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FINAL REPORT

DYNAMICS OF SOIL ORGANIC MATTER FORMATION UNDER TILLAGE AND NO TILLAGE MANAGEMENT IN TROPICAL ENVIRONMENTS

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PART I

DYNAMICS OF SOIL ORGANIC MATTER FORMATION IN CROPLANDS - CONCEPTUAL ANALYSIS

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INTRODUCTION

Soil organic matter (SOM) conservation is a key to the management of a sustainable agricultural system in many areas of the world. SOM consists of a spectrum of materials which have half lives ranging from very brief to more than several thousand years (refs. 1-2). SOM formation thus is a complicated long term process. Evaluating the effects of a soil management practice on the dynamics of SOM formation in a cropland is difficult, simply because the changes of parameters in question are small and fluctuating during an experiment of limited time. To approach the problem conceptual analysis utilizing modeling techniques is necessary. A suitable SOM model can be used to synthesize the information obtained from literature and to interpret the results of a particular study. There are numerous SOM models in literature; from the simple exponential models (refs. 3-4) to very complicated mechanistic models (refs. 5-6). The advantage of a simple exponential model is its understandable analytical solutions. The drawback of a simple exponential model is its inability to represent a real soil situation in many cases. For example, a simple exponential model does not differentiate the primary plant residue from the secondarily formed SOM, thus does not simulate SOM transformations in soil. On the contrary, a complicated mechanistic model is able to simulate transformations

of plant residue and SOM in soil. However, it usually does not have a understandable analytical solution for the physical meanings. In this report, I present a SOM model which, on one hand, simulates the essential SOM transformations in soil, and, on the other hand, provides understandable analytical solutions for the meanings of the model. A conceptual analysis of SOM dynamics in croplands can be made through the use of this model.

A GENERAL SOM MODEL

A diagrammatic representation of the general SOM model is presented in Fig. 1. The model consists of two categories of state variables, namely, the plant residue variables (PR) and the soil organic matter variables (SOM). These two categories of variables are differentiated by the time sequence of occurrence, i.e., the PR variables are primary and the SOM variables are secondary or of higher order. Within each category, the state variables are further divided into various compartments, e.g., PR1, PR2, ... PRn for plant residue variables and SOM1, SOM2, ... SOMn for soil organic matter variables according to their half lives in an ascending order. The number of compartments in the PR and SOM variables can be adjusted according to the situation. In literature, two compartments of PR and two compartments of SOM are commonly used. The half lives of PR compartments are from several months to several years (refs. 7-8) and the half lives of SOM compartments are from several years to several thousand years (refs. 7, 9-11).

The parameters m and m' are rates (g/sq. m/y) of the PR input and the SOM input, respectively. The PR input parameter m is directly related to the primary production of a cropland including the above-ground and below-ground plant residues. The SOM input parameter, m', is related to the "humified fraction" of the PR. The meaning of this SOM input parameter will be further

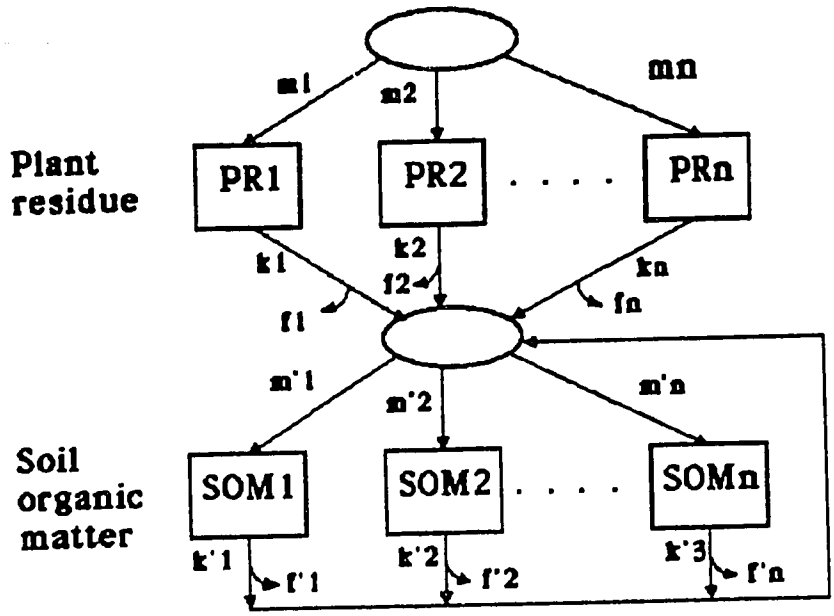

Fig. 1.1. The general SOM model.

discussed in the following section. The parameters k and k' are the first-order rate constants for the disappearance of the PR and SOM variables, respectively. The disappearance parameter k or k' consists of two parts, namely, the respiratory loss (carbon dioxide evolution) and the mass flow to other state variables (humification). Division of each k or k' into those two parts is achieved by introducing a respiratory fraction, f or f', so that the product (f)(k) represents the rate constant of carbon dioxide evolution and the product (1-f)(k) represents the rate constant of humification. These parameters of m, m', k and k' are functions of climate, vegetation and soil environment. The

parameters f and f' are characteristics of the state variables and the soil environment.

The basic equations for the SOM model are:

$$PR = PR1 + PR2 + \ldots\ldots + PRn \quad (1)$$

$$SOM = SOM1 + SOM2 + \ldots\ldots + SOMn \quad (2)$$

$$d(PRi)/dt = mi - (ki)(PRi) \quad (3)$$

$$d(SOMi)/dt = m'i - (k'i)(SOMi) \quad (4)$$

<u>The solutions of the SOM model</u>

(i) <u>At the steady state</u>. When the system is in an equilibrium, there is no net change in the value of each state variable, that is, $d(PRi)/dt = 0 = d(SOMi)/dt$, therefore,

$$(PRi)e = mi/ki \quad (5)$$

$$(SOMi)e = m'i/k'i \quad (6)$$

where (PRi)e and (SOMi)e are values of PRi and SOMi at the steady state, respectively. The time span for each PRi or SOMi to reach its respective steady state is approximated by 3/ki or 3/k'i, which is the time span needed for each variable to reach 95% of its ultimate value. The input parameters of PR and SOM, m and m', are constants at the steady state.

The ratio between any two SOM compartments, say SOMi and SOMj, at the steady state is,

$$(SOMi)/(SOMj) = (m'i/m'j)(k'j/k'i) \quad (7)$$

The mean retention time (MRT) of the organic matter in a

SOM compartment is,

$$MRT(SOMi) = 1/k'i \quad (8)$$

and the MRT for the whole SOM is

$$MRT(SOM) = (1/k'i)(SOMi)/(SOM) \quad (9)$$

(ii) <u>In a transient state</u>. In a transient state, the input parameters m and m' are not necessary constants. However, the MRT of each consecutive PR or SOM compartment usually differs by one or more orders of magnitude (refs. 8-9). For example, the MRT of the most active SOM (basically the microbiomass) is usually a few months to a year, the MRT of a slow active SOM compartment is usually several decades, and the MRT of a stable SOM is usually several hundred to several thousand years (ref. 2). Due to the large difference in MRT of the consecutive SOM compartments, only one SOM compartment will change its value significantly in a given time scale of concern (Fig. 2). The input parameters m and m' could be considered constants without serious error in this case (see the discussion in the following section). With the assumption of mi and m'i being constants, and a initial condition of (PRi)Ø = Ø = (SOMi)Ø, the value of state variables at time t, in a transient state can be calculated as follows,

$$(PRi)t = (mi/ki)(1-\exp(-ki*t)) \quad (10)$$

$$(SOMi)t = (m'i/k'i)(1-\exp(-k'i*t)) \quad (11)$$

The mean age (MA) of the organic matter in SOMi at time t is

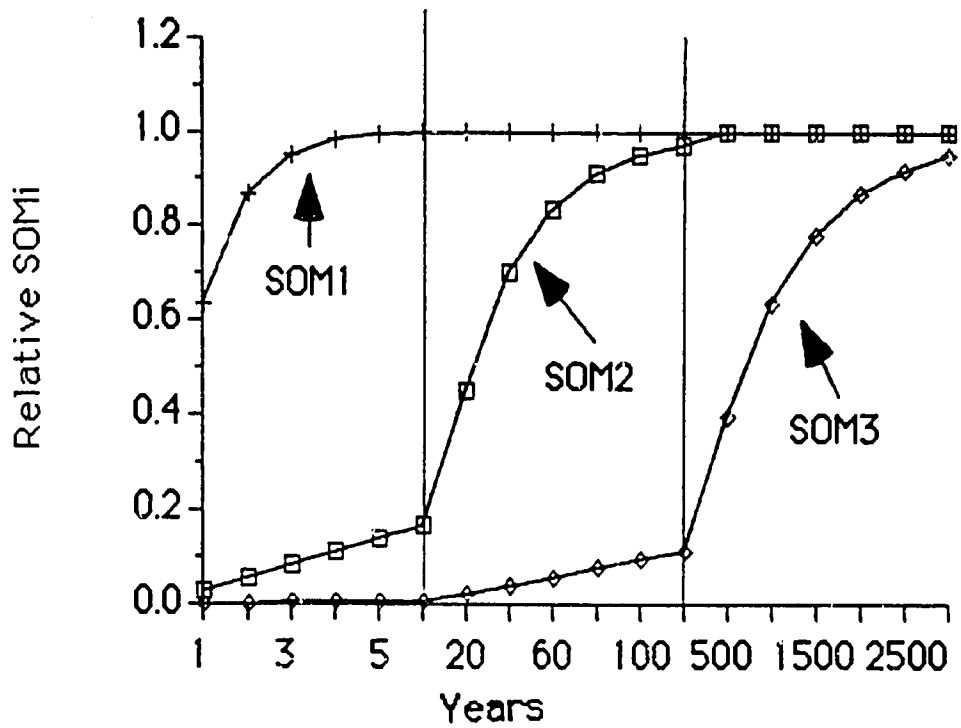

Fig. 1.2. Simulation of SOM formation in three different time scales. In each time zone, only one SOM compartment has gained size significantly. The MRT of SOM1, SOM2 and SOM3 are 1, 33 and 1000 y, respectively.

$$MA(SOMi)t = td(SOMi)/\ d(SOMi)$$
$$= (1/k'i) - (t)(\exp(-k'i*t)/(1-\exp(-k'i*t)) \qquad (12)$$

The MA for the whole soil organic matter is, therefore,

$$MA(SOM)t = MA(SOMi)t * (SOMi)/(SOM) \qquad (13)$$

DISCUSSION

1. The time span for soil organic matter to reach a steady state.

Since each SOM compartment has its own time span (approximately equals 3/k'i) to reach its steady state, the magnitude of time scale in consideration for a particular case has to be addressed when we consider the dynamics of SOM in a cropland. In a time scale of a few cropping seasons, only the most active SOM compartment (mainly the microbiomass organic matter) will reach its steady state. On the other hand, the SOM compartment with a MRT of several thousand years probably will never reach a steady state in a soil due to changes of climate, vegetative or soil conditions during such a long period. From a long-term cropland management point of view, the SOM compartment with a MRT of decades (the slow active SOM) is of main concern. The stable SOM, which has a MRT of several hundred to several thousand years, can be considered a constant in this case without serious error. Realizing a large difference in MRT of SOM compartments is important, because it greatly simplifies the solutions of a SOM model.

2. The sizes of SOM compartments.

The relative sizes of the SOM compartments at the steady state is determined by the relative ratio of m'i/k'i as described in Equation (7). The magnitude of k' has a great bearing on the final relative sizes of SOM compartments; namely the most resistant SOM compartment will dominate the whole soil organic matter. For example, in a two-compartment model, the k' value of the active SOM compartment is 30 to 50 times larger than the k' value of the stable SOM compartment (ref. 11). If the SOM input parameter m'i is in the same order of magnitude for each compartment, the final soil organic matter will be almost totally

the stable SOM. This is not the case in many real situations. In the example presented by Balesdent et al. (ref. 11), a virgin prairie soil in Missouri consists of 25% of the stable SOM with a MRT of 1000 y and 75% of the SOM with a MRT of 15 y. Assuming this soil was in a steady state, a simple calculation using Equation (7) indicates that the SOM input parameter for the stable SOM was only 0.5% of that of the active SOM. In most cases, the input parameter for a stable SOM is only a very small fraction of that of the active SOM compartment, and the relative sizes of the active and stable SOM may vary but are of the same order of magnitude.

3. The PR and SOM input parameters, m and m'.

The PR input parameter m is directly related to the primary productivity of a cropland, including above-ground and below-ground plant residue. In literature, decomposition of plant residue is commonly described in a two-compartment model which consists of easily decomposable (metabolic) and resistant (structural) plant materials. The MRT of the easily decomposable PR is about few months and the MRT of the resistant PR is about one year (refs. 5, 12). The value of the SOM input parameter m' can not be measured directly from experiments. Its value and meaning can be assessed from analysis of a model system. Considering a two-compartment SOM model, as depicted in Fig. 3, the SOM input parameter m'1 can be described in the following equation,

$$m'1=(k1)(PR1)(1-f1) + (k2)(PR2)(1-f2) + (k'2)(SOM2)(1-f'2) \quad (14)$$

After PR1 and PR2 reach their respective steady states (in a few years), the third term at the RHS of Equation (11) is a very small number in comparison to the first two terms (both SOM2 and (1-f'2) are very small at this stage) and the value of m'1 can be

approximated by,

$$m'1 = (m1)(1-f1) + (m2)(1-f2) \tag{15}$$

If we assume that f1 = f2 = f, i. e. the respiratory fraction of PR1 and PR2 are the same, Equation (15) can be expressed as

$$\begin{aligned} m'1 &= (m1+m2)(1-f) \\ &= (m)(1-f) \end{aligned} \tag{16}$$

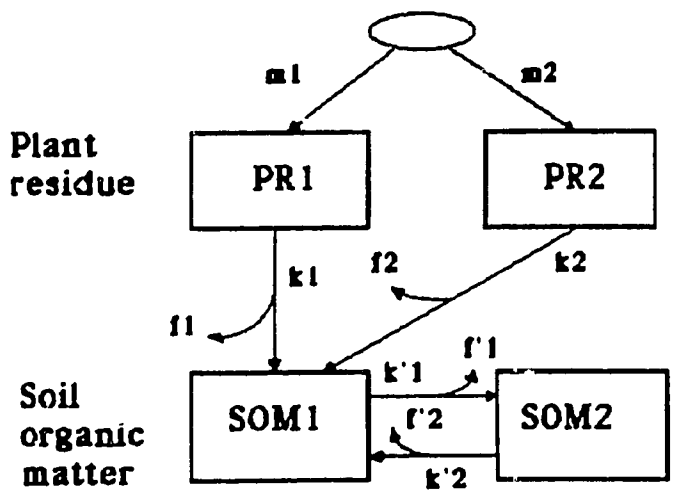

Fig. 1-3. The two-compartment SOM model.

Equation (16) says that the SOM input parameter m'1 is a fraction of the PR input parameter m. The fraction (1-f) can be considered the "humified fraction", h, of the plant residue. A simulation of the m'1 using the two-compartment model indicated that the value of m'1 approaches the humified fraction, h, in

just few years and stayed constant (Fig. 4). The above analysis indicated that the SOM input parameter approaches a constant value after few years of a system and is a fraction (the humified fraction) of the PR input parameter.

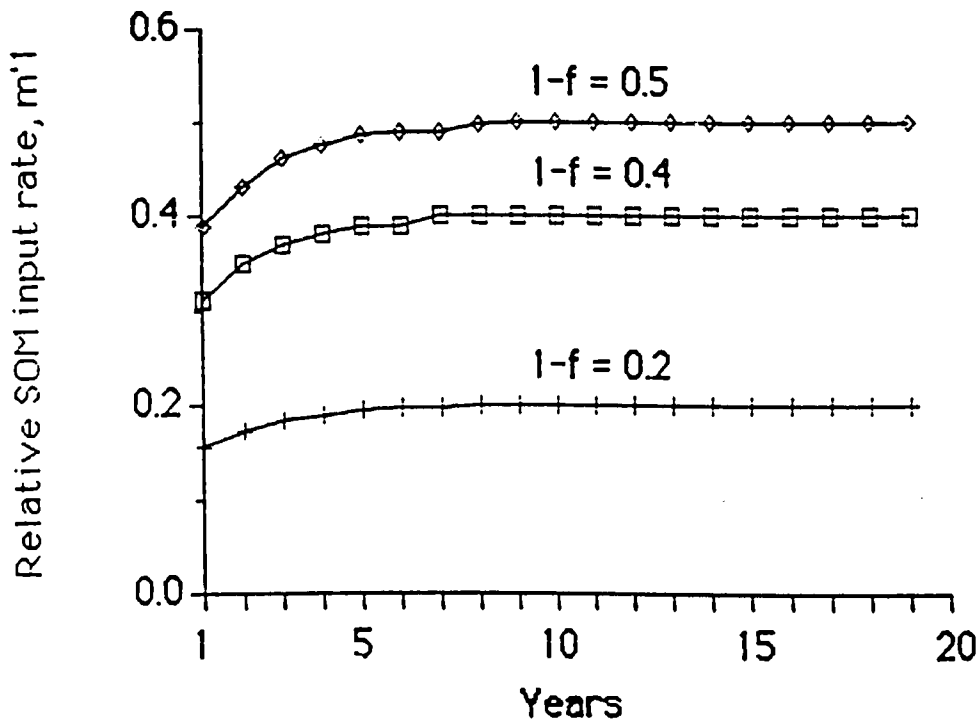

Fig. 1-4. Simulation of the SOM1 input rate m'1 as a function of time in a two-compartment model. Notice that m'1 quickly approaches the value of the PR humified fraction (1-f) in just a few years after the system begins. The MRT for PR1, PR2, SOM1 and SOM2 are 0.5, 1, 10 and 1000 y, respectively.

4. The mean age of soil organic matter.

The mean age of SOM is equivalent to the radioactive carbon dating age of the SOM. In a soil which has equilibrated with the vegetation and climate for a long time (at a steady state with respect to dynamics of SOM), the mean age of soil organic matter approaches a constant which is determined by the MRT and the relative sizes of all the SOM compartments. By definition, the MRT is the mean age of a SOM compartment at its steady state (Equation 12). It is not necessary that all SOM compartments of a soil is in a steady state in many cases, therefore, the mean age of soil organic matter is a function of time of soil development (Fig. 5). In a cultivated land, the native active SOM is replaced by the crop active SOM after a period of cultivation. The crop active SOM is usually smaller than the native active SOM which makes the relative proportion of the stable SOM, and thus the MA of the whole SOM, increased substantially after years of cultivation. Take the case in Fig. 5 as an example, the cultivation of a virgin soil resulted in changing the fraction of active SOM from 0.75 under the native vegetation to 0.50 under the crop. The corresponding change in the MA is from 258 y to 505 y. The changes of radioactive dating age of SOM after cultivation, therefore, is also a measurement of the changes in relative fraction of the native stable SOM.

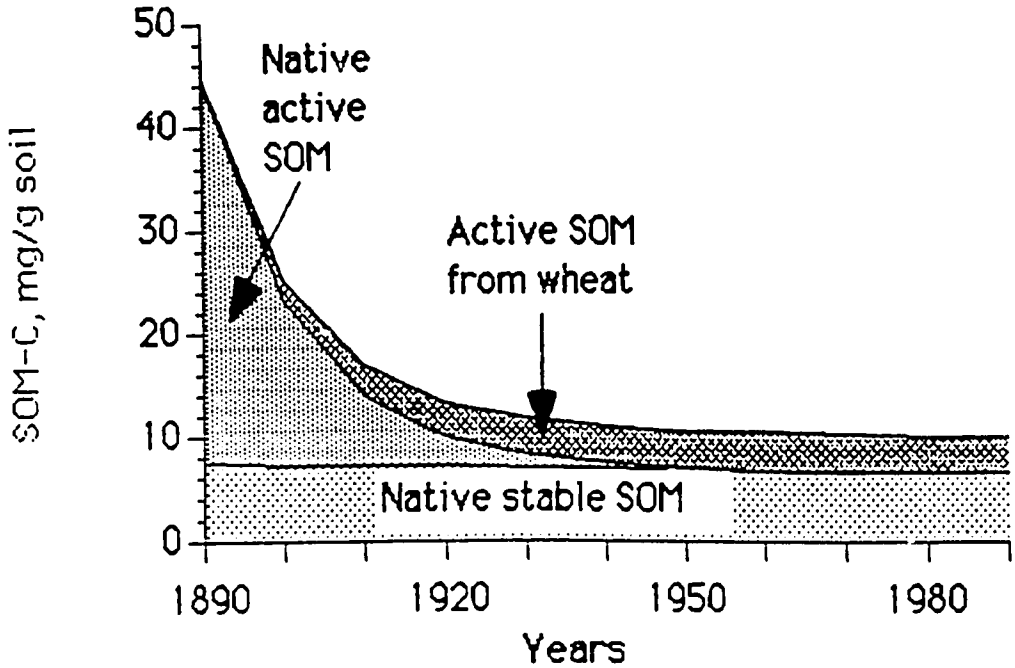

Fig. 1.5. Simulation of the SOM dynamics in the Sanborn Field case. The solid circles indicate the measured stable SOM C and the open circles indicate the measured crop C.

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PART II

Organic Matter and Soil Losses via Runoff and Erosion

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Introduction

Field measurement of soil organic matter and top soil losses via runoff and erosion is often required or desirable in soil conservation and management studies in tropical croplands. The information is useful in the estimation of soil productivity loss due to runoff and erosion.

The commonly used dynamic methods, e.q. capturing water and sediment in collectors to determine run-off erosion from a slope, are more sensitive and provide information about the eroded materials but they are much more difficult and costly to install and operate. There is a need for a simple yet effective dynamic metnod for field erosion measurement. This need is especially urgent in countries where limited means are available for soil conservation research. In this study we present a simple "litter-bag" method for the dynamic measurement of soil organic matter and top soil erosion in a cropland and estimated the soil organic matter and top soil losses in a low-input (Y-215) and a high-input (Y-412) system in the Yurimaguas Station, Peru.

Objectives

The objectives of this study are 1) test the efficiency of a "litter-bag" method for dynamic measurement of surface soil

erosion in a cropland, and 2) determine organic matter and surface soil losses via runoff and erosion in a low-input (Y-215) and high-input (Y-412) system.

Procedure

The experiment was carried out at the Yurimaguas Experiment Station, in the Amazon region of Peru. The plots of Y-215 (low-input) and Y-412 (high-input) were chosen to be the experiment sites. Nylon litter bags of 30x30 cm with 5 mm mesh on the top and 2 mm mesh at the bottom were constructed. Twenty litter bags were placed randomly and secured on the ground with nails in each experimental plot on November 6, 1987. Four litter bags from each plot were harvested at 1, 2, 4, 8, and 16 weeks intervals. Additional bags were placed on the plots at the 8th week, and harvested at the 16th week to evaluate the effects of accumulated soil on the efficiency of the bags. Bags placed side by side (paired) were used to evaluate the errors of the experiment. After being harvested, the contents of bags, (both inside and on top of the bags) were oven dried, weighed, ground, and analyzed for ash content (2 h at 600 C), organic carbon (4), total N (1), and total P (3). The area of the litter bag was used to convert the results from per bag to per acre basis.

Results

The eroded soil materials collected by the litter bag between November 6, 1987 and February 26, 1988 are listed in Table 1, along with some of their chemical properties. Analysis of variance indicated that the pooled coefficient of variation is 7%

within the side-by-side pairs; 24% within plots; and 42% within systems. This indicated that the eroded soil collected by litter bags was relatively reproducible and the larger variation within plots and systems was a reflection of the heterogeneity of the experimental sites. There was no significant difference in the amount of cumulative eroded soil between the high-input and low-input systems during the 16 weeks period (Fig. 1). There were, however, large fluctuations of the eroded soil among different periods of the experiment (Fig. 2) reflecting the rainfall factor on the erosion during each period.

The eroded soil collected in the low-input system contained more organic carbon than that of the high-input system (Table 1). This is expected since the low-input system received no tillage treatment, and thus caused accumulation of organic matter in the surface layer. Comparison of some chemical soil properties between the eroded soil and the surface 15 cm soil layer of the sites are presented in Table 2. The eroded soil contained more than twice the amount of organic carbon and twenty times the phosphorus found in the surface 15 cm soil layer of the experimental sites, an evidence of organic matter enrichment in the very top soil surface of both systems. Similar C/N ratio of the eroded soil was found for both the high-input and low-input systems and for the surface 15 cm soil layer, indicating that C and N were not eroded differentially. The N/P ratio of the eroded soil was much lower in the high-input system, which was probably due to the phosphorus fertilizer application.

The amount of eroded soil during the second 8-week period was

the same regardless of whether it was determined by one-time collection or by difference of two consecutive collections (Table 3). This implied that the efficiency of the litter bag was not affected by the amount of soil accumulation to the extent of at least 10 g/bag, or 1.1 tons/ha.

Both high and low input systems had very slight erosion during the four-month period, which was about 1 ton/ha. This represented loss of 1.6 kg N/ha, and 0.22 kg P/ha for the high-input system and 2.8 kg N/ha, and 0.19 kg P/ha for the low-input system during the four-month period. The total precipitation was 695 mm during this period.

Conclusions

The litter bag method seemed to be reproducible and sensitive in collecting eroded soil up to an amount of at least 10 g/bag (equivalent to 1.1 ton/ha). Sensitivity is one of the advantages of this method. Surface soil erosion less than 0.1 ton/ha (1 g/bag) can be easily detected. The chemical properties of the collected soil in litter bags seemed to represent the properties of the eroded surface soil of the experimental plots. The soil collected in the bags are likely representing sheet erosion in gentle sloped fields and under a low-to-moderate rainfall intensity situation. The litter-bag method could estimate surface soil erosion and onsite deposition for a specific storm event and detect spatial variability of erosion in natural field conditions. The method is not likely suitable for measuring gully erosion in steep sloped lands or under very high rainfall

intensity situation. In order to make this method applicable to more general situations, factors which affect the collecting efficiency of the litter bags such as rainfall intensity, slope, particle sizes of the eroded soil and sizes of the bag and mesh need to be further studied. The method also needs to be compared with the commonly used volumetric or dynamic methods so that results could be compared among methods.

Table 1. Eroded soils collected by litter bags at various intervals along with some of their chemical properties.

Weeks	Eroded soil		Organic C	Total N	Total P
	-g/bag-	-ton/ha-	-g/ha-		
			High-input		
1	0.244	0.027	562	41.9	5.9
2	2.092	0.232	4817	359.2	50.2
4	3.730	0.414	8598	640.7	89.5
8	4.172	0.464	9616	716.5	97.5
16	9.196	1.022	21185	1579.5	220.6
			Low-input		
1	0.986	0.110	4540	341.4	23.7
2	2.748	0.305	12656	951.2	66.0
4	3.382	0.376	15576	1170.7	81.1
8	4.531	0.503	20867	1753.2	121.5
16	8.335	0.926	38387	2797.5	193.9

Note: Values are means of 8 bags. The pooled coefficient of variation (CV) was 7% within side-by-side pairs; 24% within plots; and 42% within systems.

Table 2. Comparison of some chemical properties of the eroded soil collected by litter bags and the surface 15 cm soil of the experimental plots.

	Eroded Soil				Surface 15 cm soil			
	Org. C	Total N	Total P	C/N	Org. C	Total N	Total P	C/N
	%		ppm		%		ppm	
High-input	2.1	0.153	215	13.4	0.86	.054	11	15.9
Low-input	4.1	0.297	206	13.8	1.62	.130	5	12.5

Table 3. Comparison of eroded soils and some of their chemical properties collected by either one-time collection or by difference of two consecutive collections in litter bags.

	Soil		Total N		Total P	
	One-time	By diff.	One-time	By diff.	One-Time	By diff
	g/bag		ug/bag			
High-input	5.41	5.03	8368	7782	1172	1109
Low-input	5.16	3.81	16069	9414	1118	646

Figure 2-1. Cumulative eroded soil of the high-input and low-input systems collected during various length of sampling time in the Yurimaguas Station, Peru.

Figure 2-2. Rate of top soil erosion of the high-input and low-input systems during various period of sampling time in the Yurimaguas Station, Peru.

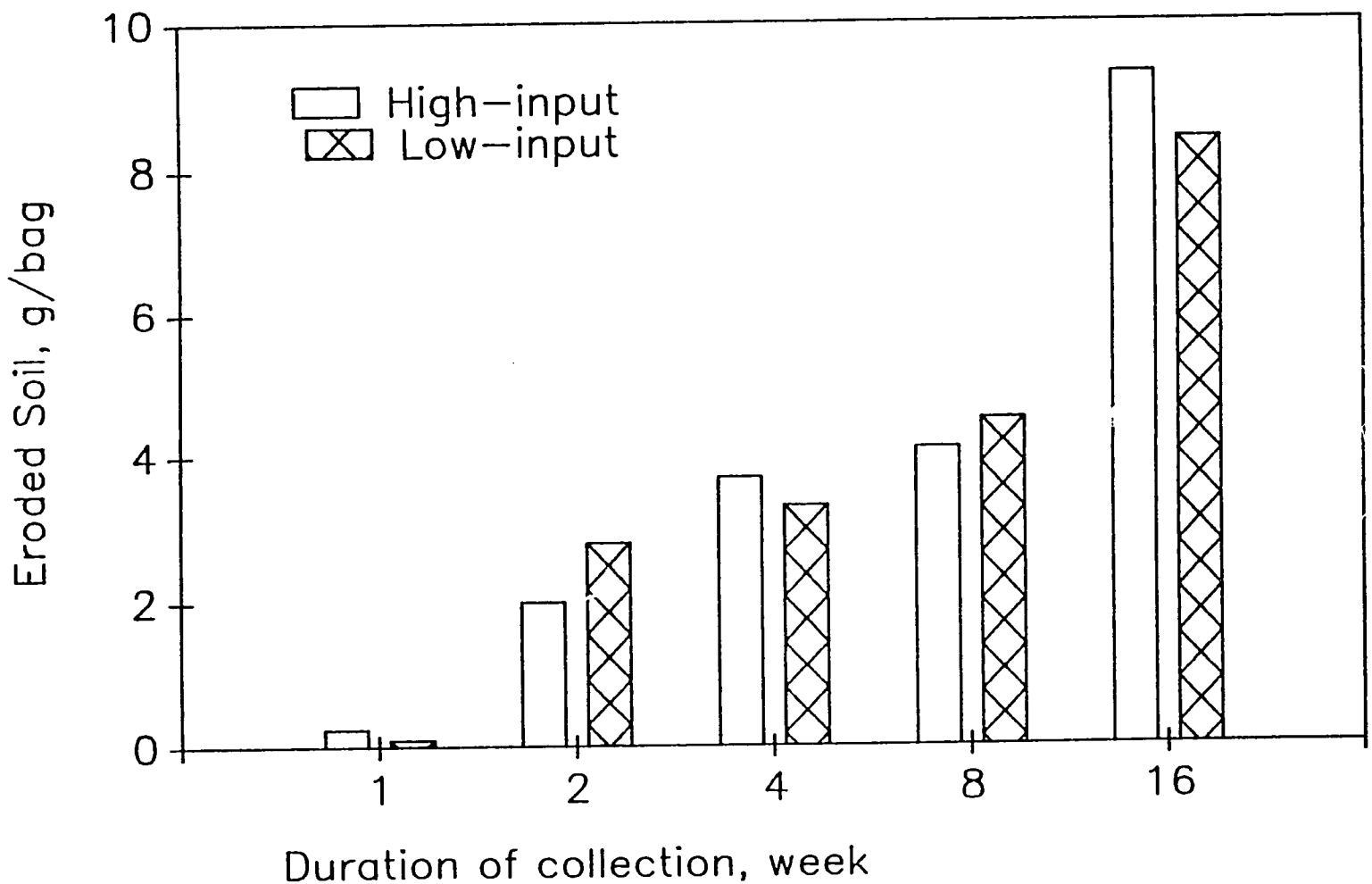
High—input
Low—input
Eroded Soil, g/bag
0
2
4
6
8
10
1
2
4
8
16
Duration of collection, week

Fig. 2-1.

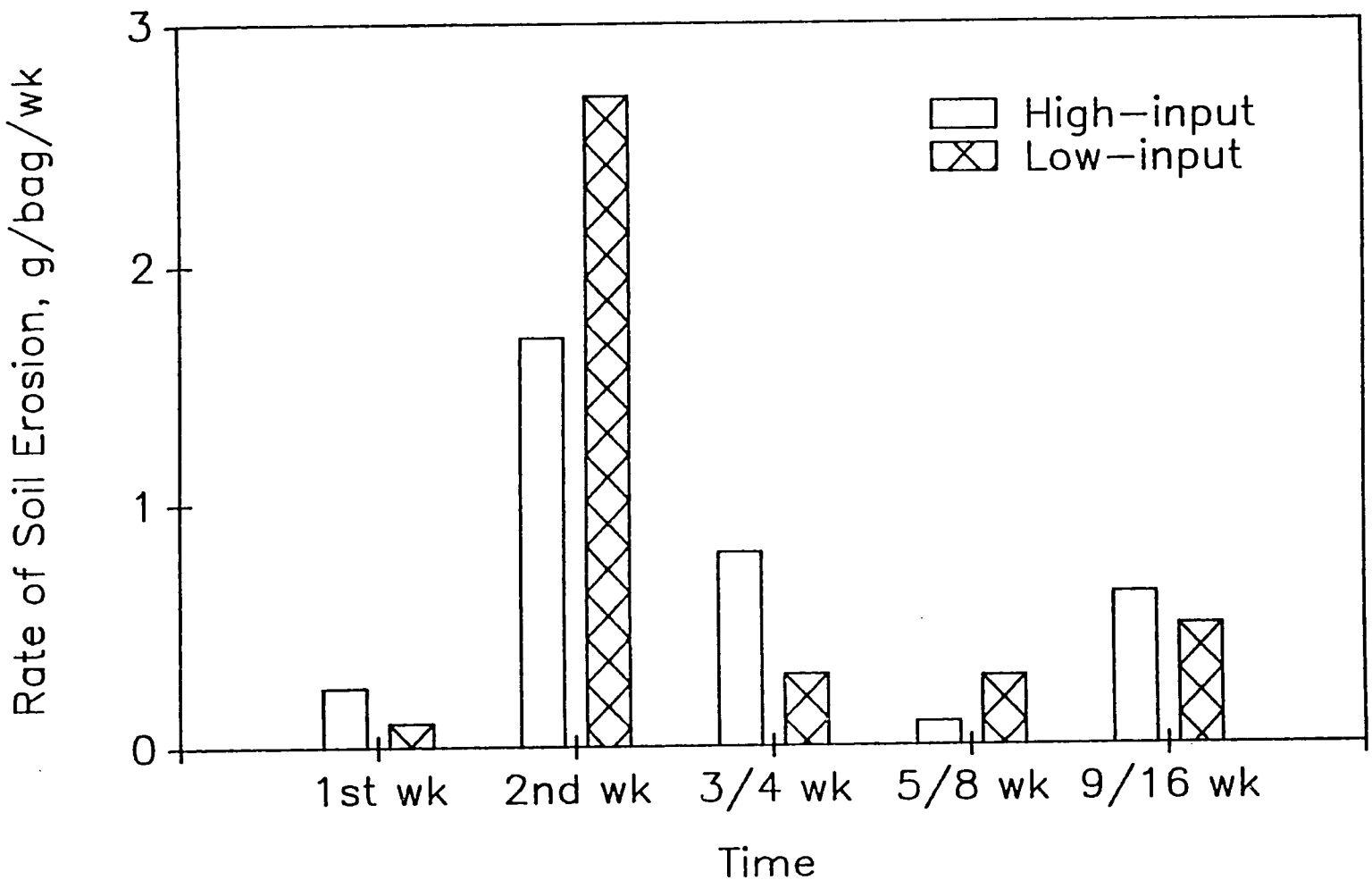
Rate of Soil Erosion, g/bag/wk
3
2
1
0
High–input
Low–input
1st wk
2nd wk
3/4 wk
5/8 wk
9/16 wk
Time

Fig. 2-2.

Part III

Soil Respiration in Different Cropping Systems

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Julio A. Alegre, N. C. State University

Introduction

Soil respiration is a measurement of soil organic matter turnover and soil microbial activity in a system. Soil respiration has been related to the productivity of a cropland in many studies. The information of soil respiration is basic to the understanding of nutrient cycling and soil organic matter dynamics in a cropping system.

Measurement of soil respiration in a cropland is often complicated by the problem of separating it from the root respiration. In this study, we attempted to estimate the soil respiration and root respiration of a low-input and a high-input systems in Yurimaguas Station of Peru. We also evaluated the effects of moisture, temperature, and crop type factors on the soil respiration and root respiration of the two systems.

Objectives

1. Test a simple field method that measures soil respiration and root respiration in a tropical cropland.

2. Evaluate the effects of soil moisture, soil temperature, and crop type factors on the soil respiration and root

respiration of a low-input and a high-input cropping system in the Yurimaguas, Station Peru.

Procedures

Carbon dioxide evolution from soil surface was measured by an alkaline CO_2 trap inside of a metal can (220 cm 2 X 25 cm) for 6 hours each time. A pair of plants were selected, and one of them the above-ground part removed 10 days prior to the carbon dioxide measurement. On the day of measurement, the above-ground part of the other plant was also removed. A metal can was placed on top of the roots of each living and dead plant by inserting the edge to the depth of 3 cm. The carbon dioxide evolved was collected in an alkaline trap inside the can from 9 am to 3 pm. The carbon dioxide was determined by HCl titration after addition of barium chloride. Soil moisture and temperature were monitored at 9 am and 3 pm at the depth of 2, 5, and 10 cm using neutron probe and thermometer, respectively. All the experiments were carried out in quadruple replicates.

Soil respiration was estimated by the carbon dioxide evolution from the dead plant sites, and root respiration was estimated by the difference of CO_2 evolution between the living and dead plant sites.

Separated experiments were carried out to monitor the time course of CO_2 evolution from soil after the above-ground part of plant was removal. Single plant of the crops in the low-input and high-input systems, namely, rice, cowpea, corn and soybean, were transplanted and grown in pots in a greenhouse for 4 weeks. The above-ground plants were then removed, and the CO_2 evolution

from soil was monitored daily from 9 am to 3 pm for 12 days. The soil moisture of the pots was maintained to a constant level throughout the experiment.

Results

The time course of CO_2 evolution from the greenhouse pots after the above-ground plant was removed is shown in Figure 1. The CO_2 evolution increased immediately following the cutting indicating the effect of adding fresh roots to the soil. This effect is levelled off after 5-6 days in comparison to the control.

The pattern of soil respiration of the low-input system (Y-215) and high-input system (Y-412) during the period between November 1987 and February 1989 is given in Figure 2. Fluctuation in soil respiration was more drastic in the low-input system than that of the high-input system. The time-weighed average of the soil respiration rate, however, was surprisingly similar for the two systems (1.623 and 1.650 g CO_2-C/m2/d for Y-215 and Y-412, respectively). The soil moisture has a significant effect while the soil temperature has no significant effect on the soil respiration rate of both systems. The soil respiration is closely related to the root respiration in the low-input system (r=0.764 *), while this relationship is not found in the high-input system (r=0.380 NS) (Fig.3).

The root respiration estimated correlated well with the stage of crop growth in both systems (Fig. 4). These results indicate that the root respiration measurements provide

reasonable estimation of the crop root activities in the field condition. The non-legume crops (corn and rice) have significantly higher root respiration rates than those of legumes (soybean, cowpea and mucuna). Rice has the highest root respiration among the five crops (Table 1)

Conclusions

1. This simple method of measuring soil respiration and root respiration in the field condition seems working well in the Yurimaguas Station, Peru. The information of soil respiration is important to the understanding of soil organic matter dynamics and nutrient cycling in a cropland. This information has been rarely found in literature. The information of root respiration may be important to the study of soil management systems because it is related to the root activity of a crop.

2. Soil respiration of the low-input system is affected mainly by the soil moisture and type of the crop while that of the high-input system is affected mainly by the soil moisture along. Both systems, however, have the same average soil respiration rate in an annual basis.

Table 1. Comparison of estimated root respiration with various crop types and total yields.

	Growth period	Root Respiration	Grain	Straw
	day	g - C/m2	t/ha	
		Low-input system		
1st corn	123	0.807	3.38	4.83
2nd corn	107	0.960	3.09	3.76
Soybean	104	0.451	1.49	1.17
		High-input system		
1st rice	120	2.424	1.21	1.57
2nd rice	138	1.532	0.85	1.11
Cowpea	75	0.345	ND	ND

Note: ND = Not Determined.

Figure 3-1(a). The time course of CO_2 evolution from the greenhouse experiments after the above-ground plants (high-input system) were removed.

Figure 3-1(b). The time course of CO_2 evolution from the greenhouse experiments after the above-ground plants (low-input system) were removed.

Figure 3-2. The pattern of soil respiration rates of the low-input and high-input systems during the 1987-1989 period.

Figure 3.3. The relationships of the soil respiration and root respiration in the low-input and high-input systems.

Figure 3-4(a). The root respiration rates of the low-input system during the 1987-1989 period.

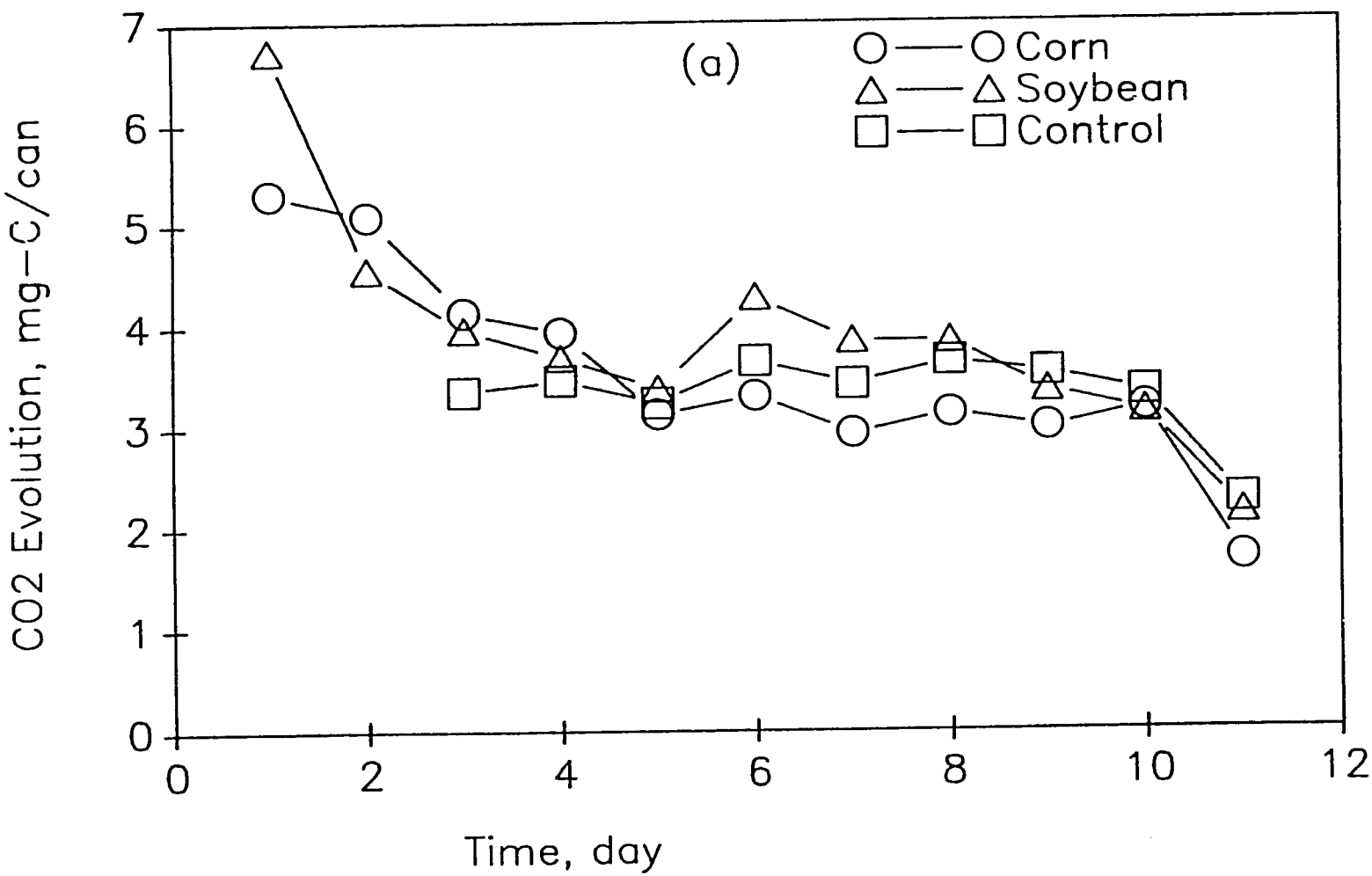
(a)
Corn
Soybean
Control
CO2 Evolution, mg-C/can
Time, day
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12

Fig. 3-1(a).

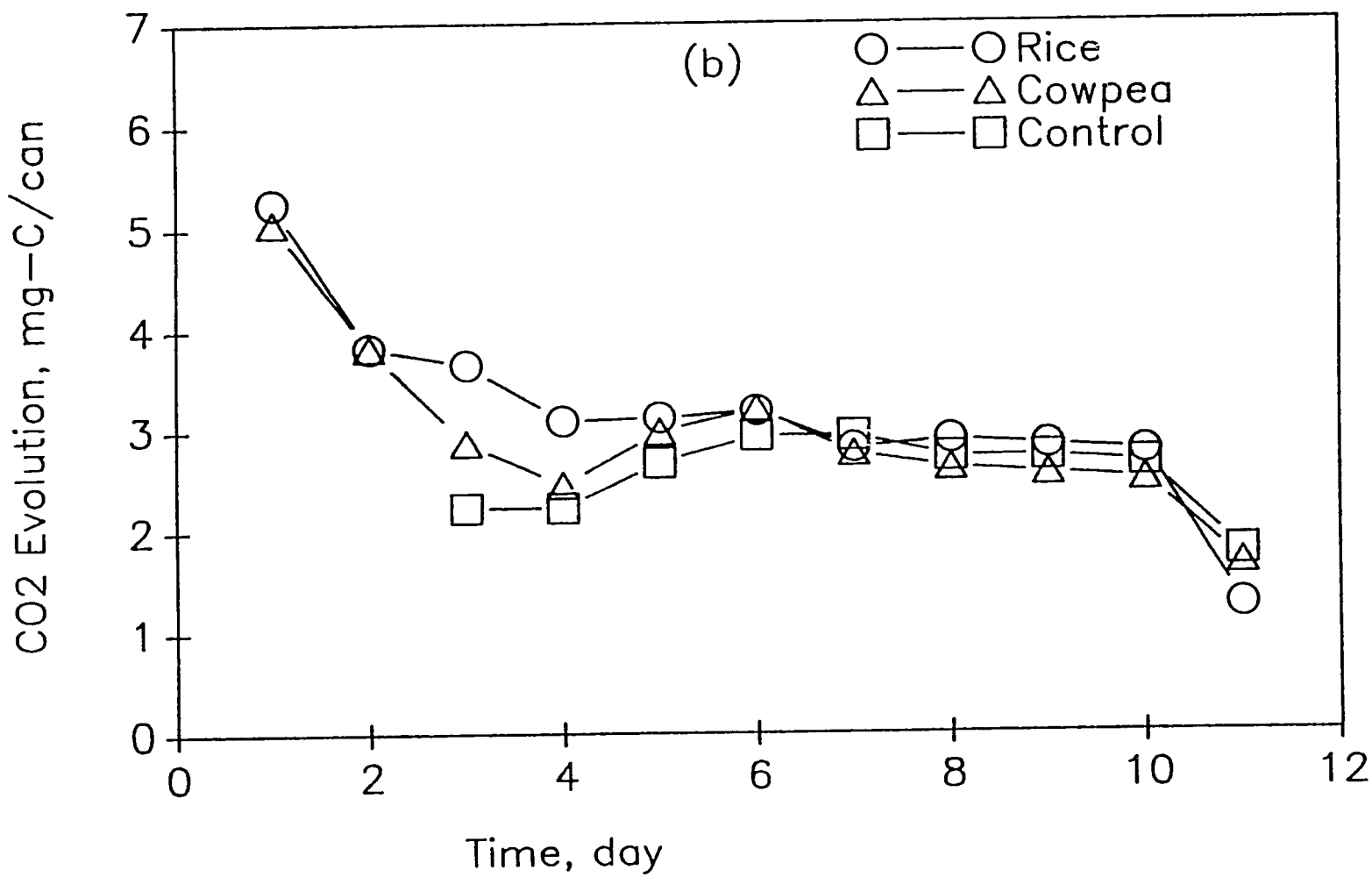
(b)
Rice
Cowpea
Control
CO2 Evolution, mg-C/can
Time, day
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12

Fig. 3-1(b).

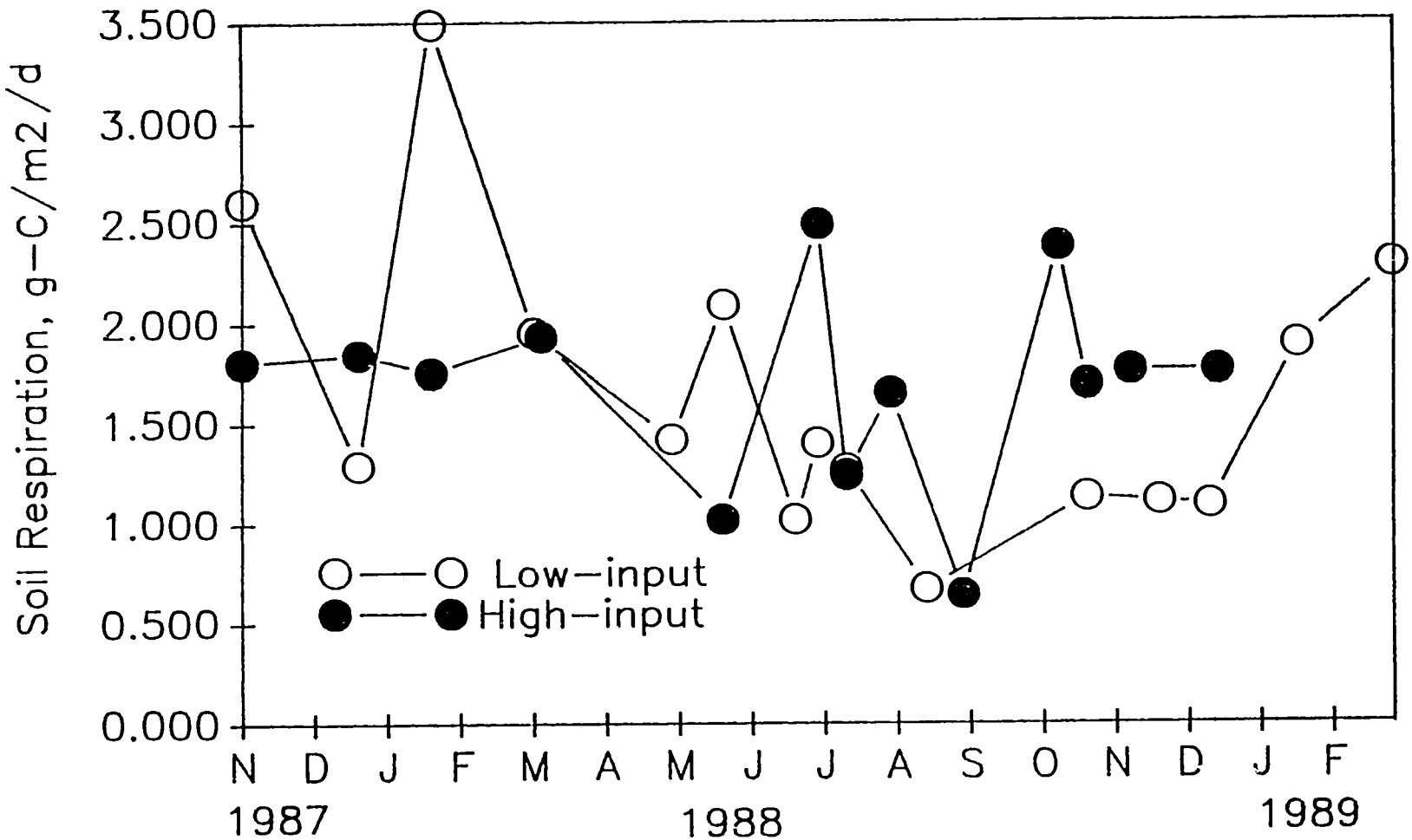
Soil Respiration, g-C/m2/d
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Low-input
High-input
N D J F M A M J J A S O N D J F
1987
1988
1989

Fig. 3-2.

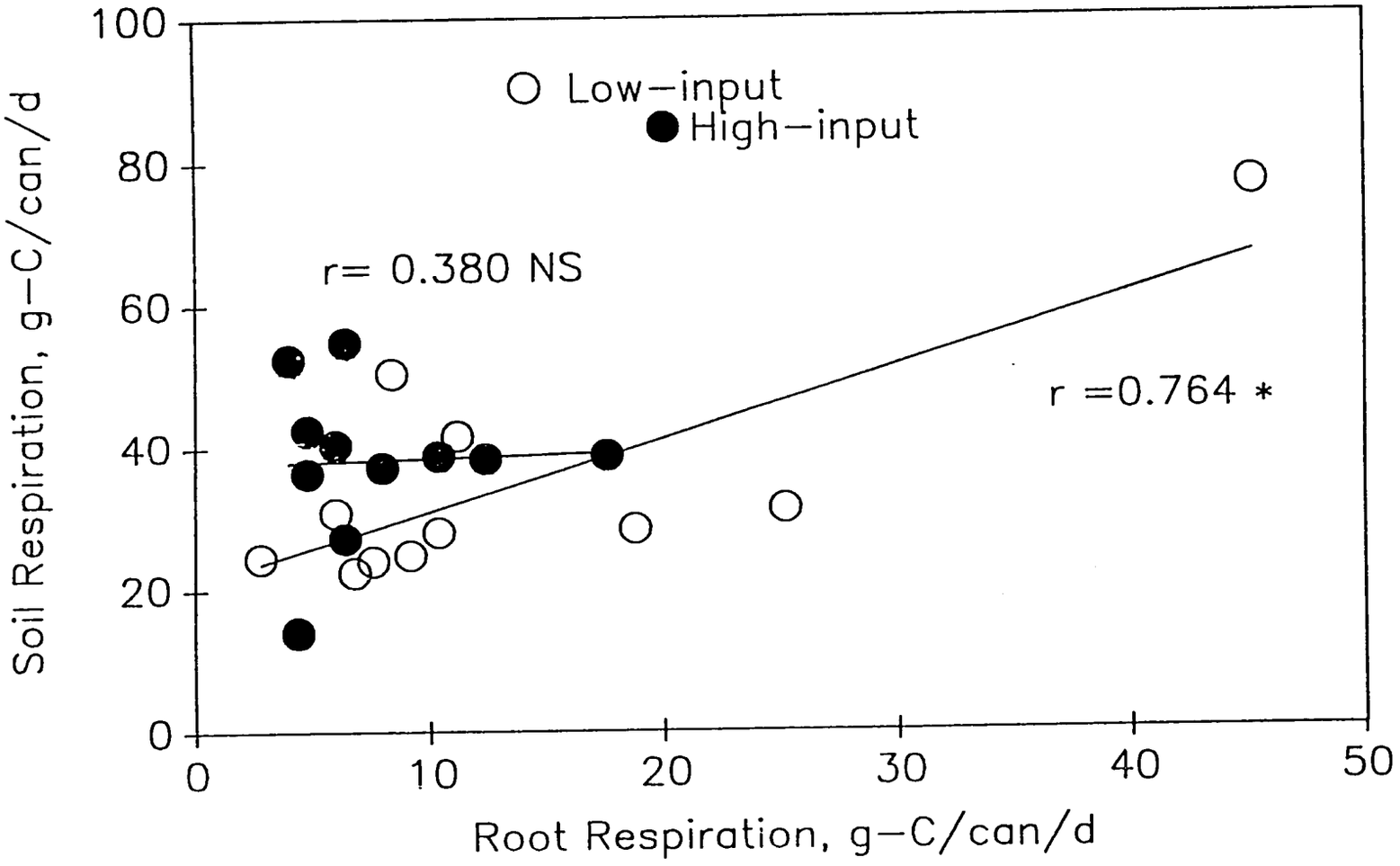
Low-input
High-input
r= 0.380 NS
r =0.764 *
Soil Respiration, g-C/can/d
Root Respiration, g-C/can/d
0
20
40
60
80
100
0
10
20
30
40
50

Fig. 3-3.

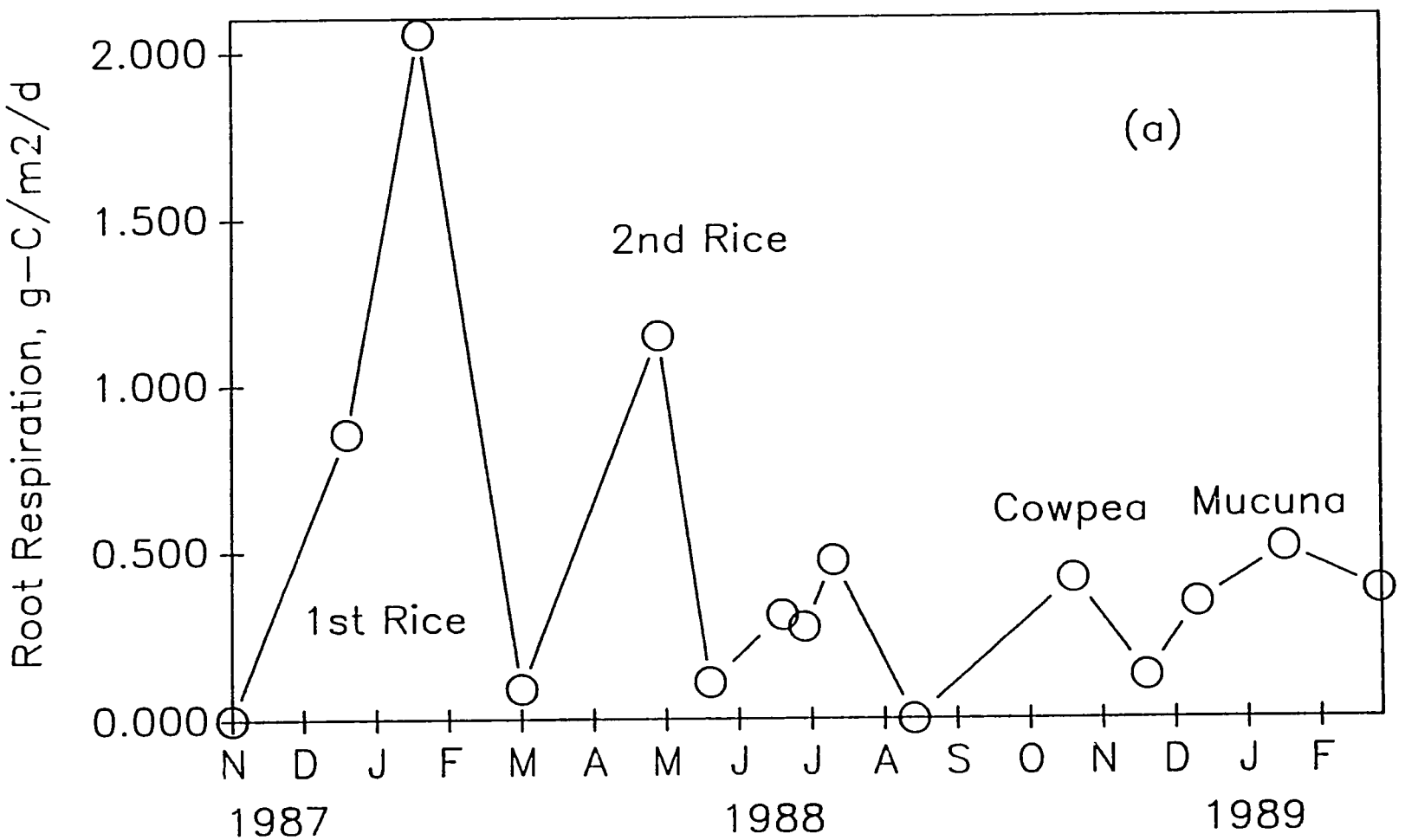
Root Respiration, g-C/m2/d
2.000
1.500
1.000
0.500
0.000
(a)
1st Rice
2nd Rice
Cowpea
Mucuna
N D J F M A M J J A S O N D J F
1987
1988
1989

Fig. 3-4(a).

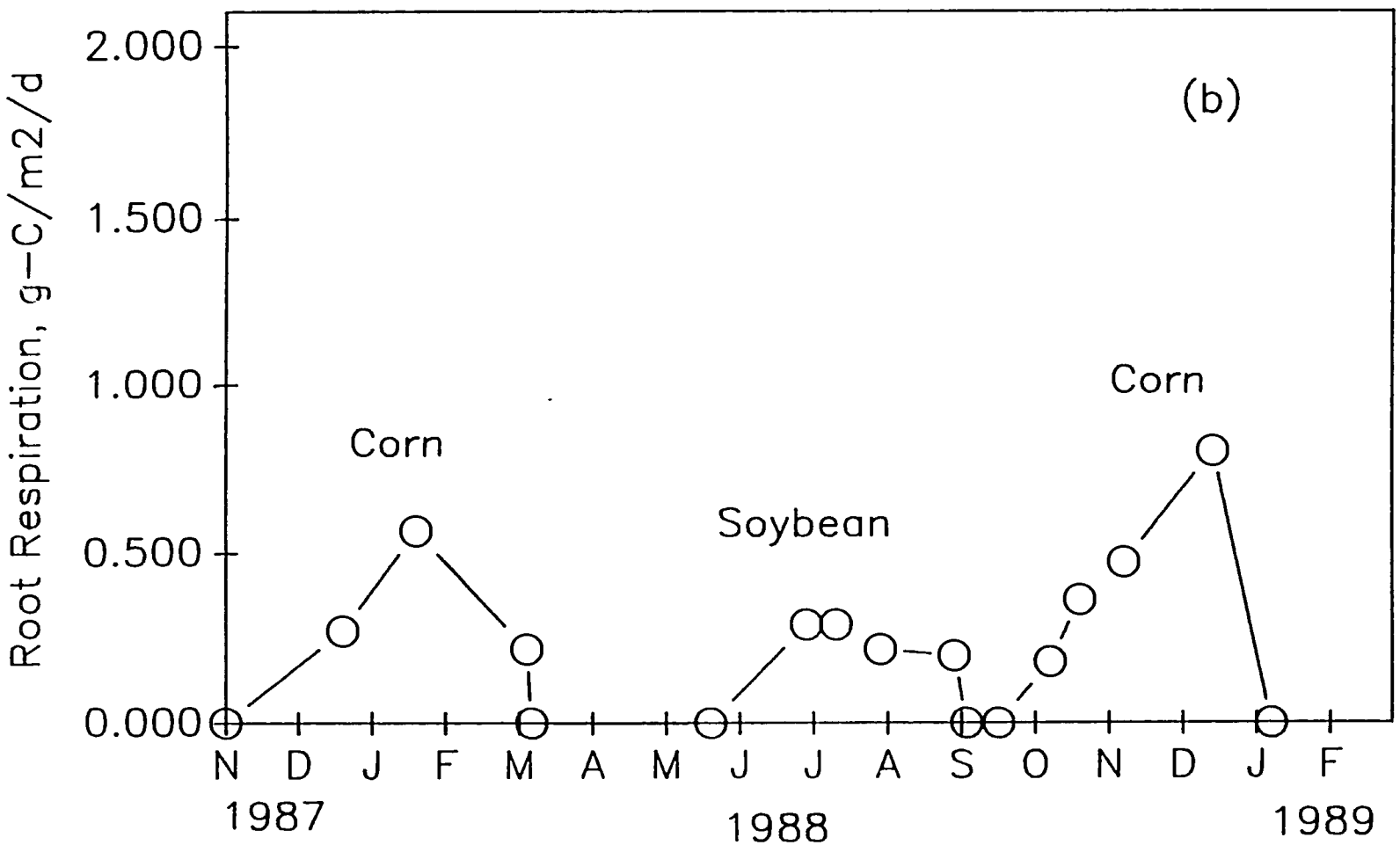
(b)
Root Respiration, g-C/m2/d
2.000
1.500
1.000
0.500
0.000
Corn
Soybean
Corn
N D J F M A M J J A S O N D J F
1987
1988
1989

Fig. 3-4(b).

PART IV

Decomposition of the Above-ground and Below-ground Crop Residues

Y. P. Hsieh, Wetland Ecology Program, Florida A & M University

Introduction

Maintenance of soil organic matter is a key to a successful cropping system in tropical area. Crop residues are usually a main source of organic matter input to a tropical cropland. The amount of soil organic matter generated each year in a humid tropical cropland is mainly determined by the quantity and quality of its crop residue input. Measurement of the decomposition patterns of crop residues is a means to estimate the quantity and quality of crop residue being incorporated into the cropland.

In this study we measure the decomposition of crop residues in a high-input and a low-input systems in the Yurimaguas Station of Peru using the litter-bag method. This information is useful for the simulation of soil organic matter and nitrogen dynamics of a cropland.

Objectives

1. To determine the quantity and quality of the above-ground and below-ground crop residues of soybean and corn (high-input system), and cowpea and rice (low-input system) in the croplands of Yurimaguas Station, Peru. 2. To evaluate the effect of crop residue input to the status of soil organic matter in the high-input and low-input system using the available information on

crop residue decomposition.

Procedures

The experiment was carried out at the Yurimaguas Station, in the Amazon region of Peru. The climate is warm and wet with annual precipitation of 2200 mm distributed relatively even throughout the year, and a mean annual temperature of 26 ^{o}C. The soil of the experiment site is a well-drained, sandy loam Typic Paleudult with 0.2% slopes. Decomposition of crop residues was measured in two cropping systems; a corn/soybean rotation high-input system and a rice/cowpea rotation low-input system. The crops at the time of experiments were corn for the high-input, and rice for the low-input systems. Two experimental plots of 5x10 m in size were laid out in each system. Nylon litter bags of 30x30 cm with 5 mm mesh on the top and 2 mm mesh at the bottom were constructed. Crop residues of corn, soybean, rice cowpea were collected in the nearby croplands and sorted into the above-ground and below-ground parts and air-dried before putting them into the litter bags. Twenty five g of the air-dried, above-ground and 10 g of the air-dried, below-ground crop residues were put into the litter bags, respectively. The litter bags of the above-ground crop residues were laid on the soil surface of the respective cropping system, and those of the below-ground crop residue were buried into the ground in a vertical position. Four litter bags were harvested from the fields at 1st, 2nd, 4th, 8th, and 16th week of the experiment. In order to estimate the contamination of surface erosion-born organic matter in the

litter bags, additional empty litter bags were placed and harvested with the crop litter bags, After being harvested, the content of each litter bag was recovered, oven-dried (60 ^{o}C for 5 d), weighed, ground, and analyzed for ash content (600 ^{o}C for 2 h). The weight of the original crop residue in the bags was obtained by substracting the organic matter content of the side-by-side empty bags from that of the crop litter bag. Analysis of variance of the experimental results was performed with a commercial statistics package (DAISY) for Apple computer.

Results and Discussion

The patterns of crop residue decomposition in the high-input and low-input systems are shown in Fig. 1. They follow the general trend of crop residue decomposition, namely, the decomposition rates decrease as the incubation time increases. To interpret the results of decomposition, a two-compartment, first-order kinetic model for the crop residue decomposition was used. A Guggenheim's plot method was used to evaluate the quantity and rate constant of the two compartments, namely:

$$\ln \text{delta } D = \ln \{Do[1-\exp(-k)]\} + kt \qquad (1)$$

where delta D is the amount of organic matter decomposed during a fixed time interval (one week), Do is the initial quantity of the organic matter in the compartment, k is the rate constant, and t is the time (Fig. 1 and Fig. 2). The results of the rate constant and quantity of the corresponding compartment are listed in Table 1. In general, the above-ground legume crop residue (soybean and cowpea) decompose faster than that of the non-legume crop residue (corn and rice), and the below-ground crop residue

decompose faster than the above-ground crop residue. The mean retention time (MRT) of the first (easily decomposable) compartments of the above-ground crop residue ranged from 1.5 to 6.8 weeks while those of the second (more resistant) compartments ranged from 0.6 to 1.8 y. The difference of decomposition among the crop residues only appeared in the first three months and the differences become insignificant at the end of one year. As the model predicts 7-20 % of the above-ground crop residue will remain in soil after one year of incorporation, with cowpea the lowest and rice the highest amount of remaining. The below-ground crop residue decomposes very fast in the beginning (MRT = 1.6 weeks) but slowed down thereafter (MRT = 1.8 y), and after one year of incorporation 24-34 % of the residue will remain in soil.

These results imply that most of the crop residues (76-93 %) will be recycled in soil in a period of less than one year. The impact of crop residue incorporation in soil is relatively short termed, and therefore, is important to the nutrient recycling but less important to the building up of soil organic matter.

Table 1. The calculated quantity and decomposition rate constant of the first and second compartments of the crop residues.

	First compartment		Second compartment	
	Quantity	Rate const.	Quantity	Rate const.
	%	/y	%	/y
		Above-ground		
Soybean	58	20.2	42	0.98
Corn	49	7.8	51	1.58
Cowpea	81	23.4	19	0.96
Rice	61	11.9	39	0.67
		Below-ground		
Soybean	42	37.9	58	0.54
Corn	42	37.9	58	0.54
Cowpea	58	34.3	42	0.56
Rice	58	34.5	42	0.56

Figure 4-1(a). The patterns of the above-ground crop residue decomposition in the high-input and low-input systems.

Figure 4-1(b). The patterns of the below-ground crop residue decomposition in the high-input and low-input systems.

Figure 4-2(a). The Guggenheim's plots of the decomposition of the above-ground crop residues.

Figure 4-2(b). The Guggenheim's plot of the decomposition of the below-ground crop residues.

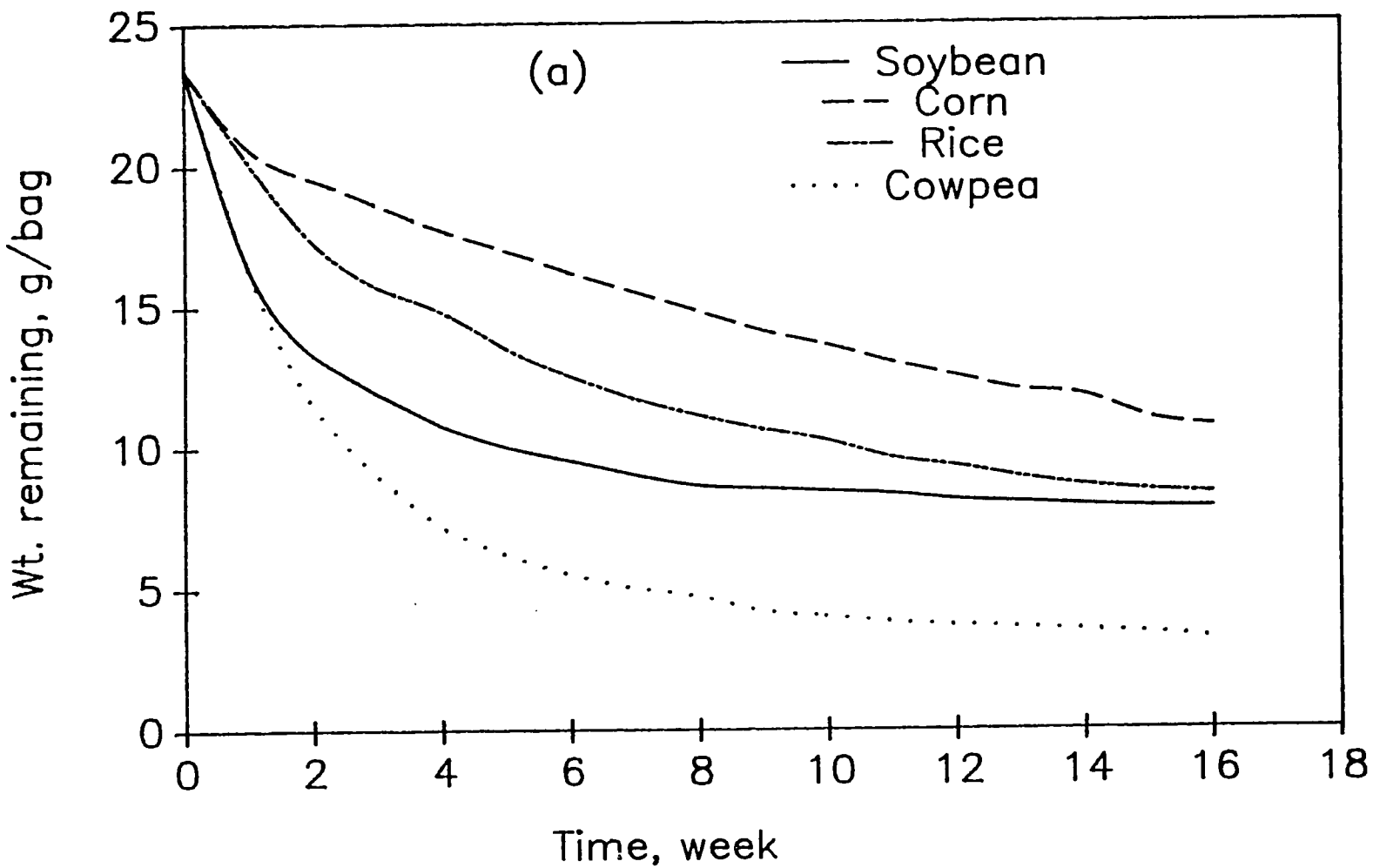
(a)
Soybean
Corn
Rice
Cowpea
Wt. remaining, g/bag
Time, week
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
18

Fig. 4-1(a).

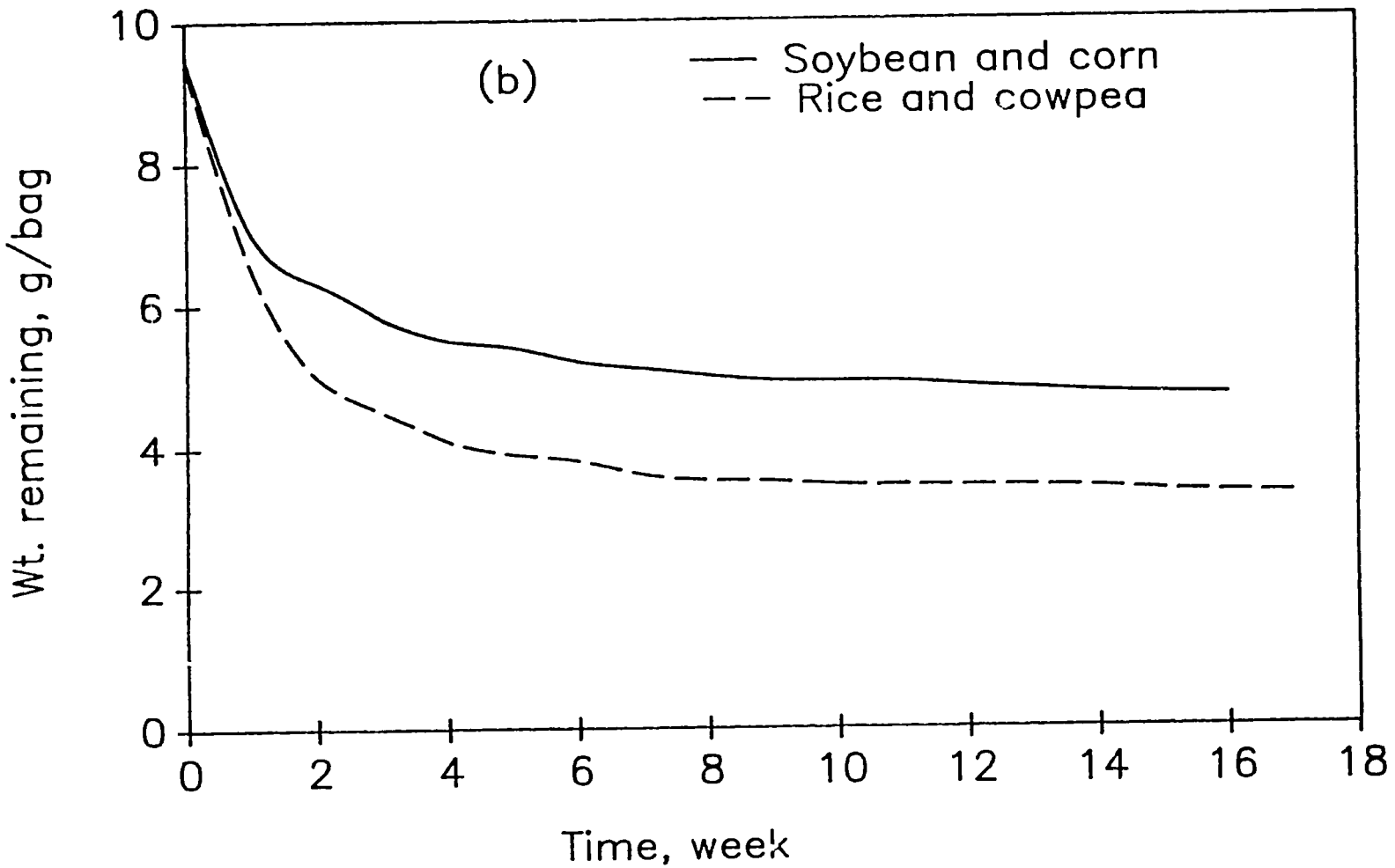
(b)
Soybean and corn
Rice and cowpea
Wt. remaining, g/bag
Time, week
0
2
4
6
8
10
12
14
16
18

Fig. 4-1(b).

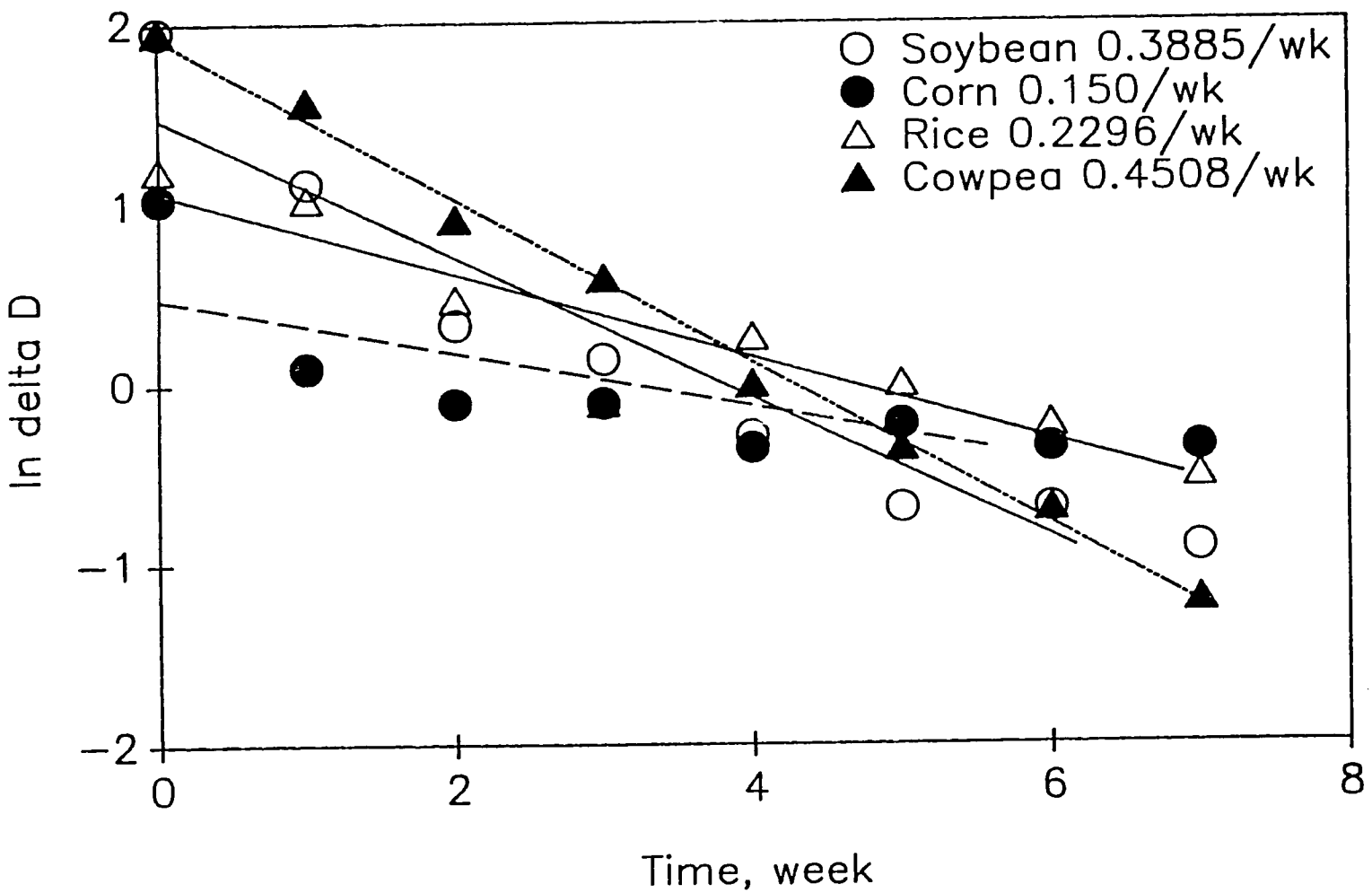
Soybean 0.3885/wk
Corn 0.150/wk
Rice 0.2296/wk
Cowpea 0.4508/wk
ln delta D
2
1
0
−1
−2
0
2
4
6
8
Time, week

Fig. 4-2(a).

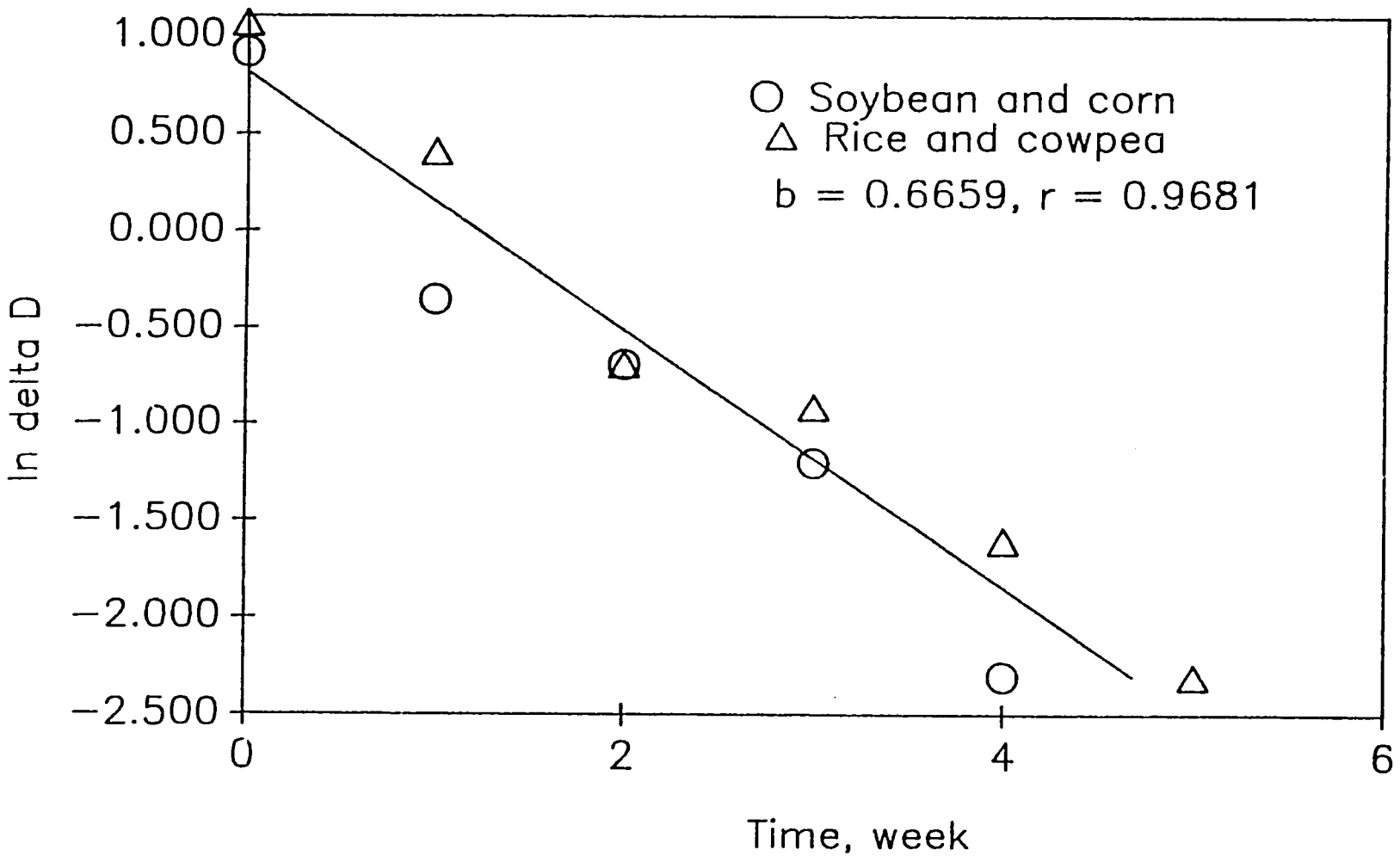
1.000
0.500
0.000
−0.500
−1.000
−1.500
−2.000
−2.500
ln delta D
0
2
4
6
Time, week
Soybean and corn
Rice and cowpea
b = 0.6659, r = 0.9681

Fig. 4-2(b).