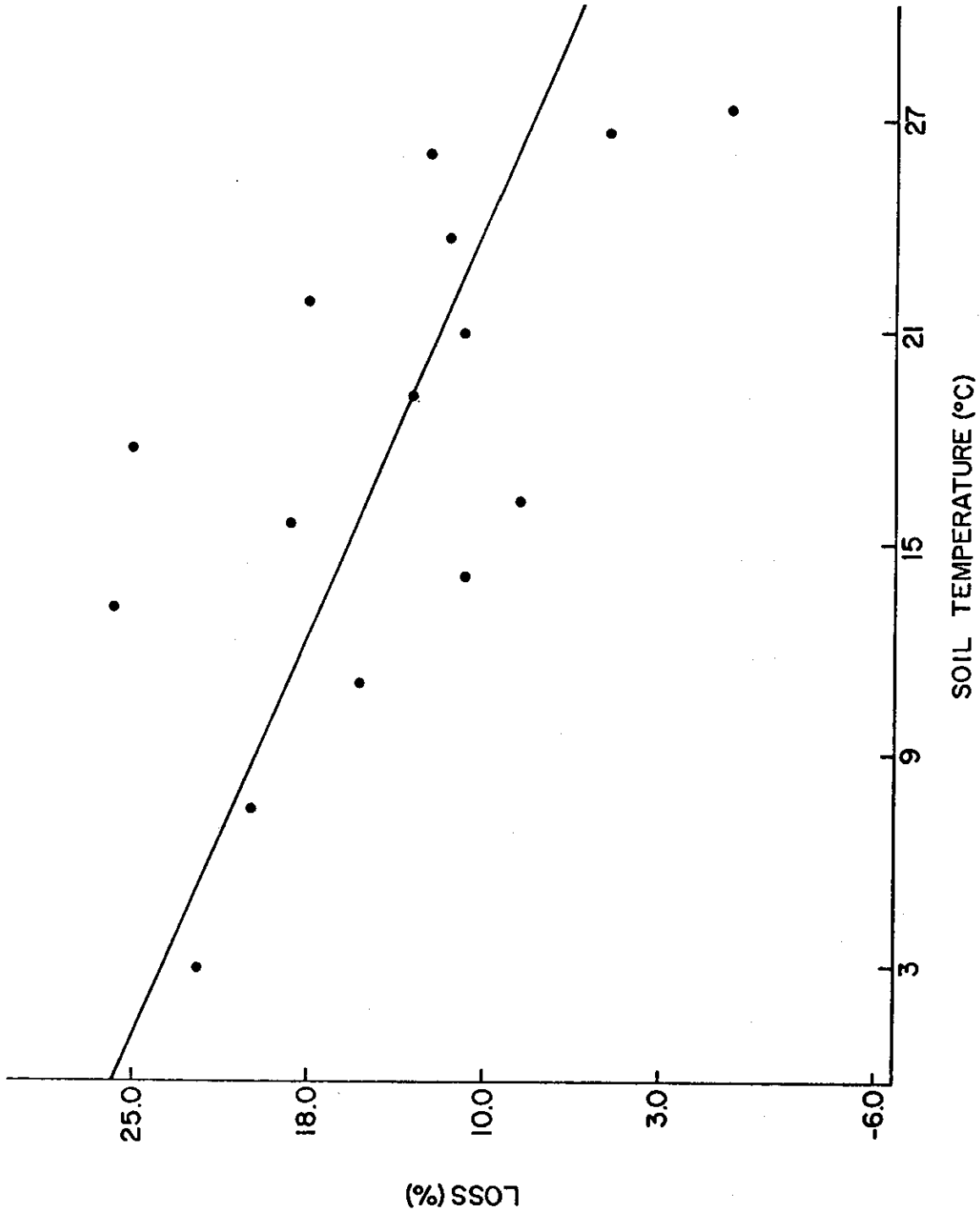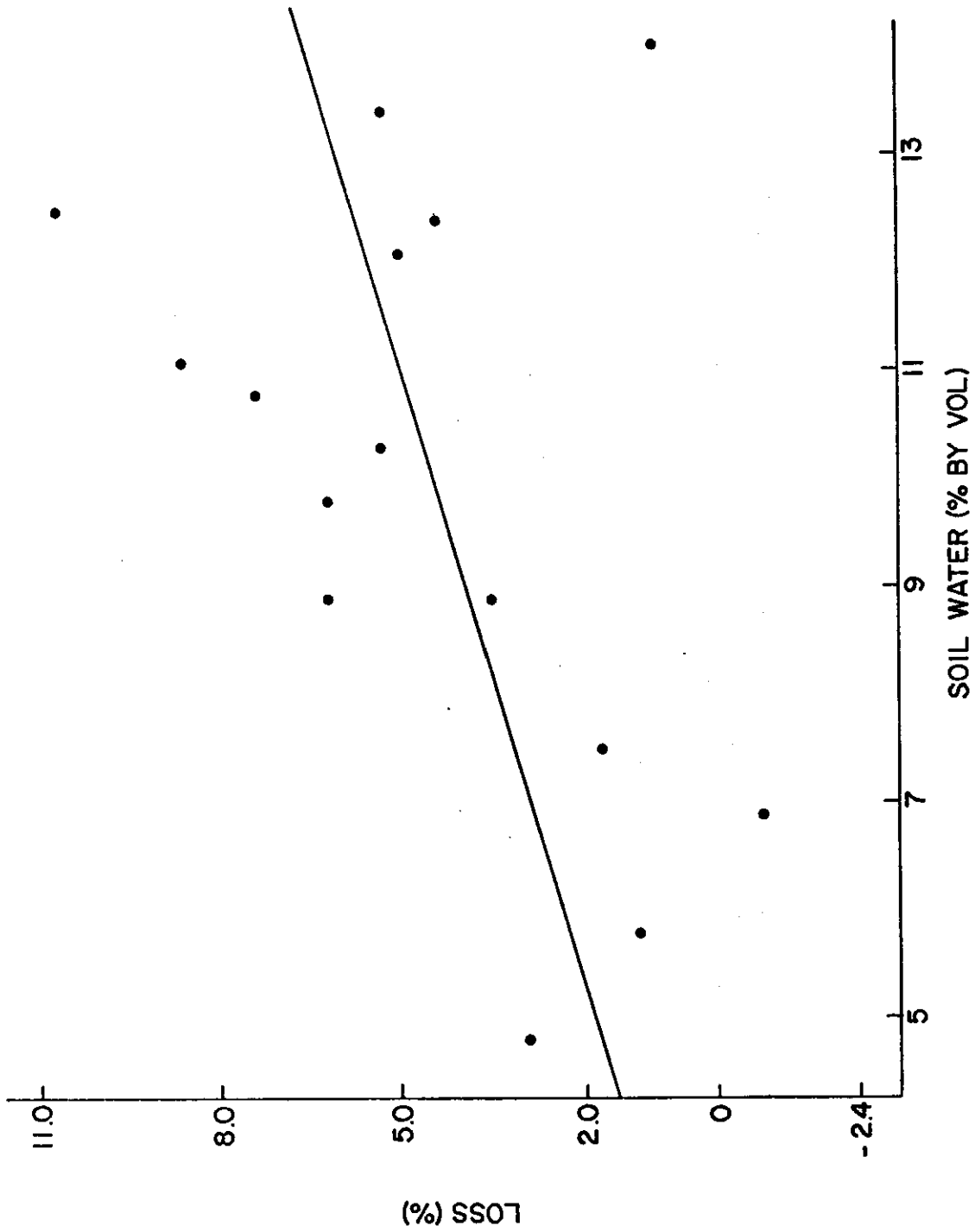Fig. 6. Pawnee "standard litter" (1971); y = 26.3450 - .6572x, r = -.649, N = 15.

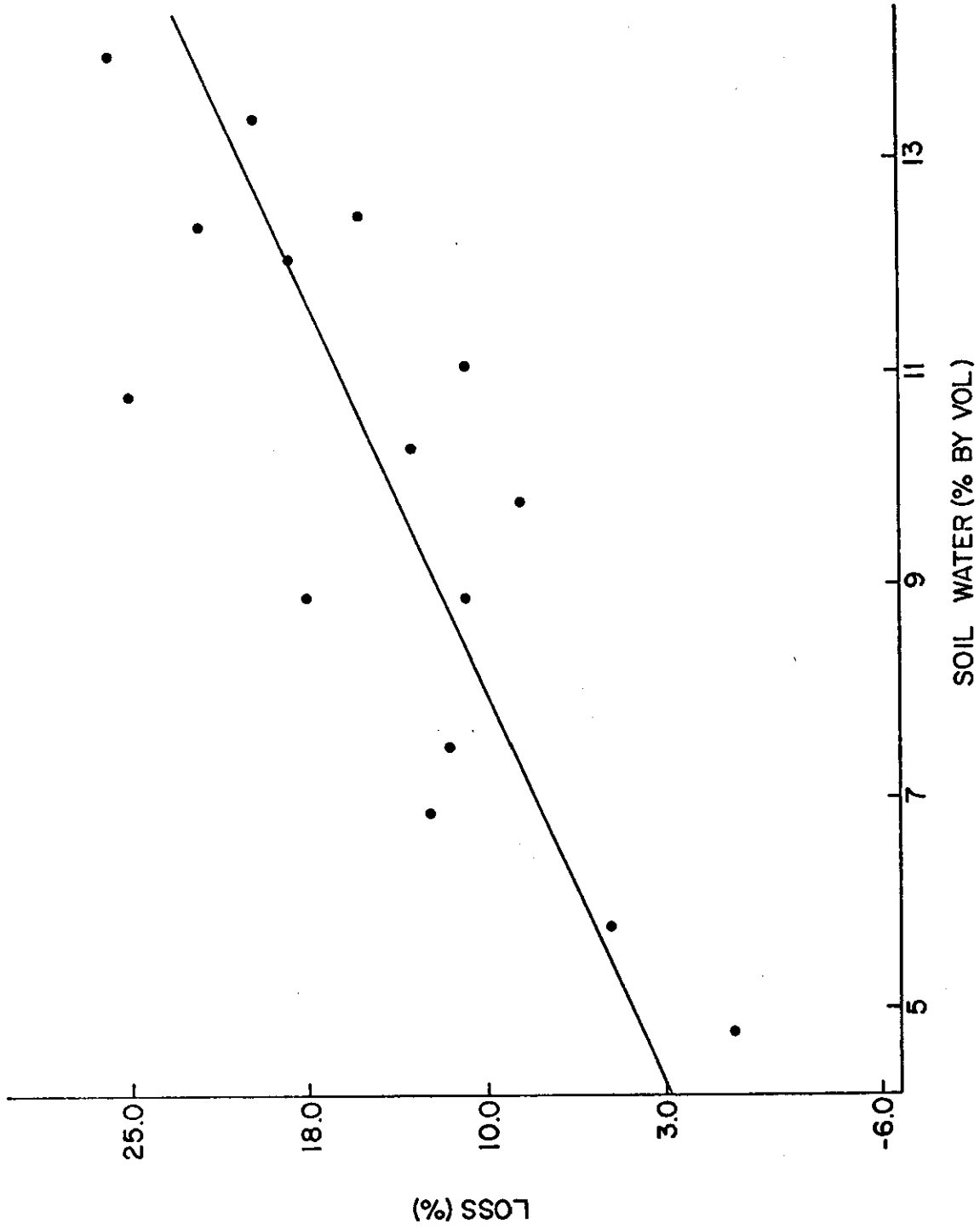Fig. 7. Pawnee (1971) cellulose weight loss; y = -.6247 + .5305x, r = .474, N = 15.

Fig. 8.   Pawnee "standard litter" (1971) ; y = -5.9024 + 2.0742x, r = .800, N = 15.

ungrazed treatments, it was thought that this total soil respiration (being a sum of litter, crowns, roots, and soil microbes) would give a good integrated picture of the total respiratory activity and yet also show differences across sites.

The general trends for grazed and ungrazed sites at Osage are similar with a peak of 5 g $CO_2/m^2/24$ hr in the grazed and around 8 g in the ungrazed (Fig. 9 and 10). The confidence intervals are such that the lines do not significantly differ in all but one case, and that one just slightly. The question marks at the beginning and end of the lines indicate that measurements were not made at these points, and the sort of respiration patterns which prevailed remain unknown. The same sort of comparison for grazed and ungrazed at the ALE Site (Fig. 11 and 12) shows a generally lower respiration, as one would expect, seldom exceeding 4 g $CO_2/m^2/24$ hr and usually remaining down between 1.5 and 2 g. In this site there was essentially no difference whatever between lines; hence there was no attempt made to draw in confidence interval bands.

A somewhat different approach was used on the Pawnee Site where two ungrazed areas were compared and one area received irrigation during the months of June and July. The nonirrigated area shows a generally decreasing trend from a high of about 5 g $CO_2/m^2/24$ hr in late April and a steady decline down through August (Fig. 13). The effect of a heavy precipitation event (about 1.5 inches) in early September is shown dramatically as it increased from about 1 up to 13 g $CO_2/m^2/24$ hr. The effect of added water in the irrigated plots is indeed marked and shows a very rapid drop as the soil dried out (Fig. 14). Once again, however, information for the early and late part of the year was not available. Some rather interesting conclusions
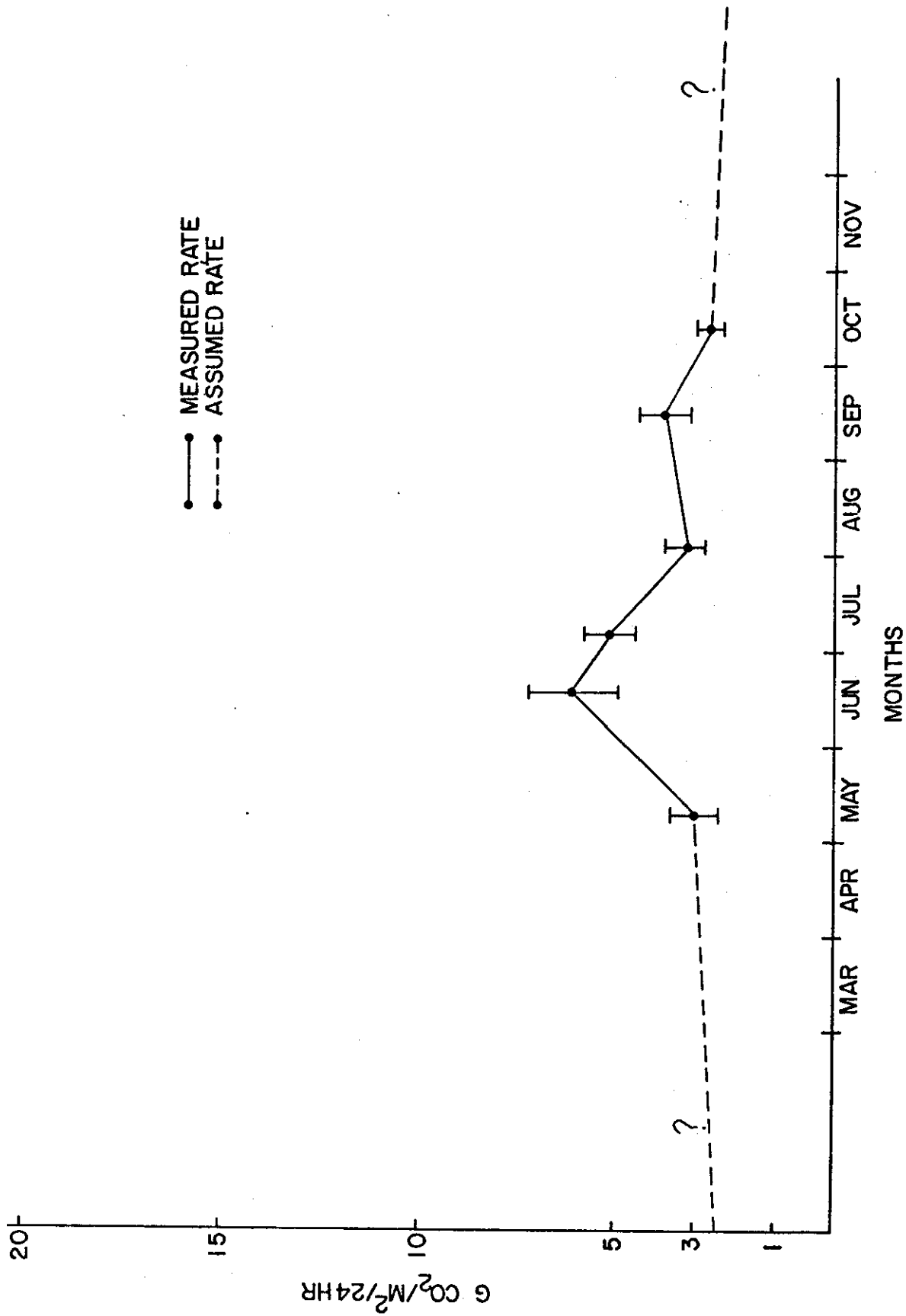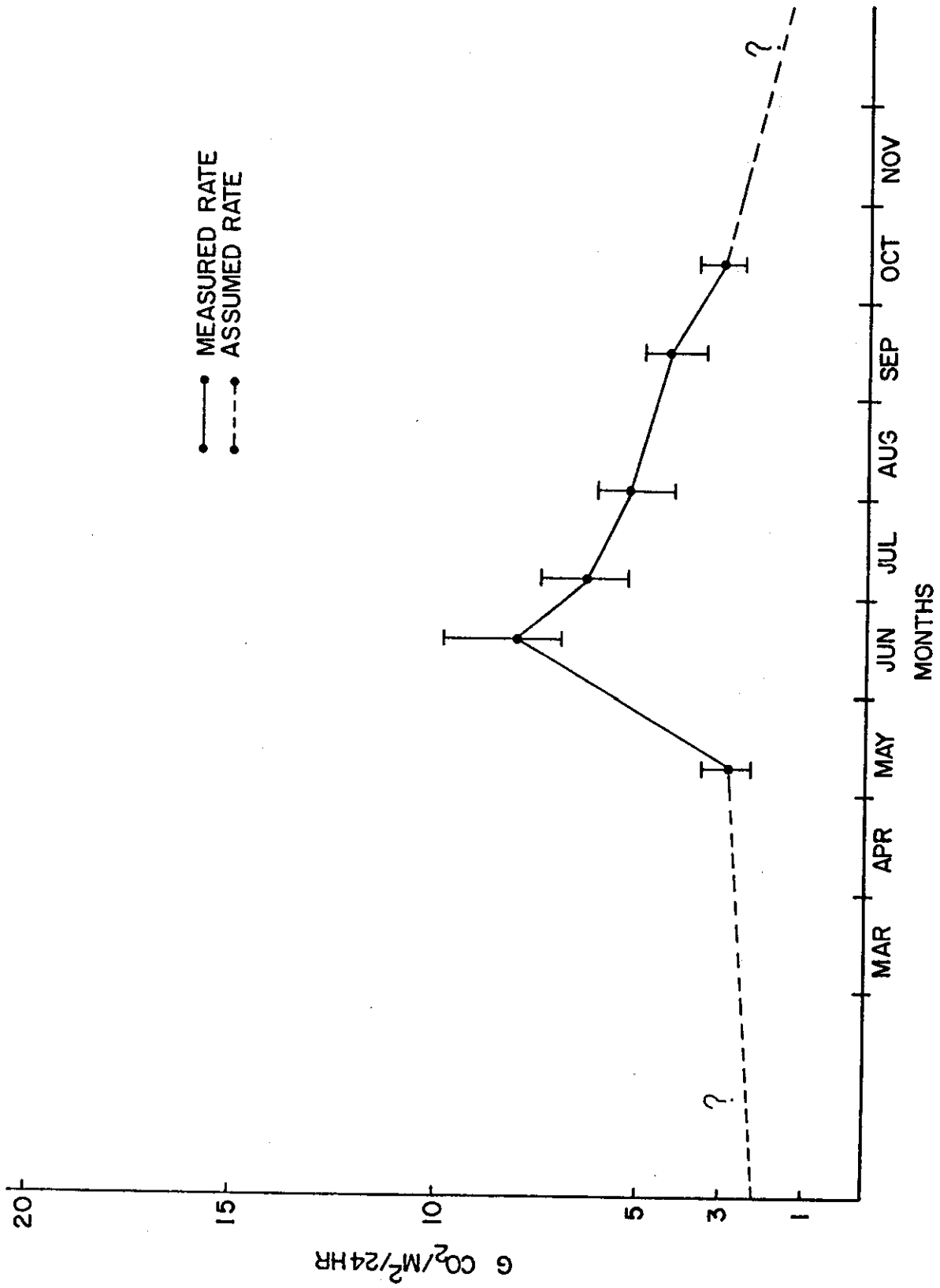
Fig. 9. CO_2 evolution for Osage (1971) grazed.

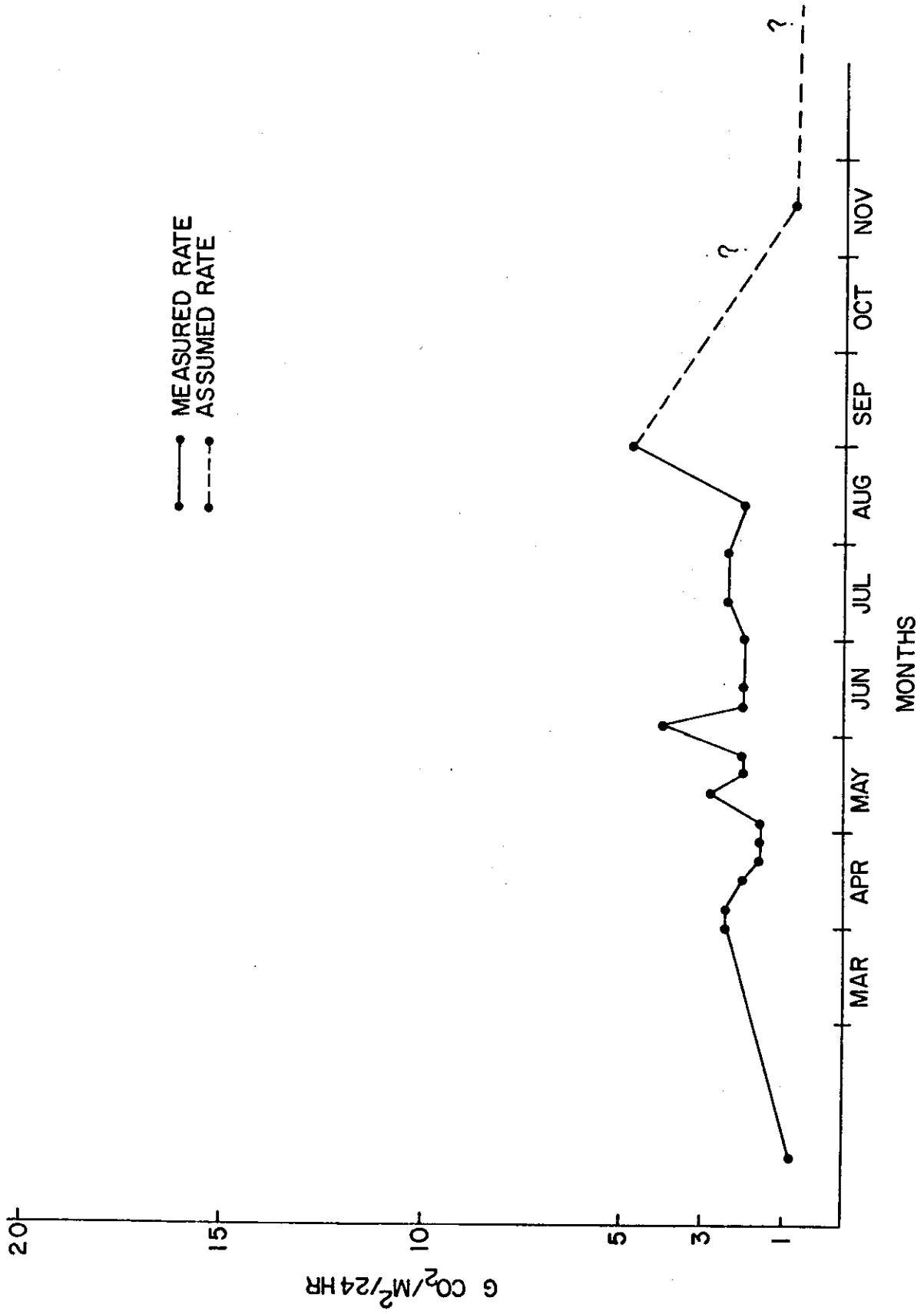Fig. 10. CO_2 evolution for Osage (1971) ungrazed.

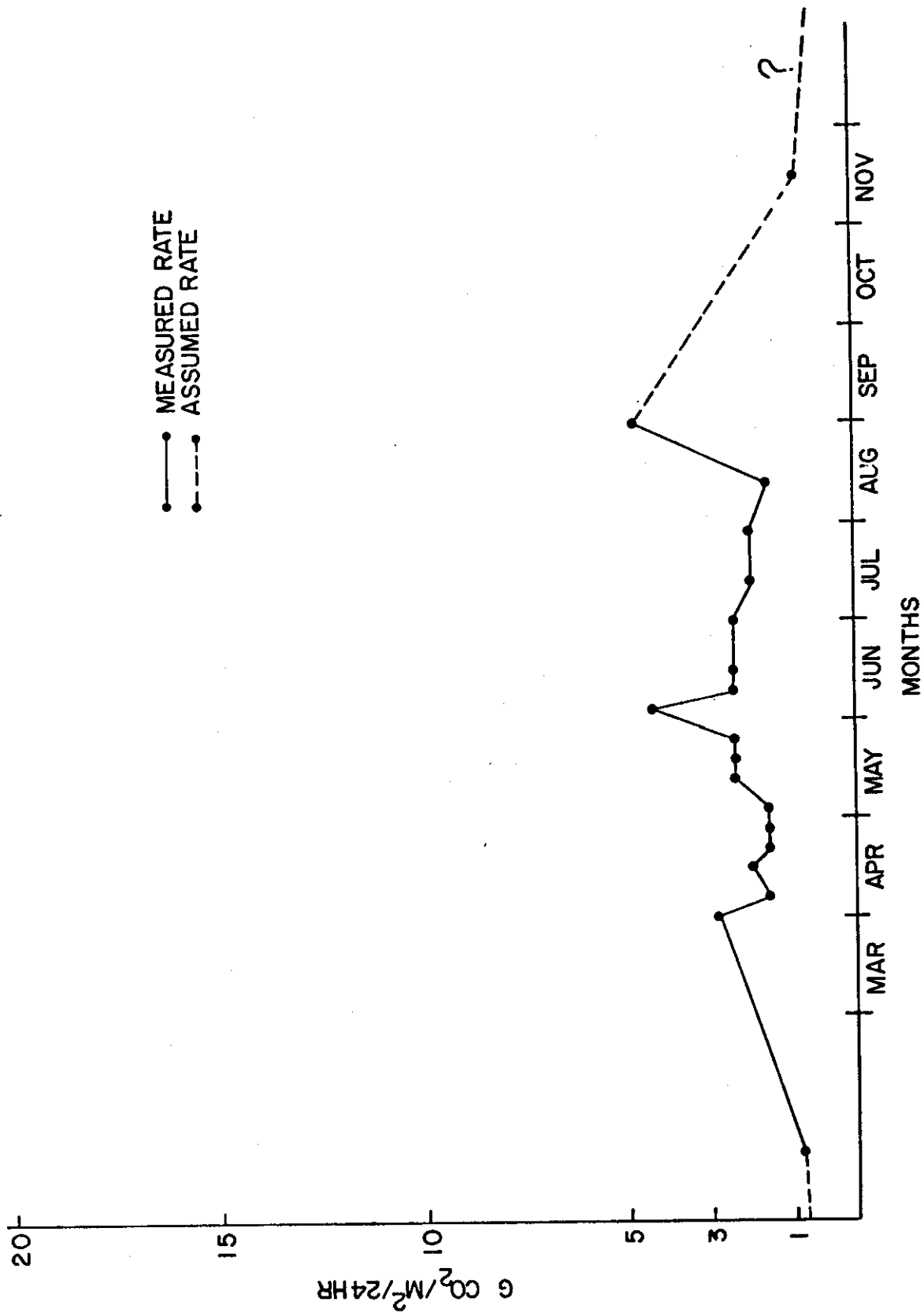Fig. 11. CO_2 evolution for ALE (1971) grazed.

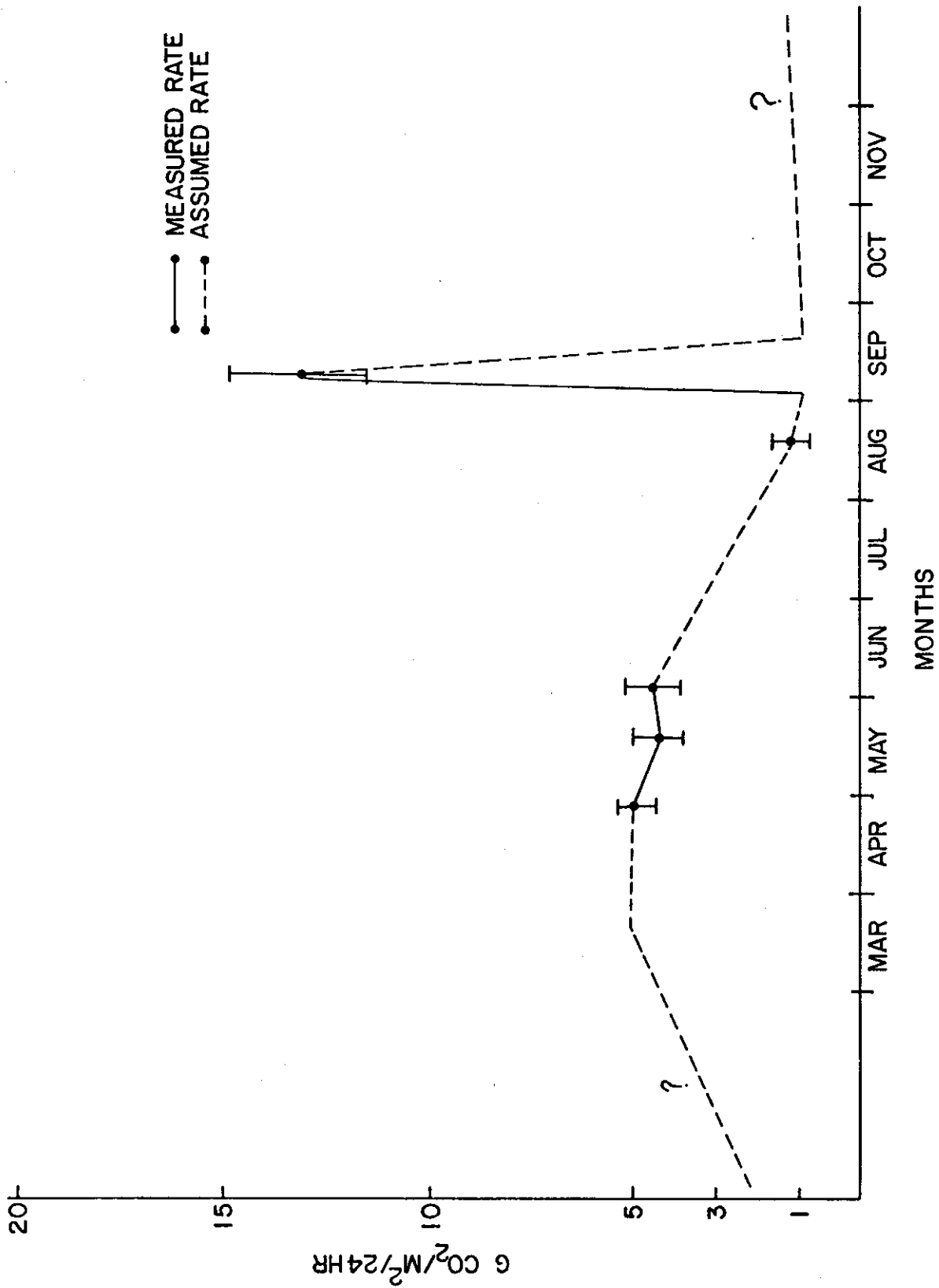Fig. 12. CO_2 evolution for ALE (1971) ungrazed.

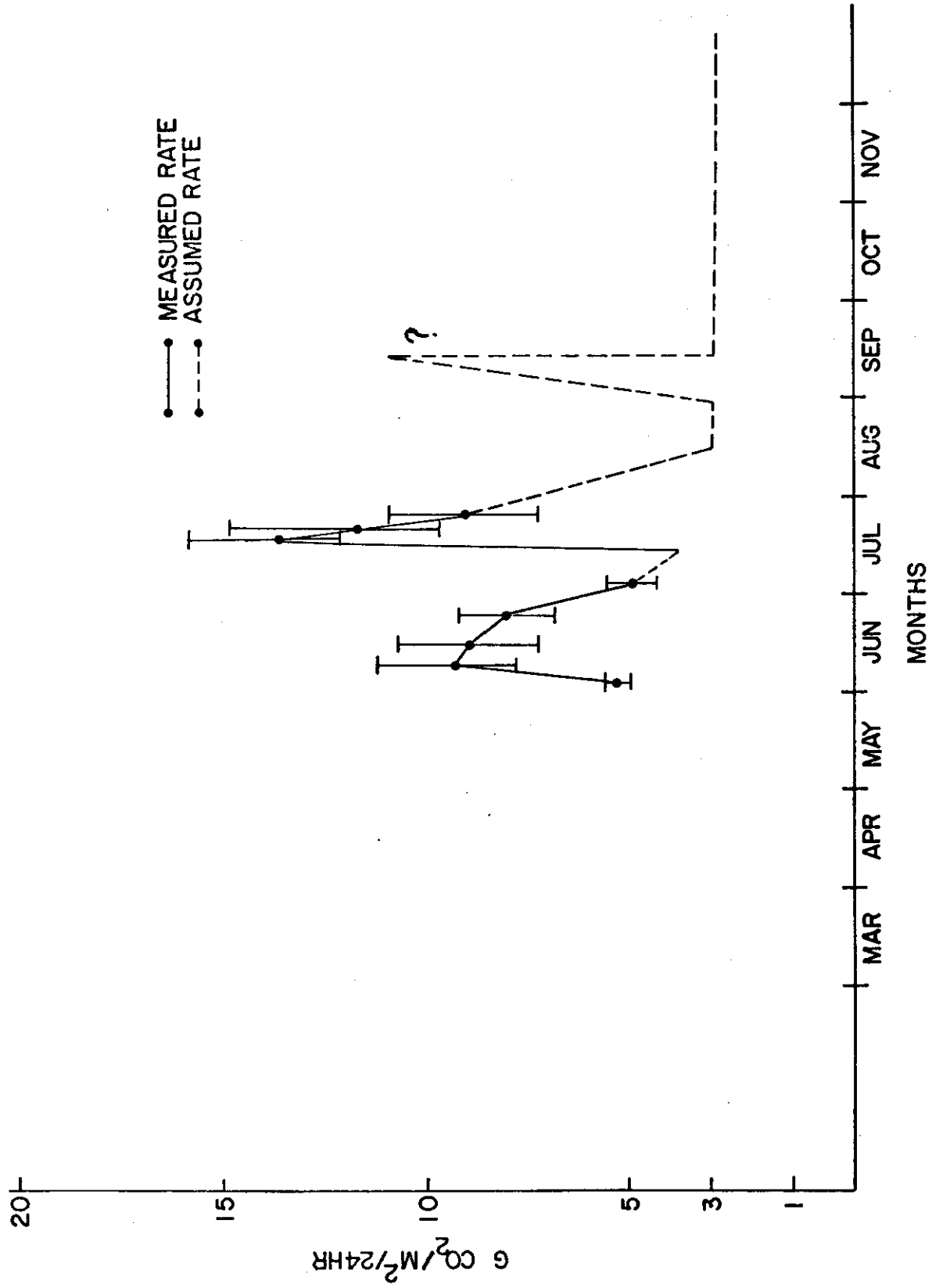Fig. 13. CO$_2$ evolution for Pawnee (1971) nonirrigated.

Fig. 14. CO_2 evolution for Pawnee (1971) irrigated.

can be drawn from fairly arid sites such as the Pawnee. The response to
addition of water is indeed rapid and quite marked in extent. In contrast,
a more mesic site such as the Osage shows a greater effect of temperature.
These effects are documented in a listing of multiple R^2's per site (Table
1): the first entry in a stepwise multiple linear regression equation is
logarithm of temperature for Osage and also ALE, whereas at Pawnee log
water enters first in all cases. The ALE results are somewhat surprising
in that temperature had the greatest effect even though it is a very arid
site. However, there were some confounding influences because the combina-
tion of temperature and water was much greater than either the temperature
or water alone, as is shown by the high values of .72 or .76 in the second
entry column. Interestingly, the ungrazed, generally drier site at Pawnee
showed a more marked influence of water, i.e., it responded more rapidly
and more markedly to a water addition such as rainfall than the irrigated
(plus i) treatment which had a significantly higher soil water regime.
Certainly more data are required from a number of different sites to see how
general these trends of effects of water and temperature are, and also we
need very much to have information at all months of the year to obtain some
idea of the pulses of carbon flowing out of the system as carbon dioxide.

Another study that has been pursued in the laboratory has been aimed
at examining seasonal patterns of both carbon dioxide evolution and oxygen
uptake using appropriate respirometers. This work has been conducted by
Donald A. Klein in 1971 and 1972 as a process study, using material from
the Pawnee Site. Klein and co-workers took a large number of soil cores
into the laboratory and ran them at a constant temperature of 25°C. They
had some cores that received no water addition and then another series which

Table 1. Soil respiration, 1971. Multiple R^2's per site.

Site	Treatment	N	First Entry	Second Entry
ALE	Grazed	20	ln T .18	ln H_2O .72
	Ungrazed	20	ln T .15	ln H_2O .76
Osage	Grazed	30	ln T .54	ln H_2O .67
	Ungrazed	30	ln T .71	ln H_2O .75
Pawnee	Ungrazed (-i)			
April-August		80	ln H_2O .64	ln T .71
	Ungrazed (+i)			
June-July		80	ln H_2O .48	ln T .49
	Ungrazed (-i)			
April-September		89	ln H_2O .35	ln T .68

received a total 6-mm rainfall addition (the median rainfall on the Pawnee Site is 5.7 mm). The general patterns of respiratory activity showed an increase from March through May and then a decreasing trend for the field condition cores with no water added. The soil cores which received simulated rainfall increased from June through mid-July and then also decreased on into August (Fig. 15, after Klein, 1972). The cores receiving "rainfall" showed a consistent difference in oxygen used to CO_2 evolved, indicating a decrease in the respiratory quotient. Klein interprets this trend as indicating a shift in the types of carbon being utilized, going from a largely carbohydrate substrate into a more proteinaceous substrate later in the season. Interestingly, the unamended control cores (the two lower lines) do not show this sort of trend, but remain essentially quite similar with a respiratory quotient close to 1. These studies have been pursued through 1972 and it will make a very interesting comparison to have a second year of data on this sort of a process. Viewing the decomposition studies in general, it is quite obvious that we have many gaps in our knowledge, not only those concerned with the carbon flow over an entire year's span but also those on information on the interties between the decomposition processes and nutrient cycling. These studies are being pursued at the Pawnee Site by C. V. Cole and F. E. Clark both with phosphorus and nitrogen. I think one of the major results to be obtained in these studies is that a great deal of the total activity in grassland decomposition occurs in the first few centimeters (between 0 and 10) and can occur very rapidly within a few hours time after a certain rainfall pulse, so that we must be very much event-oriented rather than scheduling our work at regular intervals. Hopefully, our 1972 data and that from 1973 will fill in a large number of the gaps in our existing knowledge.
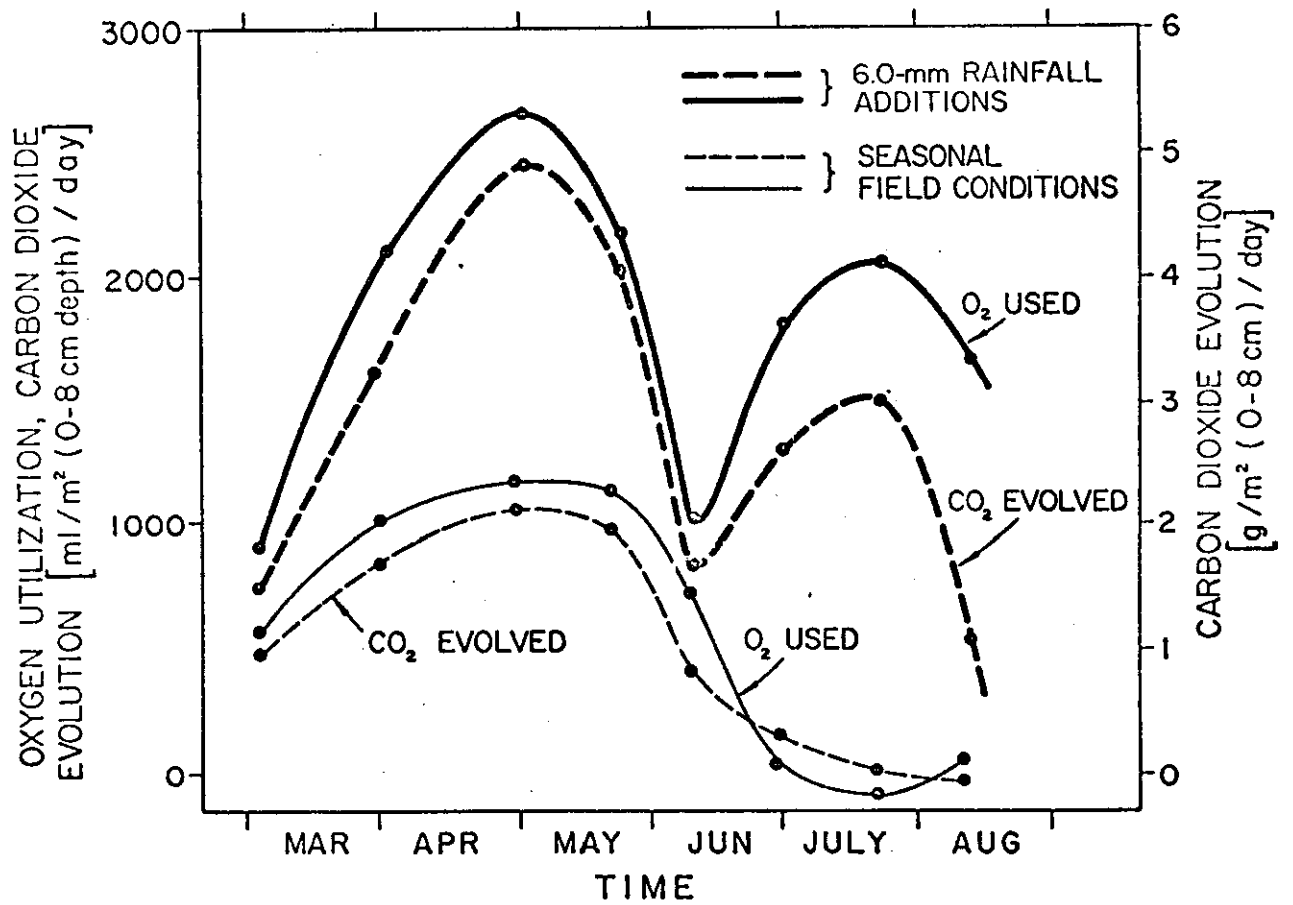
Fig. 15. Carbon dioxide evolution and oxygen utilization in unamended and moistened Pawnee Grassland soil (after Klein, 1972).

LITERATURE CITED

Klein, D. A. 1972. Decomposer subsystem, Chap. 5. *In* D. A. Jameson and M. I. Dyer [ed.] Process studies workshop report. U.S. IBP Grassland Biome Tech. Rep. Colorado State Univ., Fort Collins. (In preparation).

Macfadyen, A. 1970. Soil metabolism in relation to ecosystem energy flow and to primary and secondary production, p. 167-172. *In* J. Phillipson [ed.] Methods of study in soil ecology. IBP/UNESCO, Paris.