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IMPACT OF *IN SITU* RICE CROP RESIDUE BURNING ON AGRICULTURAL SOIL OF DISTRICT BATHINDA, PUNJAB, INDIA

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ABSTRACT

The study was carried out to explore the effect of *in situ* rice crop residue burning on physicochemical and biological properties of soil. Physico-chemical properties under investigation included soil pH, electrical conductivity, organic matter, total phosphorus, nitrogen and potassium. Result analysis showed an increase in mean pH and electrical conductivity values of soil samples from 7.94 and 245-699 µS/cm (pre-burning period) to 8.46 and 403-800 µS/cm (post-burning period). Similarly, a significant increase in soil organic matter for the post-burning period (27100 mg/kg) was observed as compared to the pre-burning period (25200 mg/kg). However, the nitrogen and phosphorus content decreased significantly in post burning period. The analysis also revealed a significant decrease in enzyme activities of amylase, cellulase, invertase and dehydrogenase in post burning samples. The causes and effects of the changes in physicochemical and biological properties of agriculture soils due to *in situ* rice crop residue burning have been discussed.

Keywords: Rice straw burning, Soil enzyme, Soil property, Macronutrients

INTRODUCTION

In situ crop residue burning is the burning of residues left in the field after crop harvesting. The residue is mainly stem of the rice plant still anchored with its roots in the soil. Crop residue burning is commonly practiced by farmers in several parts of India to get rid of the crop residue of the previous harvest. Agricultural residues mainly include straw, husks and hulls. Main contributors to biomass burning are wheat residue, maize stalks & leaves, rice straw & hulls, barley residue, millet and sorghum stalks. These residues do not have much usage and economic value. The practice is more common in agriculture intensive states like Punjab, Haryana, Rajasthan and Uttar Pradesh.

Crop residue burning is a cheap, convenient, easy and economical method for managing *in situ* crop residues. Another major reason for the wide acceptance of this practice is the time-saving in clearing the agricultural fields. Often, the farmers have very less time between harvest of one crop and sowing of the next one. However, this management measure has serious environmental and human health implications. The major environmental issues associated with crop residue burning are air pollution, climatic changes and soil pollution. The burning of crop residues also leads to human health problems due to the release of soot particles & smoke. Air pollution and climate change are due to the emission of greenhouse gases (GHGs) like carbon dioxide, nitrous oxide etc. The *in situ* crop residue burning adversely affects the soil fertility & soil properties.

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The soil is an important ecological factor since it possesses several peculiar characteristics like the correlation between soil structure & climate of the region, nature and configuration, and its role in social and economic development of living beings[1]. The burning of agricultural residue leads to significant changes in the physicochemical, biological and biochemical properties of soil[2]. Such changes depend on the intensity and duration of the fire, soil type, moisture and climatic conditions.

The crop residue burning leads to loss of valuable plant nutrients such as sulphur (S), nitrogen (N), phosphorous (P), potassium (K) and wastage of valuable carbon (C) and energy-rich residues[4,5]. Crop residue burning also affects the organic matter content in the soil.

Apart from changes in physicochemical properties and loss of nutrients, it also affects the biochemical properties i.e., activities of soil enzymes[6]. Soil enzymes play a vital role in the catalysis of those reactions that are necessary for organic matter decomposition and cycling of nutrients. Moreover, enzymes are also involved in energy transfer, crop productivity and environmental quality[7]. The soil enzymes are important indicators of soil health in terms of soil friendly microbes, worms, insects etc. The study of hydrolases enzyme is of particular importance due to their close relationship with recycling of important nutrients such as N, P, C and S. Enzymes are present in variable amounts in soil because of certain factors such as organic matter content, microbial activity, soil composition and intensity of biological processes[8]. These enzymes may include amylase, cellulase, chitinase, dehydrogenase, phosphatase, urease, and glucosidase released from microorganisms, animals and plants[9]. Agricultural management practices such as crop rotation, mulching, biomass burning etc. have diverse effects on enzyme activities of soil[10]. Hence, it is necessary to study the impact of crop residue burning on soil properties.

The main purpose of this study is to analyze the impacts of crop residue burning on agricultural soil. For this concern, the physicochemical properties, nutrient dynamics and enzyme activities were studied in soil samples of pre and post-burning periods. The study of enzyme activities would allow a greater understanding of the effects of crop residue burning on soil biological functions. The present study has been carried out in Bathinda district of Punjab, India. Rice and wheat are the major crops grown in the district. The rice is harvested in 3rd or 4th week of October and wheat is sown in 1st or 2nd week of November. This leads to very less time in-between and hence farmers of this district widely practice burning of rice crop residues. No study related to effects of rice crop residue burning on soil nutrient dynamics and soil enzymes of Bathinda district is available. In this regard, soil samples were collected from selected sites of Bathinda district during pre and post rice crop residue burning and studied for physicochemical and enzymatic properties.

EXPERIMENTAL

Materials and Methods

Site and Sampling

Soil samples were collected during pre and post *in situ* rice crop residue burning period from agricultural fields of Bathinda district of Punjab, India from 10 sites (Fig.-1) during October & November 2017. Soil samples were collected in polythene bags with the help of soil auger to a depth of 5-15 cm. A soil sample (100 g) was taken from each sampling site. The collected samples were sieved and stored at room temperature. For the enzymatic studies, soil samples were stored at 4°C.

Physicochemical Properties

Determination of EC and pH of Soil Samples[11,12]

A suspension of 30.0 g of the air-dried soil sample in 60 mL of double distilled water was taken in a 100 mL beaker covered by watch glass and stirred for 1 hour on a magnetic stirrer. The suspension was allowed to settle for 10 minutes and EC of the suspension was taken by using a calibrated EC meter. pH of the suspension was determined by adding 10 mL more double distilled water in suspension and pH was taken by a calibrated pH meter.

Soil organic matter (SOM)

For the estimation of organic matter, Walkey-Black rapid titration method[13] was used. 10 mL $K_2Cr_2O_7$ (1N) and 20 mL conc. H_2SO_4 were added to a dried sample (1 g) and the mixture was shaken for 3 h. The solution was allowed to stand for 1 h and 200 mL of double distilled water was added.

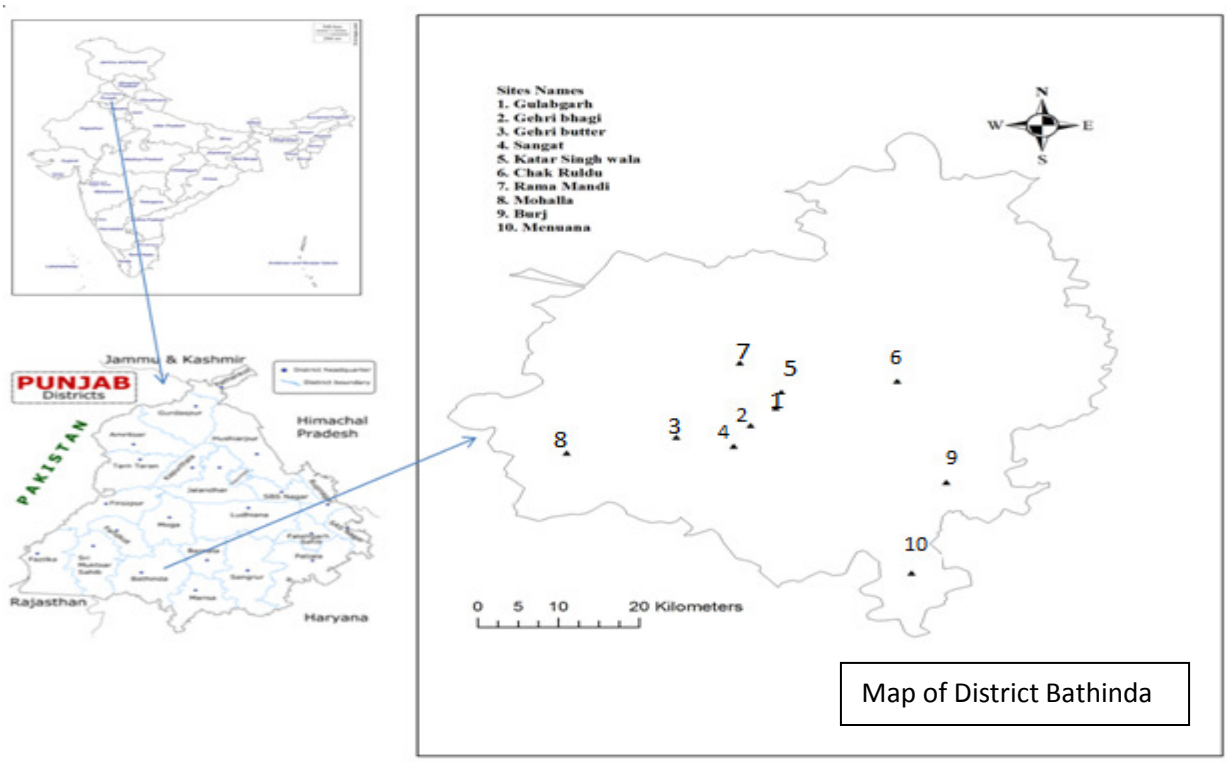

Fig.-1: Soil Sampling Locations for Pre and Post burning Period

This followed the addition of few drops of o-Phenanthroline–ferrous complex indicator. The solution was titrated against 0.5N ferrous ammonium sulphate solution. At the end point, the green color solution was sharply changed from blue to red or maroon tinge. The reading was noted and the percent (%) organic carbon was calculated using the following formula:

$$\%\ \text{Organic carbon} = \frac{(\text{Control} - \text{sample}) \times 0.5 \times\ 0.003\ \times 100\ \times \text{correction factor}}{\text{weight of soil}}$$

Correction factor: 1.33 for 1 g of sample

$$\%\ \text{Organic matter} = \%\ \text{Organic carbon} \times 1.724$$

Determination of Total P of Soil by using Allen's Method[14]

A soil sample (500 mg) was mixed in 10 mL of nitric acid and perchloric acid (1:2 (*v/v*). The mixture was digested till the appearance of white fumes. Thereafter, perchloric acid (5mL) was added for complete digestion. Digestion process was followed by cooling of the solution by adding 25 mL distilled water. The resultant solution was filtered through Whatman filter paper No. 1. Filtrate thus recovered was diluted to 100 mL by adding distilled water. 5 mL of filtrate was taken along with 5 mL of ammonium molybdate and 1.0 mL of distilled water added. Stannous chloride in glycerol (4-5 drops) was added and the final volume was maintained to 100 mL. The resultant solution was allowed to stand for 10-15 minutes. The absorbance of intense blue color developed after 15 minutes was recorded at 700 nm.
Total P content was calculated by using the following formula:

$$\text{Total Phosphorus}\ (\frac{\text{mg}}{\text{Kg}}) = \frac{\mu\text{g P} \times 100}{\text{Aliquat (5mL)}\ \times \text{weight of soil}}$$

$$\text{Total P\%} = \frac{\mu\text{g P} \times 100 \times 100}{\text{the sample in mg} \times \text{aliquat (5mL)}\ \times 1000}$$

Determination of Total Nitrogen (TN) by Kjeldahl Method (KEL PLUS Automatic Nitrogen Estimation System)

For the estimation of TN in the soil, Kelplus Distyl- EMVA Kjeldahl apparatus was used. In this method, 3.5 g mixture of $CuSO_4$ and K_2SO_4 in the ratio of 1:10 was added in 1.0 g of the soil sample. After that, 10 mL of concentrated H_2SO_4 was added and digested for 2 hours. After digestion, the solution was diluted with 40 mL distilled water. Apart from this, the distillation process was carried out in the distillation apparatus. During the distillation process, nitrogen was accumulated in the boric acid mixed indicator. The color changes from violet to green in the boric acid mixed indicator. This indicates the presence of N in the sample. Finally, distillate was titrated against 0.1N H_2SO_4 till the appearance of light blue color or violet color.

Determination of K (Flame Photometer Method)

5 g of soil sample was taken in 250 mL flask. Added 25mL of 1N Ammonium acetate and shaken for 1 hour. The content was filtered using filter paper (Whatman no.1). K present in soil samples was further estimated using flame photometer (Systronics Model No. 2180).

Biological Properties-Estimation of Enzymatic Activity in Soil

Amylase[15]

0.2 mL of toluene was added to 3 g of preserved soil sample (4°C). The mixture was kept at room temperature for 15 minutes. Thereafter, 6 mL of Sorensen buffer and 6 mL of 1% starch solution were added to the flask. The mixture was incubated at 30°C for 24 hours. After the incubation period, the mixture was centrifuged at 10000 rpm for 10 minutes. 1 mL of supernatant was taken out and 2 mL of 3, 5 dinitrosalicylic acid solution was added. The solution was put in a water bath under boiling conditions to allow color development. After the development of a dark red color, the final volume was made to 5 mL. Absorbance was recorded at 540 nm against the blank sample.

Cellulase[16]

A soil sample (1 g) was dissolved in 0.1 mL of toluene. The mixture was kept at room temperature for 15 minutes. Sorensen buffer (2 mL) and substrate solution (2 mL) were added. The whole mixture was incubated at 30°C for 24 hours. Control was prepared in the same manner as the sample was prepared. All the contents were centrifuged at 4000 rpm for 10 minutes. 1 mL of supernatant was pipetted out followed by the addition of 3, 5- dinitrosalicylic acid. The solution was kept under boiling conditions in a water bath for color development. After the development of a dark red color, the final volume was made to 5 mL. Absorbance was recorded at 540 nm against the blank.

Invertase[17]

A soil sample (1 g) was dissolved in 0.1 mL of toluene. The mixture was kept at room temperature for 15 minutes. Sorensen buffer (2 mL) and substrate solution (2 mL) were added. The whole mixture was incubated at 30°C for 24 hours. Control was prepared in the same manner as the sample was prepared. All the contents were centrifuged at 4000 rpm for 10 minutes. 1 mL of supernatant was pipetted out followed by the addition of 3, 5- dinitrosalicylic acid. The solution was kept under boiling conditions in a water bath for color development. After the development of a dark red color, the final volume was made to 5 mL. Absorbance was recorded at 540 nm against the blank. The enzymatic activities were calculated by plotting standard curves for all enzymes against a particular substrate. Glucose was used as a substrate for preparing standard curves of amylase, invertase and cellulase.

Dehydrogenase

Three percent (3%) solution of 2, 3, 5-triphenyl tetrazolium chloride, 5 g of soil sample and distilled water (2.5 mL) were mixed together. The mixture was incubated for 1 day at 37°C. Incubation of mixture was followed by addition of methanol (10 mL). The contents were shaken for 1 minute. The suspension was filtered through filter paper (Whatman No. 1). Extraction was further carried out with methanol till the disappearance of reddish color in the extract. The volume of the extract was raised to 50 mL with

methanol. The absorbance of the mixture was measured at 485 nm with methanol as blank. 1, 3, 5-triphenyl tetrazolium formazon was used for the preparation of a standard curve. The activity of dehydrogenase was expressed as µgTPF/ g/24 h.

Statistical Analysis

All the experiments were performed twice to confirm the validity of the results. Three replicates were maintained for each treatment.

RESULTS AND DISCUSSION

The impacts of biomass burning on soil were analyzed in terms of physicochemical, total organic matter, macronutrients and biochemical properties of soil in pre and post-burning periods. The post burning samples were collected within 72 h of the burning of rice crop residue.

Impact of *in situ* Rice Crop Residue Burning on Soil pH and EC

The pH analysis of the soil samples collected from the district Bathinda, indicates that the soils of the area are alkaline in nature. Further, the results of the analysis of soil samples collected during the pre and post-burning period indicate an increase in soil pH after rice residue burning. In all the 10 samples from different villages, the pH of the soil samples collected post burning period was higher than the soil collected pre-burning period as detailed in Table-1. The soil pH of the samples during the pre-burning period ranged 7.32 to 8.41 and the same was 8.03to 8.8 during post burning period (Table-3). The mean value for pH of soil samples of the pre-burning period was 7.94 and in post burning period, it increased significantly to 8.46 (Table-3).

Similar results were also observed in the case of EC. The EC of the soil samples collected in the post burning period was higher than the soil samples of the pre-burning period for all the sites (Table-1). The EC of soil samples before biomass burning ranged from 245-699 µS/cm which increased significantly from 403- 800 µS/cm (Table-3). The average increase in EC post burning was nearly 1.5 times as indicated by the mean value of EC of soil samples of pre-burning (394.8 µS/cm) and post-burning (551.7 µS/cm) (Table-3).

Impact of *in situ* Rice Crop Residue Burning on Soil Organic Matter (SOM) and Macronutrients Content

SOM was higher in agricultural soils collected post residue burning. The mean value of OM in soil samples collected pre and post residue burning was 25200 and 27100 mg/kg, respectively (Table-3). Individually, the increase in organic content in post residue burning was not significant for most of the sites (Table-2). Apart from SOM, the other important macronutrients required for plant growth are N, P and K. Hence, the effect of *in situ* rice crop residue burning on these macronutrients was also determined. The *in situ* rice crop residue burning showed a decrease in total N and P content while the K content increased.

Table-1: pH and EC of soil samples collected pre and post *in situ* rice crop residue burning

Village Name	Co-ordinates		pH Mean±S.E		EC (µS/cm) Mean±S.E	
	North Latitude	East Longitude	Pre Burning	Post Burning	Pre Burning	Post Burning
Gulabgarh	30.143	74.988	8.27±0.043	8.57±0.087	699±10.13	800±9.29
Gehri bhagi	30.115	74.96	7.83±0.033	8.03±0.023	383±4.93	476±7.4
Gehri butter	30.096	74.877	7.98±0.45	8.28±0.035	526±10.1	607±10.4
Sangat	30.082	74.941	7.32±0.04	8.32±0.054	392±8.65	504±6.87
Katar Singh wala	30.168	74.994	8.41±0.063	8.54±0.078	355±3.45	590±8.54
Chak Ruldu	30.186	75.123	7.97±0.029	8.6±0.076	281±3.20	440±13.43
Rama Mandi	30.215	74.948	8.07±0.043	8.47±0.095	331±3.42	541±7.9
Mohalla	30.071	74.755	7.86±0.05	8.56±0.082	346±4.12	532±13.5

Burj	30.024	75.178	7.8±0.022	8.8±0.065	245±2.98	803±18
Menuana	29.879	75.139	7.92±0.044	8.42±0.08	390±6.96	624±15.4

Data are represented as mean ± S.E (3 replicates)

Table-2: N, P, K and OM of soil samples collected pre and post *in situ* rice crop residue burning.

Village Name	OM (mg/kg) Mean±S.E		N (mg/kg) Mean±SE		P (mg/kg) Mean±S.E		K (mg/kg) Mean±S.E	
	Pre Burning	Post Burning	Pre Burning	Post Burning	Pre Burning	Post Burning	Pre Burning	Post Burning
Gulabgarh	29900±102	29700±292	700±12.5	560±13.6	510.4±12	454.3±16	178.17±4.44	255.17±5.65
Gehri bhagi	28900±167	30900±153	420±15.4	370±15	480.3±14	415.7±7.6	312.05±3.2	346.05±5.05
Gehri butter	20700±300	21700±564	700±17.7	560±15.6	570.4±15.4	539.4±5.43	194.67±3.54	234.67±4.23
Sangat	27900±432	28900±540	560±12.6	510±9.6	660.4±17.5	622.4±14.6	145.55±2.22	225.55±5.5
Katar Singh wala	20900±543	23900±665	580±16	420±8.8	612.6±16.7	544.5±12.5	73.66±2.56	193.66±4.31
Chak Ruldu	19500±400	23900±358	550±9.6	410±8.4	520.2±20.4	601.8±11.6	147.45±4.5	223.66±5.74
Rama Mandi	28300±329	29300±288	840±20.3	700±10.3	620.8±22.4	552.2±14.4	142.97±3.12	207.4±3.82
Mohalla	28700±452	30700±394	730±14.7	560±15.4	450.7±6.6	429.7±8.23	143.65±2.76	234.6±3.43
Burj	20300±542	23300±453	590±19.4	440±17.3	606.8±7.88	588.6±10.3	145.68±2.65	254.8±4.34
Menuana	26900±505	28900±460	850±11.5	700±14.5	840.4±21.5	800.8±17.8	241.63±3.87	298.5±4.02

Data is represented as mean ± S.E (3 replicates).

The decrease in N and P was nearly consistent in all the samples collected (Table-2). The mean value of phosphorus in soil samples of pre and the post-burning period was 587 mg/kg and 554 mg/kg, respectively. The mean % value of nitrogen, pre and post-burning was observed 0.06% and 0.05%, respectively (Table-3 and Fig.-2). The potassium content is increased in agricultural soil after the biomass burning season. The mean value of K was 172.54 mg/kg and 247.3 mg/kg in pre and post biomass burning period (Table-3 and Fig.-2). The increase was also consistent in all the 10 samples collected from different sites (Table-2).

Table-3: Range and mean values of physicochemical properties of soil samples collected pre and post *in situ* rice crop residue burning

	Pre-Burning		Post Burning	
Soil Parameter	Range	Mean± S.E	Range	Mean± S.E
pH	7.32 - 8.41	7.94 ± 0.29	8.03 - 8.8	8.46 ± 0.21
EC(µS/cm)	245 - 699	394.8 ± 130.53	403 – 800	551.7 ± 112.79
Nitrogen (mg/kg)	420 - 850	652(0.06%) ± 136.2	370 – 700	523 (0.05%) ± 115.76
Total P (mg/kg)	450.7 - 840.4	587.30 ± 111.73	415.7 – 800.8	554.94 ± 112.49
K(mg/kg)	73.66 - 312.05	172.54 ± 65.25	193.66 – 346.05	247.41 ± 45.11
OM (mg/kg)	19500 - 29900	25200 ± 4256	21700 – 30900	27120 ± 3489

Data are represented as mean ± S.E (3 replicates).

Impact of Burning on Soil Enzymatic Activities

Soil enzymes play a key role in soil biochemical functions and microbiological activities.

There is certain evidence suggesting that soil enzyme activity can be analyzed to be used as an indicator of microbial activity and soil fertility[18]. Soil enzymes respond quickly with a change in soil nutrient quality and act as good microbial indicators. Enzyme activities were tested and analyzed in this work. The results showed a significant decline in activities of all the studied enzymes for post burning soil samples while the enzymes isolated from pre-burning soil samples showed more activity (Table-4). The mean activity of amylase for the 10 samples decreased by approximately 25% while the decrease was nearly 50% or more for the cellulose, invertase and dehydrogenase (Fig.-3).

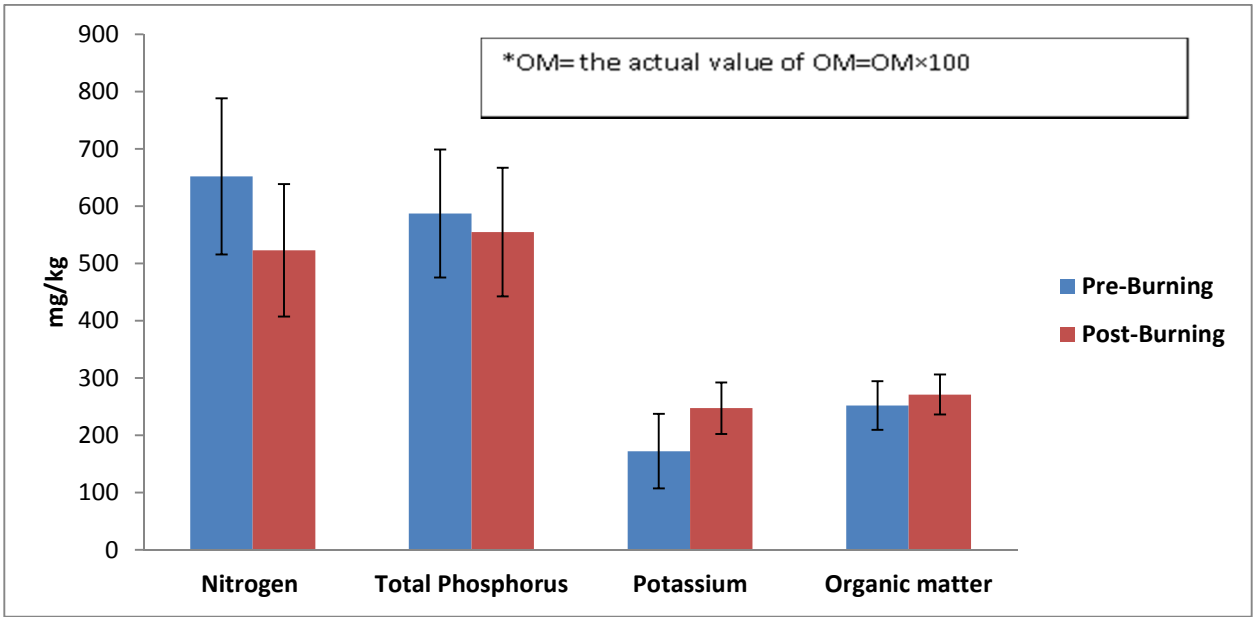

Fig.-2: Comparison of OM and N, P, K and OM of Soil Samples Collected Pre and Post *in situ* Rice Crop Residue Burning. Columns in the Graph represent Mean of N, P, K and OM for Pre and Post Burning Period (n=10) Whereas Error Bars represent Standard Deviation.

Table-4: Biochemical properties of soil samples collected pre and post *in situ* rice crop residue burning

Village Name	Amylase (µg/g/h) Mean±S.E		Cellulase (µg/g/h) Mean±S.E		Invertase (µg/g/h) Mean±S.E		Dehydrogenase (µg/g/h) Mean±S.E	
	Pre Burning	Post Burning	Pre Burning	Post Burning	Pre Burning	Post Burning	Pre Burning	Post Burning
Gulabgarh	123.28±2.2	90.65±2.7	93±3	35±1.4	289±5.4	98±4.4	21.4±1.23	8.4±0.43
Gehri bhagi	109.13±4.5	89.32±4.10	102±2.5	37±1.12	261±5.9	113±3.7	55.8±2.98	21.6±0.54
Gehri butter	86.49±4.6	69.79±2.89	72±2.9	33±1.56	255±4.6	121±5	33.8±3.2	19.4±0.89
Sangat	101.21±5.7	72.44±2.35	96±3	35±0.98	293±8.4	100±3.4	16±0.94	6.4±0.88
Katar Singh wala	76.31±4.3	61.97±1.90	82±1.98	30±0.76	193±7.4	85±3.8	70.6±4.3	29.6±1.34
Chak Ruldu	107.53±3.2	81.49±2	97±4.3	45±1.4	273±7	223±7.54	86.6±3.67	54.8±2.55
Rama Mandi	124.89±7.4	97.81±1.68	60±3.76	43±0.77	168±5.5	105±4	15.8±0.34	2.4±0.12
Mohalla	78.38±5.4	54.89±1.32	119±3.12	45±0.89	239±4.9	102±3.23	39.6±0.44	9.6±0.45
Burj	90.46±23	45.44±0.89	93±2.83	68±1.30	177±5.4	60±2.98	12.6±0.65	4.8±0.54
Menuana	129.22±3.3	74.04±2.5	133±4.45	77±1.87	259±7.9	152±4.2	80.8±2.87	35±1.23

Data are represented as mean ± S.E (3 replicates).

The results show that the pH & EC increased in soil samples collected post burning period than a pre-burning period. The enhancement of pH is due to the presence of ash in soil[19, 20]. The production and accumulation of ash may increase the pH of the soil. It may also be due to the formation of oxides,

hydroxides and carbonates of sodium and potassium in surface soils[21]. The possible reason for an increase in electrical conductivity was the collapsing of aggregates and clogging of voids by the ash and dispersed ions[22, 23].

SOM represents the largest terrestrial carbon pool[24] and is the main component of soil ecosystem that provides a protective cover to soil and regulates its temperature. It also provides habitat and substrates for soil flora and fauna[25]. In this study, the SOM of soil samples collected post *in situ* burning period was higher. It may be due to the increase of carbon mineralization process during the burning of rice straw[26]. The process of carbon mineralization depends on the intensity and temperature of burning. During high-intensity burning, the temperature reaches 450°C, whereas in moderate and low intensity burning temperature reaches 350°C and 250°C, respectively[25]. The burning severity of straw of sampling sites is in medium severity and generally, the carbon content of soils increase after medium-severity fires[27]. The impact of biomass burning on SOM is also dependent on soil type, soil moisture and the nature of the burning materials.

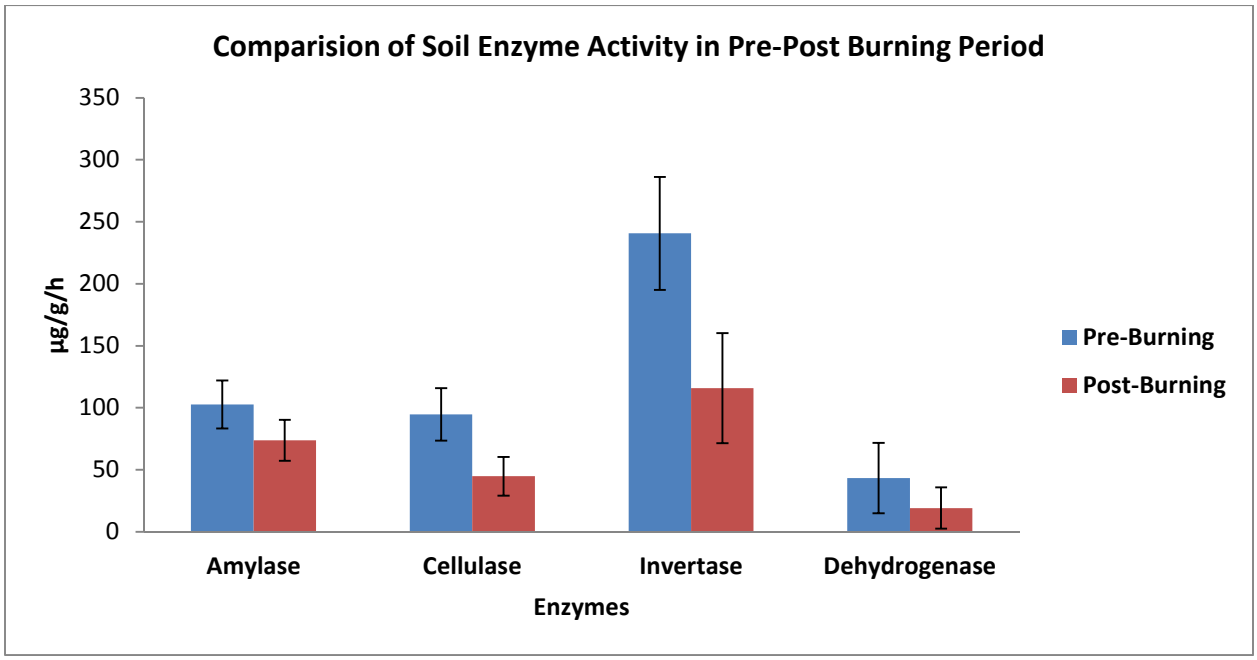

Fig.-3: Soil Enzyme Activities Pre and Post *in situ* Rice Crop Residue Burning. Columns in the Graph represent Mean of Amylase, Cellulase, Invertase and Dehydrogenase Activity for Pre and Post Burning Period (n=10) Whereas Error Bars represent Standard Deviation.

Crop residue burning affects the availability of macro and micro nutrients in the soil. The macro and micro nutrients have an influence on crop productivity and vegetation dynamics[28]. N & P are the important macronutrients of any agricultural system and their reduction affects soil fertility. The N and P content of soil samples collected post crop residue burning period was lower than soils collected pre-burning period. On the immediate effect, the volatilization process during the burning of agricultural biomass is the reason for the decrease of soil N and P content[23, 25, 29]. At 300°C, half of the N in organic matter can be volatilized[25, 30]. The K content was higher[31] in soil samples collected post burning period compared to pre-burning period. K is the main indicator of crop residue burning[32]. This may be due to leaching of extractable K and mineralization of cations from burnt crop residue[33].

Study of soil enzymatic activities is very helpful to understand the basic biochemical processes and soil fertility of any soil[34]. Amylase is a starch hydrolyzing enzyme and is constituted by α- and β-amylase. The activity of this enzyme may be influenced by certain factors such as vegetation type, environment and soil types. Amylase enzyme activities of soil may be influenced by the plants directly by supplying enzymes from their residues or indirectly providing substrates for the synthetic activities of micro-organisms[35]. Cellulases are those enzymes that degrade cellulose in plant debris into glucose, cellobiose

and oligosaccharides having high molecular weight. Invertase enzyme utilizes sucrose as a substrate and converts it into glucose and fructose. In general, increased organic matter (OM) content of the soil is an energy source for microbes[36]. But, here the results showed a decrease in enzyme activity in the soil after biomass burning despite an increase in OM. Here, the decrease in enzyme activity is due to 2 reasons: 1) the source of these enzymes are soil microbes, worms and insects. The *in situ* crop residue burning leads to the killing of these organisms and hence production of these enzymes. 2) Moreover, hydrolytic enzymes are deactivated due to high temperature during burning, thereby reducing soil enzymes activity[37]. The biological activity of the soils is strongly indicated by the presence of dehydrogenase enzyme[38]. This enzyme is responsible for the oxidation of organic matter present in the soil by transfer of electrons and protons. Dehydrogenase enzyme activities give an indication of soil potential to hold up biochemical processes that are vital to maintaining soil health and fertility. These results showed an alteration in the dehydrogenase activity of unburnt and burnt soil samples. The results are supported by the previous findings reporting that temperature affected dehydrogenase activity indirectly by influencing the redox status of soil[39]. The redox transformations are associated with the respiration activity of soil micro-organisms. The depressed soil enzyme activity was a clear indication that biomass burning changes the quality and quantity of substrates for microbes.

CONCLUSION

In situ crop residue burning significantly influences the physicochemical and biochemical properties of the soil. The burning leads to the loss of the two most important micronutrients N and P. The losses of micronutrients increase fertilizers requirement for the next crop and add to the financial burden of the farmers. An increase in soil pH and electrical conductivity is attributed to the presence of ash in soil and clogging of voids by the ash and dispersed ions. This also negatively affects agriculture. The results also revealed a decrease in activities of soil enzymes like amylase, cellulase, invertase and dehydrogenase in post burning period. This indicates the decrease of soil microbes and soil friendly insects and worms and in-turn soil health. In the end, we conclude that the *in situ* crop residue is a harmful practice for agriculture soil and the farmers. Alternate methods need to be developed for management of the crop residues instead of its burning.

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