Losses of Uniformly ^{14}C-labelled Groundnut Straw and Tissues in Soils of Semi-Arid Tropical (SAT) India

S. SINGER and H. W. SCHARPENSEEL

Institut für Bodenkunde, Universität Hamburg (Germany)

Introduction

In order to cope with future demands of increased food and fibre production in the densely populated Indian SAT, the maintenance and replenishment of soil organic matter (SOM) as a sound and slow-release nutrient pool is crucial for dryland agriculture under prevailing erratic rainfall, poverty and lack of access to the means of the "Green Revolution" (EL-SWAIFY et al., 1984, 1985; TANDON & REGO, 1989; VIRMANI et al., 1989). The necessarily enhanced utilization of organic residues and its supplementary effect on inorganic fertilizer supports recycling of a manifold of nutrients and improves sequestration of carbon in SOM, a terrestrial key pool of C which is permanently mined when continuously cropped under low input agriculture (SANCHEZ et al., 1989; SCHARPENSEEL et al., 1990, 1992). In the dry Indian SAT, farmers nutrient inputs are highly variable but low when averaged (JHA & SARIN, 1984), driven by land use, crop choice, and with regard to organic fertilizer, by availability of composted farmyard manure (FYM) and household leftovers (MOTAVALLI & ANDERS, 1991a,b). Usually, the need for cattle fodder and housing competes with the utilization of harvest residues as a soil nutrient source and economically, the scope for green manuring is bleak. However, knowledge on the fate of organic additions helps to determine better

1. a timely and efficient application of rural composts, and
2. the contribution of decomposing roots towards nutrient replenishments.

That can be partly inferred from experiments with labelled residues.

So far in India, no investigations under field conditions have been carried out with ^{14}C-labelled residues. In the tropics, precise knowledge on loss/mineralization/uptake pattern of carbon and other nutrients is still incomplete and varies considerably with soils, climate, inputs and land use (SANCHEZ et al., 1989; DUXBURRY et al., 1989; WOOMER & INGRAM, 1990).

Materials and Methods

Field studies on turnover pattern of uniformly ^{14}C-labelled groundnut straw were conducted at ICRISAT in the both predominant and constraint soils of SAT-India, alfisols and vertisols. The pellustert is a deep clayey (65% smectites) soil with high water retention and the rhodustalf a gravely, sandy (75-88% sand), shallow soil. The latter one has ca 37% kaolinite in the small clay fraction but displays tremendous spatial variation with regard to texture, rooting depth and nutrient contents (EL-SWAIFY et al., 1984) (Table 1).

Table 1
Some characteristics of the soils of field studies

Topsoil (0-12 cm)	Org. C %	Total N ppm	CEC meq	BS %	pH (H_2O)	Water % in 0-5 cm	
						0.3 bar	15 bar
Typic pellustert	0.35	450	31	84	8.6	30.6	21.3
Udic rhodustalf	0.18	250	2	53	5.2	4.2	1.8

Mean annual temperature is 26 °C, rainfall 780 mm, of which over 80% occur in the rainy season from June to September, and mean annual potential evapotranspiration accounts for 1760 mm, exceeding rainfall in 1-3 months (EL-SWAIFY et al., 1984, 1985; VIRMANI et al., 1989). As a common feature, resulting from a long lasting cropping history and a warm climate, both soils are low in SOM.

Groundnuts were raised in a "Weiss" growth chamber and continuously supplied with a $^{14}CO_2$ enriched atmosphere. After harvest, straw was dried, chopped and ground into pieces < 2 mm. Specific activity per g was 60,000-100,000 cdpm. Total carbon was determined by combustion ("Stöhlein" carbon analyzer) and ^{14}C by a "Beckmann" scintillation counter. Equivalent to 2.5 t/ha, straw was mixed with the 2-6 cm surface soil layer and added to 13 cm deep, open and rotary, plastic micro plots (8.5-9 cm d). The specific sample activities of soil and straw at $time_0$ and $time_{0+n}$ were corrected for each soil sample by its weight and percentage of particles > 2 mm. Destructive soil sampling occurred for all experiments. At each sampling time 2-3 plots were completely removed, divided into 0-6 and 6-12 cm, dried (105 °), sieved (< 2 mm) and ground. (Negligible) activity found in the deeper layer was added proportionally. For $time_0$ samples, straw was applied after soils were oven-dried. For ^{14}C, each sample was analyzed 3-5 times.

Straw was incorporated into fallow/bare plots in the open and under shade which refers to an area in each soil, covered with a black thick foil at a height of ca. 50 cm, adjusted on a wooden frame. But the foil was not tightened to the ground so air could circulate. According to rainfall in the open, the shaded area was irrigated manually.

The C/N ratio of mixed groundnut straw was 26, of leaves and stems 20 and of roots 47.

The experiments were part of a set of trials on SOM and residue application in SAT-India (SINGER, 1992; SINGER & SCHARPENSEEL, 1993).

Results and Discussion

Figs. 1 and 2 display the pattern of ^{14}C losses over 2.5 years in alfisol and vertisol when whole groundnut straw was incorporated at the onset of the rainy season 1989 in fallow/bare in the open and under shade. Drawn curves and formulas refer to calculated logarithmic decay functions. In both soils, decomposition of groundnut legume straw was higher than that of cereal sorghum straw incorporated under the same climatic condition (SINGER et al., 1990).

In the sandy alfisol, turnover proceeded fast in the rainy season in fallow/bare initially. Losses amounted to over 40% after one week and to over 50% after 4 weeks. That compares to losses of hardly 20% and c. 30% in the vertisol, respectively. Differences were slightly narrowed during observation time. After one year, about 25% of ^{14}C remained in alfisol and approx. 36% in vertisol. Residual ^{14}C amounted to 14% (alfisol) and 26% (vertisol) after 2.5

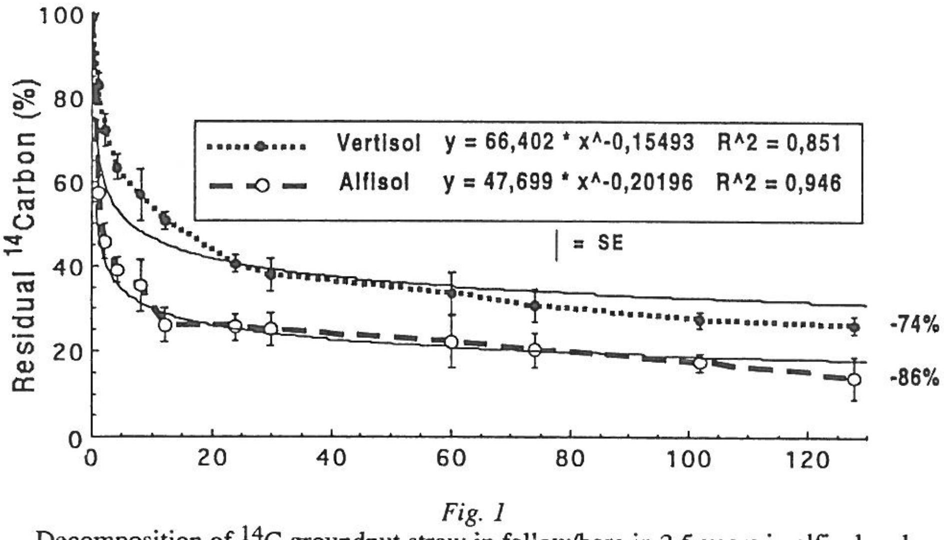

Fig. 1
Decomposition of ^{14}C groundnut straw in fallow/bare in 2.5 years in alfisol and vertisol. Weeks (27. 6. 1989-23. 12. 1991)

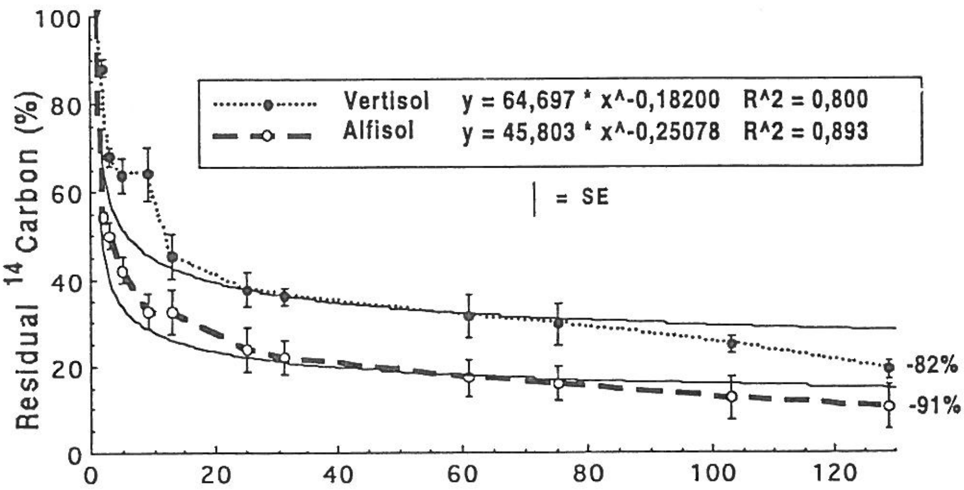

Fig. 2.
Decomposition of ^{14}C groundnut straw under shade in 2.5 years in alfisol and vertisol.
Weeks (27. 6. 1989 - 23. 12. 1991)

years. However, final losses were higher under shade as retention of ^{14}C was only 9% and 18%, respectively.

Rapid decomposition was caused by sufficient soil moisture due to intensive rains of 860 mm from June to November 1989, of them about 65 mm in the first week after straw incorporation. Thus, moisture contents were in the first 4 weeks around 100% field capacity (FC) (alfisol) and 75% FC (vertisol) in the topsoil but showed considerable variation later due to short droughty spells before moisture tension increased in September.

Under shade, moisture contents were not only higher, but also prolonged. Yet, for 1989 (June-December) mean topsoil temperatures for 24 hours in both soils were c. 24° under shade and c. 27° in the open, notwithstanding occasional differences of up to 12° at noon on sunny days. Higher ^{14}C losses under shade compared to treatments in the open have been observed also during additional experiments (SINGER, 1992).

Figs. 3, 4, 5 and 6 depict the losses of ^{14}C during 0.5 years when aboveground residues (stems and leaves) and roots were incorporated separately at commencement of the rainy season 1991 under shade and in fallow/bare in the open.

Moisture was not a limiting factor during the rainy season, but was consistently higher and prolonged under shade in both soils whereas temperature was for about 3-4 °C lower as against plots in the open.

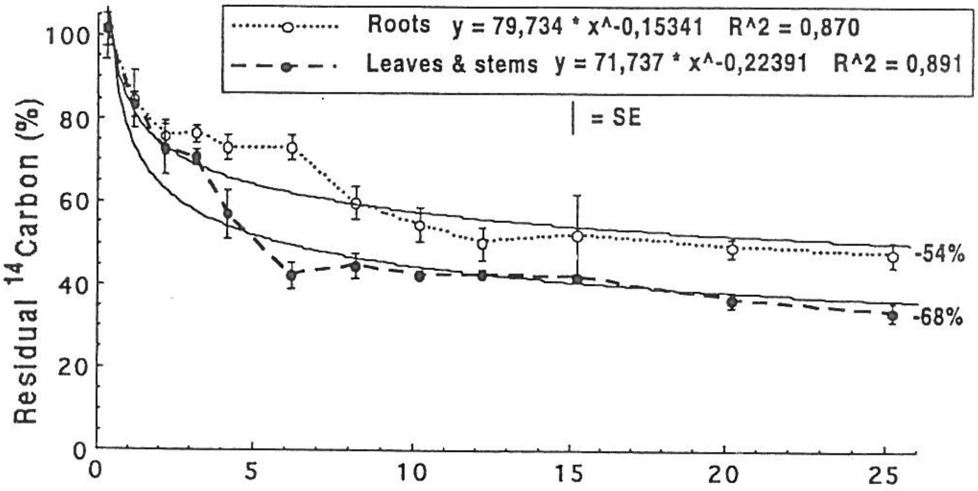

Fig. 3.
Alfisol-fallow/bare : 0.5 years decomposition of ^{14}C groundnut leaves/stems and roots. Weeks (14.6 - 6.12. 1991)

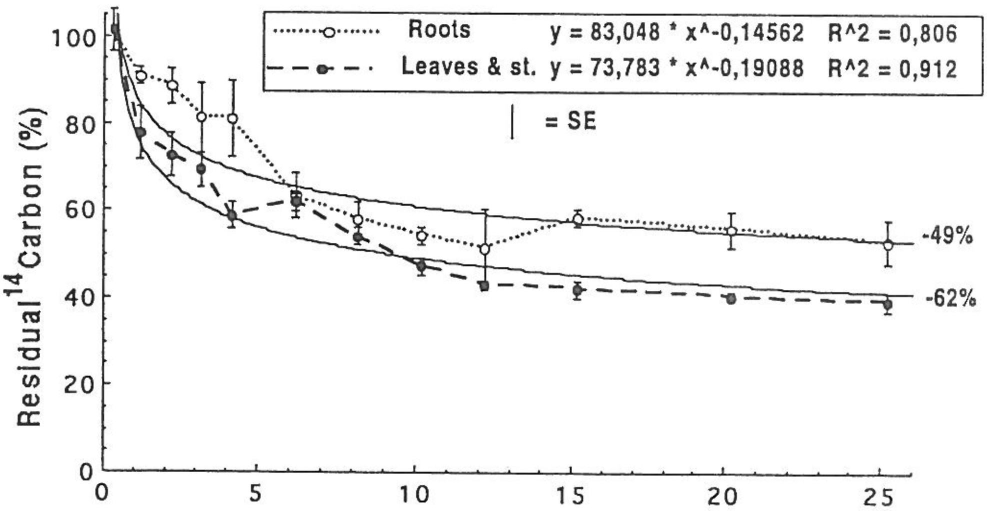

Fig. 4
Vertisol-fallow/bare: 0.5 years decomposition of ^{14}C groundnut leaves/stems and roots in rainy season. Weeks (14. 6. - 6. 12. 1991)

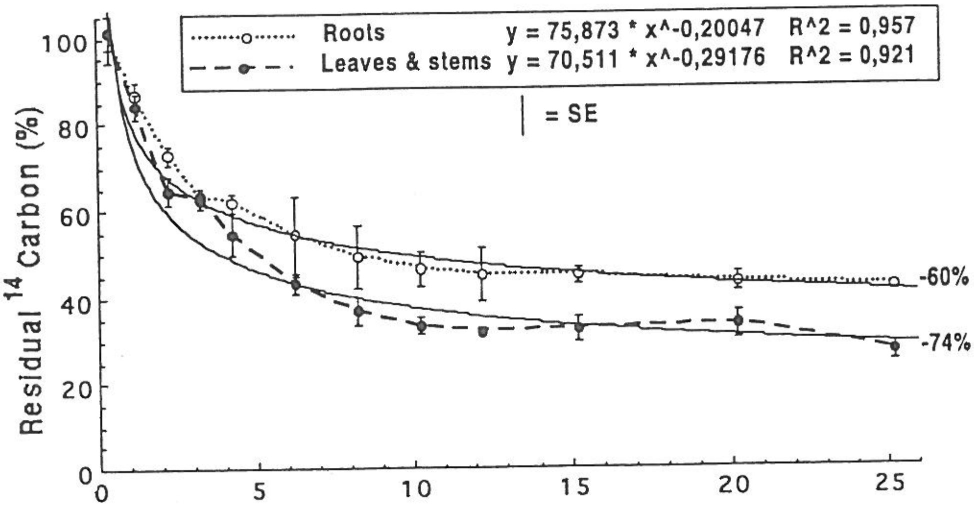

Fig. 5.
Alfisol-shaded: 0.5 years decomposition of ^{14}C groundnut leaves/stems and roots in rainy season 1991. Weeks (14. 6. - 6. 12. 1991)

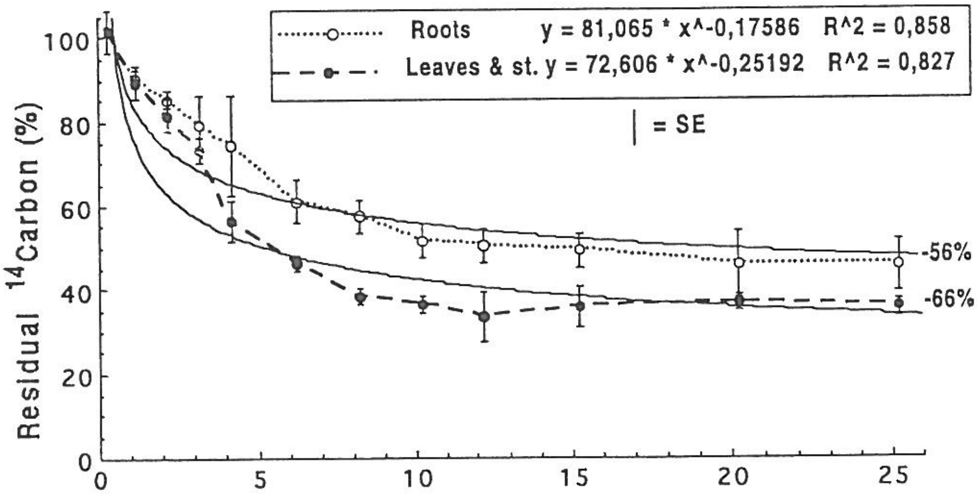

Fig. 6.
Vertisol-shaded: 0.5 years decomposition of ^{14}C groundnut leaves/stems and roots in rainy season 1991. Weeks (14. 6. - 6. 12.1991)

As a common feature (SINGER, 1992; SINGER & SCHARPENSEEL, 1993), carbon retention was discernibly lower in the sandy alfisol in all treatments than in the corresponding trials in the smectitic vertisol. Further, aboveground residues decomposed more rapidly than roots, as their losses were about 10-14% higher after 0.5 years. That likely resulted from the different C/N ratios. In addition, shading favoured higher decay rates. About 4-8% less ^{14}C was retained under shade where apparently prolonged soil moisture offset the effect of higher temperature in plots in the open field.

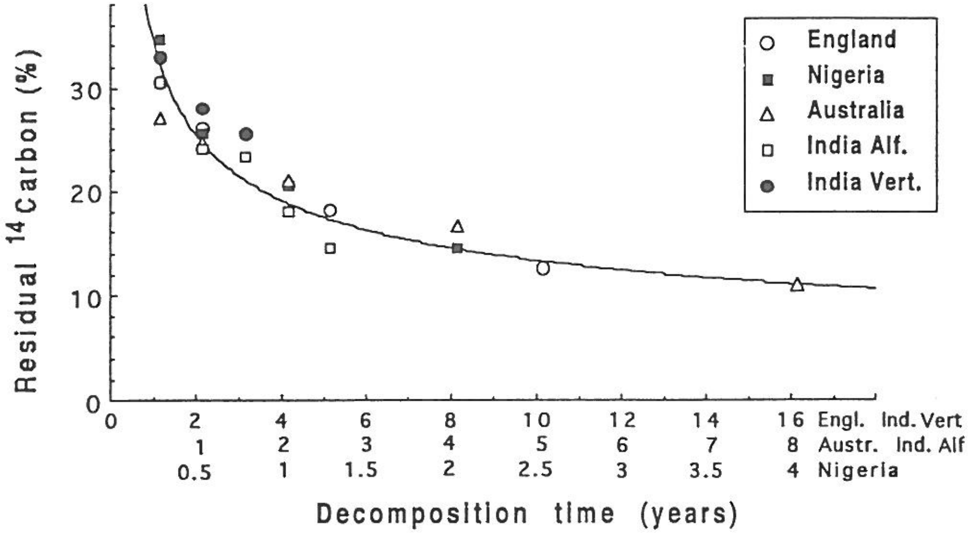

Fig. 7

Decomposition of ^{14}C crop residues (medic in Australia, ryegrass in temperate England and tropical Nigeria, and groundnut straw in alfisol and vertisol of ICRISAT in fallow/bare

For comparison, Figure 7 shows the ^{14}C retention of mixed groundnut straw in alfisol and vertisol during 2.5 years when plotted together with the due results of labelled medic from a calcareous soil in semi-arid Australia (LADD et al., 1985) and of ryegrass from tropical Nigeria and temperate England (JENKINSON & AYANABA, 1977). As in Australia both the mean annual temperature of c. 16.5° and decomposition speed was in the middle of those of temperate England and tropical Nigeria, the crop debris decay was determined by temperature. However, that does not completely apply for both ICRISAT soils, where mean annual °C is similar to the Nigerian site. Though observation time was only 2.5 years at ICRISAT, the fate of ^{14}C in the alfisol fits more into the pattern between Nigeria and cooler Australia. For the vertisol however, similar carbon retention as under temperate English climate can be assessed. Thus, other factors than temperature alone contribute to obtained different carbon losses.

Conclusions

As under prevailing warm climate soil moisture was the driving force for crop residue turnover, ^{14}C retention was generally lower in the sandy alfisol than in the clayey vertisol. Lower carbon losses in the vertisol are then attributed to its higher clay content (and quality) and its subsequent physico-chemical impact on promoting better "protection" of straw-derived metabolites. That is in accordance with several earlier investigations either in field or laboratory experiments (SÖRENSEN, 1972, 1975; THENG & SCHARPENSEEL, 1975; ABDOU et al., 1975; van VEEN et al., 1985; MARTIN & HAIDER, 1986).

Under shade, turnover of residue-derived ^{14}C was faster than in the open. That is in contrast to results from tropical Nigeria, where differences disappeared after slightly higher decomposition under shade during the first year (JENKINSON & AYANABA, 1977; AYANABA & JENKINSON, 1990).

Soils with labelled root debris retained in 0.5 years considerably more ^{14}C as against a mixture of stems/leaves at ICRISAT. But results from other climates, soils, and crops were less uniform. Compared to aboveground residues they reported either similar loss rates (JENKINSON, 1971; JENKINSON & AYANABA, 1977) or, more in accordance with our data, lower decomposition of ^{14}C roots (NYHAN, 1975; DALAL, 1979; AMATO et al., 1984; RAINA & GOSWAMI, 1988).

However, as roots likely provide the largest source for the increment of SOM (and nutrients) in low input agriculture, more emphasis should be laid upon investigations on crop varieties with a bigger root biomass.

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