Effect of soil amendment (Perlite) on some physical characteristics and *Zea mays L* productivity .

Faris A. Al-Wazzan[1], Maqsood K. Abdulrahman[2]

1. Soil Science and Water Resources Dep., College of Agriculture and Forestry, University of Mosul/ Iraq Dr.farisakram@uomosul.edu.iq

2. Ministry of Agriculture and water resources, KRG/ Iraq

maqsood.khalid@ uomosul.edu.iq

Abstract

This study investigates the effects of perlite amendments (0%, 2.5%, and 5%) on soil hydraulic properties and maize (*Zea mays* L.) productivity under drip irrigation. A field experiment was conducted in Mosul, Iraq. Using a randomized complete block design (RCBD) on silty loam soil texture during the summer of 2023. Soil hydraulic properties were analyzed using the Van Genuchten model, which revealed that the 5% perlite treatment (P2) significantly improved moisture retention, reducing the value of parameter *n* to 1.32 and increasing water holding capacity. Results showed that P2 enhanced soil moisture content (36.58% compared with control 31.99%), reduced bulk density (1.11 Mg m^{-3} compared with the control. 1.40 Mg m^{-3}), and increased total porosity (58.0% vs. 47.0%). Additionally, P2 revealed the highest saturated hydraulic conductivity (2.55 cm hr^{-1}) and infiltration rate (2.76 cm hr^{-1}), leading to a 14.4% increase in maize yield 10.3 ton ha^{-1} compared to 9.0 ton ha^{-1} in the control. These results determined perlite's potential to enhance water use efficiency and crop productivity. The study concludes that perlite is improving agricultural practices in water-scarce environments, offering practical solutions for enhancing food security in drought areas. Future research should explore the long-term effects of perlite on soil health and economic feasibility.

Keywords: Perlite, Physical Properties, Maize, Volumetric Water Content.

Introduction

Perlite is used in agriculture as a soil amendment, and it is a volcanic rock, at a high temperature (900°C) expanded more than to 4–20 times, creating a lightweight, highly porous material [1,2]. One of perlite's key characteristics is chemical neutrality, with a pH range of 6.5–7.5, and its lack of nutrients or cation exchange capacity)[3]. Despite this, perlite plays a critical role in agriculture by enhancing soil hydrological properties. It can absorb 2–3 times its weight in water, reducing irrigation costs and energy consumption while maintaining optimal moisture levels for plant growth [4]. Thus, improving the soil structure for plant growth. Perlite's inorganic structure offers further advantages, as it does not degrade over time, and resists changes in chemical composition [5,6]. Its high porosity (up to 90%) enhances water infiltration, reduces evaporation, and improves root zone aeration, which are critical for plant growth in arid and semi-arid regions [7].

Material and methods

Location:

The field experiment was conducted in Mosul University, Iraq. (43°09'10.78" E, 36°20'48.54" N, elevation: 222 m above sea level). The soil at the site is calcareous, classified as Calciorthids according to the USDA soil taxonomy.

Trial design:

The experiment was arranged in a randomized complete block design (RCBD) with three perlite application levels: 0% (control, P0), 2.5% (P1), and 5% (P2). Each treatment was replicated three times. Maize was planted in four rows per plot, with 75 cm between rows and 50 cm between blocks. Seeds were planted at a depth of 25 cm, with a germination rate of 97%. Soil preparation included deep plowing and the use of a Rotavator cultivator to ensure uniform soil structure.

Calculate Van Genuchten parameters:

Soil hydraulic properties were described by using [8]. type analytical functions that use the to describe the water-retention curve

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + |\alpha h|^n\right]^m} \quad \text{……………. (1)}$$

$\theta(h)$: Predicted volumetric water content

θ_s : water content at saturation

θ_r : Residual water content

α, n, m : Independent standards

h : Moisture tension

$$\theta p = \frac{\theta_s + \theta_r}{2} \quad \text{------------- (2)}$$

$$slope = \frac{d\theta}{dlog(hp)} \quad \text{-------------- (3)}$$

$$sp = \frac{1}{\theta s} - \theta r * \frac{d\theta}{dlog(hp)} \quad \text{------------ (4)}$$

$$m = 1 - exp^{(-0.8sp)} \quad 0<Sp<1 \quad \text{-------- (5)}$$

$$n = \frac{1}{1-m} \quad \text{-------------- (6)}$$

$$\alpha = \frac{1}{hp}(2^{\frac{1}{m}} - 1)^{1-m} \quad \text{--------- (7)}$$

Physical and chemical analyses:

Three soil samples (0–30 cm depth) were taken using an auger-hall, dry aired, and then sieved to a diameter of 2 mm for analysis before planting. Soil physical and chemical analyses were performed using standard methods [9]. The perlite and soil analyses Explained in Tables (1& 2).

Table (1): Some chemical and physical properties of Perlite

Parameter	Perlite
pH	7-7.5
Color	White
Density	75 $kg.m^3$
Granulometry	1.4 gr
Electric conductivity EC	0.1 $dS.m^{-1}$
Silica SiO_2	74.7 %
$Al1_2O_3$	13.5 %
Fe_2O_3	1.2 %
CaO	0.6 %

MgO	0.3 %
K_2O	3.9 %
Na_2O	3.3 %
H_2O	2.5 %

Table (2) : Some chemical and physical properties of soil.

ITEM	QUANTITY	UNIT
PH	7.6	
EC	0.4	dS.m-1
Organic matter	13.4	g.kg-1
Bulk density	1.45	$Mg.m^{-1}$
Total Porosity	47.0	%
Infiltration rate	2.032	cm hr^{-1}
Hydraulic conductivity	1.36	cm hr^{-1}
Clay	241	g kg^{-1}
Silt	560	g kg^{-1}
Sand	199	g kg^{-1}
Soil texture	Silty Loam	

Result and discussion

1. **Moisture content (θ_v)**

The volumetric water content (VWC) of the soil was measured weekly at a depth of 0–30 cm using a TDR 300 device under surface drip irrigation. The highest mean VWC was observed in treatment P2 (5% perlite), with an average value of **36.58%,** compared to **31.99%** in the control (P0). Treatment P1 (2.5% perlite) recorded an intermediate value of **35.03%** (Table 3, Figure 1).

These findings align with previous studies by [10,11] who demonstrated that perlite enhances available water content in soils. The increase in VWC can be attributed to perlite's high porosity and water-holding capacity, which improve moisture retention and reduce leaching losses. Perlite's ability to retain water is particularly beneficial during drought periods, as it ensures consistent moisture availability for plant roots.

Table (3): Soil Volumetric Water Content (θ_v) (%)

week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	mean
P_0	26.4	27.3	28.1	27.7	48.3	39.9	32.4	27.5	30.2	36.4	27.8	32.4	34.2	29.7	33.2	30.4	**31.99**
p_1	29.6	34.2	30.2	31.9	52.1	51.4	32.1	27.5	35.4	37.1	31.2	33	36.7	30.6	36.1	31.5	**35.03**
p_2	34.7	37.8	31.5	32.4	56.3	47.8	33.5	28.9	37.2	39.5	33.8	33.1	39.3	32.6	32.5	34.5	**36.58**

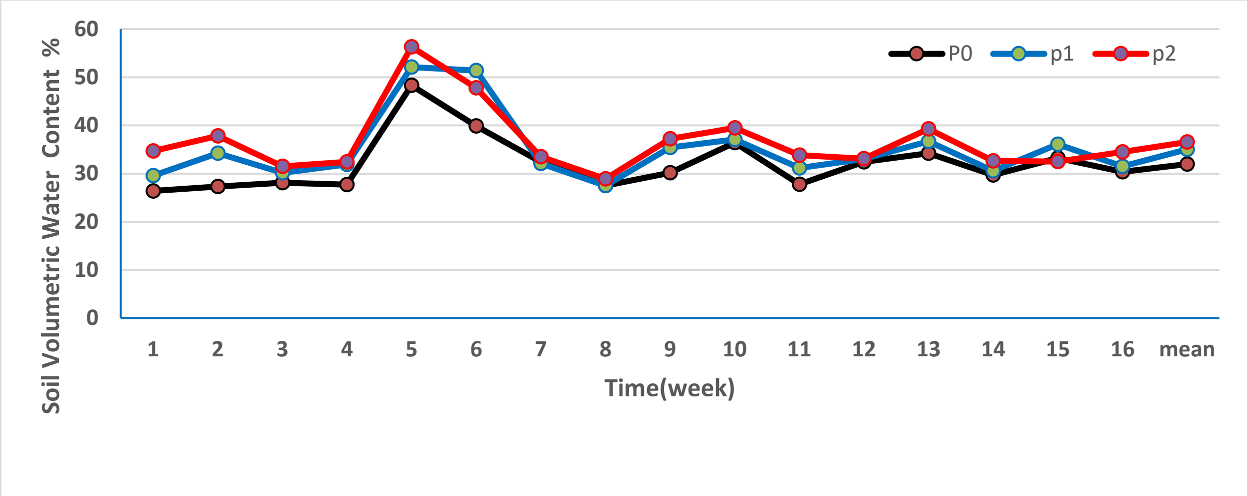

Figure (1): The relation between volumetric water content and time.

2. Soil Density and Total Porosity:

Perlite significantly reduced bulk density and increased total porosity. The lowest mean bulk density was recorded in treatment P2 (**1.11 Mg m⁻³**) compared to the control (**1.40 Mg m⁻³**). Conversely, total porosity was highest in P2 (**58.0%**) compared to the control (**47.0%**), representing a **21.2% increase** (Table 4, Figure 2). are critical for improving root zone aeration and water infiltration. These changes create a more favorable environment for root growth and nutrient uptake. Similar findings were reported by [12,13,14]. who highlighted perlite's role in enhancing soil structure and promoting better aeration.

Table (4): Soil Density and Porosity .

Treatment	Porosity (T.P) %	Bulk Density (ρ_b) Mg m^{-3}	particle Density(P_s)
P0	47.0	1.40	2.65
P1	56.8	1.18	2.69
P2	58.0	1.11	2.70

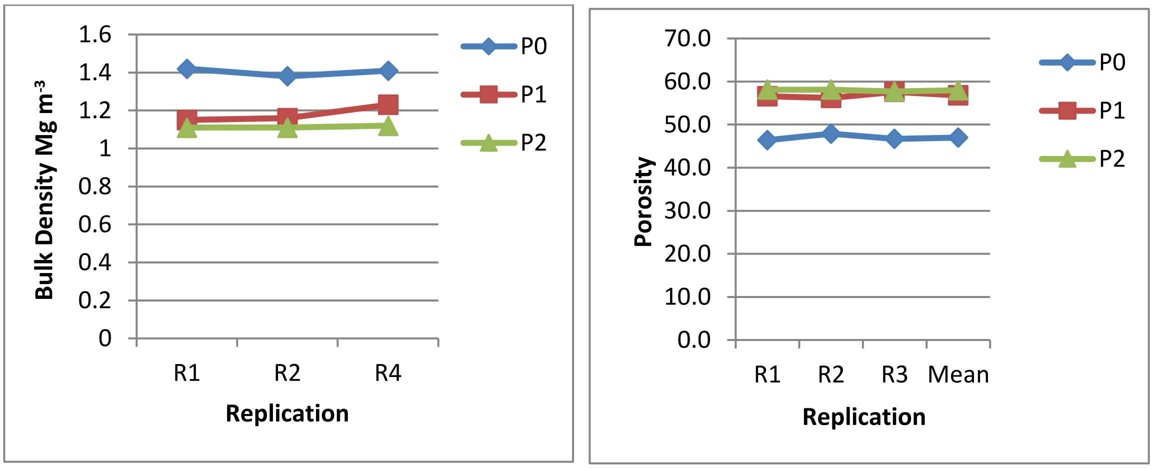

Figure (2): Bulk density and total Porosity's value for treatments.

3. Hydraulic conductivity and Infiltration rate:

The application of perlite also improved hydraulic properties, including infiltration rate (IR) and saturated hydraulic conductivity (Ks). Treatment P2 recorded the highest mean values for both parameters: **2.76 cm hr^{-1}** for IR and **2.55 cm hr^{-1}** for Ks, compared to **2.0 cm hr^{-1}** and **1.86 cm hr^{-1}**, respectively, in the control (Table 5, Figure 3). Perlite's porous structure facilitates optimal water flow through the soil matrix, reducing surface runoff and increasing water infiltration. This improvement is consistent with findings by[15,16,17], who emphasized perlite's ability to enhance soil hydrological properties. The increased infiltration rate and hydraulic conductivity contribute to more efficient irrigation and reduced water percolation.

Table (5): Some hydraulic properties of the study soil.

Treatment	Basic Infiltration rate (IR) cm hr^{-1}	Hydraulic conductivity (K_S) cm hr^{-1}	Initial water content cm.cm^{-3}
P0	2.0	1.86	0.170
P1	2.57	2.45	0.182
P2	2.76	2.55	0.191

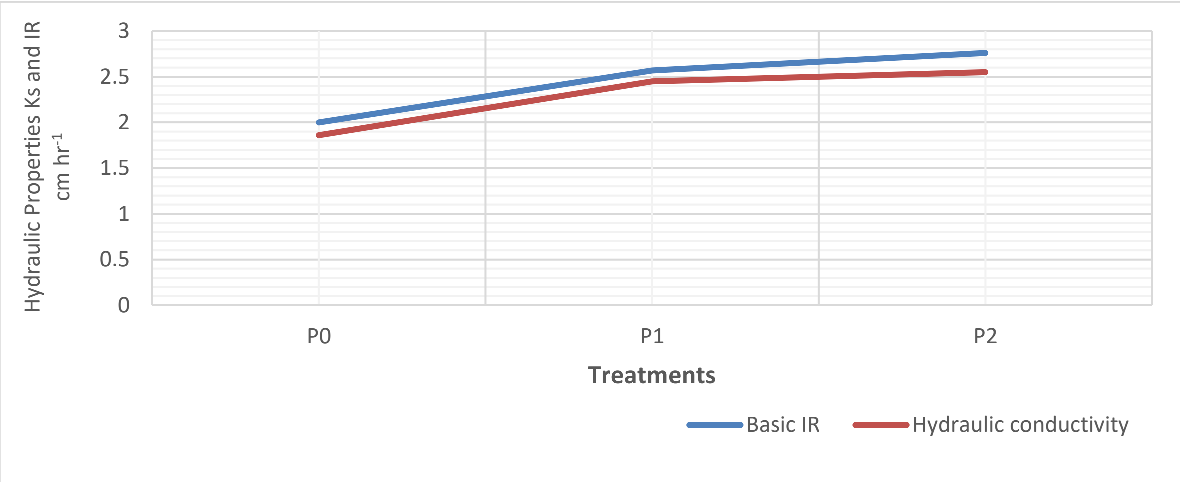

Figure (3): Saturated hydraulic conductivity and infiltration rate for all treatments

4. Predicted volumetric moisture content θ(h)

The Van Genuchten model was used to analyze soil water retention characteristics. The parameter *n* decreased with increasing perlites application, indicating enhanced moisture retention. Treatment P2 exhibited the lowest *n* value (1.32) compared to P0 (1.366) and P1 (1.342). Similarly, the parameter α decreased with perlite application, reflecting an increased air entry value (Table 6). These results demonstrate perlite's ability to improve the water-holding capacity of the soil, as confirmed by the Van Genuchten model. The findings corroborate earlier research by [18,19] who noted that perlite modifies soil pore size distribution, leading to improved water retention and aeration.

Table (6): Values of Van Genuchten parameters.

	θs	*θr*	*θs- θr*	*θp*	*Log(hp)*	*hp*	*dθ/d/log(h)*	*Sp*	*m*	*n*	*α*
P_0	0.44	0.131	0.309	0.285	2.55	354.8	0.1211	0.391	0.268	1.366	0.0175
P_1	0.456	0.138	0.318	0.297	2.71	512.8	0.1173	0.368	0.255	1.342	0.0136
P_2	0.485	0.146	0.339	0.315	2.84	691.8	0.1193	0.351	0.244	1.32	0.011

5. Yield of Maize:

Grain yield was significantly influenced by perlite application. Treatment P2 recorded the highest yield (10.3 tons ha⁻¹), representing a 14.4% increase over the control (9.0 tons ha⁻¹). Treatments P1and P2 covered by the same bar are not significantly different with same color (Table 7, Figure 4). The increase in yield can be attributed to improved soil physical properties, such as enhanced water retention, aeration, and nutrient availability. Perlite's role in reducing water stress and improving root growth has been documented by [20,21,22] .These benefits are particularly significant in arid regions, where water scarcity limits crop productivity.

Table (7): Grain Yield of Maize (ton ha^{-1}).

Treatment	*R1*	*R2*	*R3*	*Mean*
P0	9.058	8.491	9.450	9.0
P1	10.475	9.566	10.525	10.2
P2	10.757	9.625	10.525	10.3

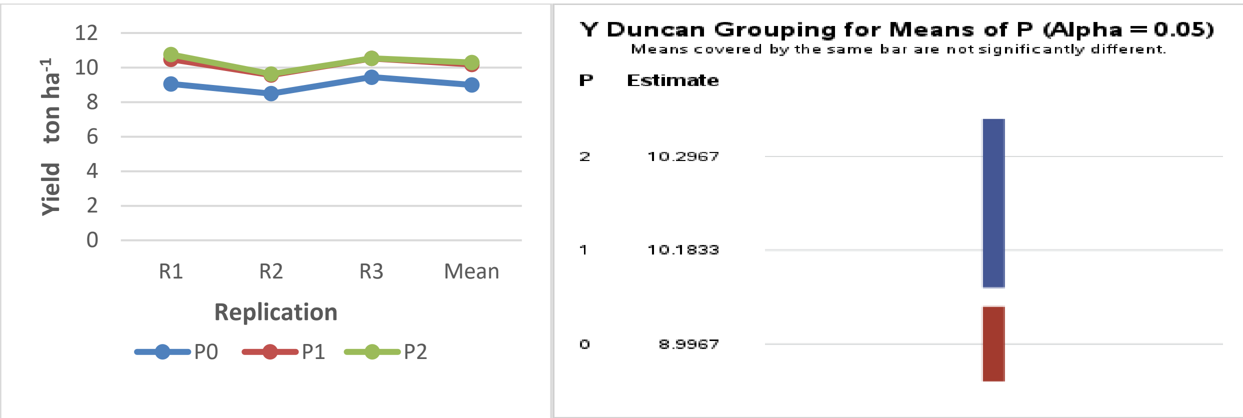

Figure (4) : Yield of Zia maize for all treatments.

6. Wetting Front Movement

The movement of the wetting front was monitored 24 hours after stopping drip irrigation. Using Surfer program Ver:13. Based on moisture content data measured using TDR . The results showed the Treatment P2 exhibited the most effective moisture distribution, both horizontally and vertically, due to perlite's high water retention capacity (Figure 5). This characteristic helps plants resist drought conditions by ensuring consistent moisture availability in the root zone. Additionally, perlite's mechanical effect on soil aggregation improves its ability to hold water, further enhancing moisture retention. These findings underscore perlite's potential to mitigate water stress and improve irrigation efficiency.

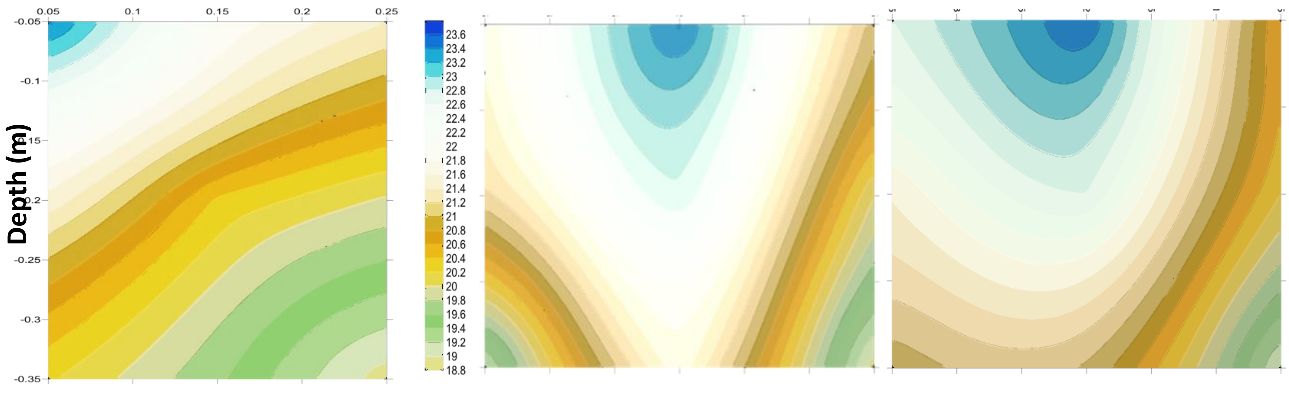

Figure (5) : Movement of the wet front in the soil

Conclusions

The results of this study demonstrate that perlite significantly improves soil physical properties and maize productivity under surface drip irrigation. Key findings include:

1. **Improved Soil Hydrology:** Perlite reduced bulk density, increased porosity, and enhanced hydraulic conductivity and infiltration rates. These changes optimize water movement through the soil profile, reducing evaporation and runoff.
2. **Enhanced Water Retention:** Perlite's porous structure and high water-holding capacity improved soil moisture content, as evidenced by the Van Genuchten model parameters (n , m , and α).
3. **Increased Crop Yield:** The application of perlite led to a 14.4% increase in maize grain yield, highlighting its potential to boost agricultural productivity in water-scarce environments.
4. **Sustainable Solution:** Perlite's inorganic nature ensures long-term stability, making it a sustainable amendment for agriculture. Its ability to normalize pH, reduce salinity, and protect plants from temperature fluctuations further enhances its utility.
5. These findings align with previous studies. who emphasized perlite's versatility in improving soil properties and supporting plant growth. The study underscores the importance of adopting innovative soil amendments like perlite to address global challenges in agriculture, particularly in arid regions.

Acknowledgment

We would like to express our gratitude to the College of Agriculture and Forestry-University of Mosul for their supporting, and their facilities, which helped to improve the value of this study.

References

1. Eirinaki, F. (2023). Development of innovative'Flooding hydroponic systems', based on Grow Boxes, filled with mixed substrates made of two organic soil improving materials and agricultural perlite products and by-products. Case study: lettuce (variety Paris Island COS D3000) (Doctoral dissertation, Perrotis College). https://repository.afs.edu.gr/handle/6000/545
2. Markoska, V., Lisichkov, K., Boev, B., & Gulaboski, R. (2018). The influence of the perlite as a substrate for improving on some water properties on the fluvial soil with an aplication of retentional curves. Journal of Agriculture and Plant Sciences, 16(1), 73-82. https://js.ugd.edu.mk/index.php/YFA/article/view/2350
3. Stratoura, M. C., Lazari, G. E. D., Badogiannis, E. G., & Papadakis, V. G. (2023). Perlite and Rice Husk Ash Re-Use As Fine Aggregates in Lightweight Aggregate Structural Concrete—Durability Assessment. Sustainability, 15(5), 4217. https://www.mdpi.com/2071-1050/15/5/4217

4. Fard, A. R. (2018) Application of advanced composite modified perlite for degradation of particle size and turbidity in treatment of 2 sewage water 3. https://dwes.copernicus.org/preprints/dwes-2017-40/
5. Mustafa, B. M., & Al-Wazzan, F. A. (2022). The variation of some soil physical properties by using water with different salinities. *Int. J. Agricult. Stat. Sci. Vol*, *18*(1), 2099-2110. https://connectjournals.com/pages/articledetails/toc036676
6. Ghehsareh, A. M., & Kalbasi, M. (2012). Effect of addition of organic and inorganic combinations to soil on growing property of greenhouse cucumber. African Journal of Biotechnology, 11(37), 9102-9107. https://www.ajol.info/index.php/ajb/article/view/127372
7. Veazie, P., Balance, M. S., Whipker, B. E., & Jeong, K. Y. (2023). Comparison of Peat–Perlite-based and Peat–Biochar-based Substrates with Varying Rates of Calcium Silicate on Growth and Cannabinoid Production of Cannabis sativa 'BaOx'. HortScience, 58(10), 1250-1256. https://journals.ashs.org/hortsci/view/journals/hortsci/58/10/article-p1250.xml
8. Van Genuchten, M. Th. (1980). A closed. From equation for predicting the hydraulic conductivity of unsaturated soil. Soil Sci. Soc. Am. J. 44:892-898. https://acsess.onlinelibrary.wiley.com/doi/abs/10.2136/sssaj1980.03615995004400050002x
9. Page, A.L., R.H. Miller and D. R. Kenney (1982). Methods of Soil Analysis Part 2nd ed. American Society of Agronomy Crop Sci. Soc. of Agronomy. https://www.taylorfrancis.com/books/mono/10.1201/9780203739433/soil-analysis-handbook-reference-methods-soil-plant-analysis-council-inc
10. Zhou, L., Liu, J. H., Zhao, B. P., Xue, A., & Hao, G. C. (2016). Effects of soil amendment on soil characteristics and maize yield in Horqin Sandy Land. In IOP Conference Series: Earth and Environmental Science (Vol. 41, No. 1, p. 012005). IOP Publishing. https://iopscience.iop.org/article/10.1088/1755-1315/41/1/012005/meta
11. Ghehsareh, A. M., Hematian, M., & Kalbasi, M. (2012). Comparison of date-palm wastes and perlite as culture substrates on growing indices in greenhouse cucumber. International Journal of Recycling of Organic Waste in Agriculture, 1, 1-4. https://link.springer.com/article/10.1186/2251-7715-1-5
12. Hasan, Ö. Z. E. R., & Dede, Ö. H. (2018). Improving physical properties of plant growing medias using Perlite. Sakarya University Journal of Science, 22(5), 1346-1350. https://dergipark.org.tr/en/download/article-file/454601
13. Samadi, A. (2011). Effect of particle size distribution of perlite and its mixture with organic substrates on cucumber in hydroponics system. https://www.sid.ir/en/vewssid/j_pdf/84820110113.pdf
14. Markoska, V., & Spalevic, V. (2020). The adsorption character of perlite, influence on nitrogen dynamics in soil. Agric. For./Poljoprivreda i Sumarstvo, 66(4), 45-55. https://www.cabidigitallibrary.org/doi/full/10.5555/20203588367
15. Jahan, S., Ahmad, F., Rasul, F., Amir, R., & Shahzad, S. (2023). Physicochemical Analysis of Vermicompost-Perlite Based Activated Biochar and its Influence on Wheat (Triticum aestivum L.) Growth Under Water Stress. Journal of Soil Science and Plant Nutrition, 1-17. https://link.springer.com/article/10.1007/s42729-023-01258-8
16. Ors, S., & Anapali, O. (2010). Effect of soil addition on physical properties of perlite based media and strawberry cv. Camarosa plant growth. Scientific Research and Essays, 5(22), 3430-3433. https://academicjournals.org/journal/SRE/article-full-text-pdf/9E1410019056.pdf
17. Al-Wazzan .F.A., and Sarbast A. M., (2022). Effects of Conservation and Conventional Tillage on some Soil Hydraulic Properties : Earth and Environmental Science. 1060 (2022) 012002. https://iopscience.iop.org/article/10.1088/1755-1315/1060/1/012002/meta
18. Rhie, Y. H., & Kim, J. (2017). Changes in physical properties of various coir dust and perlite mixes and their capacitance sensor volumetric water content calibrations. HortScience, 52(1), 162-166. https://journals.ashs.org/hortsci/view/journals/hortsci/52/1/article-p162.xml

ÖZENÇ, D. B. (2003). The Effects Of Different Water Stress And Perlite Media On Growing Of Pepper Plant (Capsicum annuum grossum var. cv. Demre). Atatürk Üniversitesi Ziraat Fakültesi Dergisi, 34(1).

https://www.proquest.com/openview/846fd1eb9fc97343d1a58f051944888e/1?pq- origsite=gscholar&cbl=5364609

19. Hamdi, G. J. (2017). Effect of perlite in reducing water stress for three genotypes of tomato (Doctoral dissertation, M. Sc. Thesis. College of Agriculture. University of Diyala.Iraq).https://www.academia.edu/download/59892487/ghassan_Jaafar_hamdi20190628-2036- 1chlb6s.pdf .

20. Al-Wazzan .F.A. (2025). Using Hydrus 1D software to prediction accumulated infiltration values for different soil texture. Siberian Journal of Life Sciences and Agriculture ISSN 2658- 6649 (Vol 17, No 3).
21. Harbawi, M. A., Al-Barhawee, N. I. K., & Al-Wazzan, F. A. (2025). Estimation of Indole-3-Acetic Acid Production from New Molecularly Characterized Rhizobacterial Strains. . Journal of Global Innovations in Agricultural Sciences . Vol ,13:1385-1394., ISSN (Online): 2788-4546; ISSN (Print):2788-4538 .