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Response of Soil, Growth, and Biomass Properties of Lupin (*Lupinus albus L.*) to Wood ash and Sawdust

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ABSTRACT

Two organic carbon resources (wood ash and sawdust) were applied in the study site to assess their profound effects on soil properties and growth and biomass properties of lupin (*Lupinus albus* L.). Because of their contribution to improving soil structure, enhanced water-holding capacity, and increased carbon sequestration. The experiments were conducted in mid-November 2022 at Grdarasha Research Station, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, Iraq. The experiment includes two organic amendments (wood ash and sawdust) as a treatment and Control.

Results showed that the application of wood ash and sawdust improved and raised the number of essential elements and heavy metals in the soil, which in turn boosted the ability of the roots

to absorb nutrients. The highest germination percentage, plant height, and leaf number were observed in the ash treatment (95.00 %, 22.00 cm, and 21.22) respectively. The great values of fresh and dry shoot weight were found in sawdust treatment 63.78 and 14 g/plant) respectively. The effects of treatments were not significant on root length and fresh and dry root weights. The final findings showed that adding various forms of organic carbon could alter the chemical characteristics of the soil. This, in turn, might have a good impact on microbes, which can subsequently help plants grow by converting, solubilizing, and mobilizing soil nutrients. Furthermore, lupin plants appeared to be a form of phytoremediation, or absorption, for certain heavy metals.

1. Introduction

Lupin (*Lupinus albus* L.), commonly referred to as lupin or lupine, exhibits a wide range of morphological forms and colors. This genus includes both annual and perennial herbaceous species. Overall, Lupin comprises approximately 280 species, although not all are recorded in the Integrated Taxonomic Information System (ITIS). Furthermore, lupin is recognized as a polymorphic species, and the taxonomic classification of its various species has been a subject of ongoing debate (Ainouche and Bayer, 1999). White lupin is a member of the Fabaceae family and can fix nitrogen. It is also drought and heavy-metal-tolerant (Pastor *et al*., 2003; Vázquez *et al*., 2006; Martínez-Alcalá *et al*., 2009). Furthermore, lupin can occasionally withstand high calcium levels, excessive nitrate, and acidity of the soil (Kerley, 2000; Vázquez *et al*., 2006). Studies have shown that lupin can form "proteoid roots," which are collections of rootlets that, in nutrient-poor environments, emit hydrogen ions and chelating agents (enzymes such as phosphatase) and organic anions. According to Ryan *et al*. (2001) and Vance *et al*. (2003), this adaptation improves the uptake of phosphorus, iron, manganese, and zinc. These attributes imply that lupins are a highly cultivable crop and a great choice for the first stages of phytoremediation of soils.

Lupin demonstrated considerable tolerance to (Cd, Pb, Cr, and Hg), as the presence of these metals did not result in significant weight differences between the treated and untreated plants. Although (Hg) translocated to the shoots more quickly than the other metals, these metals mostly accumulated in the roots (Ximénez-Embún *et al*., 2002). According to reviews by Al Mamun *et al.,* 2022 and Gadepalle *et al*., (2007), numerous organic and inorganic amendments have been studied for their potential to lower the bioavailability of metals in soils. The following organic additions were investigated: wood chips, bark chips, sewage sludge, sawdust, wood ash, compost from various sources, and manures.

The incorporation of organic matter into contaminated soils has been practiced for centuries to enhance soil fertility, promote re-vegetation, and reduce the availability of toxic metals to plants (Corzo *et al.,* 2020.; Abbott *et al*., 2001). Organic amendments can decrease the bioavailability of heavy metals by transforming them from bioavailable forms to those associated with organic matter, metal oxides, or carbonates (Walker *et al.,* 2004). Additionally, organic amendments improve soil aeration, water retention, and nutrient-holding capacities. There are several types of organic amendments used in soil remediation including compost, bio-solids, sawdust, wood ash, compost from various sources, sewage sludge, bark chips, and wood chips. Mbah and Nkpaji (2009) showed that wood ash significantly improved the growth and productivity of some crops, especially maize. In addition, several studies have shown that wood ash reduces the amount of exchangeable aluminum in the soil while increasing the effective exchange of applications and base carrying capacity (Bougnom *et al.,* 2009; Rodríguez *et al*., 2009; Agegnehu *et al*., 2016).

Fumagalli et al. (2014), study showed that the quality of soil can be restored throughout the phytoextraction stage by planting lupin plants in the winter season and following it up with a summer crop that accumulates metals from the soil. Furthermore, several studies indicated to uptake of phosphorus from arable site soils by planting lupin and ptillotus species (Shakir, 2019, Shakir, 2023). Salih et al. (2024) demonstrated that using: charcoal and humic acid will enhance and increase the attention of heavy metals in the soil. Additionally, other investigations demonstrated that charcoal significantly increased the soil's microbial activity and nutrient concentration (Kolb et al., 2009).

This study aimed to examine the effects of two different types of organic carbon resources (wood ash and sawdust) on soil properties and the growth of lupin plants. Also, investigate the ability of (*Lupinus album* L.) to absorb heavy metals from the soil

2.Materials and Methods

2.1. Study site

The experimental area was located in Grdarasha Research Station at the Department of Field Crops and Medicinal Plants, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, which is located in the governorate of Erbil, Kurdistan/Iraq (36° 00‘16“N and 44° 01‘24“E with 398 m above mean sea level).

2.2. Experimental design

The experiment was conducted at Grdarasha experimental field, Agricultural Engineering Sciences College/ Salahaddin University, Erbil, Kurdistan Region/Iraq in mid-November 2022. Seeds of white lupin were provided from Jordan as a local variety. This experiment consists of 3 replications in Randomized Complete Block Design RCBD and a plot size of 1m^2 (Width 1m x Length 1m).

Each plot contains 4 intra plant rows of white lupin with 20 cm inter-rows. 5 seeds were sown in each raw, with a seeding rate of 36 kg/h. The space between the plots and the replicates is 50 cm and 1m respectively. The experiment includes two organics amendments (wood ash and sawdust) as a treatment and control. Both treatments were applied on the soil surface of each plot and then they were stirred with soil before planting (wood ash 5 t/ha and sawdust 10 t/ha). Germination rates were calculated in the first week after planting date, 10 plants were collected from each plot then plant height, leaf number, and other growth parameters were collected on April 20, 2023.

2.3. Soil analysis

Soil samples were collected from the study site with a soil auger to a depth of 30 cm before the application of treatments and planting of the seeds (pre-treatments). However, following plant harvesting, additional soil samples were taken from the plot treatments (wood ash, sawdust, and control) (post-treatment). All soil samples were air-dried and sieved through a 2 mm pore-size sieve. Then, physicochemical parameters were determined in the laboratory.

2.4. Statistical analysis

All of the study's data were gathered and statistically examined using Minitab 19 (Minitab, 2014) and the analysis of variance (ANOVA) technique for randomized complete block design (RCBD). The Tukey multiple range test indicated that the mean comparison was satisfied at the significant 0.05 level

Table 1. Pre- and post-treatment soil analysis shows the essential elements, heavy metals and physical properties of the soil from the study site.

Elements			Pre-Treatments	Post-Treatments		
				Wood ash	Sawdust	Control
Essential elements	N	(ppm)	150.766	66	55.2	112.8
	P		7.4	5	2	2.3
	K		780	750	330	309.6
Heavy metals	Fe	(%)	3.3	3.4	3.2	3.0
	Ca	(ppm)	24.3	26.9	24.0	22.0
	Mn		331.4	366.2	334.0	271.8
	Co		13.0	12.8	12.9	9.0
	Zn		63.2	68.2	57.7	56.9
	Pb		5.1	5.5	4.6	2.4
	Ti		3611.9	3271.7	3906.1	3930.6
	V		91.6	99.5	86.9	17.6
	Ni		200.3	205.4	170.1	171.9
	Cu		35.4	26.0	20.8	34.0
Physical Properties	Ph		8.47	8.63	3.44	8.11
	Ec	µS/cm	428	355	279	229.6

N (nitrogen), P (phosphorus), K (potassium), Fe (iron), Ca (calcium), Mn (manganese), Co (cobalt), Zn (zinc), Pb (lead), Ti (titanium), V (vanadium), Ni (nickel), Cu (copper), pH (potential of hydrogen), Ec (electrical conductivity).

3. Results

3.1. Soil properties:

Table 1 shows the data from the study site's pre- and post-treatment soil analysis. Regarding essential elements important to plant growth and quality such as (N-P-K), the application of organic carbon resources (wood ash and sawdust) has positive effects on the absorption of these elements from the soil by plants. Nonetheless, the wood ash-treated soil exhibited a greater concentration of (K), presumably because the ash treatment contained potassium-containing ingredients. This finding suggested that applying wood ash to field crops might be an alternative method of fertilization. The concentrations of (Fe, Ca, Mn, Co, Zn, and Pb) in the pre-and post-treatment soils varied marginally. Furthermore, adding wood ash to the soil has decreased its concentration of (Ti and V). Sawdust-treated soil experienced a sharp decline in (pH), reaching 3.44. Compared to the pre-treatment soils, the treated and lupin-planted soil had a lower (Ec).

3.2. Germination (%):

Figure 1 illustrates the comparative effects of wood ash and sawdust treatments including the control (not treated) on the germination rates of *Lupinus albus* L. The data obtained from the germination experiment showed that the highest germination rate was observed in the wood ash treatment (95.0 %), followed by the sawdust treatment (86.66%), and lastly the control treatment with the lowest germination (83.33%). These findings indicate that ash treatment may have a greater capacity to promote the germination of *Lupinus albus* L. seeds compared to sawdust treatment and control.

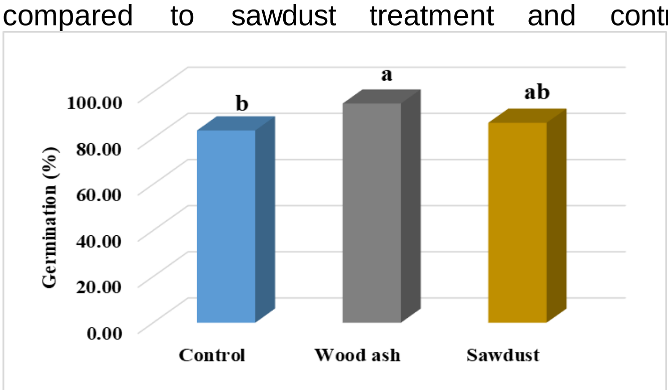

Figure 1. Effects of organic carbon resources (0, 5 and 10 t/ha) control, wood ash and sawdust on germination (%) of lupin plants. Bars featuring distinct characters indicate a significant difference in means at the significance level of ≤ 0.05.

3.3. Plant height (cm)

Figure 2 depicts the effects of wood ash and sawdust treatments on the plant height of Lupinus albus L. The data showed that the ash treatment had a significant effect on plant height with (22 cm) height, while the sawdust and control treatment resulted in the lowest plant height, with an average height (11. 33 and 10. 22 cm), respectively.

3.4. Root length (cm)

Figure 3 presents the results of the effect of wood ash and sawdust treatments on the root length of Lupinus albus L. The data obtained from this figure revealed that there were no significant differences in mean root length between the treatments and control. The highest mean root length was (20.55 cm) in the control, which was slightly different compared to the sawdust and wood ash treatments which were (18.33 and 16.34 cm) respectively.

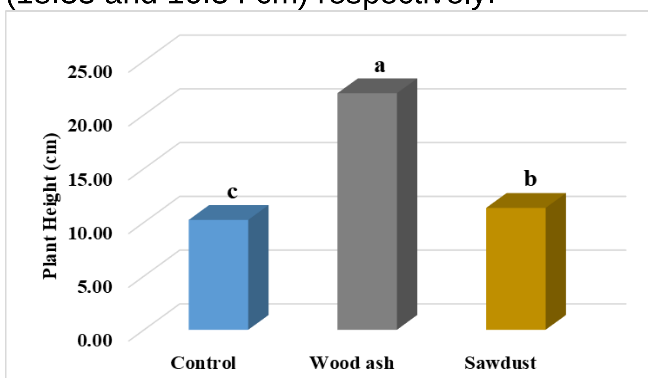

Figure 2. Effects of organic carbon resources (0, 5 and 10 t/ha) control, wood ash and sawdust on plant height (cm) of lupin. Bars featuring distinct characters indicate a significant difference in means at the significance level of ≤ 0.05.

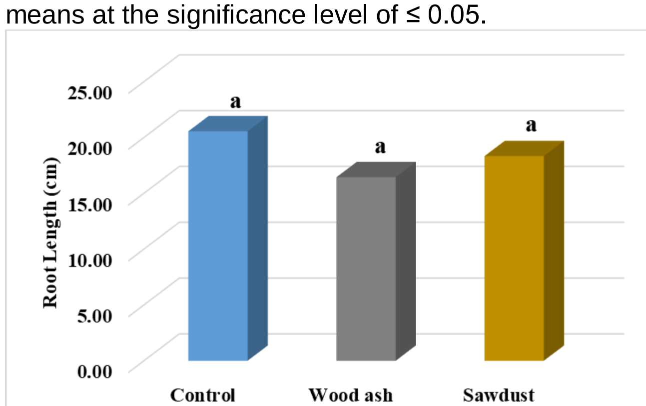

Figure 3. Effects of organic carbon resources (0, 5 and 10 t/ha) control, wood ash and sawdust on root length (cm) of lupin plant. Bars

featuring distinct characters indicate a significant difference in means at the significance level of ≤ 0.05.

3.5. Leaf number/plant

Figure 4 shows the effect of different carbon resources such as wood ash and sawdust treatments, on the number of leaves produced by *Lupinus albus* plants. The statistical analysis revealed that there was a significant difference in leaf numbers among the treatments, Specifically, the mean leaf number for the ash treatment (21.22) was significantly higher than the sawdust (12.55) and control (11.55) respectively.

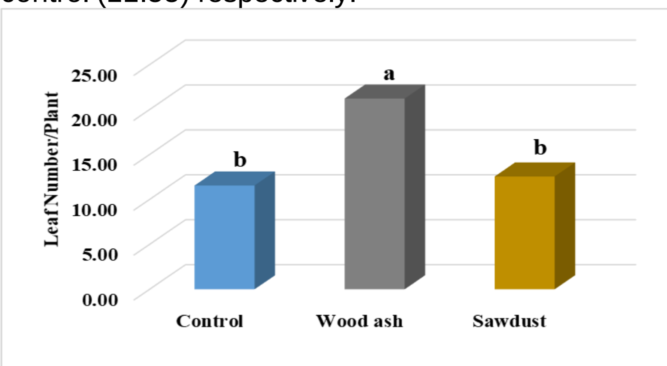

Figure 4. Effects of organic carbon resources (0, 5 and 10 t/ha) control, wood ash and sawdust on leaf number plant^{-1} of lupin plant. Bars featuring distinct characters indicate a significant difference in means at the significance level of ≤ 0.05

3.6. Fresh and dry root weight (g/plant)

Figure 5 shows the effect of ash and sawdust treatments on the fresh and dry roots' weight of lupin plants. The results obtained that there were no significant differences in the mean fresh and dry weight of roots among treatments. The data show that the highest mean fresh and dry weight of roots was observed in the wood ash treatment (20 and 16 g/plant) respectively. These results were slightly different with sawdust treatments (19.56 and 14 g/plant) and control (15.33 and 12 g/plant) respectively.

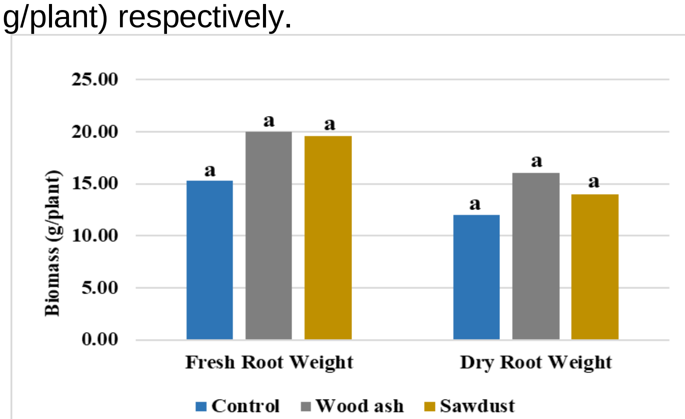

Figure 5. Effects of organic carbon resources (0, 5 and 10 t/ha) control, wood ash and sawdust on fresh and dry root weight t/ha of lupin. Bars featuring distinct characters indicate a significant difference in means at the significance level of ≤ 0.05.

3.7. Fresh and dry shoot weight (g/plant)

Figure 6 presents the findings of the effect of the wood ash and sawdust treatments on the fresh and dry weight of shoots in lupine plants. Statistical analysis was performed, and the results indicate that there was a significant difference in the mean fresh and dry weight of shoots among treatments, as demonstrated by the bars with different letters in the figure.

The findings demonstrated that the sawdust treatment produced the highest shoots fresh and dry weight (63.78 and 42 g/plant), respectively. Although, these were slightly higher than the ash treatments (60.33 and 32.67 g/plant), were significantly higher than the control (38.89 and 28.67 g/plant) respectively.

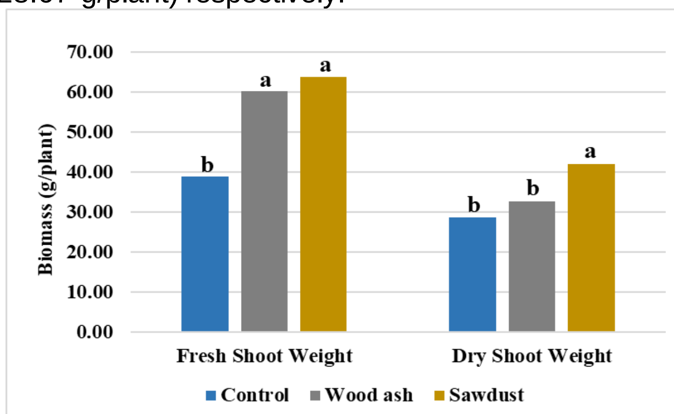

Figure 6. Effects of organic carbon resources (0, 5 and 10 t/ha) control, wood ash and sawdust on fresh and dry shoot weight t/ha of lupin plant. Bars featuring distinct characters indicate a significant difference in means at the significance level of ≤ 0.05.

4. Discussion

This study emphasized how the growth characteristics of *Lupinus albus* L. plants and soil properties are affected by various sources of organic carbon. Lupin appeared to be an effective phytoremediation for heavy metals such as (Fe, Mn, Zn, Ca, Co, Pb, and V) when comparing the control from post-treatment to pre-treatment data, according to the data, which was used to assess the effects of treatments on soil properties. As shown in (Table 1), soils were tested both before and after lupin planting. The addition of wood ash and sawdust made all of the elements, heavy metals, and essential elements more active and simpler for the lupin roots to absorb. These results are in line with another earlier research (Glaser *et al*., 2002; Lehmann *et al*., 2003;

Steiner *et al*., 2007, Chan *et al*., 2007) that showed the beneficial impacts of carbon resources on soil characteristics and plant growth. Ni *et al*. (2016), claim that sawdust enhanced plant growth by raising chlorophyll content, soluble sugar, and root activity in addition to giving the root zone the right quantity of nutrients and moisture and enhancing the morphologic and growth components. The results of this study were in agreement with the study of Salih *et al*. (2024) which investigated the influence of charcoal and humic acid treatments on soil properties. In the meantime, this study will improve the knowledge of farmers about the effective methods to increase the production of crops. Salih *et al*. (2024) study indicated that the charcoal and humic acid enhance the seed germination of lupin seeds. Furthermore, several studies have demonstrated that the charcoal treatment increased the percentage of seed germination, crop yield, and quality (Mu *et al*., 2004; Kadota and Niimi, 2004; Rondon *et al*., 2007; Steiner *et al.,* 2007; Glaser *et al*., 2002).

This study demonstrates how strongly organic carbon supplies affect lupin plant development and output. Similar results have been shown in previous studies (Salih *et al.,* 2024; Shakir and Mahmood, 2023). To increase the number of leaves generated by lupin plants, these results imply that applying wood ash may be a more effective treatment than applying sawdust. The cultivation of lupin plants may benefit from these findings in practice since more leaves on a plant could mean higher forage production.

The results show that there were no significant differences among the treatments and controls regards the root length of the lupin plant. However, previous studies demonstrated that adding organic carbon resources such as charcoal, sawdust, and humic substances may change soil structure; decrease bulk density, and increase porosity, additionally leading to increased infiltration capacity and reduced soil erosion effects (Salih *et al.,* 2024; Shakir and Mahmood, 2023; Glaser *et al.,* 2002; Oguntunde *et al.,* 2008), all of these factors may help roots take up mineral nutrients more efficiently. The findings imply that, in comparison to sawdust application, wood ash application may have a minor effect on the fresh and dry weight of roots in lupine plants. However, the wood ash treatment has increased the fresh and dry shoot weight which consequently increased the forage productivity.

5. Conclusion

The production of lupin plants and the qualities of the soil were significantly impacted by the application of wood ash and sawdust. Nonetheless, there were discernible variations across the treatments in terms of how they affected the development of plant and soil characteristics. The application of wood ash to the soils has increased Vanadium and Titanium, two heavy metals that are beneficial to human health as antioxidants and excellent treatments for diabetes. In the end, it can be concluded that sawdust and wood ash contribute significantly to improving the physical and chemical properties of soil and increasing the biomass of plants.

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Appendix

Appendix 1 shows the analysis of variance (ANOVA) for the effects of wood ash and sawdust treatments on the growth and biomass parameters of the lupin plant. Bars featuring distinct characters indicate a significant difference in means at the significance level of ≤ 0.05.

Parameters	Adj SS	Adj MS	F-Value	P-Value
Plant height (cm)	253.79	126.893	24.56	**0.001**
Leaf numbers	169.63	84.813	35.25	**0.000**
Germination (%)	216.67	108.333	19.50	**0.002**
Root length (cm)	25.43	12.717	3.96	**0.080**
Fresh Root Weight (g/plant)	56.00	28.000	3.00	0.125
Dry Root Weight (g/plant)	39.78	19.89	1.74	0.254
Fresh Shoot Weight (g/plant)	1091.3	545.66	13.30	**0.006**
Dry Shoot Weight (g/plant)	280.89	140.44	13.74	**0.006**