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Impact of Crop Residue Burning on Physico-chemical Properties of Agricultural Soil of Sagar District, Madhya Pradesh, India

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ABSTRACT
Crop residue burning is a common practice worldwide as well as in India. However, recent studies have identified a number of negative impacts on environment, agriculture and human health. However, the impact of crop residue burning on soil quality was poorly studied in the previous studies. The present study was carried out to explore the effect of wheat crop residue burning on physico-chemical properties of soil. Therefore, for study purpose, five study sites were identified on the basis of type of crop cultivated and history of burning practices. Three replicates of soil samples were taken from each site for both before and after crop residue burning and the analysis of pH, electrical conductivity, soil organic carbon, N, P, K, Cu, Zn, Fe and Mn content was carried out. Standard procedure was followed for assessment of physico-chemical properties of soil samples. Result of the present study clearly indicates the increased value of pH, soil organic carbon and potassium content in soil samples of after crop residue burning than before crop residue burning samples. On the other hand, electrical conductivity, moisture content, nitrogen, copper and zinc showed a decreased value for soil samples collected after crop residue burning than before crop residue burning. Although insignificant differences were observed at $P<0.05$ in almost all of the physical and chemical parameters of the soil after crop residue burning for most of the sites, the decreasing level of these important parameters will significantly deplete the quality of soil. As a result, the fertilizer requirement for the next crop will increase which will lead to add financial burden to the farmers. Further, due to the increase in temperature, the number of beneficial microbes and fauna get decreased, which will further add to the requirements of fertilizers. Therefore, we suggest the development of new and environment friendly strategies for the management of crop wastes.

Key words: Agriculture residue burning, Soil quality, Agricultural fire, Mycorrhiza, Nitrogen-fixing bacteria, Fertilizers.

INTRODUCTION

In many regions of the world, agricultural residue burning is a common practice used for preparing the land in a very short time for cultivation of next round of crops (Badarinath et al. 2006, McCarty et al. 2017, Verma et al. 2019). It aids in weed management, lowers the danger of pests, plant diseases (Mazzola et al. 1997, Brye et al. 2006, Roy et al. 2008, McCarty et al. 2012), and provides ash as fertilizer (Korontzi et al. 2006). Alike forest, savanna and grassland fires, crop residue burning (CRB) are one of the major types of biomass burning (Andreae and Merlet 2001) which is responsible for 8-11% of all the global fires (Korontzi et al. 2006).

India is one of the largest agro-based economies in the world, contributing a very significant proportion of the world's rice and wheat yield (Saxena et al. 2021). Traditionally, crop residues were generally used for residential cooking, industrial fuel and animal fodder (Mathur and Srivastava 2019, Meshram 2002). In recent time, the pressure on food production has significantly increased throughout the world as well as in India in order to fulfill the demand of growing population. The continually expanding production of agricultural based products consequently generates more waste and environmental pollution (Chang and Song 2010, Dumka et al. 2019). Further, rapidly increasing demand of food leaves a short time window (typically 3-4 weeks) to farmers for switching to the next cropping season (Saxena et al. 2021). Moreover, there are no economical technologies available for small fields that can collect left over agricultural residues (Cheng et al. 2014, He et al. 2015). Therefore, farmers prefer to burn the crop residues after harvest to prepare the land for next cropping as the crop residue burning (CRB) practice is less time consuming, inexpensive and quickly prepares the fields for the next crop (Venkataraman et al. 2006). In previous studies, it has been recognized as one of the most important sources of atmospheric pollution (Saxena et al. 2021, Porichha et al. 2021, Mathur and Srivastava 2019), climate change and negative impacts on human health (Johnson et al. 2005, Li et al. 2016).

India alone produced 516 million tons of crop residues in the years 2017–2018, of which 116 million tons were burned. As a result, it produced roughly176.1 Mt CO_2, 10 Mt of CO, 0.31 Mt CH_4, 0.008 Mt N_2O, 0.151 Mt NH_3, 0.814 Mt NMVOC,0.453 Mt $PM_{2.5}$ (particulate matter) and 0.936 Mt PM_{10}. In India, previous studies were mostly limited to the states of Punjab, Haryana, Rajasthan and western part of Uttar Pradesh (Saxena et al. 2021, Porichha et al. 2021, Mathur and Srivastava 2019) mainly focused on the greenhouse gases emission due to CRB practice. However, Verma et al. (2019) identified the increased agricultural residue burning activity for the state of Madhya Pradesh (M.P.), which is almost 10 times more in 2016 than 2002 with an annual increase rate of 64%.

The major crops grown in the state of M.P. are paddy, wheat, soybean, sugarcane and maize. Further, in some places cultivation of jowar, moong, gram, tur, urad, mustard, groundnut and cotton are also observed. According to the agriculture department, M.P., paddy is sown in about 20 lakh hectares, soybean approximately 60 lakh hectares and wheat about 38 lakh hectares of land. The state generates close to 33 million tons of crop residues every year, of which 80% is contributed by cereal crops especially wheat and paddy. The total residue (3.6 million tones) are burned on fields. It results into the emission of approximately 5676.46 kg/year of greenhouse gasses of which CO_2 constitutes 5666.1 kg/year, CH_4 about 10.10 kg/year and N_2O about 0.26 kg/year (Tripathi, 2015). In addition to environmental and health effects, it may also deplete the quality of soil by emitting most essential nutrients like organic carbon, nitrogen, phosphorus and Potassium (Porichha et al. 2021). Post burning temperate of soil is increased up to 35.8-42.2°C (Jitendra et al. 2017), which may decrease the population of the beneficial micro-organisms like nitrogen fixing bacteria and mycorrhiza impacting the productivity of soil. The present paper aims to assess the impact of burning wheat crop residues on soil physico-chemical properties in Sagar district of M.P. in central India.

MATERIAL AND METHODS

Study area

The present study was conducted in different areas of the district of Sagar as CRB practice is very common alike other districts like Hoshangabad, Harda, Sehore and Vidisha. Sagar district lies in the north central region of Madhya Pradesh, located at 23°50′N latitude and 78°40′E longitude, the district has a truly central location in the country. The tropic of cancer passes through the southern part of the district. The climate is typically tropical monsoonal with well-defined three seasons viz., winter, summer and rainy. Average annual rainfall of the district is 1197mm chiefly received during rainy season from mid-June to September months. Winters are moderate with mean minimum temperature of 5°C during January. Summer season is hot and dry with maximum temperature of 45°C during the month of June. Occasional showers are also received during winter season. Soils in agricultural fields are mostly deep medium black. Wheat is the principal Rabi crop grown in the area during October to March/April and the other major crop grown from July to December/ January (kharif season). Selection of sites was based on the (1) history of burning practices, (2) types of crop cultivated, (3) growing season of the crop and burning period, (4) amount of residue generated by crops and (5) on the basis of frequency and periodicity of burning. On the basis of these criteria, five study sites are found suitable for the present study (Table 1, Fig. 1).

Field sampling and collection of data

For study purpose, soil samples were taken from the pre-burned and post-burned wheat crop fields at a depth of 0–10 cm. The post-burning soil samples were taken from the same field as the pre-burned samples within 72 hours following the burning of wheat crop residue. All the samples were immediately transferred to air tight polythene bags

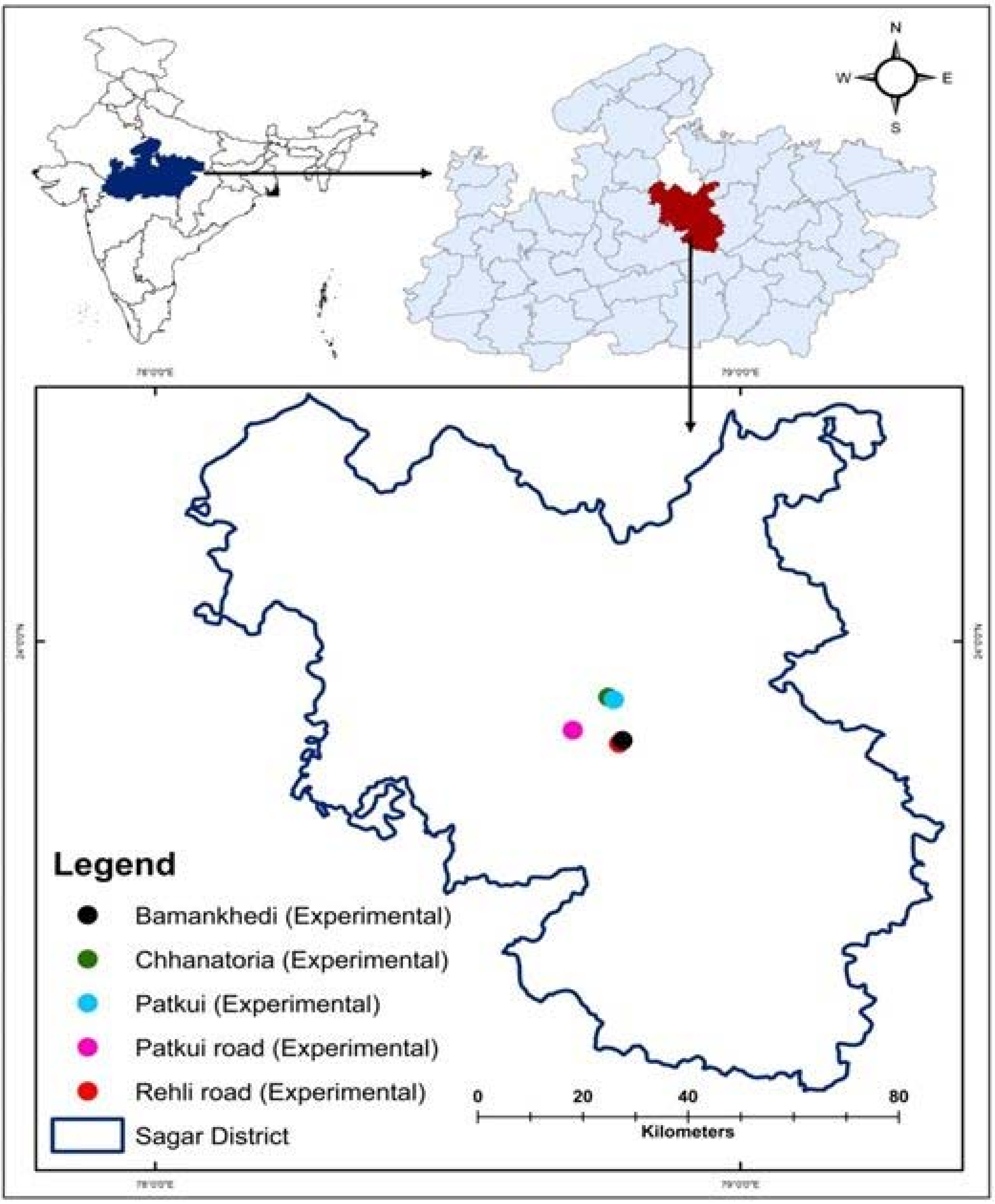

Figure 1 Study area map with soil sampling sites

Table 1. GPS locations of all of the study sites

Study sites	Name of study area	GPS co-ordinates	
Site 1	Patkui road (PR)	N 23º51’54.53”	E 078º45’55.97”
Site 2	Rehli Road (RR)	N 23º46’30.30”	E 078º49’18.54”
Site 3	Chhanatoria (CT)	N 23º52’40,91”	E 078º51’12.64”
Site 4	Patkui village (PV)	N 23º52’18.7"	E 078º46’20.9"
Site 5	Bamankhedi (BK)	N 23º50’57.71"	E 078º42’59.80"

and brought to laboratory for further studies. Temperature of the soil was measured using soil thermometer. Soil samples were sun dried for 2-4 days. Samples was ground and sieved through 2 mm sieve. Thereafter, Samples of a site were mixed and made composites.

Quantification and characterization of soil chemical properties

The impact of wheat crop residue burning on soil were analyzed for organic carbon, macronutrients (N, P, K) and micronutrients of soil in before and after burning period. Three replicates were taken for both of the sample composites (before and after residues burning) for analysis. Standard procedures were followed for analysis of different chemical parameters of soil. Electrical conductivity (EC) and pH was measured by electrical conductivity meter and pH meter respectively. Determination of soil organic carbon (SOC) was done by volumetric method (Walkley and Black 1934), available Nitrogen (extracted with alkaline permanganate) by Kjeldahl Method (Subbiah and Asija 1956), available phosphorus extracted with Olsen's method for phosphorus estimation (Olsen et al. 1954) and potassium using flame photometric method (Tooth and Prince 1949). Further, available Zinc, Copper, Iron and Manganese estimation was done by DTPA (Diethylenetriaminepentaacetic acid) extractant with the help of Atomic Absorbtion Spectrophotometer (AAS) (Lindsay and Norvell 1978).

RESULTS

Impact of wheat crop residue burning on soil pH, EC and moisture content

The pH analysis of the soil samples collected from each study sites shows that the soil of the area is alkaline in nature. The pH of soil before residue burning ranged from 7.55 to 8.03 being highest in Rehli Road (RR) site and lowest in Bamankhedi (BK) site and after residue burning, the pH of sample

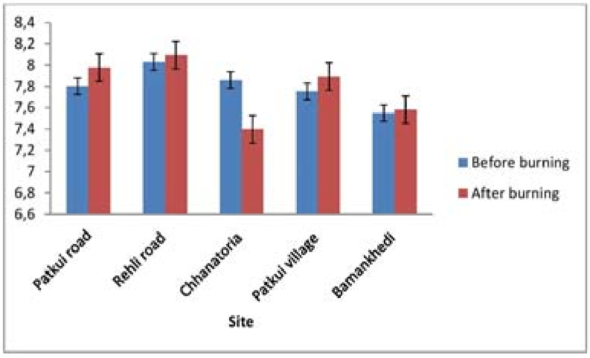

Figure 2. Comparison of pH of soil samples collected before and after wheat residue burning

varied from 7.39 in Chhanatoria (CT) site to 8.09 in BK site. Most of the sites showed a little increase in soil pH in after residue burning class as compared to before residue burning class (Fig. 2). However, no significant difference was observed in soil pH amongst the samples collected from before residue burning and after burning (Table 2).

Similarly, the EC of soil samples before residue burning showed a decreasing trend for three sites and increasing trend for two sites compared to after residue burning. EC of samples before burning class varied from 128.4±0.81 µs/ppm to 306.6±17.9 µs/ppm being highest in Patkui village (PV) site and lowest in RR site. Further, it ranged from 184.1±4.25 µs/ppm to 295.8±7.25 µs/ppm for soil samples collected after residue burning, and it was highest in PV site and lowest in RR site (Fig. 3). The EC of before residue burning and after residue burning showed significant difference for RR site (Table 2). The moisture content (MC) (%) was higher in before residue burning class compared to after residue

Table 2. pH and EC of soil samples collected before and after wheat residue burning.

Study area	pH		EC (µs/ppm)		Moisture content	
	BB	AB	BB	AB	BB	AB
PR	7.8±0.08 [a]	7.98±0.04 [a]	278.73±6.2 [a]	267.4±2.2 [a]	8.10 [a]	7.05 [a]
RR	8.03±0.04 [a]	8.09±0.01 [a]	128.4±0.8 [a]	184.1±4.2 [b]	8.05 [a]	4.62 [a]
CT	7.86±0.08 [a]	7.39±0.10 [a]	252.57±7.6 [a]	249.67±4.5 [a]	24.13 [a]	20.37 [a]
PV	7.75±0.02 [a]	7.89±0.03 [a]	306.6±17.9 [a]	295.8±7.2 [a]	21.26 [a]	13.70 [b]
BK	7.55±0.04 [a]	7.58±0.04 [a]	268.1±2.5 [a]	283.47±2.4 [a]	19.12 [a]	12.11 [b]

BB: before burning and AB: after burning. All the data are presented as Mean ± SE. Different letter in same row for a parameter indicates significant differences between before burning and after burning at $P<0.05$ for Chi square test.

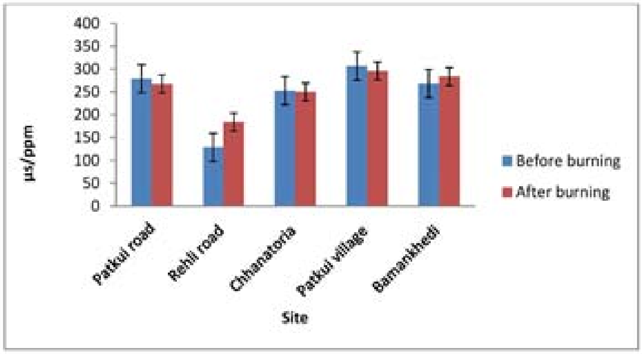

Figure 3. Comparison of EC of soil samples collected before and after wheat residue burning

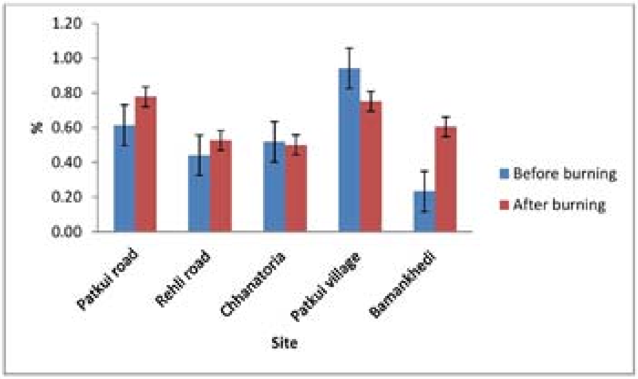

Figure 4. Comparison of SOC (%) of soil samples collected before and after wheat residue burning

burning class for all of the sites. For samples in before burning class, the MC was highest for Chhanatoria (CT) site (24.13) site and lowest for RR site (8.05). Similarly for after residue burning class, the MC was highest for CT (20.37) site and lowest for RR site (4.62). The MC of samples in before residue burning class showed a significant difference than the samples of after biomass burning class for PV site and BK site.

Impact of wheat crop residue burning on SOC, and macronutrients (N, P and K) content

The SOC (%) of soil samples before biomass burning ranged from 0.233±0.14 in BK site to 0.942±0.28 in PV site. Further, SOC of samples collected after biomass burning ranged from 0.501±0.49 I CT site to 0.778±0.35 in PR site (Fig. 4). Though significant difference was not observed between samples collected before and after biomass burning, a slight increase in SOC was found in after burning samples (Table 3). The nitrogen content (kg/ha) of soil samples before biomass burning ranged from 62.72±0.06 kg/ha in RR site to 137.984±0.06 kg/ha in BK site. Further, nitrogen content of soil samples after biomass burning ranged from 56.448±0.06 kg/ha in RR site to 94.08±0.06 kg/ha in PR site. A decrease in soil nitrogen content was observed in post burning samples (Fig. 5). A significant difference was observed for BK site in before and after burning (Table 3). The phosphorous content of soil samples, before biomass burning ranged from 7.964±0.001 to 24.059±0.003 kg/ha and from 6.388±0.001 kg/ha to 19.413±0.002 after biomass burning. No specific trend was observed for phosphorous content amongst before and after burning (Fig. 6). However, a significant difference was observed between the soil samples for CT site (Table 3). Soil potassium showed an increase in after burning samples (Fig. 7). However, two sites i.e. CT site and PV site showed a significant increase in potassium content of soil

Table 3. Organic carbon of soil samples (SOC), Nitrogen (N), Phosphorus (P) and Potassium (K) collected before and after wheat residue burning

Study	SOC (%)		N(kg/ha)		P(kg/ha)		K(kg/ha)	
area	BB	AB	BB	AB	BB	AB	BB	AB
PR	0.61±0.28 [a]	0.78±0.35 [a]	81.54±0.06 [a]	94.08±0.06 [a]	10.04±0.001 [a]	10.62±0.0015 [a]	88.27±0.005 [a]	88.35±0.19 [a]
RR	0.44±0.14 [a]	0.53±0.14 [a]	62.72±0.06 [a]	56.445±0.06 [a]	8.30±0.002 [a]	6.39±0.001 [a]	98.72±0.08 [a]	87.10±0.08 [a]
CT	0.52±0.21 [a]	0.50±0.49 [a]	87.81±0.06 [a]	75.26±0.06 [a]	24.06±0.003 [a]	9.37±0.001 [b]	36.86±0.03 [b]	53.84±0.09 [a]
PV	0.94±0.28 [a]	0.75±0.14 [a]	87.81±0.06 [a]	75.26±0.06 [a]	15.51±0.001 [a]	19.41±0.002 [a]	71.11±0.2 [b]	103.57±0.11 [a]
BK	0.23±0.14 [a]	0.61±0.07 [a]	137.98±0.06 [a]	68.99±0.06 [b]	7.96±0.001 [a]	7.47±0.001 [a]	71.55±0.2 [a]	74.15±0.12 [a]

BB: before burning and AB: after burning. All the data are presented as Mean ± SE. Different letter in same row for a parameter indicates significant differences between before burning and after burning at $P<0.05$ for Chi square test.

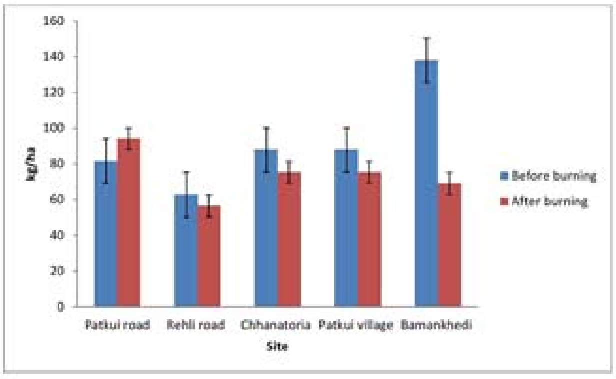

Figure 5. Comparison of Nitrogen (kg/ha) of soil samples collected before and after wheat residue burning

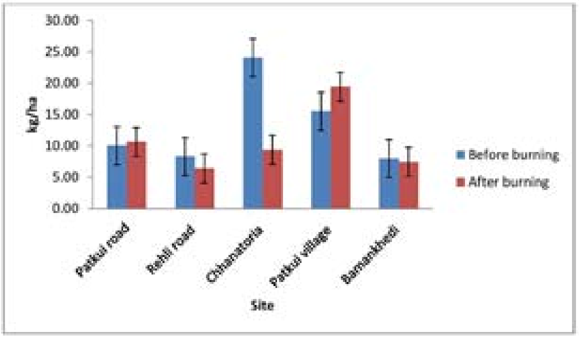

Figure 6. Comparison of Phosphorous (kg/ha) of soil samples collected before and after wheat residue burning

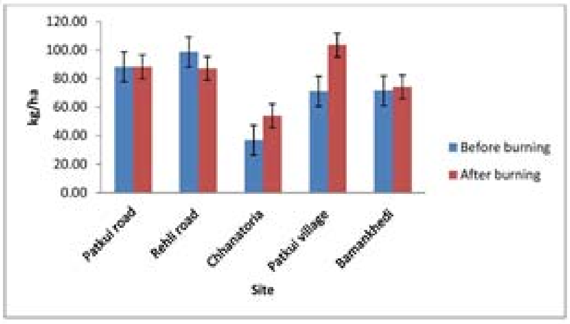

Figure 7. Comparison of Potassium (kg/ha) of soil samples collected before and after wheat residue burning

samples collected before and after biomass burning (Table 3).

Impact of wheat crop residue burning on micronutrients (Cu, Zn, Mn and Fe) content

The copper and zinc content of soil samples showed a decrease after biomass burning. However, no significant differences were observed. On the other hand, Mn and Fe did not show any general trend in after burning class. Mn and Fe content were found decreased for the remaining 2 sites and Fe content increased for 2 sites and decreased for remaining three sites. Further, significant difference for Mn content was observed for samples collected in BK site and other observations are insignificant (Table 4).

DISCUSSION

Assessment of the quality of soil acts as an important factor for the management and cultivation of different crops. Further, the appropriate quantity of available macro and micronutrients plays a crucial role in maintaining soil quality. In the present study, we found an increased trend in soil samples collected after biomass burning than before biomass burning for pH and EC for most of the sites. The increase in soil pH might be due to the presence of ash in soil (Molina et al. 2007, Schafer and Mack 2010). Further, in previous study, it was reported that the formation of oxides, hydroxides and carbonates of sodium and potassium in surface soil plays a crucial role in increasing soil pH (Ulery et al. 1993). Further, the increase in soil EC might be contributed to the collapsing of aggregates and clogging of voids by the ash and dispersed ions (Boerner et al. 2009, Certini 2005). Moreover, similar trend was observed for soil MC. The decrease in MC was due to the evaporation of moisture from soil as a result of the increase in temperature of the upper soil surface. In previous study, it was observed that the burning of agricultural residues could increase the temperature to just about 35.8-42.2°C at 10 mm depth (Jitendra et al. 2017).

The macro and micro-nutrients have an influence on crop productivity and vegetation dynamics (Ganorkar et al. 2017). The result of the present study clearly indicates the increasing trend for the SOC from before burning to after burning. It might be due

Table 4. Micronutrients (Cu, Mn, Fe, Zn) of soil samples collected before and after wheat residue burning.

Study area	Cu		Mn		Fe		Zn	
	BB	AB	BB	AB	BB	AB	BB	AB
PR	2.96 [a]	2.89 [a]	9.86 [a]	9.91 [a]	7.78 [a]	8.41 [a]	2.18 [a]	2.56 [a]
RR	1.51 [a]	1.3 [a]	9.42 [a]	9.59 [a]	13.01 [a]	14.15 [a]	3.36 [a]	2.47 [a]
CT	2.83 [a]	2.19 [a]	10.24 [a]	7.24 [a]	15.2 [a]	13.7 [a]	2.21 [a]	1.67 [a]
PV	3.28 [a]	2.9 [a]	6.3 [a]	8.73 [a]	10.31 [a]	9.15 [a]	4.89 [a]	3.25 [a]
BK	1.74 [a]	1.82 [a]	9.85 [a]	4.26 [b]	11.7 [a]	8.65 [a]	3.74 [a]	1.95 [a]

BB: before burning and AB: after burning. Different letter in same row for a parameter indicates significant differences between before burning and after burning at $P<0.05$ for Chi square test.

to the increase of carbon mineralization process during the burning of wheat straw (Bird et al. 1999). Further, a decreasing trend was observed for nitrogen and phosphorus content of soil samples. The lower values of nitrogen and phosphorus content of soil samples in after burning samples than before burning sample might be due to the volatilization process during the burning of agricultural biomass (Certini 2005, Neary et al. 1999, Caldwell et al. 2002). In the present study, we found that the K content was higher in soil samples collected after burning period compared to before burning period. Similar result was observed in previous study (Neff et al. 2005). It might be due to the leaching of extractable K and mineralization of cations from burned crop residues (Chaudhari and Jichkar 2012). Further, in earlier study, it was reported that K is the main indicator of crop residue burning (Singh et al., 2013). Moreover, the previous study of Mandal et al. (2004) revealed that the burning of what and rice residues contribute to a loss of about 80% nitrogen, 25% phosphorus, 21% potassium and 4-60% of soil sulphur. As a result the quality of soil get depleted which is detrimental for sustainable agriculture.

CONCLUSIONS

In the present study, we found 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. Further, the values of important macronutrients e.g. nitrogen and phosphorus and micronutrients e.g. copper and zinc get decreased after the burning of crop residues. Result of the present study clearly indicates the negative impact of on farm wheat residue burning on the quality of soil. Although insignificant differences were observed at $P<0.05$ in almost all of the physical and chemical parameters of the soil after crop residue burning for most of the sites, the decreasing level of these important parameters will significantly deplete the quality of soil. As a result, the fertilizer requirement for the next crop will increase which will lead to add financial burden to the farmers. Further, due to the increase in temperature, the number of beneficial microbes and fauna get decreased, which will further add to the requirements of fertilizers. Therefore, we suggest the development of new and environment friendly strategies for the management of crop wastes.

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Authors' contributions: All authors contributed equally

Conflict of Interest: The authors declare that they don't have any conflict of interest.

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