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Adoptive Irrigation for Enhanced Mango Mangifera Indica L. cv Carabao Production in Upland Areas in Bataan, Philippines

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ABSTRACT

Current challenges related to climate change include the preservation of agricultural productivity. In the Philippines, the management of irrigation is becoming increasingly important for Mango cultivation. This study emphasizes that efficient and effective irrigation can be attained by accurately determining and applying the optimal amount of water. This approach not only maintains crop yield but also promotes the judicious use of water resources. Water usage in a Mango orchard in Bataan, Philippines, was assessed using sap flow meters to provide precise measurements. The study site is at coordinates N 14° 65.988' and E 120° 46.527' in Barangay Dangcol, City of Balanga, Balanga, Bataan, Philippines. Nine Mango trees were selected and characterized for the study. Each irrigation treatment involved three Mango trees (Treatment 1 – no irrigation, Treatment 2 – 50% of irrigation water, Treatment 3 – 100% of irrigation water). Before commencing the experimental irrigation, the installed devices underwent testing, observation, and analysis. The collected data indicated an average water consumption of approximately 92.6 liters per day per Mango tree, which was applied to the designated experimental Mango trees. The findings indicate that Treatment 3 demonstrated significant advantages over other treatments, manifesting in increased fruit yield, larger individual fruit sizes, greater average fruit weight, and reduced instances of fruit rejection and deformities. This experiment concludes that the precise application of irrigation water vital to Mango tree requirements can yield an additional 85.69% in Mango production compared to non-irrigated conditions, translating to an estimated financial benefit of approximately Php 207,050.00 per hectare for the farmers.

Keywords: adoptive irrigation, Philippine Mango, Mango irrigation

INTRODUCTION

Bataan, Philippines is known as a historical site from World War II and for its treasured Mango tree, particularly the Lamao Mango Variety. This variety grew in Bataan and became famous for its unique quality and sweetness. Over the years, due to high demand, this Mango variety spread to different areas in the Philippines through various propagation techniques, especially for local and international markets. The introduction of our Carabao Mango in the international market, popularly called the "Philippine Super Mango," is identified as one of the best-known varieties (Lacap et al. 2019), contributing significantly to the local farming industry. Its popularity has led other countries to label some of their Mangoes as "Manila Mango" to attract consumers, while top tourists flock to the Philippines to taste this delectable fruit (Kirker & Newman, 2024).

Sustaining and increasing the production of this precious Mango fruit requires various management procedures, including water application techniques, to improve the existing indigenous production systems used by our farmers (Zuazo et al., 2024). According to the Department of Agriculture (DA) in 2018, the recorded average yield of Mango per hectare is only 4.10 Mt/ha, which is significantly lower compared to our neighboring Asian countries (Go, 2022). Despite numerous technologies developed and introduced to farmers, there is still a need to develop more appropriate technologies to improve and maximize the full potential of this fruit tree (Bhavsar, et al., 2023). Irrigation water use is one of the primary components during the Mango production period, alongside weeding, pruning, fertilizer application, flower induction, pest management, fruit bagging, and harvesting activities (Ausari, et al., 2023)

Moreover, the effective and sustainable use of water for agriculture has become a global priority of vital importance due to the changing climate, requiring urgent and immediate solutions given intensifying competition (Valdez et al., 2017). Irrigation serves as a fundamental practice essential not just for maintaining optimal soil physical conditions conducive to plant water uptake and transpiration, but also for its utility in nutrient delivery (Olamide, et al. 2022). Despite the existence of established models for irrigation scheduling applicable across various crops, challenges persist in accurately determining the requisite water quantities specifically designed for Mango cultivation, owing to complexities associated with soil-water-plant interactions, including crop evapotranspiration dynamics and the effective coverage of irrigated areas (Pleguezuelo, et al, 2018).

The importance of irrigation water is now the focus and priority due to the increasing demand needed for crops to sustain economic life (Khondoker, et al., 2023). The development of a micro-irrigation system is a great management tool to address the rising water demand for food production and the agricultural sector`s sustainability. Irrigation water management is a strategy to use less water with minimal losses during crop production to conserve water supplies, lessen the impact on water quality, and increase net income returns of producing crops (Alhashimi et al., 2023). In addition, to achieve sustainable agriculture, it is necessary to develop new irrigation scheduling strategies centered on guaranteeing the optimal use of available water with high efficiency rather than relying on entire crop water requirements (Liu et al., 2024). However, efficient use of water at the field level will lead to water savings and boost crop yield in terms of quantity and quality (Mallareddy et al. 2023).

The identification of the actual water demand encourages the judicious use of water and regulates the use of irrigation to satisfy this need (Shah et al., 2023). One of the most effective irrigation techniques for Mango is drip irrigation. It has advantages over conventional surface irrigation as an efficient way to apply water, especially where water is restricted, and it can play a vital role in overcoming water scarcity, mostly in water shortage areas, to distribute water equally across an agricultural field (Megersa and Abdulahi, 2015).

In addition, the availability of soil moisture is a vital factor in crop growth. Understanding the pattern of water release and soil water storage in different types of soil is essential for effective water management. This includes knowledge of physical, biological, and chemical soil processes. Such understanding is necessary to effectively manage water storage and release (Naorem et al., 2023).

Soil moisture distribution is significantly influenced by both precipitation and vegetation cover. Precipitation is essential for replenishing moisture in areas with high soil moisture levels, while vegetation aids in retaining moisture in drier regions (Peng et al., 2023). Soil moisture content (SMC) is very important in regulating water flow and supporting vegetation, serving as a vital link between the atmosphere and soil. A recent study (Qin et al. 2023) analyzed global SMC trends over the past 70 years and projected future changes for the next 70 years using climate models. The findings of this study indicated that from 2000 to 2020, SMC in the top 0-200 cm of soil globally decreased by approximately 1.284 kg/m2 per year, with significant declines observed across 31.67% of the world. This decline has accelerated in the past decade, driven by factors such as global warming and reduced precipitation. Under various climate scenarios, continued decreases in SMC are anticipated, affecting different soil layers and regions variably.

In practice, Mango farmers, particularly in the upland areas of Bataan, have not practiced irrigation application and have a limited understanding of the available soil moisture essential to Mango tree production. The adoption of modern micro-irrigation techniques like drip and sprinkler systems enhances fruit quality and increases yields, all while conserving valuable water resources (Rasul, et al. 2022; Singh & Singh, 2021). Likewise, efficient water-management strategies, such as deficit irrigation, are key elements to increasing agricultural water productivity in areas affected by water scarcity (Suna et al., 2023). This irrigation application maximizes productivity and promotes water-saving programs (Zhou, et al., 2020). Furthermore, drip irrigation at 0.75 Ep registered higher fruit weight during the first year and a greater number of fruits in the second year compared to no irrigation (Rahwa and Bhanvadia, 2023)

With the promising performance of irrigation techniques and enticing market demand for Mango, there is a need to push for adoptive water application for Mango production at the farmer's level. This hopes to enhance production and increase income, benefiting Mango farmers, particularly in the upland areas of Bataan.

METHODS

a. Technical Aspect

The project showcases the adoptive water application for Mango orchards. From the selected experimental trees, it was grouped into three which were composed of three Mango trees per group or treatment. The assigned treatments consist of no irrigation, 50% ETc, and 100% ETc. Based on the actual Mango layout, the irrigation piping and dripper with emitter requirements were installed at 1.5m to 2.5m from the trunk of the Mango tree. The identification of ETc at the Mango trees utilized the existing instruments installed in the experimental area with the following: soil moisture sensor, sap flow meter, and total weather station. The generated data in these instruments were used as a decision tool in applying irrigation water to the identified Mango trees. The volume and rate of applied water were based on the determined soil characteristics. The generated data during this period were recorded and tabulated for the whole production stages of the Mango trees. Other parameters were also observed and recorded weekly, identifying the effects of water application response of the Mango trees.

b. Experimental Setup

The experimental setup composed of three (3) rows of Mango trees in the orchard was selected, each corresponding treatment level (T_0, T_1, and T_2). Each treatment row contains 3 replicates. Treatment (T_0) is no irrigation applied or the farmers' practice and treatment (T_1) is 50% ETc while treatment (T_2) is 100% ETc. From the established treatments, T_1 and T_2 were installed drip lines with regulated water application based on the required soil moisture deficits. Also, these treatments (T_0, T_1, and T_2) used plastic mulching to cover the Mango tree canopy to prevent it from receiving water caused by rainfall and to maintain the desired soil moisture requirements based on the results of ET_C calculations generated by the instruments installed in the Mango trees. This procedure provided reliable soil moisture monitoring, water consumption, and water requirement of the soil during the experimental period.

The source of irrigation water used in the identified experimental trees for Mango was pumped out at the irrigation canal at an approximate distance of around 377 meters from the area. The water was conveyed using the solar pump going to the elevated tank near the experimental trees. From the tank, the irrigation water was applied using drippers in the Mango trees with a regulated amount of water based on the experimental treatment that was considered in the study.

c. Production aspect

As per the university's mandate, it will consistently lead the development of suitable technologies to enhance farming practices while increasing production and improving the economic status of farmers.

The study projected that the adoption of scientific irrigation techniques will begin with the active participation of farmers in improving the existing Mango orchards in the upland areas of Bataan. Eventually, these unproductive Mango orchards in the upland will be transformed into profitable enterprises that will contribute to the prosperity of farming communities.

d. Organization and Management Aspect

The project leader prepared plans and programs to achieve the objectives of the study. The composition of manpower involved in the study comprises the different fields of professions (agricultural engineer, electronic and communication engineer, and agriculturist) who will work together in delivering the required tasks.

The project executed, and the prepared work plan served as the guide in all activities undertaken in the experimental field; however, this was adjusted when the need arose during the actual implementation. The project study was coordinated at the research office of the university for the monitoring of the project, supervision of the budget disbursement, report submission, allotment, and provision of the official vehicle as required in the project. Also, the farmers cooperated and extended help by maintaining the experimental area during the conduct of the experiment.

e. Financial Aspect

The project's required budget was provided by the Department of Science and Technology (DOST) Region 3 in the Philippines. As part of its contribution to the project, BPSU covered some of the additional expenses incurred during the project duration.

f. Marketing Aspect

The project intervention seeks to enhance production by implementing an innovative and sustainable water application technique. The surplus yield will be distributed to areas with restricted supply in the local market, and will also be introduced into the global market, where the renowned Philippine Super Mango holds a strong presence. This potential market for the Mango fruit holds promising prospects for the farmers and growers in the upland areas of Bataan, Philippines, providing them with an opportunity to access a wider consumer base and secure better livelihoods.

g. Monitoring and evaluation

Scheduled monitoring was done to ensure the smooth execution of the project. The project team members continuously coordinated the scheduled visit of the project to facilitate the planned implementation of activities. The project team was also coordinated with Department of Agriculture-Local Government Units Philippines (DA-LGUs) staff and personnel as a protocol in the area and part of the team activities.

Strengthened effective technology dissemination of the project, the project team conducted regular monitoring and evaluation of the developed adoptive water application and continuously provided technical assistance for the Mango farmers. A feedback mechanism will be evaluated by the project team members based on the generated information to continuously review the introduced technology based on the farmers' experiences with Mango production.

RESULTS AND DISCUSSION

Nine (9) trees were selected with the same 30 years of age, approximately the same 10m diameter canopy size, and as much as possible a vertically straight main branch. The groundwater depth was estimated to be around 80m and beyond the ground surface which is categorized as difficult areas while the soil type in the area is heavy clay or Antipolo type. Three (3) groups of trees were prepared for irrigation treatment application (Treatment – 1 (no irrigation), Treatment – 2 (50%), and Treatment – 3 (100%)). Three (3) replicates were prepared for every treatment. Nine (9) units of Sap Flow Meters were acquired with accessories. Installed and tested the instruments. Downloaded and recorded the data generated by the instruments; Data were downloaded, graphed, and analyzed. Computed the actual water consumption of Mango trees of around 92.6 liters per day or equivalent to 100 liters per day. Design of a drip system with emitters was installed and adapted to deliver the identified water consumption per Mango tree. Installed the drip system per Mango tree in the experimental area for Treatment 2 and 3. Calibrated the drip system to deliver the identified water consumption per day per tree at 50 liters per day

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for Treatment – 2, and Treatment – 3 at 100 liters per day. The computed total water consumed for 68 days period at Treatment -2 is around 2.10 m^3 while Treatment – 3 is around 3.14 m^3 as depicted in Table 1.

Table 1. Summary of the volume of water applied per day per tree as well as the total water consumed for 68 days period.

	Treatment1	Treatment 2	Treatment 3
applied water irrigation during the intervention	without irrigation	50% of the computed requirement which is around 50 liters per day per tree	100% or equivalent to 100 liters per day per tree
computed total water consumed for a 68-day period		around 2.10 m^3	around 3.14 m^3

Before the conduct of the experiment, cleaned and removed weeds in the area to prevent infestation. Flower induction was applied to the prepared Mango trees with matured terminal buds and after 14 days flowers emerged which were estimated at around 80 to 90 percent. The plastic mulch was installed to cover the soil under the identified experimental Mango at around 10 meters in diameter to prevent evaporation losses and receive rainfall during the experimental period. Identified the initial soil moisture content in the Mango experimental area at 38.6% for Treatment – 1, 37.01% for Treatment – 2, and 38.03 for Treatment – 3 before the actual application of irrigation water. The irrigation application in the experimental trees was commenced during the third week after flower induction. The applied irrigation water in treatment – 2 is 50% of the computed requirement which is around 50 liters per day and it was delivered at 8 hours per day while Treatment – 3 is 100% or equivalent to 100 liters per day at the same delivery rate of 8 hours. Calculating the soil moisture deficit in Treatment 1 without irrigation, it was observed that the soil moisture was reduced to around 6.57% which reaches the permanent wilting point level. However, for Treatment - 2 (50%) it was observed that the average soil deficit from the applied daily irrigation water was about 30.81 liters per day that was consumed by the Mango trees while in Treatment – 3 (100%), the soil moisture deficit was recorded at an average of 56.2 liters per day per tree. The computed loss of irrigation water in Treatment – 2 is about 19.19 liters per day while in Treatment – 3 is 43.8 liters per day as presented in Table 2. Identified fruit dropped was significant to all treatments (Treatment – 1, 2, and 3) during the early fruit development even if the irrigation water was applied 21 days after flower induction (DAFI). It was also found out that Treatment – 1 has no fruit developed due to the dry condition of the soil where water is not available during fruit development while Treatment – 2 and Treatment – 3 have developed fruits even though there is an observed fruit dropped at the early stages. Also, it was observed that the amount of infestation in the experimental area was not significant.

Table 2. Summary of the soil moisture before the intervention, calculated soil moisture deficit, and computed loss of irrigation water.

Parameters	Treatment1	Treatment 2	Treatment 3
Soil Moisture before intervention	38.6%	37.01%	38.03%
calculated soil moisture deficit during intervention	6.57%	30.81 liters per day per tree	56.2 liters per day per tree
computed loss of irrigation water		19.19 liters per day	43.8 liters per day

Treatment – 2 and 3 stops the application of irrigation water application at 21 days before the harvesting period.

The computed total water consumed for 68 days period at Treatment -2 is around 2.10 m^3 while Treatment – 3 is around 3.14 m^3. The harvested Mango at Treatment – 2 is around 32.2 kg per tree, and Treatment – 3 is around 106.93 kgs per tree while Treatment – 1 recorded no Mango fruits were harvested. The computed water use efficiency for Treatment- 2 is 61.62% and Treatment – 3 is 46.2%. The computed water productivity for Treatment – 2 is only 15.33 kg/ m3 while in Treatment – 3 is only 34.05 kg/m3. The recorded and computed expenses including the drip system are about Php 3,276.00 per tree. The computed sales from yield at Treatment – 2 considering the existing farm gate price of Php 50.00 per kilo, the cost is Php 1,610.00 per tree while in Treatment – 3 it was calculated at around Php 5,348.00 per tree. Based on the expenses and harvested yield Treatment – 3 has a viable return profit of around Php 2,070.50 per tree or equivalent to Php 207,050.00 per ha as shown in Table 3.

Table 3. Summary of the computed water efficiency, fruit yield, and economic viability.

Parameters	Treatment1	Treatment 2	Treatment 3
computed total water consumed for 68 days period fruiting harvested Mango	no fruit developed due to the dry condition of the soil where water is not available during fruit development no Mango fruits	2.10 m^3 have developed fruits even though there is an observed fruit dropped at the early stages 32.2 kg per tree	3.14 m^3 have developed fruits even though there is an observed fruit dropped at the early stages 106.93 kgs per tree
Economic viability/computed sales from yield considering the existing farm gate price of Php 50.00 per kilo		Php 1,610.00 per tree	Php 5,348.00 per tree

The considered experimental Mango trees were uniformly induced and flushed with flowers in all Treatments – 1, 2, and 3. The irrigation water was applied and started during the panicle elongation at 21 DAFI in Treatment 2 (50%) and Treatment – 3 (100%), then 21 days before the harvest period was stopped. Recorded Mango harvest at Treatment – 1 has no developed fruit to harvest, Treatment – 2 (50%) is only 32.2 kg while Treatment – 3 (100%) is 106.93 kg. Computed the added expenses and activities on the part of the Mango farmers when they used to adoptive a drip irrigation system of about Php 2,033.00 per tree as the initial capital for the irrigation system that will last for more than 10 years while during production it requires monitoring and opening/ closing the valves. Results showed that the Adoptive Drip Irrigation System for Mango in the Upland can help improve the yield and income of the Mango farmers by about Php 207,050.00 per ha.

CONCLUSION

In the study conducted, the identification of the actual water consumption of Mango trees is essential, particularly the application of irrigation water during the fruiting stages to help improve the development of more fruits. The experiment proves that Mango trees with irrigation water have a higher potential for developing more fruits compared to those without irrigation. The computed water loss was 30.81 and 56.2 liters per day in both T1 and T2, respectively, indicating that the roots of the Mango trees under experiment were widely spread in the ground, and the water applied was not entirely consumed by the trees during irrigation. However, the recorded yield in the no-irrigation treatment resulted in zero fruit development due to the limited water available to sustain fruit development, while Treatment 1 and Treatment 2 yielded 32.2 and 106.93 kg per tree, respectively, providing a significant advantage to Mango farmers in the upland areas of Bataan.

It is recommended to continue the study to identify the actual water requirements of Mango trees using an advanced sensor system to establish precise water needs. Additionally, it is suggested that another study be conducted to validate the effects of applied irrigation water on Mango trees in different areas of the region.

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