

# Effect of clay-pot irrigation on *Citrullus colocynthis* plant growth for arid land restoration (A case study: southeast of Iran)

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## Research Article

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# Abstract

This study aimed to investigate growth performance of *Citrullus colocynthis* plant under clay-pot irrigation to restore vegetation in abandoned farmlands of arid regions. So, in this research, the influence of clay-pot and traditional irrigation methods experimented on some growth parameters of *Citrullus colocynthis* plant from 2019 to 2021. The experiment had been conducted in a randomized complete block design with 5 replications. In each treatment, plant growth characteristics such as shrub length, number of seeds per fruit, number of fruits per plant, number of branches per plant, dry weight of fruit, and fruit yield were measured. The results indicate that the effect of different irrigation methods on growth characteristics under the influence of irrigation methods was significantly different ( $p \leq 0.05$ ). Also finding indicate that the amounts of water consumption were significantly different at the level of five percentage ( $P < 0.05$ ) and the most appropriate irrigation method by significant increase of WUE is related to clay-pot irrigation. Based on the results of the research, the growth performance of *Citrullus colocynthis* plant during the second and third growing seasons significantly increased which non-irrigation conditions. Following the results, the period of growth of *Citrullus Colocynthis* is synchronous with the critical month (April, June, July, and September respectively) when the value of wind speed, temperature, and evaporation rate reaches its value maximum. According to the results, the implementation of clay-pot irrigation methods for the establishment of *Citrullus colocynthis* plant with high adaptability is a practical option to restore vegetation in abandoned farmlands of the study area.

## Introduction

Soil erosion and desertification phenomenon are major environmental problems worldwide, especially in the arid area (Deng et al. 2019; Ye, 2021). Moreover, water scarcity coupled with low vegetation cover in the arid area has led to serious soil erosion and associated problems in the Agriculture sector (Chaudhary et al., 2019). This process causes the land degradation intensity to increase which threatens the sustainability of ecosystem services in this area (Luo et al., 2020). So, most of these areas are affected by wind erosion the common consequences of this phenomenon are: decrease soil fertility, the occurrence of sand and dust storms, and cause problems for human migration and health (Li et al., 2020, Goudie, 2020; Zhen et al., 2020). Therefore to conserve water and soil and prevent wind erosion effects, there is an urgent need to restore vegetation cover in these areas (Cheng et al 2019; Chiu et al., 2020). Canopy cover and litter vegetation due to increases surface roughness decreases the surface wind shear stress and improve the soil properties have an important role to prevent wind erosion in the fragile area (Cheng et al. 2019; Hong et al. 2020). In this regard, restoring native vegetation in abandoned farmland, which is often affected by wind erosion is desirable to reduce soil erosion (Porensky et al., 2014; Middleton, 2018). Mainly vegetation restoration in the arid region is a prolonged process and to be successful, needs to supply the plant's water needs in the initial periods of plant growth. Hence studies in vegetation restoration of the arid area, usually try to implement long-term irrigation or harvest natural precipitation to establish native plants for the success of a restoration project (Puente and Bashan. 1993; Bashan et al. 1999; Toledo et al. 2001; Requena et al. 2001; Gao et al. 2002; Duponnois and Planchette.

2003; Puente et al. 2004; Medina et al. 2004; Marulanda et al. 2009; Benabdellah et al. 2011; Bashan et al., 2012; Lopez et al. 2012; Armada et al. 2014; Porensky et al., 2014; Ortiz et al. 2015; Ramachandran and Radhapriya. 2016; Lopez-Lozano et al. 2016; Moreno et al., 2017; Ahmed et al., 2017; Uselman et al., 2018; Ott et al., 2019; Jafari et al., 2020; Luna-Ramos et al., 2022). But due to water scarcity, access limited to water resources, and harsh climate conditions (such as high evaporation rate, high temperature, and wind speed) in the arid area it is not possible to meet the water needs of the plant in the long-term. Therefore attention to water scarcity and severe drought in arid areas, the implementation of water-saving techniques is very efficient. Irrigation with clay-pot is one of the water-saving techniques that practical option for climate change adaptation, food security, and sustainability of the livelihood (Bainbridge, 2001; Daka, 2001; Wolde-Georgis, 2010; Araya et al., 2014). Using clay pot irrigation causes water to transfer to the root zone and not be exposed to sunlight which significantly decreased the amount of evaporation and water consumption (Siyal et al., 2015). Also, reports indicated that plants can be grown around clay-pot using highly saline waters without sustaining any moisture stress (Bhatt and Kanzariya., 2017). In addition, to implement a practical irrigation method, establishing native plants with high water use efficiency (WUE) is very important to vegetation restoration in the fragile area (Ahmed et al., 2016). So it is necessary to plant native plants with high adaptation to harsh climatic conditions and have economic value (Midhat et al., 2021; Mishra et al., 2022). Research works conducted to investigate ecological survey of plant communities in arid regions indicate that, the capability of plant species to survive in the fragile area is different and plant species such as *Citrullus colocynthis* plant by high tolerance to drought conditions can be adapted to the desert area (Ahmed et al., 2016; Gogoi et al., 2019). Moreover, this plant has medicinal properties and growth capability in the soil of the fragile area and also creates a high canopy, which is an appropriate plant to control the effect of wind erosion in the fragile area (Magdy et al., 2015; Menon et al., 2016). Therefore according to the importance of the issue, implementing water-saving techniques and establishing native plants with high water use efficiency are key component agents to vegetation restoration and controlling desertification in an arid area. Iran is one of the arid regions of the world. Water shortages and severe droughts in the country, as well as population growth and the growing need to develop new food resources, have caused environmental damage and the destruction of natural resources (Jahantigh et al, 2022). Sistan region, which is located in the southeast of Iran, is one of the regions with severe climatic restrictions. More than 75 percent of this region includes barren land with poor vegetation (less than 5 percent). Due to the lack of vegetation, the main part of the region especially abandoned farmlands are always affected by wind erosion, which causes sandstorms and dust that's the most important problems for human migration and health in the region (Jahantigh and Jahantigh, 2020). Accordingly, due to the lack of vegetation and the increase in the vast of abandoned farmlands in sistana area, to restore vegetation cover it is necessary to use an efficient irrigation method whit the establishment of drought-tolerant plants to prevent soil erosion and land degradation in this region. Therefore, this study was conducted to investigate three years growth performance of *Citrullus colocynthis* plant under clay-pot irrigation in abandoned farmlands of the arid region. Consequently, the present study would be much more important for the restoration ecological in the fragile area and their development in the arid region.

# Materials And Methods

## Study area

The study area is located in the southeast of the country and north of Sistan and Baluchestan province and within the city of Nimroz and located at an altitude of 480 meters above sea level (Fig. 1). The present study was carried out at abandoned farmland in the Normohamad village of Nimroz town of Sistan and Baluchistan province, close Afghanistan border southeast of Iran. The area lies at "361466"- "361556" eastern longitudes and "3450886"- "3450896" North Latitude at the UTM coordinate system; Fig. 1. The general elevation of the study area ranges from 470 to 480 m above sea level with a general slope of 0.07 percentages from south to North. The average annual maximum, average maximum, and absolute maximum temperatures are 18, 25, and 43 degrees centigrade, respectively. The mean annual rainfall and evaporation of this region are 50 and 5000 mm, respectively, whereas, the mean annual relative humidity is 28 percentage in this area. The selected area has a dry and warm climate and is situated under the wind flow area, and experiences one of the famous winds (120-days wind) in this region. Soil salinity and alkalinity are important factors in soil limitation in the area. The vegetation of the area is poor and only drought-tolerant plants can adapt to this area (Jahantigh and Jahantigh, 2020).

## Material And Methods

In this study, the influence of the clay-pot irrigation method and traditional method has experimented on the growth performance of *Citrullus colocynthis* plant for three years. The field experiment was conducted from 2019 to 2021 and was set up with randomized complete block design treatment in 5 replications.

## Laboratory experiments

First, clay-pot irrigation systems were calibrated in the laboratory environment. For this purpose, by preparing glass plans the soil profile of the study area was simulated to assess and evaluate the Irrigation Systems Performance. To measure the wetting area around the clay pot, the water leak area of the clay -pot in soil was measured using millimeter paper (Fig. 2). The findings of the experiment were presented in Table 1.

Table 1  
Characteristics of clay-pot used in the experiment

| The side surface of the clay pot volume<br>(cm <sup>2</sup> ) | Thickness<br>(cm) | Capacity<br>(cm <sup>3</sup> ) | The volume of the water leak<br>(day /cm <sup>3</sup> ) |
|---------------------------------------------------------------|-------------------|--------------------------------|---------------------------------------------------------|
| 08/876                                                        | 2/1               | 37/428                         | 387                                                     |

## Experiment and Cultivation Management

After laboratory experiments, in field operation, plots with dimensions of 3×3 m were selected and holes with a diameter of 45 cm and a depth of 70 cm were drilled in the center of each of them. Then, irrigation methods were installed in each plot. Also to minimize the effects of other treatments a 0.5 m zone was set between adjacent plots. Seeds of *Citrullus colocynthis* plants were collected from Nimroze rangeland. The seeds of the plant were sown in each field plot on 25 January 2019.

## Measurements and calculations

In this experiment at the end of the growing season, *Citrullus colocynthis* plant characteristics including shrub length, number of seeds per fruit, number of fruits per plant, number of branches per plant, dry weight of fruit, and fruit yield were measured during three growth season (Shahid and Rao, 2014; Raja et al., 2014; Kahrom et al., 2022). The canopy diameters and litter vegetation were measured monthly during study periods. Also, the water consumption and water use efficiency (WUE) which is an indicator of the efficiency of irrigation for each growth season by harvesting fruit (for each season) was calculated (Meng et al., 2017). Eq. (1) was used to determine the amount of required water in irrigation events (Allen et al., 1998). The soil moisture was measured using TDR before each irrigation event (Laurent et al., 2005; Mehdizadeh et al., 2020).

$$I = (\theta_f - \theta) \cdot D / 100 \quad (1)$$

Where:

$\theta$  = Soil moisture before irrigation (volume percentage)

$\theta_f$  = Volumetric soil moisture at field capacity (volume percentage)

D = Effective depth of root (m)

I = Irrigation water depth (m)

The Weather parameters which have a major effect on environmental conditions such as temperature, wind speed, and evaporation rate were investigated. So to achieve this purpose temperature and wind speed data from synoptic stations located in nearly of study area were collected. To estimate evaporation, using pan evaporation is common practice to determine evaporation nearby the study area. So the amounts of evaporation by installation pan evaporation of (class A) were measured.

## Data statistical analysis

Statistical analyses were performed using Analysis of variance (ANOVA) and compare means procedure differences were analysed with Tukey's (LSD—least significant difference) test (at  $p < 0.05$ ) using the MSTAT-C and SPSS 23 software.

## Results

# Plant Characteristics

The result of the analysis of variance of shrub length, number of seeds per fruit, number of fruits per plant, number of branches per plant, dry weight of fruit, and fruit yield in the first growing season of *Citrullus colocynthis* is shown in Table 2. According to the results, the effect of irrigation methods and growth seasons on measured characteristics of *Citrullus colocynthis* plant was significantly different ( $p \leq 0.05$ ). The mean comparison of the data showed that the length of the plant under the influence of clay-pot irrigation has increased 2 times more than the traditional irrigation method, which was significant at the level of 5%. The highest number of branches was equal to 194.6 and was observed in irrigation treatment with clay-pot during the study period, which was 31.1% more than the control treatment. As well as the results of the mean comparison of data showed that there was a significant difference between irrigation methods in the number of fruits per plant, the number of seeds per fruit, the dry weight of single fruit, and fruit yield ( $p \leq 0.05$ ). So that under the effect of the clay-pot irrigation method the characteristic of plants such as the number of fruits per plant (45%), the number of seeds (21/3%) dry weight of single fruit (25/4%), and fruit yield (67/6%) significantly increase compared to traditional irrigation which was significant at the level of 5% (Table 3). Also, statistical comparison of data indicates that the effect of growth seasons on measured characteristics of *Citrullus colocynthis* plant during study periods was significantly different ( $p \leq 0.05$ ). So, the lowest amount of plant characteristics related to first-season growth, while in the third season growth significantly increased ( $p \leq 0.05$ ). The changes in plant characteristics in second-season growth were perceptible, so the value of this characteristic compared to first-season growth increased and compare to the third year decreased. The effect of the Interaction of irrigation and growth season on plant characteristics showed that there were significantly different between treatments in plant characteristics and the highest value of measured characteristics related to  $I_{CP}Y_3$  treatments, which was significant at the level of 5%.

Table 2

Analysis of variance of effective treatments on *Citrullus colocynthis* characteristics in the first year

| S.O.V                                                                                      | df | MS                   |                       |                       |                      |                            |                       |
|--------------------------------------------------------------------------------------------|----|----------------------|-----------------------|-----------------------|----------------------|----------------------------|-----------------------|
|                                                                                            |    | Shrub<br>long        | branches<br>/plant    | Seeds<br>/Fruit       | Fruits/<br>plant     | the dry weight<br>of fruit | fruit<br>yield        |
| Replace                                                                                    | 5  | 181.3 <sup>ns</sup>  | 153.15 <sup>ns</sup>  | 9301.13 <sup>ns</sup> | 4.3 <sup>ns</sup>    | 30.11 <sup>ns</sup>        | 2012.77 <sup>ns</sup> |
| I                                                                                          | 1  | 1039.12 <sup>*</sup> | 1471.34 <sup>**</sup> | 22341.1 <sup>**</sup> | 167.34 <sup>**</sup> | 33.34 <sup>**</sup>        | 4103.2 <sup>**</sup>  |
| Y                                                                                          | 2  | 373.25 <sup>**</sup> | 1102.12 <sup>**</sup> | 1067.3 <sup>**</sup>  | 102.2 <sup>**</sup>  | 15.12 <sup>**</sup>        | 3121.6 <sup>*</sup>   |
| I × Y                                                                                      | 2  | 48.12 <sup>**</sup>  | 32.35 <sup>**</sup>   | 63.12 <sup>ns</sup>   | 21.3 <sup>ns</sup>   | 3.41 <sup>**</sup>         | 632.21                |
| Error                                                                                      | 9  | 10.13                | 67.89                 | 102.12                | 8.71                 | 11.12                      | 2143.81               |
| Note: **, *: Significant at 1% and 5% probability level, respectively. ns: Not significant |    |                      |                       |                       |                      |                            |                       |

Table 3  
Comparison of effect of irrigation methods and growth season on growth features of *Citrullus colocynthis*

| Treatment                                                                                                                                                                                                                                    |                 | Shrub Long(cm)       | branches /plant    | Seeds /Fruit        | Fruits/ plant      | the dry weight of fruit(gr) | Fruit yield(k/ha)     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------------|--------------------|---------------------|--------------------|-----------------------------|-----------------------|
| I                                                                                                                                                                                                                                            | I <sub>CP</sub> | 206.7 <sup>a</sup>   | 194.6 <sup>a</sup> | 257.25 <sup>a</sup> | 22.8 <sup>a</sup>  | 25.2 <sup>a</sup>           | 1796.2 <sup>a</sup>   |
|                                                                                                                                                                                                                                              | I <sub>T</sub>  | 96.9 <sup>b</sup>    | 148.5 <sup>b</sup> | 212.1 <sup>b</sup>  | 15.7 <sup>b</sup>  | 20.2 <sup>b</sup>           | 1072.04 <sup>b</sup>  |
| Year                                                                                                                                                                                                                                         | Y <sub>1</sub>  | 111.6 <sup>c</sup>   | 38.9 <sup>b</sup>  | 227.6 <sup>b</sup>  | 12.5 <sup>c</sup>  | 19.65 <sup>b</sup>          | 904.85 <sup>b</sup>   |
|                                                                                                                                                                                                                                              | Y <sub>2</sub>  | 210.9 <sup>b</sup>   | 229.6 <sup>a</sup> | 236.7 <sup>a</sup>  | 22.6 <sup>b</sup>  | 22.3 <sup>a</sup>           | 1830.1 <sup>a</sup>   |
|                                                                                                                                                                                                                                              | Y <sub>3</sub>  | 233.3 <sup>a</sup>   | 246.2 <sup>a</sup> | 238.5 <sup>a</sup>  | 32.2 <sup>a</sup>  | 23.1 <sup>a</sup>           | 1921.26 <sup>a</sup>  |
| I × Y                                                                                                                                                                                                                                        |                 |                      |                    |                     |                    |                             |                       |
| I <sub>CP</sub> Y <sub>1</sub>                                                                                                                                                                                                               |                 | 126.4 <sup>d</sup>   | 47.3 <sup>c</sup>  | 249.25 <sup>a</sup> | 14.9 <sup>cb</sup> | 21.1 <sup>b</sup>           | 1047.97 <sup>cb</sup> |
| I <sub>T</sub> Y <sub>1</sub>                                                                                                                                                                                                                |                 | 96.9 <sup>e</sup>    | 30.4 <sup>c</sup>  | 206.1 <sup>b</sup>  | 10.1 <sup>c</sup>  | 18.2 <sup>c</sup>           | 612.74 <sup>c</sup>   |
| I <sub>CP</sub> Y <sub>2</sub>                                                                                                                                                                                                               |                 | 235.25 <sup>ab</sup> | 265.3 <sup>a</sup> | 261.25 <sup>a</sup> | 26.4 <sup>a</sup>  | 24.1 <sup>a</sup>           | 2118.39 <sup>a</sup>  |
| I <sub>T</sub> Y <sub>2</sub>                                                                                                                                                                                                                |                 | 186.7 <sup>c</sup>   | 193.9 <sup>b</sup> | 216.1 <sup>b</sup>  | 17.8 <sup>b</sup>  | 20.6 <sup>b</sup>           | 1218.833 <sup>b</sup> |
| I <sub>CP</sub> Y <sub>3</sub>                                                                                                                                                                                                               |                 | 258.3 <sup>a</sup>   | 271.3 <sup>a</sup> | 261.4 <sup>a</sup>  | 27.2 <sup>a</sup>  | 24.5 <sup>a</sup>           | 2222.15 <sup>a</sup>  |
| I <sub>T</sub> Y <sub>3</sub>                                                                                                                                                                                                                |                 | 208.2 <sup>b</sup>   | 221.2 <sup>b</sup> | 217.1 <sup>b</sup>  | 19.2 <sup>b</sup>  | 21.6 <sup>b</sup>           | 1384.56 <sup>b</sup>  |
| Note: The means with similar letters in each column are not statistically significantly different based on Tukey's honestly significant difference (LSD) post hoc test, I <sub>cp</sub> = Clay pot, I <sub>T</sub> = Traditional irrigation. |                 |                      |                    |                     |                    |                             |                       |

## Water consumption Water use index (WUE)

Table 4 presents the mean comparison data of water consumed and water use efficiency index (WUE) are presented. As shown in Table 3, there is a significant difference in the average volume of water consumed in the treatments. So the most amount of water has been used in the traditional irrigation method (3640.28m<sup>3</sup>/ha). In contrast, the lowest amount of water consumption (1250.5 m<sup>3</sup>/ha) is related to the clay-pot irrigation method, which compared to the traditional irrigation method, has 3 times more water

savings. According to the results, the water use efficiency index (WUE) is affected by the type of irrigation methods and growing season and has a significant difference at the level of 5%. In comparing the average values of the WUE index between the two irrigation methods, the findings indicate that the highest value of this index is equal to 1246993 (gr/m<sup>3</sup>) and achieved by using the clay-pot irrigation method that 1.8 times more than traditional irrigation method (745299.5). Investigation of the WUE index during tree growth season represent that, the value of this index in the second and third growth season is 3452.5 and 33745.6 times more than the first growing season that achieved non-irrigation condition. Exploring the effect of the interaction of irrigation and growth season on the WUE index demonstrates that, there were significantly different between treatments in WUE, and the highest amount of this index related to I<sub>CP</sub>Y<sub>3</sub> treatments ( $p \leq 0.05$ ).

Table 4

Comparison of the effect of irrigation methods and years on water consumption and water use efficiency index of *Citrullus colocynthis* for three year

| Treatment                                                                                                                                                                                                                                                                                         |                 | Water consumption (m <sup>3</sup> /h) | WUE index (gr/m <sup>3</sup> ) |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------------------------------|--------------------------------|
| I                                                                                                                                                                                                                                                                                                 | I <sub>CP</sub> | 1250.5 <sup>b</sup>                   | 1246993.8 <sup>a</sup>         |
|                                                                                                                                                                                                                                                                                                   | I <sub>T</sub>  | 3640.28 <sup>a</sup>                  | 745299.5 <sup>b</sup>          |
| Year                                                                                                                                                                                                                                                                                              | Y <sub>1</sub>  | 2612.1 <sup>a</sup>                   | 414.98 <sup>b</sup>            |
|                                                                                                                                                                                                                                                                                                   | Y <sub>2</sub>  | 1.1 <sup>b</sup> (P)                  | 1432701.32 <sup>a</sup>        |
|                                                                                                                                                                                                                                                                                                   | Y <sub>3</sub>  | 1.2 <sup>b</sup> (P)                  | 1564323.5 <sup>a</sup>         |
| I × Y                                                                                                                                                                                                                                                                                             |                 |                                       |                                |
| I <sub>CP</sub> Y <sub>1</sub>                                                                                                                                                                                                                                                                    |                 | 1250.8 <sup>a</sup>                   | 661.7 <sup>c</sup>             |
| I <sub>T</sub> Y <sub>1</sub>                                                                                                                                                                                                                                                                     |                 | 3640.28 <sup>a</sup>                  | 168.3 <sup>c</sup>             |
| I <sub>CP</sub> Y <sub>2</sub>                                                                                                                                                                                                                                                                    |                 | 1.06 <sup>b</sup> (P)                 | 1914321.2 <sup>a</sup>         |
| I <sub>T</sub> Y <sub>2</sub>                                                                                                                                                                                                                                                                     |                 | 1.06 <sup>b</sup> (P)                 | 1142656.1 <sup>b</sup>         |
| I <sub>CP</sub> Y <sub>3</sub>                                                                                                                                                                                                                                                                    |                 | 1.3 <sup>b</sup> (P)                  | 1985991.2 <sup>a</sup>         |
| I <sub>T</sub> Y <sub>3</sub>                                                                                                                                                                                                                                                                     |                 | 1.3 <sup>b</sup> (P)                  | 1090374.1 <sup>b</sup>         |
| Note: The means with similar letters in each column are not statistically significantly different based on Tukey's honestly significant difference (LSD) post hoc test, I <sub>cp</sub> = Clay pot, I <sub>T</sub> = Traditional irrigation, P: the amount of Precipitation during growth season. |                 |                                       |                                |

## Interpreting the canopy of vegetation

The results of three years of measuring of canopy and litter area of *Citrullus colocynthis* plant are present in Table 5. According to the results mean comparison of canopy data showed that it is significantly different between irrigation methods ( $p \leq 0.05$ ). The highest vegetation cover equal to 2.7 (m<sup>2</sup>) and related to the clay-pot irrigation method which significantly increases compare to surface irrigation (1.4 times more than the T irrigation method). Also, the results show that the average canopy area in the first growing season is equal to 0.41(m<sup>2</sup>) which significantly increased in the second and third seasons (7.6 and 8.3 times respectively). In addition, the changes in the litter of vegetation are perceptible that have a significant difference at the level of 5%. During the second growing season, the area of litter vegetation is equal to 0.23 m<sup>2</sup>, which rose to 1.49 m<sup>2</sup> in the third growth season (6.5 times more than the second growth season). According to field observation, after each growing season, the litter of *Citrullus colocynthis* plant sticking to the soil surface and creates a relatively resistant layer on the soil surface. In Fig. 3, the changes in canopy and litter of *Citrullus colocynthis* for three growth season is presented.

Table 5

Mean comparison of the effect of irrigation methods on vegetation changes in *Citrullus colocynthis* plant treatments in the second season of plant growth

| Treatment                                                                                                                                                                                                                                    |                 | The area of dried litter on the soil surface(m <sup>2</sup> ) | Canopy surface (m <sup>2</sup> ) |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------|----------------------------------|
| I                                                                                                                                                                                                                                            | I <sub>CP</sub> | 0.69 <sup>a</sup>                                             | 2.7 <sup>a</sup>                 |
|                                                                                                                                                                                                                                              | I <sub>T</sub>  | 0.48 <sup>b</sup>                                             | 1.92 <sup>b</sup>                |
| Year                                                                                                                                                                                                                                         | Y <sub>1</sub>  | 0 <sup>c</sup>                                                | 0.41 <sup>b</sup>                |
|                                                                                                                                                                                                                                              | Y <sub>2</sub>  | 0.23 <sup>b</sup>                                             | 3.1 <sup>a</sup>                 |
|                                                                                                                                                                                                                                              | Y <sub>3</sub>  | 1.49 <sup>a</sup>                                             | 3.41 <sup>a</sup>                |
| I × Y                                                                                                                                                                                                                                        |                 |                                                               |                                  |
| I <sub>CP</sub> Y <sub>1</sub>                                                                                                                                                                                                               |                 | 0 <sup>d</sup>                                                | 0.51 <sup>c</sup>                |
| I <sub>T</sub> Y <sub>1</sub>                                                                                                                                                                                                                |                 | 0 <sup>d</sup>                                                | 0.32 <sup>c</sup>                |
| I <sub>CP</sub> Y <sub>2</sub>                                                                                                                                                                                                               |                 | 0.29 <sup>c</sup>                                             | 3.73 <sup>a</sup>                |
| I <sub>T</sub> Y <sub>2</sub>                                                                                                                                                                                                                |                 | 0.18 <sup>c</sup>                                             | 2.48 <sup>b</sup>                |
| I <sub>CP</sub> Y <sub>3</sub>                                                                                                                                                                                                               |                 | 1.7 <sup>a</sup>                                              | 3.87 <sup>a</sup>                |
| I <sub>T</sub> Y <sub>3</sub>                                                                                                                                                                                                                |                 | 1.2 <sup>b</sup>                                              | 2.95 <sup>b</sup>                |
| Note: The means with similar letters in each column are not statistically significantly different based on Tukey's honestly significant difference (LSD) post hoc test, I <sub>cp</sub> = Clay pot, I <sub>T</sub> = Traditional irrigation. |                 |                                                               |                                  |

# Interpreting of the canopy of vegetation changes compare to variants of wind and temperature

The result of investigating the changes in vegetation compared to the most important climatic variable including wind speed and temperature were present in Fig. 4. Based on the result, in the first growing season of *Citrullus Colocynthis* plant, the average temperature in March was equal to 17.5 C and during May, June, July, and September significantly increased (1.7, 1.9, 2.1, and 2 times more than march respectively). Also, the result indicates that the average wind speed during the growing season is significantly different. So, in March the amount of this parameter has been at least (23 km/h) and during May, June, July, and September reach their maximum value (30, 36.6, 38.8, and 34.4 respectively).

Meanwhile, the changes of evaporation during critical months rose highly too. According to the results, in the first growing season of the plant the vegetation cover of *Citrullus Colocynthis* plant, had increased synchronously during the period that the value of wind speed and temperature reaches its value maximum. So, in March average vegetation canopy area in all treatments was the lowest value during the critical month (April, June, July, and September respectively) and significantly increased. In the second season of growth, the changes in the canopy area among all treatments are highly different. The first germination of this plant was observed in February and the average canopy area in this month reaches 0.12 (m<sup>2</sup>) and 0/32 (m<sup>2</sup>) that such as the surface layer covering the litter of vegetation. During critical months the average canopy area reaches 2.17 (May), 3.16 (June), 3.42 (July), and 3.78 (September) which compare to the first season of plant growth highly increased. Moreover, In the third season of the growing plant, the changes in the canopy area were similar to the second season and the canopy area reached its value maximum during critical months. Also, the average of litter vegetation showed a perceptibly increase in this period.

## Discussion

This study reflects the growth performance of *Citrullus colocynthis* plant in restoring vegetation in abandoned farmland of arid areas by using water-saving techniques. The resulting finding indicates that the growth performance of *Citrullus colocynthis* plant affected by the type of irrigation methods and growth season is different. So, the results of the mean comparison of growth characteristics showed that the highest length of shrub, number of branches, number of fruits per plant, dry weight of single fruit, fruit yield (2.13, 1.3, 1.4, 1.2, and 1.6 times more than traditional irrigation respectively) related to clay-pot irrigation that at 5% level was significantly different compare to traditional irrigation. Moreover, the differences were highly significant for the three growing seasons of *Citrullus colocynthis* ( $P < 0.05$ ). The highest amount of these growth characteristics related to the third growing season of *Citrullus colocynthis* plant. The reason for increasing the growth characteristics of *Citrullus colocynthis* plant with clay-pot irrigation compared to the traditional method is the performance and mechanism of water transfer to the soil profile. According to laboratory results, water transfer to the soil profile as water leak around the clay pot that cause soil moisture distribution uniformly in the soil profile. This result was

confirmed by Lucieta et al (2018). The report that the designing the clay pot, applied water transferred to the soil profile as a water leak, which caused water distribution around the roots of the plant to accord uniformly. Hence, after each irrigation event, water consumed is directly transferred to the root zone. This process caused the increase in soil moisture due to the decrease in evaporation. Installing a clay pot with a cylinder shape in the soil profile causes the pot located parallel to the root plants, which meets plant water needs properly (Neelkanth et al., 2017). This function has an effective role in plant growth that has the tap-root system. *Citrullus colocynthis* plant species is one of the plants that have very delicate, fleshy, and long tap roots (Dhakad et al., 2017; Kapoor et al., 2020). Therefore, applications of clay-pot irrigation cause an increase in the performance of the plant. So, the significant increase of plant growth characteristics in treatments, irrigated by clay-pot irrigation methods compare to traditional irrigation, confirms the issue ( $P < 0.05$ ).

Moreover, the finding represented that the lower amount of water consumption ( $1250.5 \text{ m}^3/\text{ha}$ ) is related to the clay-pot irrigation method, which compared to the traditional irrigation method ( $3640.28 \text{ m}^3/\text{ha}$ ), has 3 times more water savings. In this irrigation method, water transfers from the pores of the clay pot that regulate by the osmotic status of the soil (Araya et al., 2014). In other words, water transfers to the soil as much as the soil needs. When the soil becomes wet, water outflow from the clay pot stops, and water outflow slowly starts again when the soil becomes dry (Siyal et al., 2016). Research done to compare the efficiency evaluation of clay pots in northern Ethiopia reported that the Performance of this irrigation system through its self-regulated and reduced evaporation rate, caused water consumed significantly decreased ( $P < 0.05$ ). In addition, the results showed that the WUE index under clay-pot irrigation is 1.8 times more than the control treatment. In some reports, the higher WUE in clay pot irrigation was attributed to the better and uniform water distribution in the root zone that's consistent with the results of this research (Araya et al., 2014; Lucieta et al., 2018). Based on the results of the research, the growth performance of *Citrullus colocynthis* plant was exceptional during the study period. So the difference in growth characteristics between the three growing seasons was significant ( $p \leq 0.05$ ). In the second and third growing seasons, all growth characteristics of the plant significantly increased which non-irrigation conditions. As well, the mean comparison of canopy data showed that the canopy area in the second and third growth seasons compare to the first growth season significantly increased ( $p \leq 0.05$ ). The high growth performance of *Citrullus colocynthis* plant in non-irrigation conditions demonstrates that the water requires by this native plant is low and by tolerance, the drought condition can be adapted to the arid area. Some reports show that *Citrullus colocynthis* plant due to its unique property such as drought tolerance and high adaption to the harsh climatic area is a suitable plant to restore vegetation and controlling wind erosion and desertification in the arid zone (Ahmed et al., 2016; Gogoi et al., 2019). By the results, the *period* of growth of *Citrullus Colocynthis* is synchronous with the period that the value of wind speed, temperature, and evaporation rate reaches its value maximum. According to field observation, the canopy area whit litter of *Citrullus colocynthis* plant creates a relatively resistant layer on the soil surface during critical months that has an important role in soil conservation. As reported, most of the Sistan area due to a lack of vegetation is facing wind erosion. Moreover, harsh climatic and water scarcity in this area caused the stockholders can't farm the agricultural land. So, most

vast of these lands have sensitive soil that needs to conserve from soil erosion (Jahantigh and Jahantigh, 2019; Jahantigh and Jahantigh, 2020; Jahantigh et al, 2022). Thus the canopy and litter area created by *Citrullus Colocynthis* plant has an important role in the conservation of soil from wind erosion, especially in abandoned farmland in the Sistan area. As a result establishment of native plant whit, the Implementation of water-saving techniques in abandoned farmland in arid areas is a suitable management strategy for controlling wind erosion and desertification in fragile areas. A study carried out in farmlands of the Inner Mongolia region in China reports that due to the increasing trend of turning farmlands into desert areas and the expansion of erosion centers, the establishment of native plant with economic value while controlling wind erosion and desertification cause improve the economic conditions of the stakeholders (Chi et al., 2021).

## Conclusion

This study has investigated the growth performance of *Citrullus colocynthis* plant with the Implementation of water saving technique to restore vegetation in the abandoned farmland of the Sistan area. Due to water scarcity and severe drought in the Sistan area, the effect of the type of irrigation methods to provide the water needs of the plant is very important. The result showed that, due to the performance of clay-pot water transfer to soil profile as a water leak, which caused water distribution around the roots of plant accord uniformly. This function has an effective role in plant growth that has a tap-root system such as *Citrullus colocynthis* plant species. So that result indicates that the highest growth characteristics measured under clay pot irrigation which significantly different compared to the traditional irrigation method. Based on the results of the research, the growth performance of *Citrullus colocynthis* plant was exceptional during the study period and the growth characteristic of the plant significantly increased during the second and third growth seasons which were non-irrigation conditions. Moreover, the period of growth of *Citrullus Colocynthis* is synchronous with the period that the value of wind speed, temperature, and evaporation rate reaches its value maximum. According to field observation, the canopy area whit litter of *Citrullus colocynthis* plant creates a relatively resistant layer on the soil surface during critical months that has an important role in soil conservation.

In general, it is concluded that restoring vegetation in abandoned farmland of the study area with the Implementation of clay-pot irrigation due to significantly reduce in water consumption and increase time maintenance of soil moisture is the better irrigation method for the establishment of drought-tolerance plant species such as *Citrullus colocynthis* with high adaptation in abandoned farmlands of the study area.

## Declarations

### Financial interests

Authors declare they have no financial interests.

## Conflicts of interest

The authors declare no conflict of interest.

## Author Contributions

*All authors contributed to the study conception and design.*

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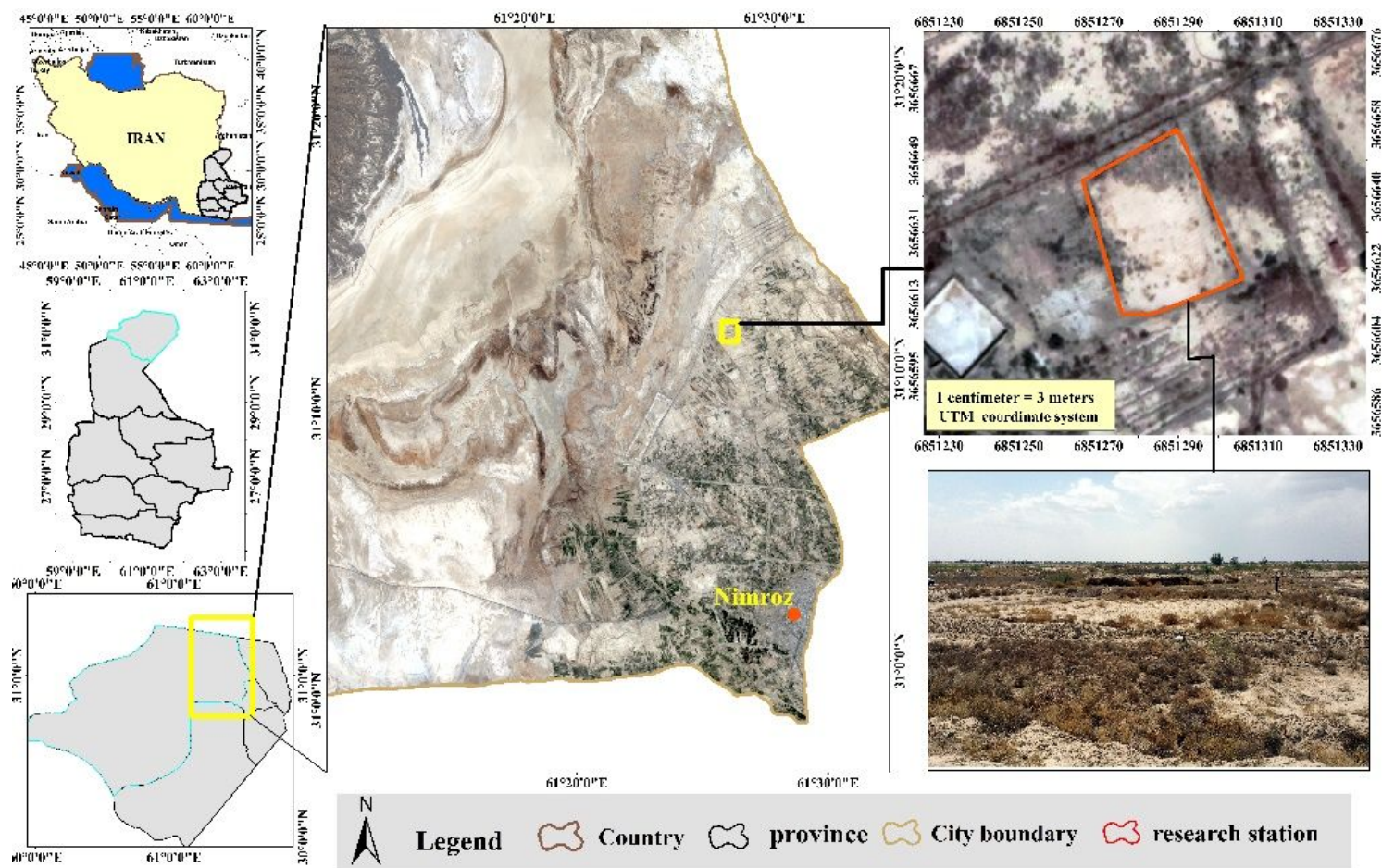
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## Figures



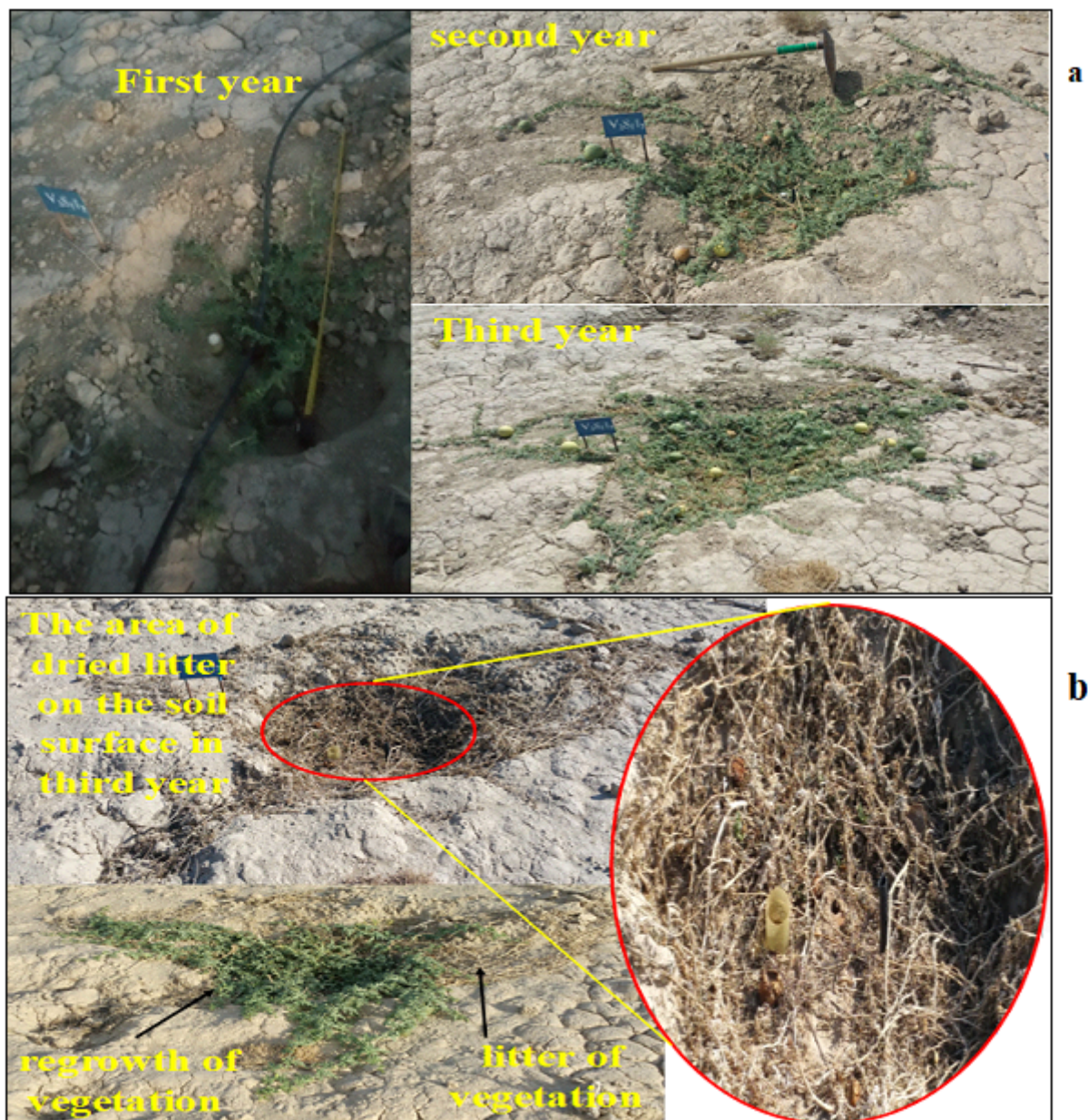
**Figure 1**

Location of the study area in the Nimroze city of Sistan and Blochestan province, southeast Iran.



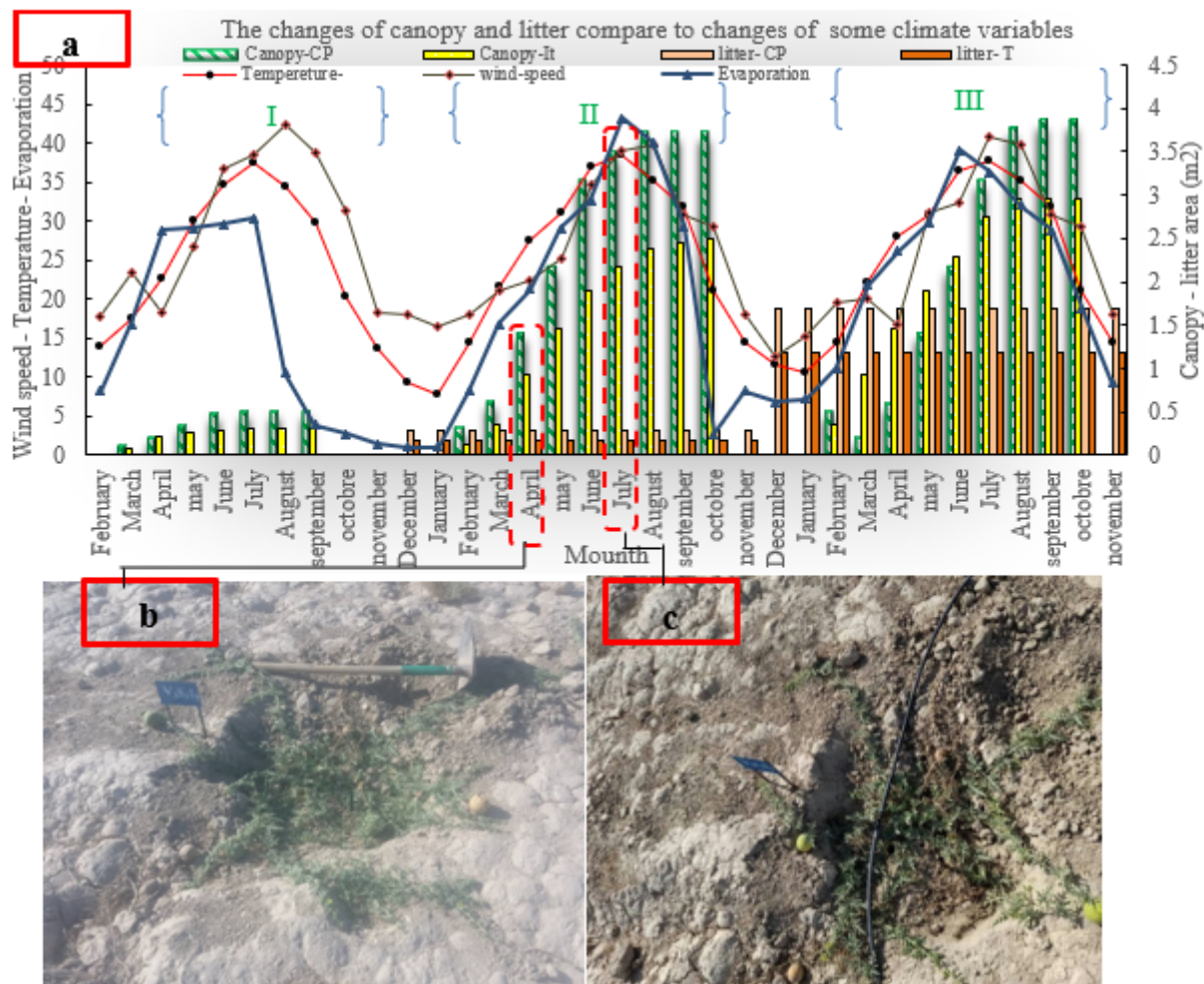
**Figure 2**

View of simulation of clay-pot irrigation system (a) and measuring the amount of water seepage and the water leak area of clay-pot (b) in glass plan with the soil of research station



**Figure 3**

The changes of canopy and litter of *Citrullus colocynthis* during the study period, a) View of the changes of vegetation cover in three growing seasons of *Citrullus colocynthis* plant, b) View of the cover of *Citrullus colocynthis* litter on the soil surface in the third growing season.



**Figure 4**

a) chart of changes in canopy and litter of *Citrullus Colocynthis* plant compare to changes in temperature, wind speed, and evaporation during the study period. b) View of Second growth season of *Citrullus colocynthis* plant, date of taken photo: 2020/4/18, average wind speed (Km/h): 21.1, average temperature (°C): 26.9, average visibility (Km): 9.7, c) View of Second growth season of *Citrullus Colocynthis* plant, date of taken photo: 2020/7/27, average wind speed (Km/h): 59.1, average temperature (°C): 38.9, average visibility (Km): 2.1, I: first growth season, II: second growth season, III: third growing season.