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# Role of soil fauna in decomposition of rice and sorghum straw

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**Abstract.** This study examines the mass loss patterns and meso-invertebrate populations during rice and sorghum straw decomposition, using litter-bag technique, in an agricultural system at Kurukshetra (29°58′ N, 76°51′ E, 250 m above mean sea level). The decomposition rates were influenced by litter quality, soil and litter moisture, leaching of water soluble substances, and colonization by the meso-invertebrates. During the cropping season, wet soil conditions favoured rapid decomposition rates. For the total sampling period of 285 days, the mass loss of rice and sorghum straw was 78·2 and 82% respectively. The single exponential model described the pattern of decomposition over time ($r^2 = 0{\cdot}88$, $P < 0{\cdot}001$). Meso-invertebrate populations were higher during rapid phase of decomposition and influenced by soil and litter moisture. Maximum meso-invertebrate density per litter bag was 77·4 ± 6·12, for rice straw and 78·4 ± 3·05 for sorghum straw. Collembola and mites were the dominant groups of fauna in litter bags. Enchytraeids formed 2·45% of the total meso-invertebrates extracted from litter bags.

**Keywords.** Decomposition; straw; mass loss; meso-invertebrates; Collembola; mites; nitrogen; C:N ratio.

## 1. Introduction

Decomposition is an important functional process which regulates to a large extent energy flow and nutrient cycling in terrestrial ecosystem (Odum 1971). It is a complex and multistep process which is brought about by combined action of leaching, activity of soil animals and microorganisms. The soil animals constitute an important group of organisms involved in decomposition of organic debris in the soil. Many workers have studied the role of soil animals in litter decomposition in natural ecosystems (Edwards *et al* 1970; Edwards 1974; Lofty 1974; Mason 1974; Wood 1976; Anderson *et al* 1983; Seastedt 1984). In agricultural systems, the role of soil fauna in decomposition has been investigated by a few workers (Coleman *et al* 1984; House and Parmelee 1985; Coleman 1985). The objective of this study was to analyze the decomposition rates of sorghum and rice straw and the meso-invertebrates associated with decomposing litter.

## 2. Study area

The study was conducted in an agricultural system in a dry subhumid region at Kurukshetra (29°58′ N, 76°51′ E, 250 m above MSL). The soil of the area is alluvial which is sandy loam in texture and slightly calcareous in nature (Duggal 1970). Some physical and chemical characteristics of soil are given in table 1. The climate is tropical monsoon with 3 recognisable seasons in a year; rainy, winter and summer seasons (Singh and Yadava 1974). Monthly variations in temperature and rainfall during the study period from September 1986 to August 1987 are shown in

**Table 1.** Soil characteristics of the study site.

| Soil property | |
|---|---|
| Soil texture | Clay loam |
| Bulk density ($g\ cm^{-3}$) | 1·35 |
| Water holding capacity (%) | 46–50 |
| pH (1:2) | 8·05–8·13 |
| Organic carbon (%) | 0·46–0·92 |
| Nitrogen (%) | 0·046–0·092 |
| Phosphorus (%) | 0·022–0·025 |

figure 1. Maximum temperature varied from 16·8–40·4°C and total rainfall was 150·6 mm.

## 3. Materials and methods

Bulk samples of sorghum and rice straw were collected from the agricultural field during September 1986 after crop harvest. The litter bags were prepared by placing 5 g chopped straw material separately into 2 mm mesh, 20 × 10 cm nylon wire netting cloth bags. The litter bags were placed at random (buried at 5 cm depth) in 2 × 0·5 m plots marked within an area of 20 × 25 m. The litter bags were set out in the field on 30 November 1986.

Four bags of each material type were recovered from the field after 15 days on the first sampling date and at one month interval on the subsequent dates up to September 1987. The material of one bag was used for determining the moisture content and other 3 bags were used for extracting meso-invertebrates from litter bags. The fauna from the litter bags was extracted by Burlese funnel method. The fauna were transferred into a jar containing water. The samples of fauna were then separated into different groups and their numbers were counted using a stereo-binocular microscope.

After the extraction of meso-invertebrates from litter bags, the material was washed under a fine jet of water. The washed material was soaked dry on blotting sheets and oven dried at 80°C. From the decrease in initial mass of litter in the bags, the decomposition rates were calculated.

The initial samples of sorghum and rice straw were analysed for phosphorus, calcium and magnesium following standard methods of Allen *et al* (1974). Total nitrogen was determined by the semi micro-Kjeldahl method. Ash content was determined by igniting 1 g oven-dried sample at 600°C in a muffle furnace for 5 h. Water soluble substances were estimated by leaching 1 g plant sample in 500 ml distilled water for 24 h. Organic carbon was analyzed by semi-micro carbon analyzer using combustion method.

A '*t*' test was used to compare mass loss and the populations of meso-invertebrates due to sampling dates and litter types. The per cent mass remaining in litter bags and populations of meso-invertebrates were related to the number of days using regression analysis following Sokal and Rohlf (1969). Correlations were also found between populations of meso-invertebrates and mass loss, litter moisture and soil moisture.

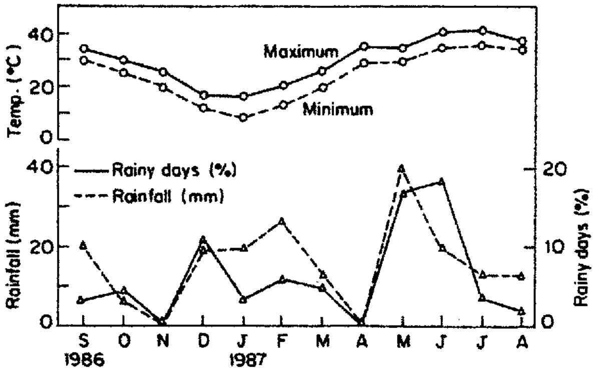


Figure 1. Monthly variations in temperature, rainfall and number of rainy days of the study area during September 1986 to August 1987.

To determine relative decomposition rates (for individual sampling dates), the following formula was used according to Anderson (1973) and Gupta and Singh (1981):

$$R=\frac{\ln W_1-\ln W_0}{t_1-t_0},$$

where $R$ = mean relative decomposition rate (g/g/day), $W_1$ = litter mass at time $t_1$ and $W_0$ = litter mass at time $t_0$.

## 4. Results

### 4.1 *Litter decomposition*

The per cent chemical composition of sorghum and rice straw in terms of ash content, organic carbon, nitrogen, water soluble components (WSC) and some nutrient elements is given in table 2. Sorghum straw was characterized by high concentration of nitrogen, phosphorus and water soluble components and narrow C:N ratio (25:1). Rice straw represented a nutrient poor substrate with wide C:N ratio (59:1).

The variations in soil water and litter moisture during the observations of decomposition rates of straw materials are shown in figure 2. On the 4 initial sampling dates during 14 December 1986 to 25 February 1987, the soil moisture content (17·9–32·6%) and litter moisture (30·3–164·0%) were high. From March to September 1987, litter moisture fluctuated between 10·2–20·7% and the soil moisture content was low (7·3–15·4%). Rainfall during May and June caused slight increase in litter and soil moisture.

Per cent mass loss for sorghum and rice straw on various sampling dates is represented in figure 3. The decomposition rates of sorghum straw were higher than that of rice straw. The mass loss data of individual sampling dates were compared using '$t$' test, the differences were significant on 4 sampling dates, i.e. 30 December 1986, 30 January, 27 March and 22 July 1987 ($t=3{\cdot}17$–$4{\cdot}27$, $P<0{\cdot}05$, d.f. = 4). The decomposition rates were high on first sampling date due to leaching of water

**Table 2.** Chemical composition of sorghum and rice straw used in decomposition experiment.

| Chemical constituent (%) | Sorghum straw | Rice straw |
|---|---|---|
| Ash | 15·0 | 14·9 |
| Carbon | 47·3 | 48·1 |
| Nitrogen | 1·87 | 0·81 |
| Phosphorus | 0·07 | 0·015 |
| Calcium | 0·48 | 0·53 |
| Magnesium | 0·12 | 0·22 |
| Water soluble compounds | 18·21 | 15·53 |
| C:N ratio | 25:1 | 59:1 |

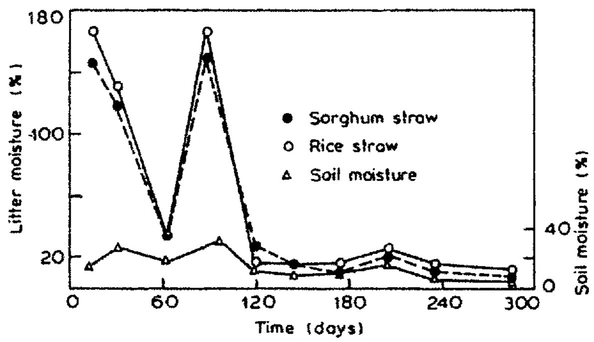


**Figure 2.** Variations in soil moisture and litter moisture of sorghum and rice during 30 November 1986 to 10 September 1987.

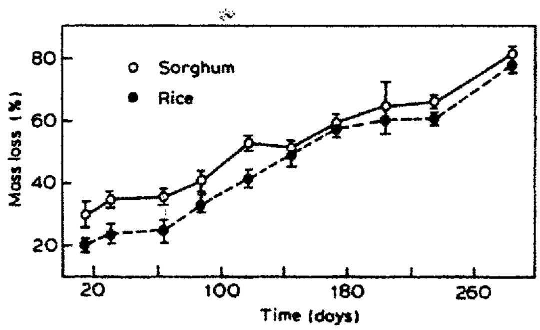


**Figure 3.** Per cent mass loss of sorghum and rice straw during 30 November 1986 to 10 September 1987.

soluble substances. The rates tended to be slow during cold winter months of December and January. Due to moderate temperature and moisture conditions in February, the decomposition rates increased up to May 1987. The low availability of moisture during July and August slowed down the activity of decomposer organisms resulting in slower rates of mass loss. During the total sampling period of 285 days, the mass loss of sorghum and rice straw was 82·0 ± 1·58% and 78·21 ± 1·63% respectively.

The mean relative decomposition rates during individual sampling dates are given in table 3. The relative decomposition rates were highest for the sampling interval 30 November to 14 December 1986. Subsequently, rates varied from 0·00107–0·0078 for sorghum straw and from 0·00026–0·0052 for rice straw. The rates were found to be high for the last sampling interval from 23 July to 10 September 1987 (table 3).

Soil and litter moisture were found to be important factors affecting decomposition rates, the rates being higher when soil was wet. The effect of soil and litter moisture was evaluated by correlating mean relative decomposition rates (RDR) of a sampling interval to its corresponding litter and soil moisture. There was no significant relationship between these abiotic variables and relative decomposition rates for both the straw materials ($r = 0{\cdot}26$–$0{\cdot}38$, d.f. = 8, $P > 0{\cdot}05$).

To determine temporal pattern of decomposition, regressions were fitted on the data of per cent mass remaining in litter bags over time. The relationship was significant and explained 88% variability in mass loss due to time. The regression equations are:

Sorghum straw:

$$\log_e y = 4{\cdot}41 - 0{\cdot}00469 \log_e X$$
$$(r^2 = 0{\cdot}88,\ \text{d.f.} = 28,\ P < 0{\cdot}01)$$

Rice straw:

$$\log_e y = 4{\cdot}52 - 0{\cdot}00434 \log_e X$$
$$(r^2 = 0{\cdot}89,\ \text{d.f.} = 28,\ P < 0{\cdot}001)$$

where $y$ = per cent mass remaining in litter bags and $X$ = time in days.

## 4.2 *Meso-invertebrates*

The colonization patterns of different meso-invertebrates during decomposition of

**Table 3.** Mean relative decomposition rates (g $g^{-1}$ $day^{-1}$) of sorghum and rice straw during 10 sampling intervals from 30 November 1986 to 10 September 1987.

| | Mean relative decomposition rate (g $g^{-1}$ $day^{-1}$) | | |
|---|---|---|---|
| Sampling interval | No. of days | Sorghum straw | Rice straw |
| 30 Nov.–14 Dec. 1986 | 15 | 0·0238 | 0·0149 |
| 15 Dec.–30 Dec. | 16 | 0·0046 | 0·00269 |
| 31 Dec.–30 Jan. 1987 | 31 | 0·00373 | 0·001193 |
| 31 Jan.–25 Feb. | 26 | 0·00326 | 0·00403 |
| 26 Feb.–27 March | 30 | 0·00728 | 0·0042 |
| 28 March–22 April | 26 | 0·00107 | 0·00573 |
| 23 April–22 May | 30 | 0·01043 | 0·00626 |
| 23 May–22 June | 31 | 0·00519 | 0·00514 |
| 23 June–22 July | 30 | 0·0032 | 0·00026 |
| 23 July–10 Sept. | 50 | 0·0115 | 0·0115 |
| Total study period | 285 | 0·0078 | 0·0052 |

Initial oven dry weight of rice straw = 4·850 g; sorghum straw = 4·880 g.

straw materials indicated that collembola and mites were the dominant group of fauna (tables 4 and 5). Meso-arthropod densities were initially low on the first 3 sampling dates during winter months. Collembola and mites exhibited their peak populations during February and March when both temperature and moisture were moderate. Due to dry conditions in summer months, the population showed a sharp decline. The availability of moisture during cropping season did not increase the density of fauna appreciably. It is evident from tables 4 and 5 that enchytraeids were present in rice straw on all the sampling dates, whereas in sorghum straw, enchytraeids were not recorded on initial dates. The other meso-invertebrates were represented by Coleoptera adults and larvae, Dipteran larvae and miscellaneous group of fauna having lesser number of species. Their density varied from 2·1–8·1 on different sampling dates.

The relationship between populations of meso-invertebrates from decomposing straw and time showed positive significant correlation for Collembola ($r = 0{\cdot}65$–$0{\cdot}68$, d.f. $= 28$, $P < 0{\cdot}001$), mites and enchytraeids on sorghum straw ($r = 0{\cdot}86$–$0{\cdot}61$,

**Table 4.** Meso-invertebrate population on decomposing sorghum straw (number per litter bag).

| Date | Collembola | Mites | Enchytraeids | Others | Total |
|---|---|---|---|---|---|
| 14 December 1986 | 12·6 ± 5·03 | 9·2 ± 2·64 | — | 6·2 ± 1·52 | 28·0 |
| 30 December | 7·1 ± 1·0 | 7·3 ± 4·04 | — | 4·5 ± 1·15 | 18·9 |
| 30 January 1987 | 13·3 ± 4·11 | 16·1 ± 4·0 | 3·2 ± 1·53 | 3·2 ± 1·15 | 35·8 |
| 25 February | 21·6 ± 1·52 | 48·3 ± 3·51 | 1·3 ± 1·52 | 7·2 ± 2·08 | 78·4 |
| 27 March | 11·1 ± 1·70 | 33·6 ± 11·87 | 5·6 ± 3·21 | 2·1 ± 2·0 | 52·4 |
| 22 April | 6·3 ± 4·16 | 7·1 ± 2·64 | — | 3·5 ± 0·57 | 16·9 |
| 22 May | 3·3 ± 0·51 | 4·3 ± 3·05 | 2·6 ± 1·15 | 3·4 ± 1·52 | 13·6 |
| 22 June | — | 2·3 ± 0·51 | 1·6 ± 0·57 | 6·2 ± 1·52 | 10·1 |
| 22 July | 5·1 ± 0·5 | 4·3 ± 2·52 | 4·6 ± 1·52 | 4·2 ± 1·15 | 18·2 |
| August | — | — | — | — | — |
| 10 September | 3·4 ± 0·51 | 2·6 ± 0·50 | 8·3 ± 2·88 | 6·1 ± 2·00 | 20·4 |
| Mean over the sampling period | 8·3 | 13·5 | 2·7 | 4·7 | 29·2 |

**Table 5.** Meso-invertebrate population on decomposing rice straw (number per litter bag).

| Dates | Collembola | Mites | Enchytraeids | Others | Total |
|---|---|---|---|---|---|
| 14 December 1986 | 10·0 ± 2·70 | 14·2 ± 2·08 | 4·3 ± 4·50 | 4·2 ± 1·52 | 32·7 |
| 30 December | 4·3 ± 0·85 | 5·3 ± 2·30 | 6·3 ± 3·21 | 3·5 ± 0·57 | 19·4 |
| 30 January 1987 | 11·3 ± 4·68 | 7·3 ± 3·21 | 1·66 ± 2·88 | 4·5 ± 1·52 | 24·8 |
| 25 February | 25·1 ± 5·50 | 37·6 ± 3·81 | 6·6 ± 2·08 | 8·1 ± 2·0 | 77·4 |
| 27 March | 11·2 ± 3·74 | 31·6 ± 7·50 | 3·0 ± 1·732 | 4·2 ± 0·57 | 50·0 |
| 22 April | 6·30 ± 2·0 | 9·3 ± 2·51 | — | 2·3 ± 0·57 | 17·9 |
| 22 May | 3·3 ± 2·36 | 6·3 ± 3·21 | 2·2 ± 1·0 | 7·0 ± 1·73 | 18·8 |
| 22 June | — | 1·6 ± 1·4 | — | 4·3 ± 1·15 | 5·9 |
| 22 July | — | 4·0 ± 3·46 | 3·6 ± 2·08 | 6·1 ± 1·0 | 13·7 |
| August | — | — | — | — | — |
| 10 September | 2·6 ± 0·50 | 5·0 ± 3·46 | 12·6 ± 5·85 | 5·3 ± 2·08 | 25·5 |
| Mean over the sampling period | 7·4 | 12·2 | 4·0 | 4·9 | 28·5 |

d.f. = 28, $P < 0.001$) and total fauna of both the materials ($r = 0.38$–$0.46$, d.f. = 28, $P < 0.001$). The relationship was not significant for other groups of fauna ($r = 0.04$–$0.17$, d.f. = 28, $P > 0.05$).

High populations of soil meso-invertebrates generally corresponded to high soil and litter moisture, the populations being higher when soil and litter moisture were high. For both rice and sorghum straw, the populations of Collembola showed significant positive correlation with soil moisture ($r = 0.65$–$0.78$, d.f. = 28, $P < 0.001$) and litter moisture ($r = 0.55$–$0.56$, d.f. = 28, $P < 0.001$). The populations of mites, enchytraeids and total fauna did not show a significant relationship with soil and litter moisture ($r = 0.01$–$0.32$, d.f. = 28, $P > 0.05$).

The Collembola extracted from the litter bags were represented by 4 families, i.e. Entomobryidae, Folsomidae, Poduridae and Sminthuridae. *Sierra indica* was the dominant collembolan species on both the straw materials. Oribatid mites (Cryptostigmata) were recorded on all the sampling dates from the straw bags having highest densities of *Schelroribates* sp. Meso-stigmatid and Metastigmatid mites were particularly abundant in later phases of decomposing straw.

Total meso-invertebrate numbers per gram of straw material attained peak values after 88 days of placement of litter bags (figure 4). The meso-invertebrate densities were low on initial sampling dates as well as during last phases of decomposition. On all the sampling dates, the number of fauna was higher on sorghum straw as compared to rice straw, however, the differences were not significant ($t = 0.01$–$0.02$, d.f. = 4, $P > 0.05$). Across the sampling dates, total number of meso-invertebrates averaged 12·54 and 14·26 individuals $g^{-1}$ straw of rice and sorghum respectively. The populations of meso-invertebrates on decomposing straw showed higher values during rapid phases of decomposition. The population of Collembola and enchytraeids on sorghum straw showed significant relationship with average mass loss ($r = 0.67$–$0.71$, d.f. = 8, $P < 0.05$). Other groups of fauna did not show significant relationship ($r = 0.21$–$0.56$, d.f. = 8, $P > 0.05$).

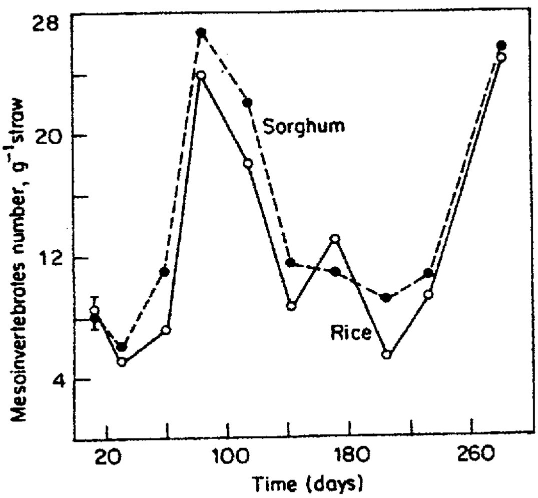


**Figure 4.** Total number of meso-invertebrates (No. $g^{-1}$ straw) during decomposition of sorghum and rice straw on various sampling dates during 30 November 1986 to 10 September 1987.

## 5. Discussion

The litter decomposition rates were influenced by litter quality, soil and litter moisture, leaching of water soluble substances and colonization by soil invertebrates. The high mass loss of straw materials on initial sampling dates could be attributed to leaching of water soluble substances that occur in the presence or absence of microflora and fauna (Witkamp and Crossley 1966; Anderson 1973; Vossbrink *et al* 1979; Gupta and Singh 1981). Under field conditions, the mass loss due to leaching amounted to 15·9 and 14·3% for sorghum and rice straw respectively. Gupta and Singh (1981) studied the role of leaching in decomposition of herbaceous litter and showed that leaching losses varied from 25–76% depending upon the nature of the plant material. The higher decomposition rates of sorghum straw in the early phase could be due to its high nitrogen content and water soluble compounds compared to rice straw.

Relative decomposition rates indicate the effect of litter type, litter moisture and wetness of surface layers of soil. The wet soil conditions during cropping season showed higher rates of decomposition. Significant relationship between decomposition rates and time clearly defined the temporal pattern of decomposition of straw materials explaining 88% variability in decomposition rates which is in conformity with the results of Anderson (1973) and Gupta and Singh (1981).

Information on the functioning of soil invertebrates in decomposition of crop residues is limited (House and Stinner 1983; Coleman 1985; House and Parmelee 1985). These studies relate to the structure of soil arthropod communities in agricultural systems. The present study showed the importance of collembola and mites in litter decomposition as these formed 26–89% of total meso-fauna extracted from the decomposing straw on various sampling dates. The populations of meso-invertebrates on decomposing straw corresponded to decomposition rates; the populations being higher during rapid phases of decomposition. For sorghum straw, collembolan populations showed significant relationship with mass loss ($r = 0{\cdot}71$). Crossley (1977) discussed the role of soil fauna in decomposition in forest ecosystems and stated that soil arthropods are less abundant than soil microflora, and have slower metabolic and turnover rates. To a large extent, decomposition of plant debris is brought about by microbial activity in the soil (Singh and Gupta 1977). McBrayer *et al* (1974) reported that soil fauna contribute less than 1% to the annual $CO_2$ evolution from forest soils. Thus, soil fauna have indirect effects on decomposition by affecting the processes as conversion of litter to faeces, fragmentation of litter, mixing of litter and soil, regulation of microflora and reducing the immobilization of nutrients through senescent fungal tissues (Edwards *et al* 1970; Crossley 1977).

For evaluating the role of soil invertebrates in decomposition, Edwards and Heath (1963) used litter bags of different mesh sizes and found that *Quercus* and *Fagus* leaves disappeared 3 times as quickly from 7 mm mesh size bags compared to 0·003 and 0·5 mm mesh bags. Gupta and Singh (1977) reported higher mass loss of litter from coarse mesh bags (89·7%) than from the fine mesh bags (55·4%). They indicated that decomposition rates are high when all groups of soil fauna and microorganisms take part in decomposition. Santos *et al* (1981) found that exclusion of microarthropods from litter by insecticides and fungicides reduced decomposition by 50%. These studies in a gross way demonstrate the impact of soil fauna on decomposition.

In this study, it was found that detritivores like collembola, mites and enchytraeids played a significant role in decomposition of straw as the populations of meso-invertebrates were higher during rapid phases of decomposition. The nutrient rich substrate (sorghum straw) had higher populations of saprophagic fauna as compared to nutrient poor rice straw. Litter and soil moisture affected the mass loss and populations of saprophagic fauna.

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