PASSAGE OF WHEAT FIRE IMPACT ON SOIL PROPERTIES AND ENVIRONMENT IN KURDISTAN REGION

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ABSTRACT

The study was conducted to examine the effect of surface burn severity (Moderate, Severe and Unburned) of wheat straw on soil properties. The results showed statistical differences in some soil physical, chemical and biological properties. Bulk density and field capacity increased statistically by the severity of fire; however, porosity and infiltration rate were statistically lower in sever burned plot when compared to unburned plot. The chemical properties, soil organic matter (SOM), P, Ca, S, Cl, K, Mo, Fe and As were not affected by the fire. The pH value was increased slightly by increasing the fire severity, while, EC was decreased when compared with the unburned plot. It was found a statistical reduction in the number of bacterial and fungal cells per gram soil in the burned plots. A moderate and severe fire reduced seed germination percentage significantly. This finding suggests that fire severity may destruct the biological, physical and some of the chemical properties of the soil, and this may impact negatively on plant growth in the next growing season.

keywords: wheat residue, soil quality, physical, chemical and biological properties, seed viability

ايقاد حقول الحنطة ما بعد الحصاد وتأثيرها على خصائص التربة والبيئة في اقليم كوردستان

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مدرس مدرس استاذ مساعد باحث باحث

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المستخلص

هذه الدراسة تهدف الى تقيم تأثير شدة الحرائق (متوسطة وحادة وغير محروقة) في حقول الحنطة ما بعد الحصاد على خصائص التربة. النتائج بينت اختلافات معنوية في بعض خصائص التربة الفيزيائية والكيميائية والحيوية. الكثافة الظاهرية والسعة الحقلية ازدادت بازدياد شدة الحريق ولكن المسامية ونسبة الترشيح انخفضت معنويا مقارنة مع القطاع الغير المحروق. الخصائص الكيميائية للتربة والمادة العضوية ونسبة ال P ، Ca ، S ، Cl ، K، Mo ، Fe ، As لم تتأثر بالحرق. قيمة ال pH ازدادت بنسبة ضئيلة بازدياد حدة الحريق، بينما ال EC انخفضت عندما قورنت بالقطاع الغير محروق. التحليل الاحصائي بين انخفاض معنوي في عدد الخلايا البكترية والفطرية في الغرام الواحد من نموذج التربة. شدة الحرائق المتوسط والشديد ادت الى انخفاض نسبة انبات البذور معنويا. ومن خلال نتائج هذا البحث يمكن الاقتراح بأن شدة الحريق تؤدي الى تدمير خصائص التربة الحيوية والفيزيائية وبعض الخصائص الكيميائية وهذا بالتالي يؤثر سلباً على نمو النبات في الموسم النمو التالي.

الكلمات المفتاحية : بقايا الحنطة، نوعية التربة، الخصائص الفيزيائية والكيميائية والحيوية، حيوية البذور

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INTRODUCTION

Burning the straw of post-harvest wheat field during summer, is a common farming practice to dispose the straw and prepare the fields for seeding the following season (46). In Kurdistan, Northern Iraq, hundreds of acres of wheat crops caught fire deliberately, which affected several villages during the summer 2019 (4). Burning have a significant impact on air pollutions and soil properties (12, 24, 46). It was also investigated that the smoke water and fire severity effect on seed bank, seed germination and seedling growth of forest species (8, 31). Identification and prediction of the main changes associated with soil properties can therefore provide a better understanding of the risks of reducing plant yield and environmental impacts due to post-fire in the wheat farms. Extensive pre and post – harvest open farm burning of straw may cause serious air pollution, which significantly impact on human health and the ecosystem (46). The median cumulative carbon dioxide and methane emissions were 257.7 Tg and 0.9 Tg, respectively, under projected climate and wildfire in Sierra Nevada of California, and also was demonstrated that climate change increases in area burned, which affects the atmosphere to ongoing decades (1, 43). Biomass burning is a major contributor to accumulate total suspended particles, which was estimated it's acute effect on asthma hospital admissions in Brazil (35). Levoglucosan is an organic compound and a unique tracer for biomass burning processes, a study showed that biomass burning activities throughout the year in Beijing led to high ambient levoglucosan concentrations and low winter to summer ratios of levoglucosan when was compared with North America and Europe (10). Another environmental risk caused by fire was estimated in the water of Lithuanian rivers, which was found increase of heavy metal (Cu, Pb and Zn) concentrations by 21–74 % in all the rivers (18). Recently, it was suggested and recommended that "the levels of potentially toxic heavy metals and metalloids in water, sediments, soils, and the resident biota should be assessed and monitored regularly, in addition, the public should be educated about the harmful effects of toxic heavy metals on human health and the environment" (3). Wildfire and prescribed fire might be challenged due to complex changes in the soil properties. The severity of aboveground and belowground burning was defined as the loss of organic matter (19), high temperature burned soil was showed a significant decrease in organic matter and surface porosity, however, low temperature burned soil was decreased infiltration rate when compared with unburned and high temperature (44). In addition, the organic matter and mineral particles in soil may affect the burn severity level, it was revealed that the degree of carbonization/aromatization was lower in the mineral soil than in the duff (24). The slash-and-burn system for cropping maize and black beans in Southern Brazil was shown no effect on soil organic matter, however, the stability of soil aggregates increased when compared to unburned soil (39). Post-fire was increased the main soil nutrients, such as Ca, Mg, K and CEC (38), but soil pH, Al and Mn were decreased after a month of the fire, and no changes were found in the level of Na, Fe and Zn, therefore, it was suggested that the low fire severity have no negative impact on soil properties (32, 34). Soil pH and fire severity are the key drives of fungal composition, total fungal, mycorrhizal, and saprotroph were higher in boreal forests of western Canada after an event of low fire severity and low pH (12). Low activity of some soil organisms was found due to the wildfires, which was suggested that wildfire modify soil chemical and biological properties (14, 38). The action of heat modifies the soil chemical and physical status (45) and thus alterations in microbial populations may be expected following soil burning. Partial or total soil sterilization immediately after fire has been reported (42); however, rapid soil re-colonization by microorganisms present in water, air or burnt soil takes place (13). Consequently, microbial response to burning probably depends mainly not on the initial effect but on the substrate changes, which induced by fire. Soil changes caused by fire are largely related to fire intensity (36), which is usually low or moderate in prescribed or controlled burning and high in uncontrolled burning which normally occurs in the dry summer-fall season.

Most research on fire effects on microorganisms has been devoted to controlled fires (13). In addition to the positive effect of wildfire on some key soil nutrients (33, 34, 38), it was found that wildfire stimulated seed germination by breaking the dormancy of some angiosperm and gymnosperm seeds (8, 21). Despite of the huge number of studies investigated the impact of wildfire on soil properties and seed bank as mentioned above, there are few researchers studied the impact of prescribed fire on soil fertility and yield in wheat farm. A study was found that burning wheat straw increased soil nutrients especially N and wheat grain yield when compared to the other agricultural practices (22), however, because of the negative impact of fire on the environment, it was suggested to incorporate the wheat straw followed by crop rotation would be the best alternative practice than burning. Furthermore, the high temperature ≥ 30°C was reduced seed germination and increased seed dormancy of preharvest wheat grain (29, 30). The surface temperature was reached to 422°C from burning oat straw (6), consequently the soil physical and biological properties were negatively impacted. Deliberate and prescribed fire impacted many privet wheats farms before and after harvest in Kurdistan region, summer 2019 [4]. Therefore, this study was focused on the impact of burning wheat residue on soil properties and viability of wheat grains and also educate public and farmers about the negative impact of fire on the ecosystem in Kurdistan region.

MATERIALS AND METHODS

Study area and sample collection

The experiment was conducted at a research center (Grdarash), College of Agricultural Engineering Sciences, Erbil, Iraq. Approximately at Latitude: 36.15’N and Longitude: 44.00’E and at 410 m above sea level. The climate is Mediterranean, with cool, humid winters and warm, dry summers. The average annual precipitation is 429 mm (25). Soil texture is silty clay loam (26). A wheat field was selected and divided in to three plots. The prescribed burning was carried out in July 2019, in two plots randomly selected, and another plot remained unburned as control (C). To produce a moderate or severe surface burn, the lines of fire were set gradually upwind or downwind of a firebreak, respectively. The fire severity was also assessed by the colour of the ash and burned wheat residue: very dark brown (Moderate (M)) and black (Severe (S)). Samples were collected randomly from four different spots of each plot (C, M and S), using an auger from the upper 30 cm layer of the soil. The samples were transferred to a soil laboratory and immediately air dried, homogenized, and ground to pass through the 2 mm sieve. The samples were stored in plastic bags at room temperature for further analysis.

Physical soil properties

To estimate bulk density, soil samples were collected using cores (metal ring 5 cm high and dimeter) following the procedure described by (7]) Soil porosity was calculated as a ratio of bulk density to particle density ($2.65 g/m^3$). Double ring infiltrometer with 18 cm inner and 36 cm outer diameters was used to evaluate infiltration capacity (28). Soil structure was estimated visually at the field by dropping down selected soil clods from 2m high. Field capacity is percentage of moisture content, samples were saturated and then were kept at room temperature to remove excess water completely for 48 hours, then samples were dried in an oven at 105°C for 24h.

Chemical soil properties

X-ray Fluorescence Spectrometer/Hand-Held Detector (CIT-3000 SMB) was used to determine the chemical composition of a sample, following manufacturer protocol. To determine pH and electrical conductivity (EC), the soils samples were mixed with distilled water in 1:2.5 soils/water ratio and then equilibrated for 24 hours (2, 37). The mixtures were then filtered using a Whatman filter paper and the pH values were measured using a pH meter model PP-203. EC was measured using a DDS- 11 AW Microprocessor Conductivity meter. The readings were recorded under constant laboratory temperature at 21°C. The percentage of organic matter content in soil samples were determined by dry combustion method using a muffle furnace, following the procedure described by Heiri et al. [15], Khoshnaw and Esmail (20). Biological activities

The population of bacteria and fungi was enumerated by the serial dilution and standard plate count method using nutrient agar media for bacteria and potato dextrose agar (PDA) media for fungi. Isolation was carried out by using the following procedures: One gram of soil sample was dispersed in 9 mL of autoclaved distilled water and thoroughly shaken. One milliliter of the above solution was transferred to 9 ml of sterile distilled water to form 10^{-2} dilutions. Similarly, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7} and 10^{-8}, serial dilutions were made for each soil sample. One milliliter of each dilution was transferred to sterile petri plates separately. Nutrient agar and PDA media at 40°C were poured in the petri plates. The contents were mixed by rotating the plates gently. Care was taken that medium did not touch the lid. The medium was allowed to solidify and the plates were incubated at 28-30°C for 5 days (27).

Germination test

Wheat seeds were collected from each plot (C, M and S), separately. 12 Petri dishes (90 mm) containing a layer of Whatman filter and 2 mL of natural mineral water (Bakoor) were prepared. Four dishes were allocated for each treatment (C, M and S). Fifty seed were placed in each dish, and incubated in the dark at room temperature for 7 days (40). The dishes were monitored and 2 mL water were added regularly. Germination percentages were calculated by dividing the number of germinated seed by total number of seeds.

Statistical analyses

IBM SPSS statistics version 25 was used for data analyzed following One-way ANOVA. Four replicates were used for physical and biological activity and germination test. For chemical properties three replicates were used. Duncan test was used to determine the differences between treatments at 0.05 level of significance.

RESULTS AND DISCUSSION

Burning surface severity was found to be decreased the soil physical properties, specifically soil porosity and infiltration rate (44). Bulk density and field capacity increased gradually by increasing the fire severity and statistically were different when compared with unburned soil (Control) (Figure 1 a, b). It was investigated that increased bulk density was due to the breakdown of aggregates and the blocking of pores by the ash and the isolated clay minerals; therefore, soil porosity was decreased [9]. Fire severity was destructed the soil structure and pores within the soil profile and also was decreased soil productivity (16). In this study was found that the soil porosity and infiltration rate in the moderate and severe burned soil, were statistically lowest, when compared with the control (Figure 1 c, d). In addition, it was examined that wheat residue improves soil physical properties by increasing infiltration rate and reducing aggregates (23). Therefore, it could be suggested that because of increasing bulk density by increasing the severity of fire, the soil porosity decreased.

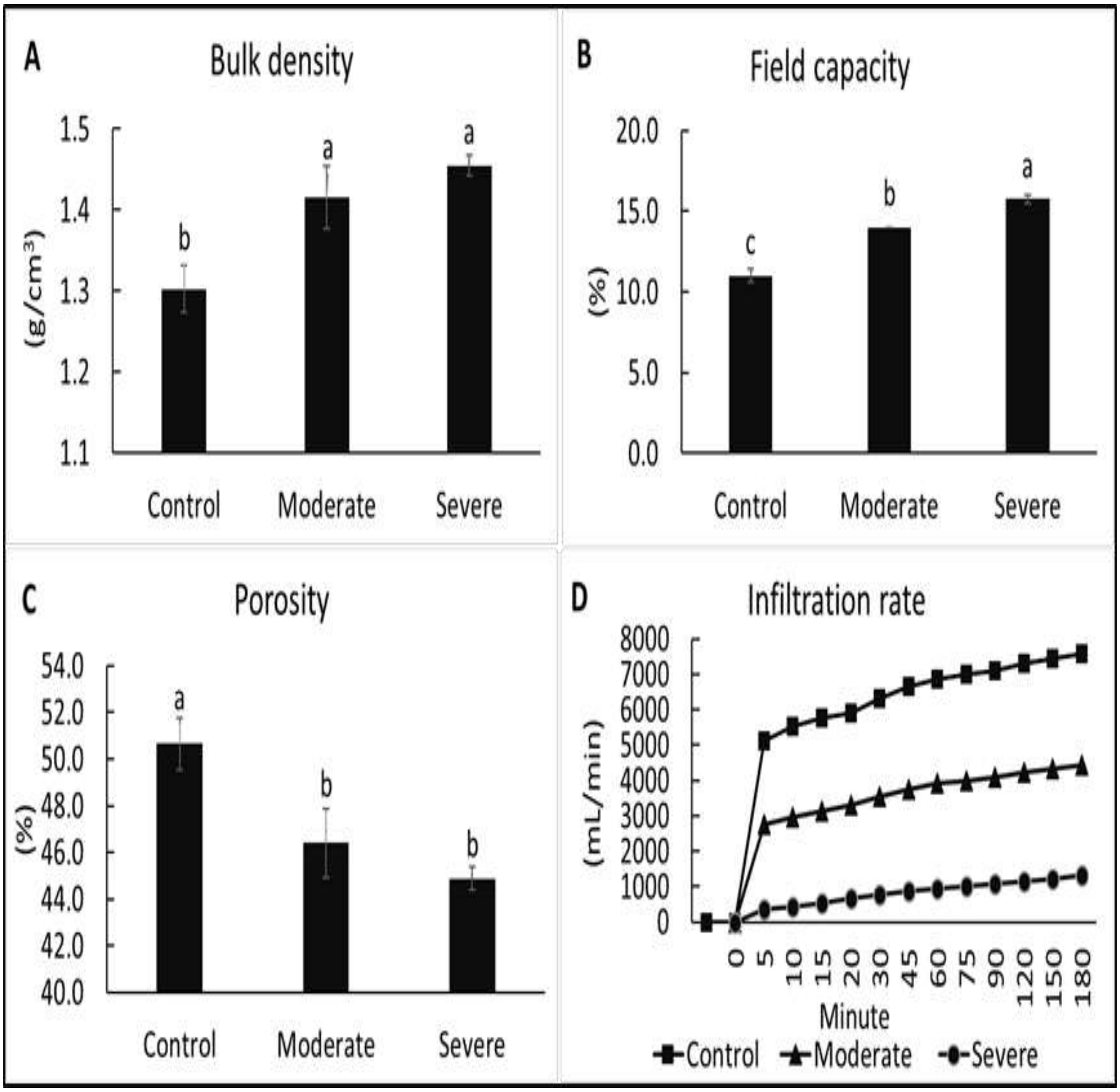

Figure 1. Influence of surface burning on some soil physical properties. Comparison in between moderate and severe surface burning and control and their effects on (A) Bulk density (g/cm3), (B) Porosity (%), (C) Field Capacity (%) and (D) Infiltration (mL/min). Different letters indicate significant differences between variables (p-value,0.05). Values represent means ± SE (N = 4).

It was investigated that fire has limited influence and for a short period of time on some major and minor nutrient elements, pH and EC [32]. Although the percentage of some nutrient elements fluctuated in the soil exposed to moderate and sever fire, no statistical differences were found in the percentage of P, Ca, S, Cl, K, Mo, Fe and As in burned and unburned soil (Figure 2 a -h). Perversely, it was reported that the prescribed fire has limited benefits and also a negative impact on long-term soil chemical properties, which found a reduction in P, ammonium and increase carbon to nitrogen ration (17). In this study was found an increase of soil pH from 7.72 in unburned surface to 7.74 in the severe burned surface (Figure 3 a), however, this statistical difference of pH 0.02 might not change the soil quality and availability of plant nutrition. No statistical differences were found in the soil EC in moderate and severe burned surface when compared with unburned soil (Figure 3 b). In agreement with previous study, it was found that increasing of soil temperature to 500 °C increased soil pH and decreased EC (5). Generally, nutrients and value of soil nutrients lost from burning was higher when compared with unburned surface (17), therefore, it may suggest that passage of wheat fire has no effect on soil chemical properties and unburned wheat residue might be more beneficial for soil in short and long-term.

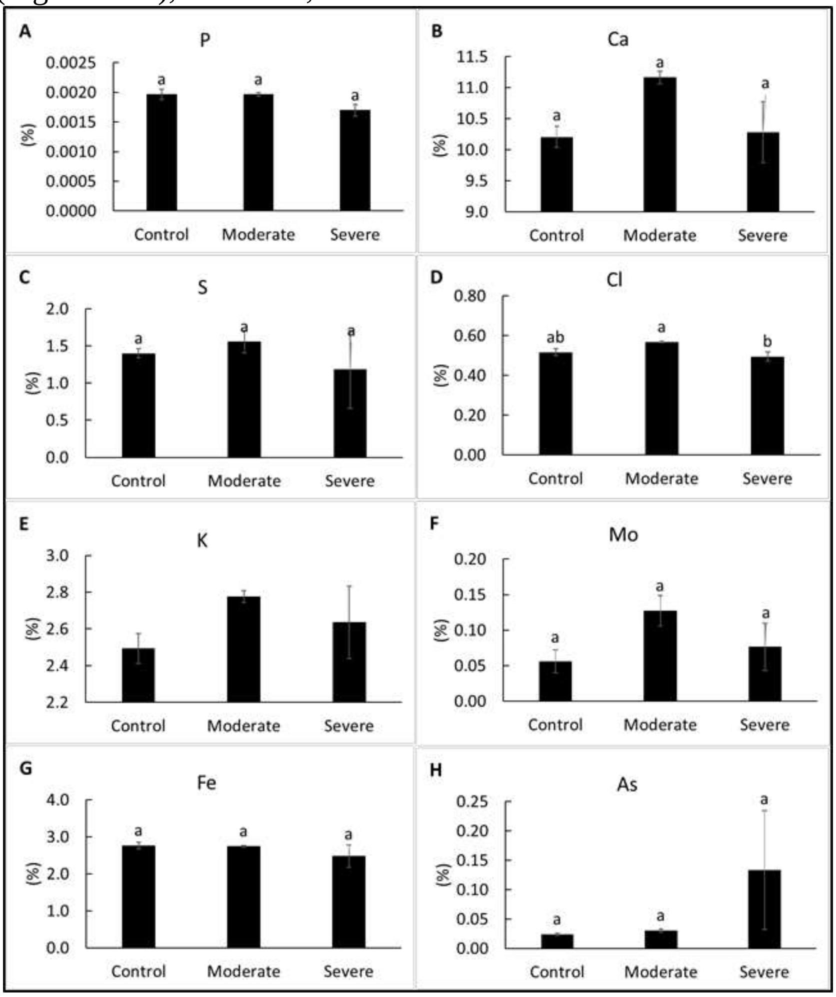

Figure 1. Influence of surface burning on some chemical elements in soil. Comparison in between moderate and severe surface burning and control and their effects on the percentage of (A) P (Phosphorus), (B) Ca (Calcium), (C) S (Sulfur), (D) Cl (Chlorine), (E) K (Potassium), (F) M (Molybdenum), (G) Fe (Iron) and (H) As (Arsenic). Different letters indicate significant differences between variables (p-value,0.05). Values represent means ± SE (N = 3).====

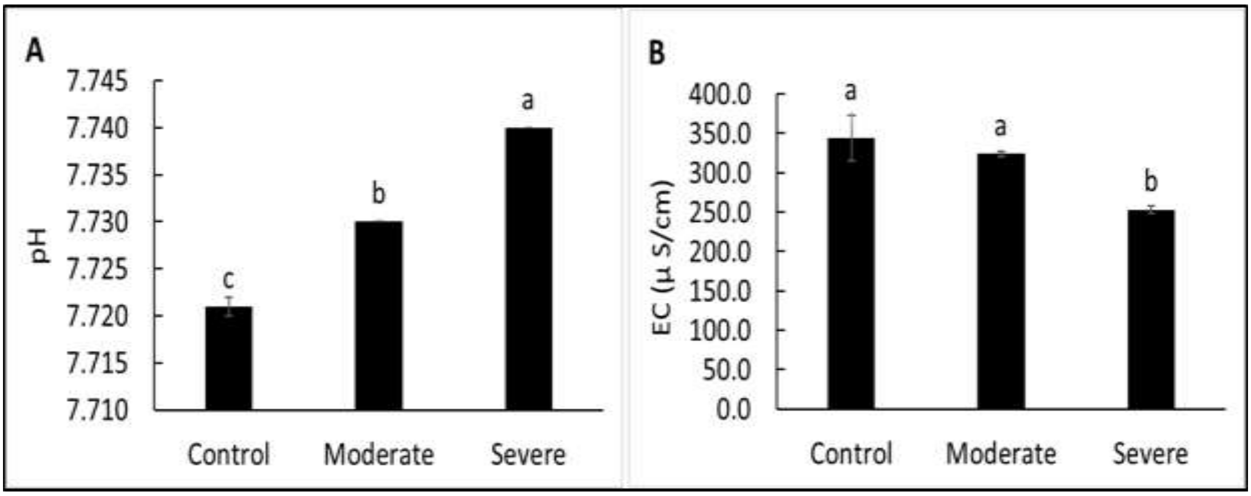

Figure 3. Influence of surface burning on pH and EC in soil. Comparison in between moderate and severe surface burning and control and their effects on (A) pH (B) EC. Different letters indicate significant differences between variables (p-value,0.05). Values represent means ± SE (N = 4).

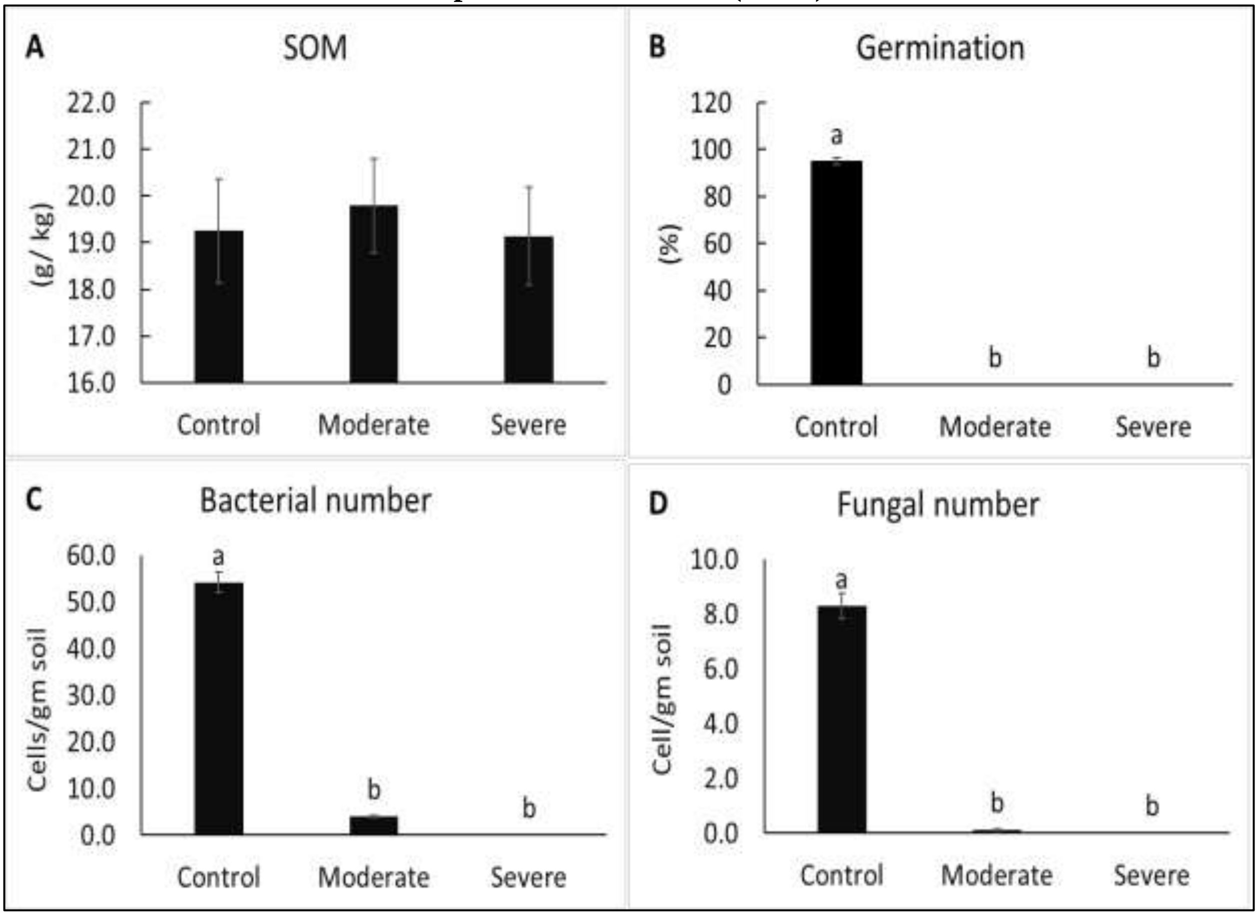

Figure 4. Influence of surface burning on soil organic matter and some biological properties. Comparison in between moderate and severe surface burning and control and their effects on (A) soil organic matter, (B) Wheat grain germination, (C) Bacterial cell per gram soil, (D) Fungal cell per gram soil. Different letters indicate significant differences between variables (p-value,0.05). Values represent means ± SE (N = 4).

Although burned wheat residue reduced soil porosity and infiltration rate (Figure 1c, d), the soil organic matter level was the same in burned and unburned soil (Figure 4 a). This result disagrees with previous reported studies, which found a statistical decrease in SOM because of fire severity (19, 44). However, the results of this study are coincided with the results reported by Virto et al. (41) who was found no effect of residue burning and no tillage on SOM. This suggests that every year burning practice has led to decrease the SOM under 5 cm depth. Burning has a negative impact not only to the environment (12) and soil physical and chemical properties, but also on biological properties including seedbank. Although burning may break seed dormancy of some species (21), but also could cause burning the embryo of seeds without the hard seed coat. For example, wheat grains were collected from fields exposed moderate and severe and unburned surface, it was found that the wheat grains were turned to ash by moderate and severe fire and the germination percentage was zero when compared with grains collected from unburned area (Figure 4 b). Similarly, fire was affected on soil microorganisms very widely and were dependent on fire severity, changes in some soil physical and chemical properties, and post-fire environmental conditions. Bacterial and fungal populations were statistically decreased by the effect of fire (Figure 4 c, d). The highest decreases in total soil fungi and bacteria was observed in severe surface burn followed by moderate burn. Several authors have found a dramatic negative effect on microbes immediately after fire, and especially on fungi (42). Similar results of decreasing microbial activities were obtained when wheat residue was burned and removed in comparison with incorporated residue (11). This suggests that residue management is important agricultural practice, which influence on soil decomposition and microbial population. Burning residue practice may have a crucial negative impact on soil quality and also on human health and environment as mentioned above. This study demonstrated that fire severity of post-harvest wheat residue increased soil aggregation, field capacity and pH. However, soil chemical, physical and biological characteristics were statistically decreased in the burned in comparison to unburned plots. It could be recommended that agricultural practice of burning farm residue has to be stopped and replaced by incorporating or leaving the residue to improve the soil quality as also suggested by (11). In addition, it is suggested to educate farmers in the developing countries of the burring risk to the environment and human health and also the beneficial effect of farm residue on soil quality.

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