Tropentag 2007
University of Kassel-Witzenhausen and
University of Göttingen, October 9-11, 2007

Conference on International Agricultural Research for Development

The Fate of Surface Residue Mulch during the Dry Winter and Spring Seasons in Zimbabwe

Nhamo Nhamo[a*], Christopher Martius[b], Patrick C. Wall[c], Christian Thierfelder[d]

[a]International Maize and Wheat Improvement Centre (CIMMYT), Zimbabwe
[b]ZEF - Centre for Development Research, University of Bonn, Germany
[c]CIMMYT, Harare, Zimbabwe
[d]University of Hohenheim, Soil Science and Land Evaluation, Germany

Abstract

Mulching is important in protecting the surface structure and reducing erosion of poorly structured degraded soils. The high intensity short duration erosive rain storms experienced at the onset of the wet cropping season in Zimbabwe makes soil cover especially important. Conservation Agriculture (CA), comprising minimal soil movement, surface mulch and crop rotation, is being researched and promoted to increase land and labour productivity while enhancing the natural resource base dedicated to agriculture. Maintaining soil cover under CA systems also contributes to soil biota biomass build-up. Given competing uses of crop residues on the farm, knowledge of mulch losses through decomposition is important in maintaining and managing the mulch over the winter and spring seasons to maintain sufficient soil cover at the onset of the rainy season. Coarse-meshed polyester litter bags were used to study the rate of maize litter loss from the soil surface. The aim of the experiment was to assess the rate of fauna-driven mulch decomposition on CA and conventionally ploughed plots. A total of 256 litter bags, mesh size 5 mm, were used to measure loss of litter mass during winter and spring in one on-station trial (Henderson Research Station) and four on-farm sites (two each from Shamva and Zimuto). The sites represented agro-ecological zones II and IV of Zimbabwe, some with heavy clay and others with sandy soils. At Henderson litter bags were applied on the soil surface of four treatments with different levels of soil movement: conventionally ploughed (CP), direct seeded (DS), manually-dug basins (BA) and manual sowing into rip lines (MR). The on-farm sites included conventional ploughing, ripper (RR) and direct seeder treatments were used. A negative exponential decay model $y = y_o e^{-kt}$ described surface litter loss data adequately. At Henderson, daily k rates were in the order BA>DS=CP>MR whereas at Chinyanga and Kajengo (Shamva) and Zhinya (Zimuto) DS>SS>CP. The influence of soil mulch on the microclimate explained the variation in decomposition between CA treatments and conventional ploughing. The measurements suggest low decompositions rates of surface applied maize litter during winter and spring. Losses can be managed by mulch supplementation to achieve adequate soil cover at the start of the rainy season. Further, the results show that decomposition during winter allows carryover of mulch on CA plots into the next season.

Keywords: Residue decomposition: mulch: reduced tillage: conservation agriculture: litter bags

[*] Corresponding author: Email: n.nhamo@cgiar.org

Introduction

Residue decomposition is a key process in both managed and natural soil systems. Research has shown that decomposition of organic materials and net primary productivity are basic processes required for nutrient recycling in ecosystems (Coleman et l. 2004; Heal et al. 1997). The application of results from decomposition studies in order to improve management of crop productivity is important. Crop residue management, which is linked to fauna activities and soil productivity on the farm, directly influences decomposition. When residues are used for mulching in conservation agriculture systems, they protect the soil surface from raindrop impact. However, in conventional ploughing systems residues are either incorporated or removed from the fields, leaving the soil surface bare and prone to erosion. Use of residues cover is critical where high-intensity rainfall is received leading to soil losses through erosion; which is the case in southern Africa. When mulching is practiced, the rate at which decomposition proceeds determines the duration of effective soil cover.

There are different forms of soil cover that available to smallholder farmers. Lal (2002) and Acharya et al. (2005) categorized mulches into organic and inorganic groups. Besides the wide availability, the main advantage of using organic mulches is that they are degradable and hence can contribute to increased soil organic matter and structure. Crop residues are produced in large quantities every year compared to other organic materials. However, currently they are not used as soil cover at the majority of farms. Farmers using conventional ploughing system clear fields of residues in winter and spring, prior to the onset of the rainy season. This practice enhances the possibilities of soil loss through erosion following heavy storms.

Decomposition rates are regulated by a combination of three factors; residue quality, physico-chemical environment and the decomposer community (Heal et al. 1997; Gonzalez and Seastedt 2001; Swift et al. 1979). Furthermore, Coleman et al. (2004) identified the influence of edaphic factors on microclimate as important regulator of the decomposition process. However, the short term interactions of all these factors and how independently they influence the decomposition of mulches is not well known. Given the relationship between decomposition litter and soil biota activities, measuring the rate of litter losses can also be used to assess the effect of soil disturbance on soil fauna. The aim of the study was to assess the amount of litter loss that occurs during winter and spring; a period prior to the onset of summer rains. The goal was to evaluate the amount of soil cover, maize litter at the beginning of summer.

Materials and methods

The study was contacted on five sites in the sub humid and semiarid rainfall zones of Zimbabwe. To main soil types were used for the study, red clayey and sandy soils (Table 1). Henderson Research station, Kajengo, Makwara and Zhinya are on sandy soils whereas Chinyanga is on red clayey soil. The study was conducted during dry winter and spring period, a period when no rain-fed crops are grown on the fields. In southern Africa winter starts in May until July and spring covers August and September. Summer is hot and wet and this constitutes the crop growing season covers the period between October to March/April.

Litter bag experiment: A total of 256 litter bags were used in this study. Maize litter was cut into small pieces and a mixture of stalks and leaves was used in each litter bag. Litter bags were installed on the soil surface for duration of 4 months. One set made up of four replicate of each treatment was drawn after every four weeks i.e., 28, 56, 84 and 132 days after installation, until the end of the experiment.

Treatments: Two conversation agriculture treatments; direct seeding (DS) and ripping (RR), all animal drawn were compared to conventionally ploughing (CP) at all the five sites. In addition at Henderson, hand made basins (BA), another conservation agriculture treatment was also used. These tillage treatments were applied during the preceding crop growing summer season. On all conservation agriculture treatments crop residue cover was maintained whereas on conventional ploughing residues were removed immediately after crop harvesting.

Data collection and analysis: From the four replicate litter bags that were sampled, mass loss was calculated from the initial mass and the contamination free mass at sampling time. Contamination from soil mineral particles was corrected using the ashing method (Coleman et al. 2004; Kurzatkowski et al. 2004). A negative exponential regression was run using SigmaPlot program and daily and monthly decomposition constant (*k*) were determined from the mass loss data.

Results

Litter loss data for conservation agriculture treatments fitted into negative exponential decay equations at all study sites. However, on clayey soil at Chinyanga, decomposition in the conventional ploughing treatment was high at the initial period (first month of incubation), and later reduced to minimal mass losses. Plotting the mass loss data produced an L-shaped graph (Figure and). Similarly, at two semi-arid sites, Makwara and Zhinya; the decomposition pattern in conventionally ploughed treatment followed an L-shape. Given that winter and spring season are characteristically dry in Zimbabwe, decomposition in conventional ploughing treatments could be responding to the soil moisture losses during this time of the year.

Table 1: Soil texture, soil organic carbon and pH (0-30 cm) at Chinyanga, Henderson, Kajengo, Makwara and Zhinya sites in Zimbabwe.

Site	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Course Sand (%)	Org. Carbon (%)	pH ($CaCl_2$)
Chinyanga	39	14	27	14	7	2.0	6.3
Henderson	5	7	nd	nd	88	0.71	5.2
Kajengo	14	9	43	22	13	1.42	5.7
Makwara	6	2	28	27	39	1.02	5.3
Zhinya	4	3	37	27	29	1.60	5.9

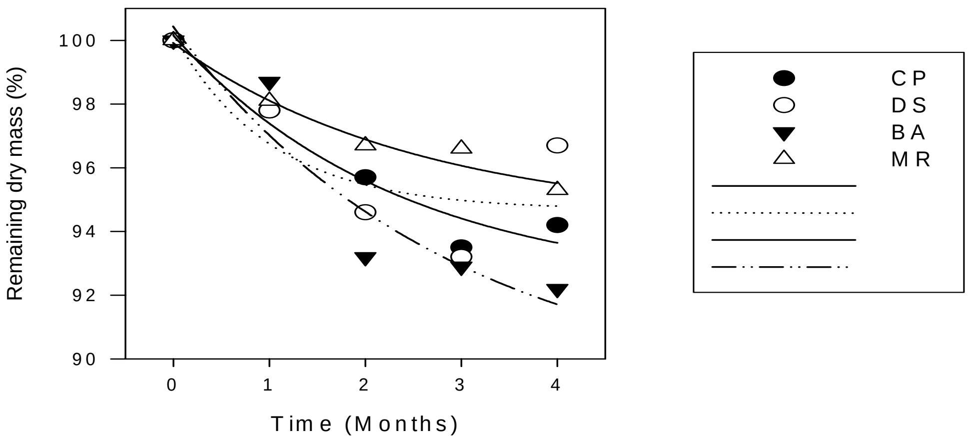
nd = not determined

Monthly decomposition rates were lowest at Henderson compared to the other sites (Table 2). In conventional ploughing treatment, Henderson and Chinyanga had lower decomposition rates than at Kajengo, Makwara and Zhinya.

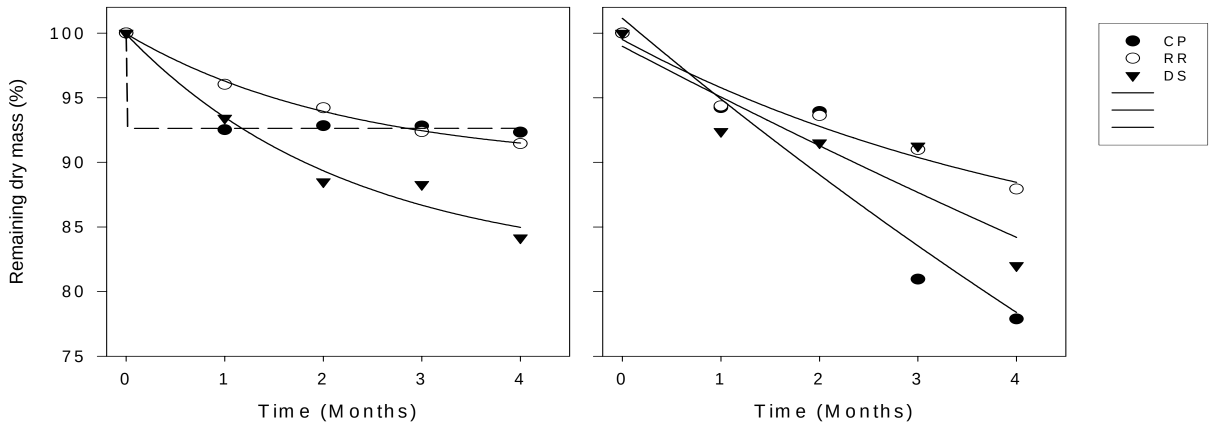
Table 2: Monthly decomposition rate constant (*k*) determination at 5 sites Henderson, Chinyanga, Kajengo, Makwara and Zhinya, Zimbabwe, in conventional, ripper, direct seeder and basin treatments during winter and spring (2006)

Treatment	Conventional ploughing		Ripper		Direct seeder		Basins	
	k	P (0.05)	*k*	P (0.05)	*k*	P (0.05)	*k*	P (0.05)
Henderson	0.017	0.016	0.011	0.008	0.017	0.035	0.017	0.027
Chinyanga	0.016	0.164	0.022	0.05	0.041	0.008	-	-
Kajengo	0.030	0.449	0.029	0.005	0.038	0.061	-	-
Makwara	0.025	0.176	0.036	0.092	0.049	0.005	-	-
Zhinya	0.068	0.418	0.022	0.012	0.014	0.134	-	-

a) Henderson



b) Chinyanga and Kajengo



c) Makwara and Zhinya

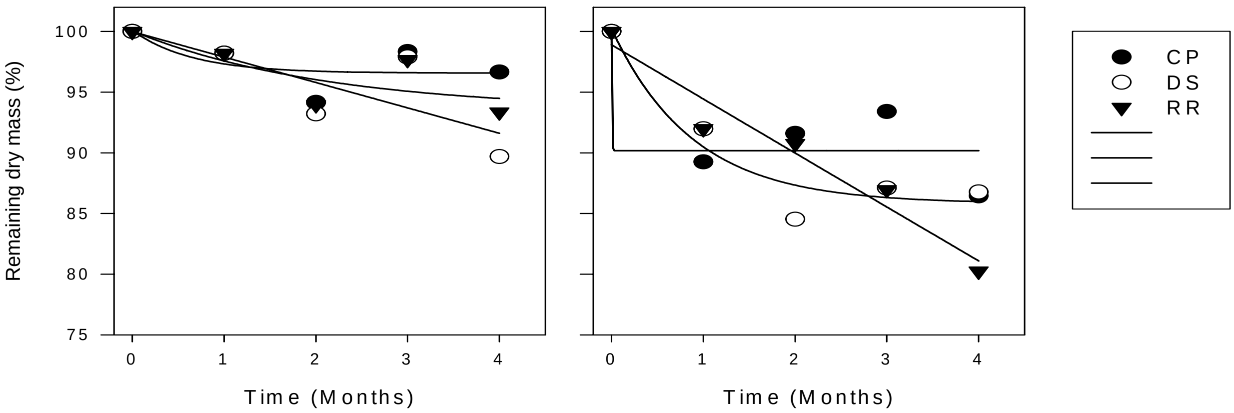


Figure 5.1 Litter losses from a decomposition experiment conducted at (a) Henderson Research station (b) Chinyanga and, (c) Kajengo during winter and spring (2006) and summer (2007) on conventionally ploughed plots (CP), ripper (RR/MR), direct seeded (DS) and basin (BA) treatments.

Discussion

The mass loss in conventionally ploughed treatments at three farms did not follow the expected negative exponential model possibly due to drying-up of the soil profiles at Chinyanga, Makwara and Zhinya (Figure 1). This pattern suggests significant moisture losses in conventionally ploughed treatment compared to the conservation agriculture treatments at each of the sites. Mulching on conservation agriculture treatments could have aided in moisture conservation throughout the dry winter and spring period, which supported fauna involved in the decomposition process. Coleman et al. (2004) reported the influence of the soil water relations on soil biological activities and indirectly on the decomposition of litter.

At Henderson and Kajengo, both in sub-humid rainfall zone, decomposition patterns in all treatments were explained by the negative exponential decay model. Given that litter of similar quality was used at all site across all treatments (C:N ratio = 52), the interaction between mulching and site characteristics could explain the differences in the decomposition rate in each treatment at different sites. Whilst the negative exponential model explained the decomposition pattern in conservation agriculture treatments, the influence of the microclimate conditions at each site were dominant leading to variability in treatment results. The mulching effect on the moisture buffering capacity of the soil was evident between conventional ploughing and conservation agriculture treatments. However, the influence of mulching on decomposition among conservation agriculture treatments was variable; possibly because of the short term nature of the experiment. The litter loss rate support our hypothesis that minimal decomposition rate leave sufficient soil cover at the end of the winter period.

Conclusions

Litter decomposition was explained by the negative exponential model on conservation agriculture treatments. The rate of maize litter loss during winter and spring, was low in both conservation agriculture and conventional ploughing treatments, and depended on microclimate conditions. Due to low the decomposition rates; sufficient soil cover can be achieved prior to the onset of the summer rains, in both sub-humid and semi-arid zones.

Acknowledgements: The authors thank BMZ for financially support provided under a grant extended to CIMMYT, ZEF-University of Bonn and University of Hohenheim.

References

Acharya, C.L., Hati, K.M., Bandyopadhyay, K.K. (2005). Mulches. In: D. Hillel (Ed) Encyclopedia of Soil in the Environment. Elsevier Ltd. pp521-532.

Coleman, D.C., Crossley, Jr., D.A., Hendrix, P.F. (2004). Fundamentals of Soil Ecology 2nd Edition. Elsevier Academic Press, USA.

Heal, O.W., Anderson, J.M., Swift, M.J. (1997). Plant litter quality and decomposition: an historical overview. In: G. Cadisch, K.E. Giller (Eds) Driven by Nature: Plant Litter Quality and Decomposition. CABI Publishing, Wallingford, UK, pp3-30.

Gonzalez, G., Seastedt, T. R. (2001). Soil fauna and plant litter decomposition in tropical and subalpine forests. Ecology 82:955-964.

Kurzatkowski, D., Martius, M., Hofer, H., Garcia, M., Forster, B., Beck, L., Vlek, P. (2004). Litter decomposition, microbial biomass and activity of soil organisms in three agroforestry sites in central Amazonia. Nut. Cycling Agroeco., 69:257-267

Lal, R. (2002). Mulch farming. In: R. Lal (Ed) Encyclopedia of Soil Science. Marcel Dekker Inc. pp844-850.

Swift, M. J., Heal, O.W., Anderson, J. M. (1979). Decomposition in Terrestrial Ecosystems. University of California Press, Berkerly.