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Impact of burning crop residues on mycorrhizal fungi in soil, urease activity, and mung bean (*Vigna radiata* (L.) R. Wilczek) growth

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This research focuses on the effect of burning crop residues on the total number of spores of mycorrhizal fungi, the activity of some soil enzymes, and the growth of the mung bean (*Vigna radiata*), in which 12 soil samples were collected before and after burning plant residues, one sample every 15 days, in addition to estimating the enzyme activity of urease (urea aminohydrolase, EC 3.5.1.5). The Completely Randomized Design (CRD) was used. Data were analyzed statistically using the computer, and LSD values were used to compare the averages of the coefficients at the 0.05 probability level in all experiments. Results shown a significant decrease in the number of mycorrhiza spores, as the first burning period recorded a percentage of 22.7 %, while the second period recorded a non-significant decrease of 2.5 %. As for the urease enzyme, a significant increase in its activity was observed with an increase of 22.9 % after the first period of burning, followed by a decrease of 24,0 % during the second. To determine the impact of burning crop residues on the germination and growth of mung bean, its seeds were grown in plastic containers containing burned and unburned soil under recorded conditions of light, humidity and temperature for 15 days, the results shown a decrease in the germination rate of seeds planted in burned soil as well as the dry root weight and the seedling vigor, while both the seedling dry root weight of the seedling and height increased. In response to burning, the chlorophyll A, B, and total chlorophyll content in mung bean leaves grown in burned soil was lower than that in unburned soil. Thus, burning plant residues led to a reduction in the number of mycorrhizal fungi, affected urease enzyme activity (which did not recover even after three months), and had an adverse effect on soil enzymes, although burning stimulated certain aspects of mung bean growth as measured by dry mass and chlorophyll content.

Keywords: crop residues, Mycorrhizal fungi, urease enzyme, plant growth.

Вплив спалювання рослинних залишків на показники кількості мікоризних грибів у ґрунті, активності уреази та процесу проростання бобів машу звичайного (*Vigna radiata* (L.) R.Wilczek)

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У цьому дослідженні основна увага приділялася впливу спалювання в полях рослинних залишків на показники загальної кількості спор мікоризних грибів у ґрунті, активності деяких ґрунтових ферментів та зростання машу звичайного (*Vigna radiata*). Для досліду було відібрано 12 зразків ґрунту до та після проведення спалювання рослинних залишків, по одному зразку кожні 15 днів, в яких проведено визначення активності ферменту уреази (карбамід-аміногідролаза, КФ 3.5.1.5). Щоб з'ясувати вплив спалювання рослинних залишків на процес проростання бобів машу звичайного, його вирощували в пластикових контейнерах (останні містили ґрунт після спалювання рослинних залишків та ґрунт на якому спалювання не здійснювалося), за оптимального освітлення, вологості та температурного режиму упродовж 15 днів. Результати досліджень показали значне зниження кількості спор мікоризних грибів, зокрема, за першого спалювання цей показник знизився до 22,7 % порівняно з показником до спалювання. Після повторного (другого) спалювання кількість спор мікоризних грибів знизилася на 2,5 % порівняно з показником до проведення спалювання. Встановлено, що активність ферменту уреази значно збільшилася на 22,9 % після першого спалювання, однак вже після повторного (другого) спалювання вона знизилася на 24,0 % порівняно з показником до спалювання. Також результати досліджень вказують на подовження терміну проростання насінин машу звичайного який висаджувалися у ґрунт після спалювання рослинних залишків, а також зниження показника сухої ваги кореня сіянців та сили їх проростання. Натомість за використання як субстрату ґрунту, на якому спалювання не здійснювалося зафіксовано збільшення сухої ваги коріння сіянців та сили їх проростання. Таким чином, спалювання рослинних залишків призводить до зниження в ґрунті кількості мікоризних грибів та порушення активності ферменту карбамід-аміногідролаза (КФ 3.5.1.5), що свідчить про негативний вплив процесів горіння на активність ґрунтових ферментів й подальшу непридатність таких ґрунтів для ефективного вирощування машу звичайного.

Ключові слова: рослинні залишки, мікоризні гриби, карбамід-аміногідролаза, проростання рослин.

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Introduction

Plant residues or crop residues are rich in carbon biomass left in the field after harvesting the economic part of the plant. The amount of plant residues increases year after year. Burning is one of the most commonly used methods for managing plant residues. Burning these residues has become an important issue in agricultural systems due to the release of pollutants and soil degradation [1].

The burning of crop residues can temporarily improve soil fertility and productivity, as soil fertility is closely related to the physical, chemical and biological properties of the soil that are naturally associated with the stock of organic matter. Burning is also used to remove plant residues after harvest and to reduce the effects of residues that may be toxic to soil microorganisms and subsequent crops [2].

The use of burning has led to numerous studies on the effects of this process on the biological components of the soil, as there is a close relationship between burning processes and the physical and biological properties of the soil. This relationship is mediated by changes that occur as a result of burning processes [3]. Burning plant residues alters the biochemical balance of the soil by releasing the chemical energy stored in the plant residues and introducing organic and inorganic materials into the ecosystem. In lands where the growth rate exceeds the decomposition rate, the stored organic materials are released [4].

The aim of the study

This study aimed to examine the effects of burning plant residues on mycorrhizal fungi, urease enzyme activity, and plant growth, all of which are directly linked to soil fertility.

Materials and methods

Agricultural land location and Soil sampling.

The agricultural land was located in the Shariah area located northwest of the holy governorate of Karbala, which was planted with eggplant during the first burning period, while it was planted with wheat during the second burning period. Crop residues were burned, as the burning took place at the beginning of November 2020, and samples were taken from the uncultivated land. The burned soil layer extended to a depth of 5–15 cm from the surface, and samples were collected, packed in sterile polyethylene bags and transported directly to the laboratory. The soil was sieved through a 2 mm mesh before testing. There are two burning periods per year for crop residues in this region. Samples were collected continuously (12 samples total), one sample every 15 days, with 6 samples after the first burning process for the period from (15/11/2020) until (02/01/2021), and 6 other samples after the second burning process for the period from (01/05/2021) to (15/07/2021), the sampling process followed to the method described by [2].

The effect of burning crop residues on the number of spores of mycorrhizal fungi in the soil.

To determine this effect, 100 g of soil were mixed with 500 ml of distilled water to make a suspension, which was left to settle for 10 minutes and then filtered through Whatman No. 42 filter paper. Then the soil particles suspended at the bottom were removed by opening the burette tap, and the burette was washed several times so that the adhering spores fell onto the filter paper (100× magnification) [5, 6].

The effect of burning crop residues on the urease activity.

Urease activity.

The activity of the enzyme was estimated by taking 1 g of soil, placing it in a test tube, and adding 0.1 M phosphate buffer (pH 7.2) and 1 ml of 3% urea solution. The mixture was incubated in 37 °C water bath for 20 minutes, followed by addition of 40 ml of KCl (0,5M), 5 ml of phenol nitro prusside solution, and 5 ml alkaline sodium hypochlorite solution. The absorbance was measured at a wavelength of 630 nm, and the enzyme activity was calculated using on the ammonia standard curve [7].

Statistical analysis.

The Completely Randomized Design (CRD) was used. Data were analyzed statistically using the computer, and LSD values were used to compare the averages of the coefficients at the 0.05 probability level in all experiments [8].

Results and discussion

The effect of burning crop residues on the spores of mycorrhizal fungi.

The results shown in ***Table 1*** indicate that burning the plant residues significantly reduced the number of mycorrhizal spores from 50.12 spores/g in the unburned soil to 38.76 spores/g in burned soil, representing a decrease of about 22.7 % after the first burning period.

Table 1

The effect of burning crop residues on spores of mycorrhizal fungi after the first burning period from 11/15/2020 to 02/01/2021

Soil type	Total number of mycorrhiza spores, spores/g							
	Duration after burning, days							
	Before burning	15	30	45	60	75	90	MEAN
Unburned	42.48	48.89	50.00	51.43	52.00	52.70	53.34	50.12
Burned	42.48	31.11	30.12	38.10	39.37	42.54	47.60	38.76
Least significant difference LSD at the level of significance 0.05	12.205							4.613
MEAN	42.48	40.00	40.06	44.77	45.69	47.62	50.47	
Least significant difference LSD at the level of significance 0.05	8.630							

Table 1 shows that the period following the burning of plant residues affected the number of mycorrhizal cells, and time led to an increase in their number, reaching 50.47 spores/g after 90 days compared to 40 spores/g at the start of the first burning period.

The total number of mycorrhizal spores in the unburned soil was 42.48 spores/g, increasing after 90 days to 53.34 spores/g, i.e. an increase of 25.56 %. In burned soil, the total number of mycorrhizal spores increased from 42.48 spores/g to 47.60 spores/g after 90 days, i.e., by 12 %. Significant differences were observed between treatments after 90 days, indicating an effect of burning on the development of the mycorrhizal spore community after the first burning period.

The same table indicates that the interaction between soil type and time after burning resulted in a statistically significant difference in spore numbers. Unburned soil recorded the highest number after 90 days (53.34 spores/g), while burned soil had the lowest (31.11 spores/g) after 15 days of burning.

The results in *Table 2* show that burning plant residues during the second period caused a non-significant decrease in mycorrhizal spore numbers – 51.00 spores/g in burned soil compared to 52.32 spores/g in unburned soil (a 2.5% reduction).

Table 2
The effect of burning crop residues on spores of mycorrhizal fungi after the second burning period from 01/05/2021 to 15/07/2021

Soil type	Total number of mycorrhiza spores, spores/g							
	Duration after burning, days							
	After burning	15	30	45	60	75	90	MEAN
Unburned	50.64	50.00	50.80	52.50	52.55	54.61	55.11	52.32
Burned	50.64	46.90	50.77	51.30	52.07	52.57	52.75	51.00
Least significant difference LSD at the level of significance 0.05	7.207							2.724
MEAN	50.64	48.45	50.79	51.90	52.31	53.59	53.93	
Least significant difference LSD at the level of significance 0.05	5.096							

Table 2 shows that the duration after burning affected spore costs, causing an increase in the number of mycorrhizal spores, reaching 53.93 spores/g after 90 days compared to 48.45 spores/g at 15 days.

In unburned soil, spore numbers rose from 50.64 to 55.11 spores/gafter 90 days (an increase of 8.8 %). In burned soil, they rose from 50.64 to 52.75 spores/g (an increase of 4.2 %). Significant differences in spore numbers were observed after 90 days, indicating that burning influenced the development of the mycorrhizal community after the second burning period.

The interaction between soil type and time after burning also had a statistically significant effect. In burned soil, the lowest number of spores (46.90 spores/g) was recorded after 15 days of burning. The obtained results differed from those of [9], who found that burning operations increased mycorrhizal fungi populations.

The effect of burning crop residues on urease activity.

The results shown in *Table 3* indicate that burning crop residues had a significant effect on increasing the urease enzyme activity. It increased from 7.36 units/ml in unburned soil to 9.53 units/ml in burned soil after the first burning period, representing an increase of 22,9 %.

Table 3
The effect of burning crop residues on the activity of the urease enzyme after the first burning period from 11/15/2020 to 02/01/2021

Soil type	The enzymatic activity of the urease enzyme, unit.ml-1							
	Duration after burning, days							
	Before burning	15	30	45	60	75	90	MEAN
Unburned	6.03	5.23	5.7	5.93	8.52	8.54	11.58	7.36
Burned	6.03	6.72	7.07	9.7	12.28	12.36	12.55	9.53
Least significant difference LSD at the level of significance 0.05	2.651							1.002
MEAN	6.03	5.98	6.39	7.82	10.40	10.45	12.07	
Least significant difference LSD at the level of significance 0.05	1.874							

Table 3 indicates that there was no significant effect immediately after burning, but after 30 days the enzymatic activity began to increase. After 45, 60, 75, and 90 days, urease activity reached 7.82, 10.40, 10.45, and 12.07 units/ml, respectively, during the first burning period.

The same table shows that the lowest urease activity (5.23 units/ml) was recorded 15 days after burning in unburned soil, while the highest activity (12.55 units/ml) was observed in burned soil after 90 days – an increase of approximately 140 %.

The interaction between soil type and time after burning had no significant effect, but the general trend indicated that enzyme activity increased with time following burning.

The results in *Table 4* show that burning residues during the second period significantly decreased urease activity, from 10.25 units/ml to 7.79 units/ml in burned soil – a reduction of 24,0 % after the second burning. The same table indicates that there was a non-significant effect on the activity of the urease enzyme. The lowest activity was recorded 15 days after the burning process and amounted to 3.54 units/ml for burned soil, while the unburned soil recorded, after 90 days, the highest enzyme activity, amounting to 16.47 units/ml, with a decrease of 79 % after the second burning period.

Table 4
The effect of burning crop residues on the activity of the urease enzyme after the second burning period from 01/05/2021 to 15/07/2021

Soil type	The enzymatic activity of the urease enzyme, unit.ml-1							
	Duration after burning, days							
	Before burning	15	30	45	60	75	90	MEAN
Unburned	12.10	5.89	7.85	8.65	9.03	11.77	16.47	10.25
Burned	12.10	3.54	5.11	7.46	7.85	8.64	9.81	7.79
Least significant difference LSD at the level of significance 0.05	3.421							1.293
MEAN	12.10	4,72	6.48	8.06	8.44	10.21	13.14	
Least significant difference LSD at the level of significance 0.05	2.419							

Table 4 indicates that there was no significant difference immediately after burning, but after 90 days, urease activity increased to 13.14 units/ml during the second burning period. The interaction between the post-burning period and soil type produced statistically significant differences in urease activity: unburned soil recorded the highest activity (16.47 units/ml) after 90 days, while the lowest activity (3.54 units/ml) occurred in burned soil 15 days after burning.

The increase in urease activity after the first burning may be attributed to higher soil temperature caused by burning, which enhances enzymatic reactions, and to the presence of fly ash and other materials that positively influence enzyme activity [10, 11]. The subsequent decline after the second burning period is likely due to the reduction in microbial biomass [12–14].

The effect of burning crop residues on plant growth (Mung bean).

After collecting burned and unburned soil samples, and for the purpose of determining the effect of burning plant residues, samples were collected from the soil exposed to burning for two periods and compared with control (unburned) soil. After preparing the samples, the mung bean seeds were cultivated, and some growth characteristics were studied for each of them under standard conditions in the growth chamber.

Rate of germination.

Figure 1 shows that there were no statistically significant differences in the germination rate between the soil subjected to burning plant residues and those not subject to burning. The unburned soil recorded the highest germination rate (84.63 %) compared to the burned soil (71.9 %). The results suggest that an increase in germination percentage is associated with higher numbers of microorganisms and their enzymatic activity in the soil, resulting from burning. However, burning may also lead to seed loss, as reported by [15–17]. According to [1], burning has negative effects on germination rate, increasing seed predation by insects and microbial attacks due to higher populations of fungi and bacteria in burned soil.

Dry weight of the seedling.

Figure 2 shows that mung bean seedlings grown in burned soil had a slightly higher dry weight (0.37 g) than those in unburned soil (0.36 g), but the difference was not statistically significant.

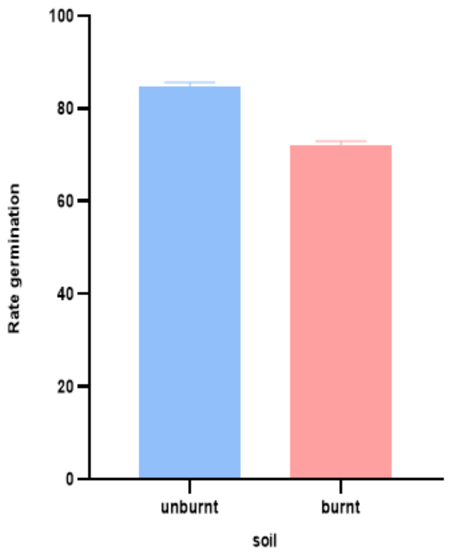

Figure 1. Effect of burning crop residues on germination rate

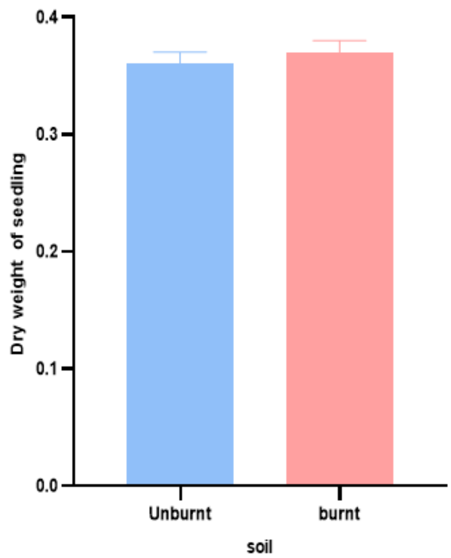

Figure 2. The effect of burning crop residues on the dry weight of the seedling

Dry weight of the root.

The results in ***Figure 3*** show that the highest root dry weight was recorded in seedlings grown in unburned soil (0.12 g) compared to burned soil (0.11 g). Thus, burning slightly reduced root biomass.

Dry weight of the shoot.

Figure 4 shows that seedlings grown in burned soil had the highest shoot dry weight (0.26 g) compared to the control (0.24 g). The response of mung bean seedlings was significant and showed statistical differences at the 0.05 probability level.

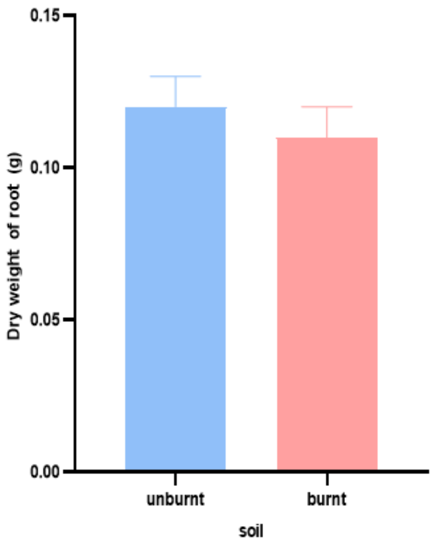

Figure 3. The effect of burning crop residues on the dry weight of the root

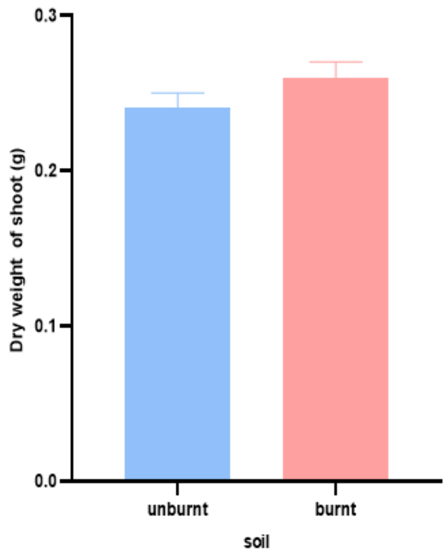

Figure 4. The effect of burning crop residues on the dry weight of shoots

Height of the seedling.

Figure 5 indicates that no significant differences were found in seedling height between burned and unburned soils. However, seedlings grown in burned soil reached 9.6 cm, compared to 7.0 cm in unburned soil after 15 days of growth, suggesting a slight stimulatory effect of burning on stem elongation.

Strength of the Seedling.

Figure 6 shows that burning crop residues led to a decrease in seedling strength, from 29.9 g in unburned soil to 26.6 g in burned soil.

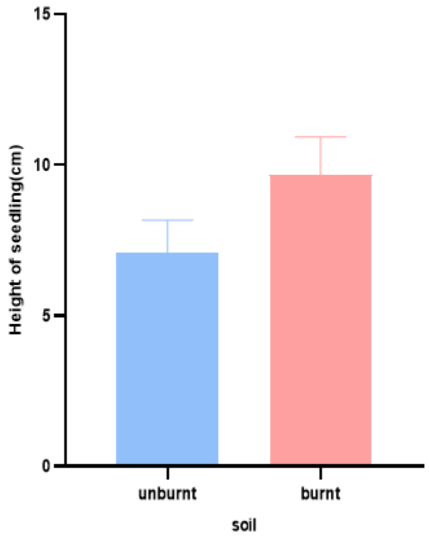

Figure 3. The effect of burning crop residues on the dry weight of the root

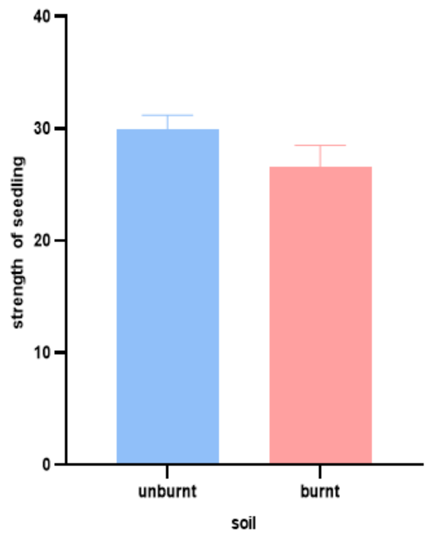

Figure 4. The effect of burning crop residues on the dry weight of shoots

Chlorophyll Content

Figure 7 shows that the highest chlorophyll A concentration in leaves was recorded in unburned soil (1.62 mg/g), while the lowest was in burned soil (1.22 mg/g). Chlorophyll B concentration decreased from 2.3 mg/g (unburned) to 1.7 mg/g (burned). Total chlorophyll (A + B) content decreased from 1.68 mg/g to 1.15 mg/g. The reduction in chlorophyll content is due to nitrogen volatilization during burning, as nitrogen is a key component of chlorophyll molecules. Loss of nitrogen from the soil and the absence of nitrogen replenishment after continuous burning lead to a decline in chlorophyll synthesis, since temperature is directly correlated with nitrogen volatilization [18–20].

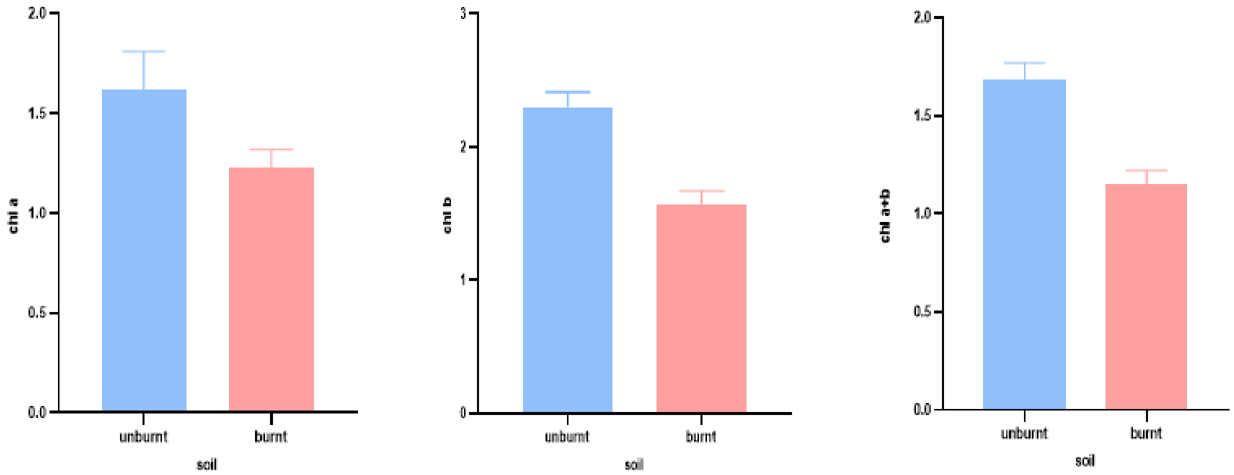

Figure 7. The effect of burning crop residues on the content of chlorophyll (A, B, and B + A)

Rate of Rooting.

Figure 8 shows the effect of burning the crop residues increased rooting, with mung bean cuttings from burned soil producing 11.38 roots compared to 9.00 roots from unburned soil, a statistically significant difference at the 0.05 level.

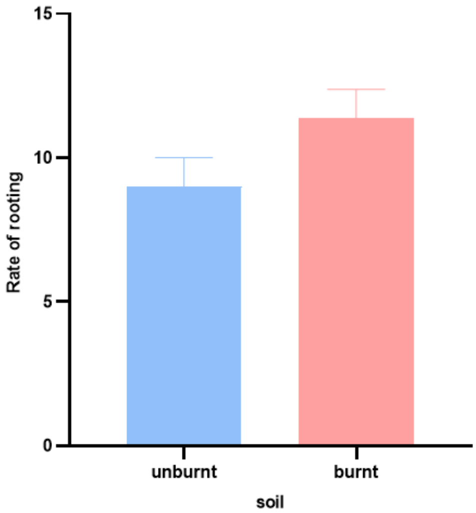

Figure 8. Effect of burning crop residues on the rate of rooting

Table 5 shows the effect of burning the crop residues on the growth characteristics of the mung bean plant.

The results showed that there were significant differences in most of the studied traits. The dry weight of seedlings in burned soil was 0.37 g compared to 0.36 g in unburned soil. The root dry weight was 0.11 g in burned soil and 0.12 g in unburned soil. The dry weight of shoots was 0.26 g in burned soil versus 0.24 g in unburned soil. The seedling height in burned soil reached 9.6 cm compared to 7.0 cm in unburned soil. Seedling strength decreased from 29.6 g in unburned to 26.6 g in burned soil. Cuttings from seedlings grown in burned soil showed a higher rooting rate (11.38) compared to unburned (9.00). No significant differences were observed in germination rate or chlorophyll A, B, and total chlorophyll content. No significant differences were shown in the germination rate and the content of chlorophyll A, B and total.

Table 5

Effect of burning crop residues on some growth characteristics of mung bean seeds

Studied Characteristics	Burning Crop Residues	Non-Burning Crop Residues
Rate of germination %	71.9	84.63
Dry weight of Seedling (gm)	0.37	0.36
Dry weight of roots (gm)	0.11	0.12
Dry weight of shoots (gm)	0.26	0.24
Height of Seedling (cm)	9.6	7.00
Strength of Seedling	26.6	29.6
Chlorophyll A concentration	1.22	1.62
Chlorophyll B concentration	1.7	2.3
Total Chlorophyll Concentration	1.15	1.68
Rate of Rooting	11.38	9.00

Notes: Each number represents the average of three replications.

The results showed that there were significant differences in most of the studied traits. The dry weight of seedlings in burned soil was 0.37 g compared to 0.36 g in unburned soil. The root dry weight was 0.11 g in burned soil and 0.12 g in unburned soil. The dry weight of shoots was 0.26 g in burned soil versus 0.24 g in unburned soil. The seedling height in burned soil reached 9.6 cm compared to 7.0 cm in unburned soil. Seedling strength decreased from 29.6 g in unburned to 26.6 g in burned soil. Cuttings from seedlings grown in burned soil showed a higher rooting rate (11.38) compared to unburned (9.00). No significant differences were observed in germination rate or chlorophyll A, B, and total chlorophyll content. No significant differences were shown in the germination rate and the content of chlorophyll A, B and total.

The increase in some growth traits may be due to the conversion of plant residues into mineral ash containing potassium, phosphorus, calcium, silicon, sulfur, aluminum, manganese, and chlorine – elements essential for plant growth and physiological processes. Potassium, for instance, helps regulate stomatal movement, enhances photosynthesis, and activates many enzymes related to respiration, energy transfer, and nitrate reduction.

Results indicated that the increase in some growth traits may be due to the conversion of plant residues into mineral ash containing potassium, phosphorus, calcium, silicon, sulfur, aluminum, manganese, and chlorine – elements essential for plant growth and physiological processes. Potassium, for instance, helps regulate stomatal movement, enhances photosynthesis, and activates many enzymes related to respiration, energy transfer, and nitrate reduction.

Conversely, the decrease in growth traits of mung bean in unburned residues may be due to the presence of phytotoxins in wheat residues (e.g., coumaric acid, hydroxybenzoic acid, and p-vanillic acid), which are released during decomposition and can inhibit vegetative growth. These compounds can persist in soil for over six weeks, whereas burning destroys most of these toxins, improving the soil environment for plant growth.

Conclusions

This study concludes that burning plant residues led to a reduction in the number of mycorrhizal fungi, and negatively affected urease enzyme activity, which did not regain its initial level even three months after the first and second burning periods. Therefore, it can be concluded that burning processes have a detrimental effect on soil enzyme activity. Although burning stimulated certain growth parameters of mung bean plants – such as increased dry weight of the green mass and chlorophyll content – the overall impact on soil biological activity was negative, indicating that burning crop residues can compromise soil fertility and long-term productivity.

Conflict of interest

The authors state that there is no conflict of interest.

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