Utilization of Soil Moisture Through Furrow Irrigation for the Growth of Chilli Pepper

Sitti Nur Faridaha, Abdul Waris, R. Rahmi

Abstract: The aim of this study is to determine the growth rate of pepper plants by providing irrigation water based on readily available water through a furrow irrigation system. This study analysis of the soil physical properties, calculate the total available water and the water requirement of plants and observe the growth of pepper plants. The irrigation is conducted once every 7 days during the growth period. The result showed that soil with sandy loam texture has total available water is 112 mm and readily available water is 55.9mm. The average water requirement of chilli pepper plants is 3.87mm/day with the highest water requirement during flowering and fertilization is 5.18 mm/day. The growth of chilli pepper plant in furrow irrigation systems is 19.8mm/week which indicated the tendency for disturbances during growth due to water stress at vegetative growth periods, with a maximum Leaf Area Index of 33.24cm^2.

I. INTRODUCTION

Chilli pepper (*Capsicum annum L.)* is one of the key horticultural commodities due to its high economic value, good nutritional content such as essential vitamin C content for collagen biosynthesis [1, 2]. Chilli pepper is a spicy food with a hot flavour that is popular in Mexico [3], United States of America, England, Ethiopia, Peru, Korea, India, Thailand, and other Asian countries [4]. About one-third of the world's population consumes Chilli pepper every day [5].

Chilli pepper cultivation is greatly influenced by a number of factors, such as rainfall, wind, sunlight, temperature, and humidity. Chilli pepper requires rainfall of 1,500 – 2,500mm/year, temperatures of 16 – 32ºC, in moderate climates with 4 – 6 months of dry weather [6]. Water availability is a primary consideration when determining a suitable time for planting Chilli peppers.

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The planting of Chilli peppers at high altitudes rely solely on rain water, thus planting during summer is inappropriate. Conversely, in low basins that are in close proximity to water sources, it is inappropriate to plant hybrid Chilli peppers during the wet season as this increases the risk of flooding and causes water drainage difficulties.

The water supply can be controlled using irrigation. Irrigation can increase the levels of soil moisture and improve crop growth and yield of Chilli pepper [7]. Irrigation is essentially the addition of water to fulfil the water needs of a plant, or plant evapotranspiration. When the water is enough, the process of absorption of nutrients and photosynthesis rate will run smoothly, thus increasing plant growth [8].

Irrigation is a solution when rainfall in an area is uncertain and is used to reduce risk of crop failure and increases the availability of nutrients and creates optimal soil moisture conditions to improve harvest results and crop quality.

Furrow irrigation is a method of water distribution that is highly suitable for Chilli pepper plants. Furrow irrigation is an above-ground water distribution system that channels water into the soil to restore soil moisture near the roots of the plant. According to Achmad and Putra (2016), the soil moisture was water that fills most or the entire soil pore [9]. Allocation of water irrigation is determined based on the water holding capacity of the soil, which indicates the amount of available water and the absorption of water by plants [10]. Furrow irrigation is suitable for medium- to smooth-textured soil with relatively high water holding capacity, allowing for lateral and vertical water movement.

In furrow irrigation systems, crops are planted in seedbeds located between furrows. The distance between furrows for Chilli pepper crops is about 1m. In addition, furrow irrigation is a simple irrigation system that can be executed at little expense in comparison to other surface irrigation systems [11, 12]. The aims of this study to determine the growth rate of Chilli plants with irrigation based on the water requirement of plants and readily available water through the furrow irrigation systems.

II. MATERIALS AND METHODS

This study was conducted at a locally-owned chilli pepper farm in the district of SidenrengRappang in the Indonesian province of South Sulawesi, Indonesia. The study location can be found at 3º 54' S latitude, 119º 48' longitude, at an elevation of about 18m above sea level.

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Data on physical environmental factors such as rainfall, air humidity, wind speed, evaporation and duration of exposure to sunlight were obtained from the Sidrap Regency Climatology Station, South Sulawesi, Indonesia.

Research plots were prepared by isolating then levelling the land. 14 parallel furrows were dug in every plot, each with a length of 15m and a distance of 1m between furrows. The base and height of each furrow were 20cm and 25cm respectively as shown in Figure 1. Chilli pepper seeds were planted at each seedbed, weeded and then harvested in accordance to the procedure commonly used by the locals. Watering was conducted once every 7 days.The soil sample collection was conducted using ring samples for analysis of physical soil characteristics such as texture, bulk density, particle density, porosity, field capacity, and permanent wilting point. The evaporation measurements were performed using an evaporation pan.

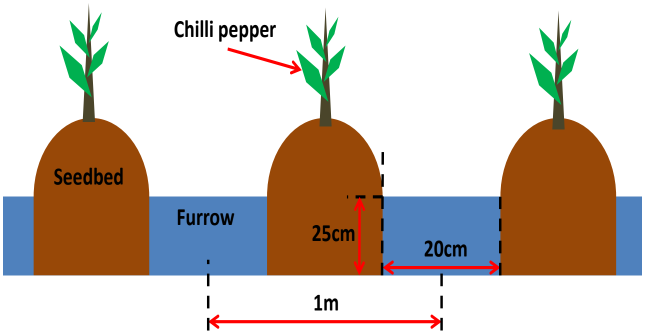

Fig. 1 The layout of the research plots

Research Parameters

The parameters measured in this study are as follows: Crop coefficient (Kc) at each phase of plant growth [13]: Crop coefficient at the initial phase of growth

$$Kc\,in = Kc_{in(Tab)}(A) + \frac{(I-10)}{(40-10)}\left[Kc_{in(Tab)}(B) - Kc_{in(Tab)}(A)\right] \quad (1a)$$

Where:

Kc in = Crop coefficient the initial phase of growth

$Kc_{in(Tab)}$ (A),(B) = Crop coefficient Chilli pepper

I = Infiltration (cm/hour)

Crop coefficient at the middle phase of growth (kc mid)

$$Kc\,mid = Kc_{mid(Tab)} + \left[0.04(U_2 - 2) - 0.004(RH_{min} - 45)\right]\left(\frac{h}{3}\right)^{0.3} \quad (1b)$$

Where:

Kc mid = Crop coefficient the vegetative phase)

$Kc_{mid\ (Tab)}$ = Crop coefficient (0,675)

U_2 = Wind speed (m/s)

RH_{min} = Minimum air humidity (%)

Crop coefficient at the end phase of growth

$$Kc\,end = Kc_{end(Tab)} + \left[0.04(U_2 - 2) - 0.004(RH_{min} - 45)\right]\left(\frac{h}{3}\right)^{0.3}$$

(1c)

Where:

Kc_{end} = Crop coefficient the end phase

$Kc_{end\ (Tab)}$ = Crop coefficient (0,925)

U_2 = Wind speed (m/s)

RH_{min} = Minimum air humidity (%)

H = Crop height (m)

Reference evapotranspiration

ET_0 =Kp x Ep (2)

Where:

Kp = pan coefficient

Ep = pan evaporation

Crop evapotranspiration

$T_c = ET_0$ x Kc (3)

Where:

ET_c = Crop evapotranspiration (mm/day)

ET_0 = Reference evapotranspiration (mm/day)

K_c = Crop coefficient

Total available water

TAW = FC – WP (4)

Where:

TAW = Total available water (%)

FC = Field capacity (%)

WP = Permanent wilting point (%)

Readily Available Water:

RAW = MAD x TAW (5)

Where:

TAW = Total available water (mm)

MAD = Management allowed deficit

RAW = Readily available water (mm)

Leaf Area Index [14]:

LAI = s/G (6)

Where:

s = Leaf area on canopy

G = Land surface area covered of canopy

III. RESULTS AND DISCUSSION

Water Requirements of Plants

The water requirements of a plant are dependent on the type, variety and development phase of the plant [15], moment and period of planting, physical characteristics of the soil, water distribution system, distance between water source and planting area, and the total area of land where the plant will be grown [16]. The crop coefficient for chilli pepper per growth phase and the water requirement are shown in Figure 2 and Figure 3 respectively.

Figure 2 illustrates the crop coefficient at the initial phase of chilli pepper growth was 0.391 to 5 weeks after planting. During the development phase of growth (5 – 8 weeks after planting) the crop coefficient was 0.68. Flowering phase had a K_c value of 1.07 for the period of 8 to 17 weeks after planting. By the time of harvest, the K_c value is 0.87.

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Allen et al., (2006) stated that the values of Kc varies over the crop development and increases from a minimum value at planting until a maximum Kc reaches full canopy cover, the Kc tends to decline at a point after a full cover is reached during the crop season [17]. The crop coefficient is intensely used to estimate crop water use and to schedule irrigation events [18, 19].

Figure 3 shows the water requirements of chilli pepper during the initial growth phase (first week after planting) was 1.22mm/day and required the greatest amount of water during the flowering and fruition phases due to the large volumes of water transpiring from the flowers and young fruits, in addition to leaves. The water needs of chilli pepper decrease to about 3.73mm/day as the harvest phase approaches, this is to improve the ripeness of the fruit and the dissolved solids in the fruit.

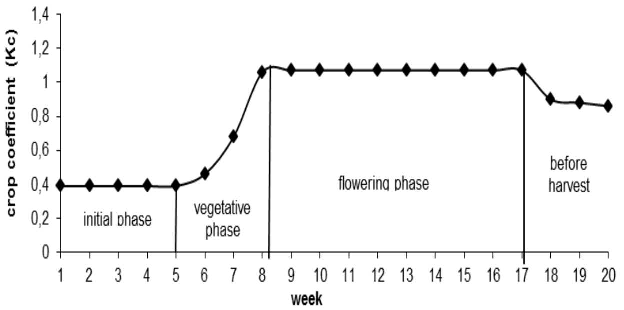

Fig. 2 Crop Coefficient for Chilli Pepper per Growth Phase

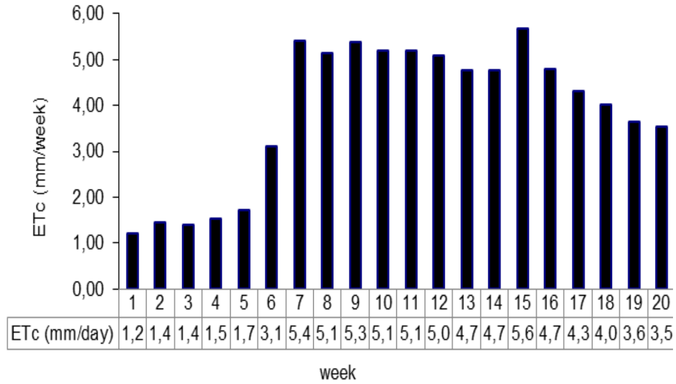

Fig. 3 The water requirements of Chilli pepper

Total Available Water

Total available water is the usable water content present around the roots of the crop [20]. Total available water for chilli peppers at the study location for the sandy clay-soil was 112 mm with 13.5% field capacity, permanent wilting point of 5.96%, and Readily Available Water (RAW) for Chilli peppers was 55.9mm. The primary issue regarding water distribution in the area was the increasing scarcity of water at certain points in time. On the other hand, the demand for water for a number of needs continues to increase [21].Chilli peppers can grow in various soil types as long as there is sufficient drainage and soil aeration. At field capacity conditions, the roots can easily absorb water. The availability of ground water for plants is dependent on the type of soil and the plant's ability to utilize the available water [22].

The ideal soil structure has the correct balance of aeration and water-retaining pores. In sandy soil, water is easily drained and evapotranspiration. Whereas, due to the structure of soil with high clay content, there will be a greater obstruction of the movement of water. Soft soil has a soft, fine-crumb structure and is more capable of retaining water. The ideal soil structure for water distribution is soil with pore structure at field capacity and a relatively high permanent wilting point of 18 – 23% [23]. Sandy clay soil has sufficient capability to store water and good aeration.

Distribution of Irrigation Water

The distribution of irrigation water to the plants usually only based on the crop water requirements or soil moisture. In this study, the distribution of irrigation water to the plants based on the crop water requirements with considering the readily available water. Figure 4 shows the Readily Available Water and the water requirements of chilli peppers, watering was conducted once every seven days, on 1, 8, 15, 22, 30, 36, 43, 50, 57, 64, 71, 78, 85, 92, 99, 106, 113, and 120 days after planting with total water irrigation averaging to 1.98L/m^2 per watering.

There were instances of rainfall during the planting period. In cases of rain, water distribution was adjusted to rainfall, readily available water, and the water needs of the crop. Watering was performed once every 7 days; overwatering of the plant could result in an extension to the duration of the vegetative period of plant development and potentially delay harvest. The distribution of irrigation water for the chilli pepper is shown in Figure 4.

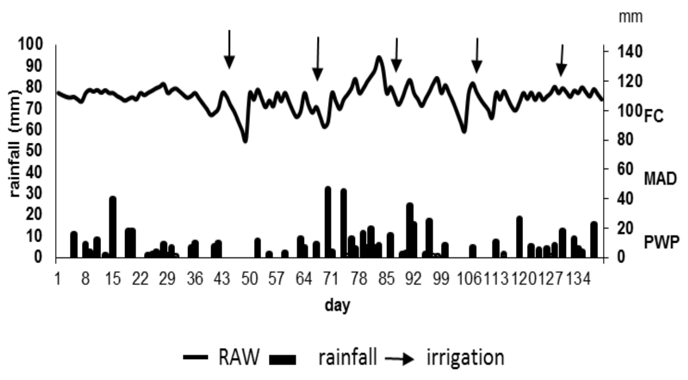

Fig. 4 The distribution of irrigation water for chilli pepper

Plant Growth

Stem height and Leaf Area Index in chilli peppers can be seen in Figure 5. Figure 5 illustrates the escalation of plant stem height occurred on the 3rd week after planting, maximum crop height was 76.20cm.

On the 10th – 13th week after planting, during the vegetative period of plant development, chilli pepper crops did not experience any significant growth. Plant growth will be upset in cases where water availability is outside of the recommended range, resulting in the plant experiencing water stress. A lack of water during the vegetative phase will cause the plant to grow shorter than normal specimens [24].

Leaf Area Index is defined as the area of soil surface covered by plant leaves per unit of measurement. Leaf Area Index is an important parameter for identifying growth [25] and crop productivity [26].

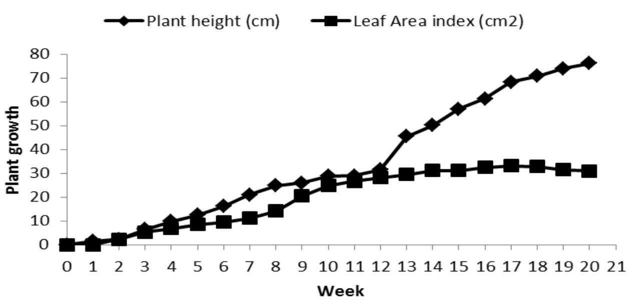

Fig. 5 The plant growth for Chilli pepper

Leaf Area Index was highest for irrigation-hydrated Chilli pepper crops (watering conducted once every 7 days) on the 17th week after planting at 33.24. A reduction of irrigation water was necessary 1 – 2 weeks before harvest to improve fruit ripeness. Water stress at the wrong time could have negative effects on the crop. Water stress could potentially stimulate shedding of the leaves and flowers, reduce fruit size, and diminish fruit count.

Plant water requirements, in addition to being dependent on available ground water, is also dependent on climate and the phases of plant development. Chilli pepper has specific water and nutrition needs for each phase of its development[27].

IV. CONCLUSION

The obtained result of this study indicates that the total available water based on field capacity and permanent wilting point chilli pepper plants in sandy clay soil is 112mm and readily available water is 55.9mm. An average plant water requirement for chilli peppers influenced by evapotranspiration and crop coefficient is 3.87mm/day. The growth of chilli pepper plants for irrigation 19.8mm/week demonstrated the tendency for water stress during flowering and fertilization periods, with Leaf area index maximum of 33.24 cm^2.

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