Effects of Irrigation Frequency and Nutrient Solution Volume on the Growth and Yield of Ginger (*Zingiber Officinale* Roscoe) Cultivated Using Soilless Culture System

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DOI: 10.29322/IJSRP.10.12.2020.p10883
http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10883

Abstract- Ginger or *Zingiber officinale* Roscoe has been cultivated for use as a spice and a medicinal herb. Irrigation frequency and volume are cultivation practices that influence the plant yield. This study was conducted to investigate the effects of irrigation frequency and nutrient solution volume on ginger plant growth and rhizomes yields soilless culture system. The experiment treatments included three irrigation frequencies (two, four and six times a day applications) and three volumes of nutrient solution (300 mL, 600 mL and 1200 mL). There were significant different between each treatment in terms of plant growth and rhizomes yield after nine months of cultivation periods. Combination of 6 times per day of irrigation frequency and 1200 mL nutrient solution gave the best ginger plant growth performance and rhizomes yield in the soilless culture system. This paper helps to elucidate the daily irrigation frequency and nutrient solution amount allowed for consistency production of ginger rhizomes.

Index Terms- ginger, soilless substrate, irrigation frequency, nutrient solution, rhizomes

I. Introduction

Ginger (*Zingiber officinale* Roscoe) belongs to a tropical and sub-tropical Zingiberaceae family, which originated from Southeast Asia. Ginger is a perennial plant with pungent aromatic rhizomes which has been cultivated for use as a spice and a medicinal herb [1]. Ginger usually is consumed as young ginger or mature ginger. Ginger is one of the most widely used herbs that contains several interesting bioactive constituents and possesses health promoting properties. 6-gingerol is a major pungent ingredient in ginger, also possesses potent anti-oxidant, anti-cancer, analgesic, anti-pyretic, anti-inflammatory, cytotoxic, anti-diabetic, anti-obesity, anti-nausea, anti-gastric and anti-proliferative activities [2].

Soilless culture system is the most intensive production method in agriculture industry. This technology can result in higher yields even under limited and adverse growing environment. Planting chillies, rock melons and tomatoes using soilless culture system has shown increase yields up to 3 – 5 times compared to those using conventional planting method [3]. Previous studies have been done to cultivate rose flower, tomato, gerbera, begonia, primrose (*Primula* spp) and cabbage using various types of organic substrates including coir dusk [4]. Important factors influencing plant growth in containers are water availability, nutrient content, air retention, moisture and soil aeration [5]. Ginger growth improved under constant elevated moisture root and water availability to the plant [6]. Furthermore, other studies reported that ginger growth enhancement under high irrigation frequency is due to availability of nutrients [7]. High irrigation frequency favours the vegetative growth, the fruit yield and the fruit quality of tomato [8]. The efficiency of the soilless culture system greatly depends on the application design and the way nutrient and water are managed. The main objective of this study is to analyze the effects of irrigation frequency and nutrient solution amount on the ginger plant growth and the rhizomes yield under soilless culture system.

II. RESEARCH METHODOLODY

Ginger var Bentong was selected and used in this study. Prior to sowing, 10-month-old ginger rhizomes were bought from a ginger plantation in Bentong, Pahang. Each of the rhizomes was cut into smaller pieces of about 7 cm long and 100 g in weight. Each of the seed rhizomes contained 2 – 3 point buds. The seed rhizomes were treated with Previcur-N prior to planting. 100% of coir dusts were used as growth media. The growth media were thoroughly mixed in a 10-litre pail before filling into 60 cm × 60 cm black polyethylene bags. One seed rhizome was planted 5 cm deep in the polyethylene bags. Each polyethylene bag was placed randomly on four irrigation lines under the side-netted rain shelter and individually irrigated with nutrient solution via a dripper on the surface of the growth medium.

The research was conducted in rain shelter at MARDI Station, Serdang, Selangor, Malaysia. A side-netted rain shelter of 30 m long ×10 m wide × 4.5 m high were used in the study. All structures were made of galvanized steel frame and insect repellent net (0.1 × 0.1 mm^2) side cladding. The rain shelter oriented in north-south direction for maximum sunlight exposure. Entrance into the shelter must be through double doors to reduce the chance of insect entry.

The experiment treatments included three irrigation frequencies (WF) (WF_2 = two times a day applications, WF_4 = four times a day applications and WF_6 = six times a day applications) and three volumes of nutrient solution (A) (A_1 = 300 mL, A_2 = 600 mL and A_3 = 1200 mL). The irrigation water was applied through drip system. The amount of nutrient solution applied for each time of irrigation frequency was 150 ml. The twice daily application was carried out at 9.30 am and 4.30 pm, meanwhile the four times a day applications were applied at 9.30 am, 10.30 am, 12.30 pm and 4.30 pm and the six times a day applications were given at 9.30 am, 10.30 am, 11.30 am, 12.30 am, 1.30 pm and 4.30 pm. The irrigation regimes were carried out until one week before harvesting time. Irrigation water applied were from tap water with electrical conductivity value of 0.4 $\mu S\ m^{-1}$. A split plot experimental design with three replications for each treatment was applied in the experiment. Each treatment consisted of 300 polybags or samples. Before the experiment began, the growth media were irrigated equally or close to field capacity.

The irrigation system, which was built in the side-netted rain shelter, consisted of a 1,500-litre tank, 1.5 Hp water pump, water filter, pressure meter and four lateral lines (28 m each) which looped to each other. Each of the lateral lines was equipped with 100 drippers that were placed into 100 polyethylene bags, side by side. The distance between each line was 1.5 m and the distance between each dripper point in the lateral line was 0.3 m. A valve was attached to an inlet to control the amount of the irrigated solution to be pumped in. A small valve was also attached to each lateral line to maintain the flow through the drip line. The nutrient solutions were supplied through 0.3 m micro tubes and arrow drippers.

All fertilizer components were water soluble. The fertilizer stocks were prepared according to [9]. The macro and micro nutrients were prepared separately as A and B stock solutions respectively, at 100× dilution. Solution A contained calcium nitrate and iron, while solution B contained all other components. All components were added one by one to ensure that they dissolved completely in the water. In preparing stock A solution, calcium nitrate was added into the container containing tap water (pH 5.5 – 6.5) and stirred until it dissolved. Then, the solution was poured into a 100-litre vessel. Iron powder was added into another container that contained tap water, stirred until it dissolved completely, and then added into the vessel. The same procedure was applied in preparing Stock B solution. The irrigation solutions were prepared in a 1,500-litre tank. Stock A and Stock B were added into the tank at 1:1 ratio until the needed electricity conductivity (EC) was achieved. The EC of the fertigation solution was between 1.8 $\mu S\ cm^{-1}$ and 2.4 $\mu S\ cm^{-1}$.
The growth of the ginger plants was measured monthly by measuring the height of plant, the number of tillers and the fresh and the dry weight of leaves/shoot and rhizomes. The ginger plants were randomly selected and the rhizomes were harvested after 3 – 9 months of sowing to determine the yield and the growth of rhizomes. The weight was measured immediately after harvest to prevent desiccation and water loss from the rhizomes. Data obtained were subjected to statistical analysis using analysis of variance (ANOVA) procedures to test the significant effect of all the variables investigated using SAS version 9.1. Means were separated using Duncan Multiple Range Test (DMRT) as the test of significance at $\rho \leq 0.05$.

III. RESULTS AND DISCUSSION

3.1 Plant growth performance

Table 1 shows the interaction of irrigation frequency and nutrient solution volume in relation to plant height, shoots and leaves biomasses and tillers number. There were significant different at 5% between each treatment in terms of plant growth performance after nine months of cultivation periods. Various combinations of treatments produced different results for each characteristic. The best plant growth performance was obtained from WF_6 x A_3 treatment. Experiment data showed WF_6 x A_3 treatment was the best parameter that provided good growth for ginger crop compared to other treatments. All plants that irrigated with 6 times per day resulted in higher plant height, shoots and leaves biomasses, and tillers number, followed by the media irrigated with a frequency of 4 and 2 times per day. Similarly, nutrient volume applied at 1,200 ml per day led to higher plant height, shoots and leaves biomasses and tillers number. The reason for this can be attributed to better water availability to the root zone. The plants attained the highest heights in WF_6 x A_3 treatment but the lowest in WF2 x A1 treatment. Combination of 1,200 ml of nutrient solution and 6 times per day of irrigation frequency was the best parameter to grow ginger in the soilless culture system. Overall, irrigation restriction on the plant decreases the photosynthetic and the stomatal conductance levels that further, affecting the plants vegetative growth [10]. Previous studies have shown that water restrictions reduced the plant vegetative growth of pomegranate, olive and cherry plants [11]. Lower plant vegetative growth resulted in plant yield reduction. Since the root volume is restricted and readily available water quantity is low, frequent irrigation in small amount is required to maximize the crop productivity in soilless culture [12]. Therefore, irrigating 20 – 30 times a day may be necessary to maintain moisture in root zone in summer time, especially for rapidly growing crops [13]. Generally, delivering constant volume of nutrient solution during each irrigation and varying the number of irrigations are better than keeping the number of irrigations constant and varying the volume [14]. However, in some cases, frequent irrigations may reduce oxygen availability to plant roots owing to excessive moisture content in root zone [12]. The development and the quality of pomegranate fruits are also affected by deficient irrigation [15].

Table 1: Effect of irrigation frequency and volume on growth parameter of ginger plant after nine months of cultivation period

Treatment	Plant height (cm)	Shoot and leaves biomass (gm)	Number of tillers	Diameter of tillers	SPAD value	Number of leaves
WF_2 x A_1	57 ± 2^f	560 ± 96^f	6^f	7^c	50^f	7^e
WF_2 x A_2	77 ± 6^d	867 ± 130^d	9^e	8^b	52^e	10^c
WF_2 x A_3	105 ± 11^b	$1,120 \pm 220^b$	10^d	7^c	55^c	13^b
WF_4 x A_1	60.5 ± 4^e	640 ± 109^e	9^e	8^b	52^e	8^d
WF_4 x A_2	84 ± 8^c	885 ± 140^d	10^d	8^b	53^d	11^c
WF_4 x A_3	114 ± 12^a	$1,280 \pm 240^b$	11^c	9^a	56^c	14^a
WF_6 x A_1	62.5 ± 5^e	680 ± 115^e	10^d	8^b	52^e	8^d
WF_6 x A_2	86.25 ± 9^c	907.5 ± 123^c	12^b	8^b	54^d	11^c
WF_6 x A_3	115 ± 16^a	$1,360 \pm 255^a$	13^a	9^a	58^a	14^a
WF_2	80.6 ± 7^d	849 ± 125^d	8^e	7^c	52^e	10^c
WF_4	86.2 ± 9^c	935 ± 142^c	10^d	8^b	53^d	11^c
WF_6	87.92 ± 10^c	982.5 ± 159^c	12^b	8^b	54^d	11^c
A_1	60.5 ± 4^e	626.67 ± 78^e	8^e	7^c	51^f	8^d
A_2	82.6 ± 9^b	886.5 ± 165^d	11^c	8^b	53^d	10^c
A_3	112 ± 12^a	1253 ± 222^b	11^c	8^b	56^b	14^a

Mean values with the same letter are not significant different at $\rho < 0.05$ Duncan Multiple Range Test (DMRT)

3.2 *Rhizomes yield*

Table 2 presents the interaction of irrigation frequencies and nutrient solution volume on rhizomes yield, and rhizomes to shoots ratio after nine months of planting periods. There were significant different between each treatment in terms of rhizomes yield after nine months of cultivation periods. The plants attained the highest yield from WF_6 x A_3 treatments. Plants from WF_2 x A_1 treatment gave rise to the lowest rhizomes yield. Irrigation frequencies of 4 – 6 times per day managed to give rhizomes yield above 1 kg provided the nutrient amount supplied were between 600 – 1,200 ml per day. Meanwhile, application of irrigation at 6 times per day resulted in better rhizomes yield regardless the nutrient volume. Similar results also were observed in the cherry tomato plant that resulted in the higher yield, the number and the weight of fruits with the application of 1,500 ml of water per day [16]. Overall, the highest irrigation frequency is more efficient for plant growth and yield regardless of the nutrient level, with four – six times a day and has significant effect on fruit yield compared to twice a day [17]. [18], stated that the frequency of fertigation has an important influence on plant yield. For crops grown in containers, it is important to consider the tendency of most root systems to grow gravitropically to form a dense layer at the bottom of the containers [4]. These conditions are able to create conducive growth area that increase aeration in the substrate and reduce drying of the surface by lifting the moisture higher up in the polyethylene bags. This increases the volume of the mix that is suitable for root development and improves access to moisture and fertiliser. This redistribution of moisture is perhaps one of the reasons for plants to have higher rhizome yield. The highest rhizome to shoots ratios were obtained from WF_6 x A_3 treatments. Increase irrigation frequency resulted in high rhizomes to shoots ratio. The lowest rhizomes to shoots ratio was obtained from $WF_{2\ x}$ A_1 treatment. The experimented data showed that water irrigated at 2 times per day reduced the rhizomes to shoots ratio drastically compared to other 4 and 6 times of irrigation per day. The high ratio of underground biomass to aboveground biomass reflects that the roots were well able to supply the top of the plant with water, nutrient, stored carbohydrates and certain growth regulators [19]. These results were similar with the study conducted by [20], who found that ginger rhizome yield increased significantly when grown using soilless system.

Table 2: Effect of irrigation frequency and nutrient solution volume on rhizomes yield and ratio parameters with different substrate and irrigation frequency.

Treatment	Rhizomes yield (g)	Rhizomes to shoots ratio
WF_2 x A_1	632 ± 11^k	1.13^n
WF_2 x A_2	1510 ± 39^g	1.74^i
WF_2 x A_3	3800 ± 75^c	3.39^c
WF_4 x A_1	870 ± 24^j	1.36^k
WF_4 x A_2	1240 ± 30^h	1.40j
WF_4 x A_3	4820 ± 87^b	3.77^b
WF_6 x A_1	910 ± 28^i	1.34^l
WF_6 x A_2	2290 ± 50^e	2.52^e
WF_6 x A_3	5560 ± 98^a	4.09^a
WF_2	1980 ± 48^f	2.33^g
WF_4	2310 ± 55^e	2.47^f
WF_6	2920 ± 65^d	2.97^d
A_1	804 ± 18^j	1.28^m
A_2	1680 ± 41^g	1.90^h
A_3	4726 ± 82^b	3.77^b

Mean values with the same letter are not significant different at $\rho < 0.05$ Duncan Multiple Range Test (DMRT)

IV. CONCLUSION

Irrigated nutrient solution 6 times per days is the best irrigation frequency to obtain high plant growth performance. Nutrient solution at 1,200 ml per day is the best amount to apply to the ginger plant. However, combination of 6 times per day of irrigation frequency and 1,200 ml of nutrient solution is the best parameter to grow ginger in the soilless culture system. The present study has shown that constant delivering volume of nutrient solution during each irrigation was able to provide conducive environment for root to growth. Otherwise, frequent irrigations can reduce oxygen availability to plant roots because of excessive moisture content in root zone. Water restrictions reduced the plant vegetative growth thus lowering ginger plant yield. There were significant different between each treatment in terms of rhizomes yield after nine months of cultivation periods. Combination of 6 times per day of irrigation frequency and 1,200 ml of nutrient solution was the best parameter to obtain higher ginger rhizome yield in the soilless culture system. Ginger plant showed positive rhizomes yield responding to application of irrigation at 6 times per day regardless the nutrient volume. Higher rhizome yield may be due to increase irrigation frequencies can create conducive growth area that increase aeration in the substrate and reduce drying of the surface by lifting the moisture higher. Application of 6 times per day of irrigation frequency and 1,200 ml of nutrient solution can be applied to obtain high plant growth performance and rhizome yield. The understanding of daily irrigation frequencies and nutrient solution amount allowed for consistency production of ginger rhizomes.

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