International Conference on
Agriculture and Allied Sciences:
The Productivity, Food Security and Ecology
ISBN-978-93-85822-71-1

Handling Crop Residue for Nutrient Cycling and Raising Soil Fertility as well as Crop Productivity

Samrat Adhikary[a*], Ritesh Kundu[a], Biplab Pal[a], Aritra Kumar Mukherjee[a], Animesh Ghosh Bag[a], Bipin Bihari[b], Kaushik Batabyal[c], Sovan Debnath[a,e] and Nintu Mandal[d]

[a]*Department of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal,741252*
[b]*Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, 813210*
[c]*Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal,741252*
[d]*Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, 813210*
[e]*ICAR-Central Institute of Temperate Horticulture, Regional Station –Mukteshwar, Nainital, Uttarakhand, 263138*
*E-mail: *samratadhikarysoil@gmail.com*

Abstract—*Today conventional agriculture production system is facing the problem of declining in agricultural growth and factor productivity, shrinkage in cultivated area, low level of soil organic matter, soil degradation, multi-nutrient deficiencies, depleted ground water resources, increased cost of production and low farm income and increased environment pollution. For overcoming these constraints crop residue management is one of the best alternatives because of its diverse and positive effect on soil health. Incorporation crop residues left in the field after harvest are the raw materials for humus formation and may represent a significant supply of nutrients to subsequent crops and ultimately it enhance to build up of SOM, soil N, P and K as well as micronutrient. However, N at 15-20 kg* ha^{-1} *as starter dose with straw incorporation increases yield of wheat and rice compared to burning. Surface retention of residues increases soil* NO_3*- by 46%, N uptake by 29%, and yield by 37% compared to burning. Residue management practices affect soil physical properties viz. soil moisture, temperature, aggregate formation, bulk density and hydraulic conductivity. Rice straw residues are highly siliceous, and have the potential of transforming electrochemical properties of acidic soils that reduces P fixation; improving base retention and increasing the soil pH. Residue incorporation coupled with organic manure increases grain yield of different cereals and improves soil physical condition. Residue incorporation results more microbial activity than residue removal or burning. Long-term studies of the residue recycling have indicated improvements in physical, chemical and biological health of soil. Other plausible option of crop residues management lies in utilizing a portion of surplus residue for producing biochar as soil amendment to improve soil health, increase nutrient use efficiency and minimize air pollution and other i.e. mushroom cultivation as converting of inedible crop residues into valuable food, surface mulch as conservation of soil moisture and weed problem, biofuel. Managing crop residues offer sustainable and ecologically sound alternatives for meeting the nutrients requirements of crops and improving crop productivity.*

Keywords: *SOM, Surface retention, Aggregate formation, Biological health, Bio fuel.*

1. INTRODUCTION

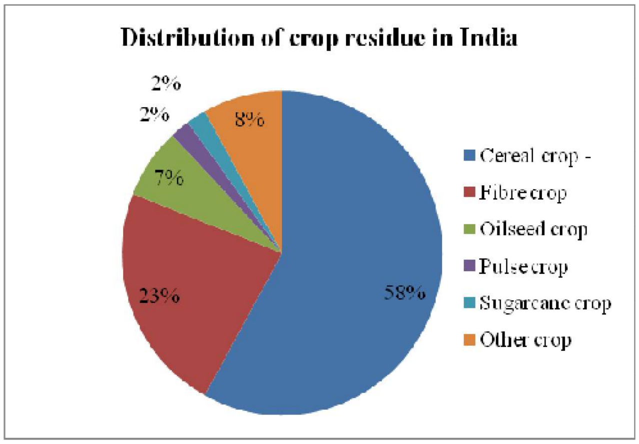
After green revolution, natural fertility of soil has been degraded due to intensive cultivation, use of high doses of chemical fertilizer and insufficient uses of organics i.e. farmyard manure, compost, crop residue, green manure, biofertilizers etc. Stagnation in agricultural production in last few years, that too with increasing use of inputs, a cause of concern, has led to awareness on the sustainability issues related to crop production. Sustainability of the most of the cropping system is at risk due to deterioration of soil health, mounting pressure on natural resources and emerging challenges of climate change. These are some sustainability issues related to crop production:

- Decline in agricultural growth and factor productivity
- Shrinkage in cultivated area
- Low level of soil organic matter (about 70 % of Indian soil are low in organic matter content)
- Soil degradation (low use of organic sources, little return of crop residues/ burning of crop residues and intensive tillage)
- Multi-nutrient deficiencies due to intensive cultivation
- Depletion of ground water resources
- Increased cost of production and low farm income
- Increasing environmental pollution

Long term studies of the residues recycling have indicated improvement in physical, chemical, biological health and also improve overall ecological balance of the crop production system. Due to diverse and positive effect on soil health, crop productivity and environmental quality crop residues serve as better option for sustainable crop production system as well as it serve as alternative means for biomass disposal contributing to nutrient cycling [1].

Generation of crop residue in India:

The Ministry of New and Renewable Energy, Govt. of India (2009) has estimated that about 500 Mt of crop residues aregenerated every year. The generation of crop residues ishighest in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt)and Maharashtra (46 Mt). Among different crops, cerealsgenerate maximum residues (352 Mt), followed by fibers (66Mt), oilseeds (29 Mt), pulses (13 Mt) and sugarcane (12 Mt).The cereal crops (rice, wheat, maize, millets) contribute 70%while rice crop alone contributes 34% and wheat ranks secondwith 22% of the crop residue**s.**



The share of unutilized residues in total residues generated by different crops in India (calculated from MNRE, 2009)

It is reported that 25-40% N, 25–35% P, 70–85% K, 40–50% S and 50-75% of micronutrients absorbed by cereals remain in the straw at maturity. Nutrients present in rice straw at harvest: 5–8 kg N, 0.7–1.2 kg P, 12–17 kg K, 0.5–1 kg S, 3–4 kg Ca and 1–3 kg Mg per ton of straw on a dry weight basis [2].Besides NPK, one ton rice and wheat residuesalso contain about 100g Zn, 777 g Fe and 745g Mn. Average nutrient content of some of the crop residues are presented below:

Crop residues	Nutrient content (%)		
	N	P_2O_5	K_2O
Rice	0.61	0.18	1.38
Wheat	0.48	0.16	1.18
Maize	0.52	0.18	1.35
Pearl millet	0.45	0.16	1.14
Potato tuber	0.52	0.21	1.00
Groundnut (pods)	1.60	0.23	1.37
Sugarcane	0.40	0.18	1.28

Different management aspects for crop residues are as follows:

- Animal feed
- Burning (Partial/complete)
- In-situ recycling as stubble mulch
- Mulching material for other crops
- Incorporation
- Composting
- Biofuel
- Electricity
- Gasification of residues
- Building material
- Paper

Importance of crop residues management:

- Improve organic carbon and N content in soil
- Acts as a buffer in soil against rapid change in soil pH
- Reclamation and management of saline and alkaline soil
- Acts as a reservoir for plant nutrients (Prevents leaching of elements, essential for plant growth)
- Incorporation of straw along with application of FYM (reduce the bulk density of soil and increases the porosity of the soil.
- Provide energy for growth and activities of microbes
- Improve soil and water conservation and sustain soil fertility and enhancing crop yields
- Raise the soil temperature in winter and lowered it in summer season

There are some factors which affect the decomposition of crop residue, these are as follows:

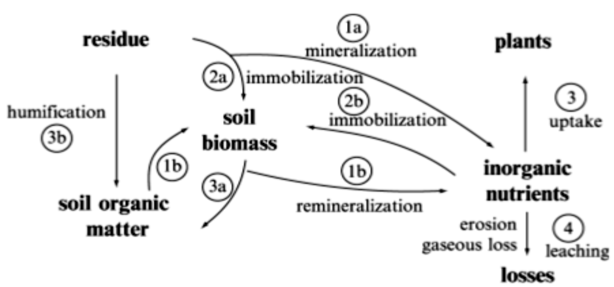
- Residue particle size: As small as the size of crop residue it provides greater surface area to the microbes for action and fasten the decomposition.
- Environmental factor: The temperature in the range of 30 to 35 ^{0}C and moisture at 60 percent of the water holding capacity is optimum for microbial activity.
- Management factor: The placement of crop residue at surface or sub-surface affect the rate of decomposition of crop residue. In several studies, it was found that surface placed residue takes greater time to decompose as compare to subsurface placed residue.

ISBN: 978-93-85822-71-1

- Availability of nutrients: The C: N ratio of crop residue affects its decomposition. The residue with higher C:N ratio incorporated into soil then it leads to immobilization of some of the if those nutrients are not presents in the soil solution in sufficient amount.
- Soil properties: The soil with higher or lower pH and the texture of soil are some of the factor which affects crop residue decomposition.

Nutrient cycling in crop residue amended soil

This conceptual model depicts the flow of carbon and nutrients among organic residues, organic andinorganic pools in soil, and the plant. Pathways of loss are also included. Decomposition and mineralization of plant residue are mediated by both soil faunal and microbial populations.



Some of the carbon and associated nutrients are mineralized immediately (pathway 1a) or are immobilized in the soil microbial pool (pathway 2a), later to be transformed into other soil organic pools via microbial by-products (3a). Recalcitrant plant material also may enter the soil organic pools directly (3b). The carbon and nutrients held in the various soil organic matter pools are subsequently decomposed and assimilated by soil biomass, resulting in additional mineralization (1b). The inorganic nutrients released by mineralization may be assimilated by soil biota via immobilization (2). Immobilization occurs simultaneously with mineralization, and the rate at which nutrients are available for plant uptake depends on the net balance between mineralization (1a plus 1b) and immobilization (2). The inorganic nutrients may also be taken up by plants (pathway 3), lost by leaching or volatilization (pathway 4), or remain in the soil [3].The size of the inorganic pool depends on the balance of the various processes that add to the pool (mineralization) and those that subtract (immobilization, plant uptake, and losses).

Effect on soil physical health

Crop Residue management practices affect soil physical properties such as soil moisture content, aggregate formation, bulk density and soil porosity. Incorporation and/or retention of crop residues in to the soils reduced bulk density and compaction of soils [4]. The Annual application of 16 t ha^{-1} of rice straw for 3 years decreased bulk density from 1.20 to 0.98 g cm^{-3} in the 0-5 cm layer on a sandy loam. Due to breakdown of aggregates and formation of surface seal by the raindrop impact, causes increase in compaction and reduction in pore proportion of the surface soil resulted in the lower infiltration. Residue retention on the surface solves this problem. Incorporation of crop residues decreased BD and increased infiltration rate, WHC, microbial population, soil fertility as compared to no residue treatment. The residue incorporation with NPK fertilizer resulted in the highest yield, nutrient uptake, improved residual soil fertility and soil microorganism's status [5]

Effect of crop residue management on soil Fertility over 11 year of rice wheat cropping system [6]

Soil property	Crop residue management		
	Burned	Removed	Incorporated
Total K (%)	390	420	61.2
Olsen P (mg/kg)	1.71	1.54	1.81
Available K(mg/kg)	14.4	17.2	20.5
Total K (%)	58	45	52
Available Sulphur (mg/kg)	34	55	61

Performance of Zero- till wheat sown into rice residue [7]

Year	No. of experiments	Grain Yield (t/ha)		% increase in yield with HS
		Happy Seeder(HS)	Conventional till (CT) over	
2007-08	46	4.59	4.50	2.0
2008-09	14	4.54	4.34	4.6
2009-10	94	4.42	4.30	2.8
Mean	154	4.56	4.42	3.24

[8] It also reported that residue incorporation under conventional tillage was the most effective in improving seed yield of greengram, while removal of the same in zero tillage had adverse impacts. It is apparent that benefits of zero tillage are accrued only when residues are retained as mulch over the soil. The yield improvement in conventional over zero tillage was 25–35%, depending upon the residue addition. However, germination of greengram was not significantly influenced due to tillage practices. Residue addition improved the N-uptake by the crop, tillage possibly helped in greater N-mineralization from the residues, resulting in higher grain and stover N in Conservation tillage with residue incorporation(CT+R). Residue additions also improved the total N, C and other nutrients content in soil, which resulted in higher N uptake.

Effect on soil biological health

Availability of nutrients like N, P, and S is particularlydependent upon soil microbial biomass (SMB) and microbialactivity, which in turn depend on the supply of organicsubstrates in soil. The population of soil flora and fauna ispositively correlated with the phyto-biomass present in soil. [4,8] It observed that soil treated with crop residues held 5-10 times more aerobicbacteria and 1.5-11 times more fungi than soil were eitherburn or removed. [9,10] The study revealed that, soil microbial biomass (C and N) decreased with decreasing amount of residue retained on the soil surface inthe zero till treatments of both rainfed and irrigated long termtrial. The soil microbial biomass reflects the soil's ability tostore and cycle nutrients (C, N, P and S) and organic matterand plays an important role in physical stabilization ofaggregates. Crop residues are also known to enhance nitrogenfixation in soil by asymbiotic bacteria (*Azotobacter chrococcum* and *A. agilis*). Due to increase in soil microbialpopulation the activity of soil enzymes responsible forconversion of unavailable to available form of nutrient alsoincreases.

Benefits of residue management:

- Reduced soil erosion
- Improve phyco-chemical properties
- Enhanced biological activity
- Control weed growth
- Increased infiltration rate
- Retained soil moisture content
- Help in nutrient cycling

Maintain soil health and qualit

Conclusion

- The recycling of its residues has the great potential to return a considerable amount of plant nutrients to the soil.
- Crop residues offer sustainable and ecologically sound alternatives for meeting the nutrients requirements of crops and improving soil health and environmental quality.
- Retention of crop residues on the soil sur- face (e.g. in conservation tillage systems) not only reduces runoff and soil erosion, but also improves soil physical characteristics (such as hydraulic properties and soil aggregation) and increases soil organic matter content, especially in the surface layer.
- Effective and efficient management of crop residues could be of much helpful to increase microbial biomass in soil.

Future work needed

- In order to interpret soil organic matter dynamics and nutrient cycling, more reliable data on yields of both above- and below-ground crop residues are needed. Evaluation of crops in terms of residue production, decomposition, and nutrient retention with the objective of improving organic inputs to soil is needed.
- Better characterization of crop residues for their chemical composition (macro- and micronutrients, organic compounds) that will help in improved prediction of release of C, N, S, and other nutrients is needed.
- The fate of nutrients in residue-amended fields should be investigated. Investigation of largely unexplained benefits that arise from crop residue recycling, such as microbiological, biological N2 fixation, pest suppression, physical, etc., is needed.

References

[1] Singh, Y. (2015) Crop residue management for ecological agriculture. *Natural Resource Management viz-a-viz climate change*. Pp. 70-79.

[2] Witt C. and Dobermann A.(2002).A Site-Specific Nutrient Management Approach for Irrigated, Lowland Rice in Asia., Better Crops International Vol. 16, No. 1.

[3] Myers R.J.K., Palm C.A., Cuevas E., Gunatilleke IUN., and Brossard M. (1994). The synchronization of mineralization and plant nutrient demand. In: The biological management of tropical soil fertility, eds P L Woomer & M J Swift, *John Wiley & Sons Chichester* UK pp 81–116.

[4] Bellakki MA, Badanur VP, Setty RA(1998). Effect of long-term integrated nutrient management on some important properties of a Vertisol. J. Indian Soc. Soil Sci.; 46:176-180.

[5] Singh G., Joint Secretary Government of India (2010). Delhi International Renewable Energy Conference Up-scaling and Mainstreaming Renewables for Energy Security, Climate Change and Economic Development.

[6] Beri V., Sidhu B.S., Bahl G.S., Bhat A.K. (1995)Nitrogen and phosphorus transformations as affected by crop residue management practices and their influence on crop yield. Soil Use Manage.; 11:51-54.

[7] Sidhu H. S., Singh M., Singh, Y., Blackwell J., Singh, V. and Gupta, N. (2011). Machinery development for crop residue management under direct drilling. In; Resilient food systems for a changing world pp. 157-158. Proceeding of the 5th World Congress on Conservation Agriculture. Incorporating 3rd farming systems Design Conference, 25-29th September 2011, Brisbane, Australia.

[8] Meena, J.R., Beheraa, Umakant, K., Chakraborty, Debasis and Sharma, A.R., (2015); Tillage and residue management effect on soil properties, crop performance and energy relations in green gram under maize-based cropping systems; *International Soil and Water Conservation Research*,(3): 261–272.

[9] Beri V., Sidhu B.S, Bhat A.K, Singh B.P.(1992) Nutrient balance and soil properties as affected by management of crop residues. In: Proceedings of the international symposium on nutrient management for sustained productivity. Department of Soils, Punjab Agricultural University, Ludhiana, Punjab, India. (Ed: Bajwa M S).; II:133-135

[10] Singh Y, Singh B, Ladha J.K., Khind, CS, Khera T.S, Bueno CS. (2004).management effect on residue decomposition, crop production and soil fertility in rice wheat rotation in India. *Soil Science Society of America Journal*; 68:320-326.

ISBN: 978-93-85822-71-1