Growth and Yield of Red Chili (Capsicum Annuum L.) as Responses to Various Interval and Frequency of Fertigation Application

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Abstract. Appropriate drip fertigation systems could increase the crop yield, as it provides timely water and fertilizer at the same time. The aim of this research was to examine the growth and yield of red chili as a results of different fertigation interval and frequency. The field experiment was carried out in Wedomartani Experimental Garden, Yogyakarta. The experiment was set in a split plot with Randomized Completely Block Design. Fertigation interval, namely, 3 days, 6 days, and 9 days were the main plots, whereas. the fertigation frequency, namely, once/day, twice/day, 3 times/day were the sub plots. A commercial AB-mix fertilizer mixed with rabbit urine was used for nutrient solution. The variance of data was analysed with post-hoc analysis using Duncan's Multiple Range Test. Parameters observed were plant height, number of leaves, number of fruits, weight of fruit, and chili shelf life. The result showed that the growth and yield (plant height, number of leaves and number of fruits) of red chili were significantly affected by combinations of fertigation interval and frequency. Three days interval applied in three times a day fertigation of nutrients supply resulted in higher plant height and leaves number, but have no significantly different from three days interval in once and twice a day frequency of fertigation. Three days interval in once and twice a day frequency resulted in higher of fruit number of chili. The interval and frequency of fertigation didn't significantly affect to the weight and storability of chilies**.**

Keywords: Fertigation, interval, frequency, red chili, yield

1 Introduction

Chilli (*Capsicum annum* L.) is a valuable agricultural vegetable crop. It contains capsaicin which causes a spicy taste. Chili is also rich of mineral ions (K^+, Zn^{2+}, Mg^{2+}, and Co^{2+}), vitamin C, vitamin A, vitamin K, and phytochemical substances (alkaloid, phenolic, limonoid substances). Chilli is commonly used in the preparation of pickles. Chili is used for medical purposes to fight various types of diseases. such as cancer, diabetes, and obesity. Capsaicin has various prophylactic and therapeutic in ayurvedic and allopathic

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medicines practices. Cayenne pepper also contains isoprenoid compounds such as carotenoids [1]

The chili production in Indonesia was 1.39 million tons in 2021, whereas in 2020, chili production in Indonesia was 1.5 million tons, this indicated a decrease in chili production of 8.09% [2]. The main factors that reduce the productivity of chilli is inefficient use of water and fertilizer, considering they are highly critical to improve the crop productivity. When applying conventional irrigation water, it is observed that there is very huge amount of water losses to the field. It causes many nutrients loss through percolation. In conventional crop cultivation, farmers commonly implemented less efficient fertilizer usage and irrigation. Increasing crop production can be done by controlled fertilization and irrigation (called by fertigation) [3]. In precision agriculture, improving the efficiency of fertilizers usage in chili cultivation can be done by combining irrigation and fertilizer in one application system termed fertigation [4].

Many studies has been conducted to develop precision agriculture. Drip irrigation applied in fertigation system is one of the precision agriculture methods that have been established for horticultural crops cultivation. Through fertigation system, nutrients configuration and application rate can be arranged matching to the plant growth, so that the use of nutrients meet the plant needs and is more efficient [5]. Drip irrigation is an irrigation system where water is dripped at low volume near the root zone of the plant. Drip irrigation can increase the irrigation efficiency by optimizing the use of available irrigation water. Drip fertigation is a method in which fertilizer is applied through an efficient irrigation system by dripping. In fertigation, the efficiency of nutrients use could be as high as 90 percent, which is better in comparison to 40-60 percent in conventional methods [6]. Therefore, it is important to study the method to reach the efficient use of water and nutrients through drip irrigation on chili. The objective of this research was to examine the growth response and yield components of red chili under various fertigation interval and frequency.

1.1 Literature Review

Chili is an annual shrub plant a with a taproot. The main stem of the chili is perpendicular, the main stem branch and the primary branch is in the Y shape. Chili leaves has pinnate structure and a single leaf has oval shape with alternating positions in branch. The shape of chili flower is small trumpet with white colour. Chili flower is perfect, comprises both an androecium and a gynoecium. The colour of young fruit is dark green and after ripe becomes bright red [7].

Irrigation technology has transformed toward the evolution of information and automation technologies such as drip irrigation [8]. The drip irrigation method is an irrigation system, where water is run under pressure through pipes. Water is released in form drips directly to the ground close to plant root in the field through drippers. Water supply should be done continuously due to their low water holding capacity. Amount of water application can be limited while increasing soil water holding capacity [9].

Fertigation reduces the cost of labour and saves energy in the application of fertilizers. Fertigation through precise frequency and interval is expected to improve the efficiency and effectiveness use of fertilizers and water. Applying fertigation systems can improve the yield until threefold, and it saves about 45 to 50 percent of irrigation water and increases productivity by about 40 percent. The benefits of drip fertigation compared to traditional fertilization include reduces nutrients loses in the area below the rooting zone, which are around 10% as compared to 40-55% in the traditional system. Moreover, it can help minimize environmental pollution, reduce fertilizer and chemicals needed, reduces soil erosion [10]. Applying drip fertigation increases nutrients absorption by plants. Appropriate

fertigation interval and frequency are an important treatment in managing irrigation, which shows the time of irrigation in the program. Water pressure and wastage of water and energy for plant growth can be overcome by adjusting the frequency and interval of irrigation accordingly.

2 Materials and methods

This study was carried out at the Experimental Garden of Universitas Pembangunan Nasional Veteran Yogyakarta in Wedomartani district. The experiment was implemented in Split plots organized in a Randomized Completely Block Design that consisted of 3 blocks. The main plots were interval of nutrients application in fertigation system, namely, three days interval, six days interval, nine days interval. The sub plots were frequency of fertigation in a day, i.e., once, two times, three times, Manure with a dosage of 5 ton/ha and lime with a dosage of 1 ton/ha were blended with the soil during land preparation before planting. Fipronil 1.5% with a dosage of 8 kg/ha was used for grub control. Nutrients solution was made by mixing fermented rabbit urine (5mL/L) and commercial ready-mix fertilizer with proportion 7.5 mL/L fertilizer A and 7.5 mL/L fertilizer B. Fertigation system operated remotely using Internet of Things program. The nutrients solution was applied from 14 days after planting until 68 days after planting. Each application discharged approximately 150 mL per plant. An irrigation network consists of tank water storage, electric pump, HDPE pipe network distribution, and water filter. Water tank position was two meters above soil surface. Water can flow with gravity force. In addition to nutrient delivery, drip irrigation was set to deliver water 3 times daily, at 07.00 AM, 12.00 PM and 18.00 PM with pipes was placed at a precision hole close to plant.

Observations were done on growth and yield parameters, namely plant height, number of leaves, number of fruits, weight of fruit, and chili shelf life. F test (α=5%) was performed to analysis the variance of data and Duncan's Multiple Range Test was used for post hoc analysis (α=5%).

3 Result and discussion

3.1 Plant height

An interaction effect between fertigation interval and fertigation frequency occurred on plant height at 4 WAP (Weeks after planting), 8 WAP, and 12 WAP. Application of nutrients in 3 days interval and applied 3 times/day resulted in the highest plant height at 4 WAP, 8 WAP, and 12 WAP. The height of plant treated with fertigation at 3 days interval and applied once/day did not significantly different from those fertigated twice/day at 4 WAP. Also it did not significantly different from those fertigated at 3 days interval applied in once/day at 12 WAP (Table 1).

Table 1. Plant height of red chili cultivated with various interval and frequency of fertigation

Fertigation interval	Fertigation frequency	4 WAP	8 WAP	12 WAP
3 days interval	once/day	18.99 abc	41.54 b	63.07 ab
	twice/day	19.48 ab	42.50 b	58.93 bc
	3 times/day	21.36 a	65.52 a	75.74 a
6 days interval	once/day	16.27 cde	33.69 b	48.04 bc
	twice/day	15.89 de	36.43 b	45.37 c

	3 times/day	16.63 bcde	40.15 b	48.11 bc
9 days interval	once/day	15.51 e	39.08 b	48.67 bc
	twice/day	18.70 abcd	43.58 b	52.08 bc
	3 times/day	17.40 bcde	37.29 b	51.22 bc
Interaction		+	+	+

Means within the same columns that followed by the same letter indicates no significant difference from one another at P≤ 0.05 (DMRT); (+) shows that an interaction occurs between combination of treatments tested

Table 2. Number of leaves of red chili cultivated with various interval and frequency of fertigation

Fertigation interval	Fertigation frequency	Number of leaves	
		4 WAP	8 WAP
3 days interval (I_1)	once/day (F_1)	19.41 ab	27.52 ab
	twice/day (F_2)	18.30 abc	27.03 ab
	3 times/day (F_3)	22.89 a	29.09 a
6 days interval (I_2)	once/day (F_1)	10.96 e	16.52 e
	twice/day (F_2)	10.89 e	16.11 e
	3 times/day (F_3)	17.11 bcd	23.41 bc
9 days interval (I_3)	once/day (F_1)	14.41 cde	20.81 cde
	twice/day (F_2)	17.04 bcd	23.00 bcd
	3 times/day (F_3)	12.63 de	18.67 de
Interaction		+	+

Means within the same columns that followed by the same letter indicates no significant difference from one another at P≤ 0.05 (DMRT); (+) shows that an interaction occurs between combination of treatments tested

An interaction effect between interval and frequency of fertigation occurred in number of plant leaves at 4 WAP and 8 WAP. The highest number of leaves was produced by plants treated with fertigation at 3 days interval and applied in 3 times/day, but it did not significantly different from those treated fertigation at 3 days interval applied once/day or twice/day (Table 2).

3.2 Number of chili fruits

An interaction effect between fertigation interval and fertigation frequency occurred in the number of chili fruits. The number of chili fruits on plant treated with fertigation at 3 days interval and applied once/day was significantly higher than those treated with fertigation at 6 days interval and applied once/day or at 9 days interval and applied twice/day, but did not significantly different from other treatments (Table 3).

Table 3. Number of fruits of red chili cultivated with various interval and frequency of fertigation

Fertigation interval	Number of chilies fruits			
	Fertigation frequency			
	once/day	Twice/day	3times/day	Mean
3 days interval	75,44 a	62,55 ab	65,55 ab	67,85
6 days interval	29,94 bc	47,00 abc	54,55 abc	48,83
9 days interval	46,67 abc	32,00 bc	48,78 abc	42,48
Mean	50,68	47,18	42,96	+

Mean followed by the same letter indicates no significant difference according to Duncan's Multiple Range Test (P≤0.05); (+) shows that an interaction occurs between combination of treatments tested

3.3 Chili fruit weight and shelf life

No interaction effect was found between fertigation interval and fertigation frequency on chili fruit weight and chili shelf life (Table 3). Either fertigation interval and fertigation frequency have no effect on the weight of chili fruit and shelf life of chili.

Table 4. Fruit weight and shelf life of red chili cultivated with various interval and frequency of fertigation

Treatments	Fruit weight of chili (g)	Shelf life of chili (day)
Fertigation interval		
3 days interval (I_1)	116,48 a	28,51 a
6 days interval (I_2)	88,09 a	23,52 a
9 days interval (I_3)	106,81 a	20,11 a
Fertigation frequency		
Once/day (F1)	109,68 p	23.27 p
Twice/day F2)	98,11 p	24.83 p
3 Times/day F3	94,04 p	24.04 p
	(-)	(-)

Means within the same columns that followed by the same letter indicates no significant difference from one another at P≤ 0.05 (DMRT); (-) shows that no interaction occurs between combination of treatments tested .

3.4 Discussion

Efficient use of fertilizers and water in chili cultivation can be improved by drip irrigation. The growth and yield of red chilies were affected by the interval and frequency of fertilization. The results of this study showed that the tallest plant height was obtained from fertigation applied every 3 days and given 3 times daily, although it did not significantly different from those plant fertigated at 3 days interval and applied once/day or twice/day at 4 WAP, 8 WAP, and 12 WAP (Table 1). The highest number of leaves was produced from fertigation application at 3 days interval and applied 3 times/day, but it did not significantly different from plant fertigated at 3 days interval and applied once/day or twice/day at 4 WAP and 8 WAP (Table 2).

With an interval of 3 days of fertigation, nutrition supply was sufficient to support plant growth until the next application. Nutrients used were combination between commercial AB mix and liquid organic fertilizer from rabbit urine. This mixture provided macro and micro nutrients needed by the plant. Commercial AB mix provided macronutrients, including Nitrogen (N), Phosfor (P), Kalium (K), Magnesium (Mg), Sulfur (S), Kalsium

(Ca), whereas liquid organic fertilizer, besides supplied macro nutrients, it also supplied micro nutrients. Watering 3 times/day will maintain good humidity during early growth until harvest time. Part of the soil pores space will be filled with oxygen and other pores will be filled with water. Water is needed by plants for various purposes, including as solvents and mediums for chemical reactions, mediums for the transportation of organic and inorganic solutes, and raw materials for photosynthesis and other chemical reactions in plants.

In comparison to longer fertigation intervals, when plants was given fertigation at 3 days interval and applied once/day, plants received more nutrients at once, lead to taller plant height and produce more leaves. Plant treated with fertigation at 3 days interval and applied once/day produced significantly higher number of chili fruits than those treated with fertigation at 6 days interval and applied once/day or at 9 days interval and applied twice/day (Table 3). Nutrients used was a mixture between liquid organic fertilizer from rabbit urine and AB Mix, apart from being able to amend the physical structure of the soil, it will also add to the availability of nutrients in the soil, both macro and micro nutrients [11]. The greater the dose of nutrients given, the greater the addition of nutrients to the soil, especially nitrogen, phosphorus and potassium. Nitrogen plays an active role in nitrogen metabolism and protein synthesis, and accelerates vegetative growth. The role of phosphate in plant physiological processes is to provide the energy needed for metabolic processes and biosynthetic reactions. The function of potassium is more catalytic but its function is physiologically important, one of which is metabolism, including the formation, breakdown, and translocation of raw materials.

The results of variance analysis showed that the weight and shelf life of chili fruits did not significantly affected by the fertigation intervals for providing nutrition at 3 days, 6 days, 9 days and applied once/day, twice/day and three times/day (Table 4). It is because the weight of the chili fruit is determined by assimilates, as a result of photosynthesis process. Hence, the availability of nutrients was important for photosynthesis process. Light has the potential to enhance the process of photosynthesis which produces energy and food sources. Adequacy of water irrigation has a good effect on cell turgor pressure. Turgor pressure plays a role in determining plant size, including enlargement and multiplication of plant cells, leaf development, and flower formation and chilies fruit development. The adequacy of raw material encourages chili fruit to have a longer storability of chilies when it is harvested when it is physiologically ripe.

4 Conclusion

Appropriate combinations between interval and frequency of fertigation impacted red chili development (plant height, number of leaves) and yield (number of red chili fruits) significantly. Fertigation given at 3 days interval and applied three times/day produced higher plant height and number of leaves, although it had no significantly different effect from fertigation at 3 days interval and applied once/day or twice/day. Three days interval of fertigation and applied once/day or twice/day more chili fruits. The interval and frequency of fertigation didn't significantly affect the weight and shelf life of chili fruits.

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