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Management of crop residue for enhancement of crop productivity and nutrient cycling

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Abstract
Today sustainable 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 (Singh, 2015). For overcoming these constraints crop residue management is one of the best alternatives because of its diverse and positive effect on soil health. Crop residues management improves organic carbon and N content in soil, affects soil pH through accumulation of CO_2 and organic acids produced during their decomposition in the soil, reclamation and management of saline and alkaline soil, behave as a reservoir for plant nutrients, decreases the bulk density of soil and increases the porosity of the soil, provides energy for growth and activities of microbes. We know that sustainability of the most of the cropping system depends on soil quality and improving the level of soil organic matter through incorporation of crop residues and other organic sources leads to improve soil quality and nutrient cycling and which also simultaneously provide alternative means for biomass disposal. Subsurface placement of rice residue as well as time of residue incorporation had a large impact on decomposition of rice residue (Singh *et al*., 2004b). The carbon and nutrient held in various soil organic matter pools are subsequently decomposed and assimilated by soil biomass resulting in additional mineralization. Immobilization process occurs simultaneously with mineralization process and the rate at which nutrients are available for plant uptake depends on net balance between mineralization and immobilization. In a long term experiment on a loamy sand soil in Punjab Agricultural University, Ludhiana, incorporation of residues of both crop in rice-wheat rotation increased the total and available P and K content of soil over removal of residues (Beri *et al*., 1995). Grain yield of wheat increased when it is sown in rice residue (Sidhu *et al*., 2011) and when residue is incorporated into soil (Ramesh Chandra, 2011). Management of crop residues offers sustainable and ecologically sound alternatives for meeting the nutrients requirements of crops and improving crop productivity.

Keywords: crop residue, enhancement, crop productivity, nutrient cycling

Introduction
After green revolution, the inherent fertility of soil has been degraded due to intensive cultivation, use of high doses of chemical fertilizer and insufficient uses of organics like farmyard manure, compost, crop residue, green manure, bio-fertilizers 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; ascend 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 environment pollution.

Innovation in crop residue management to avoid straw burning should assist in achieving sustainable productivity and allow farmers to reduce nutrient and water input, and reduce risk due to climate change. 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.

Production of crop residues in India

About 500 Mt of crop residues are generated in India annually reported by The Ministry of New and Renewable Energy (MNRE, 2016) [4] Govt. of India. Among different crops, cereals contribute the highest amount of 352 Mt (70%) followed by fibers (66 Mt), oilseeds (29 Mt), pulses (13 Mt) and sugarcane (12 Mt). Among cereals crops, rice-contribute the highest amount of crop residue i.e. 34% followed by wheat crop i.e. 22% crop residue, most of which is burnt on-farm, assuming that 50% of CRs are utilized as cattle feed and fuel. Devi *et al* (2017) reported that about 234 Mt, i.e. 30% of gross residue generated in India is available as surplus .In India; cereals are the highest contributor of surplus residues followed by fiber, oilseed, pulses and sugarcane (Figure 1).

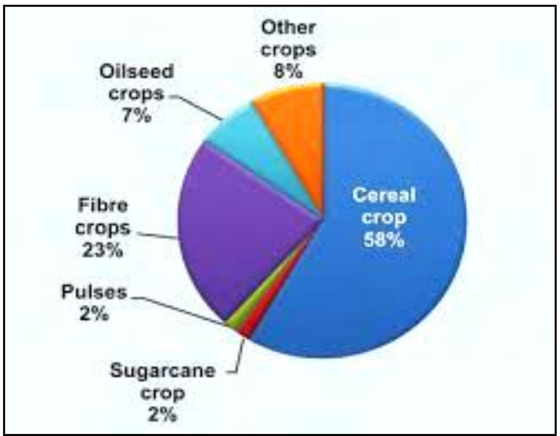


Fig 1: Surplus residue generation

Dobermann and Witt (2000) reported that nutrients present in rice straw at harvest is 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. At maturity stage, the cereals straw contains 25-40% N, 25–35% P, 70–85% K, 40–50% S and 50-75% of micronutrients. Besides NPK, one ton rice and wheat residues also contain about 100 g Zn, 777 g Fe and 745g Mn. Average nutrient content of some of the crop residues are presented below:

Crop residue	Nutrient (%)		
	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

The Ministry of New and Renewable Energy (MNRE, 2009) [7], Govt. of India has estimated that about 500 Mt of crop residues are generated in every year (Table 1)

Table 1: State-wise crop residue generated, residue surplus and burned

Sl. No	States	Residue generation*	Residue surplus*	Residue burned$
1	Andhra Pradesh	43.89	6.96	2.73
2	Arunachal Pradesh	0.40	0.07	0.04
3	Assam	11.43	2.34	0.73
4	Bihar	25.29	5.08	3.19
5	Chhattisgarh	11.25	2.12	0.83
6	Goa	0.57	0.14	0.04
7	Gujarat	28.73	8.90	3.81
8	Haryana	27.83	11.22	9.08
9	Himachal Pradesh	2.85	1.03	0.41
10	Jammu &Kashmir	1.59	0.28	0.89
11	Jharkhand	3.61	0.89	1.10
12	Karnataka	33.94	8.98	5.66
13	Kerala	9.74	5.07	0.22
14	Madhya Pradesh	33.18	10.22	1.91
15	Maharashtra	46.45	14.67	7.42
16	Manipur	0.90	0.11	0.07
17	Meghalaya	0.51	0.09	0.05
18	Mizoram 19.	0.06	0.01	0.01
19	Nagaland	0.49	0.09	0.08
20	Orissa	20.07	3.68	1.34
21	Punjab	50.75	24.83	19.65
22	Rajasthan	29.32	8.52	1.78
23	Sikkim	0.15	0.02	0.01
24	Tamil Nadu	19.93	7.05	4.08
25	Tripura	0.04	0.02	0.02
26	Uttarakhand	2.86	0.63	0.78
27	Uttar Pradesh	59.97	13.53	21.92
28	West Bengal	35.93	4.29	4.96
29	Total	501.73	140.84	92.81

Source: * self-generated table using data from MOSPI (2013-14), Ministry of New & Renewable Energy (MNRE, 2009) [7], Govt. of India, New Delhi.

$ Pathak Himanshu *et al* (2010), Senior Scientist, C.E.S. & C.R., IARI, New Delhi.

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

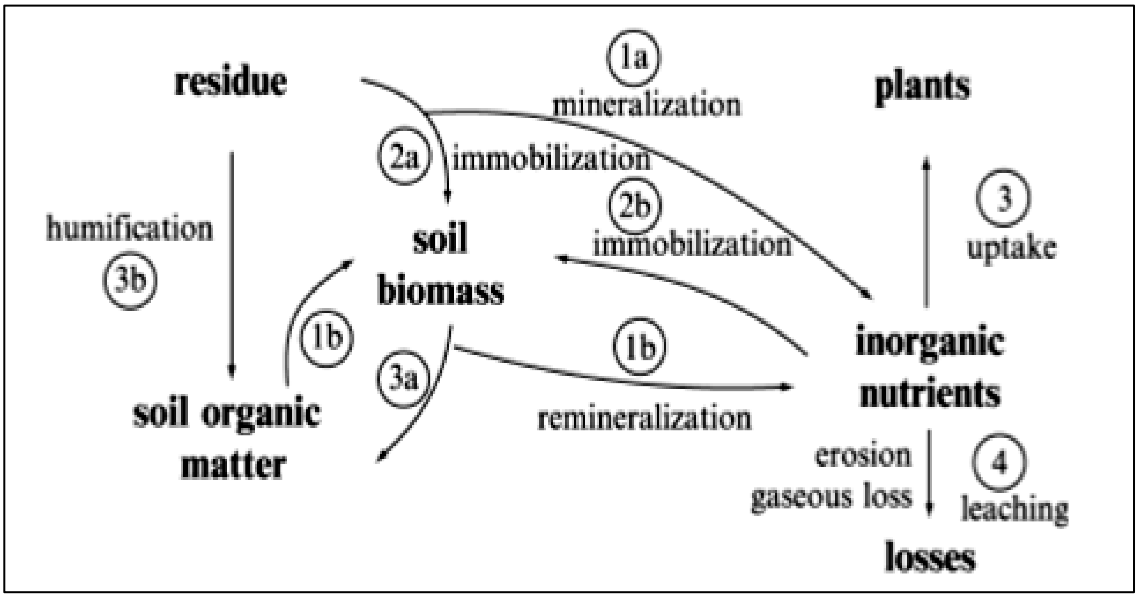
Importances of crop residues management are as follows

- 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 several plant nutrients (Prevents leaching of elements, essential for plant growth)
- Incorporation of crop residue along with application of FYM (reduces 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 fastens 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 affects 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.
- 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 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 and inorganic 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.



(**Source:** Myers *et al*., 1994)

Fig 2: Conceptual model of nutrient pathways in crop residue amended soils

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 (Myers *et al*., 1994). 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 of crop residue management on different soil properties

Meena *et al*. (2015) [6] conducted a experiment on tillage and residue management and reported that the ZT-R and ZT+R had 12 and 33% larger MWD than CT-R and CT+R, respectively indicating that the tillage effect was dominating over the residue addition. The highest C content was recorded in the treatment (ZT+R) due to addition of crop residue. Similarly, the tillage effect was found significant at the 0–15 cm layer only, with highest increase in C under ZT+R. The residue addition resulted in improvement of soil C content in the plough layer, resulting in lowering the bulk density or increasing the conductivity. (Table. 2)

Table 2: Effect of tillage and residue management practice on different soil properties

Treatments	Depth (cm)						
	Bulk Density(Mg m^{-3})		Hydraulic conductivity(cm h^{-1})		MWD (mm)	SOC (g kg^{-1})	
	0–15	15–30	0–15	15–30	0–15	0–15	15–30
CT-R	1.58	1.63	0.74	0.73	0.54	2.73	2.30
CT+R	1.50	1.68	1.36	0.40	0.66	3.58	2.48
ZT-R	1.65	1.62	0.89	0.81	0.72	3.38	2.65
ZT+R	1.59	1.61	1.26	1.13	0.74	4.35	2.15
CD (*P*=0.05)	0.09	NS	0.20	0.13	0.05	0.62	NS

(**Source:** Meena *et al.* 2015) [6]

Yang *et al.* (2010) [17] reported that the physical properties of soil were improved by rice straw retention, that is the surface soil depth was deepened, soil hardness and bulk density were decreased while porosity increased. The improvements of physical properties tended to be higher with the higher cutting heights (Table 3). Among the soil physical properties, soil hardness and bulk density decreased and porosity increased with rice straw restoration.

Table 3: Change in physical properties of soil with retention of rice straw

Division		Surface soil depth (cm)	Hardness (mm)	Bulk density (g cm-3)	Porosity (%)
Control		12.0	20.4	1.594	39.9
Cutting height (cm)	10	14.0	19.7	1.558	41.2
Cutting height (cm)	15	14.0	19.5	1.474	44.4
Cutting height (cm)	20	14.0	18.2	1.417	46.6

(**Source:** Yang *et al.* 2010) [17]

Singh *et al.* (2012) [12] reported that soil physical properties improved significantly due to residues management practices (Table: 4). A decrease in bulk density was observed in plots where chopped crop residues were incorporated along with irrigation. Particle density in the surface layer was also significantly lowered under chopping + incorporation of crop (urdbean/ mungbean) residues + irrigation. It also increased pore space and WHC by 28.9% and 38.9% respectively. All the residues incorporation treatments gave significantly higher soil available NPK content over control. Among crop residues treatments, incorporation of chopped straw + irrigation proved most beneficial in raising soil available N. The plots under crop residues removal (control) gave the lowest soil available N (196.8 kg/ha). Similarly, available P and K content in soil also increased in the range of 4 - 11.5 and 8.1-18.1%, respectively due to different methods of residues incorporation over control.

Table 4: Effect of residue incorporation on soil physico-chemical properties

Treatments	Soil physical properties				Available nutrient (Kg/ha)		
	Bulk Density(g/cc)	Patticle density(g/cc)	Pore space (%)	WHC (%)	N	P	K
Residue Management							
Mungbean[1]	1.38	2.42	45.5	37.3	228.2	18.72	146.4
Urdbean[1]	1.39	2.39	44.7	38.3	222.1	18.16	154.2
Mungbean[2]	1.38	2.38	46.8	38.3	237.7	19.58	152.1
Urdbean[2]	1.38	2.40	47.0	41.6	235.7	17.84	149.2
Mungbean[3]	1.34	2.38	47.3	42.5	240.4	18.01	148.7
Urdbean[3]	1.35	2.39	48.2	45.1	241.1	17.32	147.6
Mungbean[4]	1.32	2.36	49.6	46.4	245.3	17.46	145.7
Urdbean[4]	1.33	2.35	48.2	45.9	246.1	18.02	141.1
Control	1.44	2.50	38.2	33.4	196.8	16.65	130.5
CD (P=0.05)	0.05	0.10	3.5	3.8	14.9	0.78	9.6

1. Incorporation; 2. Incorporation + irrigation; 3. Chopping + Incorporation; 4. Chopping +Incorporation + irrigation
WHC: Water holding capacity
(Source: Singh *et al.* 2012) [12]

They also found that crop residue incorporation resulted in significantly higher SMBC over control. All the crop residues management plots were having similar SMBC values except that in urdbean crop residues where significantly lower SMBC values were observed over the rest of crop residues incorporation treatments. All the residues management treatments including control gave significantly higher SOC over its initial value of 0.28%. But the highest increase in SOC (35.48%) was recorded in direct incorporation of urdbean residues over control.

Table 5: Effect of residue incorporation on Periodic changes in microbial biomass carbon and organic carbon content in soil

Treatments	Periodic (days) change in SMBC after residue incorporation (µg /100g)				After wheat harvest		
	7	14	33	56	SMBC (µg/100g)	SOC (g/kg)	Ratio of SMBC to SOC (%)
Residue Management							
Mungbean[1]	335	347	345	351	262	3.9	6.71
Urdbean[1]	270	178	282	264	222	4.2	5.28
Mungbean[2]	345	351	358	367	322	3.9	8.25
Urdbean[2]	230	237	237	230	312	4.1	7.60
Mungbean[3]	348	369	363	378	327	3.6	9.08
Urdbean[3]	330	351	343	351	337	3.7	9.10
Mungbean[4]	355	395	377	391	320	3.5	9.14
Urdbean[4]	320	359	375	327	347	3.7	9.37
Control	240	242	268	248	132	3.1	4.25
CD (P=0.05)	4.78	4.81	5.16	4.96	39.8	0.29	NS

1. Incorporation; 2. Incorporation + irrigation; 3.Chopping + Incorporation; 4. Chopping+ Incorporation + irrigation
(**Source:** Singh *et al*. 2012) [12]

Beri *et al*. (1995) [1] conducted a long term experiment on crop residue management and found that the total and available N P K is higher in incorporated residue in the field than removed or burned. Residue incorporation in the long term has a beneficial effect in sustaining the productivity of the soil (Table 6).

Table 6: Effect of residue incorporation on soil fertility over 11 years of rice wheat cropping system

Soil property	Crop residue management		
	Burned	Removed	Incorporated
Total P (mg/kg)	390	420	612
Olsen P (mg/kg)	14.4	17.2	20.5
Total K (%)	1.71	1.54	1.81
Available K(mg/kg)	58	45	52
Available S(mg/kg)	34	55	61

(Source: Beri *et al*. 1995) [1]

Effect of crop residue management on yield and yield attributing characters

Meena *et al*. (2015) [6] reported that the residue incorporation under conventional tillage was most effective in improving the seed yield of green gram, 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 green gram 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 CT+R. Residue additions also improved the total N, C and other nutrients content in soil, which resulted in higher N uptake.

Table 7: Yield attributes and yields, N concentration and uptake in summer green gram under different tillage and residue management practices.

Treatments	Number of			1000-seed weight (g)	kg ha^{-1}				N concentration (%)		N uptake (kg ha^{-1})		
	Pods plant^{-1}	Grains pod^{-1}	Branches plant^{-1}		Seed Yield	Stover Yield	Biological yield	Harvest index	Grain	Stover	Grain	Stover	Total
CT-R	14.17	8.08	2.80	43.61	752.7	2733	3486	0.215	3.43	1.30	26.66	35.50	62.16
CT+R	16.0	8.19	3.30	44.77	1062.2	3136	4200	0.253	3.61	1.36	38.16	42.10	80.26
ZT-R	13.65	7.99	3.27	44.30	602.7	2874	3477	0.176	3.32	1.14	20.10	32.83	52.93
ZT+R	13.80	8.0	3.40	44.76	789.7	3083	3873	0.205	3.59	1.16	28.25	35.23	63.48
CD (*P*=0.05)	1.80	0.09	0.41	NS	101.3	278.1	189.4	0.0355	NS	0.14	6.687	4.442	7.962

(**Source:** Meena *et al*. 2015) [6]

Ramesh Chandra (2011) [2] worked on crop residue management and reported that the grain yield and straw yield of wheat is more in the plot where residue was incorporated than removed (Table 7).

Table 7: Grain and straw yield of wheat as influenced by residue incorporation on preceding crop.

Treatments	Grain Yield (t/ha)			Straw Yield (t/ha)		
	2002-2003	2003-2004	Mean	2002-2003	2003-2004	Mean
Removal	4.38	4.40	4.39	5.95	6.36	6.16
Incorporation	4.61	4.73	4.68	6.14	6.72	6.43
CD (P=0.05)	2.1	2.6	0.22	NS	0.31	0.27

Sidhu *et al*. (2011) [11] reported that the happy seeder (HS) works well for direct drilling in standing as well as loose residues provided the residues are spread uniformly. Data from 154 on-farm trials conducted during 2007-10 in different districts of Punjab showed that weighted average wheat yield for happy seeder sown plots was significantly more (3.24%) than the conventionally sown wheat (Table 8).

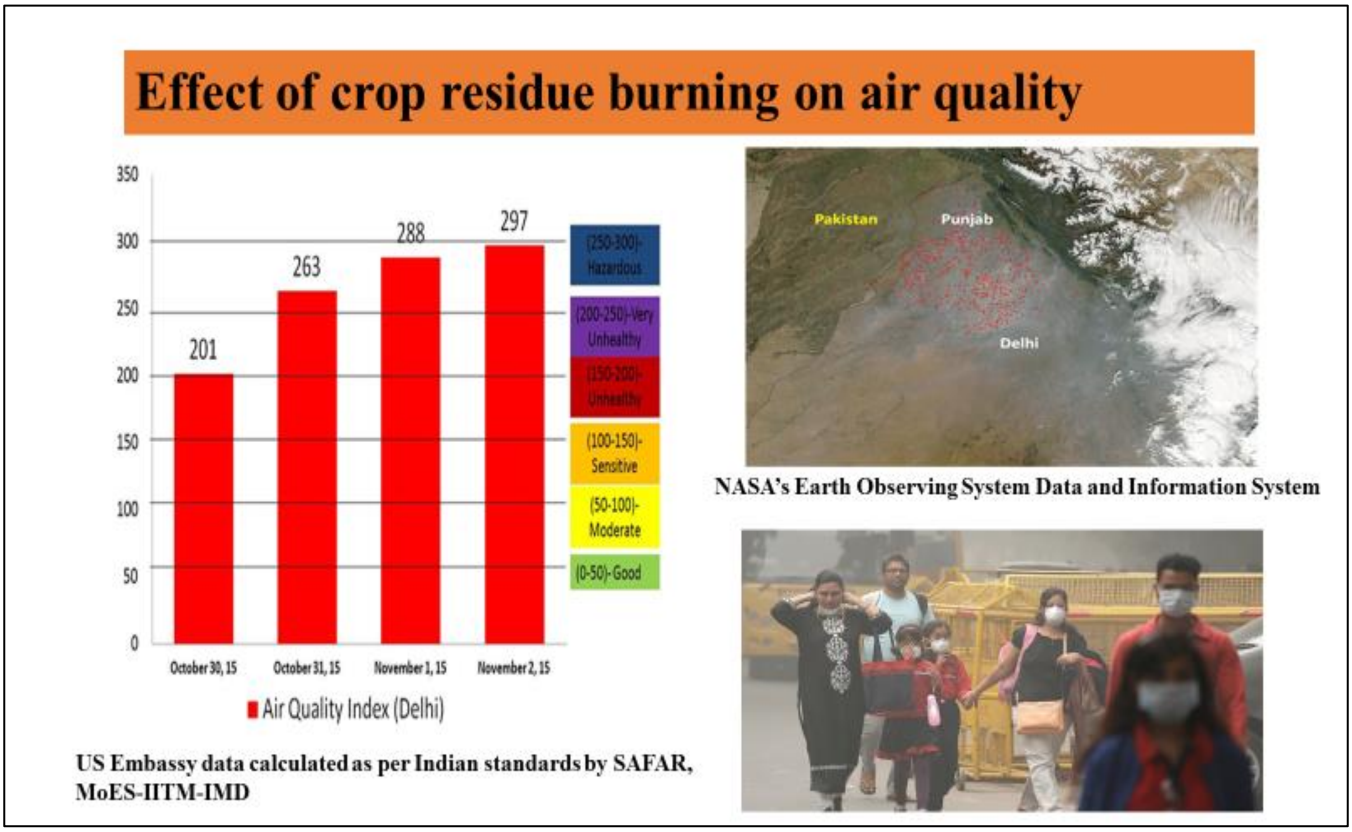
Table 8: Performance of zero till wheat sown into rice residue

Year	No. of Expts	Grain yield (t/ha)		% increase in yield with HS
		Happy seeder (HS)	Conventional till (CT) over CT	
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

(**Source:** Sidhu *et al*. 2011) [11]

Burning of crop residues

The burning of CRs is a major contributor to reduced air quality (particulates, greenhouse gases), and impacts human and animal health both medically, and by traumatic road accidents due to restricted visibility in NW India. Besides, burning of CRs leads to a loss of organic matter and precious nutrients, especially N and S. The peak in asthmatic patients in hospitals in NW India coincides with the annual burning of rice residue in surrounding fields (Yadvinder-Singh *et al*. 2010b) [15]. Presently, more than 80% of total rice straw produced annually is being burnt by the famers in 3-4 weeks during October-November (Yadvinder-Singh *et al*. 2010b) [15]. Burning of rice straw causes gaseous emission of 70% CO_2, 7% CO, 0.66% CH_4, and 2.09% N_2O (Gupta *et al*. 2004) [5].



So, burning of crop residue must be avoided, better management option for agricultural point of view is to incorporate it or to either use it as mulch in conservation agriculture.

Decomposition of crop residue

Yadvinder-Singh *et al*. (2010a) [16] reported that the incorporated rice residue lost about 80% of its initial mass at the end of decomposition cycle (140 days), whereas 50 - 55% surface placed rice residues was not decomposed at the time of wheat harvest (Fig. 3)

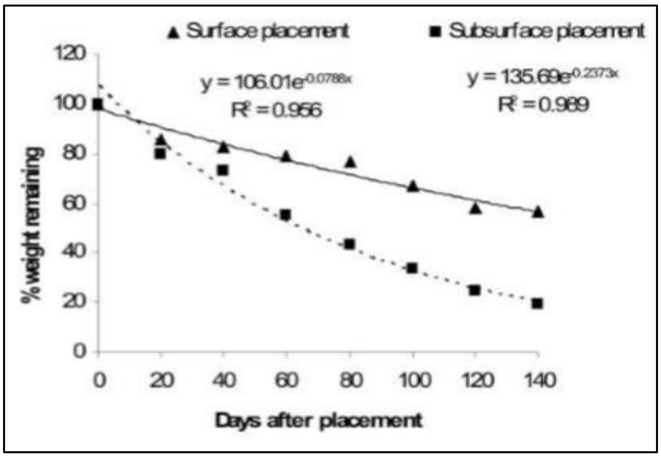


Fig 3: Rice residue decomposition during wheat season as a function of time as affected by method of placement

Yadvinder-Singh *et al*. (2004b) [15] also found that mass loss of incorporated rice residue was upto 51% by 40-day, 35% for the 20 day and 25% for 10-day decomposition treatment imposed before sowing of wheat (Fig. 4)

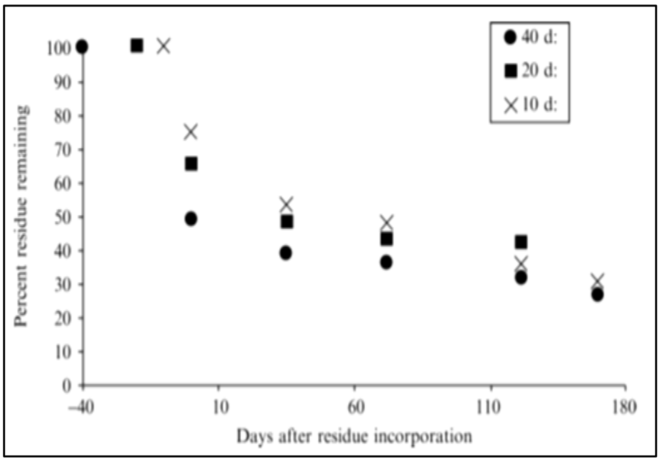


Fig 4: Effect of decomposition period on the mass remaining of litterbag rice residue

Benefits of residue management

- Reduced soil erosion.
- Improve physico-chemical properties.
- Enhanced biological activity.
- Controls weed growth.
- Increased infiltration rate.
- Retained soil moisture content.
- Help in nutrient cycling.
- Maintain soil health and quality.

Negative impact of residue management

- Initially immobilization of nutrient.
- Increase incidence of crop disease.
- Increased infestation of insect.
- Stimulation of CH_4 emission.

Conclusion

Crop residues offer sustainable and ecologically sound alternatives for meeting the nutrients requirements of crops and improving soil physical, chemical and environmental quality. It enhances microbial activity in the soil and makes the nutrient available to the plant. So, burning of crop residue should be avoided and makes the environment pollution free.

References

1. Beri V, Sidhu BS, Bahl GS, Bhat AK. Nitrogen and phosphorus transformations as affected by crop residue management practices and their influence on crop yield. Soil Use Management 1995;11:51-54.
2. Chandra, Ramesh. Effect of Summer Crops and their Residue Management on Yield of Succeeding Wheat and Soil Properties; Journal of the Indian Society of Soil Science 2011;59(1):37-42.
3. Dobermann A, Witt C. The potential impact of crop intensification on carbon and nitrogen cycling in intensive rice systems. In: Carbon and nitrogen dynamics in flooded soils: 1-25. International Rice Research Institute, Los Baños, Philippines 2000.
4. GoI, Annual Report 2016, Ministry of New and Renewable Energy, New Delhi 2016, (http://mnre.gov.in).http://www.erewise.com/current-affairs/biomass-resources in india_art52cbbb9bcd5df.html#. Vd9atPmqqko
5. Gupta PK, Sahai S, Singh N, Dixit CK, Singh DP, Sharma C *et al*. Residue burning in rice–wheat cropping system: causes and implications. Curr Sci 2004;87:1713-1717
6. Meena JR, Beheraa, Umakant K, Chakraborty, Debasis, Sharma AR. Tillage and residue management effect on soil properties, crop performance and energy relations in greengram under maize-based cropping systems; International Soil and Water Conservation Research, 2015;(3):261-272.
7. MNRE, Ministry of New and Renewable Energy Resources, Government of India, New Delhi, 2009,www.mnre.gov.in/ biomass rsources
8. MOSPI, 2013-14, http://www.mospi.gov.in/announcements/ asi-2013-14-vol-i
9. Pathak H, Bhatia A, Jain N, Aggarwal PK. Greenhouse gas emission and mitigation in Indian agriculture – A review, In ING Bulletins on Regional Assessment of Reactive Nitrogen, Bulletin No. 19 (Ed. Bijay-Singh), SCON-ING, New Delhi 2010, 34.
10. Saroj Devi, Charu Gupta, Shankar Lal Jat, Parmar MS. Crop residue recycling for economic and environmental sustainability: The case of India. Open Agriculture 2017;2:486-494.
11. Sidhu HS, Singh M, Singh Y, Blackwell J, Singh V, Gupta N. Machinery development for crop residue management under direct drilling. In; Resilient food systems for a changing worldpp. Proceeding of the 5th World Congress on Conservation Agriculture. Incorporating 3rd farming systems Design Conference, 25-29th September 2011, Brisbane, Australia 2011, 157-158.
12. Singh KK, Srinivasaro CH, Swaranalakshmi K, Ganeshamurthy AN, Kumar, Narendra. Influence of legume residues management and nitrogen doses on succeeding wheat yield and soil properties in Indo-Gangetic Plains; Journal of Food Legumes 2012;25(2):116-120.
13. Singh Y. Crop residue management for ecological agriculture. Natural Resource Management viz-a-viz climate change 2015, 70-79.
14. Singh Y, Singh BS, Ladha JK, Khind CS, Khera TS, Bueno CS. Effects of residue decomposition on productivity and soil fertility in rice-wheat rotation. Soil

Science Society of American Journal 2004b;68:854-64.
15. Yadvinder-Singh, Manpreet-Singh, Sidhu HS, Khanna PK, Kapoor S, Jain AK *et al*. Options for effective utilization of crop residues. Directorate of Research, Punjab Agricultural University, Ludhiana, India 2010b.
16. Yadvinder-Singh, Gupta RK, Jagmohan-Singh, Gurpreet-Singh, Gobinder-Singh, Ladha JK. Placement effects on rice residue decomposition and nutrient dynamics on two soil types during wheat cropping in rice-wheat system in northwestern India. Nutr cycl Agroecosyst 2010a;88:471-480
17. Yang CH, Kim TK, Ryu JH, Lee SB, Kim S, Baek NH, *et al*. Effect of rice straw application on soil physico-chemical properties; Soil Solutions for a Changing World 13, 19th World Congress of Soil Science, Brisbane, Australia 2010, 1-6.