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Application of Absorbent Polymer in Improving Moisture Retention and Growth Performance of 'Lakatan' Banana (*Musa sapientum L.*) under Nursery Condition

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Abstract

Absorbent polymers allow the soil to retain a substantial amount of moisture. This property plays a vital role in producing banana plantlets to mitigate the adverse condition of the climate. This study determines the effect of absorbent polymers in improving moisture retention in the soil and on the growth response of 'lakatan' banana plantlets under nursery conditions. Three factors were used in determining the effect: irrigation amount, irrigation frequency, and amount of polymer. The data was analyzed using Analysis of Variance (ANOVA) with a 3x3x2 factorial experiment in split-split plot design arranged in Randomized Complete Block Design (RCBD). The results of the study indicated that the interaction of the three factors had a significant effect on the morphological characteristics of the banana plantlets. The irrigation frequency and the amount of polymer significantly affected the average plant height and leaf area increment of the banana plantlets. However, the girth size was only affected by the amount of irrigation and polymer. Moisture retention was observed in the soils treated with the absorbent polymer. Partial budget analysis revealed that a benefit-cost ratio of 2.33 was obtained using twice a week irrigation frequency with a 15 mm volume of application.

Keywords: absorbent polymer, moisture retention, irrigation frequency, 'lakatan' banana

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Bananas have been an economically important fruit crop in the Philippines, having dominated the banana trade in Asia and accounting for about 90% of total export volumes in the Region. In 2012, the country was registered to have traded 98% of banana exports from all Asian suppliers (Prowse, 2013). Usually listed as belonging to the country's fruit crops with the largest production, it is a vital source of income as well for local farmers. Filipinos consider it likewise as primary staple food.

The United Nations' Food and Agriculture Organization concluded in its 2015-2016 banana market review that the production of banana in the Philippines declined in 2015 by as much as 50% since 2010 (FAO, 2017). Primary contributors for these were the adverse effects of the El Niño weather phenomenon or drought that negatively affected yields and resulted in product shortages in several of the major producing and exporting regions. The drought was the most significant factor restricting plant growth and crop productivity in the majority of agricultural fields of the world (Abedi and Pakniyat, 2010).

Like other crops, bananas require a large amount of water to grow. The available water in soil was one of the most important factors of increasing crop yields (Ghooshchi, Seilsepour, and Jafari, 2008), which means that adopting an appropriate irrigation management strategy is critical in banana cultivation. Irrigation techniques that have been used include flood, trench, basin, and micro-irrigation (drip irrigation), with the last one being the most efficient method since it provides an even distribution of water or fertilizer directly to the plants' root zone at the measured quantity.

However, despite this efficiency, the cost of drip irrigation is not economically feasible in producing lakatan banana. The system's high investment cost and the spatial development of the root zone were limited and concentrated near the dripper, making plants more susceptible to windthrow (Burt and Styles, 2007). Fortunately, there are low-cost irrigation techniques, such as polymer irrigation or absorbent polymers that enable water application into the soil, minimizing evaporation loss.

Absorbent polymer is similar to a white, sugar-like hygroscopic material mainly used in diapers. Polymers, or hydrogels, are able to absorb and store water hundreds of times their dry weight (Abedi-Koupai, Eslamian, and Kazemi, 2008), improve the water-retention capacity of the soil, regulate plant growth, and accelerate root development, as well as improve soil cluster structure and enhance nutrient absorption (Nnadi, 2012).

This study was designed to investigate the performance of tissue cultured 'lakatan' banana applied with different volumes of irrigation, absorbent polymer ratios, and irrigation frequency. It also aimed to compare the growth response among tissue-cultured lakatan banana plantlets/seedlings using the polymer irrigation method in nursery conditions.

Materials and Methods

Location of the study

The study was conducted in Purok Timog, Visayan Village, Tagum City, Davao del Norte, approximately 3 kilometers from the Timog Highway beside the HARBBCO banana plantation.

Figure 1. Location and structure of nursery

Construction of nursery

A nursery was constructed to accommodate the 18 treatments with three replications, a total of 270 samples with five plantlets per treatment. The greenhouse was built perpendicular to the direction of the sunlight (north to south direction) to reduce its effect. The nursery‘s dimensions were 24 feet wide, 72 feet long, and 10 feet high to provide ventilation as well as adequate spacing between the roofing and the plantlets. A holding area was also established to prepare seedlings and store fertilizers and pesticides. The frames were made up of high-grade bamboo poles wrapped with twine rope. Additional garden nets were placed around the nursery and under the UV-sheet to ensure protection against unwanted pests, such as birds, dogs, and insects.

Soil preparation and meriplant procurement

Soil mixture was prepared by mixing the coco coir and ensuring the same amount was placed per bag. After the soil mixture preparation, 270 pieces of 4” x 7” polyethylene bags were filled to the brim.

The banana cv. ‘lakatan’ plantlets were obtained at the University of Southeastern Philippines–Mabini Campus Tissue Culture Laboratory, Mabini, Davao de Oro. Two hundred seventy (270) samples with an average height of 5 cm were used in this study.

Experimental design and treatments

Three factors were considered in the experiment: factor 1 (main plot), which is the irrigation water requirement (25 mm/week, 20mm/week, 15mm/week); factor 2 (sub-plot), which is the irrigation frequency (once a week, twice a week, three times a week); and factor 3 (sub-subplot), which is the ration of polymer per experimental bag (0g and 5g). The experiment was laid out using a split-split-plot factorial complete block design. Each treatment comprised of 5 plantlets and was replicated three times to minimize experimental error.

Application of absorbent polymers

The absorbent polymers were mixed with the soil mixture before planting the banana plantlets with the imposed treatments. The rates of absorbent polymer applied were measured using the digital weighing scale.

Plant establishment

The nursery was covered with an ultraviolet sheet ensuring 50% shading to prevent burn damage and minimize bias. The nursery was also established with a north-south orientation to eliminate the effect of sunlight. The plantlets were planted in individual pots and put up in a partially shaded area. The plantlets were watered before transplanting. After a small hole of about 5 inches deep, the plantlets were planted in an upright position and were covered with potting mixture and pressed gently around the seedlings.

Water management

The amount of water needed to be applied was based on the literature for optimum water requirement, which was 25 mm/week (Aguilar, 2010). Different treatments were used to determine the effect of volume and frequency of irrigation on the banana plantlets grown with absorbent polymer. For the main plot, as mentioned, where the amount of irrigation (factor 1) was measured, three different amounts were tested (25 mm/week, 20 mm/week, and 15 mm/week); and for factor 2 (schedule/frequency per week), three levels were established: once a week, twice a week, and thrice a week. The manual application of irrigation using measured cups was made to ensure the accurate volume of application per plantlet.

Data gathering

Growth parameters of 'lakatan' such as plant height, pseudo stem girth, and leaf area were gathered from the experiment and measured using the digital caliper. The plant height, which was measured from the soil level to the youngest emerged petiole, was expressed in centimeters. Pseudostem girth was measured 3 cm above the base of the plantlet, also expressed in centimeters. The leaf area was measured using the formula of Kumar, Krishnamoorthy, Nalina, and Soorianathasundharam (2002):

$$\text{Leaf area} = L \times B \times N \times K1 \times K2$$

where L is the length of the third leaf, B is the breadth of the third leaf, and N is the total number of leaves, with values K1 and K2 equal to 0.80 and 0.6662, respectively.

Materials needed for data gathering

A digital caliper was used to measure plant height, pseudostem girth, and leaf length and breadth, ensuring a reading of up to 2 decimal places for accuracy. Meanwhile, the moisture percentage was calculated using a capacitive-type moisture meter probe that reads from 0 to 8 (equivalent to 0 to 80% of moisture).

Data analysis

Data collected were subjected to ANOVA (Analysis of Variance) using the STAR (Statistical Analysis for Agricultural Research) software from the International Rice Research Institute (IRRI). It was analyzed using the split-split plot design with the main factor, subfactor, and sub-subfactor arranged in a randomized block design (RCBD). The treatments with significant results for the single factors were compared using the Tukey test for the treatment combinations.

Cost analysis

This study used partial budget analysis to determine the effect of the polymer as a primary water-saving technique to reduce the cost and maintain the moisture of the soil. The formula for the partial budget analysis consists of the following:

Net change income = total benefits - total costs

Benefit-cost ratio = total benefits / total costs

where:

Total benefits = additional returns (saved from labor)
+ reduced cost (water)

Total costs = additional costs (absorbent polymer) + reduced returns

Results and Discussion

Morphological performance

Plant height. The interaction of the two factors can be observed in Table 1 for the plant height (in millimeters) at varying irrigation frequency levels and amounts of absorbent polymer applied. Irrigation frequency or factor 2 of the study has three levels assigned with letter B1 (once a week), B2 (twice a week) and B3 (thrice a week), while the amount of polymer was designated with C1 (0 grams) and C2 (5 grams).

Table 1. Average plant height increment (mm) at different irrigation frequencies and amounts of polymer

Irrigation frequency (Factor 2)	Amount of Polymer (Factor 3)		Mean with respect to Irrigation frequency
	C1 (0 gram)	C2 (5 grams)	
B1 (once a week)	14.0166c	15.3766bc	14.6966B*
B2 (twice a week)	15.6200bc	16.6756b	16.1478B*
B3 (thrice a week)	16.5711b	19.9578a	18.2644A*
Mean with respect to Amount of Polymer	15.4026B**	17.3367A**	

Means with the same letter are not significantly different
*= Mean with respect to irrigation frequency
**= Mean with respect to amount of polymer

Based on the combination of the two factors, the highest average plant height increment obtained was 19.96 mm, achieved by applying B3 (three times a week) irrigation frequency and used with C2 (5 grams of polymer) on banana plantlets. Meanwhile, the lowest increment observed was 14.02 mm, with the lowest frequency and no polymer added. Although treatments without absorbent polymer could compete with the ones applied with 5-gram polymer, the lack of polymer would only add to the cost of irrigation compared to irrigated treatments with polymer. These plantlets garnered the lowest height due to the high percolation rate of the soil media without polymer.

Results show that the plants treated with the highest level of irrigation frequency exhibited the highest average height increment, which was 18.26 mm. The reason for this is that most plants, specifically banana, need water, with plant morphology depending on water intake.

Furthermore, the results for the amount of polymer clearly show that the highest obtained average increment height was observed with C2. Polymers are specifically absorbent and can absorb moisture up to 50 times their volume. This lets them serve as a water bank for the banana plantlets, since polymers can store excess moisture during irrigation and release it slowly, which the seedlings can then absorb. Doing this eliminates the plants' water stress and increases their morphological properties, such as plant height. The critical moisture of 'lakatan' banana had been studied under greenhouse conditions, and it was found out that maintaining 30% moisture content inhibited optimal plant growth (Garcia, et. al. 2011).

The average increment plant height was also analyzed using ANOVA, with results revealing that irrigation frequency and the amount of polymer had a significant effect on banana plantlet height, and that the highest frequency of irrigation and the amount of polymer provided the highest growth. By reducing the frequency from three to two times a week, the average increment plant height decreased by 16.45%, and 22.95% for once-a-week frequency supplied with polymer. The reason for this is water stress or water lagging, which is one of the factors that affect banana growth and yield (Ismail, Yusoff, and Marziah, 2004).

Pseudostem girth. The average increment of pseudostem girth of the plantlets appeared to be similar to each other. However, it was observed that treatments with C2 (5 grams of polymer) garnered higher value compared to C1 (0 gram). ANOVA revealed that the amount of polymer had a highly significant effect on the average increment of pseudostem, with C2 being higher by 22.56% compared to C1 (0 grams of polymer) treatment. However, the irrigation amount also had a significant effect on stem girth, with the highest percentage obtained from the A1 treatment (25 mm/week) compared to the other levels, a reduction of 21.31% for the A2 treatment (20 mm/week) and 28.29% for the A3 treatment (15 mm/week).

The three factors also contributed to a significant effect on the girth size of the plantlets, and the interaction results can be seen in Tables 2, 3, and 4. Table 2 in particular shows the interaction of the irrigation amount (factor 1) and frequency (factor 2). Among the average increments of pseudostem girth obtained, the combination of the highest level of amount of irrigation and frequency had the highest girth of about 1.67 mm. The lowest was attained by a lowered level of both irrigation amount and frequency.

Table 2. Pseudostem girth (mm) at different irrigation amounts and frequencies

Irrigation Amount (Factor 1)	Irrigation Frequency (Factor 2)			Mean with respect to Irrigation Amount
	B1 (once a week)	B2 (twice a week)	B3 (thrice a week)	
A1 (25mm/week)	1.4516a	1.6050a	1.6666a	1.5744A*
A2 (20 mm/week)	1.0366b	1.2166b	1.4633a	1.2389B*
A3 (15 mm/week)	0.9833b	1.2900b	1.1133b	1.1289B*

Means with the same letter are not significantly different
*= Mean with respect to amount of irrigation

The combination of the amount of polymer and irrigation (factor 3 x factor 1) is shown in Table 3. The interaction shows the higher value obtained with the C2 treatments, with the highest irrigation amount applied (25 mm/week). The Tukey test determined that the highest obtained girth coincided with the highest level of irrigation, with reduced irrigation resulting in a girth decrease of about 20.52% if not applied with polymer with the same amount of irrigation. A difference of 26.54% can be obtained if the A3 irrigation schedule (once a week) is used alongside the polymer. Given this, labor costs may outweigh profit.

Table 3. Pseudo-stem girth (mm) at different amounts of polymer and irrigation (with once a week irrigation frequency)

Amount of Polymer (Factor 3)	Irrigation Amount (Factor 1)			Mean with respect to Amount of Polymer
	A1 (25mm/week)	A2 (20mm/week)	A3 (15mm/week)	
C1 (0 gram)	1.3944b	1.0777bc	0.9688c	1.1470B*
C2 (5 grams)	1.7544a	1.4000b	1.2888bc	1.4811A*
Mean with respect to irrigation frequency	1.5744A**	1.2389B**	1.1289B**	

Means with the same letter are not significantly different
*= Mean with respect to amount of polymer
**= Mean with respect to amount of irrigation

Providing the right amount and timing of irrigation is vital to the morphological aspect of the banana plantlets, since optimum moisture allows for better growth and yield (TNAU, n.d.) and because inappropriate amount and frequency can cause critical conditions for the plants. Given this, polymers can be used to mimic drip irrigation by ensuring moisture availability (Dahiwalkar, Divekar, and Sonawane, 2004).

The interaction between irrigation frequency (factor 2) and amount of polymer (factor 3) in Table 4 shows the higher value obtained with polymer for all frequency levels. While irrigation frequency was insignificant, the no-polymer treatment was comparable with the polymer treatment as frequency increased. Higher frequencies conveying an increase in girth do not necessarily mean that an irrigation schedule could not be regulated to optimize water use (Baiyeri and Aba, 2014).

Table 4. Pseudo-stem girth (mm) at different amounts of polymer and irrigation (with twice-a-week irrigation frequency)

Amount of Polymer (Factor 3)	Irrigation Amount (Factor 2)			Mean with respect to Amount of Polymer
	B1 (once a week)	B2 (twice a week)	B3 (thrice a week)	
C1 (0 gram)	1.0255b	1.1577b	1.2577a	1.1470B*
C2 (5 grams)	1.2888a	1.5833a	1.5711a	1.4811A*

Means with the same letter are not significantly different
*= Mean with respect to amount of polymer

Leaf area. The plantlets' leaf area was computed and analyzed using the average weekly increment. ANOVA results revealed that factor 2 (irrigation frequency) and factor 3 (amount of polymer) had a highly significant effect on leaf area. In Table 5, which shows the interaction between the two factors, observed was a higher value in the polymer treatments, with an increasing pattern coinciding with frequency. The polymer significantly holds moisture for plants that prevent over- and under-irrigation or water stress.

Table 5. Leaf Area (mm^2) at different irrigation frequency and amount of polymer

Irrigation frequency (Factor 2)	Amount of Polymer (Factor 3)		Mean with respect to Irrigation frequency
	C1 (0 gram)	C2 (5 grams)	
B1 (once a week)	12148.91	17679.49	14914B*
B2 (twice a week)	16114.84	20715.16	18415AB*
B3 (thrice a week)	19022.42	24267.21	21645A*
Mean with respect to Amount of Polymer	15762B**	20887A**	

Means with the same letter are not significantly different
*= Mean with respect to irrigation frequency
**= Mean with respect to amount of polymer

A study conducted by Garcia et al (2011) on banana plantlet irrigation determined critical moisture of 'lakatan' banana in screen-house conditions. The study showed that 30-35% moisture content available to the plant has a significant effect on its physical attributes such as plant height, with lower moisture content leading to more developed roots due to water stress at the expense of stunted plant growth. The polymer added to the plantlets' soil media inhibits this effect by locking in and retaining moisture, thus improving leaf area growth. Studies conducted by previous authors also concluded that most plants with polymer in their soil media have increased yield and improved morphological aspects (Sivalapan, 2001), as well as survival rate (Save, et al. 1995).

Moisture content retention. Figure 2 shows the comparison of the average of soil moisture per week of treatments with and without absorbent polymer applied. Based on the result, all treatments with polymer had maintained moisture efficiently compared to control or use of coco coir only, meaning that polymers can hold moisture up to 50 times its volume. This finding is also supported by the study of Temanel, et al (2019) who determined that using absorbent polymers allowed soils to retain more moisture.

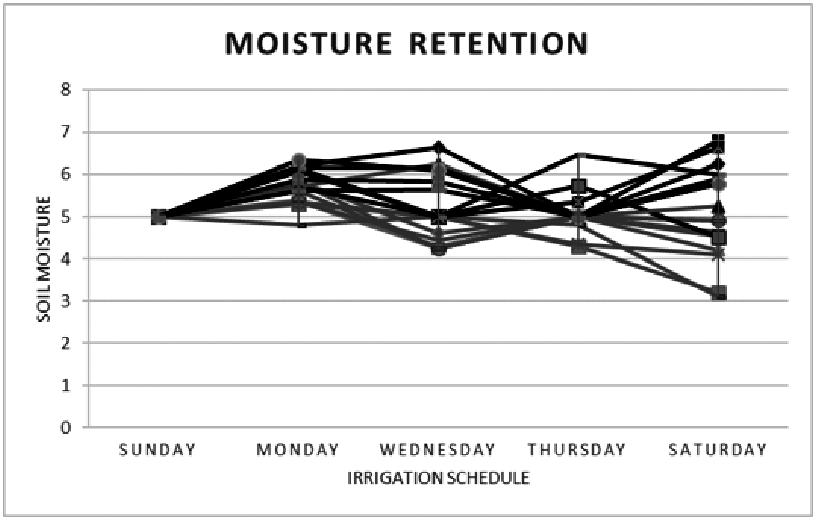

Figure 2. Soil moisture per week of factor 3 sub-subplot (Control vs. Polymer)

Partial budget analysis. Partial budget analysis is a handy tool for farm managers when it comes to making decisions in utilizing or adopting new technologies (Tigner, 2018), and this was used to determine if the technology introduced to the lakatan banana nursery was economically viable. Two factors were considered for this: labor cost, and supplies and materials. Table 6 (see next page) shows the breakdown.

Table 6. Partial budget analysis

	Php		Php
A. ADDED RETURNS Increase in morphological properties	1,036.80	**B. ADDED COSTS** Polymer+ installation	1,000.00
C. REDUCED COST **Labor**		**D. REDUCED RETURNS** B2=2% decrease in morphological properties	1,036.80
(7 weeks @ nursery)		B1=12% decrease in morphological properties	172.80
B1. Once a week Php	1,400.00		
B2. Twice a week Php	700.00		
B3. Thrice a week Php	200.00		
Irrigation			
A1.25 mm/week Php	200.00		
A2 20 mm/week Php	600.00		
A3.15mm/week Php	1000.00		

If used twice a week irrigation frequency B2 and minimum amount of water A3 (15mm/week):

TOTAL BENEFITS (A + C) = Php 2,736.80
CHANGE IN INCOME (A+C) – (B+D) = Php 1,564.00
BENEFIT COST RATIO (A+C) / (B+D) = 2.33

In computing for partial budget analysis, four significant factors were considered: added returns, added costs, reduced costs, and reduced yield. For the purposes of the study, the researchers assumed one nursery would produce 2 batches of banana plantlets. The added returns were based on the effect of absorbent polymer in increasing the morphological properties of the banana plantlets.

The added cost was the cost of procurement of the absorbent polymer (including the labor for its application per banana plantlet), while the reduced cost was based on the savings for reduced labor and amount of irrigation applied per banana plantlet. The reduced returns were based on the effect of the morphological reduction, when the irrigation amount and frequency would be decreased.

Based on the analysis, a 2.33 benefit-cost ratio (BCR) was obtained by using a bi-weekly irrigation schedule (B2) and an irrigation volume of 15 mm/week (A3), meaning this project is profitable given the aforementioned parameters.

Summary, Conclusion, and Recommendation

The application of absorbent polymer was used in this study to identify its effect on the morphological characteristics and moisture retention of banana plantlets under nursery conditions. The study was conducted using factorial split-split block design. Three factors were established in this study: the amount of irrigation (factor 1), irrigation frequency (factor 2), and the amount of polymer (factor 3) applied per plant.

For the morphological characteristics, the highest average plant height increment was obtained with C2 (5 grams of polymer) with an average increment height of 19.95 mm, which was 17% greater compared to plantlets without absorbent polymer. For pseudostem girth, the absorbent polymer obtained an average increment of 1.48 mm, which was 22.55% higher than plantlets with no absorbent polymer. Leaf area also had a higher value when applied with C2, with irrigation schedule of three times a week. An average of 24,267.21 mm^2 leaf area increment was obtained, which was 21.61% higher compared to plantlets having no polymer applied. Although treatments with no polymer obtained a significant value when the frequency of irrigation was increased, it also added the cost for the labor and amount of irrigation. Thus, absorbent polymer has saved labor and irrigation costs without sacrificing the banana plantlets' growth performance.

The polymer irrigation method consistently maintained the moisture content of growing media by about 16% higher compared to those without absorbent polymer treatments. Based on the results, the application of polymer on banana plantlets' soil enhanced the morphological characteristics of the plant by providing sufficient moisture. Additionally, using polymer was found to potentially increase the profit of banana farmers, with a benefit-cost ratio of 2.33 due to its water and labor reduction for the banana plantlets' production.

Using absorbent polymers therefore enhances the morphological characteristics of banana plantlets. It can be said that the polymer's ability to store water during the wet season and release it during the dry season could maintain the plantlets' moisture requirement, preventing water stress. The economic analysis also showed that the moisture-storing capacity of the polymer can minimize irrigation and labor.

It is highly recommended that field trials of 'lakatan' banana from growing to maturity stage must be conducted to determine the efficacy and the optimum amount of polymer in the field, along with irrigation frequency. Leaf analysis is also recommended to see if the nutrients retained in the soil were indeed absorbed and utilized by the plants.

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