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# ROLE OF PERLITE, QUANTITY AND INTERVALS OF IRRIGATION ON POTATOES (*SOLANUM TUBEROSUM* L.) GROWN IN GYPSIFEROUS SOIL

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**Abstract:** A field experiment was conducted in Anbar province during spring in gypsiferous soil to determine the effects of Perlite levels (PL), quantity, and intervals of irrigation (IQ & IT) on the growth and yield of potatoes. PLs were 0, 4, and 8% depending on soil volume to 30cm depth. IQ levels were, 100 and 50 % of NDI (net depth of irrigation) with two ITs 3 and 6 days. A split-split block design was used within Randomized Complete Block Design (RCBD) with 3 replicates. Potatoes were cultivated. Irrigation was scheduled depending on the evaporation pan class A. The studied traits were plant height (PLH), plant dry weight (PLDW), plant leaf area (PLA), main aerial stem number (MASN), and total yield (YT). The highest value of PLH was 67.17 cm for 8% PL, 3 days ITs, and 100% (NDI) depth. For the same PL (8%) with 6 days ITs and 50% of NDI the plant dry weight (PLDW) was decreased by 15.69% compared to 3 days IT and 100% of NDI. The highest YT of 29 tons. ha-1 was achieved at IT of 3 days and a level of 100% of NDI compared to 19.5 tons. ha-1 at irrigation every 6 days IT and 50% of NDI.

**Keywords:** Polymers, Irrigation Brakes, Yield, Growth, Plants.

## 1. Introduction

The gypsiferous soils consist 20% of the total area of Iraq; these soils suffer from several physical and fertile problems such as degradation and low capability of agricultural production. The gypsiferous soils need a particular scientific for agricultural use to reduce the food gape caused by increased population [1]. Irrigation management is an important process in irrigated agriculture and has received the attention of many studies concerning water use efficiency enhancement by rationalizing its consumption and reducing wastage by adopting the actual plant's need to ensure that the plant is not subjected to water deficit and achieving an acceptable economic production [2]. Water deficits are one of the most important environmental factors in limiting plant growth and reducing production in quantity and quality, the spacing of irrigation durations reduces carbonization, increases leaf aging and determines crop growth [3], plants exposure to a certain level of water potential during one or more stages of plant growth without significantly affecting production results in the saving of irrigation water [4]. The decrease of yield quantity will be insignificant in comparison with water quantities that can be used in irrigation of other crops [5]. The addition of perlite, which is the granules resulting from the heating of silicon volcanic rocks to 1500 centigrade degrees, which increases the size of 4 to 20 times the original size [6], the presence of air gaps resulting from heating increase the absorption of water by 430% of Perlite is a sterile medium free from bushes, pathogens and excellent germination medium [7]

Potato is one of the most important vegetable crops in the world in terms of production and cultivated area. It is one of the most widely used vegetable crops[8]. The total potatoes' cultivated area in the world is 110.132,19 hectares of average yield 17.19 Ton. $ha^{-1}$ [9]. [5] stated that Drip irrigated potatoes under irrigation levels (40, 60, 80 and 100%) of evaporated water resulted in a significant increase in growth indicators and tubers' yield with increased irrigation level. Irrigation of water stress-sensitive crops such as potatoes requires a systematic methodology for irrigation scheduling [10]. [11] found that the spaces among irrigation durations led to a significant decrease in vegetative growth indicators and potato yields. The treatment of irrigation every 10 days gave the lowest values of plant height, dry weight, leaf area and total yield of 69.47 cm, 52.80 gm. $Plants^{-1}$, 46.01dS2. $plant^{-1}$ and 37.0 ton. $ha^{-1}$ respectively, compared to the highest values for every 6 days irrigation treatment, which gave 87.75 cm, 66.03 gm. $Plants^{-1}$, 66.72 01dS2. $plant^{-1}$ and 53.92 ton. $ha^{-1}$, respectively. [12] found that the plant exposure to water stress reduced the leaf area when water was added after evaporation of 70, 140 and 210 mm from the evaporation pan.

He stated that the reduction in leaf area under water deficit conditions comes from the reduction of cell size due to the low water potential in plant's tissue, the reduction of its relative water content, and then its ability to expand and swell. [13] concluded that the use of polymer (hydrogels) with three levels of 0, 60 and 120 kg. $ha^{-1}$ increased the height of wheat planted in two rows after planting two months from 25.45 cm for control treatment to 32.50 and 36.24 cm for treatments 60 and 120 kg. $ha^{-1}$. The results of [14] showed a significant effect of available water in the weight of dry matter, where the plants that received below 100% available water gave the highest yield average of dry matter reached 10.1 $ton.ha^{-1}$, while plants under water stress conditions gave the lowest result of 5.8 $ton.ha^{-1}$. For this reason, the goal of this study is improving potato growth and yield characteristics in gypsum soil.

## 2. Materials and Methods

A field experiment has been done in Al-Anbar Province / Heet City within the spring season of 2018 from February to May 2018 in gypsum soil and the soil physical and chemical properties were measured on the basis of methods mentioned [15] The saturation, field capacity and permanent withering point volumetric moisture was also estimated. (Table 1). Three levels of Perlite (PL) were mixed with soil i.e., 0, 4, and 8% of soil volume to the depth 30cm mixed with soil particles. Perlite of Saudi origin characterized in [16] was used. The irrigation water quantity (IQ) had two levels of 50% and 100% of the net irrigation depth (NDI) counted from the US class A evaporation pan measurements were added. Two irrigation intervals (ITs) were considered as three and six days every irrigation time within the limited depth.

Treatments were distributed according to the Split – Split Plot Design within Randomized Complete Block Design (RCBD) with three replications. ITs have been placed in the main plots. Every main plot was divided into two sub-plots that were randomly irrigated. Every sub-plot was also divided to three lines; in which, perlite application levels (PLs) were randomly distributed.

Farm Preparation and Cultivation: Farm has been tilled, leveled and divided into three blocks. Every block was divided by the above mentioned experimental design and the split plots were also divided into lines with 10m length and 0.75 m width. DAP and potassium sulfate fertilizers were added as 300 kg $P_2O_5$ and $K_2O$ per hectare in respective, were the half potassium amount was added pre-cultivation and the other half was added after 45 days of implantation with Urea fertilizer that was applied as 300 kg per hectare [17].

**Table 1. Some of Physical and Chemical Characteristics of Farm Gypsum Soil.**

| Soil Properties | | Units | Value |
|---|---|---|---|
| Hydrogen Potential pH | | ……………. | 8.0 |
| Electrical Conductivity (1 : 1) | | $dS.m^{-1}$ | 2.5 |
| Available Elements | Nitrogen | $mg.kg^{-1}$ | 60 |
| | Phosphorus | | 30 |
| | Potassium | | 220 |
| Organic Matter | | | 9.6 |
| $CaSO_4$ | | | 180 |
| $CaSO_3$ | | | 80 |
| Soil Separates | Sand | $gm.kg^{-1}$ | 528 |
| | Silt | | 232 |
| | Clay | | 240 |
| Soil Texture | | | Sandy Clay Loam |
| Volumetric Moisture at Saturation | | % | 44.88 |
| Volumetric Moisture at Field Capacity | | | 29.74 |
| Volumetric Mosture at Withering Point | | | 940 |
| Bulk Density | | $Megagram.cm^{-1}$ | 1.27 |

Potato tubers of Riviera cultivar was cultivated on 8cm depth with 0.4 m interspace between plants after being soaked in the fungicide named (Aggressive) by 250 ml/100L water for 10 minutes. Next, tubers were put in gibberellic discs solution as a single disc per 200L water to increase growth of tubers. After that, all the treatments were irrigated (by 40 mm water deep for germination). Irrigation was then scheduled according to treatments to compensate the evaporated water from the American pan class A every 4 and 6 days by the application of 50% and 100% of net irrigation depth (NDI), where the NDI was computed by the following equations:
Calculation of evaporation – reverse transpiration (Evapotranspiration –ET-) by the equation mentioned in [18].

$ET_0 = K_p \times E_{pan}$ ………………………………….. (1)

Where:
$ET_0$: evaporation – reverse transpiration ($mm.day^{-1}$).
$E_{pan}$: evaporation measured in the pan ($mm.day^{-1}$).
$K_P$: evaporation specific coefficient of pan that differs according to pan type, surrounding vegetative cover, and soil surface nature, as mentioned in [18]. The value 0.8 was depended here on the basis of what's mentioned in [19].
Calculating the evaporation – actual transpiration that in consuming aspect equals the actual water consumption of potato crop irrigated superficially and by sprinkling; according to the following equation:

$ET_0 = K_C \times ET_0$ ……………………………… (2)

Where:
$ET_0$: evaporation – actual transpiration ($mm.day^{-1}$).
$K_C$ = Crop coefficient

Values 0.75 , 1.15 , 1.00 and 0.80 that are listed in [20] were relied on to represent crop coefficient values for the durations (03/7 – 03/27) , (03/27 – 04/16) , (04/16 – 05/11) and (05/11 – 05/20) successively.

Water: Drip irrigation system was used by drippers that drain 4 liters. $hour^{-1}$ and the irrigation water was added according to dual application system to differentiate the added water quantities into two pulses that are separated with 6 hours [21] The irrigation time was calculated according to the equation mentioned in [18].

The following vegetative growth indications were also computed:

1. Plant Height (PLH) (cm).
2. Number of Main Aerial Stems (MASN) according to their number for five treatment plants and calculating their average [22]
3. Leaf Area (LA) (dcm. plant$^{-1}$) by taking 30 discs with known area and drying them with electrical furnace on 70°C temperature. According to the following equation [23]:

$$LA\ (dcm.\ plant^{-1}) = \frac{Discs\ area\ (cm^2) \times Dryweight}{Discs\ dry\ weight\ (gm)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

4. Plant's dry weight (PLDW) (gm. plant$^{-1}$)
5. Total Yield (TY) (ton. ha$^{-1}$)

TY for each treatment (average treatment area for three replicates in $m^2$) separately and related to hectare using the equation mentioned in [24] as in the following:

$$TY = \frac{Experimental\ unit\ (m^2)}{Experimental\ unit\ yield\ (kg)} \times 10000 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

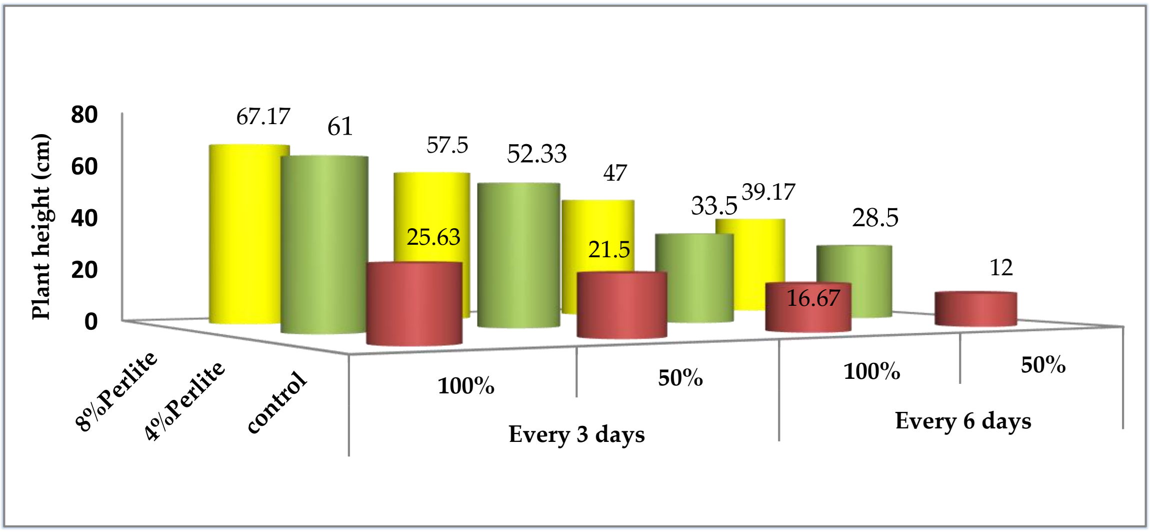
Data have been analyzed on the basis of statistical design and averages were tested according to the Least Significant Difference (L.S.D.) test with probability level 0.05 [25] using Genstat Program.

**3. Results and Discussion**

Plant Height (PLH): Table (1) shows the treatments' effect on increasing PLH values. Perlite application made a significant impression on this trait, the highest value of 39.17cm recorded at 8% of PLs addition compared with 12 and 28.5cm at 0 and 4% levels successively for any additional (NIDs). It could be attributed to the positive effect of Perlite application which increased water retention in soil, decreased hydrous stress on plants, and raised efficiency of soil cations' exchange. Thus, it facilitates root growth and activity that increase vegetative growth in the end. These results agreed with the statements of [26]

Results in figure (1) showed significant differences in PLH values by IT differences for any applied PLs, it made the highest value by every 3 days IT, they were 25.63, 61 and 67.17cm when compared with IT of every 6 days that were 16.67, 33.5 and 47cm for 0, 4 and 8% PLs successively. The cause of this decrease is that the few available water for plant and the increased drought duration could result in inhibited average cell division, cell elongation and absorption and transport; and so plant height reduction [14]. In addition, plants change their growth rate as a response to water stress by control and modify many important processes such as cell division, bio-assimilation in the cell wall and cell membranes and protein assimilation which agree with the sayings of [21].

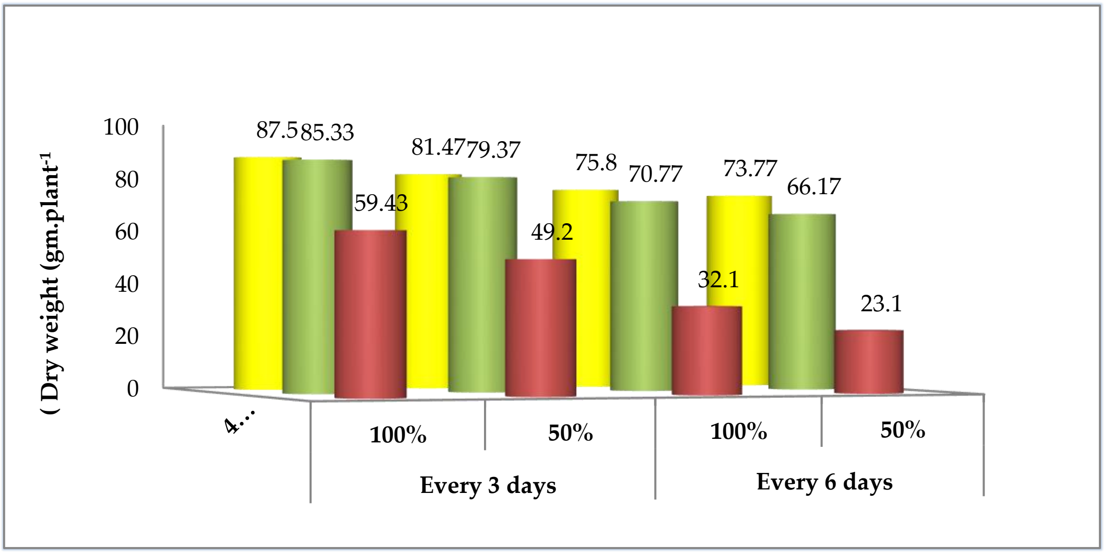
The results stated in figure (1) suggest that 100% pure NID addition had considerably increased the PLH values rather than 50% NID for any interval. It approached 16.67, 33.5 and 47 cm for 100% NID when irrigated by 6 days IT and 12, 28.5 and 39.17 cm for 50% NI depth by 6 days IT for PLs 0, 4 and 8% successively. The decrease of PLH values for 50% NID treatments and 6 days IT in comparison with 100% NID treatments and 3 and 6 days ITs could be attributed to water stress that affects physiologic activity, chemical and bio processes, reduces carbon assimilation, metabolism, flowers, nodes, hormones, plant respiration, and finally ions and nutrients absorption in the unresisting genotypes for water stress [27]–[29].




| L.S.D | A | B | C | A*B | A*C | B*C | A*B*C |
|---|---|---|---|---|---|---|---|
| 0.05 | 2.094 | 3.039 | 1.227 | 3.024 | 1.809 | 3.009 | 3.312 |

**Figure 1. Effect of Perlite Addition and Irrigation Interval Level on Plant Height (cm).**

Plant Dry weight (PLDW) (gm. plant$^{-1}$): Figure (2) states the effect of study treatments on PLDW values. Values have differed by PLs to reach the peak value at 8% level of addition comparing with 0 and 4 PLs for any additional depth of irrigation. It reached their lowest values 23.1 and 66.17 gm. plant$^{-1}$ for 0 and 4% perlite levels (PLs) in comparison with 73.77 gm. plant$^{-1}$ for 8% perlite level.




| L.S.D | A | B | C | A*B | A*C | B*C | A*B*C |
|---|---|---|---|---|---|---|---|
| 0.05 | 2.357 | 2.246 | 2.245 | 2.391 | 2.822 | 3.072 | |

**Figure 2. Effect of Perlite Application, Irrigation Level and Interval on PLDW (gm. plant$^{-1}$)**

It is caused by the positive effect of perlite application. It plays a vital role in the enhancement of soil physical properties as it increases granulation for fusion with small clay grains to form larger grains and thus increases soil permeability, penetration and aeration to provide oxygen requirements for roots respiration and living organisms activity. It also increases the soil water save and decreases loss by evaporation, enhances the drainage ability of clayey soil and thus decreases water accumulation in root spread zone. Perlite also provides optimal environment for plant roots and so enhances vegetative, radical and flower growth to reflect positively on yield properties and components [16].

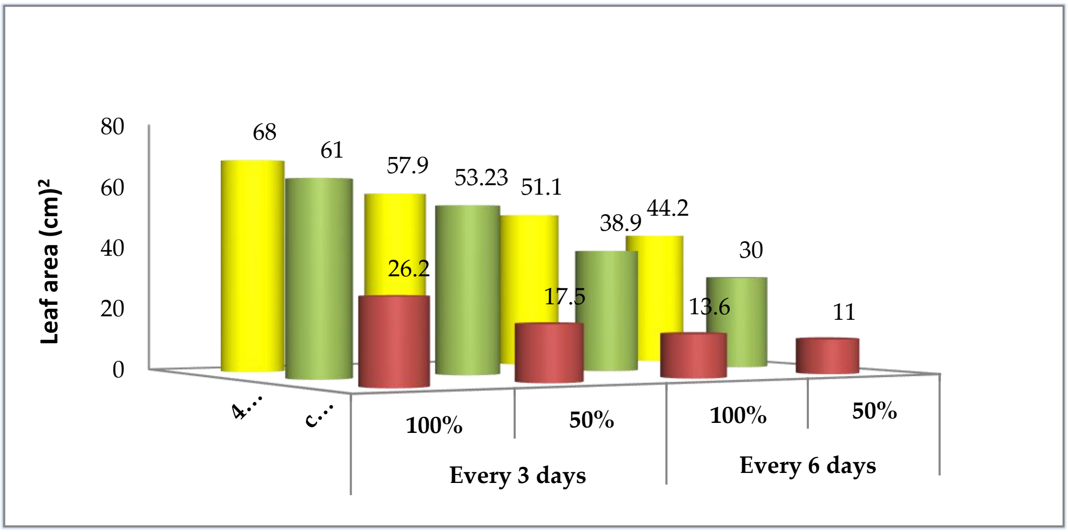
Figure (2) results have shown significant differences among values of PLDW by irrigation interval difference for any level of added perlite. They reached the peak by drying every three days and they were 59.43, 85.33 and 87.5 gm. plant$^{-1}$ in comparison with 6 days irrigation 32.1, 70.77 and 75.8 gm. plant$^{-1}$ for perlite levels 0, 4 and 8% successively.

Water disability is one of the most important environmental factors that determine plant growth and reduces production by quantity and quality. Also the extended IT would reduce carbon assimilation and hasten leaf senility with reduced nutrients absorption, reduced cell growth and elongation and epistomatic leaves that close stomata and limit crops growth [3].

The results listed in figure (2) showed that 100% deep irrigation NID has considerably increased PLDW values in comparison with irrigation on 50% NID because 100% NID for 3 and 6 days interval has increased PLDW values for a plant in a considered view. The values reached 32.1, 70.77 and 75.8 gm. plant$^{-1}$ for 100% NID when doing that every 6 days; in comparison with 23.1, 66.17 and 73.77 gm.plant$^{-1}$ for 50% NID when it's done for a 6 days interval for perlite levels 0, 4 and 8% respectfully. The drop in dry weight values for the treatments of 50% NID for 6 days irrigation interval when compared with 100% NID for 6 and 3 days irrigation interval could be attributed to the lack of irrigation water for potato which affected the extension of leaves, stems and tubers for the decrease of filling pressure which is necessary for elongation and then reduced photosynthesis. Water stress potential can also result in the inhibition of hormones functionality, especially for oxidase; therefore there's a reduced PLH, reduced branching and other vegetative growth properties [30]. It's found that exposing a plant to water stress had made noticeable reduction in growth properties (plant height, branches number, dry weight and leaf area).

Leaf Area (LA) (dcm$^2$): Figure (3) shows the effect of study treatments on LA values. It's remarked that they differed by the difference of PLs. They reached the peak at 8% level of addition, compared with 0 and 4% levels of addition for any applied depth of irrigation (NDI). They also reached their bottom 11 and 30 dcm2 for 0 and 4% perlite application in comparison with 44 dcm2 for 8% perlite application. The perlite addition has caused reduced evaporation in soil medium, excessive soil water and so increased soil storage and readiness which result in raised vegetative and flower growth [31], [32] .

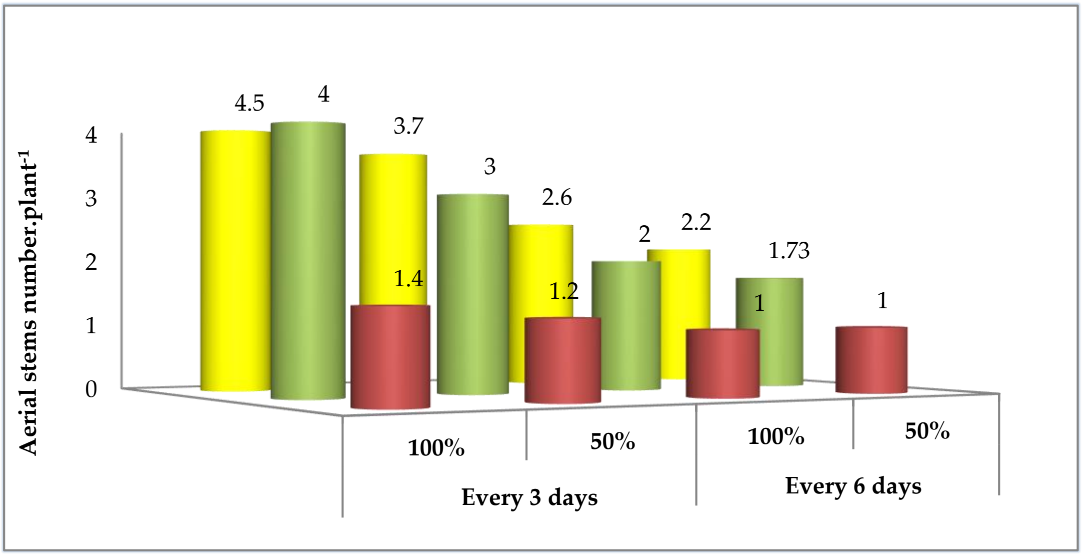
In this figure, three significant differences were noticed amongst the LA values by the IT difference for any PLs. The highest values have been spotted at three days IT and they were 26.2, 61 and 68 dcm$^2$ compared with every 6 days IT, that were 13.6 ,38.9 and 51.1 dcm$^2$ for 0, 4 and 8% IPs. The potato crop being exposed to extended IT and lowered soil moisture of (higher water potential "tension") would reduce vegetative growth indicators just like LA. The increased moisture tension on a plant would also reduce the growth processes that include cell growth and elongation and thus reduces LA. The reduction of LA could be a response to drought that caused reduction of leaf renewal and hastening plant senility and leaf fall. The results stated in figure (3) show that the 100% of had considerably increased LA values compared with 50% NID. The irrigation in 100% NI depth for 3 and 6 days IT has increased the plant LA considerably in comparison with 50% NID for 6 days IT. It also reached 13.6, 51.1 and 38.9 dcm$^2$ for 100% depth of irrigation when irrigated every 6 days in comparison with 11, 30 and 44.2 dcm$^2$ for irrigation in 50% NID in every 6 days IT for 0,4 and 8% PLs in successive way. It's possible that reduction is a result of lacked irrigation water for potato that affected leaf elongation and for the decreased fullness pressure which is necessary for elongation and then the reduced photosynthesis. Water stress also causes inhibited hormonal activity, especially for oxygen hormone, therefore the LA decreases [30] who found that exposing plant to water stress potential caused significant reduction in growth properties (Plant height, branches number, dry weight and leaf area).




| L.S.D | A | B | C | A*B | A*C | B*C | A*B*C |
|---|---|---|---|---|---|---|---|
| 0.05 | 1.955 | 1.479 | 1.391 | 1.728 | 1.888 | 1.945 | 2.657 |

**Figure 3. Effect of Perlite Addition and Irrigation Interval Level on the LA (dcm²).**

Number of Aerial Stems (MASN): Figure (4) states the study treatments effect on the MASN values. It's spotted that values differed by the difference of PLs. They reached their peak at 8% PL of addition in comparison with 0 and 4% PLs, for any NID. They also reached their bottom 1 and 1.73 at 0 and 4% PLs successively when compared with MASN of 2.2 at 8% PL.




| L.S.D | A | B | C | A*B | A*C | B*C | A*B*C |
|---|---|---|---|---|---|---|---|
| 0.05 | 1.573 | 0.105 | 0.564 | 1.551 | 1.196 | 0.654 | 1.279 |

**Figure 4. the effect of perlite application and irrigation interval level on MASN.**

The raise of MASN at high PLs is a result to the role that perlite plays on soil texture improvement, increases its stability for more permeability. It's a good indication for perlite ability to improve all the physical and chemical criteria and this is what's approved by perlite component analysis table; those which increase vegetative growth indicators. In addition, the application of perlite that has a large surface area would increase soil ability to save water by increasing the application level [32].

Figure (4) results have shown significant differences in PLDW values by different IT for any PLs. They reached their highest value when having 3 days IT; they were 1.4, 4 and 4.5 when compared with 6 days IT treatments, that were 1.2, 3.0 and 3.7 for PLs 0, 4 and 8% respectfully. The long IT and the reduction of soil water content (the increased water tension) for potato crop would decrease vegetative growth indicators such as the MASN because water stress is an inactive environmental issue that occurs in case of soil water reduction for continuous water loss by evapotranspiration potential that causes weak plant growth, reduced leaf size and elongation and stem weakness [33].

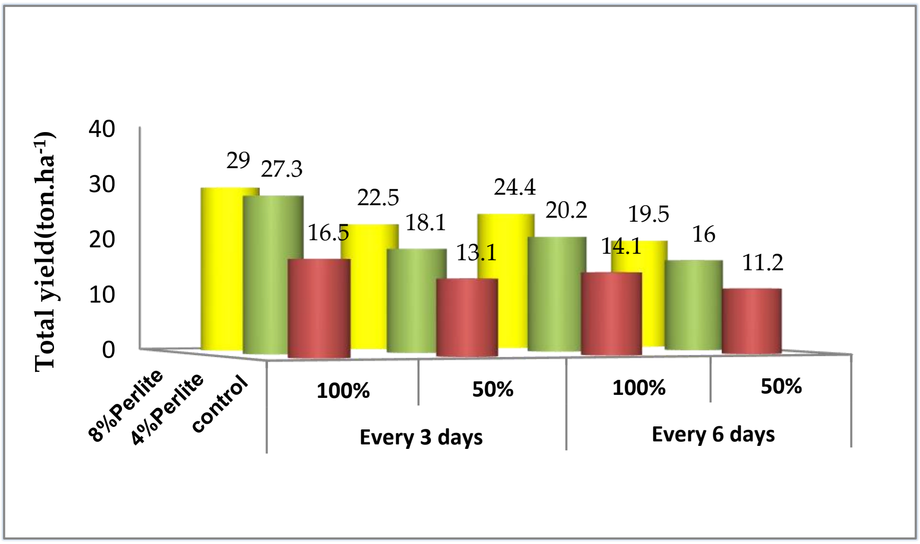
Returning to figure (3) results show that 100% NID had significantly raised leaf size values in comparison with 50% NID because 100% deep NID for 3 and 6 days IT has made significant increase in MASN values when compared with 50% depth and 6 days interval. They approached 1.0, 2.0 and 2.6 $dcm^2$ for 100% NID for every 6 days interval, compared with 1, 1.73 and 2.2 $dcm^2$ for 50% deep NID at 6 days IT for PLs 0,4 and 8% successively. The main stems increase at 100% deep application due to the available water amounts given by complete irrigation for the growth season; so the generated buds increased and received induction to cause MASN increase. That is what [34] confirmed when he referred to the fact that potato plant has urgent need for abundant ground moisture to help growing more side ground buds for new stems formation; and this is what discovered by [35], [36] as well.

Total Yield (YT) (ton $ha^{-1}$): Figure (5) shows the effect of study treatments on nodules quantity. In which, we notice that crop values have differed with added perlite levels difference. They reach the peak value at 8% level, comparing with levels 0 and 4% for any additional depth of irrigation. They also reached their bottom value 11.2 and 16 ton. $ha^{-1}$ for levels 0 and 4% when compared with 19.5 ton. $ha^{-1}$ for 8% perlite level.

The reason of perlite treated plants superiority in comparison with plants implanted in normal farm soil is attributed to perlite characteristics that wrap soil particles with water shells to loosen soil particles and thus facilitates roots penetration and so gives high ability for plants to absorb and maintain water and nutrients fresh and when roots go through soil, they form simple pathways for water move and thus lessens its bulk density. This is all reflecting on vegetative growth characters that increased to improve crop and its components. Perlite also functions in the enhancement of soil composition and stability to increase its permeability which indicates good for perlite ability to enhance all the soil physical and chemical properties; and this is what's been approved by perlite component analysis table for the increase of crop and its components. In addition, applying large surface area perlite would increase soil ability to hold water and it could increase by increasing addition level. The raise in yield and its component by perlite addition could also be attributed to the few evaporation in soil medium, so increasing soil water excess and increasing the stored water and availability by perlite application to cause therefore vegetal and fruity growth, and for all off this, yield and its components increase. Those results do agree with the discoveries of [31], [32], [37].

The results of figure (5) showed significant differences in YT values by IT ifference for any level of added perlite. They reached the highest value at 3 days IT; they were 16.5, 27.3 and 29 ton. $ha^{-1}$ compared with irrigation every 6 days 14.1, 20.2 and 24.4 ton. $ha^{-1}$ for PLs 0, 4 and 8% successively. This decrease could be a result of the extensive IT and the lowered soil moisture content (increased water tension) that would necessarily reduce vegetable growth and yield indicators for the water stress being a non-bio stresses of environment and occurs in case of reduced soil moisture due to the continuous water loss through transpiration or evaporation to cause plant growth weakness, leaf size and elongation decrease and stem weakness [33].

Figure (5) results show that 100% NID had significantly increased YT values when compared with 50% NID. Because 100% NID for 3 and 6 IT had significantly increased the YT values compared with 50% depth for 6 days IT the values reached 14.1, 20.2 and 24.4 ton. $ha^{-1}$ for NID 100% if irrigated every 6 days IT when compared with 11.2, 16.0 and 19.5 ton.$ha^{-1}$ for 50% deep irrigation with 6 days IT with PLs of 0, 4 and 8% in successive. The reduction of YT values for 50% deep NID and 6 days IT treatments when compared with 100% NID and 3 and 6 days IT could be attributed to the effect of water stress on tubers yield which agree with [30] who found that water stress is a main reason of yield reduction that could 50% or more reduces it.




| L.S.D | A | B | C | A*B | A*C | B*C | A*B*C |
|---|---|---|---|---|---|---|---|
| 0.05 | 2.966 | 2.532 | 1.949 | 2.800 | 2.727 | 2.980 | 3.924 |

**Figure 5. perlite application and irrigation interval effect on YT (ton. ha$^{-1}$).**

## 4. Conclusion

The results revealed a high powerful effects of perlite levels (PL), irrigation intervals (IT), and irrigation quantity (IQ) on plant height (PLH), total dry weight (PLDW), leaf area (LA) number of aerial stems per plant (MASN), and total yield (YT). The highest PLH was found at PL of 8%, IT of 3 days, and IQ of 100% NID compared to 6 days IT when stabilizing other factors. The PLDW was decreased significantly at 6 days IT, 50% NID, and 8% PL compared to 3 days IT and 100% NID, for the same PL. The highest YT was found at 6 days IT and IQ of 50% NID, which represent an economic revenue of corn cultivated in the gypsiferous soil that was full of problems. We can recommendation that the best way to avoid problems of economic agricultural yield of potatoes in gypsiferous soils is to follow up the 8% PL, 6 days IT, and IQ of 50% NID that increase water use efficiency of soil and decrease water consumption of potato and achieve an economic revenue of total yield.

**Supplementary Materials:**

No Supplementary Materials.

**Author Contributions:**

W. F. AL-Shamary and B. H. Alkhateb ; methodology, writing—original draft preparation, E. T. Abdel Ghani; writing—review and editing, E. T. Abdel Ghani; paraphrasing. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest:**

The authors declare no conflict of interest.

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