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Article

Evaluation of the RZWQM2 Model in Simulating Water Consumption, Water Use Efficiency, and Yield for Cabbage (Brassica oleracea. L)

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Abstract

This study aims to verify the predictability of selected measured properties of soil and plants at depletion rates of available water and the use of soil conditioners using the root zone water quality model RZWQM2. A field experiment was conducted to cultivate the Cabbage crop for the autumn of 2021 at the field experiment station F / College of Agricultural Sciences in Al-Jadiriyah region, Baghdad- Iraq. The effect of depletion rates of available water and the addition of soil conditioners on dry weight, yield, water consumption, reference and potential evapotranspiration, water absorption by the plant, and the crop water use efficiency of the Cabbage plant was evaluated using the model RZWQM2. The experiment treatments were: D1: Irrigation after depleting 30% of available water, D2: Irrigation after depleting 60% of available water, C0: without addition, C1: adding organic matter (Compost) 20 Mg.ha-1, C2: adding perlite 4 Mg.ha-1, C3: adding organic matter (Compost) 10 Mg.ha-1 + perlite 2 Mg.ha-1. A scenario was created in the RZWQM2 model to simulate the studied traits at field conditions. The results showed that the percentage of depleting 30% of available water was better than the percentage of depleting 60% of available water using the RZWQM2 model at dry weight, yield, water consumption, reference, and potential evapotranspiration, water absorption by the plant, and the crop water use efficiency of the Cabbage plant. Also, the treatment of adding compost exceeded the rest of the conditioners and the comparison treatment at depletion rates of 30 and 60% of available water in the measured properties. Furthermore, adding compost reduced water consumption compared to the rest of the study treatments.

Keywords: predictability; Irrigation; water absorption; evapotranspiration.

Introduction

Cabbage Brassica Oleracea is a vegetable crop with green or red leaves. It belongs to the family of cruciferous and is round or oval. The green Cabbage plant consists of light, soft inner leaves covered with more solid and dark outer leaves. It is one of the winter vegetable crops grown in Iraq and is considered one of the important vegetables in nutrition. The compact head is a group of wrapped leaves that covers the tip of the bud and is eaten. Likewise, it has many health benefits, such as being rich in antioxidants, helping in brain functions, digestion and protection from skin disorders and heart diseases) are widely used all over the world and can be prepared in several ways, including cooked or raw with many salads or with pickles [1]. Water is the most determining factor for plant growth and productivity and is the primary determinant of vegetation distributions around the world. Plants retain approximately 1% of the water absorbed by roots; the rest comes out by transpiration into the atmosphere. The root system consists of a complex network of individual roots that differ in age and length, initially producing slender roots that get thicker as the plant grows; root hair is the most compelling part of the soil water absorption process. [2]. Evapotranspiration is the process of losing water from the soil and plant (plant leaf stomata and stem pores). Potential evapotranspiration is defined as the upper limit of evapotranspiration that occurs under ideally standard moisture and temperature conditions for any ideally cultivated plant. It is called reference evapotranspiration when the surface is covered by a short, dense, and equal-height green plant growing under standard conditions. On the other hand, it is called actual evapotranspiration when the plant grows under field conditions; this means it is not ideal and is the most minor type of evapotranspiration value. Compost is the product of the fermentation processes of plant and animal remains, which go through stages accompanied by a gradual change in temperature. This change begins to rise until it reaches more than 65 ° C and then begins to decrease until it reaches the air temperature, which is one of the signs of compost maturity. In addition to its smell and spongy texture, the fermentation process requires aeration and humidity of about 50% [3]. Perlite is small, light white-gray grains formed from glassy volcanic rocks when rapidly heated to a temperature of 1100-760°C, as the water trapped inside evaporates, and its volume expands to 16-7 times. It has many physical properties such as high surface area, low density, thermal conductivity, ability to retain water, and chemically inert, non-toxic, and non-degradable [4]. Drip irrigation is one of the modern irrigation systems, and they are a group of main and sub-superficial tubes spread over the field, which move water utilizing pumps that generate the necessary pressure. They also contain filters and a fertilizer injector to let the water come out from small holes called emitters [5]. Computer Models provide an excellent way to translate the research application into other locations and conditions to reduce duplication in field research work. They are an excellent way to transfer integrated knowledge and technology to farmers and researchers. The Root Zone Water Quality Model RZWQM2 is a model that integrates modern knowledge of agricultural systems as a tool for research, agricultural management, environmental assessment, and technology transfer. The RZWQM2 model simulates the primary physical, chemical, and biological processes in the agricultural production system and stimulates plant growth, transport of water and nutrients, salt leaching, and herbicide movement in the root zone. The model responds to various agricultural management practices, including plowing, cultivation, harvesting, mulching with plant residues, and pest control with herbicides. The model works with Windows by managing inputs and outputs for projects and scenarios. This management can test crops' response to climatic changes such as increases and decreases in temperature, solar radiation, wind, relative humidity, and carbon dioxide. However, the degree of success in simulating the agricultural system when applying the model depends on the availability and quality of data; many new ideas were developed when applying the model. The applications of the RZWQM2 model have enhanced the understanding of agricultural systems and the integration of the model with fieldwork [6].

Materials and Methods

A field experiment was carried out for the Autumn season of 2021 at the field experiment station F / College of Agricultural Engineering Sciences in the Jadiriyah region at longitude (33 ° 16 ′ 28 ″) N and latitude (44 ° 23 ′ 26) E. The region's lands are semi-flat, 34 m above sea level, and the texture is sandy loam soils.

Representative samples of the field soil before planting for a depth of 0-30 cm were randomly collected and air-dried, then ground and passed through a sieve with holes 2 mm in diameter to perform some physical and chemical analyses. The following treatments were applied: D1: Irrigation after depleting 30% of available water, D2: Irrigation after depleting 60% of available water. Besides, C0: without addition, C1: adding organic matter (Compost) 20 Mg.ha-1, C2: adding perlite 4 Mg.ha-1, C3: adding organic matter (Compost) 10 Mg.ha-1 + perlite 2 Mg.ha-1. Soil conditioners were added 14 days before planting and mixed with the soil at a depth of 0.3 m. A plot of land with 15 x 27 m dimensions was selected and plowed perpendicularly using a moldboard plow and leveled using a mechanical leveling machine. The field was divided into four blocks, each into eight experimental units. The distance between the experimental units is 1 m, each experimental unit is a square plot of 2.5 x 2.5 m, and each plot has four planting rows. The experiment treatments were distributed to the experimental units according to the split-plot arrangement within the Randomized Complete Block Design (RCBD) with four replicates. The drip irrigation system consists of a water tank with 5000 liters capacity supplied with a valve to control the amount of added water; the tank is connected to a pump, a water filter, a fertilizer, and a pressure gauge. The water distribution network consists of the main tube with a diameter of 1.5 inches from which four sub-tubes of a diameter of 1 inch branch off. Each sub-tube is connected in turn to 32 field tubes with a diameter of 0.6 inches of type (GR) draining the emitter in which 8 liters /hour, the total number of field tubes becomes 128 tubes, while the distance between the field tubes was 0.75 m and between the emitters was 0.4 m. Chemical fertilizers were used to fertilize the crop using the pruning method, as Urea (46% N) was added at 146 kg N.ha-1, and triple superphosphate fertilizer (20% P) was added at 39 kg P.ha-1. Besides, potassium sulfate fertilizer (41.5% K) was added at 140 kg K.ha-1 in the form of two batches, the first 10 days after planting and the second 27 days after the first batch according to the fertilizer recommendation mentioned in [13]. The irrigation of soil calibration was carried out on 2/9/2021 in preparation for planting, and after planting, the plants were irrigated according to growth requirements. On 19/9/2021, the irrigation operations were carried out depending on the percentage of depletion of soil moisture after taking soil samples for depth (0-15) and (15-30) and measuring moisture by weighting method daily before carrying out the irrigation process. The irrigation process was carried out according to the treatments: Irrigation after depleting 30% of available water and irrigation after depleting 60% of available water, depending on the observation of the depth of the root by taking models from the field. Thus, the depth and volume of the added water were calculated based on equations (1 and 2) mentioned by [7]

$$d = (\theta_{FC} - \theta_{w})D \quad (1)$$

Since:-
d = depth of applied water (cm),
θFC = volumetric moisture at field capacity (cm3 cm-3),
θW = volumetric moisture before irrigation (cm3 cm-3),
D = root zone depth (cm).

$$V = A \times d \quad (2)$$

Where: V = volume of water to be added (litter),
A = wetted area (m^2).

A preliminary analysis of the study soil was carried out in Table (1), as the soil particle volume analysis was estimated using the pipette method described. In contrast, the Bulk density was estimated using the Core Sample method mentioned by Particle density: It was estimated using the Pycnometer method mentioned in [8]. At the same time, the saturated hydraulic conductivity was measured using the fixed water column method on the undisturbed soil sample mentioned in [8]. Then, Moisture content at different moisture tensions was measured using the Pressure Plate according to the method mentioned in [8]. In the same role, the electrical conductivity EC was measured for soil extract (1:1) using an EC-meter according to the method mentioned in [8]. Finally, the degree of reaction pH was measured using a pH meter using soil extract (1:1) according to the method mentioned in [9].

Property	Value	Unit
Sand	591	g.kg-1
Silt	225	
Clay	184	
Texture	sandy loam	---
Bulk density	1.34	Mg.m-3
Particle density	2.65	
moisture content at 33 kPa	0.34	cm3.cm-3
moisture content at 1500 kPa	0.16	
Available water	0.18	
Saturated hydraulic conductivity	2.71	cm. hour -1
Soil Electrical Conductivity EC1:1	1.4	dS.m-1
Soil reaction (pH)	7.4	---

Table 1. Physical and chemical analyses of soil and irrigation water.

The hydraulic conductivity was calculated based on Darcy's law and according to the equation

$$K = \frac{V}{At} \cdot \frac{L}{\Delta h} \tag{3}$$

Since:-
K = hydraulic conductivity (cm/h)
V = volume of water (cm^3),
A = section area of soil column (cm^2),
t = water collection time (h),
L = length of soil column (cm),
Δh = Difference in the water potential (cm water).
Actual evapotranspiration was calculated from the water balance equation.

$$ETa = I + P + C \mp \Delta S \tag{4}$$

Since:-
ETa = actual evapotranspiration (mm),
I = depth of irrigation water added (mm),
P = depth of rainfall (mm),
C = contribution of groundwater by capillary property (mm),
ΔS = soil moisture storage at the beginning and end of each growth stage (mm).
Field Water-Use Efficiency was calculated by applying the following

$$WUE_f = \frac{\text{yield}}{\text{water applied}} \tag{5}$$

Since:-
WUEf = Field Water-Use Efficiency ($kg.m^{-3}$),

Yield = Total Yield ($kg.ha^{-1}$),

Water applied = the volume of water added during the season (m3.ha-1).

Crop Water-Use Efficiency was calculated by applying the following equation:

$$WUE_c = \frac{yield}{ET_a} \quad (6)$$

Since:-

WUEc = Crop water use efficiency ($kg.m^{-3}$).

The reference evapotranspiration data were obtained from the Meteorological Department of the Ministry of Agriculture for the experimental period and the year 2021

Results

RZWQM2 model

The RZWQM2 model requires a database of input data, including climatic data (maximum and minimum temperature, wind speed, relative humidity, rain, and solar radiation). Along with soil data (depths, texture, bulk and particle density, porosity, saturation percentage, field capacity, permanent wilting point, saturated conductivity, electrical conductivity, degree of reaction, cations, and anions) and other data according to the scenario to be created. Moreover, the agricultural data includes the type of crop, cultivation method, planting density, depth of planted seeds, the distance between plants, the distance between planting rows, harvest date, and yield. As well as, plant dry weight, quantity, method of adding mineral and organic fertilizers, irrigation method, amount of added water, the quality, quantity, and method of adding herbicides, plowing, quality, and quantity of non-decomposed residues added). These data are adopted as input data for all scenarios before starting the model operation. Multiple scenarios were created for simulation under natural field conditions (p) and compared with the measured field data (O) that was used from the application of experiment treatments, where the performance of each scenario was evaluated according to the following equations:

Calculating the Root Mean Square Error (RMSE):

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(pi - oi)^2} \quad (7)$$

Since:-

n: the number of values,

Pi: the simulated value,

Oi: the measured value.

The value of (RMSE Mean Squared Error varies according to the studied characteristics, type of crop, method of measurement, and field management processes, so no range determines the appropriate value for that

Calculating the standard deviation of the root mean square (NRMSE) [10]

$$NRMSE = \frac{RMSE}{Oavg} \quad (8)$$

Since:-

Oavg: The arithmetic average of the measured value.

The (NRMSE) Normalized Root Mean Square error value indicates how well the RZWQM2 model has performed, and the best value is zero when the measured results fit the simulation. A value less than 1 indicates that the simulation was good.

Calculating the Mean Bias Error (MBE) [10]

$$MBE = \frac{1}{n}\sum(pi - Oi) \quad (9)$$

Mean Bias Error (MBE) values indicate a positive or negative system bias in the simulations; a positive value indicates an overestimation and a negative value indicates an underestimation.

Depletion	Conditioners	RMSE	NRMSE	MBE
D1	C0	0.142	0.055	-0.128
	C1	0.337	0.103	-0.215
	C2	0.541	0.182	-0.469
	C3	0.809	0.266	-0.615
D2	C0	0.155	0.110	-0.078
	C1	0.137	0.061	0.070
	C2	0.129	0.068	-0.032
	C3	0.184	0.095	-0.099

Table 2. Criteria for evaluating the performance of the RZWQM2 model to simulate the total dry weight of the different study treatments.

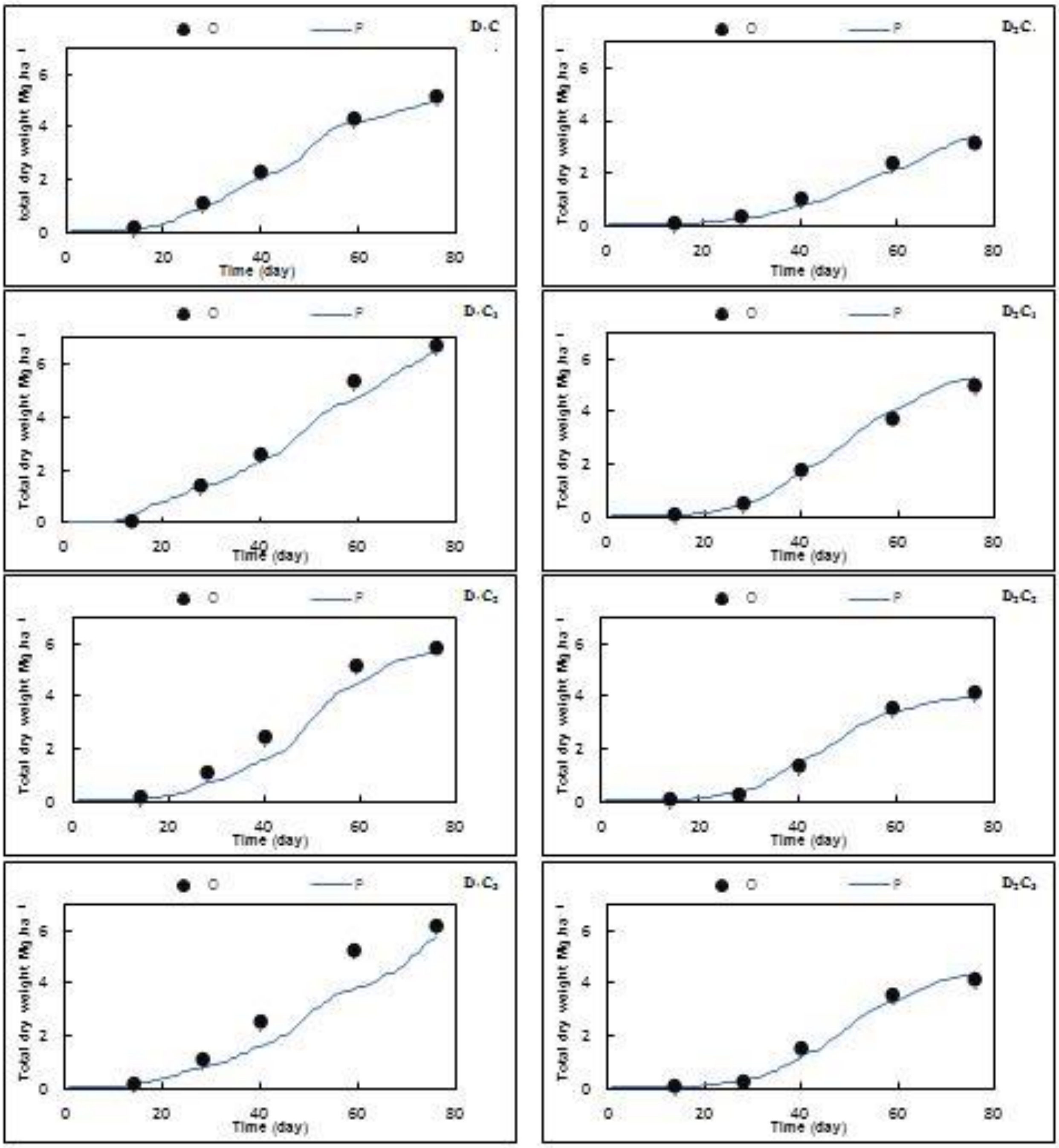


Figure 1. The measured and simulated total dry weight under normal conditions for the different study treatments.

Yield (Mg.ha-1)

It is clear from Figure 2 that the measured and simulated yield increased by adding the conditioners; the measured and simulated yield increased at the compost treatment (C1) than in the rest of the treatments. However, the measured and simulated yield increased at the treatment of adding perlite and adding perlite + compost (D1C2) (D1C3), respectively, over the comparison treatment. The measured and simulated yield decreased at 60% depletion compared to 30% depletion of the available water for treatments due to the effect of water stress on the plant, as there is inhibition of root growth, the small size of leaves, or fruit damage. As well as affecting the absorption rates of the plant, swelling pressure in plants, which keeps plant cells swollen, plants slow down the photosynthesis process and decrease the process of respiration and transpiration, which leads to a decrease in the amount of yield.

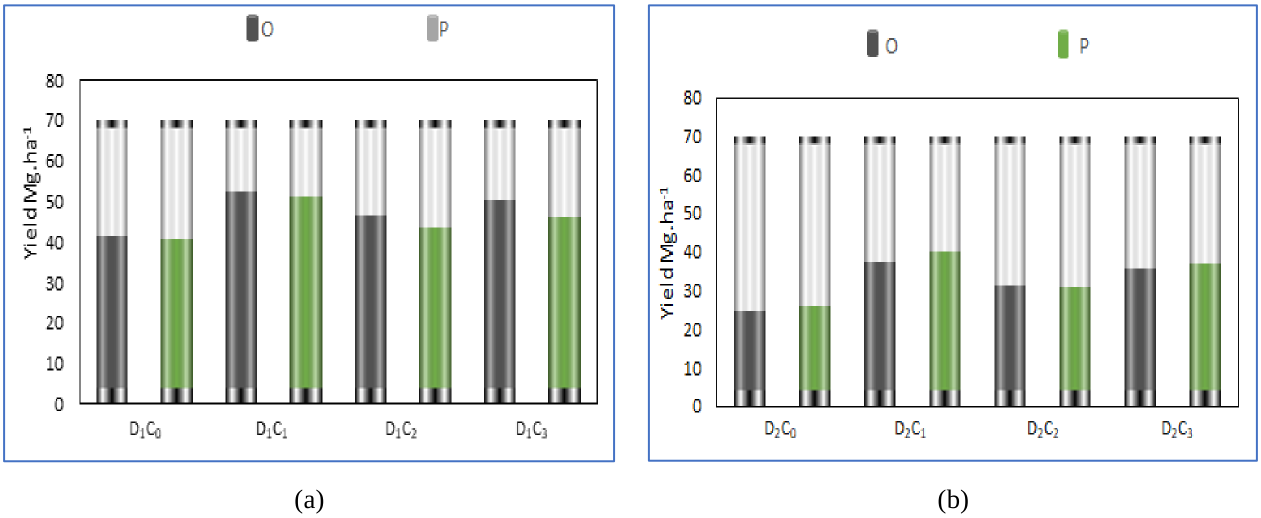


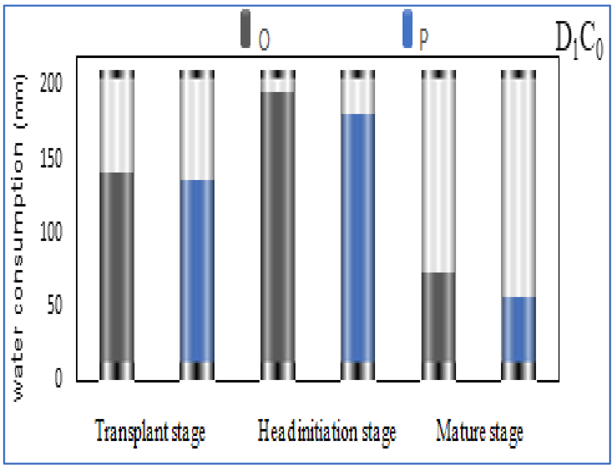
Figure 2. The measured and simulated yield under normal conditions for the different study treatments.

This is consistent with [12] when okra was grown and subjected to water stress; it was observed that it affected the growth and productivity of the okra plant. This was likewise consistent with [13], who showed that the increase in water stresses affected the Cabbage growth and yield. Similarly, it agrees with the findings of [10] in making future scenarios when using the RZWQM2 model that the yield decreased in maize yield when water stresses increased. It was also agreed with [7] that when simulating the amount of water added through the rain in the RZWQM2 model of the soybean plant, the yield increased with the increase in the amount of added water.

Water consumption (mm)

Figure 3 shows a decrease in the water consumption of the plant when adding the conditioners, as the water consumption of the compost treatment (C1) decreased more than the rest of the treatments. It correspondingly decreased at the treatment of adding perlite and adding perlite + compost (D1C2) (D1C3), respectively, than the comparison treatment. Water consumption increased by 30% over the 60% depletion of available water. For all measured and simulated treatments, adding compost at 60% depletion of available water (D2C1) obtained the lowest water consumption in the measured and simulated treatments. The addition of compost to the soil increased its ability to retain moisture more than other treatments, which is consistent with the findings of (Abd El-Mageed et al., 2018). Therefore, the water consumption of the compost treatment decreased at the depletion of 30.60% of the available water (D1C1) and (D2C1), respectively. Plant water absorption decreases when water stresses occur by controlling the main physiological processes such as photosynthesis, respiration, carbon dioxide amount, reduced root growth, and controlling the process of opening and closing stomata (reducing the size of stomata openings); these stress reduces transpiration and keeps the vessels carrying water and nutrients open, in addition to increasing their number in the root and stem.
Furthermore, adjusting the osmotic pressure for the plant's growth process continued, which reduced the plant's measured and simulated water consumption [14]. Water consumption increased with the increase in plant age at depletion of 30% and 60% of the available water due to the increase in the depth of the root and spread. Then, the increase in their efficiency in absorbing water and the increase in the number of leaves and their surface area increased the amount of water lost from

the plant through transpiration to reach its highest rate for all treatments at the leaf wrap stage, Followed by, a decrease as a result of the leaf wrapping process and head formation at the stage of plant maturity, which reduced the surface area of the Cabbage leaves, as well as the decrease in the efficiency of the roots in absorbing water. In addition, the decrease in the temperature and intensity of solar radiation at the end of the growing season of the Cabbage plant (November) leads to a decrease in the evapotranspiration process. It thus reduces the water consumption of the plant.



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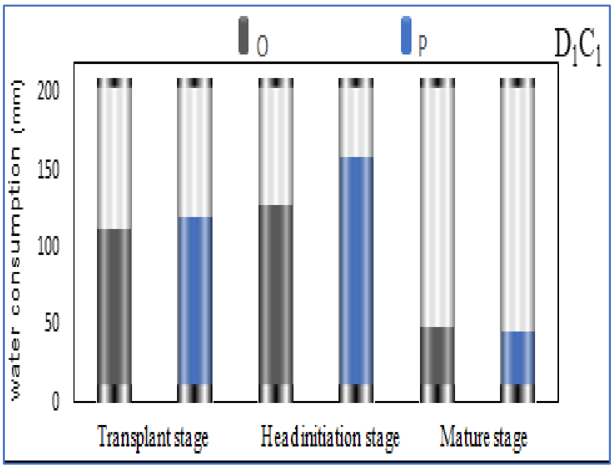

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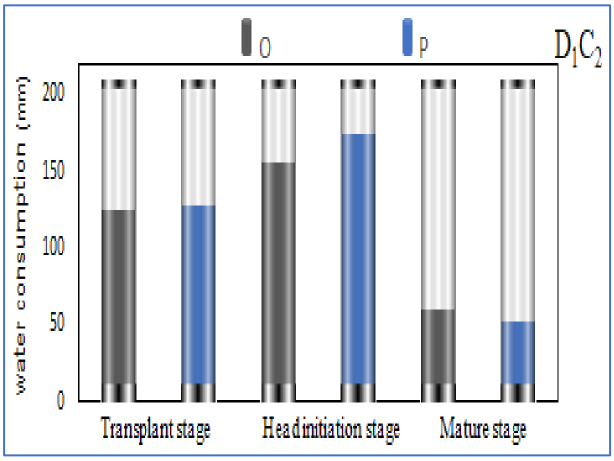

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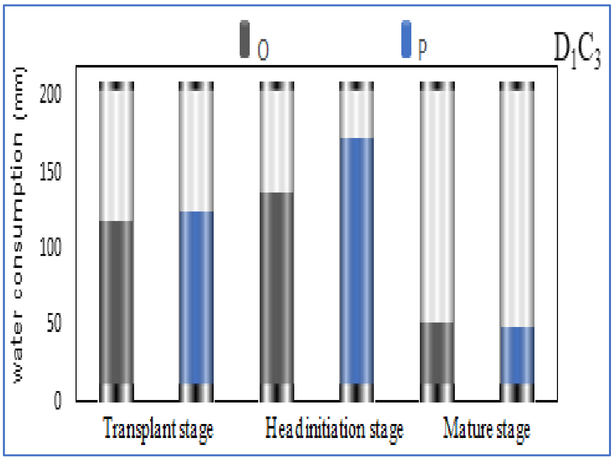

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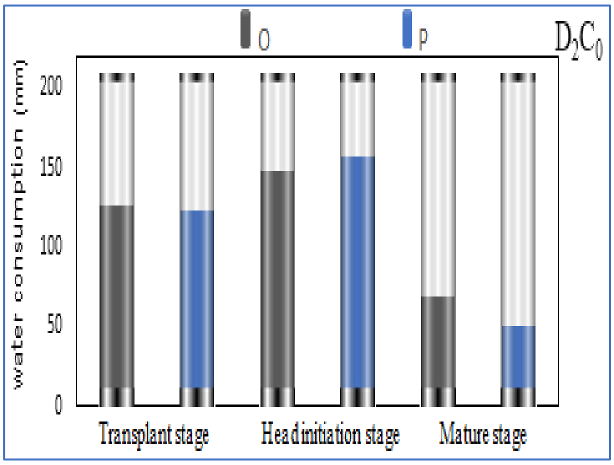

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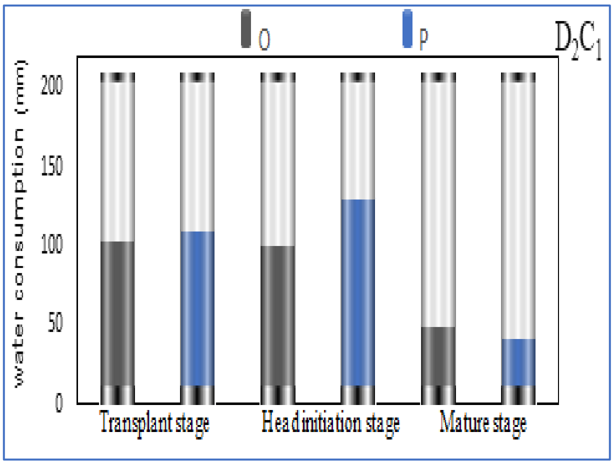

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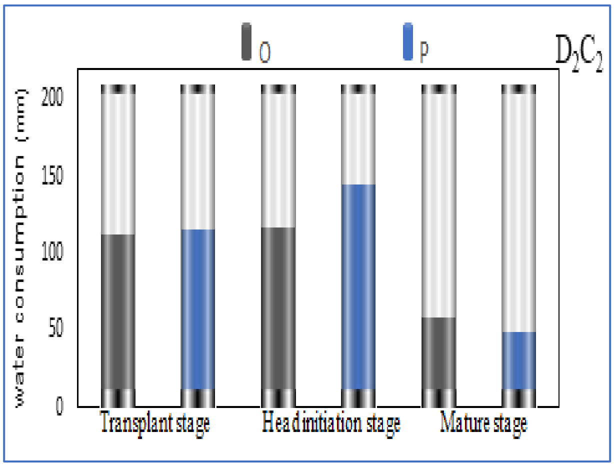

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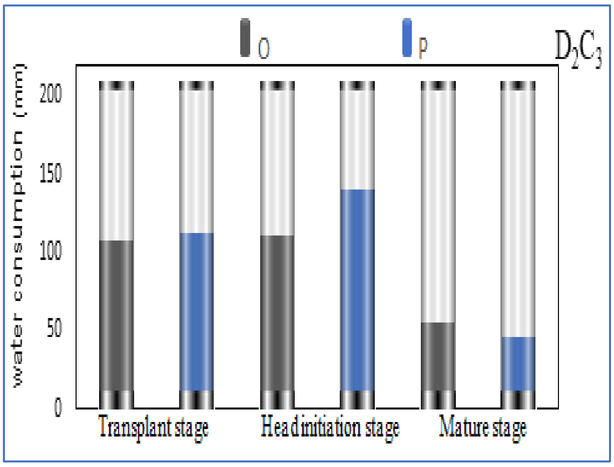

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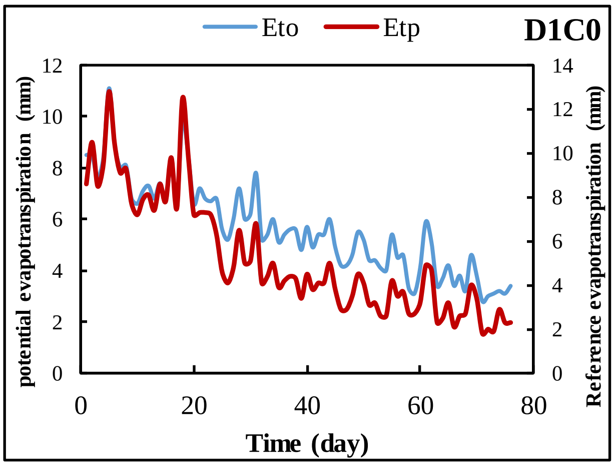
Figure 3. Actual and simulated water consumption under natural conditions during the stages of Cabbage growth.

Reference and potential evapotranspiration (mm)

Figure 4 shows that potential evapotranspiration values decreased with the progression of plant growth time at the depletion of 30 and 60% of available water for all study treatments. The values of potential evapotranspiration decreased by 60 % from 30% of available water due to the occurrence of physiological adaptations for plants to coexist with the water stress conditions. Moreover, there was a decrease in the values of potential evapotranspiration with the progression of plant growth time due to the decrease in temperature. In contrast, the amount of potential evapotranspiration increased at the compost treatment due to its ability to retain moisture. This improves plant growth and optimally carries out its biological activities. This is consistent with [13].



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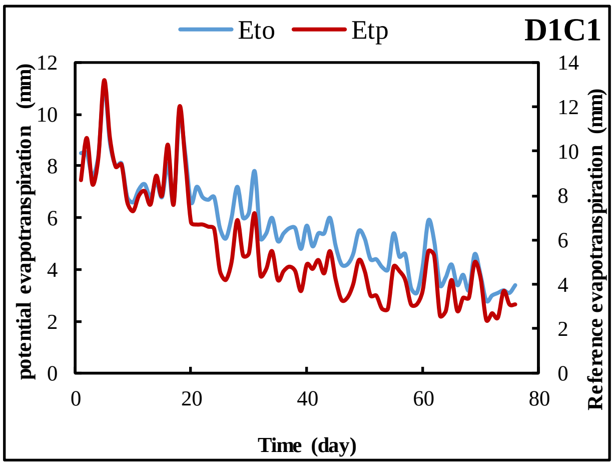

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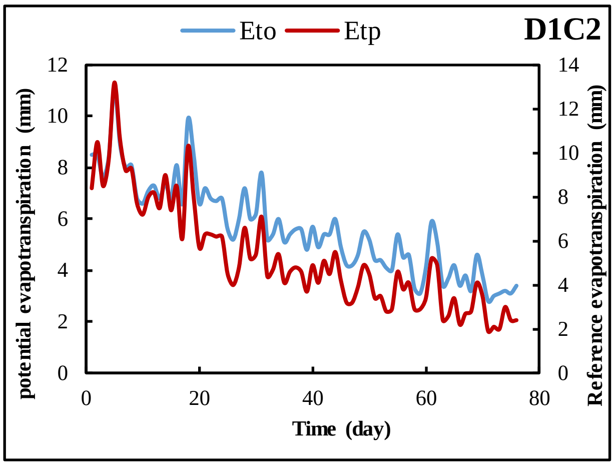

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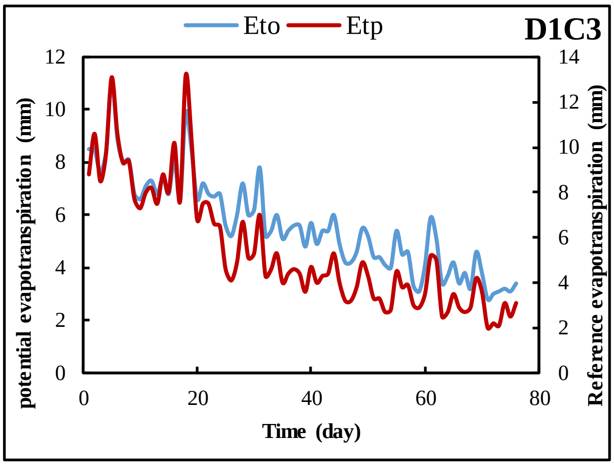

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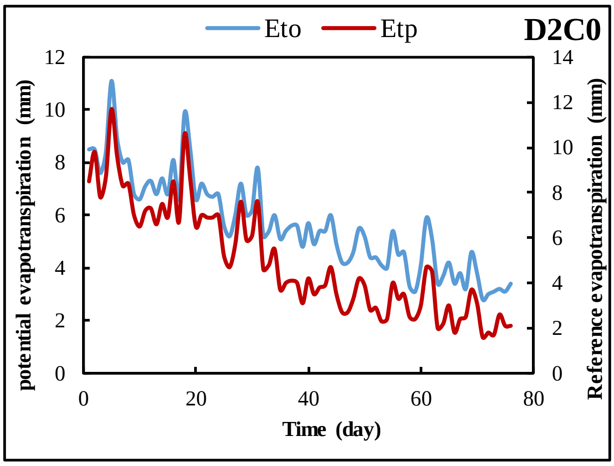

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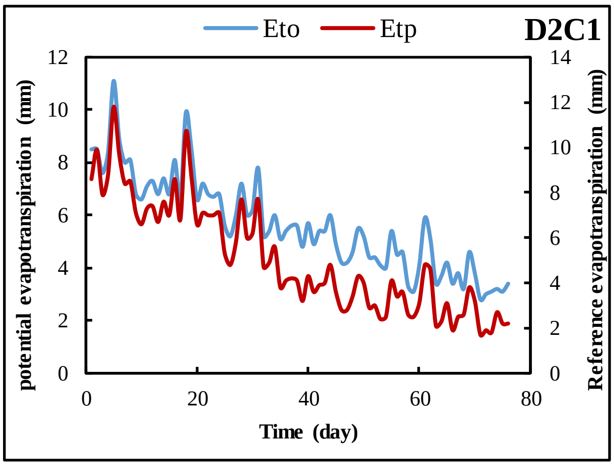

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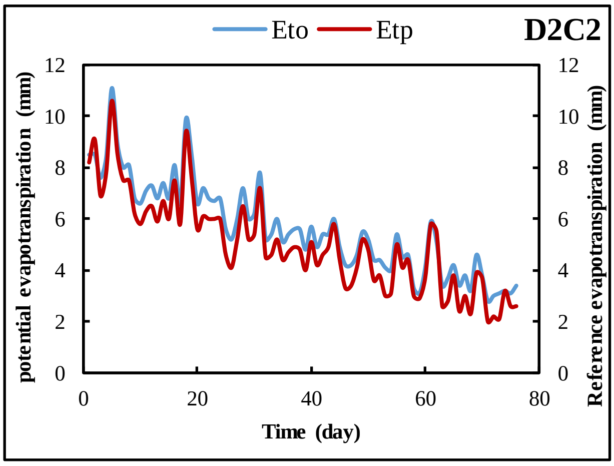

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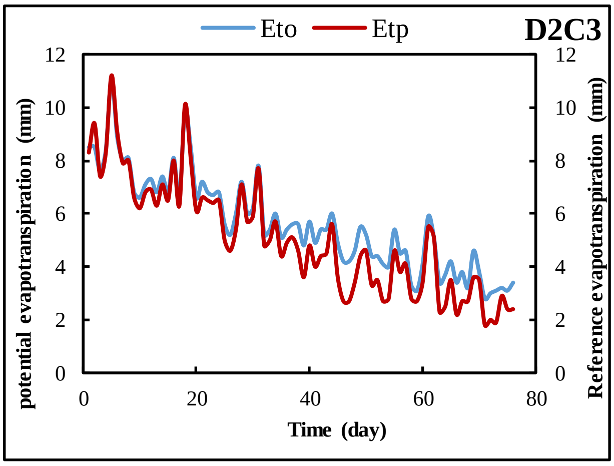

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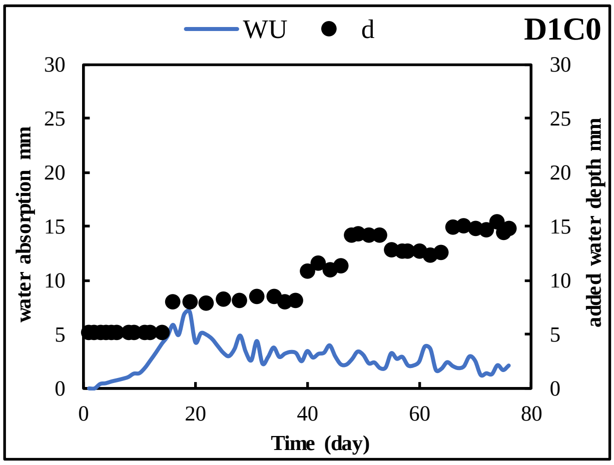
Figure 4. Reference and potential evapotranspiration simulated under natural conditions for the different study treatments.

Plant water absorption

Figure 5 shows the quantities of water absorbed by the plant with the depth of water added in each irrigation. The amount of water absorbed increased at the compost treatment (C1) than at the rest of the treatments. Also, there was an increase in the amount of water absorbed by the plant in the treatment of adding perlite (C2) and compost + perlite (C3) for comparison treatment. It was also shown that the amount of water absorbed by the plant increased at 30 to 60% of the available water, and the amount of water absorbed in the compost treatment increased at the depletion of 30% of the available water (D1C1). The plant's increase in water absorption at the compost treatment (C1) is because it increases the growth of root hairs that have the greatest effect on the absorption process. Keeping the water available for the plant increases its ability to absorb water according to its needs to carry out physiological processes. The amount of water absorbed increases with the increase of the evapotranspiration process, the density and depth of roots, the increase in the saturated water conductivity, and the soil's ability to retain moisture [6] The decrease in the water consumption for the percentage of depletion of 60 than 30% of available water is attributed to the adaptation of plants to water stresses. In addition to the fact that whenever the water stresses increase, the soil water holding capacity increases, this is consistent with [5].



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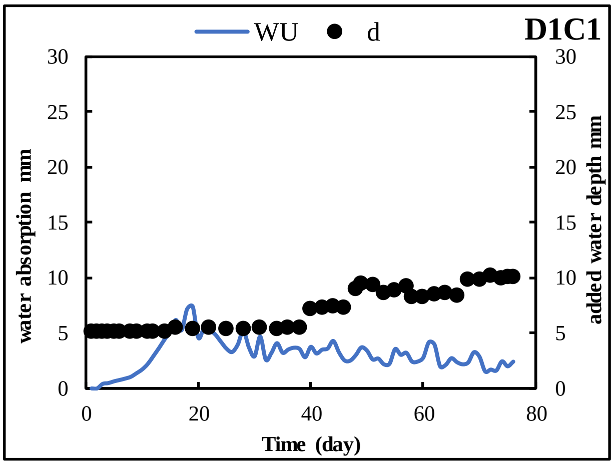

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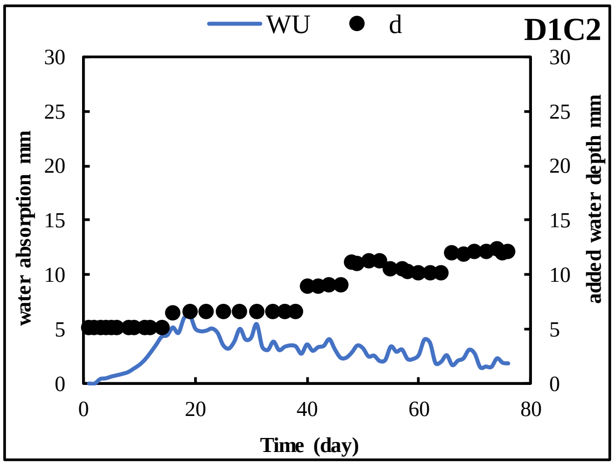

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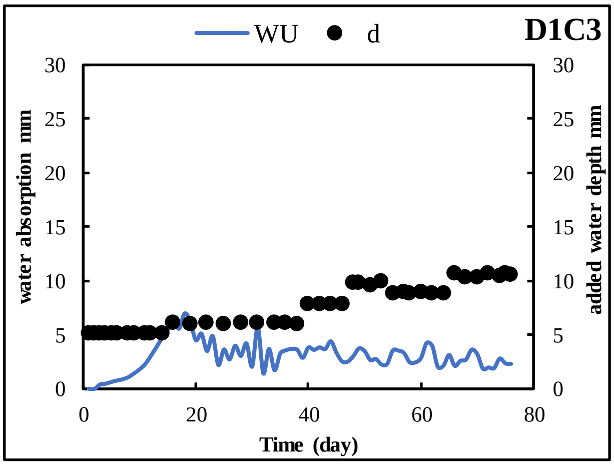

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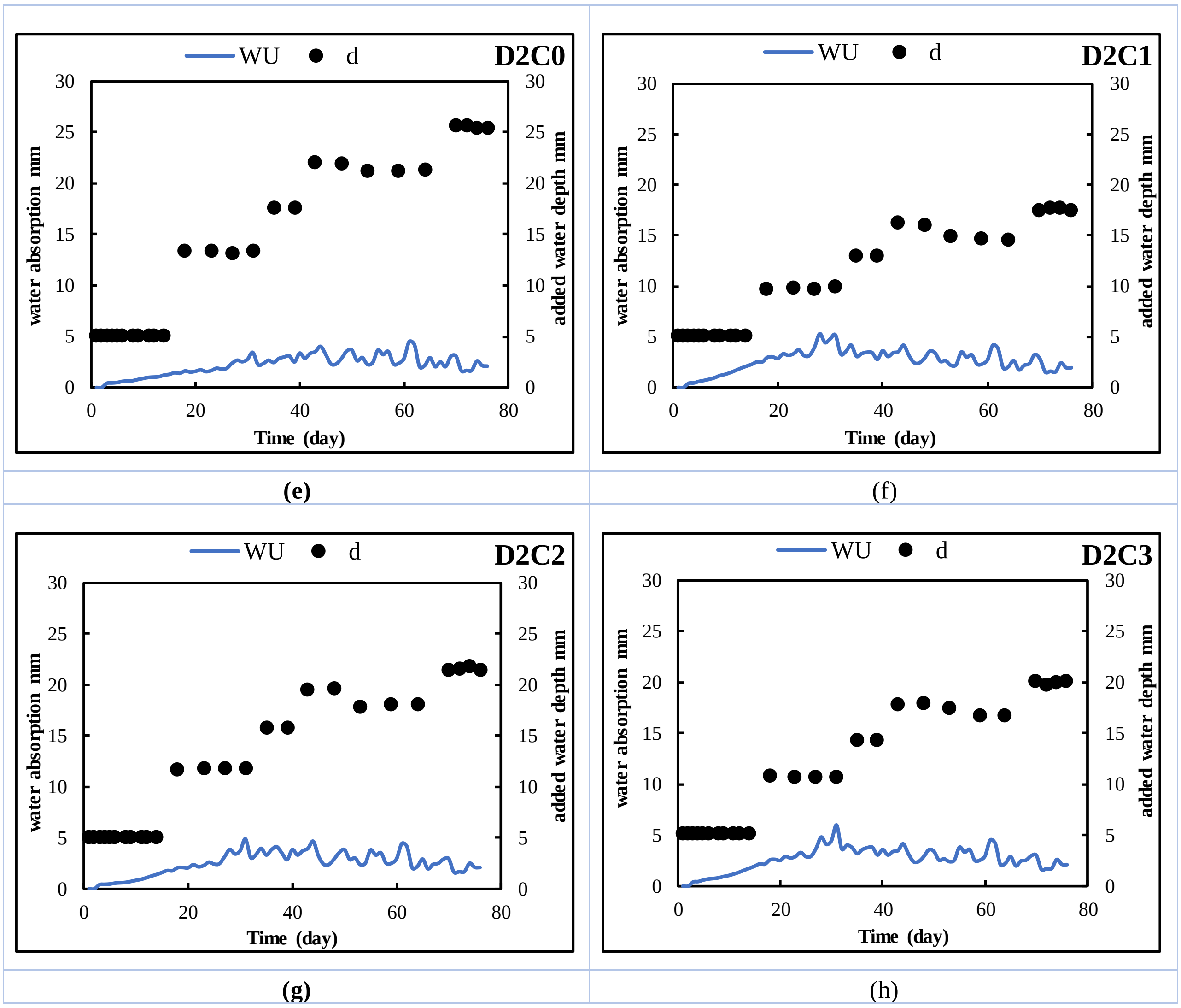

Figure 5. Plant absorption of simulated water under natural conditions and the depth of water added for the different study treatments.

Crop water use efficiency (kg.m^{-3})

It was observed from Figure 6 that the values of crop water use efficiency for the treatments of adding conditioners have increased over the comparison treatment. The values of crop water use efficiency for adding compost (C1) increased than the rest of the treatments. Also, the values of crop water use efficiency for adding perlite (C2) and compost + perlite (C3) increased than the comparison treatment. The values of crop water use efficiency for the percentage of depletion of 30% exceeded 60% of the available water. Furthermore, it is noted that the values of crop water use efficiency increased in the compost treatment at the depletion of 30% of the available water (D1C1). This increase is attributed to an increase in the yield at the depletion of 30% over 60% of the available water, as well as a decrease in the water consumption of the treatments of adding compost, which is characterized by its retention of water and chelating of nutrients that keep them available for absorption by the plant, which improves the physical, chemical, fertility and vital characteristics for soil [15], which led to its superiority over the rest of the treatments.

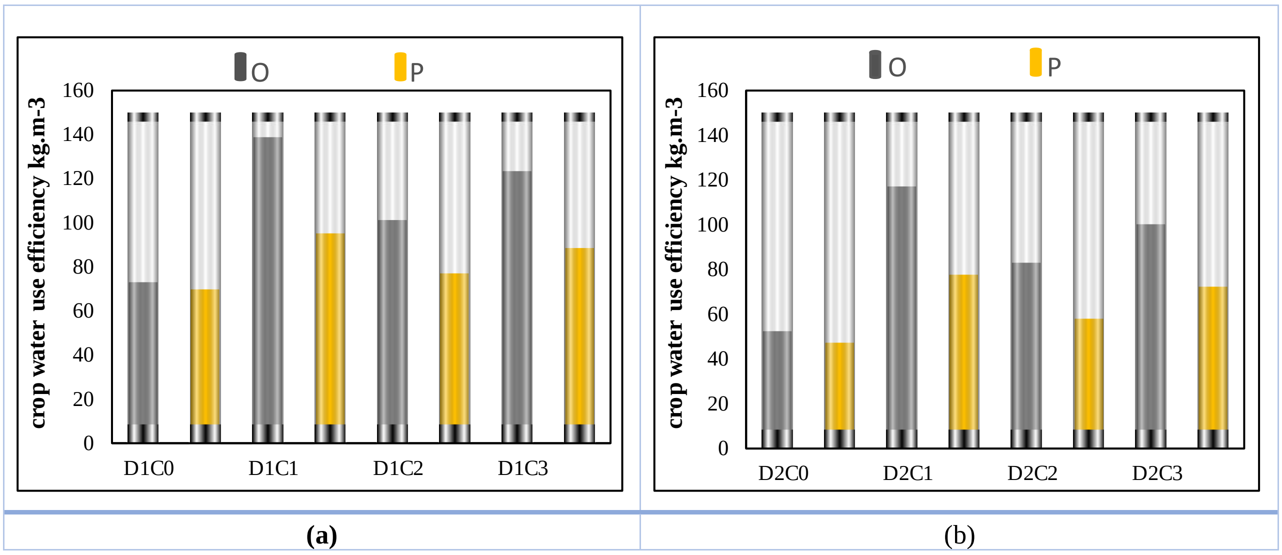

Figure 6. The different study treatments simulated Crop water use efficiency under natural conditions.

Discussion

RZWQM2 model

The total dry weight of the plant, yield, water consumption, potential evapotranspiration, plant water absorption, and crop water use efficiency are among the most important outputs of the RZWQM2 model, as a scenario was created for each of the studied treatments during the planting season of Cabbage plant for the season 2021.

Total dry weight (Mg.ha-1)

The total dry weight is defined as the weight recorded after drying the plant tissues at a temperature of 65 °C, leading to water evaporation. The dry weight is a handy and reliable indicator when looking for an assessment of plant growth, especially after applying treatments to increase productivity or the quality of the yield. This weight will provide an accurate biomass measurement directly related to the plant's vital activities. Dry weight is used to measure the weight of a part of the plant as specific plant tissues (leaves), fruits, or the whole plant. Therefore, it refers to all components of the plant except for water (Shipley and Vu, 2002). Samples of plants were taken randomly at five stages of growth on 17/9/2021, 1/10/2021, 13/10/2021, 1/11/2021, and the fifth at the time of harvest on 18/11/2021. In each stage, four plants were taken from each experimental unit, where the plant was cut from above the soil surface and air-dried for two days and then placed in the oven for 48 hours at a temperature of 65 ° C. The weights of the plants were taken before and after drying on a sensitive scale with three decimal places. It is evident from Figure 1 that the total dry weight of the simulated plant increased with the addition of conditioners to its ability to preserve moisture in the soil and chelating nutrients. The total dry weight of the simulated increased at the compost treatment (depletion of 30%) of the available water (D1C1) than in the rest of the treatments. Also, there was an increase in the treatment of adding perlite and the treatment of adding perlite + compost (D1C2) and (D1C3), respectively, over the comparison treatment. The increase in the dry weight of the plant is attributed to the addition of compost, which increases the soil's water retention and the retention of nutrients available for absorption by the plant. Besides, adding perlite preserves water and nutrients in its cavities to be available for absorption by the plant. Figure 1 also shows the decrease in the total dry weight of the plant at depleting 60% of available water due to the effect of the effectiveness of the plant's vital processes by a decrease in the amount of absorbed water, especially the ability to photosynthesis. Despite the occurrence of complex physiological and chemical adaptations to adapt to stressful environmental conditions, including long-term evolutionary adaptations such as changing the leaves' orientation or mechanisms of adaptation in the short term, such as narrowing of the vessels, growth is affected, and thus the total dry weight of the plant decreases [11]. The treatment of adding compost was the best because of the ability of compost to retain water and make it available for plants under water-stress conditions. It is noted in Table 2 that in the RMSE values, which show the average square error between the measured and simulated values, no range determines the appropriate value. In contrast, the NRMSE values were less than 1 for the simulated treatments at the depletion of 30 and 60% of the available water, which indicates the efficiency of using the model in predicting under the conditions of the experiment. However, the MBE values were negative, indicating a negative bias, except for D2C1, which was a positive bias.

Conclusion

The RZWQM2 model was used to simulate adding soil conditioners at different depletion rates in the Cabbage plant's productivity. However, the measured and simulated yield decreased due to the effect of water stress on the plant. Also, the Cabbage growth and yield were affected by the increase in water stresses. Besides, the water consumption varies for the three stages of growth of the Cabbage plant (vegetative growth, leaf wrapping, and maturity), the number of days of the growth phase, the number of irrigations in it, and the increase in the plant size, its height, and its leaf area. Furthermore, the values of potential evapotranspiration decreased due to the occurrence of physiological adaptations for plants to coexist with the water stress conditions. The plant's increase in water absorption by the compost treatment increases the growth of root hairs, which have the greatest effect on the absorption process. Finally, the increase in crop water use efficiency is attributed to an increase in the yield at the depletion of 30% over 60% of the available water.

References

1. Abd El-Hady, M.; El-Dardiry, E.I. Improving hydrophysical properties quality of compost. Journal of Applied Sciences Research, 2006, 2.12: 1137-1141.
2. Ahuja, L. R.; Ma, L. Parameterization of agricultural system models–Current approaches and future needs, Chapter 14. Agricultural system models in field research and technology transfer. Lewis Publ., Boca Raton, FL, 2002.
3. Allen, R.G.; Pereira, L.S.; Raes, D.; Smith, M. FAO Irrigation and drainage paper No. 56. Rome: Food and Agriculture Organization of the United Nations 56 (97): e156. 1998.
4. Anapalli, S. S.; Pinnamaneni, S. R.; Fisher, D. K.; Reddy, K. N. Vulnerabilities of irrigated and rainfed corn to climate change in a humid climate in the Lower Mississippi Delta. Climatic Change, 2021, 164.1: 1-18.
5. Bewick, T. A. Cabbage: Uses and production. University of Florida: Florida Cooperative Extension Service Fact Sheet HS-712, 1994.
6. Ibraheem M W, AL Mjbel A A, Abdulwahid A S, Mohammed Th. T. Characterization of the influence of diet on Japanese quail. Revis Bionatura. 2022;7(4) 21. http://dx.doi.org/10.21931/RB/2022.07.04.21.
7. Duong, T. T. T. Compost effects on soil properties and plant growth. (Doctoral dissertation), 2013.
8. Blake, G. R. Bulk Density in Black C. A.; Evans, D.D.; White, J. L.; Ensmine, L. E.; Clark, F.E. (eds) Methods of Soil Analysis Part 1. Physical and Mineralogical Properties, including Statistics of Measurement and Samples. In: Am Soc Agron. 1965. p. 604-613.
9. Duursma, R.A.; Blackman, C.J.; Lopéz, R.; Martin-StPaul, N.K.; Cochard, H.; Medlyn, B.E.. On the minimum leaf conductance: its role in models of plant water use, and ecological and environmental controls. New Phytologist, 2019, 221.2: 693-705.

10. Gao, J.; Qiao, M.; Qiu, X.; Zeng, Y.; Hua, H.; Ye, X.; Adamu, M. 2018. Estimating actual evapotranspiration distribution in the Huaihe River upstream basin based on the generalized complementary principle. Advances in Meteorology, 2018.
11. Ghehsareh, A.M.; Hematian, M.; Kalbasi, M. Comparison of date-palm wastes and perlite as culture substrates on growing indices in greenhouse cucumber. International Journal of Recycling of Organic Waste in Agriculture, 2012, 1.1: 1-4.
12. Hobi, A. A. .; AL-Helal, A. . Effect Of Alcoholic Extract Of Opuntia Ficus Indica On Semen Quality Of Awassi Rams After Different Cooling Periods. JLSAR 2021, 2, 9-13..
13. Havlin, J. L.; Beaton, J. D.; Tisdale, S. L.; Nelson, W. L. An introduction to nutrient management. Soil Fertility and Fertilizers, 6th ed.; Prentice Hall: Upper Saddle River, NJ, USA, 1999, 499.
14. Jackson, M. L. Soil chemical analysis prentice Hall. Inc., Englewood Cliffs, NJ, 1958, 498: 183-204.
15. Klute, A. Laboratory measurement of hydraulic conductivity of saturated soil. Methods of Soil Analysis: Part 1 Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling, 1965, 9: 210-221.

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