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Trace Gases Emission from Field Burning of Crop Residues|*

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Introduction

Harvesting a crop generates a huge amount of crop residue. Table 1 that gives data of residue generation for the year 1994 from the major Indian States in the north and west, provides a rough idea of this crop residue. It is seen from this Table that Uttar Pradesh tops the list of the Crop Residue Producing States followed by Punjab, Madhya Pradesh and so on.

A large part of this crop residue is burnt in the open fields since the farmers do not have any worthwhile use of this waste, and the Combine-harvestor leaves a large part of this residue in the field itself in the form of long stems and the roots, and further he is in a hurry to sow the next crop. Crop wise contribution to open burning in India is mainly due to wheat and rice residues, with small contribution from sugarcane, cotton, jute, millets, maize, and rapeseed and mustard crops as shown in Fig. 1. Data for wheat and rice crop residues burning for the various States in the Indian Union has also been collected for the year 2000, and is shown in Fig. 2.

Burning of residues give rise to emissions of aerosols, major gases, and trace gases. Aerosoles are particulates composed of a variety of organic and inorganic species. They play an important role in atmospheric chemistry, boundary layer modification, radiation budget, human health, and crop yield. Major gases emitted are CO and NOx. They are air pollutants that have significant local, regional, and global impact. Trace Gases emitted are CH_4, CO_2 and N_2O. These are Green House Gases (GHG) that are closely linked to global warming and global climate change.

Emission distribution of CO_2 due to open field burning of agriculture residue is approximately 61% for Asia, and 39% for the rest of the world, with India's share in emissions being 18% as shown in Fig. 3.

Major Concerns and Constraints

Both the big Asian countries, India and China, have gone for the Green Revolution. Green revolution has involved expansion in cultivable land area under RWS, inception of high yield varieties of rice and wheat, and mechanization of agriculture. As can be seen from Table 2, this has resulted in increased productivity of rice and wheat crops, increased residue generation, and introduction of mechanized harvesters. It may be seen from this Table that while production has increased enormously under the green revolution, it has also developed its side effects. The side effects are: i) large portion of plants is left in the fields, ii) loose straw separated from grain is left as residue in the field, and iii) about 5 – 7 Tons/Ha rice straw is left unused in the field.

Experiments have been conducted to show that increase in emissions takes place during burning period. Fig.4 and Table 3 amply demonstrate this fact. These measurements of the concentrations of trace and other gases were made at Pantnagar during May 2003. These observations belong to the burning and non-burning periods as also to an event of fire. From these measurements emission factors for the various gases were also studied and are shown as a part of the same diagram as also in Table 3.

Main constraints in Rice - Wheat cropping cycle are the short time available between the harvesting of the rice crop and sowing of the wheat crop, and the possible disposal / use /fate of the residue. As delay in wheat sowing is very sensitive to affecting yield, disposal and/or utilization of the residue needs to be done in the intervening available short time.

The crop residue can be used as industrial / domestic fuel, and fodder, as also in packaging, bedding, wall construction, in-situ incorporation, green manuring, and thatching. However, these uses have not been tapped for commercial purposes, and so the farmer is left with no other option except burning the crop residue in the open field itself. This is a very quick mode of disposal and hardly costs anything to the farmer. However, this exercise ends in wastage of resources and loss in soil nutrition, as also it has many other adverse impacts on human and crop health.

* *Paper presented in the workshop on Agricultural Waste Burning held at PAU, Ludhiana on 29/07/2006*

Table 1 Residue generation from major states in India for 1994 (Gg)

STATES	RICE	WHEAT	TOTAL
Uttar Pradesh	13284	33189	46473
Punjab	9890	20251	30141
Madhya Pradesh	8115	10727	18841
Bihar	8041	6443	14484
Haryana	2810	10928	13738
Maharashtra	3112	1646	4757
Gujarat	1179	2555	3734
Himachal Pradesh	141	829	970
Total (Gg)	**46571**	**86567**	**133138**

Residue Burning in Rice-Wheat Cropping System: Causes and Implications
Prabhat K. Gupta, **Shivraj Sahai**, Nahar Singh, C. K. Dixit, D. P. Singh, C. Sharma, M. K. Tiwari, Raj K. Gupta and S. C. Garg. **Current Science**, Vol. 87, No. 12, 25 December 2004, pp 1713-1717

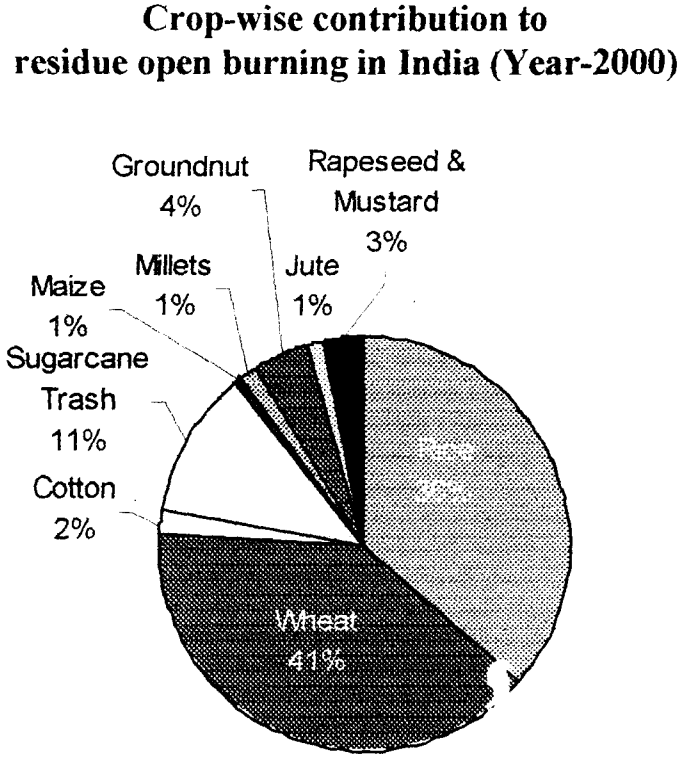
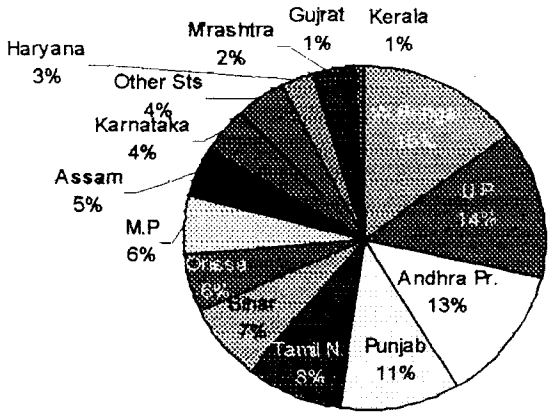


Figure 1



Statewise contribution to Rice field residue burning

Year-2000

Statewise contribution to Wheat residue field burning

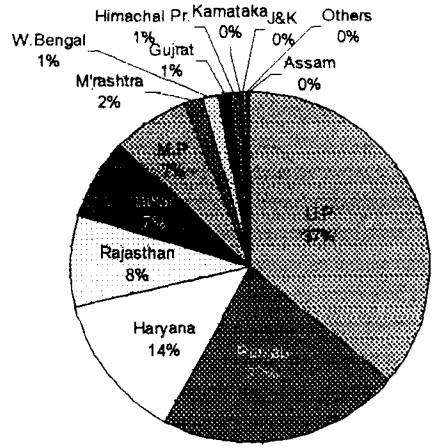


Figure 2

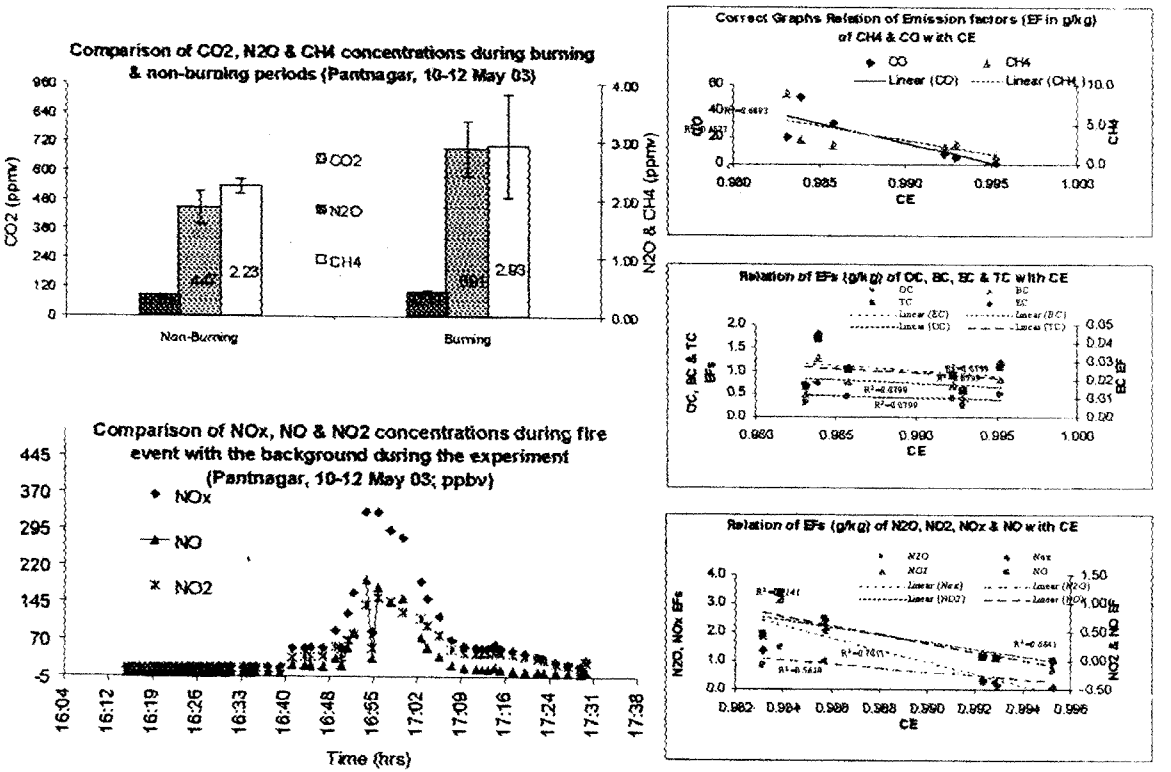

Comparison of CO2, N2O & CH4 concentrations during burning & non-burning periods (Pantnagar, 10-12 May 03)
CO2 (ppmv)
N2O & CH4 (ppmv)
CO2
N2O
CH4
2.23
2.83
Non-Burning
Burning
Comparison of NOx, NO & NO2 concentrations during fire event with the background during the experiment (Pantnagar, 10-12 May 03; ppbv)
NOx
NO
NO2
Time (hrs)
Correct Graphs Relation of Emission factors (EF in g/kg) of CH4 & CO with CE
CO
CH4
Linear (CO)
Linear (CH4)
CE
Relation of EFs (g/kg) of OC, BC, EC & TC with CE
OC
BC
TC
EC
Linear (EC)
Linear (BC)
Linear (OC)
Linear (TC)
OC, BC & TC EFs
BC EF
CE
Relation of EFs (g/kg) of N2O, NO2, NOx & NO with CE
N2O
Nox
NO2
NO
Linear (Nox)
Linear (N2O)
Linear (NO2)
Linear (NO)
N2O, NOx EFs
NO2 & NO EFs
CE

Figure 4

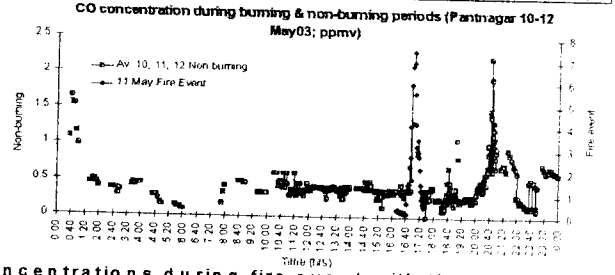
Table 3

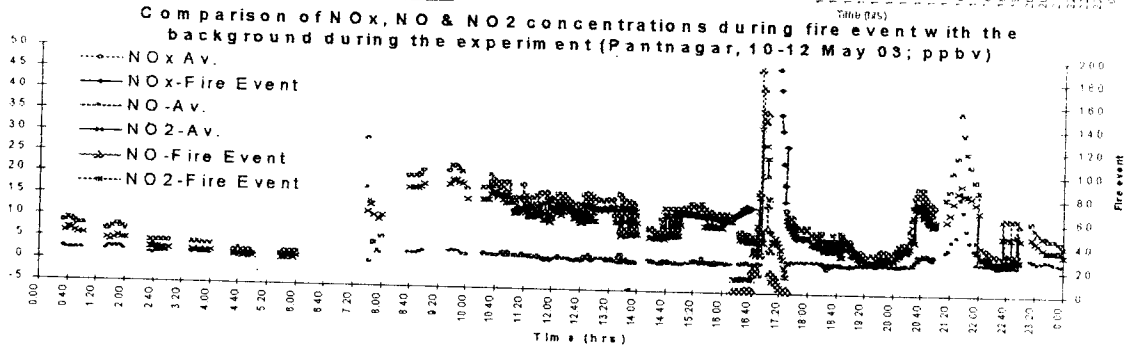
STUDY OF TRACE EMISSIONS FROM FIELD BURNING OF WHEAT RESIDUE (PANTNAGAR)

Emission Factor	g/kg							
Type of Biomass	CH_4	CO_2	CO	N_2O	NO_x	NO	NO_2	Reference
Bagasse (energy Use)					0.68			Kato et al, 1996
Crop Res (as fuel)					1.3			Streets and Waldhoff, 1998
Cr. Res (house stoves)					0.004-2.2			Zang et al., 2000
Agricultural residue	2.7	1515 ± 177	92 ± 84	0.07	2.5 ± 1			And & Merlet
Forest biomass	1 - 10.8	1531-1690	46 - 152			0.4 - 1.1		Ward et al
Wheat Straw	7.37 ± 2.72		155.53 ± 21.75	0.34 ± 0.21				Our Earlier Works at NPL*
Rice Straw	5.52 ± 3.08		82.19 ± 19.57	0.48 ± 0.45				Our Earlier Works at NPL*
Wheat Straw	3.55 ± 2.66	1787.44 ± 35.40	0.81 - 70.2	0.22 - 1.47	0.09 - 5.26	0.01 - 1.58	0.05 - 1.60	Present work

Background values observed during wheat field burning experiment at Pantnagar

Gases	Ambient Concentrations	Units
CO2	375	ppmv
N2O	0.327	ppmv
CH4	1.8	ppmv
CO	0.2	ppmv
NOx	8.21	ppbv
NO	1.2	ppbv
NO2	6.7	ppbv





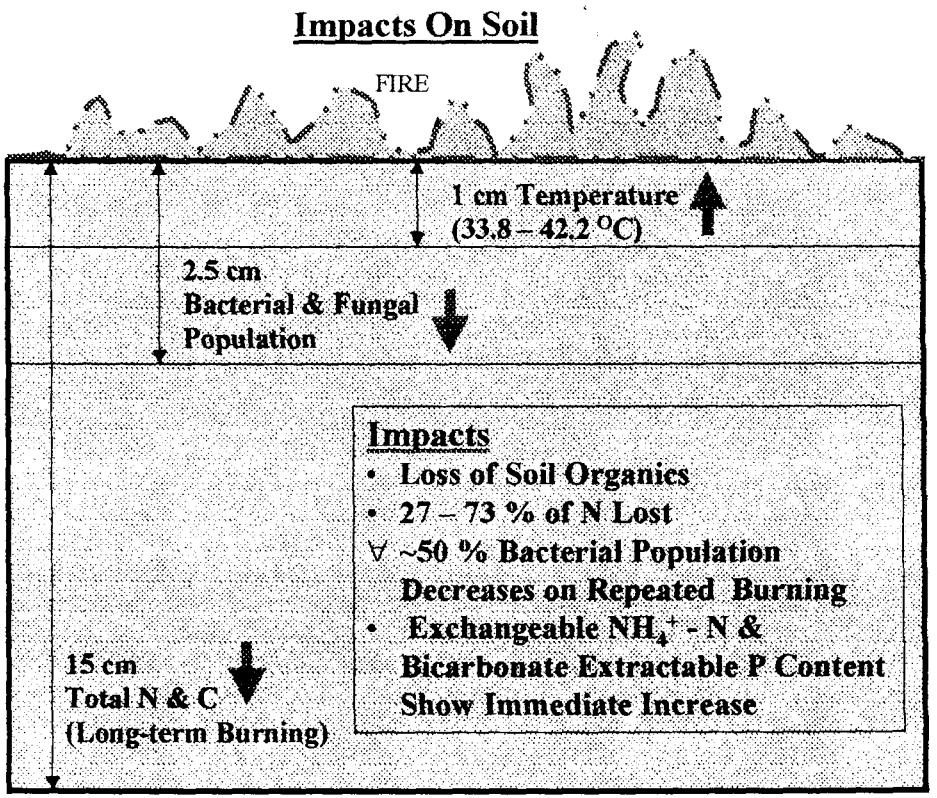

Impacts On Soil
FIRE
1 cm Temperature
(33.8 – 42.2 °C)
2.5 cm
Bacterial & Fungal
Population
Impacts
• Loss of Soil Organics
• 27 – 73 % of N Lost
∀ ~50 % Bacterial Population
Decreases on Repeated Burning
• Exchangeable NH_4^+ - N &
Bicarbonate Extractable P Content
Show Immediate Increase
15 cm
Total N & C
(Long-term Burning)

Figure 5

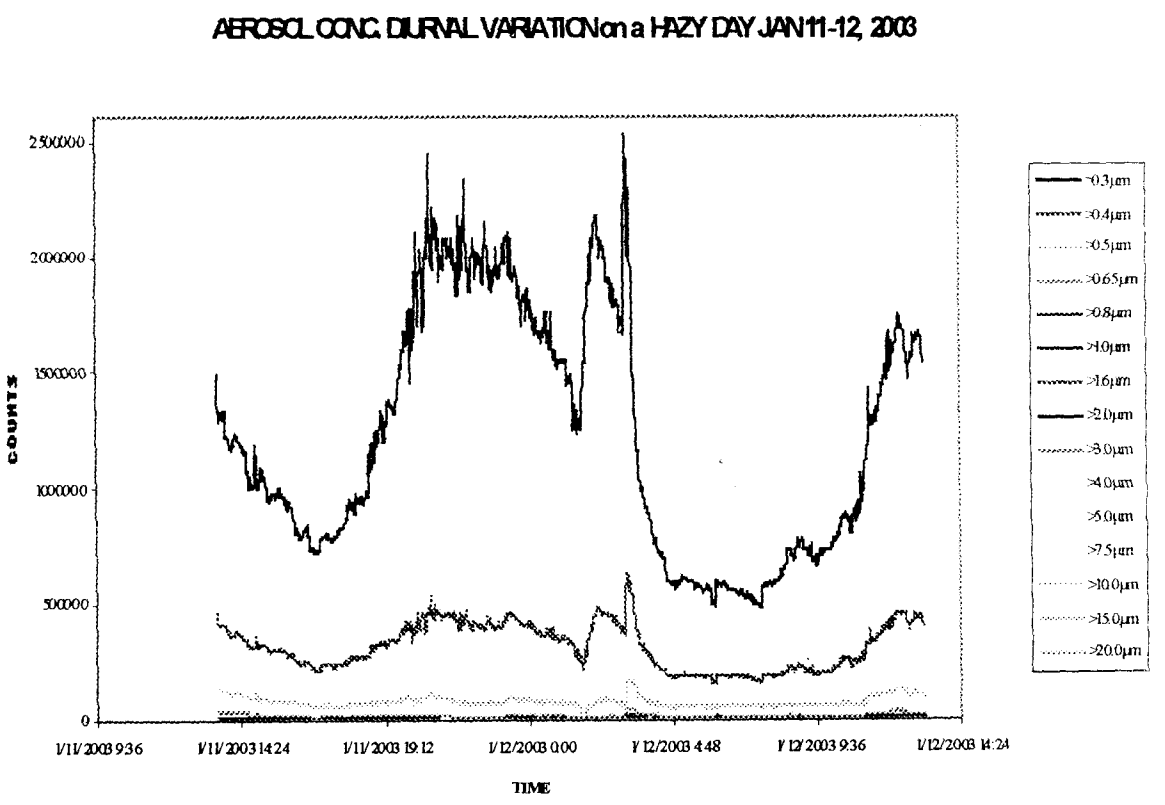
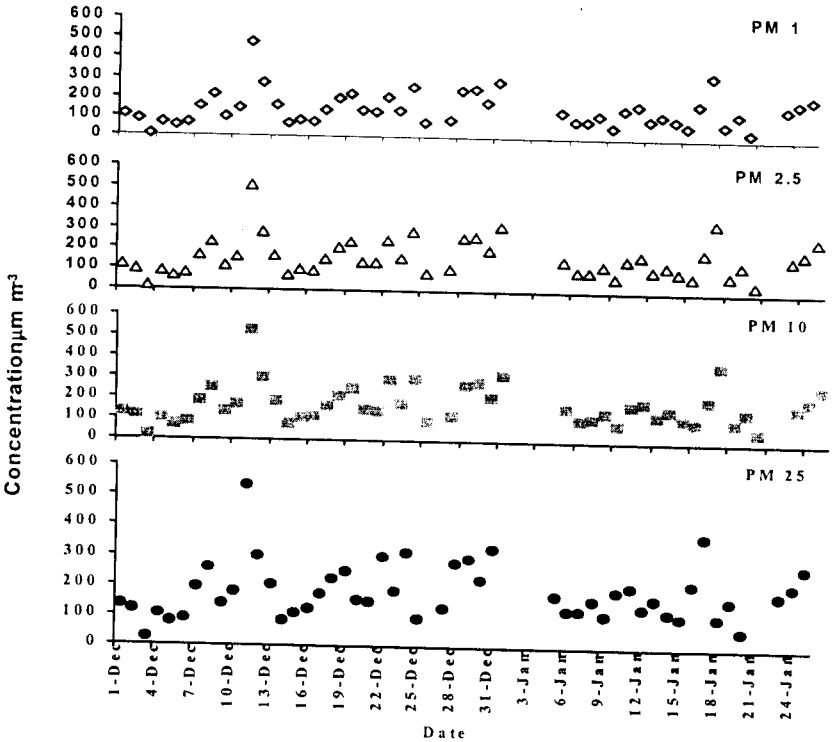

AEROSOL CONC. DIURNAL VARIATION on a HAZY DAY JAN 11-12, 2003
2500000
2000000
1500000
1000000
500000
0
COUNTS
1/11/2003 9:36
1/11/2003 14:24
1/11/2003 19:12
1/12/2003 0:00
1/12/2003 4:48
1/12/2003 9:36
1/12/2003 14:24
TIME
>0.3µm
>0.4µm
>0.5µm
>0.65µm
>0.8µm
>1.0µm
>1.6µm
>2.0µm
>3.0µm
>4.0µm
>5.0µm
>7.5µm
>10.0µm
>15.0µm
>20.0µm

Figure 6



Mass-size variation by QCM

Figure 7

Impact of Burning

Burning of crop residue in the open field results in impacts on soil and the atmospheric boundary layer. These can be described as follows:

Impact on Soil: After burning of the residues in the open field, it loses its organics as also its bacterial and fungal population. About 50% bacterial population decreases on repeated burning. Approximately 27 – 73% of Nitrogen is also lost. It has been estimated that 2.4 kg/Ton of N is lost from wheat residue burning. Out of this 40 – 80% N is lost as NH_3. Further, 40 – 60% of S is also lost from the residue. The soil thus shows immediate increase in the exchangeable NH_4^+ - N and bicarbonate extractable P content as shown in Fig.5.

Influence on Atmospheric Boundary Layer: Burning of the crop residue in the open fields also affects the atmospheric boundary layer. It results in more deep inversions, which is responsible for more accumulation of GHG and particulates (especially fine particulates), and increased RSPM loading. The concentration of the aerosols of different sizes as a function of diurnal variations on a hazy day (11-12 January, 2003) in Delhi can be seen in Fig.6. The abundance of the fine particles in the boundary layer on such a day is clearly seen in this plot. The concentrations of the Mass- Size variations of the fine particles on a number of days during December 2002 and January 2003 at Delhi have also been measured and are shown in Fig.7. It may be seen from this plot that the fine particles of all sizes have more or less the same concentration, and further that the concentration changes from day to day depending upon the conditions in the lower atmosphere and the depth of nocturnal inversion and daytime mixing height (monitored by Radiosonde and Sodar).

Mitigation Options

Residue management and technological modifications are the two available mitigation options. In residue management, residue may be removed for fodder and industries or it may be incorporated in-situ in the field itself. Crop harvesting is done these days with Combine-harvester. Utilization of residue in Combine-harvested RWS is infested with the problem of its collection as it is practically difficult since straw and husk are lying scattered in the field, and their collection and removal from the field is not economically feasible. Under these conditions, the options left are i) In-situ incorporation and ii) Burning in the field. In in-situ incorporation decomposition takes long time that will delay and hamper the sowing of the wheat crop, while the other option to get rid of the residue is easier. Thus to avoid burning in the fields, more technological developments in the harvesting implements / machines are needed so that no delay in the sowing of wheat crop occurs.

Effect on yield due to different residue management practices in rice has been worked out. The yield on residue removal is 5.37 Tons/Ha, on residue burning it is 5.54 Tons/Ha, and on in-situ incorporation it is 5.81 Tons/Ha. These data show that in-situ incorporation is marginally the best practice, if it has no economical and other problems.

FUTURE NEEDS

- **Government Should Monitor & Discourage Burning Through Incentives & Technology Transfer**
- **Proper Policy maker -Researcher-Farmer Interface**
- **Technological Improvements in Implements**
- **Investigate Fast Decomposition of Residue**
- **Provision for Collection of Residue in Combine Harvesters**
- **Reliable Data on RWS Management on Decomposition & Nutrient Release Rates and the Production of Phytotoxic Compounds from Rice & Wheat Residue**
- **Long-term Experiments at Different Sites for Variation in Temperature, Moisture Regimes, Soil Mineralogy & Agriculture Management in RWS**
- **Development of Realistic Computer Simulation Models to Accommodate the Dynamics Involved With RWS**

CONCLUSION

Impacts of Replacement of Traditional Harvesting Practices with Combine Harvesting Technologies

- **Larger Amount of Residues Compared to Traditional Practice**
- **Residue Remains in the Field**
- **Collection & Removal of Residue from Field is not Feasible Resulting in Burning**

Impacts of Residue Burning in RWS

- **Unwanted Emissions Affecting Regional & Global Environments**
- **Loss of Fixed Plant Nutrients**
- **Degradation of Soil Properties**

Requirements

- **Modification in Combine Harvesters**
- **Maximum Collection & Sustainable Utilization of Residue in RWS**