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ORIGINAL ARTICLE

Effects of Various Irrigation Levels and Biochar-Based Fertilizers on Peanut Production

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A R T I C L E I N F O

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A B S T R A C T

Biochar-based fertilizers, customized to specific soil conditions, have piqued public attention to enhance soil quality and carbon sequestration. The incorporation of biochar into agricultural fields can become a primary factor in the preservation of soil productivity and fertility. However, there is still no conclusive experimental evidence to support this claim. In this study, a split-plot experiment was carried out according to a randomized complete block design (RCBD) using three replications to evaluate the influence of irrigation and varied amounts of biochar-based fertilizer on peanut plants' yield to determine the water use efficiency (WUE). The primary treatment with different irrigation cycles and no irrigation, and the sub-treatment with biochar-based fertilizer of 50, 100, and 150 kg N ha^{-1} and no fertilizer, were performed in Sulaymaniyah which is located in the east of the Kurdistan Region of Iraq. The results revealed that the seven-day irrigation cycle produces the largest pods and seeds, with 4325 and 2435 kg ha^{-1} yields, respectively. The 100 kg ha^{-1} biochar-based fertilizer yielded the highest output, with a pod yield of 3652 kg ha^{-1} and a seed yield of 1921 kg ha^{-1}. According to the results of the interaction between irrigation management and biochar-based fertilizer, the irrigation treatment had a maximum seed yield of seven-day and the fertilizer treatment had a maximum seed output of 100 kg N ha^{-1} with an average of 3462 kg ha^{-1}. The variance analysis results indicate that water use efficiency in irrigation management, different levels of biochar-based fertilizer, and their combined effect on total biomass, seed, and pods were significant.

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Introduction

Peanut or groundnut is a tropical and subtropical plant that is an annual oil seed (Nadaf *et al*., 2020). Apart from oil, peanut by-products contain a variety of additional functional substances such as minerals, vitamins, antioxidants, polyphenols, fibers, and proteins that can be used as a nutritional supplement in various processed meals (Dima *et al*., 2019; Hirpara *et al*., 2019). The peanut, like beans and peas, belongs to the legume family and is a popular food crop (da Silva *et al*., 2018). This plant originated in South America, specifically in the Gran Chaco region of Brazil. It was then transported to western Africa and the eastern portion of the continent, where it made its way into India and Asia (Morales *et al*., 2019). Peanuts are often grown in the highlands and rainfed environments, which are negligible in terms of rainfall volume and dispersion (Launio *et al*., 2018; Morales *et al*., 2019; De Santis *et al*., 2021). Drought has been one of the limiting factors in the cultivation of peanuts in the country in recent years. Its impact on crop productivity has necessitated specific water consumption and effective utilization (Daudi *et al*., 2018; Abady *et al*., 2019). A higher peanut yield could be achieved with the application of fertilizers. Most farmers employ insufficient and unevenly distributed mineral nutrients in traditional agriculture, leading to low peanut output, particularly on sandy soil (Zhang *et al*., 2020). As a result, adequate nutrient management is critical for achieving maximum quality and yield in vegetable oil seed crops (Zhao *et al*., 2021). In light of the increased demand for healthy and safe food and worries about environmental degradation caused by the excessive use of agrochemicals, organic farming has risen to prominence as a global issue (Eyhorn *et al*., 2019).

Regarding food production, organic farming is typically seen as a significantly more sustainable option (Meemken and Qaim, 2018). Organic matter treatments improved root growth and nutrient uptake, leading to increased yields, according to a study conducted on five crops in Japan (Solaiman *et al*., 2010). Another advantage of greater organic material utilization is that it can reduce pollution produced by agro-industrial waste (Montemurro *et al*., 2015; Mo *et al*., 2018).

Nevertheless, inappropriate usage of organic fertilizers can lead to an accumulation in groundwater, which can then be transferred to crops if they are absorbed by the plant roots (Diaz-Vazquez *et al*., 2021). Biochar, a type of carbon-rich biomass carbonization material made of plant mineral residue, has gained growing public and scientific attention in recent years (Özçimen and Ersoy-Meriçboyu, 2010; Abdipour *et al*., 2019; Khan *et al*., 2019; Seow *et al*., 2021). Biochar also can enhance soil characteristics and agronomic performance (Smider and Singh, 2014). In several investigations, biochar administration has been shown to affect soil attributes such as microbial activity, pH, and water holding capacity (Van Zwieten *et al*., 2010; Enders *et al*., 2012). Additional research has shown that plants can absorb more nutrients after being treated with biochar (Xiang *et al*., 2017; Gonzaga *et al*., 2019; Sikder and Joardar, 2019). Several researchers, on the other hand, found no substantial impacts of biochar on biomass yield, plant nutrition, or soil characteristics after biochar administration in the field (Jeffery *et al*., 2011; Frank *et al*., 2014; Molajou *et al*., 2021; Soleimanian *et al*., 2022). Until recently, most biochar research has been done on pure biochar in tropical regions, greenhouses, or labs (Mukherjee and Lal, 2013; Zhang *et al*., 2016). Biochar experiments in the field frequently yield results that differ from those in the lab.

Furthermore, the fluctuation due to varied site conditions is significantly greater, but it is quite realistic. As a result, tests in the field with relevant agronomically fertilizer types are more representative of real-world settings in terms of the reaction of the agricultural ecosystem with varying agricultural processing techniques, weather conditions, and soil qualities. Therefore, in this study in a field experiment, the impact of irrigation and biochar-based fertilizer on yield in peanut plants, as well as the best irrigation and biochar-based fertilizer in Sulaymaniyah, located in the east of the Kurdistan Region of Iraq, is investigated.

Material and Methods

Located in the Kurdistan region, Sulaymaniyah is a mountainous city. It is located at 35.53°N 45.45°E and is 831 m above sea level (Murad and Salih, 2020). From the north, it is surrounded by Qaiwan, Goizha, and Azmar mountains; from the south, it is encircled by Baranan (1373m); and from the east, it is enclosed by Shahrazur plain (Abdulrahman *et al*., 2019). Temperatures tend to be lower during the summer months, and it receives more precipitation during the winter than the other major population centers in the country. Temperatures range between 0 to 39^{o}C on average. Snowfall is expected in the winter. It snows once or twice a year. It accounts for 26% of the country's total peanut production (Fig. 1) (Al-Hilfy and Al-Salmani, 2019).

In terms of climate, this area falls under the category of being one of the moderately temperate and humid zones. Fig. 2 and Table 1 contain information on climatic data and soil parameters at the test location, respectively.

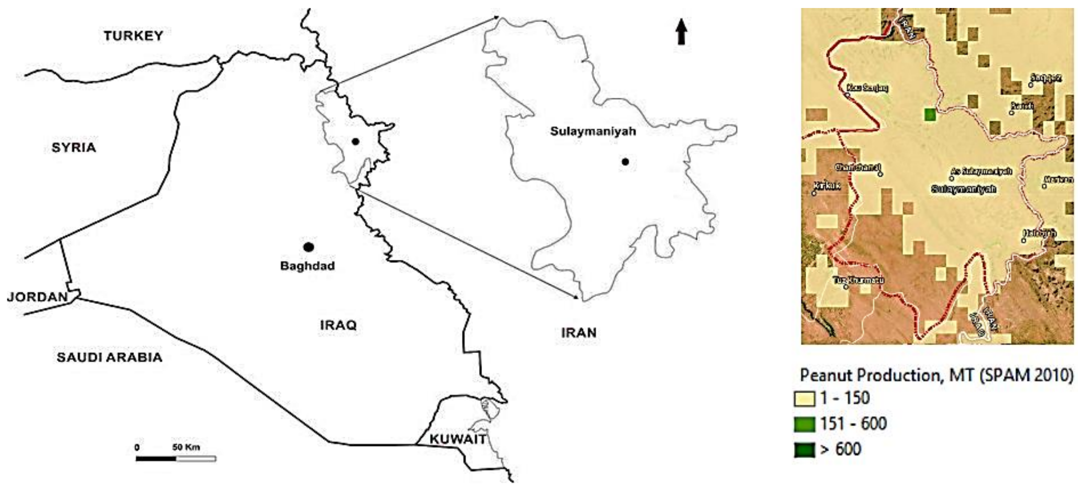
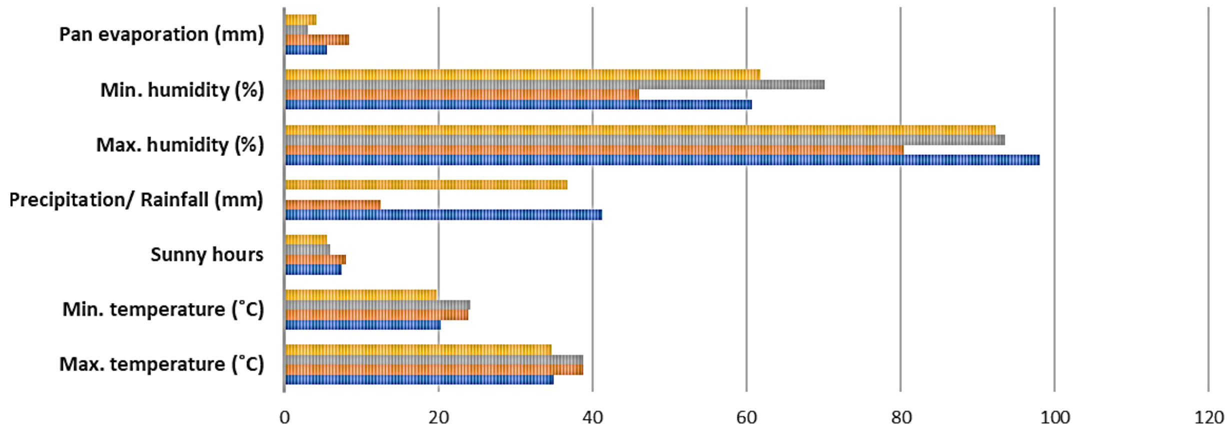


Fig. 1. Map of Iraq showing area of Sulaymaniyah. It is responsible for 26% of Iraq's total peanut production.



	Max. temperature (˚C)	Min. temperature (˚C)	Sunny hours	Precipitation/ Rainfall (mm)	Max. humidity (%)	Min. humidity (%)	Pan evaporation (mm)
September	34.7	19.7	5.5	36.7	92.3	61.8	4.2
August	38.8	24.1	6	0	93.5	70.1	3.1
July	38.8	23.9	8	12.5	80.4	46	8.4
June	35	20.3	7.5	41.2	98	60.7	5.6

Fig. 2. Information regarding meteorological data.

Table 1. Soil properties of the test site.

Soil Texture	Soil Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Electrical Conductivity (ds m^{-1})	Organic Carbon (%)	Total Nitrogen (%)	Absorbable Phosphorus (mg kg^{-1})	Absorbable Potassium (mg kg^{-1})
Salty clay	0-15	49	34	17	0.583	0.59	0.074	0.06	261
Salty clay	15-30	49	34	17	0.536	0.57	0.059	2.36	203

The split plots were examined in this study using a randomized complete block design with three replications on the ground. Each experimental unit was 6×2.5 meters and featured seven rows of plants. It was decided to irrigate when the crop had used up a certain percentage of the water that was available in the soil in the root zone (at the point where available water was depleted by 60%, irrigation was imposed). The main treatment with irrigation cycles of 7, 14, and 21 days and no irrigation were considered control. The sub-treatment was biochar-based fertilizer of 50, 100, and 150 kg N ha^{-1} and no fertilizer. Before sowing the seeds, a total of 180 kg of triple superphosphate fertilizer was distributed equally across the field based on the results of the chemical decomposition of the soil. The irrigation method used in this experiment was the type of surface irrigation with atmospheric and ridge systems. The distance between the two ridges was 85 cm, and the plants within the ridge were 35 cm apart. The irrigation water given to each experimental unit was measured using a water flow meter. The planted type of peanut used in this investigation was a local cultivar of almond with a planting date of June 10^{th}. The seeds were disinfected with carboxin-thiram fungicide at a rate of 1.8 per thousand before sowing. The product was harvested on September 25th. TDR TRIME-FM model recorded the amount of soil moisture at depths of 0-15, 15-30, 30-45, and 45-60 cm during the growth phase, indicating moisture changes in different soil layers around the roots. To calculate seed and pod yield, pods and ripe seeds were weighed on a precise laboratory scale after two rows of plants were removed from the sides.

At the flowering time, the leaf relative water content (RWC) was measured in one step. The leaf was taken from the plant and transported to the laboratory to evaluate the RWC before sunrise. The leaf fresh weight (FW) was instantly measured after the sample was sent to the laboratory. After that, the sample was placed in a flask filled with distilled water to absorb water and reach full swelling. The lid of the container was covered with aluminum foil to prevent water vapor from escaping. The container holding the sample was kept in the dark for 6.5 hours at a temperature of approximately 6^{o}C to prevent inhalation. After the time had passed, the leaf was removed from the container, and its surface water was weighed using a dry paper towel. The resultant weight is referred to as the turgid weight (TW). Afterward, the leaf was placed in an envelope and dried for 72 hours at 75^{o}C. Weighing the leaf sample after this period was used to determine the leaf's dry weight (DW). Having the leaf weight in the field (FW), the turgid weight (TW), and leaf dry weight (DW), the relative leaf water content (RWC) was calculated (Omae *et al*., 2005). After removing two rows of crops from both sides, 12 plants were randomly picked to determine the quantity of total biomass in each plot. Then the pods, leaves, and stems were placed in the oven at 75°C for 48 hours. The samples were weighed using a one percent scale after drying. From the total weight of dry pods (along with seeds), dry stem weight, and dry leaf weight, total biomass weight in grams was obtained (Hooshmand *et al*., 2019), then converted to kilograms per hectare. To calculate the weight of 100 seeds in each plot, 200 g of dried pods were chosen as a sample, pods were separated from them, and 100 seeds were chosen randomly and weighed on a one-hundredth scale in grams (El-Habbasha *et al*., 2014). The harvest index value in each plot was calculated by dividing the total weight of dry grain by total biomass (Djaman *et al*., 2013). Irrigation and rainwater were used to provide the amount of water consumed throughout the plant growth phase. Table 2 shows the amount of water utilized in each management and the number of irrigations.

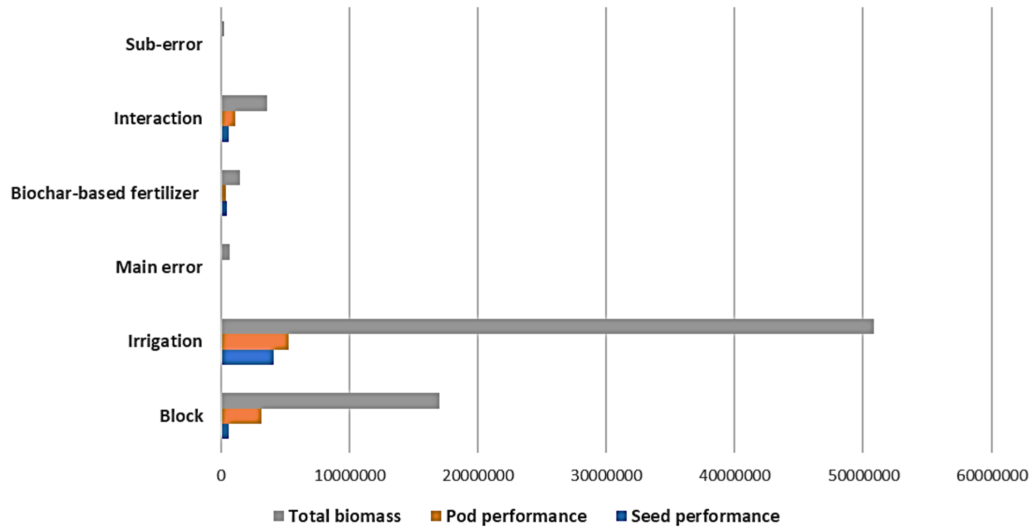
MSTATC and Excel software was used to analyze the data and compare the means of the measured parameters (Duncan test at 5% level).

Table 2. The total number of irrigation shifts as well as the total volume of water used for each irrigation management system.

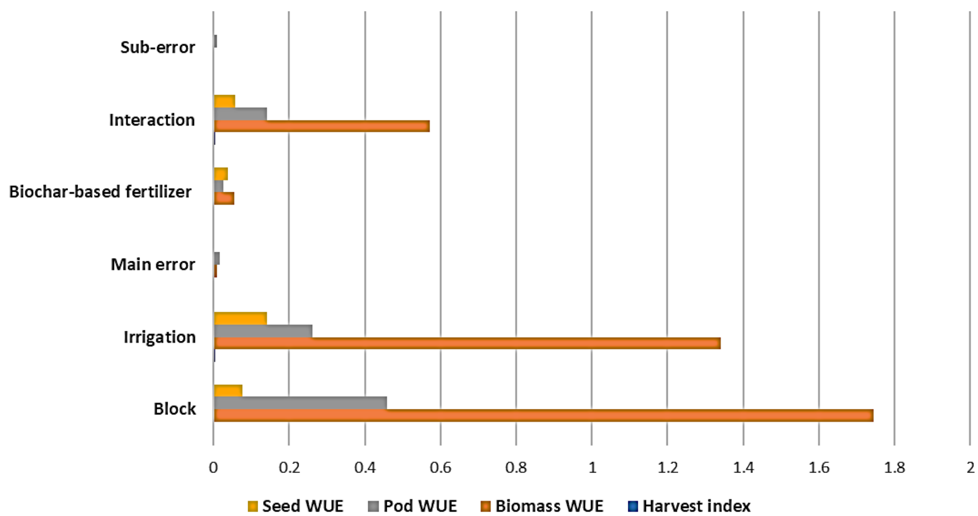
Irrigation management	Number of irrigations	Water consumption (mm)
No irrigation	-	250
7	10	341
14	6	325
21	4	280

Results

Irrigation management and biochar-based fertilizer and their interaction with seed yield were significant at a 1% probability level (Fig. 3 and Table 3). The effect of irrigation management and biochar-based fertilizer and their combined effect on pod yield were significant at a 1% probability level.

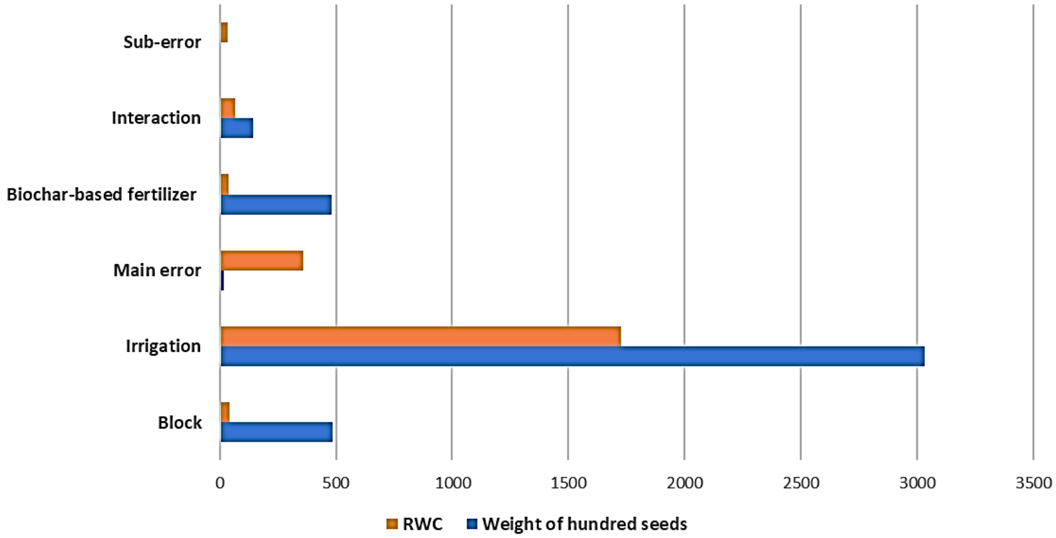


(a)

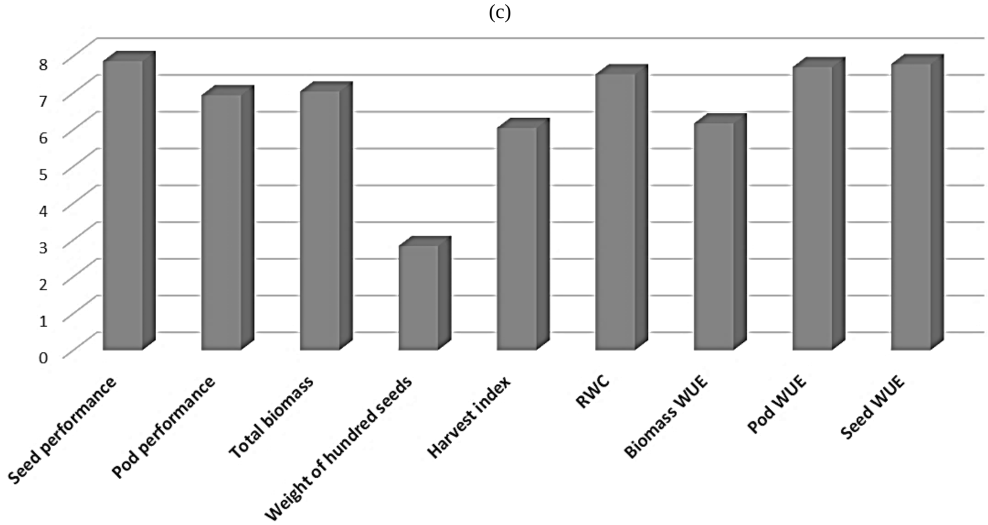


(b)

Fig. 3. Analysis of variance of measured parameters in irrigation management conditions and biochar-based fertilizer (mean squares), (a) total biomass, pod, and seed performance, (b) WUE of seed, pod, and biomass, (c) weight of 100 seeds and RWC, (d) coefficient of variation.



(c)



(d)

Fig. 3. Continued.

Table 3. Analysis of variance of measured parameters in irrigation management conditions and biochar-based fertilizer.

Sources of change	df	Mean Squares								
		Seed performance	Pod performance	Total biomass	Weight of hundred seeds	Harvest index	RWC	Biomass WUE	Pod WUE	Seed WUE
Block	2	615048.78	3165117.12	16977191.1	483.48	0.00102	40.086	1.7442	0.459	0.07752
Irrigation	3	4091687.16	5225611.98	50812232.28	3033.48	0.00408	1725.84	1.34028	0.26112	0.14178
Main error	6	30421.5	45121.74	696173.46	17.7072	0.00102	360.3252	0.00816	0.01632	0.00204
Biochar-based fertilizer	3	440361.54	386633.04	1485943.14	480.828	0.00204	39.3312	0.05406	0.0255	0.03774
Interaction	9	562723.8	1126210.56	3548444.34	144.1566	0.0051	65.4534	0.57222	0.14076	0.05814
Sub-error	24	14715.54	46581.36	227363.1	1.33212	0.000102	34.8738	0.00306	0.00816	0.00204
Coefficient of variation (%)		7.8642	6.936	7.038	2.8356	6.0486	7.5072	6.171	7.701	7.7826

The amount of total biomass in the 7-day irrigation treatment with the value of 1036.12 kilograms per hectare was superior to other treatments. The amount of 100 kilograms of biochar-based fertilizer per hectare with an average of 7476.60 kilograms per hectare was the highest and the treatment without fertilizer with an average of 6654.48 kilograms per hectare had the lowest amount of total biomass (Table 4).

Table 4. Comparison of the simple mean of the measured parameters in irrigation management conditions and biochar-based fertilizer.

Treatments	Total biomass (kg ha^{-1})	Weight of hundred seeds (g)	Harvest index	RWC (%)	Biomass WUE (kg m^{-3})	Pod WUE (kg m^{-3})	Seed WUE (kg m^{-3})
Irrigation							
No irrigation	6123.96	24.07	0.20	77.52	2.31	1.33	0.49
7-day	1036.12	61.51	0.24	97.92	3.01	1.26	0.73
14-day	8632.10	47.02	0.21	71.40	2.45	1.02	0.51
21-day	7631.23	35.09	0.23	75.48	4.35	1.07	0.54
Biochar-based fertilizer							
No fertilizer	6654.48	34.27	0.21	81.60	2.43	1.12	0.52
50 fertilizer per ha	6972.72	39.37	0.23	78.54	2.52	1.18	0.59
100 fertilizer per ha	7476.60	48.45	0.24	82.62	2.59	1.23	0.64
150 fertilizer per ha	6818.70	45.70	0.21	79.56	2.54	1.15	0.52

When compared to non-irrigation treatments of 14 and 21 days, the 7-day irrigation treatment had the largest seed output (Fig. 4a). Irrigation management for seven days with 4325 kg ha^{-1} had maximum yield (Fig. 4b).

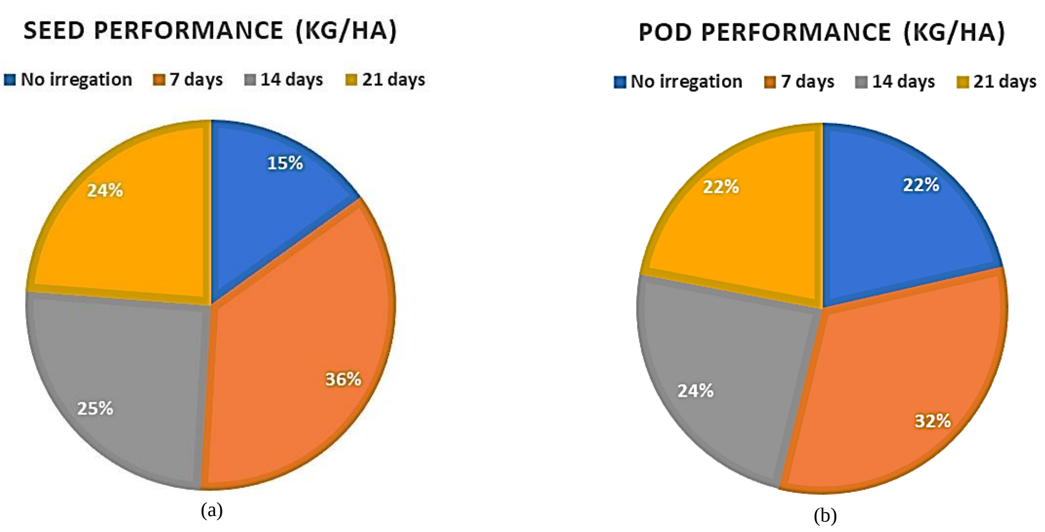
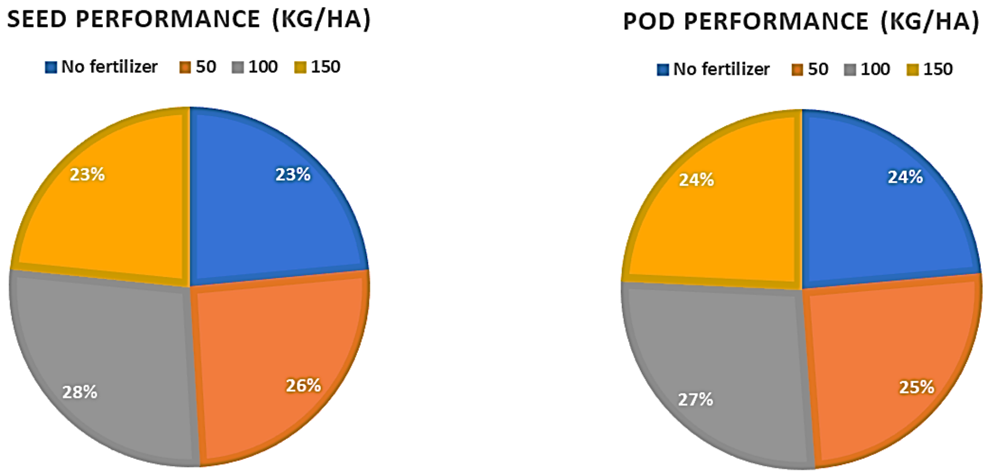


Fig. 4. Seed yield (a) and pod yield (b) in irrigation management.

The amount of fertilizer application of 100 kg N ha^{-1} compared to treatments without fertilizer, 50 and 150 kg N ha^{-1}, was associated with increased output (Fig. 5a). The interaction impact of irrigation management and biochar-based fertilizer revealed that the irrigation treatment had a maximum seed yield of 7 days and the fertilizer treatment had a maximum seed production of 100 kg N ha^{-1} with an average of 3462 kg ha^{-1}. Biochar-based fertilizer values also showed that fertilizer treatment of 100 kg N ha^{-1} had the highest yield of pods with 3652 kg ha^{-1} (Fig. 5b).



(a) (b)

Fig. 5. Seed yield (a) and pod yield (b) at biochar-based fertilizer levels.

Discussion

The effect of irrigation management and biochar-based fertilizer and their interaction showed that the amount of total biomass was significant at a probability level of 1%. Different levels of irrigation management and biochar-based fertilizer interaction indicate the significance of the harvest index at the 5% probability level for irrigation management and the 1% probability level for biochar-based fertilizer management and their interaction.

Conclusions

The variance analysis results indicate that water use efficiency in irrigation management, different levels of biochar-based fertilizer, and their combined effect on total biomass, seed, and pods were significant. The effect of irrigation management on the relative water content of the leaves was significant at a probability level of 5%. At the same time, there was no significant difference between different levels of biochar-based fertilizer and the interaction between irrigation and biochar-based fertilizer. The results of the present study showed that irrigation and biochar-based fertilizer affected the total biomass traits, 100-seed weight and harvest index in peanuts, and the yield of seed and grain in irrigation management from rainfed conditions (without irrigation) to irrigation with a seven-day cycle leading to maximum yield of seed and pod. Biochar-based fertilizer application at 100 kg ha^{-1} had the highest yield of seed and pod. The highest efficiency of seed and pod WUE was observed in irrigation for seven days and fertilizer amount of 100 kg N ha^{-1}. According to the research results, irrigation management for seven days and the amount of biochar-based fertilizer of 100 kg per hectare can be suggested as irrigation management and biochar-based fertilizer in peanut plants for the region's conditions.

Conflict of interests

The authors declare no conflict of interest.

References

Abady S, Shimelis H, Janila P (2019) Farmers' perceived constraints to groundnut production, their variety choice and preferred traits in eastern Ethiopia: implications for drought-tolerance breeding. Journal of Crop Improvement 33, 505–521.

Abdipour M, Hosseinifarahi M, Najafian S (2019) Effects of humic acid and cow manure biochar (CMB) in culture medium on growth and mineral concentrations of basil plant. International Journal of Horticultural Science and Technology. 6(1), 27-38.

Abdulrahman HH, Ahmed AQ, Abtar AN (2019) Parametric Studies on Solar Performance of Iwan in Traditional Houses in Sulaymaniyah's old Town. Sulaimania Journal for Engineering Sciences 6.

Al-Hilfy IH, Al-Salmani SA (2019) Effect of Planting Date and Calcium Spraying on Peanut Quality. Advances in Environmental Biology. 13, 7–13.

da Silva AC, Silva Viana J, Ferreira de Oliveira JF, Cordeiro Junior JJF, Goncalves EP, Gomes da Silva VS, Ribeiro Soares AN (2018) Application of dairy residue in peanut ('*Arachis hypogaea*'L.) cultivated in Northeastern Brazil. Australian Journal of Crop Science. 12, 1144–1149.

Daudi H, Shimelis H, Laing M, Okori P, Mponda O (2018) Groundnut production constraints, farming systems, and farmer-preferred traits in Tanzania. Journal of Crop Improvement. 32, 812–828.

De Santis P, Mengistu DK, Kidane YG, Nankya R, De Santis B, Moracci G, Debegnach F, Marsiglia R, Reverberi M (2021) Negligible Levels of Mycotoxin Contamination in Durum Wheat and Groundnuts from Non-Intensive Rainfed Production Systems. Sustainability 13, 10309.

Diaz-Vazquez D, Carrillo-Nieves D, Orozco-Nunnelly DA, Senés-Guerrero C, Gradilla-Hernández MS (2021) An integrated approach for the assessment of environmental sustainability in agro-industrial waste management practices: the case of the tequila industry. Frontiers in Environmental Science. 9, 229.

Dima M, Diaconu A, Drăghici R, Drăghici I, Croitoru M, Constantinescu E, Sturzu R (2019) Variability Of Characteristics And Traits In Some Genotypes Of Foreign Peanuts Grown On The Sandy Soils Of Southern Oltenia. Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series. 49, 71–74.

Djaman K, Irmak S, Rathje WR, Martin DL, Eisenhauer DE (2013) Maize evapotranspiration, yield production functions, biomass, grain yield, harvest index, and yield response factors under full and limited irrigation. Transactions of the ASABE. 56, 373–393.

El-Habbasha SF, Okasha EM, Abdelraouf RE, Mohammed ASH (2014) Effect of pressured irrigation systems, deficit irrigation and fertigation rates on yield, quality and water use efficiency of groundnut. International Journal of ChemTech Research. 15, 01.

Enders A, Hanley K, Whitman T, Joseph S, Lehmann J (2012) Characterization of biochars to evaluate recalcitrance and agronomic performance. Bioresource Technology. 114, 644–653.

Eyhorn F, Muller A, Reganold JP, Frison E, Herren HR, Luttikholt L, Mueller A, Sanders J, Scialabba NE-H, Seufert V (2019) Sustainability in global agriculture driven by organic farming. Nature Sustainability. 2, 253–255.

Frank A, Frank R, Popović L (2014) Role of Drought Early Warning and Social Planning in

Industrial Growth. International Journal of Industrial Engineering and Management 5, 45.

Gonzaga MIS, da Silva PSO, de Jesus Santos JC, de Oliveira Junior LFG (2019) Biochar increases plant water use efficiency and biomass production while reducing Cu concentration in Brassica juncea L. in a Cu-contaminated soil. Ecotoxicology and Environmental Safety. 183, 109557.

Hirpara DV, Sakarvadia HL, Jadeja AS, Vekaria LC, Ponkia HP (2019) Response of boron and molybdenum on groundnut (*Arachis hypogaea* L.) under medium black calcareous soil. Journal of Pharmacognosy and Phytochemistry. 8, 671–677.

Hooshmand M, Albaji M, zadeh Ansari NA (2019) The effect of deficit irrigation on yield and yield components of greenhouse tomato (Solanum lycopersicum) in hydroponic culture in Ahvaz region, Iran. Scientia Horticulturae. 254, 84–90.

Jeffery S, Verheijen FG, van der Velde M, Bastos AC (2011) A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. Agriculture, Ecosystems & Environment. 144, 175–187.

Khan TA, Saud AS, Jamari SS, Ab Rahim MH, Park JW, Kim HJ (2019) Hydrothermal carbonization of lignocellulosic biomass for carbon rich material preparation: A review. Biomass and Bioenergy. 130, 105384.

Launio CC, Luis JS, Angeles YB (2018) Factors influencing adoption of selected peanut protection and production technologies in Northern Luzon, Philippines. Technology in Society. 55, 56–62.

Meemken EM, Qaim M (2018) Organic agriculture, food security, and the environment. Annual Review of Resource Economics. 10, 39–63.

Mo J, Yang Q, Zhang N, Zhang W, Zheng Y, Zhang Z (2018) A review on agro-industrial waste (AIW) derived adsorbents for water and wastewater treatment. Journal of Environmental Management. 227, 395–405.

Molajou A, Afshar A, Khosravi M, Soleimanian E, Vahabzadeh M, Variani HA (2021) A new paradigm of water, food, and energy nexus. Environmental Science and Pollution Research. 1–11.

Montemurro F, Ciaccia C, Leogrande R, Ceglie F, Diacono M (2015) Suitability of different organic amendments from agro-industrial wastes in organic lettuce crops. Nutrient Cycling in Agroecosystems. 102, 243–252.

Morales M, Oakley L, Sartori AL, Mogni VY, Atahuachi M, Vanni RO, Fortunato RH, Prado DE (2019) Diversity and conservation of legumes in the Gran Chaco and biogeograpical inferences. PloS One. 14, e0220151.

Mukherjee A, Lal R (2013) Biochar impacts on soil physical properties and greenhouse gas emissions. Agronomy. 3, 313–339.

Murad SH, Salih YMM (2020) Comparable Investigation for Rainfall Forecasting using Different Data Mining Approaches in Sulaymaniyah City in Iraq. International Journal of Advances in Life Science and Technology. 4, 11–18.

Nadaf H, Chandrashekhara G, Babu H (2020) Aflatoxin contamination in groundnut under normal moisture and moisture stress field conditions. J. Pharmacogn. Phytochem. 9, 1083–1088.

Omae H, Kumar A, Egawa Y, Kashiwaba K, Shono M (2005) Midday drop of leaf water content related to drought tolerance in snap bean (*Phaseolus vulgaris* L.). Plant Production Science. 8, 465–467.

Özçimen D, Ersoy-Meriçboyu A (2010) Characterization of biochar and bio-oil samples obtained from carbonization of various biomass materials. Renewable Energy. 35, 1319–1324.

Seow YX, Tan YH, Mubarak NM, Kansedo J, Khalid M, Ibrahim ML, Ghasemi M (2021) A review on biochar production from different biomass wastes by recent carbonization technologies and its sustainable applications. Journal of Environmental Chemical Engineering. 107017.

Sikder S, Joardar JC (2019) Biochar production from poultry litter as management approach and effects on plant growth. International Journal of Recycling of Organic Waste in Agriculture. 8, 47–58.

Smider B, Singh B (2014) Agronomic performance of a high ash biochar in two contrasting soils. Agriculture, Ecosystems & Environment. 191, 99–107.

Solaiman ZM, Blackwell P, Abbott LK, Storer P (2010) Direct and residual effect of biochar application on mycorrhizal root colonisation, growth and nutrition of wheat. Soil Research. 48, 546–554.

Soleimanian E, Afshar A, Molajou A (2022) A review on water simulation models for the WEF Nexus: development perspective. Environmental Science and Pollution Research. 1–17.

Van Zwieten L, Kimber S, Morris S, Chan KY, Downie A, Rust J, Joseph S, Cowie A (2010) Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. Plant and Soil. 327, 235–246.

Xiang Y, Deng Q, Duan H, Guo Y (2017) Effects of biochar application on root traits: a meta-analysis. GCB Bioenergy. 9, 1563–1572.

Zhang D, Yan M, Niu Y, Liu X, van Zwieten L, Chen D, Bian R, Cheng K, Li L, Joseph S (2016) Is current biochar research addressing global soil constraints for sustainable agriculture? Agriculture, Ecosystems & Environment. 226, 25–32.

Zhang J, Yun G, Feng GUO, Li X, Wan S (2020) Research progress on the mechanism of improving peanut yield by single-seed precision sowing. Journal of Integrative Agriculture. 19, 1919–1927.

Zhao S, Lü J, Xu X, Lin X, Luiz Mr, Qiu S, Ciampitti I, Ping He (2021) Peanut yield, nutrient uptake and nutrient requirements in different regions of China. Journal of Integrative Agriculture. 20, 2502–2511.