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Bio-chemical properties and nutrient availability in soil as influenced by *in-situ* paddy residue burning in semi-arid region of Punjab

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Abstract
The study compared the effects of paddy residue burning on soil bio-chemical properties and nutrients of arid soils collected from different villages of Sangat block, Bathinda, Punjab. Soil dehydrogenase activity ranged from 42.9- 57.4and 14.0- 23.7 µg TPF produced $g^{-1}h^{-1}$in upper soil (0-15 cm), 38.0- 48.5and 14.9-48.5µg TPF produced $g^{-1}h^{-1}$ in lower soil (15-30 cm)under unburned and burned conditions.Due to residue burning the DHA was decreased, ranged from 48.9 - 73.5% and 51.0- 64.4% in upper and lower soil respectively. The acid phosphatase activity ranged from 92.5- 136.9 µg pNP produced $g^{-1}h^{-1}$ in upper soil (0-15 cm) and 85.1-121.1 µg pNP produced $g^{-1}h^{-1}$ in lower soil (15-30 cm) under unburned location. Similarly, it varied between 41.3-65.8 and 47.4-72.9 µg pNP produced $g^{-1}h^{-1}$ in upper and lower layers in burned condition. The residue burning decreased acid phosphatase activity from 47.7 - 67.3 % in upper (0-15 cm) soil and 33.6 - 61% in lower (15-30 cm) soil. Likewise, alkaline phosphatase varied 109.5-154.9 and 54.9-78.5µg pNP produced $g^{-1}h^{-1}$ in upper soil (0-15 cm) and 97.5-143.6 and 63.8-97.2 µg pNP produced $g^{-1}h^{-1}$ in lower soil (15-30cm) under unburned and burned situation. The alkaline phosphatase activity decreased between 44.0- 61.5% in upper layer and 17.5 -55.6% in lower layer by stubble burning. The soil reaction (pH) of soils ranged from 8.2-8.6 and 8.3- 8.7 in upper (0-15cm) and lower (15-30cm) soil under unburned soil conditions and increased by 1.8- 9.8 % in upper (0-15cm) and 1.0- 9.5% in lower (15-30 cm) soil. Like soil pH, electrical conductivity (EC) was also increased and ranged from 0.38 -1.29 dSm^{-1} in upper soil (0-15cm) and 0.29-0.93 dSm^{-1} in lower soil (15-30 cm) under unburned conditions, whichwas increased from 1.2 -7.4% and 0.2-4.8 % in upper and lower soils, respectively. Soil organic carbon ranged from 4.5-7.6 and 1.6-5.7 mg kg^{-1} in upper (0-15 cm) and lower (15-30 cm) soil layer under unburned conditions and decreased by 44.4 - 76.9% and 31.3- 74.2% in upper and lower layer due to residue burning, respectively. The N and S availability under unburned conditions was reported between 260 -325 mg kg^{-1} and 34.5 -64.8 mg kg^{-1} in upper soil (0-15 cm) and 222.6 -283.4 mg kg^{-1} and 27.1 -53.7 mg kg^{-1} in lower soil (15-30 cm) layer. The residue burning decreased the N and S by 59.0-66.5% and 37.7- 49.0% in upper (0-15 cm) soil and 44.5-56.3% and 28.4-36.3% in lower (15-30 cm) soils, respectively. Under unburned conditions P and K ranged from 30.9-45.3 mg kg^{-1} and 254.0- 403.8 mg kg^{-1} in upper (0-15 cm), while its, ranged from 28.1-37.5 mg kg^{-1} and 160.4-310.3 mg kg^{-1} in lower (15-30 cm) soil. The residue burning increased P and K availability by 1.2-10.7% and 5.9- 20.3% in upper (0-15 cm) soil, 1.1-7.2 % and 2.3-25.07% in lower (15-30 cm) soil, respectively.

Keywords: Paddy residue, burning, dehydrogenase, phosphatases, nutrient availability

Introduction
The paddy- wheat cropping system is an extensively practiced in north western states of India, widespread throughout the riverine plains of Haryana and Punjab and produce a huge amount of agricultural wastes in the form of straw and stubbles. The agricultural residue mainly leaves and stubbles are utilized as animal fodder, roofing and shedding of homes, cattle shed, domestic usage fuel and small scale industrial raw material and fuel. Still, a bulky part of the stubbles and straw is not employed and remains in the agricultural farms. The dumping of huge quantity of farm yield residue is a far reaching problem for the farmers. The disposal of paddy straw is a serious concern due to its huge bulk material and slow degradation rate. Moreover, it cannot be used as animal feed because of its low digestibility, low protein, high content of lignin and silica. Due to many problems the straw is disposed through open-burning, which causes soil nutrient losses as well as serious environmental problems. The Punjab occupies only 1.53 per cent of India's geographical area but contributes the most to the central rice procurement pool. About 133.82 tonnes of rice was produced during *Kharif*2017-18 [1]. Farming practices for harvesting rice and wheat are highly mechanised in the state and leave a huge amount of scattered, root-bound paddy straw in the field.Farmers have only 10-15 days between harvesting paddy and planting the next crop.

Since that is not enough time to clear and prepare the fields, and removing the rice straw left in the field is a labour-intensive exercise,they burn the paddy residue (stubble) in situ under open environment. An open-burning crop residue in field produces hydrophobic components of organic matter, vaporizes big part of organic matter in the top soil, and adversely affects the soil conditions. Yilmaz*et al.*[2] found soil respiration rates significantly decreased after wheat stubble burning in the south eastern Turkish Plain soils of 0 to 3 cm depth and concluded that soil functions and bioactivity were strongly dependent on the retaining the stubble residues of wheat in those soils. Open burning of crop residuals are aimed at timely and budgetary management of the soil for the next crop[3, 4, 5]. The crop residue burning not only causing environmental problems but also affects soil health. Therefore, the study was carried out to assess the effect of open-field rice residue burning on bio-chemical properties and nutrient availability in soil undersemi arid region.

Materials and methods

Bathinda district is situated in the southern part of Punjab, lies between 29 °33' and 30 °6' North latitude and 74 °38' and 75°46' East longitude. The surveyed area (Fig. 1) Sangat block (30°211' N latitude and 74°945' E longitude) falls in semi-arid region of Punjab. In the present study from each villages, five surface (0-15cm) and sub surface (15-30cm) soil samples were collected from 10 villages of Sangat block after harvesting of paddy crop during *Kharif*2018. As the farmers fired the residues in scattered manner, therefore, samples collected from completely residue burned area, referred as burned field condition and samples collected from unburned area of same field referred as unburned field conditions. The samples were collected in labelled plastic bags and transferred immediately to the laboratory. The samples were passed through 2-mm sieve and divided into two fractions: one fraction for the determination of chemical fractions, which were kept at room temperature and the other fraction for measuring soil biological parameters which was stored at 4ºC. Dehydrogenase activity (DHA) in soil was determined using the reduction of 2, 3, 5-triphenyltetrazolium chloride (TTC) method [6],and the colour intensity was measured at 485 nm by spectrophotometer. The DHA was expressed as microgram (µg) triphenylformazane (TPF) produced g^{-1} dry soil h^{-1} at 37°C. Acid and alkaline phosphatase activity were estimated following the method reported by Tabatabai and Bremner[7], after soil incubation with modified universal buffer (pH 6.5 for acid phosphatase and pH 11.0 for alkaline phosphatase) and p-nitrophenyl phosphate (ρ-NP) at 37°C, the producedyellow colour intensity was measured colorimetrically at 440 nm. Acid and alkaline phosphatase activities were expressed as microgram (µg) ρ-nitro phenol produced g^{-1} dry soil h^{-1}.The pH and EC of the soils were determined in 1:2 soil-water suspensions using a glass electrode pH meter and conductivity meter respectively [8]. The organic carbon was determined by wet digestion method [9]. Available nitrogen was determined by alkaline potassium permanganate distillation method as described by Subbiah and Asija[10].The available P in the soil was extracted by employing Olsen extractant (0.5M $NaHCO_3$, pH 8.5) as described by Olsen *et al.*[11]. Available S was determined by extracting soil samples with 0.15% $CaCl_2$ [12] and S in the extract was estimated by turbidimetric method [13]. The available K was extracted by using neutral ammonium acetate and the content was determined by aspirating the extract into flame photometer [8]. Microsoft Excel software (Microsoft Corporation, USA) was used for statistical analysis of data.

Results and discussion

Soil biological properties

The dehydrogenase activity (DHA) represents total microbial activity in soils showed in Fig. 2. It varied village to village and ranged from 42.9 µg TPF produced $g^{-1}h^{-1}$in Nandgarh to 57.4 µg TPF produced $g^{-1}h^{-1}$ in Jai Singh Wala in upper soil (0-15cm) and 38.0 µg TPF produced $g^{-1}h^{-1}$in KalJharani to 48.5 µg TPF produced $g^{-1}h^{-1}$in PakkaKhurd in lower soil (15-30cm) under unburned field conditions. However, it ranged from 14.0 µg TPF produced $g^{-1}h^{-1}$in Nandgarh to 23.7 µg TPF produced $g^{-1}h^{-1}$in Pakka Kala in upper soil (0-15cm) and 14.9 µg TPF produced $g^{-1}h^{-1}$in Machana to 487.5 µg TPF produced $g^{-1}h^{-1}$in Chak Attar Singh Wala in lower soil (15-30cm) under burned field conditions.The Fig. 1also revealed that due to stubble burning DHA decreased in both soil layer, ranged from 48.9- 73.5% and 51.0- 64.4% in upper (0-15 cm) and lower soil (15-30 cm), respectively. The acid and alkaline phosphatase activities of soils in different villages were presented in Fig. 2. The minimum (92.5 µg pNP produced $g^{-1}h^{-1}$) and maximum (136.9 µg pNP produced $g^{-1}h^{-1}$) acid phosphates activity was reported in Kaljharani and Machana, respectively with mean value of 116.9 µg pNP produced $g^{-1}h^{-1}$in upper soil layer (0-15cm) and 85.1 µg pNP produced $g^{-1}h^{-1}$(Kaljharani) to 121.4 µg pNP produced $g^{-1}h^{-1}$(Machana) with mean value of 104.2 µg pNP produced $g^{-1}h^{-1}$in lower layer (15-30cm) under unburned condition. Whereas, it varied from 41.3 µg pNP produced $g^{-1}h^{-1}$(Kaljharani) to 65.8 µg pNP produced $g^{-1}h^{-1}$(Pakka Kala) with mean value of 50.6 µg pNP produced $g^{-1}h^{-1}$in upper soil (0-15 cm) and 47.4 µg pNP produced $g^{-1}h^{-1}$(Machana) to 72.9 µg pNP produced $g^{-1}h^{-1}$(PakkaKalan) with mean value of 60.4 µg pNP produced $g^{-1}h^{-1}$in lower layer (15-30cm) under residue burnt soils. It was observed that residue burning decreased acid phosphatase activity in soils, ranged from 47.7 - 67.3 % in upper layer (0-15 cm) and 33.6 – 61.0 % in lower soil layer (15-30 cm). Minimum (109.5 µg pNP produced $g^{-1}h^{-1}$) and maximum (154.9 µg pNP produced $g^{-1}h^{-1}$) alkaline phosphates activity was reported in Ghudda and Machana, respectively with mean value of 133.2 µg pNP produced $g^{-1}h^{-1}$in upper soil layer (0-15cm) and 97.5 µg pNP produced $g^{-1}h^{-1}$(Ghudda) to 143.6 µg pNP produced $g^{-1}h^{-1}$(Machana) with mean value of 116.0 µg pNP produced $g^{-1}h^{-1}$in lower layer (15-30cm) under unburned situation. while, it ranged from 54.9 µg pNP produced $g^{-1}h^{-1}$(Jassibagwali) to 78.5 µg pNP produced $g^{-1}h^{-1}$(Nandgarh) with mean value of 65.2 µg pNP produced $g^{-1}h^{-1}$in upper soil (0-15 cm) and 63.8 µg pNP produced $g^{-1}h^{-1}$(Machana) to 97.2 µg pNP produced $g^{-1}h^{-1}$ (Nandgarh) with mean value of 77.4 µg pNP produced $g^{-1}h^{-1}$in lower layer (15-30cm) under residue burnt conditions. The alkaline phosphatase activity was decreased between 44.0% to 61.5% in upper layer (0-15 cm) and 17.5 % to 55.6% in lower layer (15-30 cm).

The soil biological properties were higher in the surface (0-15cm) as compared to sub surface soils (15-30 cm).The results suggest that microbial activity in surface soil was perhaps influenced by the inputs added as well as litter-fall. DHA in soil depends on the content of soluble organic carbon and, the increased organic matter in the surface soil enhances the soil enzyme activities [14]. This result is in agreement with the observation made by Adak *et al.* [15] and Yadav and Gupta [16].The heat generated from burning raises the soil temperature and causes depletion of the microbial population. The residue burning increase the sub soil temperature to nearly 33.8-42.2°C at 10mm depth [17] and decreased the number of soil micro-organisms, and negatively affected their distribution and activities[18,19]. Like dehydrogenase activity, acid and alkaline phosphatase activity was also higher in surface (0-15cm) soil compare to subsurface soil (15-30 cm). Alkaline phosphatase activity is derived from micro-organisms only, while acid phosphatase is contributed both by plant roots and soil-inhabiting microbes[20]. George *et al.*[21] reported a higher rhizospheric phosphatase activity in some agroforestry species. Alkaline reaction of the soil might also have increased alkaline phosphatase activity over acid phosphatase activity. The pH of the soil solution exerts a strong control on these enzyme activities [20]. Heat generated from burning of residue raises soil temperature leading to death of beneficial micro-organisms and decreased the acid and alkaline phosphatase activity in soils.According to many studies, soil micro-organisms were died at the temperature up to 50- 160ºC. Therefore, rice straw burning influenced not only the number and richness of microorganisms, but also caused a change of the distribution of soil microorganisms [22]. Prieto- Fernandez *et al.*[23] indicated that rice straw burning generally decreased the biomass of micro-organisms, but the impact on bacteria is greater than that on fungi [24].

Soil chemical properties

The data on soil pH and EC under both conditions (Fig. 3) revealed that pH of the soils ranged from 8.2-8.6 and 8.3- 8.7 in upper (0-15 cm) and lower (15-30cm) soil layers under unburned soil conditions. However, under burned conditions, pH increased and ranged from 8.8-9.2 with mean value of 8.9 and 8.9- 9.4 with mean value of 9.2 in upper (0-15 cm) and lower (15-30 cm) soil layers, respectively. The Fig. 3 also exposed that after residue burning pH was increased 1.8- 9.8 % at upper layer (0-15cm) and 1.0- 9.5% at lower (15-30 cm) soil. Similar to soil pH, soil ECwere also increasedand ranged from 0.38 -1.29 dSm^{-1} with mean value of 0.70 dSm^{-1} in 0-15cm soil layer and 0.29-0.93 $dSm^{-1}$with mean value of 0.51 dSm^{-1}in 15-30 cm soil layer under unburned soil conditions. Whereas, variation in EC was reported from 0.53- 1.32 dSm^{-1} with mean value of 0.77 dSm^{-1}in 0-15cm soil layer and 0.38-0.95 dSm^{-1} with mean value of 0.57 dSm^{-1}in 15-30 cm soil layer under burned soil conditions. It was also observed that due to residue burning in field the EC was increased from 1.2 -7.4% and 0.2-4.8 % in upper and lower soil layers, respectively. The organic carbon content of soils was presented in Fig. 3. A wide range of OC were reported, varied from 4.5 mg kg^{-1} in JasssiBhagwali to 7.6 mg kg^{-1} in Jai Singh Wala with mean value of 5.9 mg kg^{-1} in upper soil (0-15cm) and 1.6 mg kg^{-1} in Machana to 5.7 mg kg^{-1} in Bajak with mean value of 4.2 mg kg^{-1} in lower soil (15-30cm) under unburned conditions. However, it ranged from 1.5 mg kg^{-1} in PakkaKhurd to 2.7 mg kg^{-1} in Jai Singh Wala with mean value of 2.2 mg kg^{-1} in upper layer (0-15cm) and 0.7 mg kg^{-1} in JasssiBhagwali to 3.1 mg kg^{-1} in Bajak with mean value of 2.1 mg kg^{-1} in lower soil (15-30cm) under burned conditions.The Fig. 3 also revealed that OC was decreased in both soil layer, ranged from 44.4 - 76.9% and 31.3- 74.2% in upper (0-15cm) and lower (15-30cm) soil layer due to stubble burning, respectively.

The higher soil pH in lower layers could be due to increase in accumulation of exchangeable of cations. This finding is in agreement with Yadav and Gupta [16] and Yadav*et al.*[25] and who reported increased in soil pH with increased in soil depth.The upper soil layers showed higher EC as compared to lower layers, due to salts released through weathering in the arid/semi-arid regions with limited rainfall are usually deposited at some depth in the soil profile. Similar findings were also reported Yadav and Gupta [16] and Yadav*et al.*[25].The residue burning resulted increase in soil pH value may be due to ash, acieration due to burning and buffering capacity of the soil. Snyman[26] stated that ash material due to burning of plant biomass is a rich source of cations. Similarly, Soil EC was also increased in this study due to residue burning; which was supported by findings of Liexiang Li *et al.*[27] and Kaur *et al.*[28].The more organic carbon as compared to lower layer may be due to incorporation of FYM and crop residues in soils. Decreased in organic carbon was also observed by Yadav and Gupta [16] and Yadav*et al.*[25] with increase in soil depth. Rice stubble burning decreased the organic carbon in both soil layers, due to combustion of organic matter and release in the atmosphere [29].

Soil nutrient availability

The nitrogen availability under unburned conditions was reported between 260 -325 kg ha^{-1} with mean value of 295 kg ha^{-1} in 0-15 cm soil layer and between 222.6 -283.4 kg ha^{-1} with mean value of 252.3 kg ha^{-1} in 15-30 cm soil layer (Fig. 4). Due to residue burning, the nitrogen availability in soils decreased and ranged between 101.8- 110.2 kg ha^{-1} with mean value of 106.6 kg ha^{-1} in 0-15 cm soil layer and between 109.5 -147.9 kg ha^{-1} with mean value of 126.1 kg ha^{-1} in 15-30 cm soil layer. It was also observed that upper soil layer lost higher (59.0-66.5%) nitrogen compared to lower soil layer (44.5-56.3%). Similar to nitrogen, the available S were reported between 34.5 -64.8 kg ha^{-1} with mean value of 51.2 kg ha^{-1} in 0-15 cm soil layer and between 27.1 -53.7 kg ha^{-1} with mean value of 41.2 kg ha^{-1} in 15-30 cm soil under unburned conditions (Fig. 4). Due to residue burning, the S availability decreased and ranged 20.1- 37.8 kg ha^{-1} with mean value of 29.3 kg ha^{-1} in 0-15 cm soil layer and ranged 17.8 -35.5 kg ha^{-1} with mean value of 27.5 kg ha^{-1} in 15-30 cm soil layer. It was also observed that upper soil layer lost higher (37.7- 49.0%) S as compared to lower soil (28.4-36.3%). Higher organic matter and microbial activity are responsible for higher N and S in upper soils compared to lower soils, as soil organic matter is a critical source of nitrogen and sulphur in soil [30]. Low N and S were reported in residue burning conditions as compared to unburned conditions. The soil organic matter is critical source of nitrogen and sulphur in soil. So, loss of soil organic matter through burning has a great potential to reduce N and S availability in soil. Decreased in nitrogen content in organic matter and direct volatilization of N was reported by Wan *et al.*[31]. The available P and K in soil under both conditions (Fig. 5) shown that under unburned soil conditions P and K ranged from 30.9-45.3 kg ha^{-1} with mean value of 38.04 kg ha^{-1} and 254.0- 403.8 kg ha^{-1} with mean value of 332.6 kg ha^{-1} in upper soil (0-15 cm), while, it varied from 28.1-37.5 kg ha^{-1} with mean value of 32.8 kg ha^{-1} and 160.4-310.3 kg ha^{-1} with mean value of 236.9 kg ha^{-1} in lower soil (15-30cm). However, due to residue burning P and K ranged from 34.2-45.9 kg ha^{-1} with mean value of 39.77 kg ha^{-1} and 301.3-440.5 kg ha^{-1} with mean value of 380.2 kg ha^{-1} in upper soil (0-15 cm), although it ranged from 29.8-38.9 kg ha^{-1} with mean value of 34.3 kg ha^{-1} and 173.6-320.3 kg ha^{-1} with mean value of 263.8 kg ha^{-1} in lower soil (15-30cm).The P and K availability was increase by 1.2-10.7% and 5.9- 20.3% in 0-15cm,1.1-7.2 %and2.3-25.07% in 15-30 cm, due to residue burning. The upper soil layers contained higher available P and K compared to lower layer in the study. The high available P content is attributed to the regular application of phosphatic fertilizers and the immobile nature of phosphate ions in soils which must have resulted in accumulation of P in soils. Whereas, higher content of available K is attributed to the prevalence of Illite - a potassium rich mineral in these soils. Moreover, as the ground waters of south-western district have considerable amount of dissolved potassium, irrigation with such waters also results in higher amounts of available K in these soils [32]. Medium to high P and K content in soils of arid tract of Punjab has also been reported [25, 33, 34].The available P was higher in burnt conditions compared to un-burnt conditions, due to results of heating induced mineralization of organic P and release of aborbed P [35] as well as supply of P during frequent ash from the burnt residues.Snyman[36] and Sommer*et al.*[37] reported that virtually all the phosphorus content of standing phytomass were added to the soil as ash, and P is a less mobile soil nutrient. Similarly, due to heating during residue burning, K is also released from lattice layers of K bearing minerals present in the soil. Many researchers [27, 28, 38, 39] also reported that soil available P and K content were increased due to in-situ residue burning.

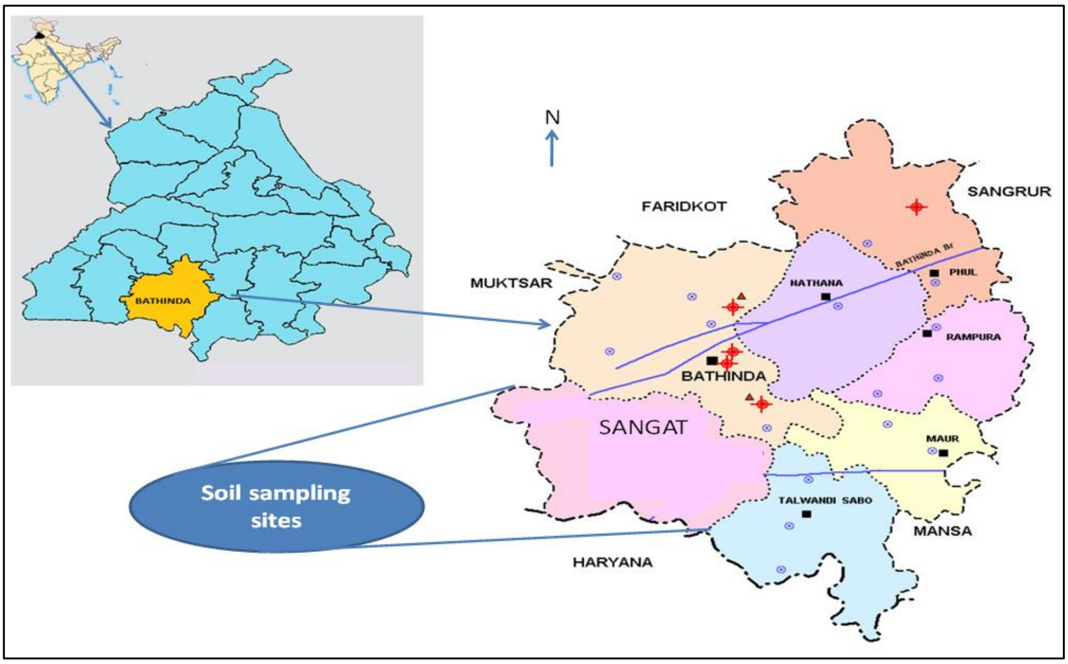
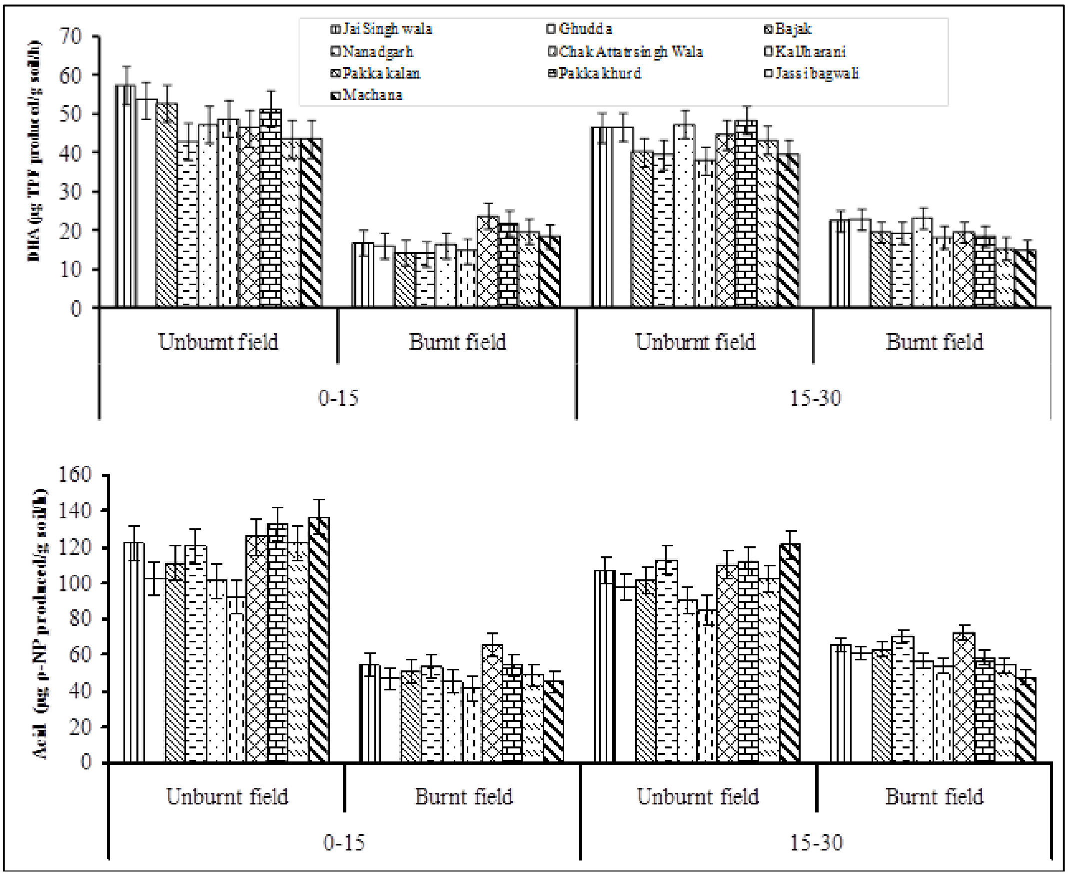


Fig 1: Location map of the surveyed area.



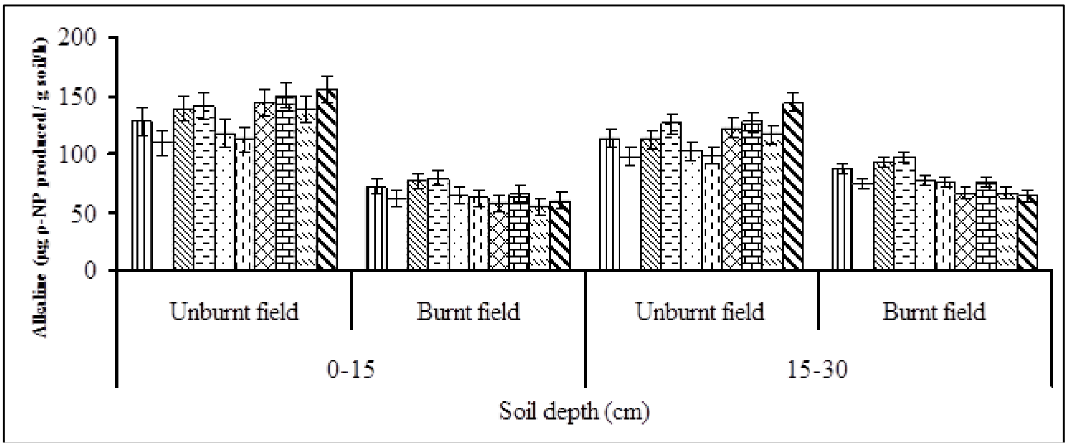


Fig 2: Dehydrogenase and phosphatase activity of soil under unburned and burned field conditions (Bars represent the standard error of mean).

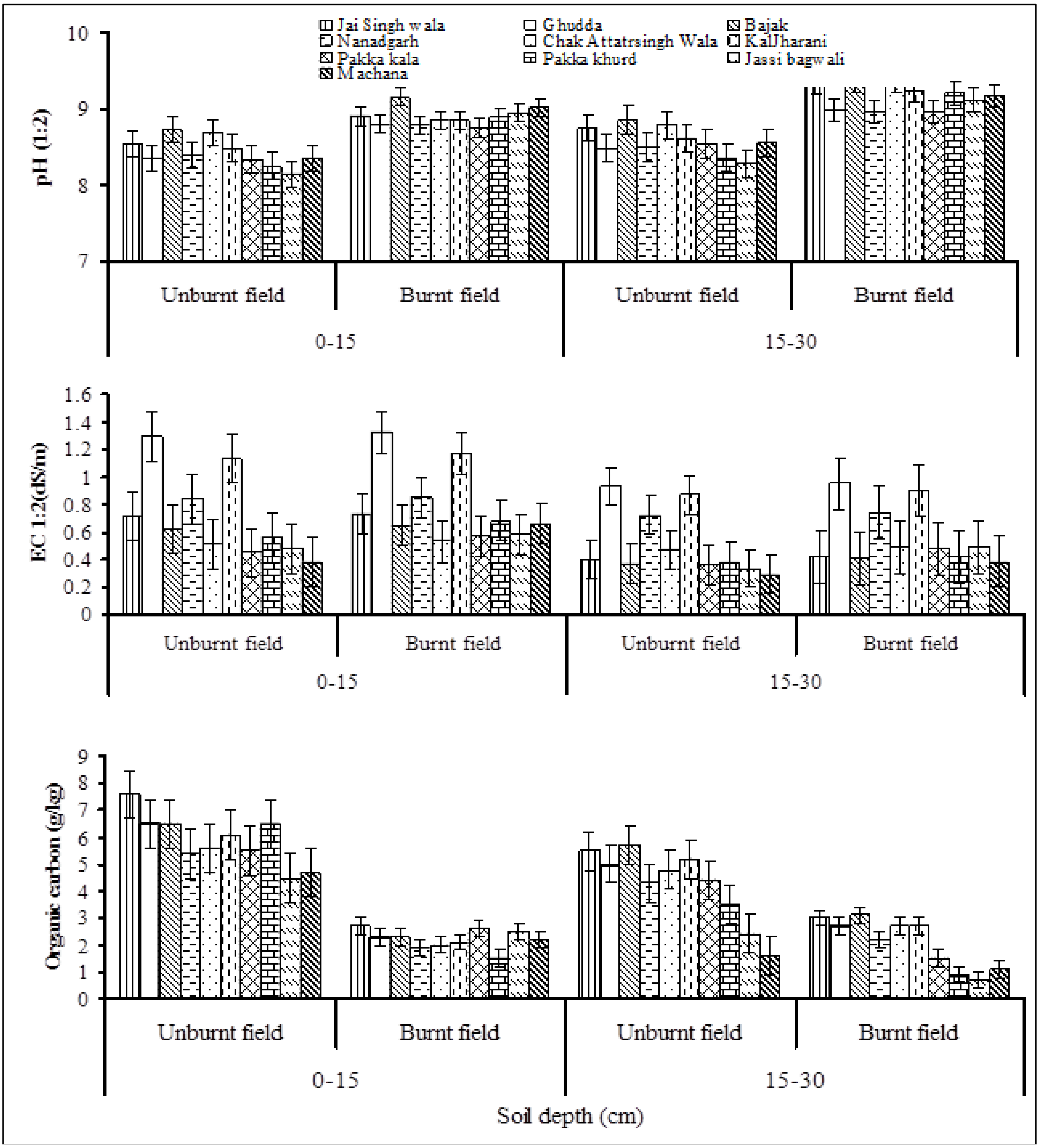
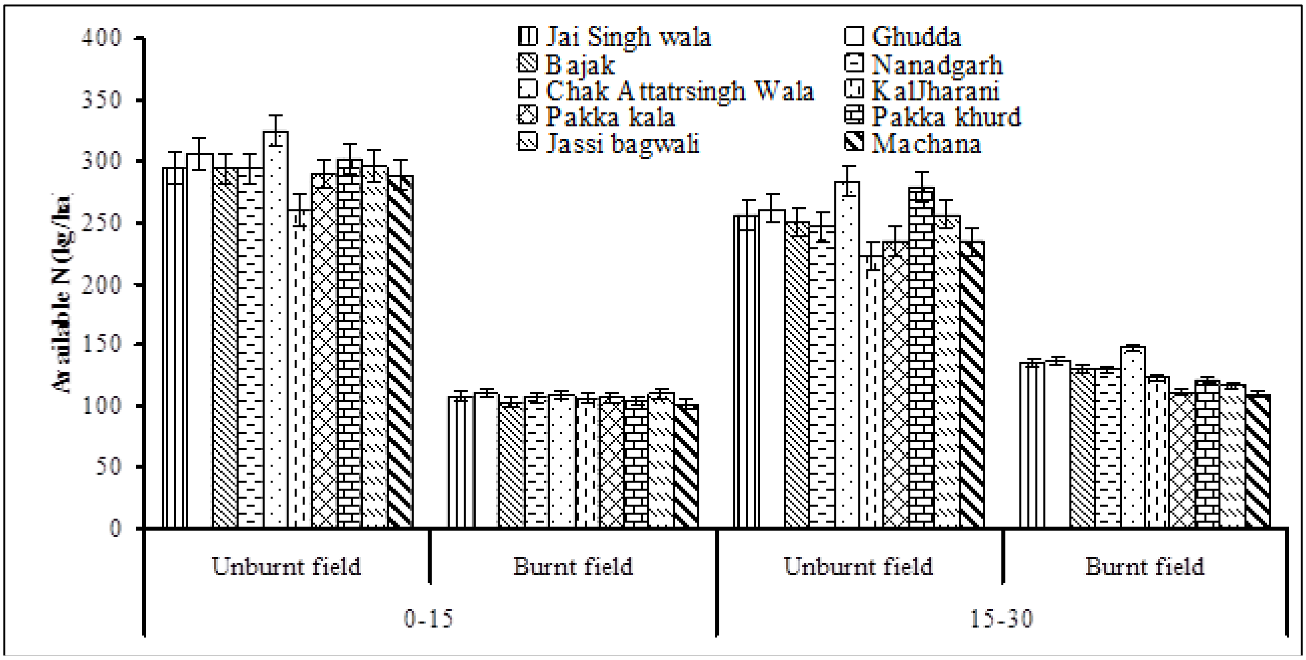


Fig 3: Soil reaction (pH), electrical conductivity (EC) and organic carbon of soil under unburned and burned field conditions (Bars represent the standard error of mean).



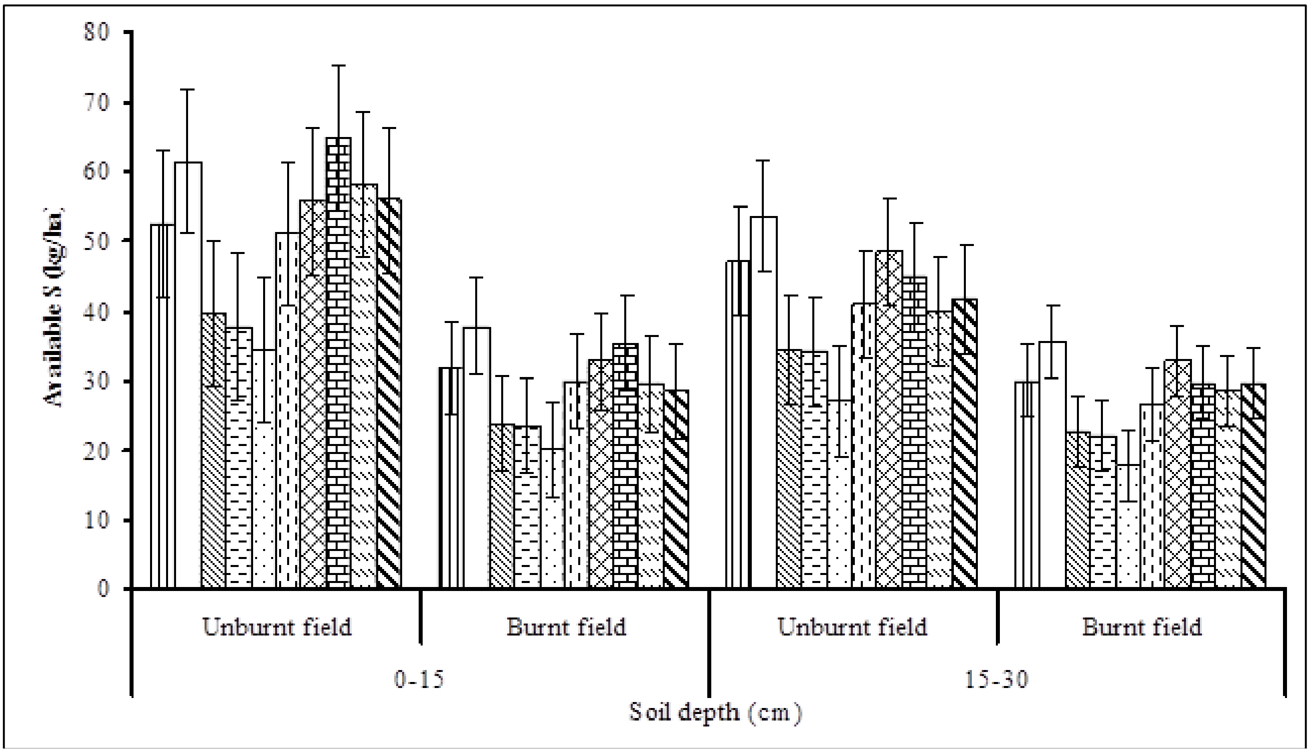


Fig 4: Available N and available S of soil under unburned and burned field conditions (Bars represent the standard error of mean).

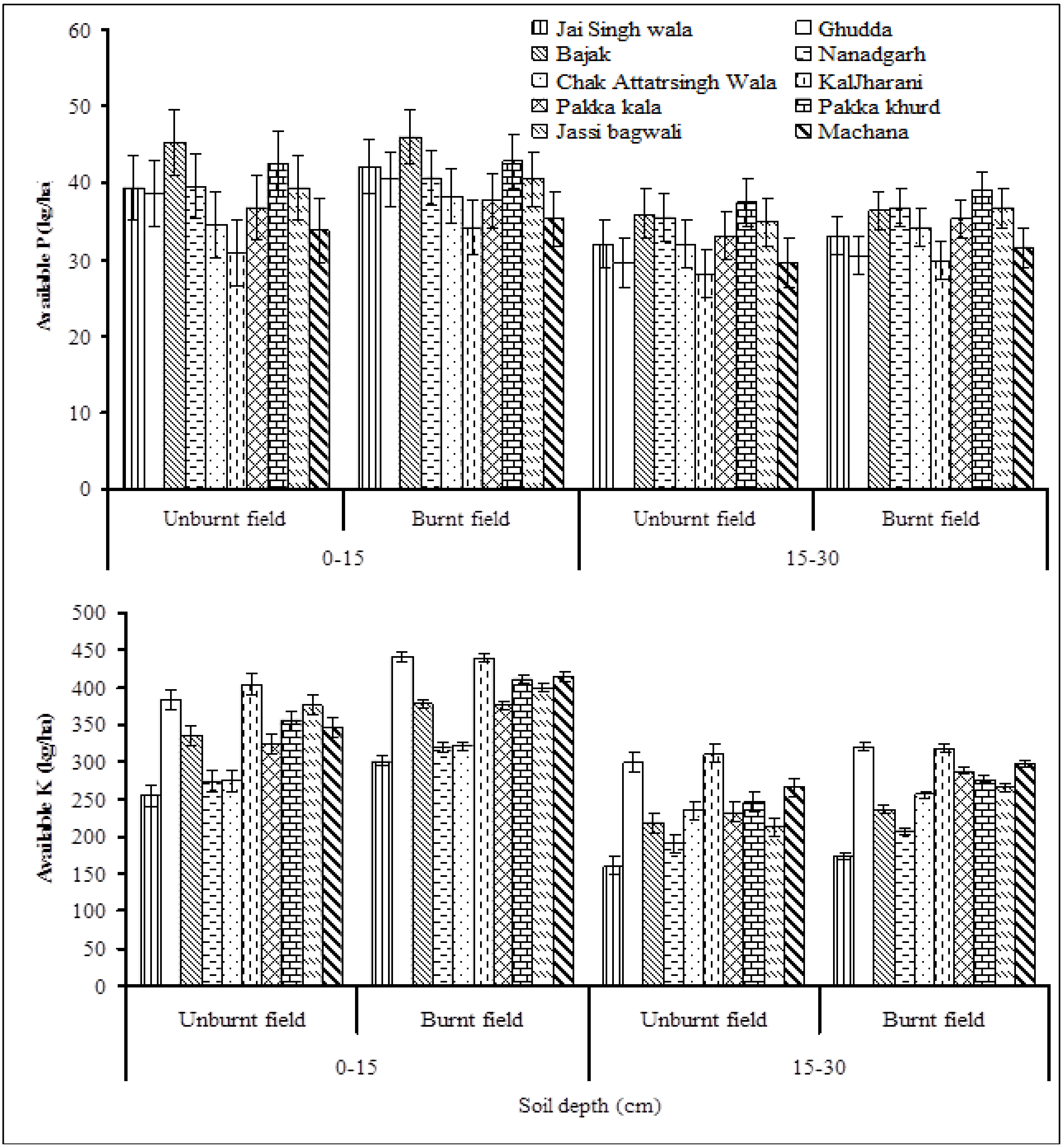


Fig 5: Available P and available K of soil under unburned and burned field conditions (Bars represent the standard error of mean).

Conclusion

Crop residue burning influences the biochemical properties and nutrient availability in soil. The burning leads to decreased microbial population, enzymes activity and loss of nutrients (N and S), increased soil pH and electrical conductivity, which are not suitable for plant growth. The nutrient deficiency increased fertilizer requirement for crops and add to the extra financial burden of the farmers. An increase in soil pH and EC is attributed to the presence of ash in soil and clogging of voids by the ash and dispersed ions. It is concluded that the in situ crop residue burning is harmful practice for environment as well as soil health. Adoption of alternate methods of crop residue management by farmers of the region will prove immensely useful because of reduced air pollution and recycling of nutrient instead of its burning.

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