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Water Productivity of Mustard Green (*Brassica juncea* L.) with Variation of Irrigation Systems

Nova Anika[1,✉], Muh. Kusmali[1], Harmiansyah[1], Setyadi Gumaran[1], Meli Hikmawati[1], Ridwan[2]

[1] Biosystems Engineering Department, Institut Teknologi Sumatera, INDONESIA
[2] Agricultural Engineering Department, University of Lampung, INDONESIA.

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Corresponding Author:
✉ nova.anika@tbs.itera.ac.id

ABSTRACT

Drip irrigation and self-watering are two examples of irrigation technology improvements that employ effective and efficient watering methods. Water productivity may be used as a benchmark to compare irrigation efficiency and agricultural productivity. The purpose of this study was to assess mustard green's water productivity under conventional, drip, and self-watering irrigation systems. The effect of irrigation variation on mustard green growth was studied using a non-factorial technique with a completely randomized design (CRD). The design has three treatments and six replications. This study examined the following variables: height, number of leaves, yield, irrigation water utilized, and water productivity of mustard green. The study found that mustard green plants require 0.69 mm/day of water in the vegetative phase, 2.83 mm/day in the generative phase, and 1.69 mm/day in the final phase. The use of different watering systems has a significant influence on mustard green's height and leaf number. Self-watering at 15 g/L provides the maximum water productivity for mustard green, followed by drip irrigation at 8.46 g/L and conventional irrigation at 7.69 g/L.

1. INTRODUCTION

Climate change and environmental devastation result in limited water resources to meet growing water needs (Sirait *et al*., 2020). Agriculture continues to be the largest user of water. In order to fulfill water and food demands, agricultural water productivity must be increased in order to yield more crops per drop. Water productivity is expressed as the yield produced per unit volume of water (Ren *et al*., 2021). Increased water production is associated with increased irrigation efficiency. Innovative irrigation practices can enhance water efficiency, gaining an economic advantage for farmers while also reducing environmental burden (Levidow *et al*., 2014).

Drip irrigation, also known as trickling irrigation, is a method of irrigation where water is applied to the soil at very low rates (2–20 liters/hour) through a network of small-diameter plastic pipes that have outlets known as emitters or drippers (Bhavsar *et al*., 2023). In principle, drip irrigation uses the gravitational force of water from a certain height to the root area of the plant. The use of drip irrigation can reduce the risk of salinity in plants because salts that accumulate around the roots will be leached (Witman, 2021). Water requirement efficiency in drip irrigation reaches 80% to 95%, which can save and overcome water loss due to percolation and evaporation (Udiana *et al*., 2014).

Self-watering refers to irrigation technology that provides effective and efficient watering solutions. Self-watering, also known as capillary wick irrigation, is a sub-irrigation method that uses a device (strip) to transport water from a reservoir to the plant-growing medium (Roonjho *et al*., 2022). Wicking is a substance that sucks water from a container and absorbs it into the soil through the roots of plants. Self-watering has the advantage of being very economical and suitable for use on narrow ground with limited irrigation water supply (Sajuri & Yansyah, 2022). Aside from that, self-watering is quicker to set up than drip irrigation because it just involves the use of plastic bottles as a planting medium.

Mustard green is a popular vegetable in Indonesia. Mustard greens contain lipids, protein, calcium, carbohydrates, iron, phosphate, and vitamins A, B, and C (Ibrahim & Tanaiyo, 2018). In Indonesia, the demand for mustard green has risen to 727.467 tons by 2021 (BPS-Statistics Indonesia, 2023). Mustard green may be grown all year if their water requirements are satisfied. As a result, research on the water productivity of mustard green utilizing self-watering irrigation is required to determine mustard green production with optimum water consumption.

2. METHODOLOGY

2.1. Study Location

This research was carried out from May to July 2023 at the Institut Teknologi Sumatera in Jati Agung District, South Lampung Regency.

2.2. Tools and Materials

Tools used in this research are water storage tanks, PVC pipes, emitters, stopwatches, plastic bottles, iron solder, scissors and flannel, and polybags. The materials needed are mustard plant seedlings and fertilizers such as urea. SP36. and KCL

2.3. Design of Experiment

This study utilized three irrigation systems: conventional, drip, and self-watering, with six replications and 18 samples. This experiment used a randomized block design. Polybags (30 cm × 30 cm) filled with soil weighing about three kilograms are used as mustard green planting media in both conventional and drip watering systems. Each polybag contains a plant that has been planted in loam-textured soil. Self-watering planting media consisted of plastic bottles with a diameter of 8 cm and loam-textured soil. Urea, SP36, and KCL fertilizers were used in each sample during cultivation (Table 1).

The cultivation of mustard greens lasts 35 days. Weeds are removed manually during cultivation. The Penmen Monteith formula is used to determine the water requirements of mustard green plants. Water is applied daily in the morning for both conventional and drip irrigation systems. Water is given once at the beginning of planting in a self-watering irrigation system, provided in a planting medium bottle.

Table 1. Fertilizer dosage for mustard green cultivation

Fertilizer	Dosage (g/m^2)	
	Preplant	3 weeks after planting
Urea (40%)	18.7	18.7
SP36 (36%)	31.1	0
KCL (60%)	11.2	11.2

2.4. Mustard Green Water Requirement Calculation

Evaporation and plant coefficients determine plant water requirements (Tan *et al*., 2022). The *ETo* value was derived using meteorological data from the Technical Implementation Unit of Meteorology, Climatology, and Geophysics at Institut Teknologi Sumatera during a four-year period (2018-2021). The climatic data included the quantity of sunlight, and the air humidity, the daily average air temperature, and wind speed. *ETo* was estimated with an evaporation calculator based on the Penman-Monteith formula, which is the FAO's recommended method (Equation 1). *ETc* was determined using Equation 2, while the Kc value for mustard green is obtained following FAO guidelines.

$$ETo = \frac{0,408\Delta\ (Rn\text{-}G) + \gamma \frac{900}{T+273} U_2\ (e_S\text{-}e_S)}{\Delta + \gamma\ (1+0,34\ U_2)} \tag{1}$$

$$ETc = ETo \times Kc \quad (2)$$

where ETo is potential evapotranspiration (mm/day), ETc is crop evapotranspiration, Rn is solar radiation on the plant surface (MJ/m^2/day), G is a change in soil heat (MJ/m^2/day), T is average air temperature (C), U_2 is wind speed (m/s) e_s is saturated vapor pressure (kPa), e_a is actual vapor pressure (kPa), Δ is vapor pressure slope curve (kPa/C), γ is psychometric constant (kPa/C), and Kc is plant coefficient.

2.5. Plant Growth Measurement

Mustard green growth is assessed by plant height and the number of leaves. Plant height is measured from bottom to top. The number of leaves is determined by observing the leaves that have fully opened. The number of leaves and plant height were measured every 10 days.

2.6. Mustard Green Water Productivity

Water productivity refers to the efficiency or advantages derived from each unit of water consumed. The impact of water consumption on water productivity may be measured in physical terms, such as total biomass or harvested goods (Fuadi *et al*., 2016). The water productivity of mustard green was determined using Equation 3.

$$WP = \frac{Y}{W} \quad (3)$$

where WP is water productivity (kg/m^3), Y is yield (kg), and W is water consumption.

2.7. Data Analysis

The quantitative data collected in this study were plant height, number of leaves, and yield. Plant height and the number of leaves were examined using ANOVA at the 5% level. If the analysis of variance showed treatment had a substantial influence, Duncan's new multiple range test (DMRT) was performed.

3. RESULTS AND DISCUSSION

3.1. Mustard Green Water Requirement

The potential evapotranspiration during the vegetative phase (0-10 days after planting) is 2.31 mm/day, the generative phase (11-20 days after planting) is 2.35 mm/day, and the final phase (21-30 days after planting) is 2.81 mm/day (Figure 1). The prolonged intensity of sunlight increases potential evapotranspiration, particularly during the generative phase,

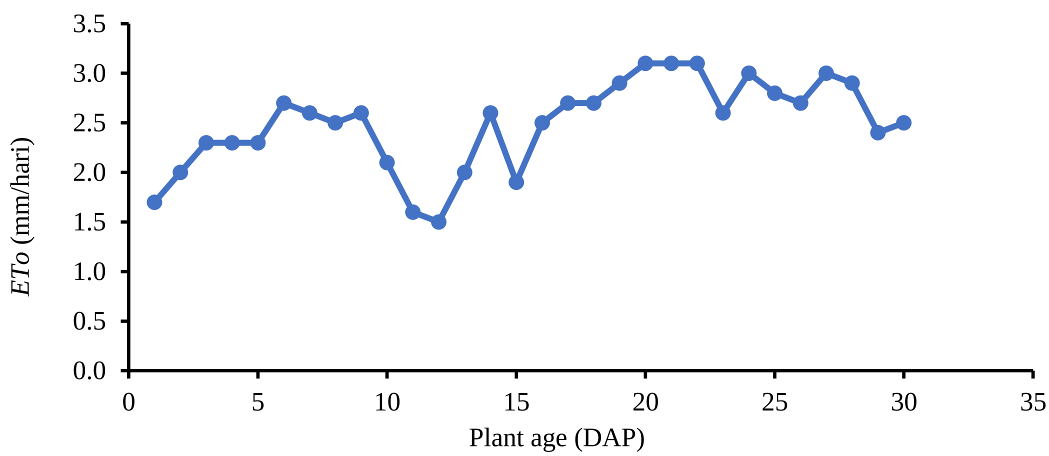

Figure1. Potential evaporations (*ETo*)

resulting in high levels of evaporation (Ekaputra *et al*., 2017). Meanwhile, high air humidity leads to the lowest evaporation (Fausan *et al*., 2021). According to the 2022-2023 planting season, the wet season runs from October 2022 to January 2023, while the dry season runs from February 2023 to September 2023. In this study, mustard green planting started in July 2023, therefore it was included in the dry season.

Mustard green's water requirements are classified into three categories according on its growth phase: vegetative, generative, and final. The generative phase has the highest plant water need (2.83 mm/day), whereas the vegetative phase has the lowest, 0.69 mm/day (Table 2). The generative phase is a time of rapid growth that needs an abundance of water. When the mustard green is in the generative phase, its surface reaches its greatest size, resulting in more evaporation; in the vegetative phase, the mustard green's surface remains tiny, resulting in less evaporation (Ekaputra *et al*., 2017).

Conventional irrigation utilized 1.33 liters of water, as did drip irrigation. Self-watering (Figure 2) requires 1.62 liters of water (Table 3). Self-watering consumes more irrigation water than traditional or drip irrigation. Drip and conventional irrigation differ from self-watering irrigation in that both distribute water daily according to plant needs and a predefined schedule.

Table 2. Mustard Green water requirement

Growth Phase	ETo (mm/day)	Kc	ETc (mm/day)	Etc (L/day)	ETc (L/periode)
Vegetative	2.31	0.3	0.69	0.018	0.18
Generative	2.35	1.2	2.83	0.072	0.72
Final	2.81	0.6	1.69	0.043	0.43

Table 3. Water requirement using different irrigation systems

Growth Phase	Conventional Irrigation and Drip Irrigation (l/period)	Self Watering (l/period)
Vegetative phase	0.18	0.32
Generative phase	0.72	0.87
Final	0.43	0.59
Final Soil Moisture	-	0.16
Total	1.33	1.62

(a) (b) (c)

Figure 2. Mustard green with different irrigation systems: (a) conventional; (b) drip, and (c) self-watering

3.2. Mustard Green Growth Parameter

3.2.1 Mustard green height

Self-watering produced the highest mustard green height, which averaged 25.3 cm (Figure 3). The study found that mustard greens reached an average height of 17.1 cm 20 days after planting. According to a prior study, plant height at 20 days (3 weeks) after planting was approximately 15.9 cm (Amprin and Suryanto, 2019). Plant height might vary depending on soil type and planting media. Smaller soil particles store more water and have higher capillary rise (Howe & Smith, 2020). This affects water and nutrient storage and the growth of plants. Moreover, water promotes cell turgidity, which can boost plant cell development (Bungaalus *et al*., 2022).

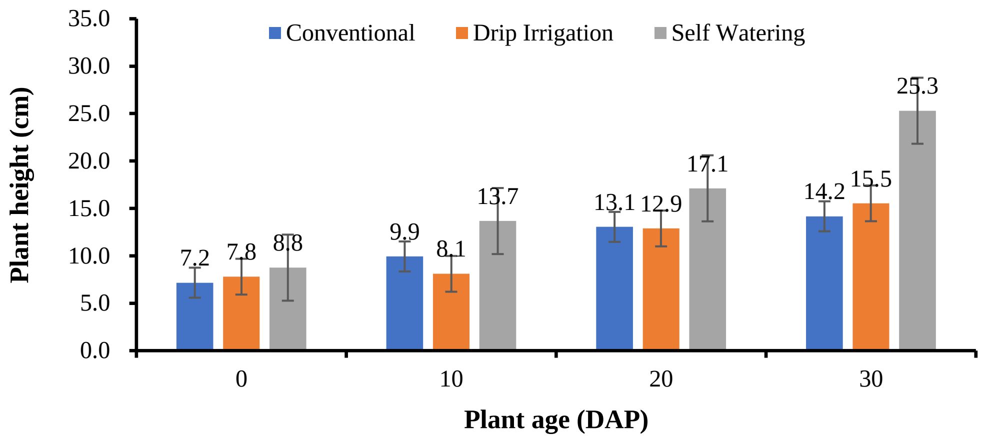

Figure 3. Mustard green height

The ANOVA analysis found a significant difference ($p < 0.05$) in the effect of irrigation systems on mustard green height development (Table 4). Plant height differed between drip irrigation and self-watering (Table 5). Self-watering can minimize water loss in plants by automatically providing water lost through evapotranspiration, hence maintaining soil moisture at the roots and promoting plant height growth (Sajuri & Yansyah, 2022).

Table 4. Tests of the effects of irrigation system variation on mustard green height

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	480.813	7	68.688	7.613	0.002
Intercept	6050.000	1	6050.000	670.533	0.000
Treatments	442.413	2	221.207	24.517	0.000
Replications	38.400	5	7.680	0.851	0.544
Error	90.227	10	9.023		
Total	6621.040	18			
Corrected Total	571.040	17			

Tabel 5. DMRT of irrigation system variation on mustard green height

Irrigation Systems	Plant height (cm)
Conventional Irrigation	14.2^{a}
Drip Irrigation	15.5^{a}
Self -watering	25.3^{b}

3.2.2. The number of leaves of mustard green

Between days 0 and 30 following planting, the number of mustard green leaves increased (Figure 4). The study discovered that self-watering generated the most leaves. According to previous studies, the maximum number of mustard green leaves was roughly seven (Amprin & Suryanto, 2019), which is similar to the number of leaves in this research. The number of leaves shows the plant's ability to produce plant tissue through the process of photosynthesis.

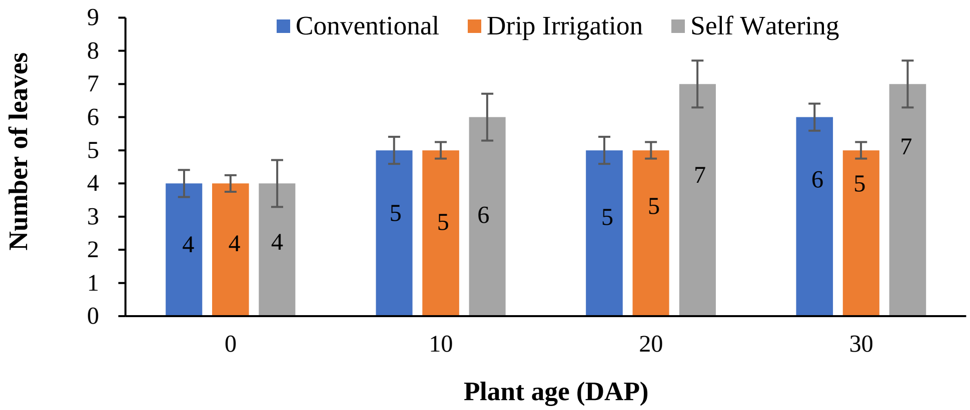

Figure 4. The number of leaves of mustard green

Table 6 shows a substantial correlation ($p < 0.05$) between irrigation system variations and the number of leaves. Water is a crucial component of plant physiology since it is the fundamental building unit of protoplasm. The DMRT results revealed a significant difference in the number of leaves between self-watering and drip irrigation (Table 7). Self-watering with a flannel wick offers strong capillarity and provides the water required by plants to generate an ideal number of leaves (Amprin & Suryanto, 2019).

There was no significant difference in the number of caisim leaves with traditional irrigation vs drip irrigation or self-watering. Nutrient availability influences the quantity of leaves produced (Isnaeni *et al*., 2021). The kind and dose of fertilizer used in this study were consistent across all treatments. Aside from that, the number of leaves is affected by the availability of water for plants (Triana *et al*., 2018), which affects the nutrient absorption process. In this study, the quantity of mustard green leaves with drip irrigation was lower than with conventional irrigation and self-watering, which might be attributed to different water availability for each sample, since the emitter uniformity in this study was 93%–96%.

3.3. Mustard Green Water Productivity

According to Table 8, a self-watering system gave the best output of mustard green, around 24 g/plant. Self-watering offers a high yield since water may be absorbed continuously, whereas drip and traditional irrigation systems give water depending on plant water requirements and a timetable (Amprin & Suryanto, 2019). In comparison to hydroponics, the mustard green yield in this research is lower, at less than 77 g/plant (Rakhman *et al*., 2015).

The water productivity of mustard green was best under self-watering, at 15 g/L, whereas conventional irrigation was the lowest, at 7.69 g/L (Table 8). The water productivity of mustard green using a drip irrigation system is 8.46 g/L. The application of a drip irrigation system results in water productivity of 7,157 g/L (Darmaputra *et al*., 2022), while in this study, the water productivity of mustard green using a drip irrigation system is 8,46 g/L. Self-watering increased mustard green yield by double that of conventional and drip irrigation, despite consuming 23% more water. Self-watering has high water productivity because water may be absorbed constantly, whereas drip and conventional irrigation systems deliver water based on plant water needs estimates and a timetable (Amprin & Suryanto, 2019). Furthermore, water productivity varies with field management, climate, and soil parameters (Li *et al*., 2021).

Table 6. Tests of the effects of irrigation system variation on mustard green leaf number

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17.889[a]	7	2.556	1.840	.184
Intercept	624.222	1	624.222	449.440	.000
Treatments	14.778	2	7.389	5.320	.027
Replications	3.111	5	.622	.448	.806
Error	13.889	10	1.389		
Total	656.000	18			
Corrected Total	31.778	7			

Table 7. DMRT of irrigation system variation on mustard green leaf number

Irrigation Systems	Mustard Green leaves number
Conventional Irrigation	6[ab]
Drip Irrigation	5[a]
Self-Watering	7[b]

Table 8. Mustard green water productivity

Irrigation Method	Yield (g)	Water Used (L)	Water Productivity (g/L)
Conventional	0.010	0.0013	7.69
Drip Irrigation	0.011	0.0013	8.46
Self watering	0.024	0.0016	15.00

4. CONCLUSIONS

Variations in irrigation systems impacted mustard green growth and water productivity. The maximum water production of mustard green was attained with self-watering at 15 g/L, followed by drip irrigation at 8.46 g/L and conventional irrigation at 7.69 g/L. Despite using 23% more water, self-watering doubled mustard green production compared to drip and traditional irrigation.

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