RESEARCH ON THE CHARACTERISTICS AND APPROPRIATE IRRIGATION REQUIREMENT FOR THE GROWTH STAGES OF BANANA

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Abstract: *Banana is a fruit crop, characterized by a soft, cylindrical stem; the foliage is long, translucent, green, and smooth, cluster roots that go deep underground and grow over time. In Vietnam, banana trees are listed as the main crops and bring high economic value. Like some other fruit crops, bananas have growth characteristics divided into four main periods. Depending on each stage of development, bananas have different irrigation requirements. Currently, the demand for banana products in the world is very high; the potential for banana export is an opportunity to develop the agricultural economy in particular and the country's economic development in general. However, the productivity and quality of banana crop depends on many factors, some of which are the main factors such as soil, seedling quality, pests and diseases, and especially an appropriate irrigation requirement for the growth stages of banana. Therefore, in this study, we focused on determining the appropriate irrigation regime for the growth stages of banana crops to improve yield and product quality.*

The research results determined that on one hectare of bananas with 2,000 trees, the amount of water required for the entire period is 1.578,67 m^3/ha. Besides, the results also showed that the water demand for each growth stage is different; that is the highest water demand at the stage of banana flowering and fruit raising with an irrigation requirement of up to 18.62 liters/tree/time, while the young tree stage has the lowest water demand with an irrigation requirement of only 4.3 liters/tree/time.

Keywords: *Banana, In vitro, irrigation requirement, water demand.*

1. INTRODUCTION

Bananas are plants that require a lot of water and are grown all over the world, most commonly grown in countries with tropical climates, several studies have shown that the impact of climate change on agricultural production, the main factor limiting the growth, development and yield of bananas is irrigation requirement and temperature in banana growing areas, the weather and climate changes have changed crop structure, regional planning, and irrigation techniques; pests and diseases; Degrading land and water resources... has directly affected the development process, productivity and quality of banana crops.. In recent years, some research results on banana crops, banana breeding and technical measures to care for banana trees, The results of the studies have given relatively uniform recommendations, from breeding, planting, care, and pest control. In the world, banana growing seasons vary widely depending on growing regions but are determined to be the most suitable from the end of the dry season to the beginning of the rainy season [1]. In Puertorico and some ideal growing areas,

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bananas can be grown all year round. Meanwhile, in other regions, planting seasons need to be arranged to avoid harsh sunlight at the beginning of the season and especially to avoid cold when flowering. Many research results have confirmed that different planting seasons greatly affect watering requirements, water needs, productivity and fruit quality. Planting density and spacing vary between banana varieties, depending on soil fertility and many other factors. Thick planting helps banana gardens increase their ability to resist wind and storms, but limits bud production, makes it difficult to prevent pests, and only achieves high profits in the first crop. In the coming seasons, the fruit becomes smaller and mushy. The common planting density in Central America and South Africa is 1.235 trees/ha. Planting up to 1.976 trees/ha, productivity increased by 4 tons/ha. However, if the density is increased to 3.212 trees/ha, the yield tends to decrease. Planting density in Surinam fluctuates greatly between 600-4.400 trees/ha but a density of 2.000-2.500 trees/ha is determined to be the most appropriate [2].

Research results in Ecuador have determined that with the amount of N - P_2O_5 - K_2O fertilizer calculated for 1 hectare of 600 - 100 - 600 kg, the first season yield only reached 30 tons at a planting density of 1.500 trees/ha but achieved up to 55 tons if planted up to 3.000 trees/ha. Fruit yield in second season is higher with values of 47 tons and 65 tons, respectively. There are no significant differences in fruit quality indicators between the above planting densities. To maintain high yields in the next seasons, it is necessary to pay attention to pruning buds and for denser planting densities, the amount of fertilizer must be increased. However, if the planting density is too thick, profits tend to decrease. In recent years, in the Philippines, Australia, Taiwan and many countries that grow bananas for export, they have begun to focus on designing banana gardens in the style of planting double rows of 2-4 single rows and leaving wide paths to create favorable conditions for growing banana trees, care, harvesting and transportation [3].

Determining water demand and fertilization methods has attracted the research attention of many scientists. Most research results indicate that banana have high water demand are very voracious, and emphasize the need for balanced fertilization. In Puertorico, the common amount of fertilizer per hectare is 250 - 325 kg, 125 - 163 kg of phosphorus and 500 - 650 kg of potassium. However, the appropriate amount of fertilizer for each region must be determined through research because it depends greatly on banana types characteristics, soil type and planting density.… Therefore, the appropriate dosage and fertilization method in this region is sometimes not highly effective in many other regions. However, the recommended NPK fertilization ratio in many countries is 8:10:8. Inorganic fertilizers are most effective under balanced fertilization conditions combined with organic fertilizers and irrigation requriments [4].

In Vietnam, the Northern Delta and midlands have two main growing seasons: spring, from February to April, and autumn, from August to October**.** Planted in the spring, the plant survives very easily, but when it blooms, it gets cold, so the fall season is currently a popular planting season. In other regions, the main planting time is the beginning of the rainy season [5]. Banana trees have wide adaptability, are easy to grow and can be harvested quickly, only 11-12 months after planting for Musa bananas and 15-16 months for artocarpus interger bananas. In Vietnam, bananas are grown quite commonly, on many different types of soil and terrain. This is also one of the few fruit trees capable of developing into large-scale concentrated commodity production areas. The current growing areas

with large area and output are the Mekong Delta, the Red River Delta and the North Central region. The Central Highlands, Southeast and Northern Mountainous regions have many prospects for developing banana production due to the large amount of unexploited land fund and especially due to the conversion of crop structure that has been and is being implemented in the area. Planting density is an important factor affecting banana yield. In Vietnam, bananas are grown a lot in household gardens, mixed with many other crops and fruit trees, so the planting density is very arbitrary, sparse or too thick and is mainly determined according to people's experience. At the scale of commodity production, banana planting density varies depending on variety and growing conditions. Common planting densities for Artocarpus interger bananas and bananas range from 2.000-2.500 trees/ha [6]. Researching scientific and technological solutions for banana production helps form large-scale concentrated export banana production areas, improving productivity and efficiency of banana production and achieving income of 150 - 200 million VND/ha that has significantly improved the lives of producers, while also improving the efficiency of labor and land use [7]. The appropriate amount of fertilizer for 1 banana tree in 1 season (1 vụ) is 50-60 g nitrogen, 30-40 g phosphorus and 70-80 g potassium [8]. banana varieties from sproutingand banana plants in vitro are both good planting materials. On Red River alluvial soil in Phu Tho area, the amount of fertilizer calculated for 1 banana root is 200 g nitrogen, 40 g phosphorus and 480 g potassium to achieve the highest economic efficiency and productivity, 16 kg/plant. NIf the care and fertilization are not appropriate for the growth stages of the banana tree, some symptoms of nutrient deficiency will also be manifested on the banana tree [9]. Currently, most banana trees are planted in rows and irrigated using the surface irrigation method (irrigation in rows), only a few places have proactive, water-saving irrigation systems in the form of drip irrigation, sprinkler irrigation. The banana tree is a fruit tree, a shallow plant that grows in moist soil. In particular, most irrigation techniques are still done traditionally, mainly depending on rain water, so productivity and quality are very limited, quality is uneven, and production efficiency is not high. In fact, in recent years, banana research and development has been receiving attention and investment from the Government and has achieved very encouraging results. Up to now, research on bananas has focused mainly on conservation and evaluation of genetic resources, selection of new varieties, cultivation of in vitro and development of intensive farming techniques suitable for different agro-ecological regions. Calculating and determining the irrigation requirements in each growth stage of banana plants to bring about high efficiency in banana production is extremely important. Some research results show that lack of water can cause choking of leaves and flowers, reducing the elongation of leaf sheaths, and leaf stalks becoming very close to each other [10]. The above reality shows that productivity, output and quality of bananas in Vietnam are revealing some remaining limitations such as low productivity and low quality of bananas due to many reasons, including ensuring appropriate irrigation requirements during each growth period of banana trees is a key issue and directly affects banana productivity and quality. Inappropriate watering irrigation, especially in the period before banana flowering, if the water needs are not met, it will be very dangerous for the yield and quality of bananas, Therefore, in this study, focusing on calculating and determining the appropriate irrigation irrigation for banana plants in each growth stage is really necessary, contributing to improving productivity and product quality of bananas.

2. METHODS AND DATA

2.1. Method

Banana is a fruit tree and grows in moist soil, In order for banana trees to grow well and yield high yields, the moisture in the arable soil layer must be properly maintained based on an irrigation formula to increase production (appropriate irrigation method) and calculation method to determine irrigation requirement for each growth stage of banana trees based on the principle of calculating water balance, concretize in the moist soil layer that nourishes the plants.The equation has the form [11]:

$$\Sigma m_i = (W_{hi} + W_{ci}) - (W_{0i} + \sum P_{0i} + \Delta W_i) \quad (1)$$

In there:

Σm_i - Total amount of irrigation requirement for irrigation during the period (m3/ha)

W_{hi} - amount of water lost during the calculation period (m^3/ha)

$$W_{hi} = 10.ET_c.t_i \quad (2)$$

ET_c - Field surface evaporation intensity (or water loss intensity, mm/day)

t_i - water loss time (number of days).

W_{ci} - The amount of water needed to be stored in the arable soil layer at the end of the calculation period (m3/ha), Wci can be calculated as follows:

$$W_{ci} = 10.\beta_{ci}.\gamma_k.H_i \ (m^3/ha). \quad (3)$$

γ_k - dry density of soil (ton/m^3).

β_{ci} - Soil moisture at the end of the period can be calculated as (%) dry density of the soil.

The amount of water contained in the soil at the end of the Wci period is controlled according to conditions:

$$W_{\beta mini} \leq W_{ci} \leq W_{\beta maxi} \quad (4)$$

In there:

$$W_{\beta max\ i} = 10.\gamma_k.\beta_{maxi}.H_i \ (m^3/ha). \text{ Hoặc } W_{\beta max\ i} = 10.A.\ \beta_{maxi}.H_i \quad (5)$$

$$W_{\beta mini} = 10.\gamma_k\ .\beta_{mini}.H_i \ (m^3/ha). \text{ Hoặc } W_{\beta mini} = 10.A.\ \beta_{mini}.H_i \quad (6)$$

W_{oi} - The amount of water available in the soil at the beginning of the calculation period is determined according to:

$$W_{oi} = 10.\gamma_k.\beta_{0i}.H_{0i} \ (m^3/ha). \text{ or } W_{oi} = 10.A.\ \beta_{0i}.H_{0i} \quad (7)$$

$\sum P_{0i}$ - Amount of water used by plants during the calculation period:

$$\sum P_{0i} = \sum \alpha_i.C_i.P_i \quad (8)$$

In there:

P_i - The actual amount of rain falling on the field according to the calculated frequency (mm).

C_i - The coefficient represents the amount of rainwater that can infiltrate into the ground, determined experimentally: $C_i = 1 - \sigma_i$

σ_i - flow coefficient, determined experimentally.

α_i - rainwater use coefficient, through determined calculation.

ΔW_i - Amount of water that crops can use during the calculation period:

$$\Delta W_i = W_{Hi} + W_{ni} \quad (9)$$

W_{Hi} - The amount of water that plants can use is due to the increase in soil depth as plant roots grow:

$$W_{Hi} = 10.\gamma_k.\beta_{0i}.(H_i - H_{i-1}) \quad (10)$$

W_{ni} - The amount of underground water that

plants can use due to the capillary creep effect that allows plants to absorb this amount of water. This amount of water depends on the depth of the water table and the type of soil in the growing area. When there is a lack of experimental data, it can be determined according to the formula:

$W_{ni} = K_{ni}.ET_C$ (11)

In there: K_{ni} - The groundwater use coefficient depends on the depth of the water table and soil type and is determined experimentally.

Detemination of irrigation requirement total (entire of period) m (m^3/ha):

$\sum m_i = m_1 + m_2 + ... + m_n$ (m^3/ha-season); (12)

In there: mi: Irrigation per time (m^3/ha)

2.2. Data requirements

Planting season mainly depends on the expected harvest season and favorable weather conditions for banana growth, Bananas are cultivated in two main seasons as winter-spring and summer-autumn. In Viet Nam, there are many banana types. In this study, Musa banana (chuối tiêu hồng) is selected to calculate irrigation requirements during growth and development. The banana tree's growing season from planting to harvest is about 11-12 months, so if you want to harvest at any time, plant it back to the corresponding time. The growth and development period of bananas is shown in the following table 1.

Table 1: Growth period and appropriate irrigation formula

Growth stage	Period		Number of date	Soil depth (cm)	Coefficient K_C	Appropriate irrigation form (%)
	from	to				
The young tree stage (init)	15/I	24/II	40	30	0,50	60-80
Stage of growth and flower bud	25/II	9VIII	160	50	1,20	70-85
Stage of flowering and fruit growing	10/VIII	25/XI	70	60	1,50	70-85
Stage ripening & preparing for harvest	26/XI	26/XII	30	60	1,00	60-80

Figure 1: The stages of young and growing bananas

Figure 2: The stages of flowering and fruiting

2.3. Principle of calculation

The principle of calculating the irrigation requirement for banana is based on a system of two equations including the water balance equation (1) and the appropriate irrigation formula (4), specifically equation (1) has two unknowns, which are W_{ci} and $\sum mi$. To solve the water balance problem and maintain soil moisture in the range of 60%-85%, the determined calculation steps are performed as follows:

Step 1: We will solve according to the trial method, assuming $\sum mi$ then calculate W_{ci} according to equation (1)

Step 2: Check the constraint conditions according to the appropriate irrigation formula above. If the results satisfy the constraint conditions, the result will be correct. The calculation process to determine the irrigation regime is described in the block diagram below:

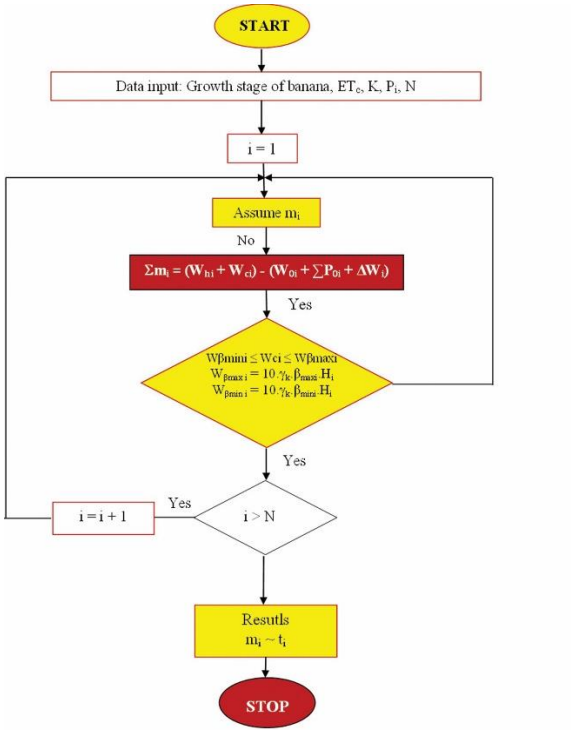

Figure 3: Diagram of the calculation process to determine the irrigation requirements

Equation (1) is carried out according to the trial method by creating a spreadsheet, the growth period of a banana crop is divided into many small sub-periods, with known soil moisture at the beginning of the period and known water losses (due to infiltration and evaporation of the field surface), the amount of precipitation is also known, first, assume a value of irrigation level m then use the water balance equation to determine the soil moisture at the end of that calculation period (end of the day). Compare this soil moisture according to the appropriate irrigation equation (constraints condition of the equation). If found suitable, m is assumed to be appropriate. If not appropriate, m must be re-assumed specifically as follows:

- If with m assumptions, we can calculate $W_c < \{W_{min}\}$ then re-assume m by increasing m and re-determining Wc until suitable ($\{ W_{min} \leq Wc \leq \{W_{max}\}$) then stop.

- If with m assumptions, we can calculate $Wc > \{W_{max}\}$, then re-assume m by reducing m and redefining Wc until suitable ($\{W_{min}\} \leq Wc \leq \{W_{max}\}$) then stop.

In case the rain is too heavy (not irrigation, m=0), but $Wc > \{W_{max}\}$, we must stop irrigation or drain the rainwater to avoid flooding and maintain appropriate soil moisture according to the appropriate irrigation formula, Then only retain moisture in the soil equal to $\{W_{max}\}$. Repeating this cycle until the end of the banana tree's growth period, we will determine the number of irrigation times, irrigation requirement for each irrigation time, the total irrigation requirement of the entire period for banana growth and development.

3. RESULTS AND DISCUSSION

Banana is a plant that needs a lot of water, however, too much water content in the soil can easily damage the roots, affecting the growth process of the banana. Therefore, gardens must create drainage systems and plots for low-lying gardens. In addition, the impact of climate change is becoming more and more complicated, with rain and temperature changing erratically, leading to changes in irrigation requirements during the growth and development stages of banana crop, so it is really necessary to research and apply appropriate irrigation methods to grow banana trees well and maintain soil moisture between 60 - 85%.

Table 2: Summary of irrigation times, irrigation days, and irrigation requirements for banana crop

TT	Growth stages	Time (day/month)	Duration (day)	irrigation times	Irrigation requirements (mi)		irrigation interval (day/time)	Number of irrigation times	Soil moisture (%)
					(liter/tree/time)	(m^3/ha/time)			
1	The young tree stage (init)	15/I	1	m1	3,00	6,0	3	14 times	60%
			3	m2	3,25	6,5	3		**63%**
			6	m3	3,51	7,0	3		**66%**
			9	m4	3,72	7,4	3		**69%**
			12	m5	4,00	8,0	3		**73%**
			15	m6	4,24	8,5	3		**77%**
			18	m7	4,41	8,8	3		**80%**
			21	m8	4,45	8,9	3		**78%**
			24	m9	4,50	9,0	3		**77%**
			27	m10	4,50	9,0	3		**78%**
			30	m11	5,00	10,0	3		**78%**
			33	m12	5,25	10,5	3		**78%**
			36	m13	5,30	10,6	3		**79%**
		24/II	40	m14	5,41	10,8	3		**79%**
2	Stage of growth and flower bud		45	m1	6,49	12,98	5	33 times	**81%**
			50	m2	7,79	15,58	5		**81%**
			55	m3	9,35	18,69	5		**82%**
			60	m4	11,22	22,43	5		**83%**
			65	m5	11,22	22,43	5		**84%**
			70	m6	12,00	24,00	5		**84%**
			75	m7	12,00	24,00	5		**84%**
			80	m8	12,00	24,00	5		**84%**
			85	m9	12,00	24,00	5		**84%**
			90	m10	12,00	24,00	5		**83%**
			95	m11	12,00	24,00	5		**81%**
			100	m12	12,00	24,00	5		**80%**
			105	m13	12,00	24,00	5		**78%**
			110	m14	12,96	25,92	5		**80%**
		9/V	115	m15	13,61	27,22	5		**81%**
			120	m16	14,29	28,58	5		**84%**
			125	m17	14,29	28,58	5		**84%**
			130	m18	15,00	30,01	5		**85%**
			135	m19	15,00	30,00	5		**84%**
			140	m20	15,00	30,00	5		**83%**
			145	m21	15,00	30,00	5		**83%**
			150	m22	15,00	30,00	5		**82%**
			155	m23	15,00	30,00	5		**81%**
			160	m24	15,00	30,00	5		**80%**

TT	Growth stages	Time (day/month)	Duration (day)	irrigation times	Irrigation requirements (mi)		irrigation interval (day/time)	Number of irrigation times	Soil moisture (%)
					(liter/tree/time)	(m^3/ha/time)			
			165	m25	15,00	30,00	5		**79%**
			170	m26	15,00	30,00	5		**79%**
			175	m27	15,30	30,60	5		**78%**
			180	m28	15,61	31,21	5		**79%**
			185	m29	15,92	31,84	5		**79%**
			190	m30	16,24	32,47	5		**80%**
			195	m31	16,56	33,12	5		**81%**
			200	m32	16,89	33,78	5		**82%**
		9/VIII	205	m33	17,23	34,46	5		**83%**
3	Stage of flowering and fruit growing		210	m1	18,09	36,18	5	14 times	**82%**
			215	m2	19,00	37,99	5		**81%**
			220	m3	19,95	39,89	5		**80%**
			225	m4	19,95	39,89	5		**81%**
			230	m5	20,00	40,00	5		**82%**
			235	m6	21,20	42,40	5		**83%**
			240	m7	22,47	44,94	5		**85%**
			245	m8	21,80	43,60	5		**84%**
			250	m9	20,00	40,00	5		**82%**
			255	m10	18,40	36,80	5		**77%**
			260	m11	17,66	35,33	5		**74%**
			265	m12	15,90	31,80	5		**72%**
			270	m13	13,99	27,98	5		**70%**
			275	m14	12,31	24,62	5		**69%**
4	Stage ripening & preparing for harvest		285	m1	9,60	19,21	10	3 times	**67%**
			295	m2	7,20	14,40	10		**65%**
		26/XII	305	m3	5,33	10,66	10		**61%**
Total of irrigaion requirements						**1.578,67**		**64**	

In the table 2, the research results determined that on one hectare of bananas with 2,000 trees, the amount of water required for the entire growth stage is 1.578,67 m^3/ha. Depending on

the growth stage of bananas, irrigation requirements are different, specifically: (i) In the figure 4, 5 and table 2 show that young tree stage (init): in this stage with banana seeds in vitro crop, the soil moisture is maintained at 60-80% with an irrigation time of 3 days/per time, corresponding to an irrigation requirement of 4.3 liters/tree/irrigation time and the necessary water demand during this period of 121.08 m^3/ha. (ii) In the figure 4, 5 and table 2 show that growth and flower bud stage: During this period, banana trees grow rapidly to ensure soil moisture is maintained at 70 - 85% with an irrigation time of 5 days/per time, corresponding to an irrigation requirement of 13.5 liters/tree/time and the necessary water demand during this period of 891.89 m^3/ha.

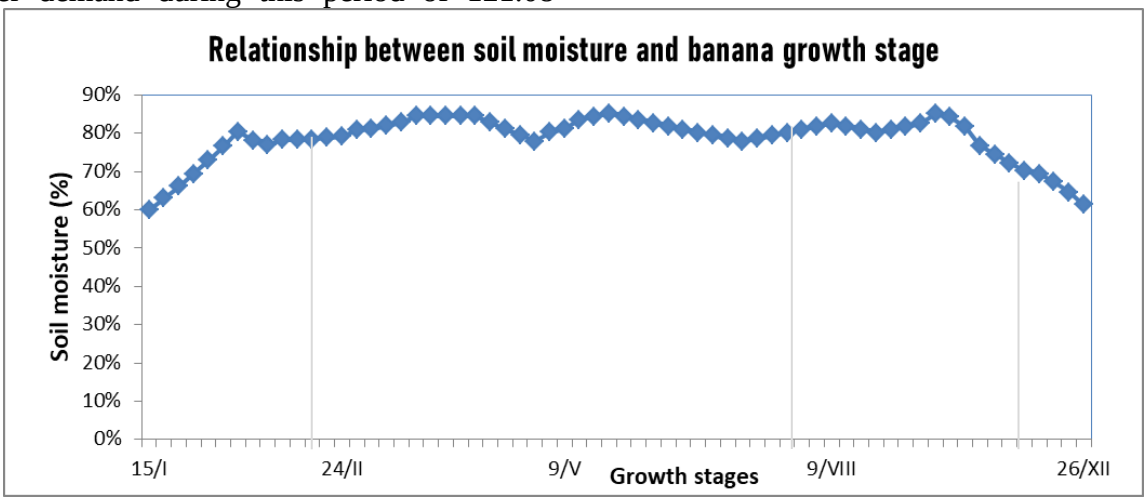

Figure 4: Relationship between soil moisture and banana growth stage

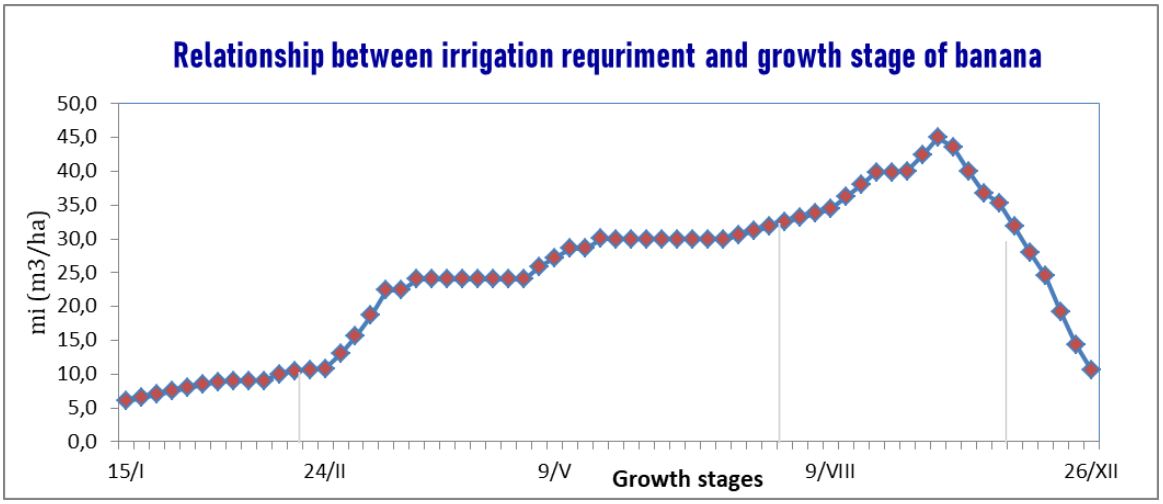

Figure 5: Relationship between irrigation requriment and growth stage of banana

(iii) In the figure 4, 5 and table 2, the results show that stage of banana flowering and fruit growing (bananas come out of the chamber): In this stage, banana crops need lots of water to ensure soil moisture is maintained at 70 - 85% with an irrigation time of 5 days/per time, corresponding to irrigation requirement of 18.62 liters/tree/time and the necessary water demand during this period of 521.43 m^3/ha. (iv) In the figure 4, 5 and table 2, the results show that stage of banana ripening and preparing for harvest: In this period, the bananas are ready to

ripen (1 month before harvest). During this period, to maintain 60-80% soil moisture, with an irrigation time of 10 days/per time, corresponding to an irrigation requirement of 7.38 liters/tree/time and the necessary water demand during this period of 44.27 m^3/ha.

Research results also show that the irrigation requirement of bananas changes during each growth stage to ensure the maintenance of appropriate moisture in the soil, with the highest water demand at the flowering and fruit growing stage (Bananas come out of the chamber) with an irrigation requirement upto 18.62 liters/tree/time, while the young crop stage has the lowest irrigation requirement with a watering regime of 4.3 liters/tree/time each time.

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