Techno-Science Research Journal V13 (1) (2025) P 1-7

Content list available at ITC

Techno-Science Research Journal

Journal Homepage: http://techno-srj.itc.edu.kh/

Techno-Science Research Journal

Effect of Different Irrigation Methods on Water Use Efficiency in Rice Soil Column Test

Channtola Sot[1*], Chenda Lai[1,2], Mengheak Phol[1], Pinnara Ket[1,2]

[1]*Faculty of Hydrology and Water Resources Engineering, Institute of Technology of Cambodia, Russian Federation Blvd., P.O. Box 86, Phnom Penh, Cambodia*

[2]*WAE Research Unit, Institute of Technology of Cambodia. Russian Federation Blvd, PO Box 86, 120404 Phnom Penh, Cambodia*

Received: 12 September 2023; Revised: 28 January 2024; Accepted: 25 March 2024; Available online: 30 April 2025

Abstract: *Rice plays a crucial part in Cambodia's agricultural landscape,serving as a primary food source for the population. The limited water in dry season becoming an increasing concern in the region,optimizing irrigation methods is to modify water consumption in rice production. This study was conducted to investigate the effect of three irrigation methods on the grain yield and water use efficiency of rice crops in soil columns under a nethouse with glass roof. A field experiment was conducted at the Cambodia Agriculture Research and Development Institute (CARDI), Cambodia. Rice was planted in February 2023 under different three irrigation methods. Three irrigation regimes were examined during the growing period as follows: shallow deep shallow irrigation (T1), shallow frequency irrigation (T2),and continuous soil field capacity with irrigation depth at 10 mm daily (T3). Plant parameter and water amount data were collected during the growing period to evaluate the total yield and water use efficiency (WUE) of rice. The total average irrigation depth of different irrigation methods were 1050.67, 830.69 and 616.8 mm for T1, T2 and T3,repsepectively. According to results of effect on grain yield and WUE were found significant difference. Both grain yield and WUE of T1 treatment obtained the highest value followed by T2,and T3 treatment,respectively.*

Keywords: Rice soil column; Water use efficiency; Water-saving irrigation

1. INTRODUCTION

Rice stands as the lifeblood of Cambodia's agricultural landscape, supporting both food security and livelihood [1], [2]. The water source for Cambodia's rice cultivation in the dry season mostly depends on small ponds, rivers, and streams beside the field, or pumping groundwater due to the lack of irrigation systems [3]. In the coming decades, the rice cultivation need to be increased to feed the increasing population while limited water and land resources and under climate change. Currently, Cambodia's population is 15 million people in 2019, and is expected to increase 1.27 per cent in 2030 [4].

Cambodia is known to be prone to the climate change especially food and drought that often damage to the agriculture activities [5]. Despite these challenges, most of the farmer still practice the tranditional cultivation such as flooded irrigation method that consumes a large amount of water. Therefore, there is an urgent need to use water efficiency through different practices and technologies to mitigate against the climate change and water shortage for rice production in Cambodia.

Therefore, water-saving methods are key to approaching high water use in conventional irrigated rice fields. The established literature demonstrated that nearly 2 decades years identify irrigation methods that are resilient to maintance and enhance water use efficiency and potentially rice yield [6], [7]. Different irrigation practices or methods such as direct seeded rice [8], continuous soil saturation [9], alternate wet and dry [9], and noon-flood mulching condition [10] have been introduced to reduce water consumption and improve crop water productivity in rice enviroments. However. there are limited studies on irrigation water saving for rice cultivation in Cambodia.

To address this gap, this study aims investigate the effect of three different water-saving irrigation methods on Cambodian rice. The three irrigation water saving methods

* Corresponding author: Channtola Sot
E-mail: sot_channtola@gsc.itc.edu.kh; Tel: +855 96 467 2324

are i) shallow deep shallow irrigation, ii) shallow frequency, iii) continuous soil field capacity. Two irrigations water saving methods, shallow deep shallow irrigation and shallow frequency were introduced by Gansu Academy for Water Conservation of China.

2. METHODOLOGY

2.1 Description of study area and experimental site

The field experiment of rice cultivation in the soil columns under different irrigaton regimes was conducted at Cambodia Agricultural Research and Development Institute (CARDI), Phom Penh (11°28' 32" N, 104° 48' 2" E), from 28 February to 14 June 2023 under net house with glass roof .

The climate of the experimental site is influenced by the monsoon winds. Average temperature has a hot and humid climate with average temperature range from 25 to 30 ^{0}C.

Table 1. Physical and chemical properties of soil

Parameter	Prateah Lang soil		
Soil layer	**0-21 cm**	**21-40 cm**	**40-50 cm**
% Clay	31.68	35.17	51.50
% Silt	14.40	11.70	14.50
% Sand	53.92	53.13	34.00
Bulk desity (g/cm3)	1.46	1.72	1.69
pH	5.04	5.42	5.55
EC (µs/cm)	47.54	20.01	16.57
FC (cm3/cm3)	0.34	0.23	0.35
WP(cm3/cm3)	0.28	0.16	0.24
Total available water(cm3/cm3)	0.06	0.07	0.11
Hydraulic conductivity (m/s)	9.E-06	7.E-07	9.E-06
Total Nitrogen (%)	0.06	0.06	0.04
Available Phosphorous (mg/kg)	202.53	158.78	167.42
Exchangeable Potassium (meq/kg)	0.06	0.06	0.03

Note: Soil column samples three layers of soil horizontal. The soil of each layer was sampled from 0-21, 21-40, and 40-50 cm.

2.2 Soil material and soil column preparation

There was 12 undisturbed bulk soil samples using PVC with height of 60 cm and diameter of 15 cm were collected using from an active paddy field site (12°33'11.63"N, 105° 2'36.35" E) in the Kampong Thom province, Cambodia on December 2022 for the experimental at CARDI. The soil type is called Prahteah Lang [11]. The PVC tube of the soil column with a height of 60 cm and a diameter of 15 cm. The schematic of the soil column of the experiment was shown in **Error! Reference source not found.**. The 30 cm top of top soil columns of sample was plowed by hand. The graval and sand was included at the bottom of column for drainage.

The root depth of rice was found in the soil layer deeper than 30 cm below the soil surface [12]. The soil profile of the experiment provided three different soil layers. The soil physico-chemical properties were analyse and shown in Table 1. Soil texture were determined using a hydrometer [13]. Bulk density was defined by the core ring method[14]. Hydrualic conductivity was measured by saturated hydraulic conductivity method [15]. The total available water was determined by soil moisture pressure plate apparatus [16]. Soil pH and electrical conductivity (EC were determined in 1:5 soil and water-extracted liquid by using pH and EC meter device [17]. Available soil Nitrogen (N) was measured using the Kjeldahl method [18]. Available soil phosphorus (P) was measured according to the Olsen method [19]. Exchangeable soil potassium (K) was determined using a flame photometer [20].

The average result of pH and EC of the soil were acceptance to growing in this range. Additionally, N P K fertilizer of the soil was provided more nutrients to rice crops. The value bulk density on top soil of rice was better in soil structure and porosity for rice root as it allowed for root penetration, water movement and nutrient availability. Moreover, the hydraulic conductivity of the soil was beneficial as it allowed for efficient water infiltration, reducing the risk water logging for plant. The physico-chemical properties of soil plant growth condition was detailed by [21].

The soil column was plowed at 30cm, by removing the left direct of the soil and filling the soil back into the column. A bottom valve was to support the saturation condition while starting rice condition and a cover PVC pipe was fitted to ensure that there was no soil loss whilst allowing excess water. However, during the experiment atmospheric conditions were applied by letting the valve open.

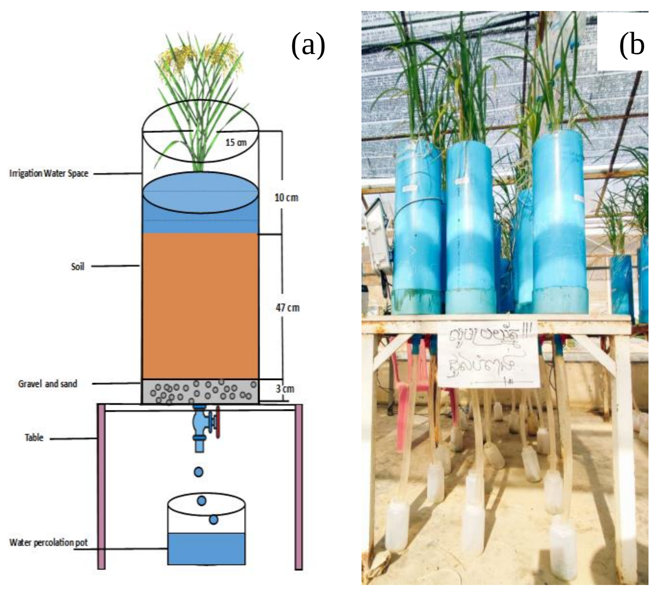

Fig 1.(a) Schematic diagram of the rice soil column experiment; and (b) physical diagram of the rice soil column experiment device

2.3.Rice meterail and cultivation

The 3 months rice cultivar, fragant Sen Kra Ob 01 (SKO-01), developed by CARDI was selected for the experiment. The four seed rices were sown in the each soil column in late Febraury and harvested in mid-June 2023. Each soil column was sowed with four seedlings.

The dose of fertilizers recommaded from CARDI were used for each treatment. Total of fertilizer of concentration was used for 427.68 kg/ha of NPK (100:40:80) included N (0.136 g as urea), P (0.16 g as single superphoshate) and K (0.23 g as KCl) were applied and incorporated two days before sowing stage of rice. P and K were applied at tillering stage as same amount as sowing stage

2.4 Experimental design and treatments

Three irrigation treatments: Shallow Deep Shallow irrigation (T1), Shallow Frequency irrigaiotn (T2), and continuous soil field capacity with irrigation depth at 10 mm daily (T3) were applied. Each treatment was replicated for three time. **Error! Reference source not found.** illustrated that the 3 irrigation treatment applications during the growing season. Shallow Deep Shallow irrigation (T1) was adapted from the flooded irrigation by keeping the water level between 10 cm to 70 cm. Shallow Frequency irrigation (T2) was designed base on the flood irrigation method, maintaining the water level within the range of 10 cm to 30 cm. Continuous soil field capacity with irrigation depth at 10 mm daily (T3) was adapted by trying to keep soil at field capacity with the irrigation depth of 10 cm as daily through the growing season.

2.5. Data collection

Evapotranspiration data in th net house was mearsured using pan evaporation. estimated the evapotranspiration (ET0) data. The coefficient Kp of 0.75 of the pan with value was determined based on [22]. Temperature was measured by using Thermometer (Working temperature –30 to +50 ^{0}C, ETI). Input of irrigation and output of percolated data in each experimental soil column were recorded daily.

Above ground biomass were collected from total plants in each column after harvesting and dried it in oven at 70 ^{0}C for 2 days. Grain yield was used air dried method for 2 days before weighting on mass balance. Additionally, the plant height was recorded every 7 days (From lately April to early June).

2.2.4 Water use efficiency

Water use efficiency (WUE) is defined as the ratio of the crop yield to irrigation water applied [23]. WUE can be increased by practicing deficit irrigation, improving irrigation technology scheduling, and improving agronomic practices that lead to yield increase. WUE was calculated according to [24] as follows:

$$\text{WUE (kg/m}^3\text{)} = \text{Yield (kg)/Total water applied(m}^3\text{)} \quad \text{(Eq. 1)}$$

Table 2. Three different irrigation treatments design

Irrigation treatment		R stage	E stage	L stage	J-B stage	H-F stage	M stage	Y stage
T1	Upper limit of irrigation amount above soil surface (mm)	30	30	Field drying	70	70	30	
	Lower limit of irrigation amount above soil surface (mm)	10	10	Field drying	20	20	10	Water draining
T2	Upper limit of irrigation amount above soil surface (mm)	30	30	Field drying	30	30	30	
	Lower limit of irrigation amount above soil surface (mm)	10	10	Field drying	10	10	10	Water draining
T3	Irrigation amount above soil surface (mm)	10	10	10	10	10	10	10

Note: R,Rice growth for 24 days after sowing stage ; E,Early tillering stage; L, Later tillering stage; J-B,Joint-booting stage; H-F, Heading-flowering stage; M,Milk stage; Y,Yellow ripening stage. Different three irrigation methods (T1: Shallow depth Shallow irrigation; T2: Shallow frequency irrigation; T3: Continuous soil field capacity with irrigation depth at 10 mm daily)

2.3 Statistical analysis

Statistical analyse was perfomed using R version 4.0.4. To investigate the effect of different four irrigation methods on yield and water use efficiency of rice crops, the grian yield and water use efficiency data in this study were analyse statistically using analysis of variance (ANOVA), Least Significant Different (LSD) test at 5 % level of significance was conducted to exmine statisticant differences between means. The mean values of each treatment were designed by letters (a,b) which represent the significant degree of the difference between the means. Mean represented by two letters in common indicates that the difference is not significant or weakly significant.

3. RESULTS AND DISCUSSION

3.1 Irrigation water balance

Fig 1 shows the variation of weather condition (Evapotranspiration and temperature), average irrigation depths and average percolation of different treatments during growing season from March to May 2023 starting from the early tillering stage to yellow repening stage.

Fig 1 (A) gives the maximum and minimum variation temperature was between 35 to 45 ^{0}C and 25 to 27 ^{0}C respectively from March to May 2023 from the early tillering to late tillering stage, and maximum between 34 to 43 ^{0}C and minimum between 27 to 30 from lately May to early June 2023 from heading-flowering stage to harvest stage. The daily evaporation and ETo varies between evaporation was 3-4 mm/day and 0.8-3 mm/day respectively.

Fig 1 (B) shows the maximum average irrigation depths applied for T1 are between 10-30mm/day from early tillering to late tillering stage and increasing to between 40-70mm/day from the late tillering stage . For T2, the irrigation depth applied were between 15-30mm/day during the growting season. For T3, the irrigation depths of 10mm were applied.

Fig 1 (C) illustrates the percolation rates of T1 were between 0 to 17 mm/day. For T2, the percolation rate resulted in range of 0 to 10 mm/day. There was no percolation for the treatment T3.

3.2 Effect of irrigations on plant height growth

Fig 2 shows the growth of rice heights from the heading flowering stage to yellow ripening stage. T1 illustrate the highest growth from 70 to 80 cm, while T2 and T3 show similar growth from 70 to 79 cm.

A previouse study indicated that initial growth in rice plant height was slow under flooding condition but increased progressively after emerged from water. However, using saturated conditions was rapid at rice initial growth. Under different irrigation methods (flooding and saturated condition) of rice cultivation provided variation height in any specific rice growth stage [25]. Meanwhile, the result of rice height under T2 treatment was also accelerate growth rate at beginning, however slowly growth after next rice growth stage compared to T1 treatment.

3.3 Effects of irrigations on plant above ground biomass, total height, grain yield

Total irrigation depths

Fig 3 and Table 3 illustrates total average irrigation depths of different treatments. T1, T2 and T3 consumes the amount of water depth of 801.1mm, 653.9mm, 616.8mm respectively. T1 consumed 1.2 times compared to T2 and T3. This noted that the monitoring the irrigation depths was by manual water application, resulting in limited accuracy of precise irrigation depth.

Above ground biomass

Fig 4 illustrates the effect of the treatments to the above ground biomass. There are not slightly difference between the total biomass of the treatments (P > 0.05). T1, T2 and T3 gave the biomass yields of 10.6, 10.5, 8.9 g/column respectively. T3 decreased the biomass of around 16% compares to T1 and T2.

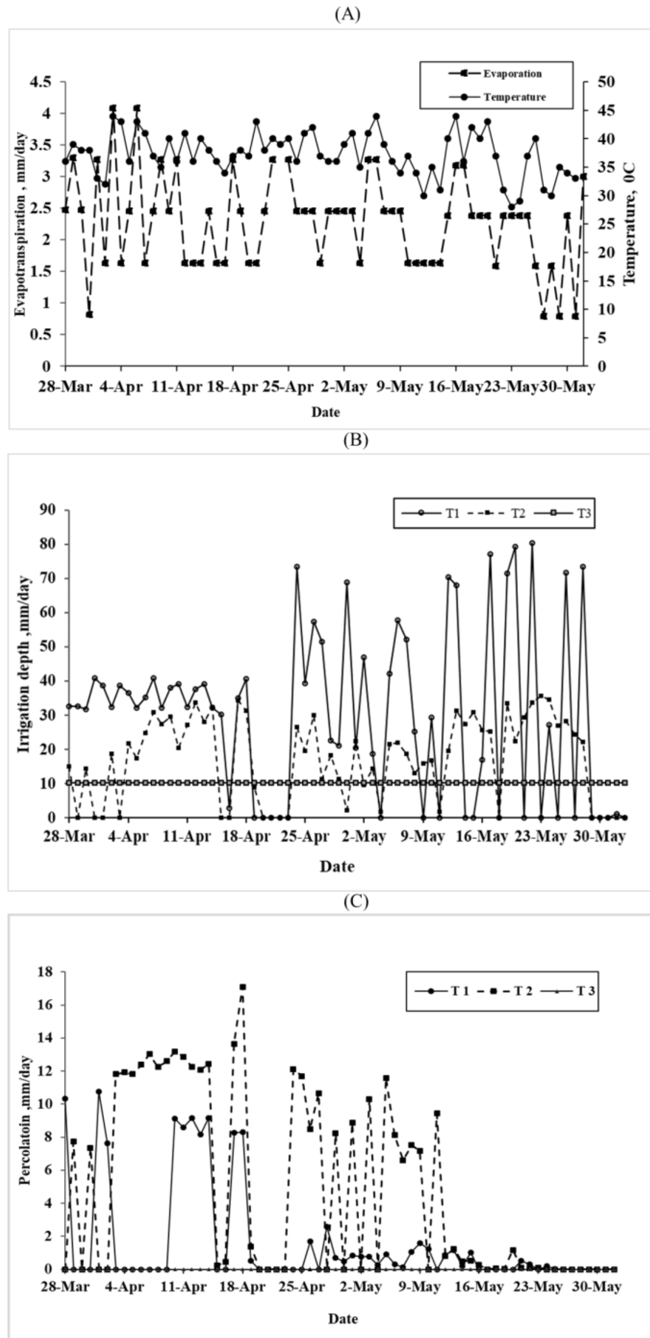

Fig 1. Irrigation water balance. (A) Daily evapotranspiration and temperature ; (B) Daily irrigation depth data; (C) Daily percolation under the net house with glass roof. Different three irrigation methods (T1: Shallow depth Shallow irrigation; T2: Shallow frequency irrigation; T3: Continuous soil field capacity with irrigation depth at 10 mm daily)

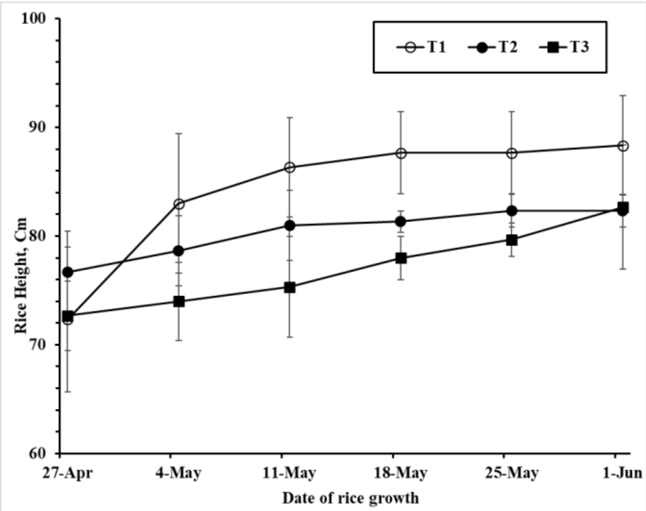

Fig 2. Average rice plant height under three irrigatoin methods (T1: Shallow depth Shallow irrigation; T2: Shallow frequency irrigation; T3: Continuous soil field capacity with irrigation depth at 10 mm daily).

Final rice plant heigh

The rice height of T1 treatment was greater than T2 and T3 treatement, while the lower was found in T3 treatmentat harvesting stage (Final plant height). All above of the height

Fig 4 shows the effect of irrigations to the total plant heights. T1, T2 and T3 gave the average plant height between 88.3, 82.3 and 82.7 cm respectively. The difference of the plant height were around 5cm between T1 and T2/T3. Based on CARDI, the standard rice height of the Sen Kra Ob 01 are between 107 to 114 cm. The current height of rice plants are less than the standard height of 17 to 23%.

The difference of the current rice height to the standard would be due to the effect of temperature stress during the growing season. Previouse studies also indicated that the optimum condition of rice growth in tropical regions should be between 25 to 35 ^{0}C [26], in which the current study, the temperatures during the growing season were between 35-45 ^{0}C with 5 ^{0}C above the optimum condition. Krishnan et al., [27] also found the effect of temperature stress in reducing the rice height.

Statistical analysis given in Table 1 indicated that the yield obtained significant different among three irrigation treatment (P<0.05). However, the grain yield between T2, and T3 treatment according to LSD at 0.05 level showed weakly sinificant.

Remarkably, the T2 and T3 reduced the rice yields of 37% and 41% compared to T1.

Based on CARDI, the standard rice yield of the Sen Kra Ob 01 are 3900 kg ha^{-1}. The current height of rice yield of T1 are less than the standard height of 3.7 time. The low yield of the current study could be also due to the stress of the temperature during growing season. In addition ally, Krishnan et al., [27] also found the effect of temperature stress in reducing the rice yield.

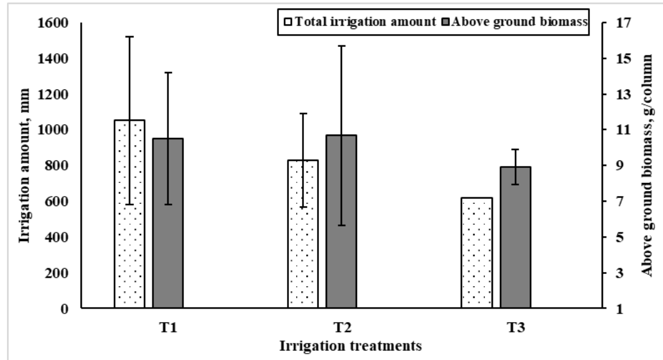

Fig 3. Average of irrigation amount and above ground biomass. Different three irrigation methods (T1: Shallow depth Shallow irrigation; T2: Shallow frequency irrigation; T3: Continuous soil field capacity with irrigation depth at 10 mm daily)

Table 3. Irrigation depth, WUE and Grain yield of rice crop under three irrigations

Treatment	Irrigation depth	Grain yield	WUE
	mm	Kg ha^{-1}	Kg m^{-3}
T1	1050.67±468	1037.5±377.1^{a}	0.106±0.04^{a}
T2	830.69±261	354.6±26^{b}	0.047±0.02^{ab}
T3	616.8±0	140.72±37.4^{b}	0.022±0.006^{b}

Noted: the mean value with different letter indicates the statistically significant different (P<0.05)

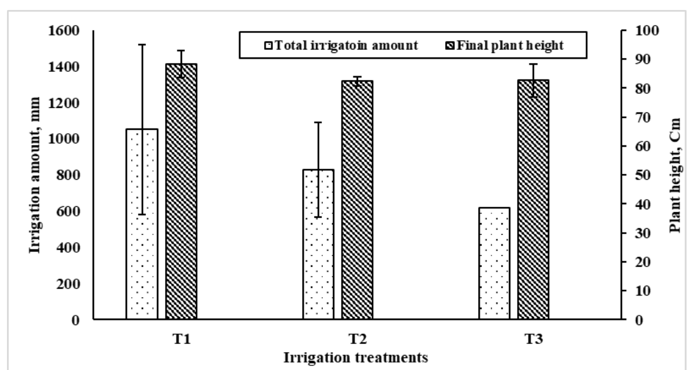

Fig 4. Average of irrigation amount and final plant height. Different three irrigation methods (T1: Shallow depth Shallow irrigation; T2: Shallow frequency irrigation; T3: Continuous soil field capacity with irrigation depth at 10 mm daily)

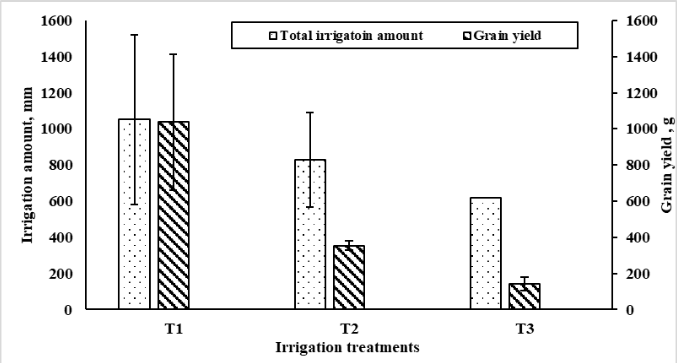

Fig 5. Average of irrigation amount and Grain yield . Different three irrigation methods (T1 :Shallow depth Shallow irrigation ;T2: Shallow frequency irrigation ;T3: Continuous soil field capacity with irrigation depth at 10 mm daily)

3.5 Water use efficiency (WUE)

Fig 6 and Table 3 show the effect of irrigation on WUE. Data given in Table showed that, there was a significant different (P<0.05) among the treatments. It is indicated that the WUE of T1 with 0.129 Kg m^{-3} was the highest of the treatments, while T3 gave lowest WUE.

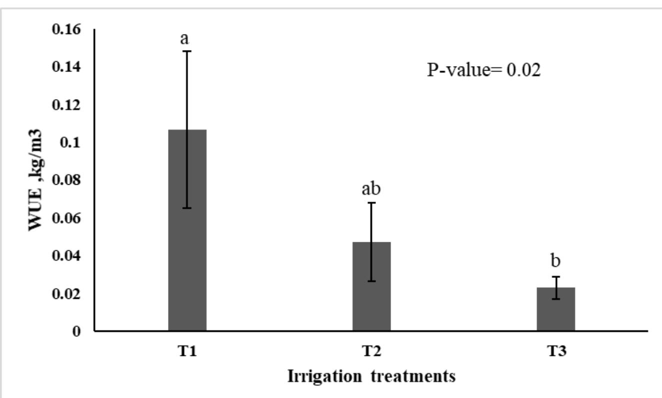

Fig 6. Water use efficiency (WUE) of rice plants under f irrigation regimes. Shallow Deep Shallow irrigation (T1), Shallow Frequency irrigaiotn (T2), and continuous soil field capacity with irrigation depth at 10 mm daily (T3). Graph bars with different letter (a,b) differ significantly from each other (P<0.05)

3.5 Relationships between irrigation water and yield, and irrigation water and WUE

According to the findings of the study, there is linear relationship between total irrigation amount (I) and grain yield (Y) (Fig 7) , and WUE (W) (Fig), to high level of significance. The relations show that the decreasing of water level up to the field capacity made decreasing of yield and WUE accordingly.

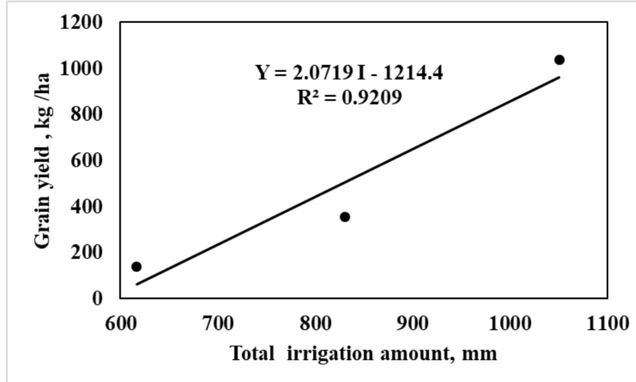

Fig 7. Relationship between total irrigation amount and grain yield

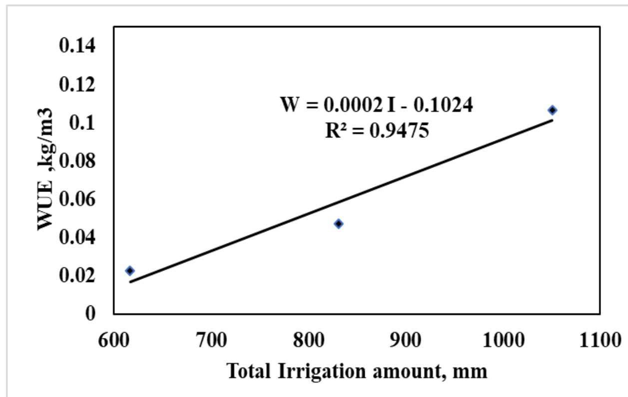

Fig 8. Relationship between total irrigation amount and WUE

4. CONCLUSION

Under the conditions of presented, effect of three different irrigation methods on grain yield and WUE of rice crops. The statistical analysis revealed that variouse irrigation methods had a noteworthy influence on both rice yield and WUE irrigation. The study findings illustrated that the application of the T1 treatment throughout the entire growing period led to enhanced growth parameters such as plant height and aboveground biomass, ultimately resulting in increased rice yield. Although, farmers require maintenance of the water standing level following to irrigation design of T1.

This study indicated that, the highest water use efficiency (0.106 kg.m^{-3}) of rice was obtained under T1 irrigation followed by T2, and T3 treatments, respectively. The lowest water use efficiency (0.022 kg m^{-3}) was found under T3 treatment. The results also indicated that the adoption of water-saving techniques, specifically the T3 treatment, turned result in a decrease in yield, applied a limited amount of irrigation depth under high temperature.

Alternatively, additional research might be necessary to elucidate the reasons for the reduced yield despite the favorable conditions provided for rice growth.

ACKNOWLEDGMENTS

We would like to acknowledge to the Gansu Academy for Water Conservancy of China and Institute of Technology of Cambodia for financial support and Cambodia Agriculture Research Development for experimental site to conduct this research.

REFERENCES

[1] B. Yu and S. Fan, "Rice production response in Cambodia," Agric. Econ., vol. 42, no. 3, pp. 437–450, 2011.
[2] S. Kea, H. Li, S. Shahriar, N. M. Abdullahi, S. Phoak, and T. Touch, "Factors influencing Cambodian rice exports: An application of the dynamic panel gravity model," Emerg. Mark. Finance Trade, vol. 55, no. 15, pp. 3631–3652, 2019.
[3] R. Cramb, C. Sareth, and T. Vuthy, "The commercialisation of rice farming in Cambodia," White Gold Commer. Rice Farming Low. Mekong Basin, pp. 227–245, 2020.
[4] NIS, "General Population Census 2019 Cambodia," p. 50, 2019.
[5] N. Monin, The Impacts of Climate Change on Agriculture and Water Resources in Cambodia: From Local Communities' Perspectives, no. 125. 2021.
[6] A. Borrell, A. Garside, and S. Fukai, "Improving efficiency of water use for irrigated rice in a semi-arid tropical environment," Field Crops Res., vol. 52, no. 3, pp. 231–248, 1997.
[7] E. A. Abioye et al., "A review on monitoring and advanced control strategies for precision irrigation," Comput. Electron. Agric., vol. 173, p. 105441, 2020.
[8] S. Vijayakumar et al., "Potassium fertilization to augment growth, yield attributes and yield of dry direct seeded basmati rice (Oryza sativa)," Indian J. Agric. Sci., vol. 89, no. 11, pp. 1916–1920, 2019.
[9] T. Chapagain, A. Riseman, and E. Yamaji, "Achieving more with less water: Alternate wet and dry irrigation (AWDI) as an alternative to the conventional water management practices in rice farming," J. Agric. Sci., vol. 3, no. 3, p. 3, 2011.
[10] Z. Zhang, S. Zhang, J. Yang, and J. Zhang, "Yield, grain quality and water use efficiency of rice under non-flooded mulching cultivation," Field Crops Res., vol. 108, no. 1, pp. 71–81, 2008.
[11] P. White, A. Dobermann, T. Oberthür, and C. Ros, "The rice soils of Cambodia. I. Soil classification for agronomists using the Cambodian Agronomic Soil Classification system," Soil Use Manag., vol. 16, no. 1, pp. 12–19, 2000, doi: 10.1111/j.1475-2743.2000.tb00164.x.
[12] S. Yoshida and S. Hasegawa, "The rice root system: its development and function," Drought Resist. Crops Emphas. Rice, vol. 10, pp. 97–134, 1982.
[13] A. N. Beretta et al., "Análisis de textura del suelo con hidrómetro: Modificaciones al método de Bouyoucus," Cienc. E Investig. Agrar., vol. 41, no. 2, pp. 263–271, 2014, doi: 10.4067/S0718-16202014000200013.
[14] G. R. Blake and K. H. Hartge, "Bulk density. In Methods of Soil Analysis, Part 1—Physical and Mineralogical Methods," Agron. Monogr. 9 Am. Soc. Agron. Sci. Soc. Am., vol. 9, no. 11718, pp. 363–375, 1986.
[15] J. Bouma and L. W. Dekker, "A method for measuring the vertical and horizontal Ksat of clay soils with macropores," Soil Sci. Soc. Am. J., vol. 45, no. 3, pp. 662–663, 1981.
[16] H. P. Cresswell, T. W. Green, and N. J. McKenzie, "The Adequacy of Pressure Plate Apparatus for Determining Soil Water Retention," Soil Sci. Soc. Am. J., vol. 72, no. 1, pp. 41–49, 2008, doi: 10.2136/sssaj2006.0182.
[17] R. K. Schofield and A. W. Taylor, "The Measurement of Soil pH," Soil Sci. Soc. Am. J., vol. 19, no. 2, pp. 164–167, 1955, doi: 10.2136/sssaj1955.03615995001900020013x.
[18] Food and Agriculture Organization of the United Nations, "Standard operating procedure for soil nitrogen Kjeldahl," pp. 1–21, 2021.
[19] FAO, "Standard operating procedure for soil available phosphorus," Food Agric. Organ., 2021.
[20] B. Y. Pauline and M. HALD, "The flame photometer for the measurement of sodium and potassium in biological materials," J Biol Chem, pp. 499–510, 1946.
[21] K. S. Tale and S. Ingole, "A review on role of physico-chemical properties in soil quality," Chem. Sci. Rev. Lett., vol. 4, no. 13, pp. 57–66, 2015.
[22] R. M. Allen, Richard G.;Pereira, Luis S.; Dirk, "FAO Irrigation and Drainage Paper Crop by," Irrig. Drain., vol. 300, no. 56, p. 300, 1998.
[23] M. S. Al-Jamal, S. Ball, and T. W. Sammis, "Comparison of sprinkler, trickle and furrow irrigation efficiencies for onion production," Agric. Water Manag., vol. 46, no. 3, pp. 253–266, 2001, doi: https://doi.org/10.1016/S0378-3774(00)00089-5.
[24] FAO, "Crop Evapotranspiration: Guidelines for computing crop water requirements," FAO Irrig. Drain. No, 1998.
[25] A. Afifah, M. S. Jahan, M. Khairi, and M. Nozulaidi, "Effect of various water regimes on rice production in lowland irrigation," Aust. J. Crop Sci., vol. 9, no. 2, pp. 153–159, 2015.
[26] S. Hussain, A. Khaliq, B. Ali, H. A. Hussain, T. Qadir, and S. Hussain, "Temperature extremes: Impact on rice growth and development," Plant Abiotic Stress Toler. Agron. Mol. Biotechnol. Approaches, pp. 153–171, 2019.
[27] P. Krishnan, B. Ramakrishnan, K. R. Reddy, and V. R. Reddy, "High-temperature effects on rice growth, yield, and grain quality," Adv. Agron., vol. 111, pp. 87–206, 2011.