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Production of spinach under variable water supply

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Abstract
The effects of a variable water supply on the growth and yield of spinach grown in cocopeat medium was examined in a field experiment. Three irrigation treatments; (T1) common practice (T2) crop water requirement; and (T3) time scheduling were monitored through the season from transplanting to harvest, 28 days (from January and February 2018) after planting located in a shade house. For T1, spinach was irrigated 2 times per day until the medium surface is wet. An estimated value of crop evapotranspiration (ETc) was determined for spinach during this period in T2, giving a water requirement of 3.72 mm/day (for January 2017) and 4.04 mm/day (for February 2017). The irrigation interval was three days and scheduled water was given based on the ETc value in T2 for T3. There were no significance response to the irrigation treatments for plant height, number of leaves, canopy diameter and leaf length despite differences in biomass production measured. Plant fresh weight and root length density was more sensitive in T3. The insignificant difference was hypothesized to be contributed by that cocopeat medium used in this study that had provided satisfactory available water for the spinach growth regardless different amount of irrigation water applied.

Keywords: spinach, variable water supply, irrigation, crop water requirement, irrigation time scheduling

Introduction

In agriculture, plant should be irrigated with the actual amount of water needed to ensure that the plant can grow well and save the cost for irrigation. Kumar and Sahu (2013) stated that proper irrigation management can reduce irrigation water requirement and increase the yield.

Over irrigation or excessive water can affect plant respiration as the roots cannot take in gases. Under irrigation or water deficit, caused the plants to a water stress. Flexas et al. (2006) and Chaves et al. (2009) reported that water stress can immediately affect the photosynthesis of the plant by reducing the carbon dioxide intake since the stomata is close. Therefore, by knowing the actual crop water requirement and time to irrigate, the plant damage can be reduced, increase irrigation cost efficiency and yield.

There are many leafy vegetables that are essential in our life for nutrient and vitamins. One of the leafy vegetables that is rich with vitamin, mineral and antioxidant is spinach. However, it is one of the leafy vegetable that is very sensitive to water. A small change of water application to the spinach can be detected through the observation within one growing period.

Thus, managing water requirement for spinach is very important because it can affect its production yield. Bennett and Harm (2011) stated that there are relationship between the crop yield and water supply in the field that depend on the sensitivity of the crops. The optimum or deficit water supply to the crop will affect the increasing or decreasing of the production yield. Therefore, managing water requirement to the crop is very important to the yield and also able to save the irrigation cost.

Materials and methods

Experimental site

The experiment was conducted at Faculty of Agriculture University Putra Malaysia facility, shade house Field 15 (coordinate: 2.984138, 101.732884). The west region of Malaysia is having a tropic climate with lots of rainfall and sunshine. The maximum and minimum average daily temperatures during the experimental period were 27 °C and 35 °C, respectively. The medium used in the shade house was cocopeat perlite mixture.

Planting material

Spinach (*Spinacia oleracea)* is a vegetable that is rich with chlorophyll that was selected as the plant material in this study. Spinach is an annual plant with short growth cycle between 25 – 30 days after transplanting and is commonly grown in the summer or rainy season. The leaves are round bowl shape, oily light green in colour and less fibrous, heat tolerant and diseases resistant. In this study, the seed of the spinach was sowed in the tray seedlings. The media for the spinach seedling in tray was peat moss media. For the purpose of transplanting, 120 polybags were prepared filled with cocopeat as the media. Spinach seedlings aged 2 weeks were transplanted into the growing medium at 29 January 2018.

Experimental design

The study was designed in a Random Completely Block Design (RCBD) with four replications. Each of the replication had three treatments and labelled as T1: common irrigation practice, T2: crop water requirement irrigation and T3: irrigation time scheduling. For one experimental plot, 10 spinach were grown. The arrangement design for this experiment is show in the Figure 1.

T2	T3	T2	T1
T3	T1	T3	T2
T1	T2	T1	T3

Figure 1: Arrangement of experimental design for spinach

Treatment 1 is for common practice where spinach was irrigated 2 times per day until the surface of cocopeat is wet. In treatment 2, the spinach was irrigated based on the spinach crop water requirement. Climatic data from CLIMWAT 2.0 software; daily temperature, relative humidity, wind speed, sunshine hours and solar radiation was obtained to calculate the monthly reference crop evapotranspiration (ET_o) in CROPWAT 8.0 software. Crop evapotranspiration (ET_c) can then be calculated with the crop coefficient (K_c) was equal to 1 as recommended by Allen et al (1998) . The crop water requirement calculation is shown in table 1. For treatment 3, the growth of spinach was observed as the effect of irrigation time scheduling. In this irrigation time scheduling, the time interval will be determined first. The irrigation time scheduling for spinach is shown in Table 2.

Data collection

Data were collected during 29 January until 1 March 2018. The effect of the treatments on the plant development of spinach was measured by taking the plant height, number of leaves, canopy diameter and leaf length. The plant height of the spinach was measured from the cocopeat medium surface until the top of the plant top while the number of leaves was counted each week. The canopy diameter was measured from one leaf tip to the other end and for the leaf length it was measured from the bottom to the tip of the leaves. The fresh weight and root length were measured at the end of this study. For each of the treatment, plants were removed from the medium and fresh weight of spinach was taken with using the electronic scale (Model OHAUS PA2202) and the root length was measured with a ruler.

Data analysis

The effect of each treatment on the growth parameter i.e, plant height, number of leaves, canopy diameter, leaf length, fresh weight and root length of the spinach were analysed using Statistical Analysis Software (SAS). Analysis of Variance (ANOVA) was performed to find significant effect of different growth parameters. Mean comparison using Least Significant Difference (LSD) test at $P < (0.05)$ was employed for mean comparison. Differences were considered significant when the P value was < 0.05.

Results and discussion

Plant height, number of leaves, canopy diameter and leaf length

The result in plant growth of the spinach from day 14 until 28 after transplanting is shown in Table 3. In the second week there was a significant difference between treatment T1, T2 and T3 for plant height. The result for T1 (3.4 cm) was significantly difference with T2 and T3, while T2 (4.90 cm) had the highest height compared to T3 (4.31 cm) and T1 (3.4 cm). However, at 28 days after transplanting there were no significant difference between all treatments. , For number of leaves, canopy diameter and leaf length showed no significant difference between treatments in day 14 and 28.

The reason for significant difference in T1, T2 and T3 for plant height at day 14 after transplanting was because the cocopeat medium is known for high water holding capacity. Therefore at early stage, the medium did not receive enough water to reach the maximum water holding capacity which corresponded to the different respond of plant height in the treatments. However, at day 28 after transplanting (end growing season), the cocopeat medium had reached the maximum water holding capacity and could possibly had been in the saturated state. At this stage, the available water for plant roots to extract is sufficient regardless of the different amount of water given to the plants.

Table 1: Steps to calculate the volume of water based on crop water requirement.

Steps	Values
Crop Evapotranspiration	ET_c Jan = 3.72 mm/day ET_c Feb = 4.04 mm/day
Area of Polybag	16 800 mm^2
Volume of Water	Volume of water: Jan = 3.72 mm/day × 16 800 mm^2 = 62 496 mm^3= 60 ml Feb = 4.04 mm/day × 16 800 mm^2 = 67 872 mm^3 = 70 ml

Table 2: Steps to calculate the volume of water based on irrigation time scheduling.

Steps	Values
Available water (Sa) : obtained from water retention curve (Ilahi, W.F.F, 2017)	0.33 m3 / m3 = 330 mm/m
Effective root depth, D : spinach, root depth (Allen et al., 1998)	0.18 m
Permissible deficit, p (Allen et al., 1998)	0.25
Net irrigation application depth (d) : d = (Sa × p) D	= (Sa × P) D = (330 mm/m × 0.18 m) 0.25 = 11.88 mm
Crop water requirement	Jan = 3.72 mm/d Feb = 4.04 mm/d
Irrigation interval = d/ET_c Where ET_c is the crop evapotranspiration (mm/day) and d is the net irrigation application depth (mm).	Jan = 11.88/ 3.72 = 3.19 = 3 days Feb =11.88/ 4.04 = 2.94 = 3 days
Irrigation frequency The irrigation water need was calculated from the net irrigation application depth (mm) divided by the irrigation intervals (days). The value gives the amount of water need to irrigate each day for every irrigation interval.	Medium = cocopeat Irrigation water need (mm/d) = 11.88 mm/3 days = 3.96 mm/d Total volume (l/day) = 66 528 mm^3/day = 70 ml Frequency application per day = 2 Volume per application = 35 ml

Table 3: Plant height, number of leaves, canopy diameter, and leaf length of spinach with treatments, T1: common irrigation practice, T2: crop water requirement irrigation and T3: time scheduling irrigation at the early and end stage of spinach. Values are means ± Standard error (n = 10).

Days After Transplanting	Treatment	Plant Height (cm)	Number of leaves	Canopy Diameter (cm)	Leaf Length (cm)
14	T1	3.4±0.10b	5.7±0.12a	5.74±0.42a	2.23±0.24a
	T2	4.90±0.23a	5.8±0.22a	6.31±0.38a	2.53±0.25a
	T3	4.31±0.34ab	5.6±0.37a	5.28±0.48a	2.07±0.21a
28	T1	18.15±2.36a	18.15±2.36a	5.27±0.48a	7.84±0.52a
	T2	21.4±1.03a	22.38±0.58a	25.7±0.59a	8.71±0.40a
	T3	21.3±2.71a	21±4.54a	24.8±1.99a	7.84±0.52a

Values in each column with same letter did not differ significantly at P < 0.05 according to LSD.

Fresh weight and root length of the spinach

In this study, the fresh weight and root length (figure 2) of the spinach were collected at the end of the growing season. Based on table 4, the fresh weight was highest in T3 (26.43 g) followed by T2 (23.68 g) and T1 (18.82 g). Although there were some differences in fresh weight among the three treatments, there were no significant differences in the fresh weight and root length spinach between treatments when analysed with ANOVA. As cocopeat is a medium with high water holding capacity, different irrigation practice with different amount of water given to the plants did not affect the fresh weight and root length of spinach. Although spinach is a type of plant that are sensitive to water, the cocopeat medium had shown to provide sufficient water for the plants to grow and produce good yield at different irrigation water regime.

Figure 2: The spinach that was harvesting to get the fresh weight and root length

Table 4: Fresh weight and root length of the spinach in treatments likes T1: common irrigation practice, T2: crop water requirement irrigation and T3: time scheduling irrigation at the early and end stage of spinach. Values are means ± Standard error (n = 10).

Treatment	Fresh Weight (g)	Root Length (cm)
T1	18.82 ± 2.68a	11.37 ± 0.36a
T2	23.68 ± 2.42a	11.99 ± 0.45a
T3	26.43 ± 4.80a	12.45 ± 1.15a

Values in each column with same letter did not differ significantly at P < 0.05 according to LSD.

Comparison between the irrigation common practices with the irrigation crop water requirement and irrigation time scheduling on the spinach.

Results had shown that with the use of cocopeat as growing medium, there were no significant difference between the growth parameters, fresh weight and root length of the spinach. Significant difference was only observed for plant height after transplanting which was caused by the insignificant available water in the medium.

The study showed that regardless of different amount of watergiven to the spinach; similar yields can be obtained if the spinach is grown using cocopeat as a medium.Based on the three irrigation treatments results, the best practice is to accurately irrigate the water to spinach according to its crop water requirement and irrigation time scheduling.

Conclusions

The outcome of this study showed that spinach grown in cocopeat medium had no significant difference in growth when irrigated by common irrigation practices, irrigation based on crop water requirement and irrigation time scheduling. This was proven from the results of the plant height, number of leaves, canopy diameter, leaf length, fresh weight and root length of the spinach which had no significant difference between treatments.

The main factor that affected the irrigation of the spinach is the medium used to plant the spinach. Cocopeat is a fibrous material which absorb and holds water tight in the material. Cocopeat is also known for its high water holding capacity which can hold water in pores at higher rates and longer period. It can be concluded that the actual amount of water required for spinach growth in cocopeat based medium is according to its crop water requirement and can be scheduled to its irrigation time scheduling for better irrigation water management.

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