

## **Effect of wood vinegar on the availability of phosphorus, nitrogen, and potassium in sandy loam soil**

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### **Abstract**

A field experiment was performed at the College of Agriculture Research Station, University of Kufa, on sandy loam soil to investigate the impact of wood vinegar on the availability of phosphate, nitrogen, and potassium in this soil. Five concentrations of wood vinegar (0, 1, 5, 25, and 50 ml L<sup>-1</sup>) were utilized and administered in routine infusions for a period of three months .

The results demonstrated that wood vinegar markedly influenced the availability of soil nutrients in comparison to the control treatment, with distinct variations evident across all application rates. The third application of the BCH25 treatment yielded the maximum phosphorus concentration at 11.56 mg kg<sup>-1</sup>, surpassing the control treatment's 8.18 mg kg<sup>-1</sup>, so demonstrating that the medium concentration of vinegar was most effective in enhancing phosphorus availability. The BCH25 therapy exhibited the most favorable response to nitrogen on the third application, attaining 37.3 mg kg<sup>-1</sup>, in contrast to 7.67 mg kg<sup>-1</sup> for the control group. This is ascribed to heightened microbial activity and the mineralization of organic matter due to frequent treatments. The BCH25 treatment for potassium had superior performance, recording 113.5 mg kg<sup>-1</sup> in contrast to the control treatment's 27.58 mg kg<sup>-1</sup>. This illustrates vinegar's function in dissolving salts and liberating ions owing to its mild acidity.

The findings indicate that a medium concentration (25 mL<sup>-1</sup>) of wood vinegar was the most efficacious in enhancing soil chemical characteristics and augmenting the availability of vital plant nutrients by reducing pH and promoting microbial activity in the soil.

**Keywords: Wood vinegar; Nutrient availability; Sandy soil; NPK.**

### **Introduction**

A multitude of studies has been undertaken to augment soil productivity by strengthening its chemical and physical qualities, utilizing natural amendments that provide enduring benefits without the adverse environmental effects often linked to synthetic alternatives. [1] found that these treatments significantly enhance vegetative development and the nutritional quality of trees, leading to increased yields and improved fruit production .

The ongoing degradation of soil jeopardizes food security. Consequently, it is imperative to restore and rectify degraded soils. It is recommended that wood vinegar, obtained from the decomposition of biochar through slow thermal degradation at 500°C for 5 hours, be utilized [2]. Statistical data from the Iraqi Ministry of Environment suggests a decline in precipitation in recent years, resulting in diminished water levels and quality for both surface and groundwater. This has adversely affected soil qualities, especially chemical properties like plant-available

nitrogen, phosphorus, and potassium, which are crucial for plant nutrition and directly influence production. This research intends to investigate the impact of wood vinegar on certain chemical properties of soil, given the significance of this topic.

**Materials and Methods:**

The experiment was conducted at the Research Station/University of Kufa, affiliated with the College of Agriculture/University of Kufa, using a sandy-mixed soil

**Table (1) shows some chemical and physical properties of the experimental soil**

Soil analysis		Results	
Ph			7.70
EC		dsm <sup>-1</sup>	1.9
N-NH <sub>4</sub> <sup>+</sup>		mg/kg-1	5.6
K <sup>+</sup>		mg/kg-1	10.3
P		mg/kg-1	19.41
organic matter		g/kg-1	4
Soil texture			sandy mix
Soil separators	Sand	g/kg-1	826
	Silken clay	g/kg-1	106
	Clay	g/kg-1	68
Electrical conductivity (EC) of water		dS m <sup>-1</sup>	3.804
PH of water			7.051

The study examined the impact of varying amounts of wood vinegar on soil pH and salt levels. Five concentrations of wood vinegar (0, 1, 5, 25, and 50 ml L<sup>-1</sup>) were administered in batches to the soil over a three-month period to assess its impact on soil pH and salinity (EC). Projected chemical characteristics :

Available nitrogen was extracted using potassium chloride (KCl), and its concentration was quantified using a Kjeldahl

device, following the methodology outlined by [3.]

Available Phosphorus: Soil phosphorus was recovered utilizing sodium bicarbonate (NaHCO<sub>3</sub>). The extract was stained with a solution of ammonium molybdate and ascorbic acid. The phosphorus concentration was measured with a spectrophotometer at a wavelength of 882 nm, following the methodology outlined by [3]. Pre-prepared potassium

Potassium from prepared soil was extracted utilizing a flame photometer, as documented by [3.]

### Results and Discussion

Table (2) presents the results of the treatment differences, which were significant as determined by the least significant difference (LSD) test (0.05). The LSD values for the initial, subsequent, and final applications were 0.8, 1.0, and 0.7 mg kg<sup>-1</sup>, respectively, demonstrating that the wood vinegar treatments significantly influenced phosphorus availability in the soil relative to the control treatment .

In the initial application, the BCH1 treatment exhibited the highest phosphorus concentration (9.54 mg kg<sup>-1</sup>), above the control treatment (8.59 mg kg<sup>-1</sup>). with contrast, values diminished with treatments with elevated vinegar concentrations, such as BCH25 and BCH5. This is due to the initial application releasing some dissolved organic molecules, which facilitated the release of phosphorus. Simultaneously, the elevated levels of organic acids and phenols temporarily suppressed the activity of microorganisms involved in phosphorus mineralization [2.]

In the second application, phosphorus concentrations markedly elevated in the majority of treatments, with BCH50 exhibiting the highest value (11.08 mg kg<sup>-1</sup>), succeeded by BCH1 (10.58 mg kg<sup>-1</sup>). This enhancement is ascribed to the augmented efficacy of microbial breakdown of organic compounds generated by wood vinegar, resulting in the

liberation of organic acids, including acetic and lactic acids. These acids solubilize phosphorus associated with calcium and iron in alkaline soils, hence enhancing its accessibility to plants [4; 5 .]

In the third application, data indicated that treatment BCH25 attained the maximum phosphorus content (11.56 mg kg<sup>-1</sup>), succeeded by BCH5 (10.06 mg kg<sup>-1</sup>), whereas values diminished in treatments with either very low or very high concentrations of wood vinegar. The medium concentration (25 ml L<sup>-1</sup>) was the most effective in improving phosphorus availability over the medium term, attributed to the balanced presence of organic acids and phenolic compounds in the vinegar, which created an optimal environment for the activity of phosphate-solubilizing microorganisms [6; 7 .]

Upon examining the numbers in the table, we observe a reduction in accessible phosphorus levels for the wood vinegar treatments, which are inferior to the control treatment, particularly following the initial application. This is ascribed to the qualities of soil, which vary in certain aspects, notably chemical properties. The environment may also play a role, as the treatment facilitated phosphorus adsorption via the soil's cation exchange capacity .

The enhancement of soil cation exchange capacity is ascribed to the organic chemicals in wood vinegar, which ameliorate soil characteristics and augment microbial activity, perhaps resulting in increased phosphorus uptake by plants.

**Table (2) Effect of different levels of wood vinegar on the availability of phosphorus mg kg<sup>-1</sup> in the soil at the three times.**

Third addition	Second addition	First addition	treatment
3.94	10.58	9.54	BCH1
10.06	2.76	3.05	BCH5
11.56	9.45	2.01	BCH25
2.89	11.08	8.92	BCH50
8.18	8.32	8.59	Control
0.7	1.0	0.8	LSD(0.05)

Table (3) presents the results of significant differences among treatments as determined by the least significant difference test at the 0.05 significance level. The LSD values for the three additions were 8.53, 6.45, and 5.93 mg kg<sup>-1</sup>, respectively, demonstrating that wood vinegar significantly influenced nitrogen buildup in the soil .

In the first additive, the BCH1 treatment exhibited the highest nitrogen concentration (26.35 mg kg<sup>-1</sup>) relative to the control treatment (17.4 mg kg<sup>-1</sup>), but the concentrations were markedly lower in BCH25 (4.47 mg kg<sup>-1</sup>) and BCH5 (7.36 mg kg<sup>-1</sup>). The disparity arises because lower doses of wood vinegar enhanced the initial decomposition of organic matter, thereby temporarily elevating the rate of nitrogen fixation in the soil, whereas higher concentrations emitted phenolic compounds and organic acids that inhibited the activity of nitrogen-fixing bacteria [2.]

In the second application, nitrogen content markedly increased across most treatments, with BCH50 exhibiting the highest value

(33.62 mg kg<sup>-1</sup>), followed by BCH1 (30.22 mg kg<sup>-1</sup>). This suggests that repeated application enhanced microbial activity associated with nitrogen mineralization, especially as the organic constituents in wood vinegar degraded into simpler molecules more easily assimilated by microbes [5; 8]. Moreover, enhanced soil aeration and microbial activity over time facilitated the conversion of organic nitrogen into assimilable mineral forms [7 .]

In the third addition, the BCH25 treatment exhibited the maximum nitrogen content (37.3 mg kg<sup>-1</sup>), succeeded by BCH5 (26.2 mg kg<sup>-1</sup>), but the nitrogen levels in BCH1 and BCH50 diminished relative to the control treatment (7.67 mg kg<sup>-1</sup>). The findings demonstrate that a medium concentration of wood vinegar (25 ml L<sup>-1</sup>) was the most effective in improving nitrogen availability over the medium term, attributed to the balanced carbon-to-nitrogen (C:N) ratio in the vinegar, which created an ideal environment for organic matter decomposition while minimizing nitrogen loss as NH<sub>3</sub> or N<sub>2</sub> O [9; 6.]

**Table (3) Effect of different levels of wood vinegar on nitrogen availability mg kg<sup>-1</sup> in the soil at the three times.**

Third addition	Second addition	First addition	Treatment
9.97	30.22	26.35	BCH1
26.2	6.33	7.367	BCH5
37.3	21.52	4.475	BCH25
6.67	33.62	18.3	BCH50
7.67	11.2	17.4	Contrul
5.92	6.44	8.53	LSD(0.05)

Table (4) shows the results, which revealed clear and significant differences between the treatments according to the least significant difference (LSD) test (0.05). The LSD values for the first, second, and third applications were 10, 40, and 12, respectively, indicating that wood vinegar had a significant effect on potassium availability in the soil.

In the first application, treatment BCH1 achieved the highest potassium concentration (82.15 mg kg<sup>-1</sup>) compared to the control treatment (50.1 mg kg<sup>-1</sup>), followed by BCH50 (57.48 mg kg<sup>-1</sup>), while the values decreased significantly in treatments BCH25 and BCH5. This increase is attributed to the fact that adding wood vinegar at low concentrations helped dissolve some soluble salts and release potassium ions from exchange complexes. This was due to the acidic effect of the vinegar, which temporarily lowered the soil pH, thus increasing potassium solubility [4; 2.]

In the second application, a significant increase in potassium content was observed. The BHC50 treatment (103.4 mg kg<sup>-1</sup>) recorded the highest value, followed by BCH50 (103.4 mg kg<sup>-1</sup>) and BCH1 (92.48 mg kg<sup>-1</sup>). This marked improvement is attributed to the accumulation of dissolved organic compounds over time, which

increased microbial activity that releases nutrients. Additionally, the soil solution experienced increased ion mobility due to improved physical structure and reduced cohesion between fine particles [5; 8]. Furthermore, the continued biodegradation of acetic acid components, such as organic acids and esters, helped release potassium from cation exchange complexes (CECs) in the topsoil layers.

In the third application, the highest potassium value was observed in the BCH25 treatment (113.5 mg kg<sup>-1</sup>), followed by BCH5 (81.48 mg kg<sup>-1</sup>) and BHC5 (81.52 mg kg<sup>-1</sup>), while values were lower in BCH1 and BCH50 compared to the control treatment (27.58 mg kg<sup>-1</sup>). These results indicate that moderate concentrations of wood vinegar were the most efficient in improving potassium availability at the end of the experiment, due to the balance of organic vinegar components and the availability of acids that stimulate element release without causing microbial inhibition or excessive salinity [6; 10]. Furthermore, the gradual decomposition of the vinegar compounds contributed to the slow and continuous release of potassium, enhancing soil fertility in later growth stages.

In general, it can be said that wood vinegar contributed to a gradual increase in potassium

availability as the additions progressed, especially at moderate concentrations (25 ml L<sup>-1</sup>), reflecting its role as an effective organic

improver that enhances the chemical properties of the soil and increases the availability of macronutrients [2; 7.]

**Table (4) Effect of different levels of wood vinegar on the availability of potassium mg kg-1 in the soil at the three times.**

Third addition	Second addition	First addition	Treatment
33.4	92.48	82.148	BCH1
81.48	29.65	25.633	BCH5
113.5	67.2	16.9	BCH25
24.58	103.4	57.475	BCH50
27.58	37.83	50.1	Contrl
12	40	10	LSD(0.05)

**Conclusion**

The findings of this study demonstrate that wood vinegar significantly improves the chemical properties of sandy loam soil and enhances the availability of key macronutrients . Among the tested concentrations , the medium level (25 ml L-1) was the most effective in increasing the

availability of phosphorus , nitrogen , and potassium . This improvement is mainly attributed to involved in nutrient minerlization consequently , wood vinegar can be considered apromising organic amendment for enhancing the fertility of nutrient-deficient sandy soils.

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