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STUDY OF PHYSICO-CHEMICAL CHARACTERIZATION AND BURNING BEHAVIOUR OF PADDY HUSK

[1]Sobha Vinod, [2]Ajay Patel

[1]Research Scholar, [2]Assistant Professor and Co-guide
[1]Department of Environmental Science,
[1]SRM University, Sonipat, India

Abstract: Paddy waste like straw and stubble is being burnt by the farmers in Haryana due to continuous cropping and high labor costs. This has led to severe air pollution problems in the NCR.

In this study four different varieties of PUSA paddy crop straws are collected and tested from five paddy cultivating districts of Haryana. The four varieties collected of PUSA are characterized physically and chemical analysis of the straw is done to understand the nature of the straw for Nitrogen, Organic carbon content, Phosphorus, and potassium in the straw. Then the straw is burnt in the flame chamber to understand its flame behavior.

This study is done basically to understand the constituency of the paddy straw to estimate the loss happening by the burning of the stubble. Also, the burning behavior of the straw is studied to understand the effect of stubble burning on the air quality and the level of pollution. This study is to make the farmers understand that burning of straw is leading to a great loss of nutrients and also it is affecting the air quality of Haryana and NCR region.

Index Terms - Physico-chemical characters, Organic Carbon content, Flame behaviour, crop residue burning, Kjeldahl's method, Walkley and Black method, Bulk density, Porosity, Mineralizable Nitrogen, Carbon dioxide, Carbon monoxide, Sulphur, Volatile organic compounds.

1.INTRODUCTION

India is a country based on Agrarian Economy. Agriculture is the backbone of our country. Farming has grown tremendously with Green Revolution in the states of Punjab, Haryana, Delhi and Western U.P. and food is now available to most of the population in India. But with hybrid seeds and irrigation facilities being available throughout the year the farmers in this belt of India are cultivating their land all through the year and are not leaving the land uncultivated. This continuous cropping has started practices like –Stubble Burning to clear the land within a day and with no additional labour cost. But it has led to several problems which includes loss of plant nutrients, health problems, death of microbes in the soil, air pollution, global warming, smog and even reported accidents and deaths.

Paddy stubble is rich in nutrients which is being burnt by the farmers of Northern Paddy cultivating states of Punjab, Haryana, and Western U.P. of India, since the labour cost has risen, and it takes about a month or two to remove the stubble. Mechanisation has brought with it the ill effect of leaving behind the crop stubble on the ground which has to be removed either by hand or some machine. To avoid all these problems the farmers of India have resorted to burning of the stubble in the farm. This has led to widescale pollution and health risks to the people in the NCR and in the national capital N. Delhi particularly in the months when the stubble is being burnt. To comprehend paddy stubble content, characteristics, and possible uses or disposal techniques, physico-chemical characterization is crucial. This characterization offers useful data for energy production, composting, recycling, and other applications. In rice straw, corn cob, farmyard manure, and sunflower heads decreasing particle size also decreases pH (Kiran et al., 2021).

The chemical composition of rice husks is 38% cellulose and 18% hemicellulose and 22% lignin, and contains a large amount of silica, which makes it a good basis for biochar production. (Saeed et al., 2021)
Although rice straw has many benefits over other feedstocks in producing biogas, including non-interference with food supply, low price, and relatively high biogas production, direct utilization in anaerobic digestion is limited (Dahadha et al. 2017). Recalcitrant lignocellulosic structure makes rice straw difficult to be broken down by microorganisms. This slows hydrolysis, the first rate-limiting step of the anaerobic digestion process, which subsequently leads to inefficient biogas production. (Alengebawy et al., 2023)

Traditionally, biogas production from rice straw is based on solid-state anaerobic digestion, which is operated at a total solid content of more than 15%. Solid-state anaerobic digestion has various problems, such as inefficient biogas production, hindered mass transfer between lignocellulosic biomass and microbes, process instability, inhibition from intermediate products such as ammonia and volatile fatty acids, and problems in end-product management (Yang et al. 2015).

Moreover, Paddy stubble and husk are difficult to degrade due to its high specific area and porous structure. (Severo et al., 2020a)
Rice straw is characterized by a slow decomposition rate; thus, some farmers avoid rice straw soil incorporation especially in intensive cropping systems with 3 weeks interlude. (Douthwaite et al., 2020)

In terms of total carbon dioxide equivalent (CO_2-eq) per ha converted from CH_4 and N_2O, recent research at IRRI showed that rice straw soil incorporation emitted about 3500 to 4500 kg CO_2-eq ha^{-1} (Rosamanta 2017) which is about 1.5–2.0 times higher than when rice straw was removed.

In the present modern civilization, all along with mechanized agriculture, farmers all over the world in general and states of Punjab and Haryana in India in particular complain that rice straw has become a huge problem for them because they follow mechanized agriculture, have shortage of labour, need fast clearance of their fields for next crop etc. When rice/wheat is harvested by a combine harvester it leaves a significant length of straw on the field. Moreover, both wheat and rice are long-duration crops and with a short period available between rice harvesting and wheat plantation, increasing labour cost and non-availability of any user-friendly and cost-effective technology to make the use of crop residue, burning of stubble seems the easiest and quickest way to get rid of rice straw to the farmers. In the absence of assured returns, farmers find stubble burning an economic way of managing the agro waste. (Verma, 2014)

Extensive stubble burning releases massive toxic air pollutants in the northern states of India (Kulkarni et al. 2020). The onset of winter and retreating monsoon (October to November) with northwest wind causes the spreading of such pollutants in the surrounding areas and degradation of air quality (Cusworth et al. 2018). India's capital Delhi and surrounding region (NCR) is landlocked by the surrounding states, i.e., Haryana and Uttar Pradesh, and the Hindu Kush Himalayan mountainous range bounds the entire region in the north. Such a landscape distribution and northwest wind transport the toxic air pollutants from the crop field of Haryana and Punjab to the NCR. In addition to the pollutants from stubble burning, the use of firecrackers during the festivals in October and November, fossil fuel burning, and industrial emissions degrade the air quality in the NCR (Kulkarni et al. 2020). More than 46 million population in Delhi and NCR experience severe air quality each year during the onset of winter, i.e., October and November (Census 2011). (Das et al., 2023)

Crop residue burning (CRB) contributes to high particulate matter (PM) concentration in ambient air in Delhi and NCR region. High PM2.5 concentration in ambient air poses adverse health effects to public. During CRB period, the mean daily PM2.5 concentrations increased almost four times (193-270 µg/m3) the ambient air quality standard for PM2.5 (60 µg/m3) adopted by India. The study observed increase in respiratory complaints across all age groups (>10-60y) during CRB period. However, the elderly group (>40-60y) reported maximum number of respiratory complaints during CRB. The decline in lung function based on test parameters (FEV1, FVC and PEF) with poor air quality during CRB period was noted in all age groups. The youngest age group (>10-18y) reported the highest reduction in lung function as compared to other age categories (>18-40y and >40-60y) for both male and female groups. The adverse effect of CRB (PM2.5) on lung function was found to be more pronounced in females than males in the youngest age category (>10-18y). We noted at least 10% decline in LFT parameters (FEV1, FVC, PEF) in males and at least 15% decline in female population with every 100 unit (µg/m3) increase in PM2.5 concentration. On-field and off-field stubble management interventions should be encouraged to reduce the health effects in the farmers. (Central Pollution Control Board et al., 2021)

Stubble burning has been reckoned among the major contributors of air pollution especially in South Asia. It is a significant source of gaseous pollutants such as, carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), and methane (CH_4) as well as particulate matters (PM_{10} and $PM_{2.5}$) causing serious damage to human health and the environment. It was reported that the burning of 63 Mt of crop stubble releases 3.4 Mt of CO, 0.1 Mt of NO_x, 91 Mt of CO_2, 0.6 Mt of CH_4 and 1.2 Mt of PM into the atmosphere. The situation is more austere in India due to the intensive rice-wheat rotation system which generates large amount of stubble. It was estimated that about 352 Mt of stubble is generated each year in India out of which 22% and 34% are contributed by wheat and rice stubble respectively. About 84 Mt (23.86%) of the stubble is burnt on-field each year immediately after harvest. The disastrous haze observed over India during the winter season has been linked to stubble burning as it coincides with the burning periods (October-November). During this time, most Indian cities, especially within the National Capital Region (NCR) experience harsh pollution often reaching the severe levels of the air quality index (AQI). (Abdurrahman et al., 2020)

Burning of agricultural crop residue to clear fields is a major contributor to air pollution. When rice farmers in north-western India burn their fields, fine particulate matter (PM2.5) concentrations in Delhi, the highly populated capital city located downwind of burning areas, spike to about 20 times beyond the World Health Organization's threshold for safe air. Living in areas where crop burning is intense—measured using daily satellite imaging data over a 5-month period—is associated with a 3-fold higher risk of acute respiratory infection—one of the leading global causes of lost disability-adjusted life years. Children are particularly susceptible to the health effects of crop burning. (Chakrabarti et al., 2019)
Solutions to eliminate crop burning exist but require further investments. We found that crop-burning abatement would be highly cost-effective and, in northern India, would avert disability-adjusted life years equivalent to US$1.529 billion over a 5-year period. Reducing crop burning would benefit human health.

There is a lack of market demand for the stubble, which attracts the farmers to opt for Kharif crop residue burning to prepare the land for the successive Rabi cropping in November (Singh et al. 2021). Such biomass burning emits particulate matter (PM) and various gaseous compounds as Carbon dioxide (CO2), Carbon monoxide (CO), Sulphur dioxide (SO2), Nitrogen dioxide (NO2), and various volatile organic compounds (VOCs), etc. (Das et al., 2023b)

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2.AbbreviationsandAcronyms

PM=Particulate Matter, CO= Carbon Monoxide, CRB=Crop Residue Burning, U.P.=Uttar Pradesh, VOC=Volatile organic compounds,

II. Objectives

1. Physical characterization of straw obtained from four different varieties of Paddy.
2. Chemical Analysis of paddy straw.
3. Understanding the gas characteristics of burning paddy straw.

III. RESEARCH METHODOLOGY

The methodology section outline the plan and method that how the study is conducted. This includes Universe of the study, sample of the study,Data and Sources of Data, study's variables and analytical framework. The detailsare as follows;

3.1Population and Sample

Haryana has a total area of 4.421 million hectares with a population of 25.3 million. It is situated between 27°39' and 30°35' north latitude and 74°28' and 77°36' east longitude. Haryana is also one of South Asia's most economically developed areas, with its agricultural and manufacturing industries growing steadily since the 1970s. Despite recent industrial expansion, Haryana remains predominantly an agricultural state. Approximately 70% of inhabitants are involved in agriculture. Wheat and rice are the main crops farmed here. Haryana produces all its own food and is the second largest contributor to India's central pool of food grains. Haryana's principal crops are wheat, rice, sugarcane, cotton, oilseeds, pulses, barley, maize, and millet.
Samples of paddy stubble is collected from the 5 districts of Haryana which are based on random sampling technique. The five districts are chosen based on the productivity of Paddy in these districts.

3.2 Data and Sources of Data

For this study primary data has been collected by first doing the survey of farmers in the five districts of Haryana which are rice cultivating districts of Haryana.
The area of research is in the state of Haryana which covers five districts which are major producers of paddy. -

1. Kurukshetra
2. Karnal
3. Kaithal
4. Panipat
5. Sonipat

The paddy straw and stubble is collected from these districts and chemical and physical analysis of this farm waste is done.

3.3 Theoretical framework

In order to characterize paddy stubble physico-chemically, the following are the essential stages and variables:
1. Sample Collection- Samples of paddy stubble is collected from the 5 districts of Haryana which are based on random sampling technique. The five districts are chosen based on the productivity of Paddy in these districts.
2. Sample Preparation for testing-
Sample is grounded and homogenized for ensuring consistency in analysis.
The stubble collected was checked first for the sample weight. Then it was put through oven to get the actual weight of the stubble.
3. Physical Properties testing-
The size range of particles contained in the trash can be understood by analysing the particle size distribution using methods such as sifting or laser diffraction.
Bulk Density: The bulk density is determined of the waste material to evaluate its packing properties. Bulk density was calculated by weighing the material and using the formula of (Grossman and Reinsch, 2002) as

$$\text{Bulk Density kg/m3} = \frac{\text{Dry weight of mix}}{\text{Volume of mix}}$$

Porosity is computed, a property that represents the volume of vacant spaces present in the material. Porosity is calculated by taking 10ml stubble powder in water about 15 ml and leaving it for 24hrs. in water. Then finding the difference in water from the initial amount taken.
pH is measured by taking 10gm sample in 20ml water which is shaken well in shaker for 2 hours. Then pH is measured using pH meter. The pH of the stubble is tested using Litmus paper or indicator solution to understand whether the stubble is acidic or basic as it helps to put the stubble into proper usage.
Moisture content of the sample is tested by oven drying at a specific temperature until a constant weight is achieved. This gives the dry weight of the sample.

The colour and odour are tested by observation of the paddy stubble as it determines its reuse and recycling potential. This is important if it is used for manufacturing of plates, cutlery, bags, or fabrics.

Chemical Analysis of Stubble

The elemental analysis of stubble is done to determine elemental composition which includes -Carbon content, Nitrogen, Phosphorus and Potassium content.

1. Determination of Organic Carbon and Organic matter in the sample-

1 N solution of $K_2Cr_2O_7$ is made as 49.035gm of $K_2Cr_2O_7$ is dissolved in distilled water to make up 1 litre. Then 140gm of Ferrous Ammonium Sulphate (FAS) is dissolved in 0.5N H_2SO_4 and made up to 1 litre.

1gm air dried sample of stubble is passed through 425-micron sieve and the sieved component is collected in 500ml conical flask. 10ml potassium dichromate(1N) is added along with 20ml sulphuric acid which is then allowed to stand for 30minutes. Then 200ml distilled water is added and it is cooled at room temperature. 0.5 Ferrous Ammonium Sulphate is titrated until colour changes from blue to green.

Calculations-

a) Organic Carbon (%) = 0.03xNx10x(1-S/B)

N=Normality of sample

B=Blank burette reading

S=Sample burette reading

b) Organic matter (%) =1.72x Organic Carbon

2. Determination of Potassium in the given sample-

1 gm of air-dried sample is taken in a conical flask. To this sample 100ml of 40% Ethyl Alcohol is added. After shaking it well 10 minutes waiting time is given. The sample is then filtered through filter paper (Whatman no.50). Wash the sample residue on the filter paper with absolute ethyl alcohol. Transfer the residue to beaker and add 100ml of ammonium acetate solution. Stir it and allow standing overnight. Filter the supernatant through filter paper and collect the filtrate. The total volume of sample extract is noted.

Potassium(mg/l) = A x V/W x 10000

Where, A= Potassium content of sample extract(mg/l)

V= Total volume of sample extract(ml)

W= Weight of air-dry sample/sediment taken for extraction

3. Determination of Mineralizable Nitrogen (Available nitrogen) by Kjeldahl's method

1gm sample is collected and digested in Kjeldahl flask with 0.5gm copper sulphate and 7gm potassium sulphate till colourless. Measure 20ml of 2% boric acid containing mixed indicator in 250ml conical flask and it is placed under receiver tube. The receiver tube is dipped in boric acid. The tap water is run through the condenser. Add 100ml of 2.5% NaOH solution and immediately attach to rubber stopper fitted in alkali trap. Switch the heaters on and continue distillation until about 100ml of distillate is collected. First remove conical flask containing distillate and then switch off the heater to avoid back suction. Titrate distillate against 0.02M H2SO4 taken in burette until pink colour starts appearing. Run a blank without sample. Carefully remove Kjeldahl flask after cooling and drain contents in sink.

$$\text{Available Nitrogen Content (mg/kg)} = \frac{(A-B) \times N \times 14 \times 1000}{\text{Wt. of sample}}$$

Were,

A = Volume of 0.02M H_2SO_4 used in titration against absorbed in boric acid.

B = Volume of 0.02M Sulphuric acid used in blank titration

1ml of 0.02 H_2SO_4 = 0.56mg N (1000 ml of 1M H_2SO_4 = 14g Nitrogen)

4. Determination of Phosphorus (Titrimetric Method)

5 gm of oven dried sample is taken in a silica crucible. It is heated on a Bunsen burner at a low flame until the substance is charred. Extract the ash with hot HNO3, filter and wash. Make the volume to 100ml.Take 50ml of the molybdate solution,10ml of Conc.HNO3 in two tubes. Add HNO3 first and then add molybdate solution. Stir the mixture gently and allow to stand overnight. Collect the canary yellow Ammonium phosphomolybdate by filtration over Whatman No.40 or 42 filter paper. Wash the precipitate first by decantation and twice with 2% HNO3 and then with KNO3 solution. Wash until the precipitate is acid free and test with a strip of blue litmus paper. Transfer the precipitate along with the filter paper to the original beaker and dissolve the yellow precipitate in measured volume of 0.1N NaOH solution, added in excess from a burette. Use the phenolphthalein as indicator and titrate the excess of NaOH with 0.1N HCl.

Calculations-

The conversion factors are-

1ml of 0.1N NaOH = 0.0001351g P.

= 0.000309g P2O5

The Di phosphorus pentoxide content expressed as a percentage by mass, is equal to

$$\frac{141,95}{4\,425,84} \times m_1 \times \frac{V_1}{V_0} \times \frac{100}{m_0} = 3,207 \times \frac{V_1}{V_0} \times \frac{m_1}{m_0}$$

Where,

M0 is the mass, in grams, of the test potion.

M1 is the mass, in grams, of the precipitate.

V0 is the volume, in millilitres, of the aliquot portion taken from the extraction solution,

V1 is the volume, in millilitres, of the extraction solution.

141,95 is the relative molecular mass of Di phosphorus pentoxide.

4 425,84 is twice the relative molecular mass of quinoline phosphomolybdate.

5.Testing the burning behaviour of stubble

Burning behaviour of these samples are checked by burning the stubble in the flue Gas analyser. For performing the flue gas analysis, a probe is inserted into the flue of the furnace between the draft diverter and the heat exchanger. An electrochemical probe is used to do this analysis.

Equations

Eq.1 Bulk Density kg/m3 = $\frac{\text{Dry weight of mix}}{\text{Volume of mix}}$

Eq.2 Organic Carbon (%) = 0.03xNx10x(1-S/B)

N=Normality of sample

B=Blank burette reading

S=Sample burette reading

Eq.3 Organic matter (%) =1.72x Organic Carbon

Eq.4 Potassium(mg/l) = A x V/W x 10000

Where, A= Potassium content of sample extract(mg/l)

V= Total volume of sample extract(ml)

W= Weight of air-dry sample/sediment taken for extraction

Eq.5 Available Nitrogen Content (mg/kg) = $\frac{(A-B) \times N \times 14 \times 1000}{\text{Wt. of sample}}$

Were,

A = Volume of 0.02M H_2SO_4 used in titration against absorbed in boric acid.

B = Volume of 0.02M Sulphuric acid used in blank titration

1ml of 0.02 H_2SO_4 = 0.56mg N (1000 ml of 1M H_2SO_4 = 14g Nitrogen)

Eq.6 1ml of 0.1N NaOH = 0.0001351g P.

= 0.000309g P2O5

The Di phosphorus pentoxide content expressed as a percentage by mass, is equal to

$$\frac{141,95}{4\,425,84} \times m_1 \times \frac{V_1}{V_0} \times \frac{100}{m_0} = 3,207 \times \frac{V_1}{V_0} \times \frac{m_1}{m_0}$$

Were,

M0 is the mass, in grams, of the test potion.

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141,95 is the relative molecular mass of Di phosphorus pentoxide.

4 425,84 is twice the relative molecular mass of quinoline phosphomolybdate.

IV. RESULTS AND DISCUSSION

4.1 Results of Descriptive Statics of Study Variables

Table 1.Descriptive Statistics of Chemical Analysis of 4 Paddy varieties

Organic Carbon (% by mass)		Nitrogen (% by mass)		Potassium (% by mass)		Phosphorus (% by mass)	
Mean	0.19375	Mean	0.00505	Mean	0.019275	Mean	0.0022
Median	0.188	Median	0.00495	Median	0.021	Median	0.0022
Standard Deviation	0.026762847	Standard Deviation	0.000387298	Standard Deviation	0.005116232	Standard Deviation	0.000182574
Range	0.063	Range	0.0009	Range	0.0109	Range	0.0004
Minimum	0.168	Minimum	0.0047	Minimum	0.0121	Minimum	0.002
Maximum	0.231	Maximum	0.0056	Maximum	0.023	Maximum	0.0024

Table 2.Descriptive Statistics of Physical Analysis of 4 paddy varieties

Porosity of Stubble (%)		pH Level		Moisture Content (%)		Bulk Density of Stubble (kg/m3)		Grain Size (mm)	
Mean	0.47505	Mean	7.11	Mean	0.11725	Mean	359	Mean	7.725
Median	0.48255	Median	7.095	Median	0.118	Median	356	Median	8.05
Standard Deviation	0.016872166	Standard Deviation	0.373720038	Standard Deviation	0.005188127	Standard Deviation	10.89342309	Standard Deviation	0.747373
Range	0.0351	Range	0.89	Range	0.011	Range	24	Range	1.58
Minimum	0.45	Minimum	6.68	Minimum	0.111	Minimum	350	Minimum	6.61
Maximum	0.4851	Maximum	7.57	Maximum	0.122	Maximum	374	Maximum	8.19

Table 3. Descriptive Statistics of Flame Analysis of 4 varieties

Particulate Matter (mg/n3)		Sulphur Dioxide (ppm)		Nitrogen Dioxide (ppm)		Carbon Dioxide (ppm)		Carbon Monoxide (ppm)		Hydrocarbon (ppm)	
Mean	144.25	Mean	16.75	Mean	543.75	Mean	1069.75	Mean	65.5	Mean	1696

Median	142.5	Median	18	Median	579	Median	1059.5	Median	63	Median	1750
Standard Deviation	6.396613687	Standard Deviation	9.53502316	Standard Deviation	206.6194166	Standard Deviation	46.58594209	Standard Deviation	55.56078	Standard Deviation	148.9876952
Range	14	Range	23	Range	415	Range	110	Range	114	Range	316
Minimum	139	Minimum	4	Minimum	301	Minimum	1025	Minimum	11	Minimum	1484
Maximum	153	Maximum	27	Maximum	716	Maximum	1135	Maximum	125	Maximum	1800

Table 1. Descriptive Statistics
The table presents descriptive statistics for organic carbon, nitrogen, potassium, and phosphorus content. The organic carbon content averages 0.194% with a standard variation of 0.027%. Nitrogen has the lowest average (0.005%) and standard deviation (0.0004%) among the four elements.
Table 2.Descriptive Statistics
The table provides the descriptive data for several stubble characteristics. On average, stubble has 0.4750% porosity and a bulk density of 359 kg/m3. The standard deviation demonstrates that each property varies. For example, grain size might vary by as much as 0.75 mm. The pH fluctuates between mildly acidic (6.68) and slightly basic (7.57).

Table 3.Descriptive Statistics
The table contains descriptive statistics for air contaminants. The average quantity of particulate matter is around 144.25 mg/n3, whereas the concentration of hydrocarbons is around 1696 ppm. The standard deviation figures show that each pollutant's concentration varies.

Result Discussion

The potential uses of paddy stubble, such as composting, bioenergy production, or nutrient recycling in agriculture can be known and to ensure safe and sustainable disposal practices when needed, performing a thorough physico-chemical characterization of the stubble is necessary.
Based on physical characteristics we can conclude that all of four varieties have relatively comparable characteristics.
pH value is not varying much as pH varies between mildly acidic to slightly basic nature.
Based on chemical characterization we can conclude that the nutrient content varies in each variety. Organic carbon content is highest in Basmati rice, while nitrogen content is highest in Pusa 1718, Pusa 1121 has highest level of potassium and Basmati has highest level of Phosphorus content.
Hence burning of stubble is not preferable by any means as it will result in the loss of nutrients present in the stubble. The physical characteristic of the stubble is useful to put the stubble to some other use like utilization for removal of heavy metals, biochar production, making bricks etc.
The burning behaviour of the stubble indicates that burning of the stubble of each variety of paddy is harmful as hazardous gases like carbon dioxide, carbon monoxide, nitrogen dioxide, sulphur dioxide along with particulate matter are being released by burning of stubble.Each pollutants concentration is varying indicating that pollution is caused which is hazardous for all organisms.

Figures and Tables

Table 4 : Physical Composition

Paddy variety	Moisture content (%)	Grain Size(mm)	Bulk density of stubble (kg/m3)	Porosity of stubble (%)	pH
1121	11.5	8.0	374	48.51	6.68
1718	12.1	8.1	350	48	7.2
1509	11.1	8.19	352	48.51	7.57
Traditional Basmati	12.2	t6.61	360	45	6.99

Table 5 : Chemical Composition

S. No.	Chemical Characterization (% by mass)	Test Method	Paddy Variety			
			1121 Var	**1718 Var**	**1509 Var**	**Basmati**
1	Organic Carbon	Walkley Black method	16.8	19.2	18.4	23.1
2	Nitrogen	Kjeldahl's method	0.47	0.56	0.49	0.5
3	Potassium	Flame photometry	2.3	1.91	1.21	2.29
4	Phosphorus	Atomic Absorption Spectroscopy	0.21	0.23	0.2	0.24

S. No.	Parameter	1121 Var	1718 Var	1509 Var	Basmati	Method
1	Particulate Matter(mg/Nm3)	139	153	148	139	Flue Gas Analyzer
2	Sulphur Dioxide(ppm)	28.4	24	23.8	17	Flue Gas Analyzer
3	Nitrogen dioxide(ppm)	298.7	715	410	443	Flue Gas Analyzer
4	Carbon dioxide(ppm)	1076	1064	1085	1025	Flue Gas Analyzer
5	Carbon monoxide(ppm)	27	125	25	100	Flue Gas Analyzer
6	Hydrocarbon(ppm)	1800	1484	1740	1700	Flue Gas Analyzer

Table 6.Burning behavior of paddy straw

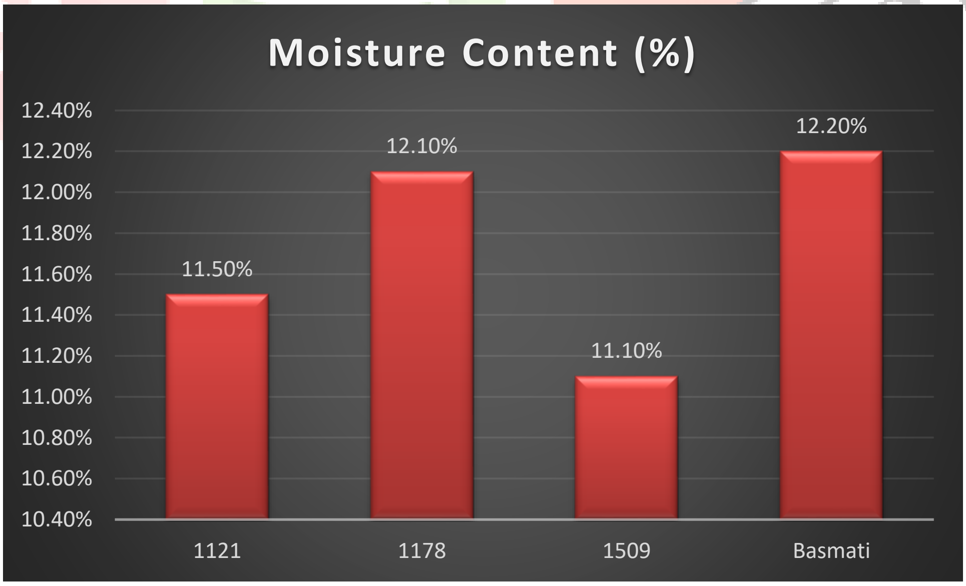

Figure 1 : Moisture Content

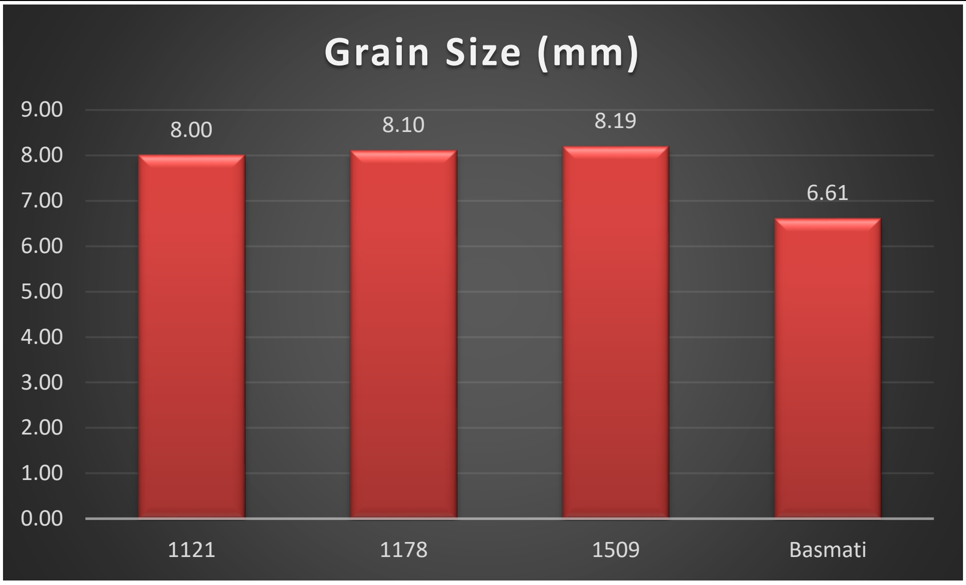

Figure 2 : Grain Size

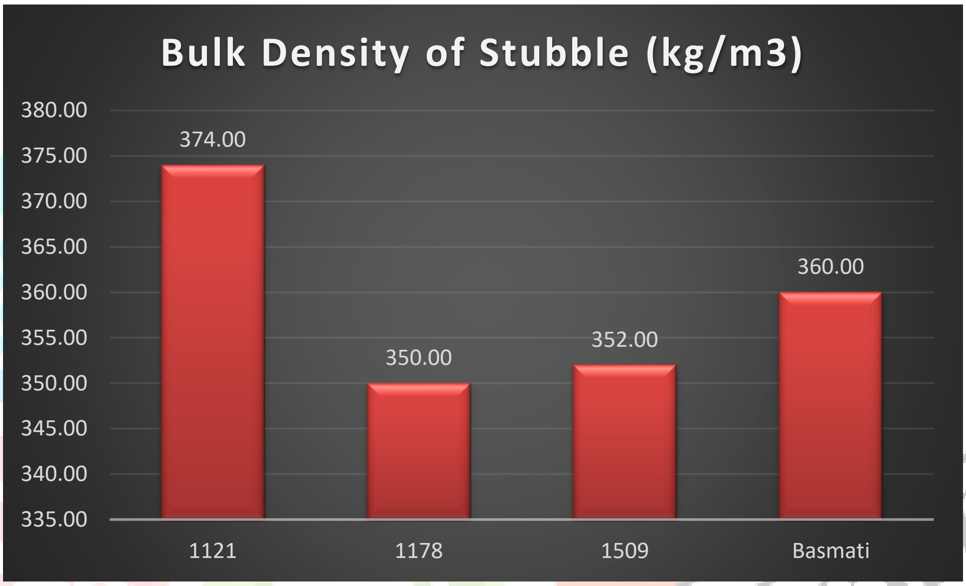

Figure 3 : Bulk Density of Stubble

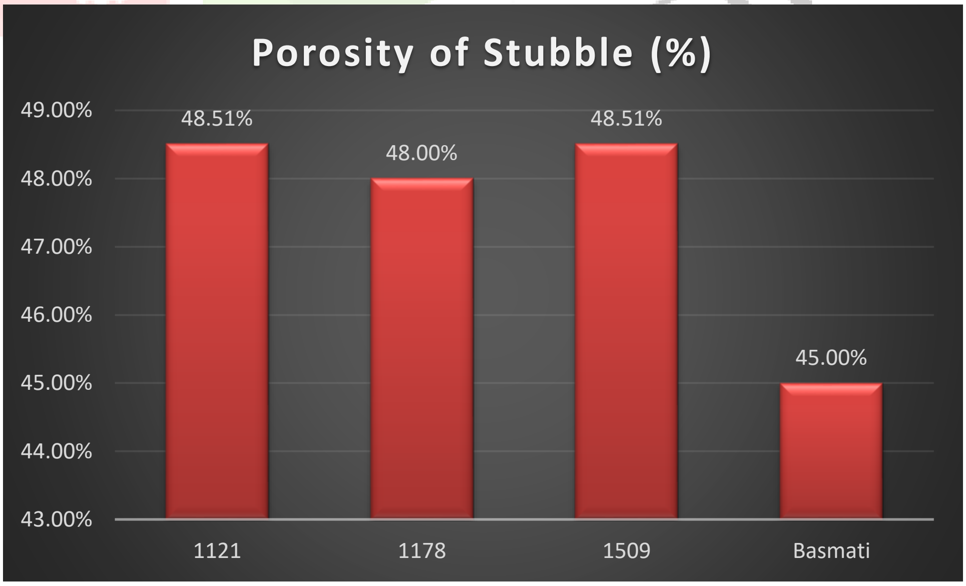

Figure 4 : Porosity of Stubble

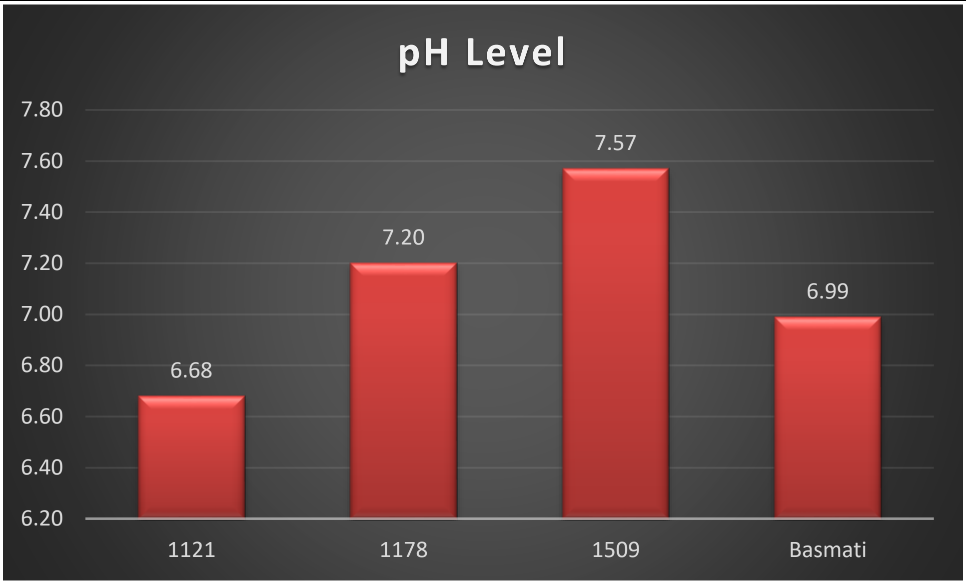

Figure 5 : pH Level

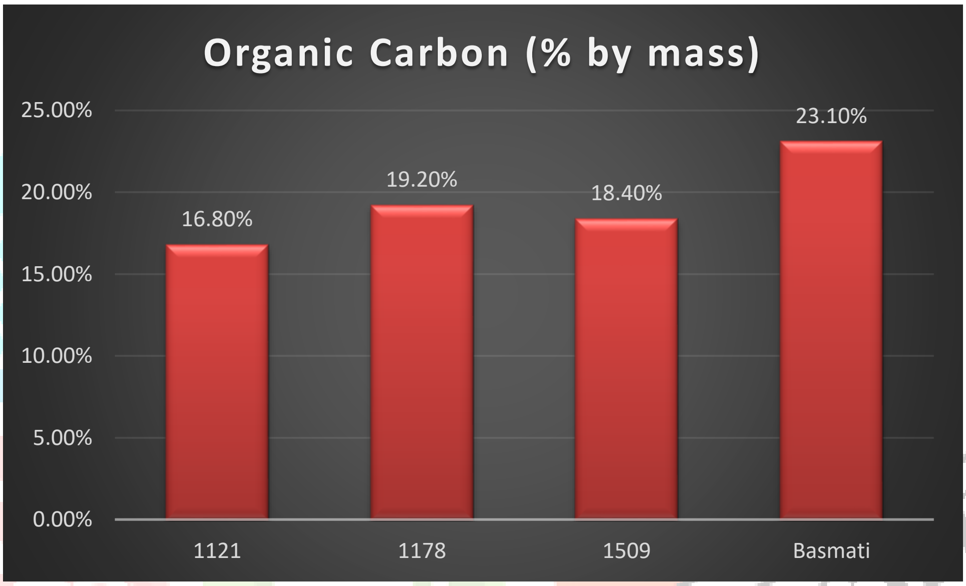

Figure 6 : Organic Carbon

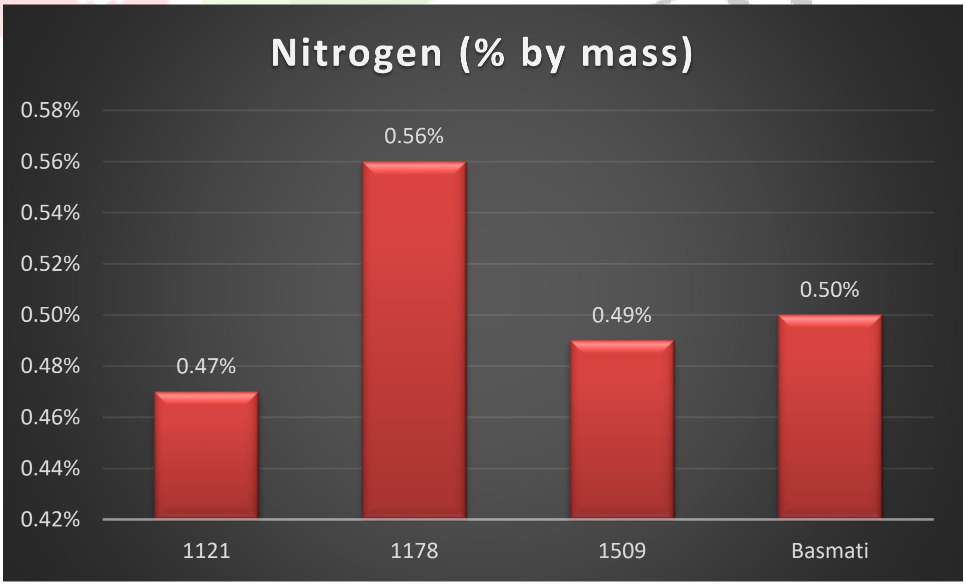

Figure 7 : Nitrogen

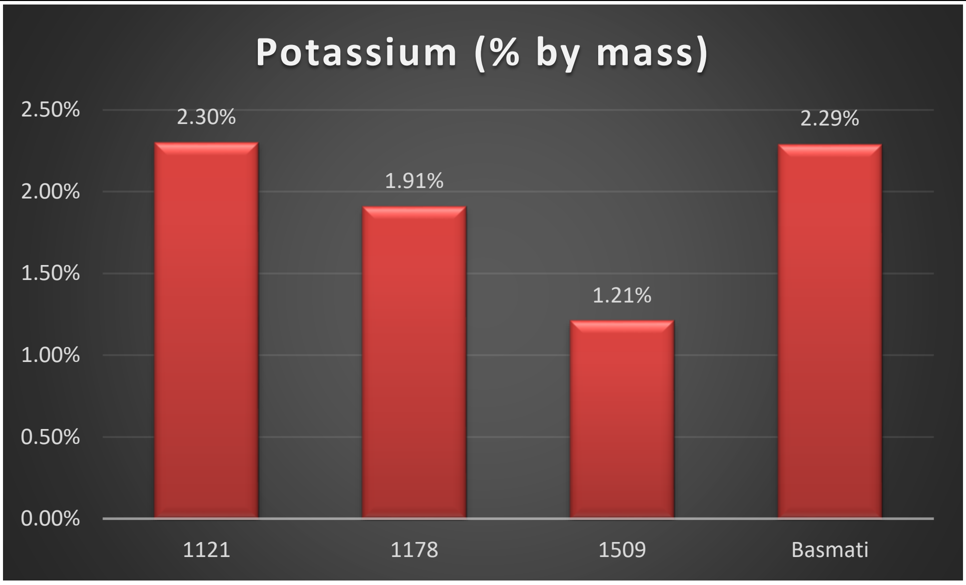

Figure 8 : Potassium

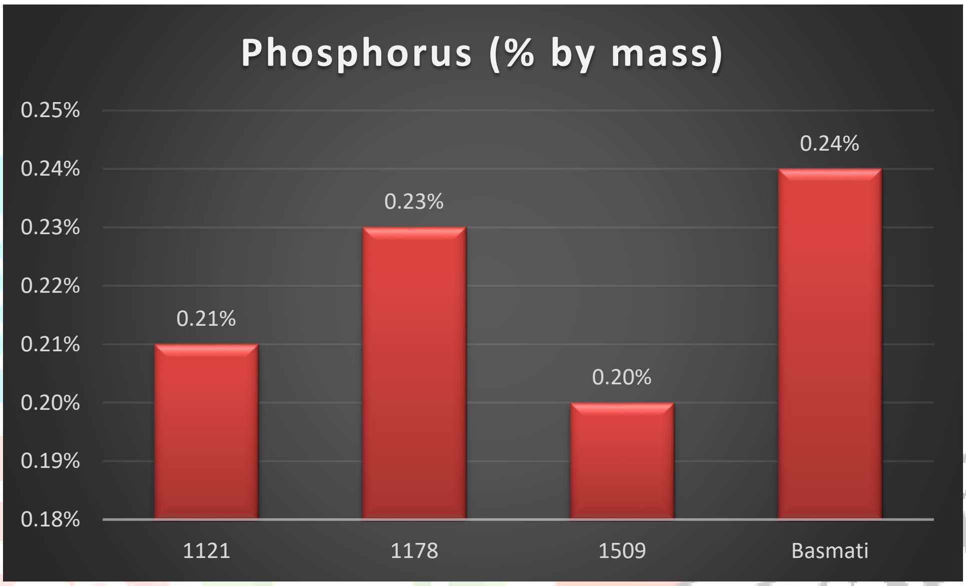

Figure 9 : Phosphorus

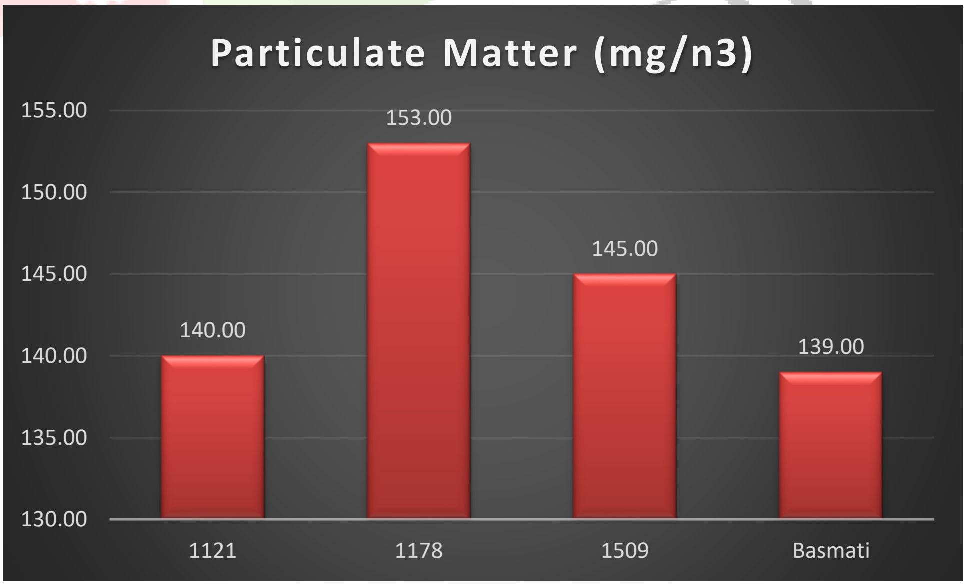

Figure 10 : Particulate Matter

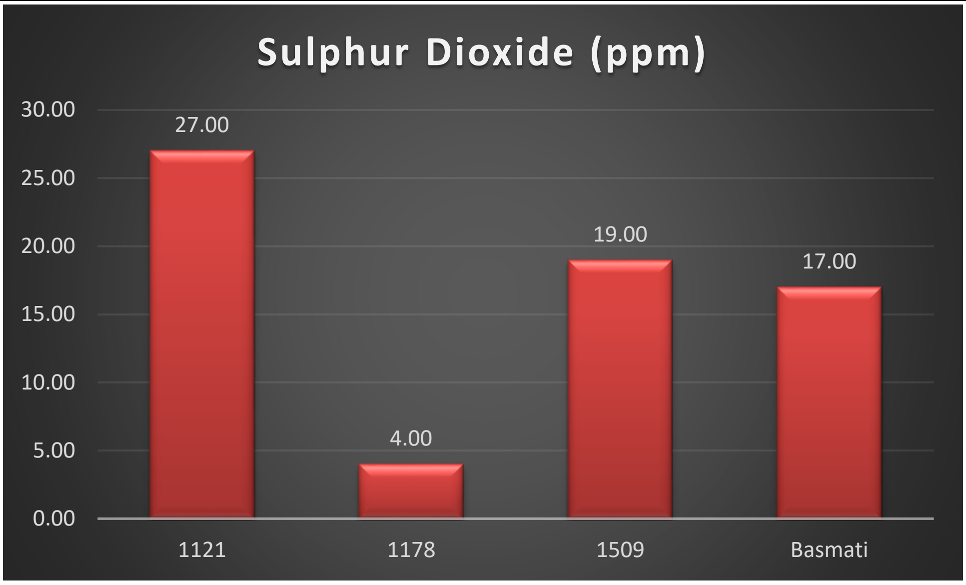

Figure 11 : Sulphur Dioxide

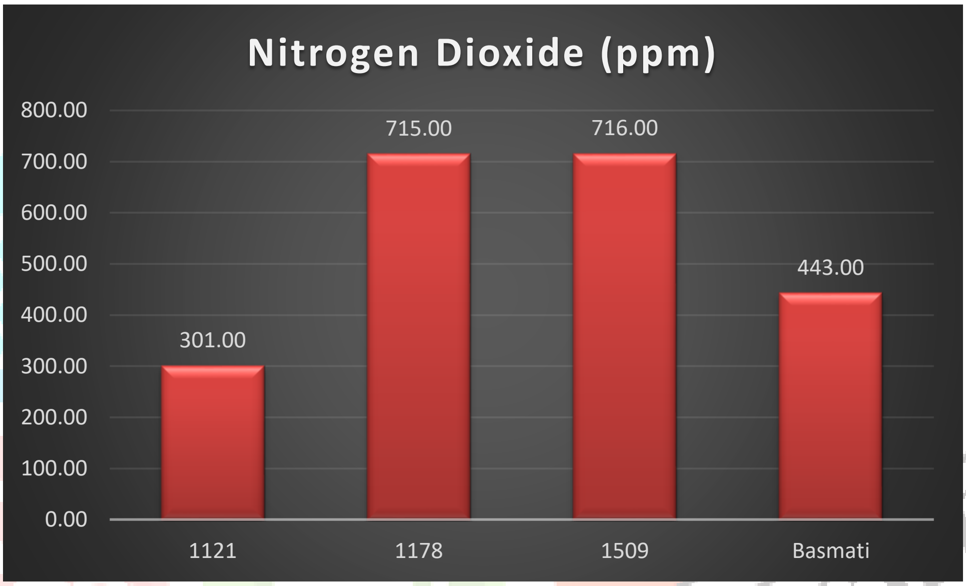

Figure 12 : Nitrogen Dioxide

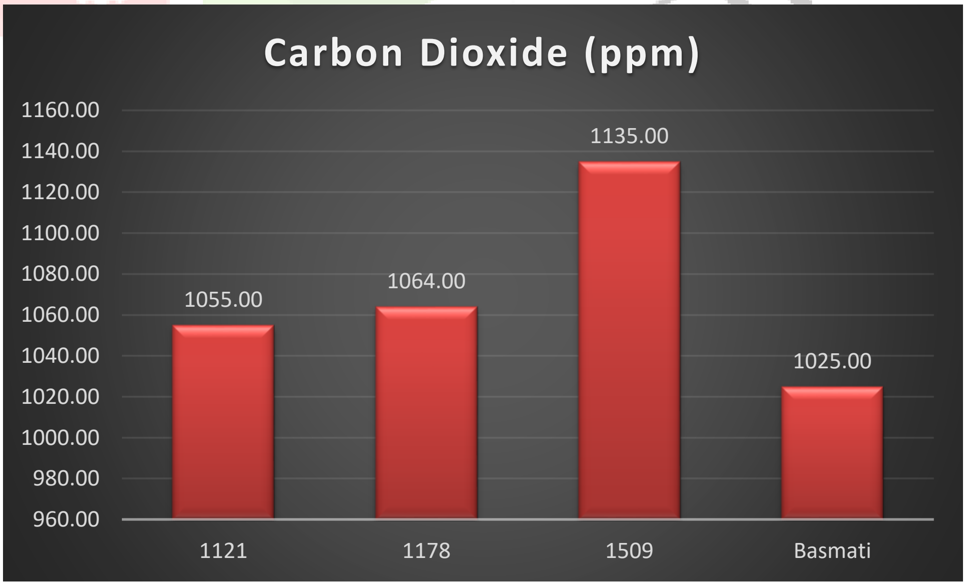

Figure 13 : Carbon Dioxide

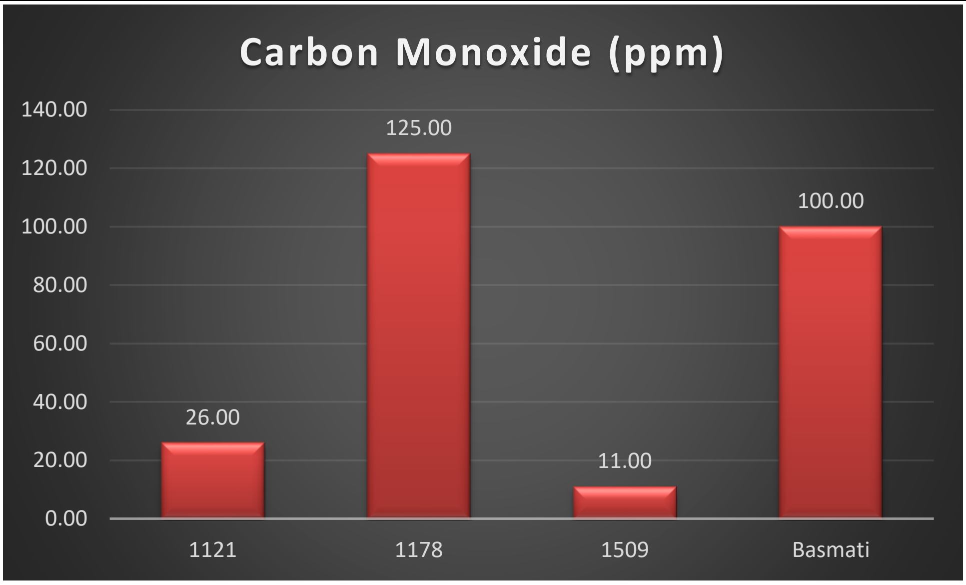

Figure 14 : Carbon Monoxide

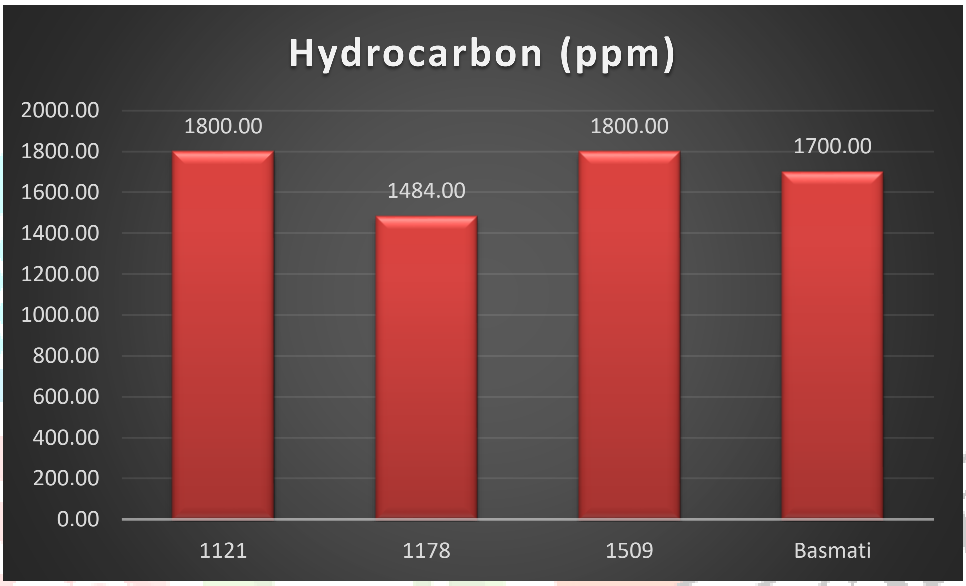

Figure 15 : Hydrocarbon

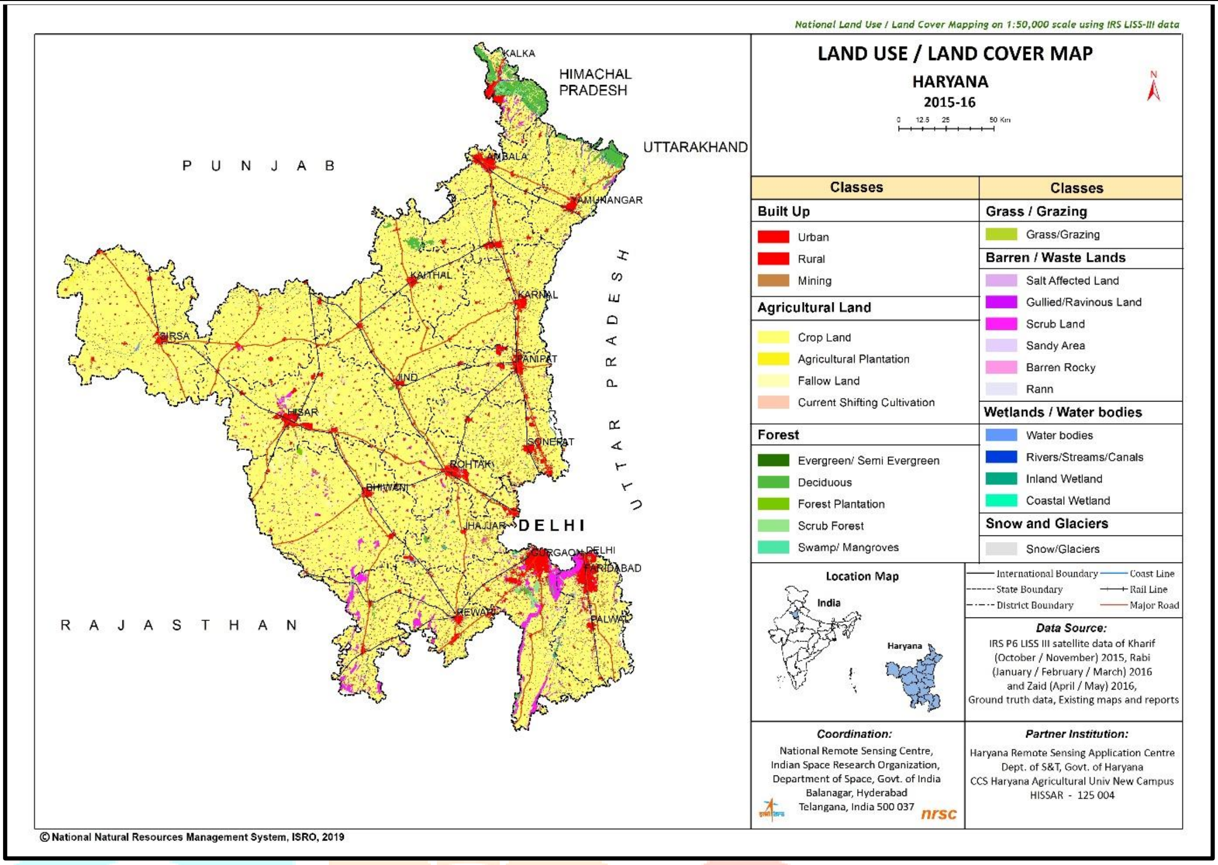

Figure 16.Land Use Land Cover Map of Haryana

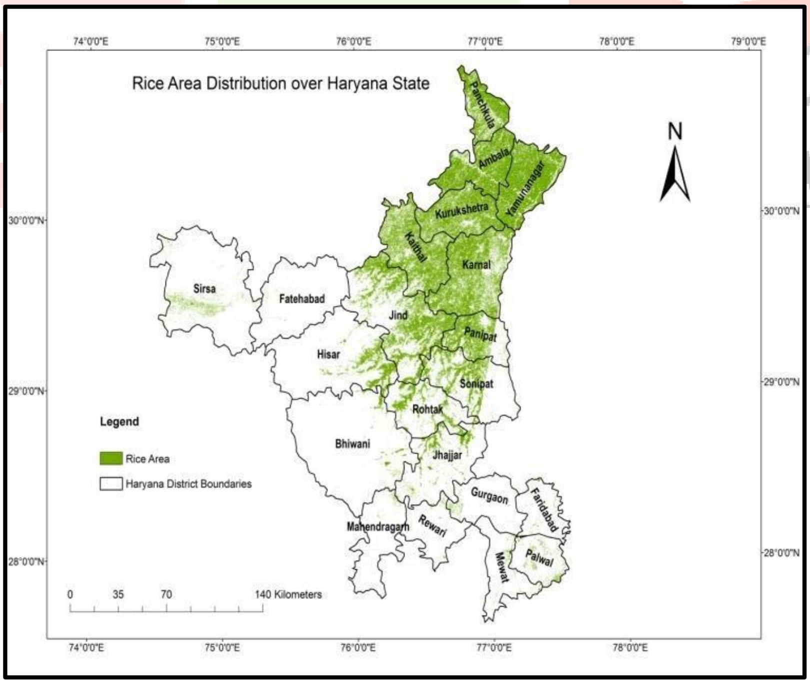

Figure 17.Rice Area Distribution over Haryana State

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