

Water production by thermoelectric method and its effect on seed germination of wheat, foxtail millet, and radish

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ABSTRACT

One of the sources of water is air-water vapor. To evaluate water supply with air-water vapor, a study was conducted as a factorial experiment in a completely randomized design with three replications. The studied factors included irrigation method (irrigation by thermoelectric module and control) and plant species (wheat, foxtail millet, and radish). Analysis of variance showed that the interaction effect of plant species and irrigation method on all seed germination characteristics was significant. The mean comparison showed that irrigation by thermoelectric module germinated wheat, foxtail millet, and radish seeds. So that all the seeds germinated. Irrigation by thermoelectric module increased seed germination, caulicle length, radicle length, caulicle weight, radicle weight, seed vigor based on length, seed vigor based on weight, and root to shoot ratio compared to the control (without irrigation). Overall, irrigation by the thermoelectric module can germinate the seeds of wheat, foxtail millet, and radish and can be considered as a new method of irrigation in arid and semi-arid regions where farmers do not have access to water for growing plants.

Highlights

- Thermoelectric module can germinate the seeds.
- Thermoelectric module increased caulicle length, radicle length, caulicle weight, radicle weight, seed vigor based on length, seed vigor based on weight, and root to shoot ratio.
- Irrigation by the thermoelectric module can be considered as a new method of irrigation.

1. Introduction

Drought is a natural phenomenon that occurs in all regions. Drought due to climate change has a negative effect on freshwater resources (Seo et al., 2022). Drought affects agriculture, the environment, and socio-economic issues. Climate change is increasing drought and reducing farmers' food security (Alahacoon and Amarnath, 2022).

Dew is one of the sources of water supply that is often neglected. To form dew, the air hits the cold surface and water vapor condenses into water droplets. Dew can wet the crop canopy and be used for evaporation and transpiration (Moratiel et al., 2016). Dew and hoar frost together account for 4.2-6% of the total annual rainfall in the alpine grassland. In drier months, dew and hoar frost make up 16.1% of the total monthly rainfall. Dew and hoar frost are of ecological importance. Dew and hoar are involved in the water budget of low-lying mountains and alpine grassland (Groh et al., 2018). In the arid valley of the

Andes, the annual deposition of night dew is about 5-10 mm per year and acts as one of the water sources in meeting the water needs of natural vegetation, especially in dry seasons (Kalthoff et al., 2006). In the study of dew formation among *Haloxylon ammodendron* trees, it was found that air temperature, relative humidity, the difference between air temperature and dew point, and wind speed were effective on dew formation. The dew formation threshold was 50% air relative humidity and 4.27 m/s wind speed. With the increasing canopy of *H. ammodendron*, the amount of dew produced increased (Zhuang and Zhao, 2017). In the study of the amount of water produced in different condensers with different dimensions, it was found that passive dew condensers with a surface of 1 square meter provided enough water for the survival of tree seedlings during drought season (Snyder et al., 2018). Dew can be effective up to 3% in soil moisture. Collecting and storing dew with an area of 2 square meters in the amount

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of 4.5 liters per plant per month can easily meet the needs of a tree sapling (Tomaszkiewicz et al., 2017). Evaluation of dew formation characteristics in a semi-arid region in China showed that the dewfall was 1/18th rainfall, but the number of dew formation days was 2.6 times that of rainy days. Dew is therefore a vital source of water to reduce dry periods and support plants (Jia et al., 2019). The water-energy nexus is important in the production of atmospheric water. Today, hybrid atmospheric water production systems and problems of new atmospheric water production techniques are investigated (Raveesh et al., 2021). High quality water is produced by condensation. Factors such as climate and structure affect the quantity and quality of air condensation. There is a lot of interest in growing plants in closed water systems worldwide (Jurga et al., 2023). Sunlight is a cheap and available source of atmospheric water production. Nowadays, integrated systems are used because they use several methods to cool water vapor. This method increases productivity (Shafeian et al., 2022). In the study of the effect of factors such as temperature and relative humidity on the performance of the atmospheric water production system, it was seen that hot and humid air produced more water with less energy consumption. This study showed that the production of atmospheric water is a suitable method for India, which is prone to water scarcity (Raveesh et al., 2023).

Seed germination is one of the drought-sensitive stages. In the study of the drought effect of polyethylene glycol (PEG) on kenaf seed germination, it was observed that seed germination increased at 10% PEG concentration compared to control and 20% PEG concentration. Radicle growth was reduced at 10% PEG concentration (Tang et al., 2019). Drought induced by PEG reduced seed germination and seedling growth of wheat (Wang et al., 2020). PEG-induced drought decreased germination and seedling growth in *Vigna unguiculata* L. Walp. while increasing proline content (Carvalho et al., 2019). Drought induced by PEG reduced the percentage and rate of seed germination in Cantaloupe (*Cucumis melo* L.) and radish (*Raphanus sativus* L.) (Bakhshandeh and Gholamhosseini, 2019).

Production of water from water vapor in the air is one of the new sources of irrigation. Research on the use of air-water vapor for irrigation of plants is limited, so this study was conducted to determine the seed germination characteristics of wheat, foxtail millet, and radish using water produced by the thermoelectric method.

2. Materials and methods

To evaluate water production with thermoelectric module and its effect on seed germination of wheat (*Triticum aestivum* L.), foxtail millet (*Setaria italica* (L.) P. Beauv.), and radish (*Raphanus sativus* L.), a laboratory study was conducted as a factorial experiment in a completely randomized design with three replications in the Faculty of Agricultural Science and Engineering of Razi University in 2016. The studied factors included irrigation method (irrigation by thermoelectric module and control) and plant species (wheat, foxtail millet, and radish). Controls were intact seeds that were not irrigated.

The control treatment was used to ensure that the air humidity did not affect the germination of seeds. The seeds were placed in a Petri dish containing a filter paper. Seeds of control treatment and seeds related to irrigation treatment with thermoelectric module were both placed in the relevant Petri dishes. In the irrigation treatment with the thermoelectric module, the device was first connected to electricity. The filter paper was then placed on the module until sufficient moisture was absorbed by the filter paper. The filter paper was then placed on the bottom of the Petri dish and the seeds were placed on it.

The thermoelectric module used had dimensions of 4 cm by 4 cm by 0.5 cm. The internal resistance of the device was 2.5 to 2.8 ohms. The voltage used was 12 volts. Cooling power was 60 to 72 watts. The device model was TEC1-12706.

After one week, seed germination characteristics including seed germination percentage, caulicle length, radicle length, caulicle weight, and radicle weight were calculated. The seed germination criterion was two millimeters of growth of the caulicle. Caulicle length and radicle length were measured with a ruler.

To measure caulicle and radicle weight, caulicle and radicle were first placed in a paper bag, and then transferred to an oven at 75 ° C. After 24 hours, caulicle dry weight and radicle dry weight was measured with a digital scale. Seed vigor based on length and seed vigor based on weight were obtained by the following equations (Eq. 1 and 2), respectively (Yosefi and Heidari, 2022).

$$\text{Seed vigor based on length (\%cm)} = \text{Seedling length (cm)} \times \text{Seed germination (\%)} \quad (1)$$

$$\text{Seed vigor based on weight (\%mg)} = \text{Seedling weight (mg)} \times \text{Seed germination (\%)} \quad (2)$$

Before data analysis, outliers were identified and deleted if necessary. First, the data were analyzed for a variance to determine significant effects. Then the means were compared. SAS software was used to analyze the data. Data were compared using Duncan's test at a 5% probability level.

3. Results

Analysis of variance showed that the interaction of irrigation method and plant species on germination percentage, caulicle length, radicle length, caulicle weight, radicle weight, seed vigor based on length, seed vigor based on weight, and root to shoot ratio was significant (Table 1).

Mean comparisons showed that irrigation with thermoelectric module resulted in 100% germination of wheat, foxtail millet, and radish, while in control (without irrigation) no seeds germinated (Figure 1A). Mean comparisons showed that the seeds irrigated with a thermoelectric module had a longer caulicle length than the control seeds. The caulicle length was the highest in wheat and the lowest in foxtail millet (Figure 1B). Mean comparisons showed that the seeds irrigated with a thermoelectric module had a longer radicle length than the control seeds. The radicle length in radish was longer than in foxtail millet and wheat (Figure 1C). Mean comparisons showed that the seeds irrigated with a thermoelectric module had higher caulicle weight than the control seeds.

The caulicle weight was the highest in radish and the lowest in foxtail millet (Figure 1D).

The mean comparison showed that the seeds irrigated with a thermoelectric module had higher radicle weight than the control seeds. Radicle weight was highest in wheat and lowest in foxtail millet (Figure 2A). The mean comparison showed that the seeds irrigated with a thermoelectric module had higher seed vigor based on length than the control seeds. Seed vigor based on length in wheat and radish was higher than foxtail millet (Figure 2B).

The mean comparison showed that the seeds irrigated with a thermoelectric module had higher seed vigor based on weight than the control seeds. Seed vigor based on weight was highest in wheat and lowest in foxtail millet (Figure 2C). Mean comparisons showed that in wheat and foxtail millet, seeds irrigated with thermoelectric module had a higher root-to-shoot ratio than control. Root to shoot ratio was highest in foxtail millet and lowest in radish (Figure 2D).

Table 1. Analysis of variance of the effect of water production by thermoelectric method on seed germination traits of wheat, foxtail millet, and radish

Source of variation	df	Germination	Caulicle length	Radicle length	Caulicle weight	Radicle weight	Seed vigor based on length	Seed vigor based on weight	Root to shoot ratio
Irrigation (I)	1	45000**	69.38**	113.58**	96.56**	69.46**	44471156**	3373650**	1.62**
Plant species (P)	2	0**	2.25**	2.57**	20.01**	39.77**	66379**	823155**	0.42**
I×P	2	0**	2.94**	3.43**	22.94**	52.74**	66379**	997785**	0.51**
Error	12	0	0.02	0.23	0.01	0.05	2461	2333	0.01

** indicates significance at the probability level of 1%.

4. Discussion

Hosseini et al. (2020) reported that dew-irrigation resulted in seed germination and growth of flax, fenugreek, and fennel, which is consistent with the results of the current study. Seed germination is a stage with low water requirements. The amount of moisture required for seed germination is two to three times the weight of the seed (Bewley and Black, 1978). Due to the low water requirement of seeds for germination and seedling growth, this irrigation method can be used to germinate seeds in areas that do not have access to water resources for growing plants. Drought tolerance during *Periploca sepium* seed germination was due to the higher activity of antioxidant enzymes and the accumulation of some salts (An and Liang, 2013). Different wheat cultivars had different responses to different levels of dryness caused by polyethylene glycol (Blum et al., 1980). The drought caused by polyethylene glycol decreased the germination percentage of castor bean (*Ricinus communis* L.) seeds, which is consistent with the results of this study (Babaei et al., 2023).

Dew is an important source of water available in arid or semi-arid regions, and some researchers have sought to measure the amount of dew produced in ecosystems. Dew is reported to form in 53% of the nights in the Mongolia Plateau sandy ecosystem. The dew produced was about 0.15 mm per night and both plant species C3 and C4 used dew (Liu et al., 2020). By using waste rock burials, the air vapor temperature can be lowered to the dew point and water can be produced. These rock wastes can contribute to reforestation in arid areas (Juřička et al., 2020). In the study of the effect of dew on the sand desert ecosystem, it was found that the relative humidity threshold for dew formation and absorption was 30% and dew was involved in the moisture budget and photosynthetic performance of vegetation (Zhuang et al., 2021).

Various methods for dew collection have been studied by researchers such as superhydrophilic / superhydrophobic hybrid surfaces (Hou et al., 2020), hierarchical superhydrophobic surfaces (Rykaczewski et

al., 2013), cactus spines (Yi et al., 2019), and tailoring silicone (Liu et al., 2021).

Irrigation of plants at the seed germination stage with thermoelectric module probably has higher water use efficiency than conventional field irrigation methods, because, in this method, only a part of the soil is wet. With this method, water can be provided to seeds and plants continuously. This method of irrigation does not require a piping system and some costs such as irrigation fittings will be reduced. Due to the novelty of this method, its design at the farm scale requires special research.

The reduction of some seed germination characteristics such as caulicle length, caulicle weight, radicle weight, and seed vigor in foxtail millet compared to wheat and radish may be due to the thermophilic nature of this plant.

Water production with a thermoelectric module is suitable for dry and semi-dry areas. In these areas, due to sunny weather, electricity can be generated by solar panels. Due to the high wind speed in these areas, it is possible to generate electricity from wind. Clean energies such as wind and solar energy protect the environment. The thermoelectric module can also be used for afforestation and desert greening.

As a renewable resource, the sun has the ability to provide fuel for life on earth and clean and sustainable energy for all its inhabitants. Solar energy can be converted into electricity through solar photovoltaic modules. The advantages of solar energy are a renewable energy source and its diverse applications, and the disadvantages of solar energy include high cost, dependence on weather, expensive solar energy storage, high volume occupation, and creating pollution caused by the transportation and installation of solar systems with the emission of greenhouse gases (Novasi, 2024). Wind energy is also one of the fastest growing energy sources in the world due to its many advantages. Some of its advantages are the cheapness of wind energy, the inexhaustibility of wind energy, the cleanness of the source, and the stability of wind energy. Disadvantages of wind energy include noise pollution of wind energy, damage to wildlife, pollution

caused by the production of wind energy production facilities (Hills, 1996; Pakpasabeghlim, 2024).

Considering the high cost of electricity to extract water from the air, the thermoelectric module can be used in sensitive plant growth stages such as germination and establishment, which require little water. In addition, this module can be used in arid and semi-arid areas for supplementary irrigation in rainy conditions for plants that

require little water, such as medicinal plants. According to the above, little energy is consumed in low-input systems such as dry farming of medicinal plants, so energy consumption for water production by thermoelectric method has little effect on the stability of the system. Using renewable and cheap energy such as solar energy to produce electricity increases the stability of the production system.

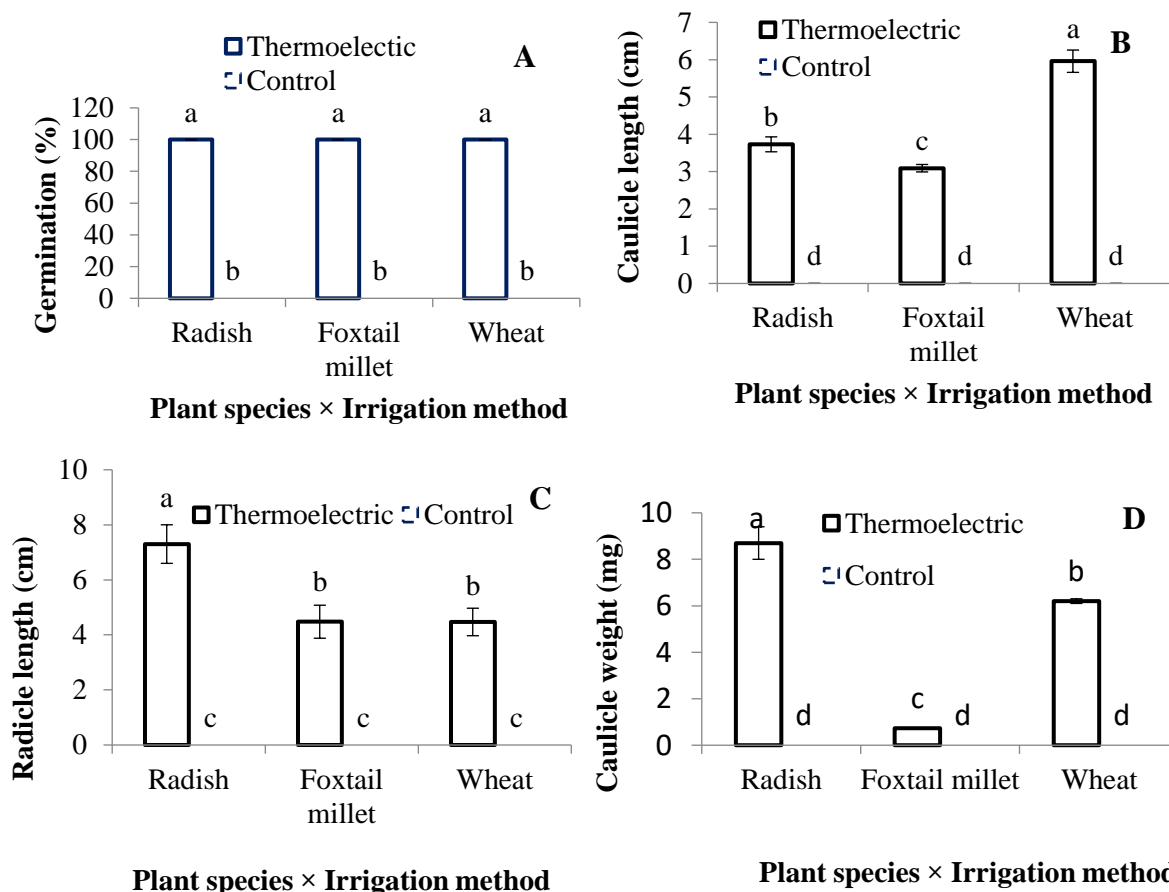


Figure 1. Mean comparisons of the effect of irrigation method and plant species on germination characteristics of wheat, foxtail millet, and radish. A: Seed germination percentage, B: Caulicle length, C: Radicle length, and D: Caulicle weight. Thermoelectric and Control are the method of irrigation with thermoelectric module and without irrigation, respectively. The means with at least one common letter in each trait according to the Duncan test at a 5% probability level are not significantly different. The bar shows mean ± standard error.

Due to the fact that thermoelectric irrigation has the same water quality as distilled water, therefore plant irrigation with thermoelectric method does not cause soil salinity, while micro-irrigation methods such as drip irrigation cause soil salinity and decrease soil quality in the long run due to the presence of salts in the water. Other irrigation methods, such as surface irrigation, which consume a lot of water, can make water and soil salty much faster. If the supply of electricity for water production by thermoelectric method is from fossil sources such as oil, it can cause air pollution. The production of the necessary facilities for thermoelectric irrigation is expensive and is involved in the production of carbon dioxide, but it should be kept in mind that the thermoelectric irrigation system requires a lot of facilities because in this irrigation method, electric wires take the place of water pipes. The pipes in

drip irrigation are mostly plastic and have a lot of cost and pollution.

Water production by thermoelectric method increases in conditions. Climatic factors such as air humidity are effective in producing water from the air. The higher the air humidity, the more moisture can be extracted from the air by spending less energy. Harvesting water is more suitable in humid environments or in seasons with high air humidity. In arid and semi-arid regions, air humidity is low, but it is possible to produce water from air. It is suggested to conduct similar research on water production by thermoelectric method in farm conditions in different seasons of the year in terms of air humidity. The reaction of different plants to the thermoelectric irrigation method will definitely be different. Since the production of water by thermoelectric method is energy intensive, it is

necessary to conduct more research on dry and medicinal plants that require less water. Considering that the thermoelectric method uses cold to produce moisture from

the air, probably cool-season and warm-season plants will have different reactions to this irrigation method, and more research can be done in this field.

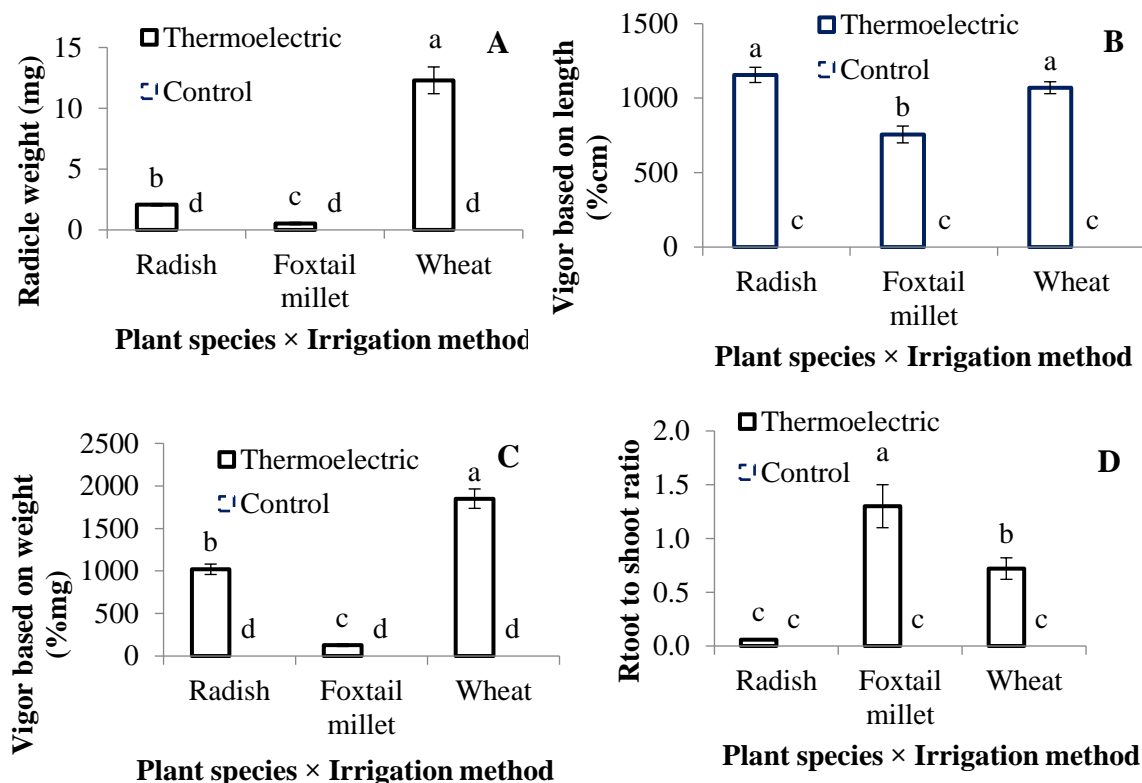


Figure 2. Mean comparisons of the effect of irrigation method and plant species on germination characteristics of wheat, foxtail millet, and radish. A: Radicle weight, B: Seed vigor based on length, C: Seed vigor based on weight, and D: Root to shoot ratio. Thermoelectric and Control are the method of irrigation with thermoelectric module and without irrigation, respectively. The means with at least one common letter in each trait according to the Duncan test at a 5% probability level are not significantly different. The bar shows mean \pm standard error.

5. Conclusion

Irrigation by thermoelectric module improved all seed germination traits such as seed germination percentage, caulicle length, radicle length, caulicle weight, radicle weight, and seed vigor in wheat, foxtail millet, and radish and can be considered as a new method of irrigation in arid and semi-arid regions where farmers do not have access to water for growing plants. The following are recommended. 1. Evaluation of water production system by the thermoelectric method in different climates in terms of relative humidity and air temperature. 2. Evaluation of the amount of electricity and surface of the thermoelectric device on the amount of water production and the rate of germination and plant growth. 3. Evaluation of different seeds in terms of seed size, shape, and appendages in irrigation method using the thermoelectric device.

Conflicts of interest

The authors declare no competing interests.

References

Alahacoon, N., & Amarnath, G. (2022). Agricultural drought monitoring in sri lanka using multisource satellite data. *Advances in Space Research*, 69(11), 4078-4097. doi: 10.1016/j.asr.2022.03.009

- An, Y., & Liang, Z. (2013). Drought tolerance of periploca sepium during seed germination: Antioxidant defense and compatible solutes accumulation. *Acta Physiologiae Plantarum*, 35, 959-967. doi: 10.1007/s11738-012-1139-z
- Babaei, M., Pirdashti, H., & Bakhshandeh, E. (2023). Ultrasonic waves improve aged seed germination of castor bean (*Ricinus communis* L.) under drought and salt stresses. *Acta Physiologiae Plantarum*, 45, 90. doi: 10.1007/s11738-023-03563-2
- Bakhshandeh, E., & Gholamhosseini, M. (2019). Modelling the effects of water stress and temperature on seed germination of radish and cantaloupe. *Journal of Plant Growth Regulation*, 38(4). doi: 10.1007/s00344-019-09942-9
- Bewley, J. D., & M, B. (1978). Imbibition, germination, and growth In: *Physiology and biochemistry of seeds in relation to germination*. Berlin, Heidelberg: Springer. doi: 10.1007/978-3-642-66668-1_4
- Blum, A., Sinmena, B., & Ziv, O. (1980). An evaluation of seed and seedling drought tolerance screening tests in wheat. *Euphytica*, 29, 727-736. doi: 10.1007/bf00023219
- Carvalho, M., Matos, M., Castro, I., Monteiro, E., Rosa, E., Lino-Neto, T., & Carnide, V. (2019). Screening of worldwide cowpea collection to drought tolerant at a

- germination stage. *Scientia Horticulturae*, 247, 107-115. doi: **10.1016/j.scienta.2018.11.082**.
- Groh, J., Slawitsch, V., Herndl, M., Graf, A., Vereecken, H., & Pütz, T. (2018). Determining dew and hoar frost formation for a low mountain range and alpine grassland site by weighable lysimeter. *Journal of Hydrology*, 563, 372-381. doi: **10.1016/j.jhydrol.2018.06.009**.
- Hills, R. L. (1996). *Power from wind: A history of windmill technology*: Cambridge University Press.
- Hosseini, S. S., Heidari, H., Ghobadi, M. E., & Nosratti, I. (2020). Effect of dew-irrigation on seed germination in flax, fenugreek, and fennel. *Water Supply*, 20(1), 269-276. doi: **10.2166/ws.2019.166**
- Hou, K., Li, X., Li, Q., & Chen, X. (2020). Tunable wetting patterns on superhydrophilic/superhydrophobic hybrid surfaces for enhanced dew-harvesting efficacy. *Advanced Materials Interfaces*, 7(2), 1901683. doi: **10.1002/admi.201901683**
- Jia, Z., Wang, Z., & Wang, H. (2019). Characteristics of dew formation in the semi-arid loess plateau of central shaanxi province, china. *Water*, 11, 126. doi: **10.3390/w11010126**
- Jurga, A., Pacak, A., Pandelidis, D., & Kaźmierczak, B. (2023). Condensate as a water source in terrestrial and extra-terrestrial conditions. *Water Resources and Industry*, 29, 100196. doi: **10.1016/j.wri.2022.100196**.
- Juříčka, D., Pecina, V., Kusbach, A., Vlček, V., Novotná, J., Pařílková, J., Otgonsuren, B., Brtnický, M., & Kynický, J. (2020). Thermal regime of semi-natural dew collector's perspective for afforestation of semi-arid landscapes. *Environmental Technology & Innovation*, 20, 101125. doi: **10.1016/j.eti.2020.101125**
- Kalthoff, N., Fiebig-Wittmaack, M., Meißner, C., Kohler, M., Uriarte, M., Bischoff-Gauß, I., & Gonzales, E. (2006). The energy balance, evapo-transpiration and nocturnal dew deposition of an arid valley in the andes. *Journal of Arid Environments*, 65, 420-443. doi: **10.1016/j.jaridenv.2005.08.013**.
- Liu, M., Cen, Y., Wang, C., Gu, X., Bowler, P., Wu, D., Zhang, L., Jiang, G., & Beysens, D. (2020). Foliar uptake of dew in the sandy ecosystem of the mongolia plateau: A life-sustaining and carbon accumulation strategy shared differently by c3 and c4 grasses. *Agricultural and Forest Meteorology*, 287, 107941. doi: **10.1016/j.agrformet.2020.107941**.
- Liu, X., Trosseille, J., Mongruel, A., Marty, F., Basset, P., Laurent, J., Royon, L., Cui, T., Beysens, D., & Bourouina, T. (2021). Tailoring silicon for dew water harvesting panels. *iScience*, 24, 102814. doi: **10.1016/j.isci.2021.102814**.
- Moratiel, R., Martínez-Cob, A., Tarquis, A. M., & Snyder, R. L. (2016). Soil water balance correction due to light rainfall, dew and fog in Ebro river basin (Spain). *Agricultural Water Management*, 170, 61-67. doi: **10.1016/j.agwat.2015.12.013**.
- Novasi. (2024). Solar energy; Its advantages and disadvantages. Accessed 30 Aug 2024. From: <https://novasi.ir/solar-energy/>
- Pakpasabeghlim. (2024). What is wind energy? Know the advantages and disadvantages of wind energy. Accessed 30 Aug 2024. From: <https://pakpasabeghlim.ir/wind-energy/>
- Raveesh, G., Goyal, R., & Tyagi, S. K. (2021). Advances in atmospheric water generation technologies. *Energy Conversion and Management*, 239, 114226. doi: **10.1016/j.enconman.2021.114226**.
- Raveesh, G., Goyal, R., & Tyagi, S. K. (2023). Parametric analysis of atmospheric water generation system and its viability in indian cities. *Thermal Science and Engineering Progress*, 39, 101682. doi: **10.1016/j.tsep.2023.101682**.
- Rykaczewski, K., Paxson, A. T., Anand, S., Chen, X. M., Wang, Z. K., & Varanasi, K. K. (2013). Multimode multidrop serial coalescence effects during condensation on hierarchical superhydrophobic surfaces. *Langmuir*, 29, 881-891. doi: **10.1021/la304264g**
- Seo, J., Won, J., Choi, J., Lee, J., & Kim, S. (2022). A copula model to identify the risk of river water temperature stress for meteorological drought. *Journal of Environmental Management*, 311, 114861. doi: **10.1016/j.jenvman.2022.114861**.
- Shafeian, N., Ranjbar, A. A., & Gorji, T. B. (2022). Progress in atmospheric water generation systems: A review. *Renewable and Sustainable Energy Reviews*, 161, 112325. doi: **10.1016/j.rser.2022.112325**.
- Snyder, V. A., Vázquez, M. A., Seldon, J., Beale, A. J., & Ramos, R. (2018). Preliminary evaluation of dew condensers and their use for tree seedling irrigation in puerto rico. *The Journal of Agriculture of the University of Puerto Rico*, 102(1-2), 1-20. doi: **10.46429/jaupr.v102i1-2.17528**
- Tang, D., Wei, F., Qin, S., Khan, A., Kashif, M. H., & Zhou, R. (2019). Polyethylene glycol induced drought stress strongly influences seed germination, root morphology and cytoplasm of different kenaf genotypes. *Industrial Crops and Products*, 137, 180-186. doi: **10.1016/j.indcrop.2019.01.019**.
- Tomaszkiewicz, M., Abou Najm, M., Zurayk, R., & El-Fadel, M. (2017). Dew as an adaptation measure to meet water demand in agriculture and reforestation. *Agricultural and Forest Meteorology*, 232, 411-421. doi: **10.1016/j.agrformet.2016.09.009**.
- Wang, S., Wei, M., Wu, B., Cheng, H., Jiang, K., & Wang, C. (2020). Does N deposition mitigate the adverse impacts of drought stress on plant seed germination and seedling growth?. *Acta Oecologica*, 109, 103650. doi: **10.1016/j.actao.2020.103650**.
- Yi, S. Z., Wang, J., Chen, Z. P., Liu, B., Ren, L., Liang, L., & Jiang, L. L. (2019). Cactus-inspired conical spines with oriented microbarbs for efficient fog harvesting. *Advanced Materials Technologies*, 4, 1900727. doi: **10.1002/admt.201900727**
- Yosefi, M., & Heidari, H. (2022). Evaluation of wheat tolerance during germination and early growth stages to detergent-contaminated water. *Tenside Surfactants Detergents*, 59(1), 95-103. doi: **10.1515/tsd-2021-2380**

Zhuang, Y., & Zhao, W. (2017). Dew formation and its variation in *Haloxylon ammodendron* plantations at the edge of a desert oasis, northwestern China. *Agricultural and Forest Meteorology*, 247, 541-550. doi: **10.1016/j.agrformet.2017.08.032**

Zhuang, Y., Zhao, W., Luo, L., & Wang, L. (2021). Dew formation characteristics in the gravel desert ecosystem and its ecological roles on *Reaumuria soongorica*. *Journal of Hydrology*, 603, 126932. doi: **10.1016/j.jhydrol.2021.126932.**