# Effect of Phosphorus and Perlite Addition and Aspirin Spraying on Improving the Growth and Yield of Barley Grown in Saline Soil

DHUHA ABDULLAH MHMOOD [1]
duhaabdullah@uodiyala.edu.iq

Hussein Aziz Mohammed [2]
husseinaziz@uodiyala.edu.iq

[1,2]Department of Soil Science and Water Recourses College of Agriculture, University of Diyala, Diyala, Iraq

## Abstract

A pot experiment was conducted at the Graduate Research Station, College of Agriculture, University of Diyala, Iraq, during 2025–2026 growing season to evaluate the individual and interactive effects of phosphorus, perlite, and foliar application of aspirin on selected physiological and yield traits of barley grown in saline clay soil. The experiment included 36 plastic pots, each sown with 25–35 seeds and irrigated using a T-Tape drip irrigation system. Treatments were arranged in a factorial experiment (2 × 2 × 3) based on a randomized complete block design (RCBD) with three replicates. The factors consisted of two soil-applied phosphorus levels (0 and 5 g $kg^{-1}$ soil), two perlite levels (0 and 25 g $kg^{-1}$ soil), applied once before sowing, and three foliar aspirin at (0, 10, and 20 g $L^{-1}$), applied twice during the growing season. Phosphorus application significantly increased available soil phosphorus, leaf area, and grain yield per plant. Perlite significantly enhanced leaf area and grain yield per plant, whereas foliar application of aspirin, particularly at 20 g $L^{-1}$, produced the greatest improvement in leaf area and total plant yield. However, aspirin had no significant effect on soil pH or relative chlorophyll content. Moreover, the two-way and three-way interactions among phosphorus, perlite, and aspirin produced the highest values for most of the studied traits.

**Keywords:** Barley; Phosphorus; Perlite; Aspirin; Total plant yield.

## Introduction

Barley (*Hordeum vulgare* L.) is one of the world's major cereal crops owing to its diverse applications in human nutrition, animal feed, and forage production. Its adaptability to arid and semi-arid environments makes it a strategic crop for enhancing global food security **[1]**.

Phosphorus is an essential macronutrient regulating barley growth and productivity through its role in energy transfer, cell division, and root development. Adequate phosphorus availability improves nutrient uptake, water-use efficiency, and photosynthetic performance, leading to enhanced growth and grain yield **[2]**. The **[3]** reported that soil and nano-phosphorus applications significantly improved growth traits, plant phosphorus concentration, and soil phosphorus availability, with 90 kg P $ha^{-1}$ producing the best results. Similarly, **[4]** found that applying 90 kg $P_2O_5$ $ha^{-1}$ significantly increased grain yield per plant.

Perlite is an inorganic soil amendment widely used to improve soil physical properties by increasing porosity, enhancing aeration, reducing bulk density, and

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promoting root growth. It also improves water retention and nutrient availability, thereby enhancing plant performance under adverse environmental conditions **[5]**. **[6]** demonstrated that perlite application at 250 kg $ha^{-1}$ significantly increased leaf area, chlorophyll content, and grain yield per plant in barley and wheat.

Aspirin (acetylsalicylic acid) has recently received considerable attention as a plant biostimulant due to its ability to regulate physiological processes. Foliar application enhances photosynthetic efficiency, chlorophyll accumulation, enzymatic activity, and water status while mitigating environmental stress. Consequently, it improves vegetative growth, physiological performance, and yield in barley **[7]**. Likewise, The **[8]** reported that foliar application of 1 mM salicylic acid significantly increased chlorophyll content and grain yield compared with the untreated control

## Materials and Methods

The experiment was conducted at the Graduate Research Station, College of Agriculture, University of Diyala, Iraq, during the 2025–2026 growing season to investigate the effects of phosphorus and perlite soil application, and foliar application of acetylsalicylic acid (Aspirin), on the growth and productivity of barley. Soil samples were air-dried, ground, and passed through a 2-mm sieve before physical and chemical analyses were performed at the Soil and Water Resources Laboratory, College of Agriculture, University of Diyala (Table 1). Thirty-six plastic pots, each filled with 20 kg of soil and spaced 1 m apart, were arranged into three blocks of 12 experimental units each. Barley seeds were sown on 20 October 2025 at a rate of 25–35 seeds per pot and irrigated using a T-Tape drip irrigation system.

The experiment consisted of three factors: phosphorus applied at 0 and 5 g $kg^{-1}$ soil, perlite applied at 0 and 500 g $pot^{-1}$, both incorporated once before sowing, and foliar application of acetylsalicylic acid (Aspirin) at 0, 10, and 20 g $L^{-1}$.

Spray solutions were prepared by dissolving the required concentrations in water with 0.1 mL $L^{-1}$ liquid soap as a surfactant. Foliar applications were performed twice during the growing season, on 19 November 2025 and one month later, in the early morning to maximize absorption and minimize evaporative losses. The treatments were arranged in a 2 × 2 × 3 factorial experiment using a randomized complete block design (RCBD) with three replicates, resulting in 12 treatment combinations and 36 experimental units. Data were analyzed using SAS software, and treatment means were compared using the least significant difference (LSD) test at the 0.05 probability level

Table 1. Physical and chemical characteristics of the experimental soil

| Measured trait | Value | Unit |
|---|---|---|
| PH | 7.5 | - |
| EC | 10.18 | ds $m^{-1}$ |
| Available Nitrogen | 13 | mg $kg^{-1}$ |
| Available Phosphorus | 10.7 | mg $kg^{-1}$ |

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| | | |
|---|---|---|
| Available Potassium | 167 | mg $kg^{-1}$ |
| Organic matter | 1.2 | % |
| Calcium carbonate (CaCO3) | 23 | g $kg^{-1}$ |
| Sand | 19.6 | g $kg^{-1}$ |
| Clay | 46.88 | |
| Silt | 33.52 | |
| Soil texture | Clay | - |

**Experimental Measurements**

**1. Available soil phosphorus (mg P $kg^{-1}$ soil)**

Available soil phosphorus was determined according to the Olsen and Sommers method **[9]**, as described by **[10]**.

**2. Soil pH**

Soil pH was measured using a pH meter in a 1:2.5 soil-to-water suspension following the procedure described by **[10].**

**3. Relative chlorophyll content (mg $g^{-1}$ FW)**

Relative chlorophyll content was determined from 1 g of fresh leaf tissue collected from five plants. The samples were homogenized in 20 mL of 80% acetone, filtered, and absorbance of extract was measured at 663 and 645 nm using a UV–Visible spectrophotometer. Chlorophyll content was calculated according to **[11].**

**4. Leaf area ($cm^2$ $plant^{-1}$)**

Leaf area was estimated using the disc method according to Watson (1958) using the following equation:

**Leaf area = (Total leaf dry weight / Disc dry weight) × Disc area**

**5. Total plant yield (g $pot^{-1}$)**

Total plant yield was determined by harvesting all plants from each experimental unit, recording the total grain weight, and expressing the results as g $pot^{-1}$

**Results and Discussion**

**1- Available Soil Phosphorus (mg P $kg^{-1}$ soil)**

As shown in table 1, phosphorus application significantly increased available soil phosphorus. The second phosphorus level (5 g $kg^{-1}$ soil) produced highest mean value (17.84 mg P $kg^{-1}$ soil) compared with untreated control (14.67 mg P $kg^{-1}$ soil), representing an increase of 21.61%. In contrast, neither perlite application nor foliar spraying with aspirin had a significant effect on available soil phosphorus.

The interaction between phosphorus and perlite significantly affected available soil phosphorus, with highest mean (18.70 mg P $kg^{-1}$ soil) recorded under phosphorus

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application, whereas lowest value (14.64 mg P $kg^{-1}$ soil) was obtained in absence of phosphorus combined with 25 g $kg^{-1}$ soil perlite. Likewise, the phosphorus × aspirin interaction showed that combination of 5 g $kg^{-1}$ soil phosphorus and 10 g $L^{-1}$ aspirin produced the highest mean (18.46 mg P $kg^{-1}$ soil), while the control treatment recorded the lowest value (13.80 mg P $kg^{-1}$ soil). Similarly, the perlite × aspirin interaction reached its maximum value mean (17.71 mg P $kg^{-1}$ soil) at 25 g $kg^{-1}$ soil perlite combined with 20 g $L^{-1}$ aspirin, whereas control treatment recorded the lowest value mean (14.68 mg P $kg^{-1}$ soil). The three-way interaction among phosphorus, perlite, and aspirin also significantly influenced available soil phosphorus, with the highest mean (20.13 mg P $kg^{-1}$ soil) and lowest mean (12.63 mg P $kg^{-1}$ soil) recorded under the combined treatment and control, respectively.

Table 1. Effects of phosphorus and perlite application and foliar aspirin spraying on available soil phosphorus concentration (mg P $kg^{-1}$ soil)

| Phosphorus (g $kg^{-1}$ soil) | Perlite (B) (g $kg^{-1}$ soil) | Aspirin (g $l^{-1}$) | | | Phosphorus * Perlite |
|---|---|---|---|---|---|
| | | 0 | 10 | 20 | |
| 0 | 0 | 12.63 | 14.76 | 16.70 | 14.70 |
| | 25 | 14.96 | 13.66 | 15.30 | 14.64 |
| 5 | 0 | 16.73 | 18.10 | 16.13 | 16.98 |
| | 25 | 17.13 | 18.83 | 20.13 | 18.70 |
| L.S.D 0.05 | | 4.16 | | | 2.40 |
| Phosphorus * Aspirin | | | | | Phosphorus average |
| 0 | | 13.80 | 14.21 | 16.00 | 14.67 |
| 5 | | 16.93 | 18.46 | 18.13 | 17.84 |
| L.S.D 0.05 | | 2.94 | | | 1.70 |
| Perlite * Aspirin | | | | | Perlite average |
| 0 | | 14.68 | 16.43 | 16.41 | 15.84 |
| 25 | | 16.05 | 16.25 | 17.71 | 16.67 |
| L.S.D 0.05 | | 1.70) N.S( | | | 2.94 |
| Aspirin | | 15.36 | 16.34 | 17.06 | |
| L.S.D 0.05 | | (N.S) 2.08 | | | |

## 2. Soil pH

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The results presented in Table (2) showed that the application of phosphorus and perlite, foliar spraying with aspirin, and their two- and three-way interactions had no significant effect on soil pH.

Table 2. Effects of phosphorus and perlite application and foliar aspirin spraying on Soil pH

| Phosphorus (g kg⁻ ¹ soil) | Perlite (B) (g kg⁻ ¹ soil) | Aspirin (g l$^{-1}$) | | | Phosphorus * Perlite |
|---|---|---|---|---|---|
| | | 0 | 10 | 20 | |
| 0 | 0 | 7.66 | 7.60 | 7.60 | 7.62 |
| | 25 | 7.66 | 7.56 | 7.63 | 7.62 |
| 5 | 0 | 7.66 | 7.63 | 7.53 | 7.61 |
| | 25 | 7.50 | 7.56 | 7.56 | 7.54 |
| L.S.D 0.05 | | (N.S) | | | )N.S( |
| Phosphorus * Aspirin | | | | | Phosphorus average |
| 0 | | 7.66 | 7.58 | 7.61 | 7.62 |
| 5 | | 7.58 | 7.60 | 7.55 | 7.57 |
| L.S.D 0.05 | | (N.S) | | | ) N.S(0.06 |
| Perlite * Aspirin | | | | | Perlite average |
| 0 | | 7.66 | 7.61 | 7.56 | 7.61 |
| 25 | | 7.58 | 7.56 | 7.60 | 7.58 |
| L.S.D 0.05 | | 0.11 | | | )N.S( |
| Aspirin | | 7.62 | 7.59 | 7.58 | |
| L.S.D 0.05 | | (N.S) | | | |

**3. Relative chlorophyll content (mg g⁻ ¹ FW)**

Table 3 shows that neither phosphorus nor perlite application significantly affected the relative chlorophyll content of leaves. Likewise, aspirin spraying had no significant effect on relative chlorophyll content. The interaction between phosphorus and perlite was also non-significant; however. The interactions of no phosphorus with aspirin at 10 g L⁻ ¹ and phosphorus application with aspirin at 20 g L⁻ ¹ both produced highest chlorophyll content mean (1.37 mg g⁻ ¹), whereas no phosphorus combined with aspirin at 20 g L⁻ ¹ resulted in lowest value mean (1.18 mg g⁻ ¹). For perlite × aspirin interaction, perlite application combined with aspirin at 10 or 20 g L⁻ ¹ recorded

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highest chlorophyll content mean (1.37 mg $g^{-1}$), while lowest value mean (1.18 mg $g^{-1}$) was observed under no perlite combined with aspirin at 20 g $L^{-1}$. The three-way interaction showed that control treatment produced highest relative chlorophyll content mean (1.49 mg $g^{-1}$), whereas lowest value mean (1.05 mg $g^{-1}$) was obtained from combination of no phosphorus, perlite application, and aspirin spraying at 20 g $L^{-1}$.

Table 3. Effects of phosphorus and perlite application and foliar aspirin spraying on relative chlorophyll content (mg $g^{-1}$ FW)

| Phosphorus (g $kg^{-1}$ soil) | Perlite (B) (g $kg^{-1}$ soil) | Aspirin (g $l^{-1}$) | | | Phosphorus * Perlite |
|---|---|---|---|---|---|
| | | 0 | 10 | 20 | |
| 0 | 0 | 1.49 | 1.34 | 1.31 | 1.38 |
| | 25 | 1.23 | 1.40 | 1.05 | 1.23 |
| 5 | 0 | 1.23 | 1.40 | 1.43 | 1.36 |
| | 25 | 1.20 | 1.27 | 1.31 | 1.26 |
| L.S.D 0.05 | | 0.27 | | | (N.S) |
| Phosphorus * Aspirin | | | | | Phosphorus average |
| 0 | | 1.36 | 1.37 | 1.18 | 1.30 |
| 5 | | 1.21 | 1.34 | 1.37 | 1.31 |
| L.S.D 0.05 | | 0.19 | | | (N.S) |
| Perlite * Aspirin | | | | | Perlite average |
| 0 | | 1.36 | 1.37 | 1.37 | 1.37 |
| 25 | | 1.21 | 1.34 | 1.18 | 1.24 |
| L.S.D 0.05 | | 0.19 | | | 0.11 |
| Aspirin | | 1.29 | 1.35 | 1.28 | |
| L.S.D 0.05 | | (N.S) | | | |

**4. Leaf area ($cm^2$ $plant^{-1}$)**

Table 4 shows that phosphorus application (5 g $kg^{-1}$ soil) significantly increased the leaf area mean of barley plants to 28.30 $cm^2$ $plant^{-1}$, compared with 19.21 $cm^2$ $plant^{-1}$ in the control, representing a 47.32% increase. Perlite application at (25 g $kg^{-1}$ soil) also significantly enhanced leaf area mean, reaching 26.23 $cm^2$ $plant^{-1}$ versus 21.28 $cm^2$ $plant^{-1}$ in control (23.26% increase). Similarly, aspirin spraying at 20 g $L^{-1}$ significantly increased leaf area to 25.55 $cm^2$ $plant^{-1}$, exceeding control (22.05 $cm^2$ $plant^{-1}$) by 15.87%.

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Significant interaction effects were also observed. The phosphorus × perlite interaction produced highest leaf area (31.43 cm² plant⁻ ¹), whereas control recorded lowest value (17.40 cm² plant⁻ ¹). Likewise, phosphorus application combined with aspirin at 20 g L⁻ ¹ resulted in greatest leaf area (30.65 cm² plant⁻ ¹), while the control showed lowest value (18.00 cm² plant⁻ ¹). For perlite × aspirin interaction, combination of perlite (25 g kg⁻ ¹ soil) and aspirin at (20 g L⁻ ¹) produced highest leaf area mean (28.45 cm² plant⁻ ¹), whereas the control recorded lowest value (19.95 cm² plant⁻ ¹).The three-way interaction of phosphorus, perlite, and aspirin at 20 g L⁻ ¹ achieved maximum leaf area mean (34.60 cm² plant⁻ ¹), while control treatment recorded minimum value (16.20 cm² plant⁻ ¹).

Table 4. Effects of phosphorus and perlite application and foliar aspirin spraying on Leaf area (cm² plant⁻ ¹)

| Phosphorus (g kg⁻ ¹ soil) | Perlite (B) (g kg⁻ ¹ soil) | Aspirin (g l$^{-1}$) | | | Phosphorus * Perlite |
|---|---|---|---|---|---|
| | | 0 | 10 | 20 | |
| 0 | 0 | 16.20 | 17.40 | 18.60 | 17.40 |
| | 25 | 19.80 | 21.00 | 22.30 | 21.03 |
| 5 | 0 | 23.70 | 25.10 | 26.70 | 25.16 |
| | 25 | 28.50 | 31.20 | 34.60 | 31.43 |
| L.S.D 0.05 | | 5.20 | | | 2.85 |
| Phosphorus * Aspirin | | | | | Phosphorus average |
| 0 | | 18.00 | 19.20 | 20.45 | 19.21 |
| 5 | | 26.10 | 28.15 | 30.65 | 28.30 |
| L.S.D 0.05 | | 3.94 | | | 2.33 |
| Perlite * Aspirin | | | | | Perlite average |
| 0 | | 19.95 | 21.25 | 22.65 | 21.28 |
| 25 | | 24.15 | 26.10 | 28.45 | 26.23 |
| L.S.D 0.05 | | | | | 2.33 |
| Aspirin | | 22.05 | 23.67 | 25.55 | |
| L.S.D 0.05 | | 2.65 | | | |

**5. Total plant yield (g pot⁻ ¹)**

Table 5 indicates that phosphorus application(5 g kg⁻ ¹ soil) significantly increased total yield per plant mean to 165.98 g pot⁻ ¹, compared with 119.78 g pot⁻ ¹ in control, representing a 38.57% increase. Perlite application at (25 g kg⁻ ¹ soil) also significantly enhanced total yield, reaching 153.61 g pot⁻ ¹ versus 132.15 g pot⁻ ¹ in the control (16.24% increase). Likewise, aspirin spraying at 10 and 20 g L⁻ ¹ significantly increased total yield to 149.75 and 143.72 g pot⁻ ¹, respectively, corresponding to increases of 10.79% and 6.33% over control.Significant interaction effects were also observed. The phosphorus × perlite interaction produced highest total

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yield (175.70 g pot$^{-1}$), whereas control recorded lowest value (108.03 g pot$^{-1}$). Similarly, phosphorus combined with aspirin at 20 g L$^{-1}$ resulted in highest total yield (171.35 g pot$^{-1}$), while control produced lowest value (111.10 g pot$^{-1}$). The perlite × aspirin interaction showed that perlite (25 g kg$^{-1}$ soil) combined with aspirin at 20 g L$^{-1}$ achieved greatest total yield (159.30 g pot$^{-1}$), whereas control recorded the lowest yield (123.10 g pot$^{-1}$). The three-way interaction of phosphorus, perlite, and aspirin at 20 g L$^{-1}$ produced highest total yield per plant (178.40 g pot$^{-1}$), while control treatment recorded lowest value (100.0 g pot$^{-1}$).

Table 5. Effects of phosphorus and perlite application and foliar aspirin spraying on Total plant yield (g pot$^{-1}$)

| Phosphorus (g kg$^{-1}$ soil) | Perlite (B) (g kg$^{-1}$ soil) | Aspirin (g l$^{-1}$) | | | Phosphorus * Perlite |
|---|---|---|---|---|---|
| | | 0 | 10 | 20 | |
| 0 | 0 | 100.00 | 108.00 | 116.10 | 108.03 |
| | 25 | 122.20 | 132.20 | 140.20 | 131.53 |
| 5 | 0 | 146.20 | 158.30 | 164.30 | 156.26 |
| | 25 | 172.30 | 176.40 | 178.40 | 175.70 |
| L.S.D 0.05 | | 6.25 | | | 4.12 |
| Phosphorus * Aspirin | | | | | Phosphorus average |
| 0 | | 111.10 | 120.10 | 128.15 | 119.78 |
| 5 | | 159.25 | 167.35 | 171.35 | 165.98 |
| L.S.D 0.05 | | 6.85 | | | 3.25 |
| Perlite * Aspirin | | | | | Perlite average |
| 0 | | 123.10 | 133.15 | 140.20 | 132.15 |
| 25 | | 147.25 | 154.30 | 159.30 | 153.61 |
| L.S.D 0.05 | | 6.85 | | | 3.25 |
| Aspirin | | 135.17 | 143.72 | 149.75 | |
| L.S.D 0.05 | | 5.65 | | | |

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The increase in available soil phosphorus following phosphorus application (table 1) can be attributed to the higher phosphorus concentration in the soil solution and the saturation of phosphorus fixation sites on soil colloids, thereby increasing its availability for plant uptake and reducing fixation losses during the growing season [12]. The improvement in vegetative growth, particularly leaf area (table 4), may be explained by the essential role of phosphorus in cellular energy metabolism. Phosphorus enhances ATP synthesis, providing the energy required for cell division and expansion in meristematic tissues. In addition, phosphorus is a structural component of thylakoid membranes, improving light harvesting and carbon assimilation, which ultimately promotes leaf expansion and biomass accumulation [13]. The increase in total plant yield is likely associated with enhanced ATP production, improved root development, and more efficient translocation of photoassimilates to developing grains, resulting in greater grain filling and dry matter accumulation [14**]**. The increases in relative chlorophyll content, leaf area, and total plant yield following perlite application may be attributed to improvements in soil physical properties, particularly greater porosity, aeration, and water-holding capacity. These changes enhance root growth, nutrient uptake, photosynthetic efficiency, and biomass accumulation, leading to improved plant growth and productivity [15]. The positive effects of aspirin spraying on leaf area and total plant yield may be attributed to its ability to enhance photosynthetic efficiency, stimulate cell division and expansion, improve nutrient uptake, and promote the translocation of assimilates to reproductive organs. These physiological responses increase leaf growth, dry matter accumulation, and ultimately total plant productivity **[16]**; [17].

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