Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2020; SP6: 245-250

Mandeep Kumar
Department of Genetics and Plant Breeding, Lovely Professional University, Jalandhar, Punjab, India

J Pranay Reddy
Ph.D Scholar, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

Sitaram Kumawat
Assistant Manager, Research and Development, Anheuser Busch Inbev, Jaipur, India

Reshu Bansal
Partnership Development Manager, Anheuser Busch Inbev, Jaipur, India

Davinder Pal Singh Badwal
Department of Agricultural Sciences, Sant Baba Bhag Singh University, Khiala, Jalandhar, Punjab, India

Correspondence
Davinder Pal Singh Badwal
Department of Agricultural Sciences, Sant Baba Bhag Singh University, Khiala, Jalandhar, Punjab, India

International Web-Conference
On
New Trends in Agriculture, Environmental & Biological Sciences for Inclusive Development
(21-22 June, 2020)

Impact of stubble burning in Punjab - A review

Mandeep Kumar, J Pranay Reddy, Sitaram Kumawat, Reshu Bansal and Davinder Pal Singh Badwal

Abstract
One of the major problems faced by our environment is crop residue burning, also known as stubble burning. Due to wide availability of modern tools and technologies for harvesting, a vast amount of residue is generated in the fields. The common practice to get the fields free from such residue is stubble burning. Such practices pose a wide variety of environmental problems. Residue burning emits carbon sinks in air causing pollution which is harmful for human-beings as well as flora and fauna. This study brings the problem of agriculture waste burning was 35 million tonnes in forefront. So, there is an immediate need to monitor such stubble burns so that effective measures could be taken to protect our environment from such a global menace. Burning of paddy straw results in nutrient losses, 385 million tonnes of organic carbon, 59000 tonnes of nitrogen, 20000 tonnes of phosphorous, 34000 tonnes of potassium. It also influences the nutrient condition of soil. The paddy stubble burn also has adverse effect on health also, so crop stubble management is necessary. Manual detection is not enough to monitor such widely spread problem. The efficient approach to detect stubble burned areas in various parts of Punjab using remotely sensed images and present government schemes is presented which could be utilized to prevent the large scale environmental degradation.

Keywords: fires, stubble burning, remote sensing, digital image processing, paddy and environment

Introduction
Agriculture is the primary activity of production which acts as a supporting service for both secondary and tertiary activities. A lot of crops are grown every year in Punjab with rice and wheat as the major crops. In Punjab, rice is generally sown in May-August and harvested during the period of September-November. Wheat is sown in October-November and harvested in April-May. On harvesting, along with the desired crop so produced, a lot of residue is also generated which may be termed as stubble. And as very little time is available between harvesting of rice and sowing season of wheat and vice-versa, so farmers often choose the easy way out to get rid of the residue generated along with harvested crop is burning it in the fields itself. Hence, this practice is termed as stubble burning. Earlier when the harvesting was done manually, stubble so generated was less in amount and could be managed by the farmers. But now with the advent of mechanized harvesting, a large amount of stubble is generated which is difficult to handle.

Causes of burning stubble in the field as explained by farmers
Paddy straw burning is currently practiced on a large scale in Punjab to clear the fields for Rabi Crop sowing i.e. mainly wheat and potato, because the time window available between the harvesting of the paddy crop (20 September to 15 November, depending upon the varieties of paddy) and the sowing of next crop is very short (2-3 weeks). Large scale burning takes place in areas where farmers grow vegetables just after the harvesting of paddy. Burning of paddy straw is most common in combine harvested fields because it leaves harvested paddy straw and standing stubbles (25-30 cm height) in the field. Environmentally sustainable paddy crop residue management practices along with traditional methods for sowing of wheat and other costs entail incremental costs for the farmers. Farmers prefer burning of stubble to avoid incurring such costs.

Fig 1: Wheat stubble burns at a village in Patiala on November 1, 2019

Adverse effects of crop residue burning

It is estimated that burning of one tonne of paddy straw accounts for loss of 5.5 kg Nitrogen, 2.3 kg phosphorus, 25 kg potassium and 1.2 kg sulphur besides, organic carbon. Generally crop residues of different crops contain 80% of Nitrogen (N), 25% of Phosphorus (P), 50% of Sulphur (S) and 20% of Potassium (K). If the crop residue is incorporated or retained in the soil itself, it gets enriched, particularly with organic C and N. Heat from burning residues elevates soil temperature causing death of beneficial soil organisms. Frequent residue burning leads to loss of microbial population and reduces level of N and C in the top 0-15 cm soil profile, which is important for crop root development. Crop residues burning is a potential source of Green House Gases (GHGs) and other chemically and radioactive important trace gases and aerosols such as CH_4, CO, N^2O, NOx and other hydrocarbons. It is estimated that upon burning, Carbon (C) present in rice straw is emitted as CO^2 (70% of Carbon present), CO (7%) and CH_4 (0.66%) while 2.09% of Nitrogen (N) in straw is emitted as N_2O. Besides, burning of crop residue also emits large amount of particulates that are composed of wide variety of organic and inorganic species. Many of the pollutants found in large quantities in biomass smoke are known or suspected carcinogens and could lead to various air borne/lung diseases (GOI, 2019) [3].

Stubble burn cases in Punjab

The area under Paddy Cultivation during the year 2018-19 in the state of Punjab is 31.03 lakh hectares (as reported) out of which 5.11 lakh hectares is devoted to basmati paddy variety and 25.92 lakh hectares to non-basmati paddy variety. The total quantity of paddy straw generated during the year 2018-19 is 201.70 lakh mt. Paddy straw burning is prevalent in all districts. Sangrur, Muktsar, Ludhiana, Ferozpur and Bhatinda accounted for large volume of paddy straw burning in the state (GOI, 2019) [4].

Districts	Fire Events (01 Oct - 30Nov)			Percent reduction/ increase in fire events during 2018	
	2016	2017	2018	w.r.t. 2016	w.r.t. 2017
AMRITSAR	2171	1368	1406	35.2	+2.8
BARNALA	5701	3430	3279	42.5	4.4
BATHINDA	8846	5783	6348	28.2	+9.8
FARIDKOT	4630	3472	3058	34.0	11.9
FATEHGARH SAHIB	2461	1643	866	64.8	47.3
FEROZPUR	13645	9957	9993	26.8	+0.4
GURDASPUR	2221	1599	1172	47.2	26.7
HOSHIARPUR	905	497	199	78.0	60.0
JALANDHAR	4663	2134	1395	70.1	34.6
KAPURTHALA	3136	1627	751	76.1	53.8
LUDHIANA	9546	4769	3053	68.0	36.0
MANSA	5652	4506	4317	23.6	4.2
MOGA	6393	2786	2730	57.3	2.0
MUKTSAR	7037	5458	5786	17.8	-6.0
SBS NAGAR	1366	691	305	77.7	55.9
PATIALA	6546	5034	4217	35.6	16.2
RUPNAGAR	719	329	91	87.3	72.3
SANGRUR	11862	8430	7782	34.4	7.7
SAS NAGAR	366	246	199	45.6	19.1
TARN TARAN	4513	3320	2748	39.1	17.2
Total	102379	67079	59695	41.7	11.0

Fig 2: District wise number of fire events in the state of Punjab (Source- GOI, 2019) [3]

As per the data provided by Punjab Remote Sensing Department in Ludhiana, as many as 7326 incidents of wheat-straw burning were recorded from April 15 to May 19 this year. The maximum number of these incidents was recorded in Amritsar and Sangrur, with 703 each, followed by 605 incidents in Bathinda, 582 in Tarn Taran and 555 incidents in Gurdaspur. Maximum number of fire incidents in the state was reported on May 12 this season when 1291 such incidents were recorded, with Amritsar recording 233 incidents in a single day (Amarpal Singh, Hindustan times, 2019) [1]. The period between October 15 and November 15 is considered critical, as this is when most stubble burn cases take place. The 45% increases in stubble burning incidents were seen till October 11 with most number of cases in Tara taran, Amritsar and Patiala. (The week, Oct 2019, Singh *et al*. 2017a; Singh *et al*. 2017b; Singh *et al*. 2017c; Singh *et al*. 2018; Tiwari *et al*. 2018; Tiwari *et al*. 2019a; Tiwari *et al*. 2019b; Kour *et al*. 2019; Singh *et al*. 2019) [13-21]. District Taran-taran has seen with highest number of stubble burn cases at 705, while Amritsar with 500 cases at second spot. Patiala district recorded as many as 431 cases, according to Punjab Pollution Control Board (Vikas Vasudeva, The hindu, Oct 2019) [24]. According to NASA's fire alert services, Punjab registered 35,518 burning cases from September to November 7, which is 13.51 per cent lower than last year (41,066) whereas Haryana recorded 16 per cent more such incidents this year in comparison to the 2018 paddy season (India today, Nov 2019) [2]. According to NASA MODIS, VIIRS (Global Forest Watch) Punjab burnt 14.58% in September, 34.41% in October. The top most stubble burning centres of Punjab are Ferozepur, Taran taran, Sangrur, Patiala during Jan-Nov 2019 (Dipu Rai, India today, Nov 2019) [2]. According to data released by Punjab Remote Sensing Centre (PRSC) 48,155 stubble burn cases were found till 10 Nov, 2019 as compared to 40,774 till 10 Nov, 2018.

Fire Spots due to Stubble Burn

The remote images of Punjab are obtained from sensors of

Resourcesat-1; LISS-III (24m resolution) and AWIFS (56 m resolution). The remote images of various dates are obtained. Each image is composed of multiple bands which are concatenated to form a single mosaic. As the remote images are of very large size and hence constitute a huge number of pixels. After analyzing and processing the images, the following results are obtained. The pixels pink in colour indicates the presence of fire (Kaur and Rani, 2019) [7].

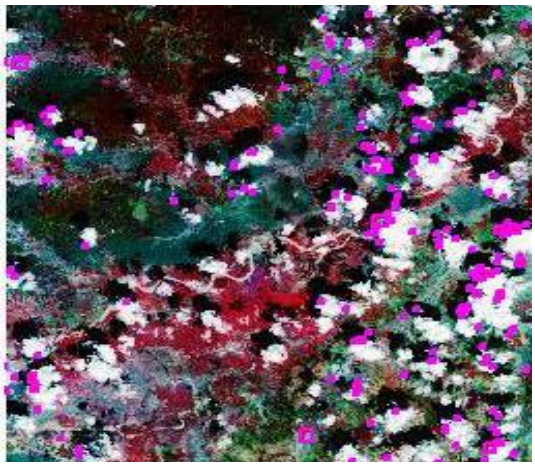

Fig 3: Pink colored pixels indicate fire on 24 Oct 2009 detected by FIRMS
(Source- G Singh, 2008)

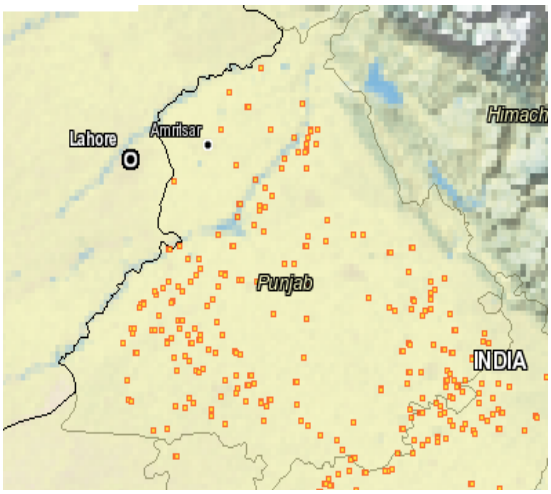

Fig 4: Actual fire spots on 24 Oct 2009 detected by FIRMS
(Source- G Singh, 2008)

Key Findings

Poor rural air quality

The air quality in rural areas of Ludhiana and Sangrur worsened during the peak burning time (25 October 2018 to 15 November 2018). As against the daily standard of 60 microgram per cubic metre for $PM_{2.5}$ in Sangrur, $PM_{2.5}$ levels in November ranged between 219 microgram per cubic metre and 630 microgram per cubic metre.

Another interesting observation was the difference in air quality among paddy-intensive regions (Ludhiana and Sangrur) and Pathankot and Hoshiarpur, where less paddy is cultivated. During the peak burning season, the average $PM_{2.5}$ value for Pathankot ranged from 32 microgram per cubic metre to 114 microgram per cubic metre; for Hoshiarpur, it ranged from 50 microgram per cubic metre to 155 microgram per cubic metre. The analysis clearly indicates that air quality is better in districts where less paddy is cultivated and less paddy residue burned (Kumar *et al.*, 2015) [8].

Paddy stubble management has been a major concern in the recent Air Quality Crisis in the North-Western region of India. Crop residue burning produces gases like Carbon Dioxide (CO_2), Carbon Monoxide (CO), Methane (CH_4), Nitrogen Oxides (NOx), and Sulphur Oxides (SOx) and a large amount of particulate matter (PM_{10} –$PM_{2.5}$). Release of such pollutants results in eye irritation, dryness of eyes, lung diseases, and chest congestion in people residing in the areas. In 2018, Punjab generates 50.75 million tonnes of crop residue of which 19.65 million tonnes is burnt. The problem of Air Quality is particularly acute during the October-November period in the NCR region. Although 80 percent of the pollution is due to vehicular emission, construction, industrial pollution etc. while stubble burning contributes 25-30 percent in peak days of stubble burning (Ministry of Agriculture & Farmers Welfare, 2019) [3].

Effects of crop stubble burning on the fertility of the soil

Rice stubble burning results in extensive impacts both on and off farm, e.g., losses in soil nutrients (vital compounds such as Nitrogen, Phosphorus, Potassium and sulphur from top soil layer, making the land less fertile), soil organic matter, production and productivity, air quality, biodiversity, water and energy efficiency on humans and animal health (Kumar *et al.*, 2015) [8]. As per the Punjab, Department of Agriculture, the soils of Punjab state are generally the organic carbon in Punjab soil has been reduced to very low and deficient levels due to the insufficient application of organic manures and non-recycling of crop residues. The burning of crop stubble in open fields has adverse impact on the fertility of the soil, reducing the amount of nutrients present in the soil. In one hectare 5 tons of straw were left, by burning the straw there was loss of valuable nutrients (Joydeep Thakur, Hindustan Times, 2017) [6].

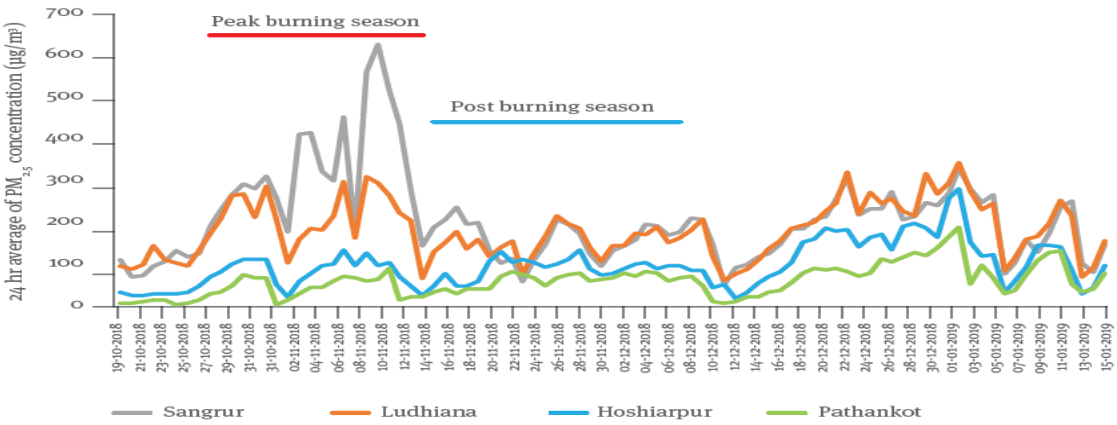

Fig 5: $PM_{2.5}$ level across Ludhiana, Sangrur, Hoshiarpur, and Pathankot Source: (CEEW analysis, 2018)

Health Impacts of Pollution Due to Residue Burning

Burning of paddy stubble leads to the emission of dangerous chemicals, dioxins like polychlorinated dibenzo-p-dioxins, polycyclic aromatic hydrocarbons (PAH's) and polychlorinated dibenzofurans (PCDFs). Furthermore, the release of CO_2 in the atmosphere due to paddy stubble burning results in the depletion of the oxygen layer causing greenhouse effect. Due to burning of crop stubble results in the death of animals by polluted air, as the high levels of CO_2 and CO in the blood can convert normal haemoglobin into deadly haemoglobin and severe adverse impacts especially for people suffering from respiratory disease, cardiovascular disease. Pregnant women and small children are also likely to suffer from the smoke produced by stubble burning. The off-field impacts are related to human health due to normal air quality degradation resulting in exacerbation of respiratory, eye and skin diseases (Kumar *et al.*, 2015) [8].

"These are very fine particles and can penetrate into our lungs, trigging a range of ailments. The elderly, children and those suffering from chronic respiratory and cardiac problems are particularly at risk," said Dr. A. Mohan, professor, Department of pulmonary medicine and sleep disorders, AIIMS.

Policy mandates to reduce paddy residue burning

The Cabinet Committee on Economic Affairs (CCEA) considered the proposal on 7 March 2018 and approved the scheme with the total outgo from the Central funds of Rs.1151.80 crore (Rs. 591.65 crore in 2018-19 and Rs. 560.15 crores in 2019- 20). Recently, the Government of India ordered the National Thermal Power Corporation (NTPC) to combine crop residue pellets (nearly 10 percent) with coal for generating electricity. This provided farmers with a monetary return of around Rs. 5500 (US$ 77) per ton crop residue (Gupta, 2019). A new central sector scheme, 'Promotion of Agricultural Mechanization for *In-Situ* Management of Crop Residue in the States of Punjab, Haryana, Uttar Pradesh and NCT of Delhi', was approved in 2018 to 'address air pollution and to subsidize machinery required for *in-situ* management of crop residue' for the period from 2018-19 to 2019-2020. A provision of INR 1,151.80 crore has been made under this scheme, of which Punjab will receive INR 695 crore. The scheme is implemented to promote the 'usage equipment and machines for in-situ management of crop residue' (GOI, 2019) [4].

Dr. Mohapatra stated that the Central Sector Scheme was launched with a total outgo of Rs.1151.80 Crores for the period from 2018-19 to 2019-20 by the Government of India to tackle air pollution and to subsidize machinery required for in-situ management of crop residue in the States of Punjab, Haryana, Uttar Pradesh and NCT of Delhi. Within one year of its implementation utilizing an amount of Rs. 500 crore, the happy seeder/zero tillage technology was adopted in 8 lakh hectares of land in the North - Western States of India. Under the scheme, financial assistance @ 50% of the cost is provided to the farmers for purchase of *in-situ* crop residue management machines on individual ownership basis. The financial assistance for establishment of Custom Hiring Centres of *in-situ* crop residue management machinery is @ 80% of the project cost (PIB, 2019) [9].

Management of stubble burning

For managing stubble burning Rs 695 crores are sanctioned for 2018-2020, central government has disbursed Rs 269 crores. Rs 250 crores spent by state government to provide 25,000 machines, 15,367 machines are delivered and rest to be delivered till end of October, 2018 (Ishani Duttagupta, The economics times, 2018). The major equipments developed by PAU are: (i) Happy Seeder Machine for planting in standing paddy stubbles; (ii) Tractor Operated Paddy Straw Chopper; (iii) Straw Collector and Baler; (iv) Residue Incorporation in Soil; (v) Compositing Techniques using Paddy Straw (Kumar *et al.*, 2015) [8].

Name of the Machine/ Equipment	Number of the Machines
SMS	3634
Happy Seeder	9758
Reversible M.B	3034
Shrub Master/Cutter cum Spreader	86
Straw Chopper	4486
Rotary Slasher	484
Zero Till Drill	3437
Rotavator	3690
Total	28609

(Source- GOI, 2019) [3]

Happy Seeders

Rationale of concurrent use of super straw management system (SMS) the Turbo Happy Seeder, is recognized as a significant technological innovation for *in-situ* residue management. It was a step forward for developing viable solution to rice crop residue burning. A straw management system (SMS) named as Super-SMS has been developed and commercialized by Punjab Agricultural University, Ludhiana, to equip the combine harvesters with mechanized straw spreaders, which help in uniformly spreading the rice residue as a part of the process of harvesting rice. Harvesting of rice by super SMS fitted combine harvesters allows concurrent sowing of wheat, which saves time, energy and one irrigation by utilizing the residual moisture of rice fields. Most importantly, it dispenses the need for crop residue burning. This valuable eco-friendly innovation is an attractive option for adoption by the farmers.

Increase in average yield of wheat by 2-4% compared to conventional till wheat (Sidhu *et al*, 2015) [10]. Economical cost of production, through savings in the cost of labour, fuel, chemicals, etc. saves about 20 liters of fuel per hectare due to sowing of wheat in a single operation. A total saving – 20×4.3 mha = 86 million liters of diesel fuel per season (Singh *et al*, 2015) [10].

Fig 6: Concurrent use of SMS-fitted combine (Source-NAAS, 2017)

Fig 7: Sowing of wheat seed by Happy seeder in paddy.

Steps taken by Govt. to reduce Stubble burn

1. KVKs organized 416 capacity building programmes, in which more than 16,000 farmers, machine/tractor operators and other stakeholders were trained on use of machinery for *In-situ* crop.
2. In 2017, KVKs of Punjab converted 25 villages as "Zero Stubble Burning Villages" whereas in 2018, the number of Zero Stubble Burning villages increased to 76.
3. To create awareness among farmers, more than 25 publications of books were released by ICAR-ATARI, LUDHIANA on *In- Situ* Crop residue management.
4. The Deputy Director Agriculture and other agriculture department members were directed for awareness through village level/block level and district level camps.
5. The State of Punjab have distributed 12082 machines to the farmers on individual ownership basis and have established 3950 Custom Hiring Centres which includes Cooperative Societies and Farmers Groups. Total 28609 machines have been distributed in the State during 2018-19.
6. Hon'ble Prime Minister of India, Sh. Narendra Modi recognised Shri S. Gurbachan Singh's as Real Champion of "MISSION ZERO BURNING" and appreciated his efforts in paddy straw management with convergence of KVK-PATIALA.
7. The village Kalar Majari of Patiala district was declared as "Zero Stubble Burn Village" in convergence with KVK, Patiala (GOI, 2019) [4].

Conclusion

Stubble burning definitely affects environment, air quality and general well being either straightly or discursively. Rice stubble burning has been identified as a major environmental and health hazard in Punjab. Extremely important to understand the underlying causes and the existing situations as o why the farmers burn stubble and then deal with the basic problem. Farmers left with few options but to burn the rice stubble due to lack of labour during the harvesting period and limit time available for preparing the field for wheat cultivation, and the burning is cheaper and requires less effort. Alternative efforts are made through kisan camps, trainings, workshops to informing farmers about the alternative usage of crop residues to overcome the burning. The state government, in collaboration with centre has rolled out schemes for providing subsidy on mechanical implements like happy seeders, Baler, shredders etc, and only a small number of farmers have access to these implements at the moment. The main theme is to cultivate the land with zero tillage to overcome the stubble burning by conservation agriculture. With the adoption of conservation agriculture-based technologies these residues can be used for improving soil health, increasing crop productivity, reducing pollution and enhancing sustainability and resilience of agriculture.

References

1. Amarpal Singh, Hindustan Times, 2019, https://www.hindustantimes.com/chandigarh/over-7-300-stubble-burning-cases-in-punjab-amritsar-sangrur-top-list/story-kL3uSKHShi7XCRi3HMtXFI.html
2. DIU, India Today, 2019, https://www.indiatoday.in/diu/story/punjab-burned-less-paddy-straw-this-year-while-haryana-jumped-1617223-2019-11-09
3. Government of India. Review of the Scheme "Promotion of Agricultural Mechanisation for In-Situ Management of Crop Residue in State of Punjab, Haryana, Uttar Pradesh and NCT of Delhi. New Delhi: Ministry of Agriculture and Farmers Welfare, 2019.
4. Government of India. Review of the scheme "Promotion of agricultural mechanisation for *in-situ* management for *in-situ* management of crop residue in state of Punjab, Haryana, Uttar Pradesh and NCT of Delhi. New Delhi: Ministry of Agriculture and Farmers Welfare, 2019.
5. Ishani Dasgupta, The Economic Times, 2018. https://economictimes.indiatimes.com/news/politics-and-nation/north-india-stares-at-pall-of-smoke-as-stubble-burning-kicks-off/articleshow/66297750.cms
6. Joydeep Thakur, Hindustan Times, 2017. https://www.hindustantimes.com/delhi-news/stubble-burning-begins-hold-your-breath-delhiites-that-deadly-smog-is-coming/story-ahzIniEIeYF12iBDHtGHpO.html
7. Kaur A, Rani J. An approach to detect stubble burned areas in Punjab by digitally analyzing satellite images. Journal for Research. 2016; 2(6):64-69.
8. Kumar P, Kumar S, Joshi L. Socioeconomic and environmental implications of agricultural residue burning - A Case study of Punjab, India"- Springer, 2015.
9. PIB, 2019, https://pib.gov.in/newsite/PrintRelease.aspx?relid=192608
10. Sidhu HS, Singh M, Singh Y, Blackwell J, Lohan SK, Humphreys E *et al*. Development and evaluation of the Turbo Happy Seeder for sowing wheat into heavy rice residues in NW India. Field Crops Res. 2015; 184:201-212.

11. Singh G. A multi-sensor approach for burned area extraction due to crop residue burning using multi-temporal satellite data, 2008.
12. Singh J. Paddy and wheat stubble blazing in Haryana and Punjab states of India: A menace for environmental health. Environ qual manage, 2018, 01-07.
13. Singh C, Tiwari S, Boudh S, Singh JS. Biochar application in management of paddy crop production and methane mitigation. In: Singh, J.S., Seneviratne, G. (Eds.), Agro-Environmental Sustainability: Managing Environmental Pollution, second ed. Springer, Switzerland, 2017a, 123-146p.
14. Singh C, Tiwari S, Singh JS. Impact of Rice Husk Biochar on Nitrogen Mineralization and Methanotrophs Community Dynamics in Paddy Soil, International Journal of Pure and Applied Bioscience. 2017b; 5:428-435.
15. Singh C, Tiwari S, Singh JS. Application of Biochar in Soil Fertility and Environmental Management: A review, Bulletin of Environment, Pharmacology and Life Sciences. 2017c; 6:07-14
16. Singh C, Tiwari S, Gupta VK, Singh JS. The effect of rice husk biochar on soil nutrient status, microbial biomass and paddy productivity of nutrient poor agriculture soils *Catena*. 2018; 171:485-493.
17. Tiwari S, Singh C, Singh JS. Land use changes: a key ecological driver regulating methanotrophs abundance in upland soils. Energy, Ecology, and the Environment. 2018; 3:355-371.
18. Tiwari S, Singh C, Boudh S, Rai PK, Gupta VK, Singh JS. Land use change: A key ecological disturbance declines soil microbial biomass in dry tropical uplands. Journal of Environmental Management. 2019a; 242:1-10.
19. Tiwari S, Singh C, Singh JS. Wetlands: A Major Natural Source Responsible for Methane EmissionA. K. Upadhyay *et al*. (Eds.), Restoration of Wetland Ecosystem: A Trajectory towards a Sustainable Environment, 2019b, 59-74p.
20. Kour D, Rana KL, Yadav N, Yadav AN, Rastegari AA, Singh C *et al*. Technologies for Biofuel Production: Current Development, Challenges, and Future ProspectsA. A. Rastegari *et al*. (Eds.), Prospects of Renewable Bioprocessing in Future Energy Systems, Biofuel and Biorefinery Technologies. 2019a; 10:1-50.
21. Singh C, Tiwari S, Singh JS. Biochar: A Sustainable Tool in Soil 2 Pollutant Bioremediation R. N. Bharagava, G. Saxena (Eds.), Bioremediation of Industrial Waste for Environmental Safety, 2019b, 475-494p.
22. The week, 2019, https://www.theweek.in/news/india/2019/10/13/farm-fires-go-up-45-per-cent-in-punjab-officials-say-will-be-less-than-2018.html
23. TOI, 2019 https://timesofindia.indiatimes.com/india/stubble-burni ng-cases-in-punjab-cross-48000-set-to-cross-last-years-count/articleshow/72014694.cms
24. Vikas Vasudeva, The Hindu, 2019, https://www.thehindu.com/news/national/other-states/rise-in-stubble-burning-cases-in punjab/article2977 2360.ece