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Effect of dew-irrigation on seed yield and physiological traits in chickpea

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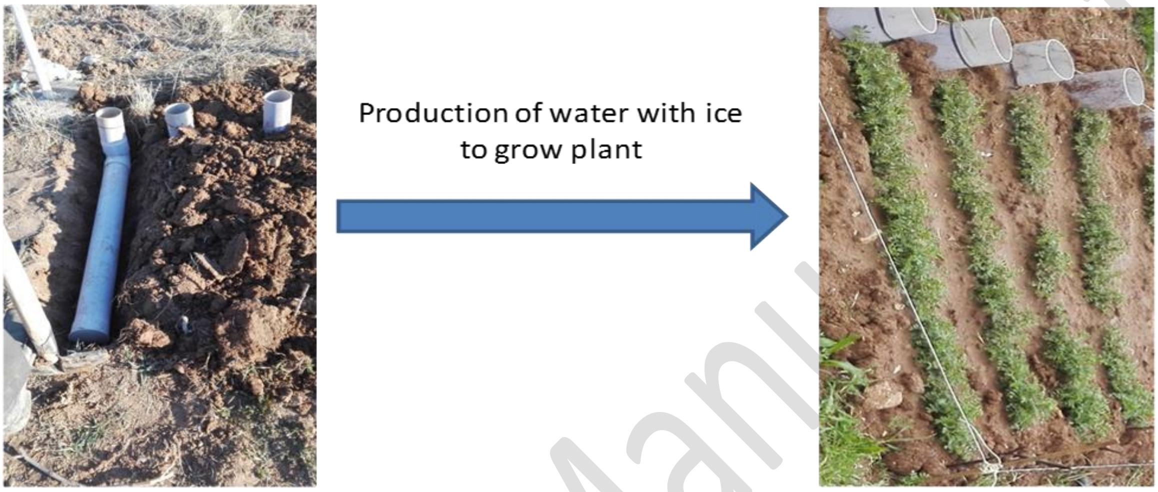
GRAPHICAL ABSTRACT



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ABSTRACT

Water shortage leads researchers and farmers to find new water resources. Water production from air vapor is a new idea. A field experiment was designed to determine the effect of dew-irrigation on chickpea seed yield and physiological traits. The field experiment included three treatments (dew-irrigation, conventional irrigation, and dryland farming). Irrigation treatments had no significant effect on chlorophyll a, chlorophyll b, total chlorophyll, chlorophyll a/b, relative water content, seed yield and yield attributing traits, and morphological traits. The mean comparison showed that dew-irrigation had higher stomatal conductance, chlorophyll fluorescence parameter (FV/FM), and photosynthesis performance index compared to dryland farming (62, 16, and 245% increase, respectively). Conventional irrigation had a higher photosynthesis performance index compared to dryland farming. Some plant physiological traits such as stomatal conductance clearly showed the positive effect of dew-irrigation on plant growth. The study of different levels of energy for water production can be informative in the next experiments.

1. Introduction

The agricultural sector is the world's largest consumer of water, and in arid areas, irrigated farming consumes 50 to 85 percent of total water (Hamdy, 2001). Due to the limited resources of water and sometimes lack of access to water resources in some areas, it is necessary to find unconventional resources of water (Owusu-Boateng and Adjei, 2014 ; Mohammadi, Ghazavi and Mirzaie, 2021). One of the new methods of irrigation is the use of humidity in the air (Fu et al., 2023; Shan et al., 2023; Zhu et al., 2023). In the study of condensation irrigation systems, it was found that the average water production capacity was 4 liters for 8 hours over a 25-meter pipe. Also, by studying the temperature along the pipe, it was determined that by passing the pipeline beginning, the production of drinking water would also be lower (Yousefi and Boroomand Nasab, 2015). Lindblom and Nordell (2007) conducted a condensation irrigation system; it found that the water produced by the system was about 70% higher when used for irrigation compared to when it was used in drinking water production. The use of saltwater is another application of the condensation method. Saltwater in the system of condensation irrigation is evaporated by the energy generated by solar radiation and humidifies the air inside the distillation system to saturation. Then, this warm and humid air is transferred to the sub-pipe system, where it loses its heat and condensates water. This condensed water can be collected and used at the end of the pipes (Lindblom and Nordell, 2006).

Drought is one of the most common environmental stresses that has limited agricultural production through disturbances in physiological processes and reduces plant yields (Armand, Amiri, and Ismaili, 2015;

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Basyal and Walker, 2023; Karimzadeh Fard, Soleymani and Javanmard, 2023). It has been reported that drought decreased mung bean yield by the dry weight of the plant (Ghassemi-Golezani et al., 2014) and harvest index (Tomas et al., 2003). Shoot weight loss under drought conditions in bean has also been reported (Ashraf and Iram, 2005). Boutraa and Sanders (2001) reported that drought reduced yield and yield components of bean (*Phaseolus vulgaris*) during both flowering and seed-filling stages. Singh (2007) reported that the mean reduction under drought in bean seed yield and seed weight was 60% and 14%, respectively.

Chlorophyll content in plants is one of the important factors in preserving photosynthetic capacity (Yu et al., 2023; Zhou et al., 2023). Drought reduced the amount of chlorophyll in sunflower (Manivannan et al., 2008). The decrease in photosynthesis is due in part to the reduction of chlorophyll content. The main role of carotenoids is to prevent oxidative damage. Under stress conditions, the amount of carotenoids is reduced and cannot play a protective role (Bruce, Edmeades and Bar, 2002: Wang et al., 2010). The high drop in chlorophyll content at high levels of drought could be attributed to the reduction in the transfer of minerals and water required by the leaves due to a decrease of suction due to transpiration in the xylem (Hosseinzadeh, Amiri and Ismaili, 2016). Reducing the FV/FM ratio under drought can indicate that electron transfer from photosystem II to photosystem I is affected and reduced by drought (Lu and Zhang, 1988). In a study, drought significantly reduced the FV/FM ratio in chickpea (Rahbarian et al., 2011).

In drought conditions, it has been reported that the amount of photosynthesis and stomatal conductance of mung bean plants decreases (Afzal et al., 2014). Drought decreased the leaf relative water content in lentil (Salehpour et al., 2009) and bean (Turkan et al., 2005). The closure of the stomata and the reduction of stomatal conductance due to drought have been associated with an increase in the amount of abscisic acid in the leaves (Abdul Jaleel et al., 2009).

According to researchers' idea, the drought results in stomatal closure and decreases the fixation of carbon dioxide. It results in the production of active oxygen species and disrupts the natural mechanisms of the cell (Hu and Schmidhalter, 2005). Ultimately, yield is reduced. The first response of all plants to water shortages is to close stomata to reduce water loss through transpiration (Mahajan and Amania, 2005).

Previous research on water production from air vapor has mainly focused on the rate of water production without considering the plant response. The difference between the present study and the previous studies is the production of dew from the air vapor trapped in the soil and the plant's use of the produced water. So far, no system has been investigated to reduce soil temperature to produce dew and use it for irrigation. This research was conducted with the aim of determining the morphological and physiological characteristics of chickpea under dew-irrigation.

2. Materials and methods

2.1. Experimental site and design

This research was carried out at the Research Farm, Agriculture and Natural Resources Campus, Razi University, Kermanshah in 2017. The experimental site has a longitude of 47 ° 20 ', a latitude of 34 ° 21', an altitude of 1319 m, a temperate climate, an average annual maximum and minimum temperature of 22.2 °C and 5.9 °C, and rainfall rate of 441 mm per the study year. This experiment was conducted in a randomized complete block design with three replications. Each block had three plots (dew-irrigation, conventional irrigation, and dryland farming). The space between plots was one meter. Each plot has a width of one meter, a length of 1.4 meters, four rows of planting with a distance of 35 cm, and a distance between the plants of 20 cm. Treatments were:

A) Dew-irrigation: After chickpea planting, the plants were irrigated every eight days. But from flowering to seed filling, a liter of ice was placed inside each plastic pipe every day under the planting line. These plastic pipes were placed underneath the soil, on which a row of chickpea was planted. These pipes were placed under the soil without any leakage.

B) Conventional irrigation: The plants were irrigated every eight days.

C) Dryland farming: To start uniform germination of the field in the studied treatments, the dry farming treatment was irrigated only once. Then the plants went through their growth stages with precipitation.

2.2. Dew-irrigation system and crop practices

On 27/2/2017, the soil was plowed and leveled. Then it was plotted. In dew-irrigation, pipes with a diameter and length of 10 cm and one meter, respectively, were used. One side of the pipe was capped, and the other side was a knee with a height of 20 cm. This knee was toward the top of the soil to be a valve for entering the ice into the pipes embedded below the planting line. The pipe containing water and ice (a one-liter sealed bottle of ice was placed inside the pipes) was placed in a soil depth of 10 cm. The duration of the treatment application was from 7/5/2017 to 13/6/2017 (from the flowering to the physiological maturity stage).

Chickpea seeds, Cultivar ILC482, were planted on each row manually at a depth of 2 to 3 cm below the soil. The seeds were densely planted and later thinned when the seedlings had 2-3 leaves. The farm was irrigated immediately after planting. Weeds were controlled by hand weeding during the chickpea growth period. Weed species in the field included *Carthamus oxycantous, Convolvlus arvensis, Galium aparine L., Chenopodium album, Glycyrrhiza glabra, Sorghum halepense,* and *Hordeum bulbosum.*

2.3. Sampling of physiological and morphological traits

Plant height: at maximum vegetative growth, plant height was measured. Relative water content (RWC): On 31/5/2017, leaf relative water content was measured by selecting the youngest developed leaf from each plot at the end of the podding. For this purpose, in each plot, three plants were randomly selected, and three green leaves were separated from each plant. RWC was calculated using Eq. 1 (Valipour, Heidari and Bahraminejad, 2023).

$$RWC\% = (FW-DW) / (TW-DW) \times 100 \quad (1)$$

where, FW, TW, and DW are the leaf fresh weight, turgid weight, and dry weight, respectively.

Chlorophyll Measurement: On 31/5/2017, the maximum greenness stage, sampling was performed to measure chlorophyll a, chlorophyll b, and total chlorophyll content. In this method, three plants per plot and five leaves per plant were randomly selected. After pouring liquid nitrogen on the leaves, the sample was powdered with molcajete. 125 mg of powdered sample was placed in a microtube and ethanol alcohol 96% was added to the samples at a rate of 250 *µl*. The samples were then placed in a centrifuge. Subsequently, samples were read using Elisa (EL 808, Bio Tek) at 663, 646, and 470 wavelengths. Finally, the values were put in equation 2 and 3 to obtain chlorophyll a and b. (Lichtenthaler and Wellburn, 1983).

$$\text{Chlorophyll a} = 12.21\ (A_{663}) - 2.81\ (A_{646}) \quad (2)$$
$$\text{Chlorophyll b} = 20.13\ (A_{646}) - 5.1\ (A_{663}) \quad (3)$$

The total chlorophyll and chlorophyll a to chlorophyll b ratio was calculated using the chlorophyll a and b.

Stomatal conductance: Three plants per plot and three green and fully developed leaves per plant were randomly selected to measure stomatal conductance. Stomatal conductance was measured with a porometer device. The device was used from 10 a.m. to 2 p.m. because most transpiration occurs at this time. On 3/6/2017 (after irrigation), the stomatal conductance was measured.

Photosynthetic parameters: Three plants and one fully developed and green leaf per plant were randomly selected to measure the chlorophyll fluorescence efficiency index or the photosynthesis performance index and FV/FM (maximum quantum yield in dark-adapted conditions, indicates the maximum photosynthesis II performance). A chlorophyll fluorimeter was used to measure these traits on 8/6/2017.

2.4. Sampling for seed yield and yield attributing traits

To calculate the yield and traits related to chickpea yield, after the removal of the border effect, three plants per plot were randomly selected and harvested. The harvest date was 1/7/2017.

Traits such as pod length, pod diameter, pod number per plant, pod number containing a single seed, pod number containing two seeds, empty pod per plant, 100-seed weight, seed weight per plant, seed yield, straw weight per plant, straw yield, biological weight per plant and biological yield were measured. At first, the samples were dried at 72 °C for 24 hours. Then they were weighed with a digital scale with milligram accuracy. The biological yield was obtained from the sum of the seed yield and the yield of straw. The biological weight was obtained from the sum of seed weight and straw weight. The harvest index was obtained by dividing seed yield by biological yield.

2.5. Data analysis

Data were analyzed by SAS (Ver. 9.1.3) software. Means were compared by the Duncan test at the probability level of 5%. MINITAB (Ver. 11.12) software was used for normality test and outlier detection

3. Results and discussion

3.1. Weather

Meteorological data including rainfall, air temperature and, air relative humidity during the growing period of chickpea is given in Table 1. According to this Table, the peak of rainfall was in April and there was no rainfall in June. Regarding the temperature, the air temperature was increasing from May to June, and in June the temperature reached the maximum during the growth period of chickpea. Air relative humidity was at its maximum value in April and reached its minimum value at the end of the growth period, i.e., June. The two factors of air relative humidity and temperature are effective in the formation of dew, considering that the dew-irrigation system was applied in May and June, it can be said that the weather conditions at this time are not very favorable for the formation of dew, especially in terms of relative humidity in June.

Table 1. Meteorological data related to monthly rainfall, average monthly temperature and, average monthly relative humidity during the chickpea planting period in 2017.

Meteorological parameter	March	April	May	June
Precipitation, mm	68	132.5	22.1	0
Mean temperature, °C	7.1	12.5	18.7	23.7
Mean humidity, %	50	57	46	24

3.2. Leaf chlorophyll and relative water content

The mean comparison showed that there was no significant difference between irrigation treatments in terms of chlorophyll a, chlorophyll b, total chlorophyll, chlorophyll a/b, and relative water content (Table 2). Several reports indicate that maintaining the content of photosynthetic pigments such as chlorophyll a, chlorophyll b, and carotenoids in drought conditions helps to stabilize photosynthesis (Beyk Khurmizi et al., 2013). Studies have shown that carotenoids can be one of the factors that reduce stress, and on the other hand, maintain the complex structure of chlorophyll and plant photosynthesis (Wang et al., 2010). Reduction of chlorophyll content has been reported in drought conditions in olive, bean, and wheat (Armand, Amiri and Ismaili, 2015; Bayoumi et al., 2009; Guerfel et al., 2008). The leaf relative water content of lentil was reduced by drought (Salehpour et al., 2009).

Table 2. Mean comparisons of irrigation treatments in terms of physiological traits in chickpea.

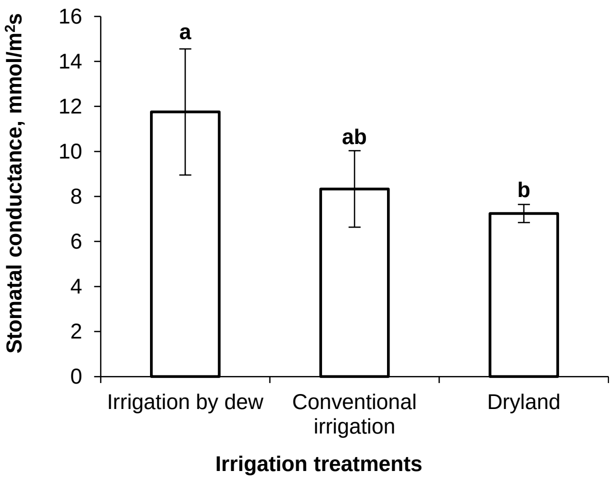
Irrigation treatments	*Chl a, mg/g	Chl b, mg/g	Total chl, mg/g	Chl a/b, mg/g	Leaf relative water content, %
Conventional irrigation	13.1 ±3.0a	3.1±0.7a	16.2±3.7a	4.2±0.1a	40.6±2.7a
Dew-irrigation	10.1±1.8a	2.5±0.4a	12.6±2.2a	4.0±0.1a	35.8±0.4a
Dryland	9.6±0.8a	2.4±0.2a	12.1±1.0a	4.0±0.0a	41.6±4.2a

*Means with the same letter have no significant difference according to the Duncan test at the probability level of 5%. The values represent the mean ± standard error.

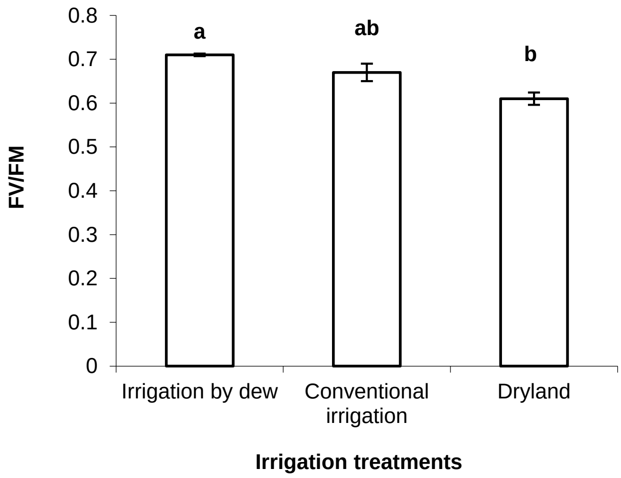
3.3. Stomatal conductance, FV/FM, photosynthesis performance index

A comparison of the mean showed that dew-irrigation had higher stomatal conductance, chlorophyll fluorescence parameter (FV/FM), and photosynthesis performance index compared to dry land conditions. The increase rate was 62, 16, and 245% for stomatal conductance, FV/FM, and photosynthesis performance index, respectively (Fig. 1a, b, c). Stomatal closure and stomatal conductance reductions are due to drought (Abdul Jaleel et al., 2009). The reason for higher stomatal conductance in dew-irrigation is probably that there is always moisture at the root zone of the plant, and the root of the plant is kept cool. Therefore, stomatal conductance and photosynthesis have been continual. In addition, the traits associated with the stomata are momentary, so they are more affected by dew-irrigation than other traits.

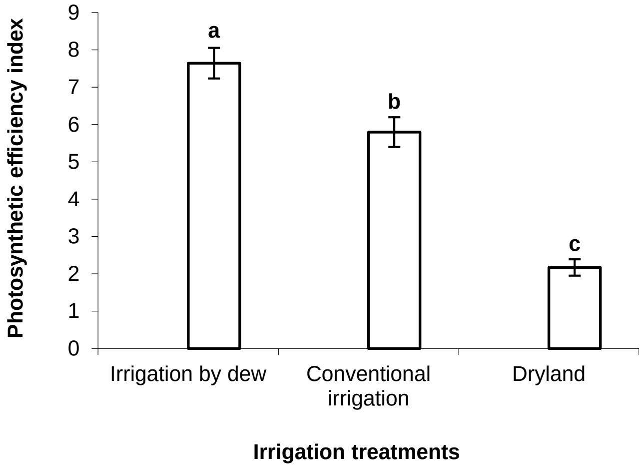
Turgescence is a highly susceptible process to drought and its loss due to stress reduces the opening of the stomata (Kumar and Purohit, 2001). The accumulation of Abscisic acid in the guard cells due to sending a drought signal from root to leaf and reducing water content is one of the most important reasons for the closure of the stomata in the plant (Afzal et al., 2014; Lopez, Ortiz Cereceves and Kelly, 2004). Studies on legumes such as bean have shown that under drought, the concentration of CO_2 in the leaves decreases through stomatal closure (Armand, Amiri and Ismaili, 2015). Reduction of the FV/FM ratio under drought conditions has been reported in different plants such as chickpea, bean, corn, and wheat (Ashraf, Nawazish and Athar, 2007; Lu, Lu and Zhang, 2002; Sikder, Foulkes and West, 2015). Other consequences of drought are the destruction of thylakoid membrane proteins, which reduces the electron transfer rate, increases the chlorophyll fluorescence, and reduces the performance of the photosystem II (Piper et al., 2007; Tilahun and Sven, 2003). Reducing the amount and activity of the RuBisCo enzyme and inhibiting the synthesis of ribulose bisphosphate are other effects of drought (Pagter, Bragato and Brix, 2005). Oxidative stress is another effect of drought (Armand, Amiri and Ismaili, 2015). Free oxygen radicals by peroxidation and chlorophyll decomposition reduce light-dependant reactions of photosynthesis and reduce the production of energetic materials such as NADPH and ATP required for dark reactions of photosynthesis (Benson-Calvin cycle) (Hosseinzadeh, Amiri and Ismaili, 2016).



(a)



(b)



(c)

Fig. 1. Mean comparison of irrigation treatments in terms of stomatal conductance (a), FV/FM (b), and photosynthesis performance index (c) in chickpea. Means with the same letter have no significant difference according to the Duncan test at the probability level of 5%. The values represent the mean ± standard error.

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3.4. Stem height and stem number

The mean comparison showed that there was no significant difference between irrigation treatments in terms of stem height and stem number (Table 3). Drought reduced plant height in chickpea (Nayyar et al., 2006) and soybean (Jaleel et al., 2009). Apparently, by shortening the growth period due to drought, the plant height decreases (Katarina et al., 2014). In research on rice, the dry weight of stems, leaves, and roots decreased by increasing water shortage. Reducing the dry weight of the stems can be accompanied by a reduction in leaf production and a reduction in leaf number (Sikuku et al., 2010).

Table 3. Mean comparisons of irrigation treatments in terms of morphological traits in chickpea.

Irrigation treatments	*Stem height, cm	Stem number	Pod number containing single seed per plant	Pod number containing two seeds per plant	Empty pod number per plant	Pod number per plant	Pod length, cm	Pod diameter, cm
Conventional irrigation	41.1±1.9a	3.0±0.0a	20.9±4.8a	4.7±1.6a	1.4±0.3a	26.7±5.9a	2.2±0.0a	1.0±0.0a
Dew-irrigation	40.3±2.2a	4.1±0.4a	16.8±3.7a	2.9±0.6a	2.0±0.2a	21.7±4.4a	2.1±0.0a	1.1±0.0a
Dryland	45.6±1.4a	3.4±0.2a	20.3±6.2a	3.2±1.0a	2.4±0.8a	26.0±5.5a	2.2±0.1a	1.0±0.1a

*Means with the same letter have no significant difference according to the Duncan test at the probability level of 5%. The values represent the mean ± standard error.

3.5. Number of pods containing a single seed per plant, number of pods containing two seeds per plant, number of empty pods per plant, and number of pods per plant

The mean comparison showed that there was no significant difference between irrigation treatments in terms of the number of pods containing a single seed per plant, number of pods containing two seeds per plant, number of empty pods per plant, and number of pods per plant (Table 3). Under water deficit stress conditions, the reproductive phase duration and the amount of current photosynthesis decrease, resulting in lower flower formation in the plant, which affects the number of fertile pods and seed production (Goldani and Rezvani, 2007). Leport et al. (1999) reported that water deficit stress affects seed yield by increasing the number of empty pods and decreasing the seed filling period. Drought reduced the number of pods in chickpea genotypes (Rahman and Uddin, 2000). Mild stress during the growing season has resulted in better absorption of photosynthetic materials through the reproductive sinks compared to the vegetative reservoirs, which results in the survival of most cotton bolls (White and Raine, 2004).

3.6. Pod length and diameter

The mean comparison showed that there was no significant difference between irrigation treatments in terms of pod length and diameter (Table 3). Pirzad, Jalilian and Akbari Bavandi (2015) reported that drought reduced the pod length and diameter of mung bean (*Vigna radiata* L.).

3.7. Seed yield and yield-attributing traits

The mean comparison showed that there was no significant difference between irrigation treatments in terms of seed number per plant, 100-seed weight, seed yield, straw yield, seed weight per plant, straw weight per plant, biological weight per plant, biological yield, and harvest index (Table 4).

Table 4. Mean comparisons of irrigation treatments in terms of seed yield and yield-attributing traits in chickpea.

Irrigation treatments	*Seed number per plant	100-seed weight, g	Seed yield, g/m^2	Straw yield, g/m^2	Seed weight per plant, g	Straw weight per plant, g	Biological weight per plant, g	Biological yield, g/m^2	Harvest index, %
Conventional irrigation	30.2±8.0a	24.9±0.6a	106.3±25.2a	86.4±18.8a	7.4±1.8a	6.0±1.3a	13.5±3.1a	192.7±43.9a	55±1a
Dew-irrigation	22.6±4.7a	31.5±2.6a	98.1±12.2a	81.3±5.5a	6.9±0.8a	5.7±0.4a	12.5±1.2a	179.4±17.1a	54±2a
Dryland	26.8±4.0a	28.3±2.7a	107.6±17.9a	82.9±6.5a	7.5±1.3a	5.8±0. 5a	13.3±1.6a	190.6±23.7a	56±3a

*Means with the same letter have no significant difference according to the Duncan test at the probability level of 5%. The values represent the mean ± standard error.

Unlike the results of this study, many researchers have reported a reduction in the dry matter of aerial parts and reduced production of photosynthetic materials due to water stress (German and Teran, 2006; Kisman, 2003). Ohashi et al. (2009) reported that drought reduced number of pods per plant, number of seeds per plant and seed dry weight per plant in soybean. Drought stress has been reported to minimize mung bean yield through plant dry weight (Ghassemi-Golezani et al., 2014). Another research showed that drought reduced the yield of mung bean by reducing the dry weight of the plant and harvest index (Tomas et al., 2003). Generally, drought affects all aspects of plant growth and most of its physiological aspects, which depend on the intensity and timing of the stress (Finch-Savaga and Elston, 1982). Some studies have also reported insignificant or minor effects of drought on plant yield and yield components. Among the chickpea yield components, the 100-seed weight is less affected by different levels of moisture (Canci and Toker, 2009). Zabet et al. (2003) stated that in the mung bean, traits such as 100-seed weight had the least damage due to water deficit stress. Due to the small size of the seeds, drought did not have a significant effect on 100-seed weight (Paroda and Thomas, 1988). Edstorm and Schwankl (2002) evaluated the impact of three irrigation methods including surface drip irrigation, sub-surface drip irrigation, and micro-jet on almond trees for ten years. Their results showed that there was no significant difference between the three irrigation methods in terms of crop production. The insignificant effect of irrigation treatments (including dew-irrigation) on the seed and biological yield of chickpea in the present experiment may be due to that the study year was wet according to meteorological reports. Chickpea is a dry land crop, a fairly drought-resistant and low-water plant, so it might not be necessary to add moisture to the soil due to soil favorable moisture conditions in the wet year. The lack of significant difference in seed yield between conventional irrigation and dry land also confirms this subject. If the effects of dew-irrigation were investigated under drier conditions, such as the warm season or on warm season plants, the results could be meaningful. The energy required to produce water with dew is a challenge. A cheap source can be sunlight. Sunlight can be used in the form of a solar refrigerator to produce ice.

4. Conclusions

Some plant physiological traits such as stomatal conductance clearly showed the positive effect of dew-irrigation on plant growth. The insignificant difference among irrigation treatments in terms of seed yield in chickpea may be due to that the chickpea is a fairly drought-resistant and low-water plant. The use of more energy to produce dew than the values used in this study is proposed in the next experiments.

Author Contributions

Hassan Heidari: Designed and wrote the paper.
Saiede Sargol Hosseini: Performed the experiment.
Mohammad Eghbal Ghobadi and Iraj Nosratti: Revised the manuscript.

Conflict of Interest

There is no conflict of interest in this article.

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Data Availability Statement

Data will be available when needed.

References

Abdul Jaleel, C. P. *et al.* (2009) 'Drought Stress in plants: a review on morphological characteristics and pigments composition', *International Journal of Agriculture and Biology*, 11, pp. 100-105. Available at: http://www.fspublishers.org (Accessed: 5 May 2024).

Afzal, A. *et al.* (2014) 'Water deficit – induced regulation of growth, gas exchange, chlorophyll fluorescence, inorganic nutrient accumulation and antioxidative defense mechanism in mung bean [*Vigna radiata* (L.) wilczek]', *Journal of Applied Botany and Food Quality*, 87, pp. 147-156. Available at: https://ojs.openagrar.de/index.php/JABFQ/article/view/2781 (Accessed: 5 May 2024).

Armand, N., Amiri, H., and Ismaili, A. (2015) 'Interaction of methanol spray and water – deficit stress on photosynthesis and biochemical characteristics of *phaseolus vulgaris* L. CV.sadry', *Photochemistry and Photobiology*, 92(1), pp. 102-110. doi: https://doi.org/10.1111/php.12548

Ashraf, M., and Iram, A. (2005) 'Drought stress induced changes in some organic substances in nodules and other plant parts of two potential legumes differing in salt tolerance', *Flora*, 200, pp. 446-535. doi: https://doi.org/10.1016/j.flora.2005.06.005

Ashraf, M., Nawazish, H., and Athar, H. (2007) 'Are chlorophyll fluorescence and photosynthetic capacity potential physiological determinants of drought tolerance in maize *(Zea mays* L.)', *Pakistan Journal of Botany*, 39, pp. 1123-1131. Available at: https://www.escholar.manchester.ac.uk/uk-ac-man-scw:158074 (Accessed: 5 May 2024).

Basyal, B., and Walker, B.J. (2023) 'Arbuscular mycorrhizal fungi enhance yield and photosynthesis of switchgrass (*Panicum virgatum* L.) under extreme drought and alters the biomass composition of the host plant', *Biomass and Bioenergy*, 177, 106936. doi: https://doi.org/10.1016/j.biombioe.2023.106936

Bayoumi, I. *et al.* (2009) 'Interventions to improve medication reconciliation in primary care'. *Annals of Pharmacotherapy*, 43, pp. 1667-75. doi: https://doi.org/10.1345/aph.1M059

Beyk Khurmizi, A. *et al.* (2013) 'Interactions of vermicomopst and salinity on some morphological, physiological and biochemical traits of bean (*Phaseolus vulgaris* L.) seedlings', *Iranian Journal of Pulses Research*, 4(1), pp. 81-98. Available at: https://ijpr.um.ac.ir/article_29698.html (Accessed: 5 May 2024).

Boutraa, T., and Sanders, F. E. (2001) 'Influence of water stress on grain yield and vegetative growth of tow cultivars of bean (*Phaseolus vulgaris* L.)', *Journal of Agronomy and Crop Science*, 187, pp. 251-257. doi: https://doi.org/10.1046/j.1439-037X.2001.00525.x

Canci, H., and Toker, C. (2009). 'Evaluation of Yield Criteria for Drought and Heat Resistance in Chickpea (*Cicer arietinum* L.)', *Journal of Agronomy and Crop Science*, 195, pp. 47-54. doi: https://doi.org/10.1111/j.1439-037X.2008.00345.x

Bruce, W. B., Edmeades, G.O., and Bar Ker, T. C. (2002) 'Moleclar and Physiological approaches to maize improvement for drought tolerance', *Journal of Experimental Botany*, 53, pp. 13-25. doi: https://doi.org/10.1093/jxb/53.366.13

Edstorm, J.P., and Schwankl, L.J. (2002) 'Microirrigation of almonds. Proc. 3^{rd} IS on Pistachios and Almonds', *Acta Horticulturae*, 591, pp. 505-508. doi: https://doi.org/10.17660/ActaHortic.2002.591.76

Finch–Savage, W. E., and Elston, J. (1982) 'The effects of temperature and water stress on the timing of leaf death in *Vicia faba*', *Annals of Applied Biology*, 100, pp. 567-579. doi: https://doi.org/10.1111/j.1744-7348.1982.tb01424.x

Fu, Y. *et al.* (2023) 'NTillandsia biomimetic design, sponge-gel layer: Rapid capture of water vapor from the atmosphere', *Surfaces and Interfaces*, 42, p. 103356. doi: https://doi.org/10.1016/j.surfin.2023.103356

German, C., and Teran, H. (2006) 'Selection for drought resistance in dry bean landraces and cultivars', *Crop Science*, 46, pp. 2111-2120. doi: https://doi.org/10.2135/cropsci2006.01.0029

Ghassemi – Golezani, K. *et al.* (2014) 'Some physiological responses of mung – bean at different plant densities to water deficit', *International Journal of Biosciences*, 4 (12), pp. 19-26. Available at: http://www.innspub.net (Accessed: 5 May 2024).

Goldani, M., and Rezvani, P. (2007) 'The effects of different irrigation regimes and planting dates on phenology and growth indices of three chickpea (*cicer arietinum* L.) cultivars in Mashhad', *Journal of Agricultural Sciences and Natural Resources*, 14, pp. 229-242. Available at: https://www.sid.ir/paper/440512/en (Accessed: 5 May 2024).

Guerfel, M. *et al.* (2008). 'Impacts of water stress on gas exchange, water elations, chlorophyll content and leaf structure in the two main Tunisian olive (*Olea europaea* L.) cultivars', *Scientia Horticulturae*, 119(3), pp. 257-263. doi: https://doi.org/10.1016/j.scienta.2008.08.006

Hamdy, A. (2001) 'Wastewater as a source: perspectives and challenges', UNESCO, International symposium on frontiers in urban water management: deadlock or hope, Workshop 2: Recycling and reuse at different scale, Marseille, France, 18 – 20 June. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000122949 (Accessed: 5 May 2024).

Hosseinzadeh, S. R., Amiri, H., and Ismaili, A. (2016) 'Effect of Vermicompost fertilizer on photosynthetic characteristics of chickpea (*Cicer arietinum* L.) under drought stress', *Photosynthetica*, 54 (1), pp. 87-92. doi: https://doi.org/10.1007/s11099-015-0162-x

Hu, Y., and Schmidhalter, U. (2005) 'Drought and salinity: A Comparison of their effects on mineral nutrition of plants', *Journal of Plant Nutrition and Soil Science*, 168, pp. 541- 549. doi: https://doi.org/10.1002/jpln.200420516

Jaleel, C. A. *et al.* (2009). 'Drought stress in plants: a review on morphological characteristics and pigments composition', *International Journal of Agriculture and Biology*, 11, pp. 100-105. Available at: http://www.fspublishers.org (Accessed: 5 May 2024).

Karimzadeh Fard, S., Soleymani, A. and Javanmard, H. (2023) 'Plant growth regulators affecting maize leaf senescence and area index impact yield under drought', *Biocatalysis and Agricultural Biotechnology*, 51, 102749. doi: https://doi.org/10.1016/j.bcab.2023.102749

Katarina, N. *et al.* (2014) 'Potassium to alleviate the adverse effect of water deficit in mung bean [*Vigna radiata* L. Wilczek]. *International Journal of Current Research in Biosciences and Plant Biology*, 1 (3), pp. 33-40. Available at: https://www.academia.edu/12512657/Potassium_to_Alleviate_the_Adverse_Effect_of_Water_Deficit_in_Mungbean_Vigna_radiata_L_Wilczek_ (Accessed: 5 May 2024).

Kisman, A. (2003) Effects of drought stress on growth and yield of soybean. Science Philosophy Term paper. Borgor Agriculture University (Institute pertanian Borgor). Available at: http://www.rudyct.com/PPS702-ipb/07134/kisman.htm (Accessed: 6 Jun 2018).

Kumar, A., and Purohit, S. S. (2001) 'Plant physiology fundamentals and applications', Second enlarged edition. India: Agrobios. Available at: https://www.amazon.in/Plant-Physiology-Fundamentals-Applications-Kumar/dp/8177540947 (Accessed: 5 May 2024).

Leport, A. *et al.* (1999) 'Physiological responses of chickpea genotypes to terminal drought in a Mediterranean type environment', *European Journal of Agronomy*, 11, pp. 279-291. doi: https://doi.org/10.1016/S1161-0301(99)00039-8

Lichtenthaler, H., and Wellburn, A. R. (1983) 'Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvent', *Transaction,* 11, pp. 591-592. doi: https://doi.org/10.1042/bst0110591

Lindblom, J., and Nordell, B. (2006) 'Water production by underground condensation of humid air', *Desalination*, 189, pp. 248-260. doi: https://doi.org/10.1016/j.desal.2005.08.002

Lindblom, J., and Nordell, B. (2007) 'Underground condensation of humid air for drinking water production and subsurface irrigation', *Desalination*, 203, pp. 417-434. doi: https://doi.org/10.1016/j.desal.2006.02.025

Lopez, C., Ortiz Cereceves, J., and Kelly, J.D. (2004) 'Biomass distribution, maturity, acceleration and yield in drought–stressed common bean cultivars', *Field Crop Research*, 85, pp. 203- 211. doi: https://doi.org/10.1016/S0378-4290(03)00161-8

Lu, C., and Zhang, J. (1998) 'Effects of water stress on photosynthesis, chlorophyll fluorescence and photoinhibition in wheat plants', *Australian Journal of Plant Physiology*, 25, pp. 883-892. doi: https://doi.org/10.1071/PP98129

Lu, Q., Lu, C., and Zhang, J. (2002) 'Photosynthesis and chlorophyll a fluorescence during flag Leaf senescence of field – grown wheat plants', *Journal of Plant Physiology*, 159, pp. 1173-1178. doi: https://doi.org/10.1078/0176-1617-00727

Mahajan, S., and Amania, T. (2005) 'Cold, salinity and drought Stresses: An overview', *Archives of Biochemistry and Biophysics*, 444, pp. 139-158. doi: https://doi.org/10.1016/j.abb.2005.10.018

Manivannan, P. *et al.* (2008) 'Osmoregulation and antioxidant metabolism in drought-stressed *Helianthus annuus* under triadimefon drenching', *Comptes Rendus Biologies*, 331(6), pp. 418-425. doi: https://doi.org/10.1016/j.crvi.2008.03.003

Mohammadi, A., Ghazavi, R., and Mirzaie, R. (2021). 'The effects of municipal treated wastewater and sludge on some vegetative characteristics of Nitraria Schoberi', *Journal of Applied Research in Water and Wastewater*, 8(2), pp. 118-123. doi: https://doi.org/10.22126/arww.2021.6401.1210

Nayyar, H. *et al.* (2006) 'Differential Sensitivity of macrocarpa and microcapa types of chickpea (*Cicer arietinum L.*) to water stress: association of contrasting stress response with oxidative injury', *Journal of Integrative Plant Biology*, 48, pp. 1318-1329. doi: https://doi.org/10.1111/j.1744-7909.2006.00350.x

Ohashi, Y. *et al*. (2009). 'Differences in the responses of stem diameter and pod thickness to drought stress during the grain filling stage in soybean plants', *Acta Physiologiae Plantarum*, 31, pp. 271–277. doi: https://doi.org/10.1007/s11738-008-0229-4

Owusu-Boateng, G., and Adjei, V. (2014) 'The potential utilization of grey water for irrigation: A case study on the Kwame Nkrumah University of Science and Technology, Kumasi Campus', *Journal of Applied Research in Water and Wastewater*, 1(1), pp. 28-34. Available at: https://arww.razi.ac.ir/article_48_11.html (Accessed: 5 May 2024).

Pagter, M., Bragato, C., and Brix, H. (2005) 'Tolerance and physiological responses of *Phragmites australis* to water deficit', *Aquatic Botany*, 81, pp. 285-299. doi: https://doi.org/10.1016/j.aquabot.2005.01.002

Paroda, R. S., and Thomas, T. A. (1988) 'Genetic resources of mung bean in India', in Shonmugasundaram, S., and Mclean, B. T. (eds), Mung bean proceedings of the second international symposium, Asian Vegetable Research and Development center, Bankok, Tailand, 16-20 Nov. pp. 19-28. Available at: https://worldveg.tind.io/record/7056 (Accessed: 5 May 2024).

Piper, F.I. *et al.* (2007) 'Differential photosynthetic and survival responses to soil drought in two evergreen Nothofagus species', *Science*, 64, pp. 447-452. doi: https://doi.org/10.1051/forest:2007022

Pirzad, A., Jalilian, J., and Akbari Bavandi, V. (2015) 'Improving grain yield of mung bean (*Vigna radiata* L.) using zeolite under water deficit conditions', *Research in Field Crops*, 3(1), pp. 1-13. Available at: https://journal.urmia.ac.ir/article_20024.html (Accessed: 5 May 2024).

Rahbarian, R. *et al.* (2011) 'Drought Stress effects on photosynthesis, chlorophyll fluorescence and water relations in tolerant and susceptible chickpea (*Cicer arietinum L.*) genotypes', *Acta Biologica Cracoviensia Series Botanica*, 53, pp. 47-56. doi: https://doi.org/10.2478/v10182-011-0007-2

Rahman, S. M., and Uddin, A. S. M. (2000) 'Ecological adaptation of chickpea to water stress', *Legume Research*, 23, pp. 1-8. Available at: https://arccjournals.com/journal/legume-research-an-international-journal/ARCC4085 (Accessed: 5 May 2024).

Salehpour, M. *et al*. (2009) 'Evaluation of water stress and nitrogen fertilizer effects on relative water content, membrane stability index, chlorophyll and some other traits of lentils (*Lens culinaris L.*) under hydroponics conditions', *Research Journal of Environmental Sciences*, 3, pp. 103-109. doi: https://doi.org/10.3923/rjes.2009.103.109

Shan, H. *et al.* (2023) 'Improving solar water harvesting via airflow restructuring using 3D vapor generator', *Device*, 1 (4), p. 100065. doi: https://doi.org/10.1016/j.device.2023.100065

Sikder, S., Foulkes, J., and West, H. (2015) 'Evaluation of photosynthetic potential of wheat genotypes under drought condition', *Photosynthetica*, 53, pp. 47-54. doi: https://doi.org/10.1007/s11099-015-0082-9

Sikuku, P. A. *et al.* (2010) 'Effects of water deficit on physiology and morphology of three varieties of NERICA rain fed rice (*Oryza sativa* L.)', *ARPN Journal of Agricultural and Biological Science*, 5, pp. 23-28. Available at: https://www.academia.edu/91895733/Effects_of_water_deficit_on_physiology_and_morphology_of_three_varieties_of_nerica_rainfed_rice_Oryza_sativa_L_ (Accessed: 5 May 2024).

Singh, S. H. (2007) 'Drought resistance in the race durango dry bean landraces and cultivars', *Agronomy Journal, 99*, pp. 1919-1225. doi: https://doi.org/10.2134/agronj2006.0301

Tilahun, A., and Sven, S. (2003) 'Mechanisms of drought resistance in grain: PSII stomatal regulation and root growth', *Ethiopian Journal of Science*, 26, pp. 137-144. doi: https://doi.org/10.4314/sinet.v26i2.18209

Tomas, M. *et al.* (2003) 'The effect of timing and severity of water deficit on growth development, yield accumulation and nitrogen fixation of mung bean', *Field Crops Research*, 86(1), pp. 67-80. doi: https://doi.org/10.1016/S0378-4290(03)00120-5

Turkan, I. *et al.* (2005) 'Differential response of lipid peroxidation and antioxidants in the leaves of drought–tolerant *P. acutifolius* gray and drought – sensitive *P. vulgaris* subjected to polyethylene glycol mediated water stress', *Plant Science*, 168, pp. 223-231. doi: https://doi.org/10.1016/j.plantsci.2004.07.032

Valipour, M., Heidari, H., and Bahraminejad, S. (2023). 'Plastic-covered ridge-furrow planting increases pea (*Pisum sativum* L.) grain yield and rainwater use efficiency', *The Journal of Horticultural Science and Biotechnology*, 99 (1), pp. 57–74. doi: https://doi.org/10.1080/14620316.2023.2237019

Wang, L. *et al.* (2010) 'Salicylic acid alleviates decreases in photosynthesis under heat stress and accelerates recovery in grapevine leaves', *BMC Plant Biology*, 10, pp. 34-48. doi: https://doi.org/10.1186/1471-2229-10-34

White, S., and Raine, S. (2004) 'Identifying the potential to apply deficit irrigation strategies in cotton using large mobile irrigation machine'. 4th International Crop Science Congress, Brisbane, Australia, 26 Sep-1 Oct. Available at: https://www.cabidigitallibrary.org/doi/pdf/10.5555/20193228299 (Accessed: 5 May 2024).

Yousefi, B., and Boroomand Nasab, S. (2015) 'Desalination using the condensation irrigation system, a case study of the research farm of Shahid Chamran University of Ahvaz', *Water and Wastewater Consulting Engineers,* 26(3), pp. 127-133. Available at: https://www.wwjournal.ir/article_7859.html?lang=en (Accessed: 5 May 2024).

Yu, Y. *et al.* (2023) 'The B-box transcription factor PabBBX27 in the regulation of chlorophyll biosynthesis and photosynthesis in poplar (*Populus alba* × *P. Berolinensis*)', *Industrial Crops and Products*, 203, p. 117159. doi: https://doi.org/10.1016/j.indcrop.2023.117159.

Zabet, M. *et al.* (2003) 'Effect of water stress on different traits and determination of the best water stress index in mung bean (*Vigna radiata*)', *Iranian Journal of Agricultural Science*, 34(4), pp. 889-898. Available at: https://jijas.ut.ac.ir/article_17555_48ab048ccdccfe000973ca33717ad3bc.pdf (Accessed: 5 May 2024).

Zhou, Z. *et al.* (2023) 'Enhancing leaf photosynthesis from altered chlorophyll content requires optimal partitioning of nitrogen', *Crop and Environment*, 2, pp. 24-36. doi: https://doi.org/10.1016/j.crope.2023.02.001

Zhu Z. *et al.* (2023) 'Method to delay frost formation under high relative humidity by choosing proper heat exchange temperature difference and air velocity', *Case Studies in Thermal Engineering*, 45, p. 102922. doi: https://doi.org/10.1016/j.csite.2023.102922