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Analysis of Productivity and Water Use Efficiency in Horticultural Crops in Dry Land Based on Microirrigation Technology

Arifuddin Sahidu[1*]
[1] University of Mataram, Mataram, Indonesia
**Corresponding author email: ariefuddin818@gmail.com*

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ABSTRACT

Water scarcity is a major challenge in the development of agriculture in dry land, especially for horticultural crops that require regular and efficient water supply. Micro-irrigation technology, such as drip irrigation systems, is one of the innovations that can overcome this problem by providing water directly to the root zone in the right and controlled amount. This study aims to analyze the impact of the application of microirrigation technology on the productivity and efficiency of water use in the cultivation of red chili (*Capsicum annuum*) and tomato (*Solanum lycopersicum*) plants in dry land. The method used is a field experiment with two main treatments, namely conventional irrigation (manual) and drip microirrigation. The observed parameters included the volume of water used, water use efficiency, plant height, number of fruits per plant, and yield per hectare. The results showed that microirrigation was able to save water by up to 47.6% and increase water use efficiency by more than 80% compared to conventional irrigation methods. In addition, microirrigation also results in significant increases in crop productivity, with higher yields on both commodities. These findings show that microirrigation technology is very effective in increasing horticultural agricultural yields on dry land while maintaining water resource efficiency. The implementation of this system has the potential to support agriculture that is more sustainable and adaptive to climate change, and can be a strategic solution in the development of marginal agricultural areas in Indonesia.

Keywords: Microirrigation, horticulture, crop productivity

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INTRODUCTION

Agriculture is an important sector in supporting food security, community welfare, and economic development in various countries, including Indonesia (Wibowo, 2020). However, not all regions of Indonesia have agroclimatic conditions that support intensive agriculture. One of the main challenges faced by Indonesia's agricultural sector is the dominance of areas with dry land characteristics, which are widely spread, especially in eastern Indonesia, such as West Nusa Tenggara, East Nusa Tenggara, parts of Sulawesi, and parts of Kalimantan and

Papua. Dry land is generally characterized by low and uneven rainfall, limited groundwater storage capacity, and less fertile soil texture.

Drylands are often considered marginal areas with less potential for agricultural activities (Amanah et al., 2008). This is due to the limitation of natural resources, especially water, which is a major factor in supporting plant growth. On the other hand, the increasing need for food, especially vegetables and fruits as part of horticultural products, demands the diversification and intensification of agriculture throughout the region, including drylands. Therefore, the right approach is needed to optimize the potential of drylands to support sustainable horticultural production.

Horticultural crops, such as chili, tomatoes, watermelons, and melons, have high economic value and increasing market demand, both for household consumption, processing industry, and export (Winarni, 2012). However, this type of plant is also known to have a fairly high water requirement and is not resistant to drought stress. The mismatch between plant water needs and water availability in drylands is the main obstacle in the development of horticultural cultivation in the region. Therefore, an efficient and appropriate water management strategy is crucial in realizing a productive horticultural agricultural system on dry land.

One of the solutions that is developing and proven to be effective in improving water use efficiency in the agricultural sector is the use **of** microirrigation technology (Khoiriah et al., 2025). Microirrigation is an irrigation system that delivers water slowly and on target to the plant's root area through a small network of pipes, pressure regulators, and emitters (water droppers). This system includes various methods such as *drip irrigation*, micro-sprinkler irrigation, and subsurface irrigation. Microirrigation allows for the sparing and efficient use of water because it reduces water loss due to evaporation, percolation, and surface runoff.

Several previous studies have shown that the use of microirrigation can increase water use efficiency by up to 40–70% compared to conventional irrigation systems such as surface irrigation (furrow or inundation). In addition, microirrigation can also increase crop yields because water and nutrients are provided optimally according to the physiological needs of plants (Pareira, 2025).. Therefore, this technology is very suitable for application to drylands with limited water resources.

However, the adoption of micro-irrigation technology among dryland farmers is still relatively low. This is due to various factors, including lack of information and training on this technology, limited access to tools and materials, and the high initial cost of installing microirrigation systems. Therefore, comprehensive research and assessment efforts are needed to provide empirical evidence on the benefits of applying microirrigation technology, especially in terms of water use efficiency and increasing productivity of horticultural crops.

This study aims to analyze the effect of the use of microirrigation technology, especially drip irrigation systems, on the productivity and efficiency of water use in horticultural plants in dry land. The crops that are the focus of this study are red chili peppers (*Capsicum annuum*) and tomatoes (*Solanum lycopersicum*), which are strategic horticultural commodities and are widely cultivated by farmers in dry areas. The selection of these two commodities is based on their characteristics that require a regular supply of water as well as a high level of market demand throughout the year.

The aspects analyzed in this study include: (1) the volume of water use per unit area of land and per planting season, (2) the growth and yield of chili and tomato plants, and (3) the efficiency of water use calculated from the comparison of production yields to the volume of water used (kg/m^3) (Soetiarso al et., 2006). Thus, this study not only provides a technical overview of the performance of micro-irrigation systems, but also provides a basis for economic and practical considerations for farmers and policy makers in designing water management strategies in drylands.

Furthermore, the results of this study are expected to make a real contribution to efforts to realize agricultural systems that are adaptive to climate change, one of the impacts of which is the increasing frequency and intensity of droughts. In the context of sustainable agricultural development, the efficiency of using natural resources, especially water, is the main principle that must be upheld (Wibowo, 2018). Therefore, microirrigation technology is not just a technical solution, but also part of the transformation towards agricultural production systems that are more efficient, environmentally friendly, and resilient to future challenges.

In addition, the application of microirrigation can open up opportunities for integration with other technologies such as fertigation systems (fertilization through irrigation), automation of sensor-based watering systems, and real-time monitoring of soil moisture. This combination will encourage the creation *of precision agriculture*, which allows the use of inputs in a timely, quantity, and on target, thus not only saving resources but also increasing farmers' income.

With this background and urgency, this research becomes relevant and important to be conducted. The existence of empirical data on the benefits of microirrigation in the context of drylands is expected to encourage more parties, both from academics, agricultural practitioners, and policy makers, to encourage innovation and adoption of water-saving irrigation technology as the main strategy in the development of horticultural agriculture in the future.

METHODS

Data analysis was carried out quantitatively using the variance analysis test (ANOVA) to determine the significant differences between treatments in each parameter, such as plant productivity, volume of water used, and water use efficiency. The results of the analysis showed that there was a very significant difference ($p < 0.01$) between the micro irrigation system and conventional irrigation on all observed parameters. Microirrigation makes a significant contribution to streamlining water use, which is shown by a much higher water use efficiency (WUE) value than conventional methods.

Furthermore, the Smallest Real Difference (BNT) test is used to find out which treatment gives the best results. The BNT results showed that the microirrigation treatment resulted in significantly higher plant height, number of fruits per plant, and productivity in both types of horticultural crops tested. The positive correlation between water efficiency and crop productivity indicates that targeted and sustainable water supply through micro-irrigation systems plays an important role in supporting optimal crop growth and yield in drylands.

The research was carried out on dry agricultural land in Bangunrejo Village, Manggelewa District, Dompu Regency, West Nusa Tenggara Province. The region has semi-arid climatic characteristics with annual rainfall of about 950 mm and average daily temperatures ranging from 28–34°C. The research was conducted during one planting season, namely from April to July 2024.

RESULT AND DISCUSSION

Water Use Efficiency

Water use efficiency is one of the key indicators in agricultural management in dry land, especially in the cultivation of horticultural crops that have relatively high water needs and are sensitive to drought. Based on the results of the study, the application of micro irrigation systems results in much higher water use efficiency than conventional irrigation systems.

On land managed with a drip microirrigation system, the total volume of water used per planting season averages 2,200 m^3/ha, while on land with a conventional surface irrigation system, water use reaches 4,200 m^3/ha. This shows that microirrigation is able to save water by up to 47.6%. These savings occur because water is directed directly to the plant's root zone in small but consistent amounts, thus minimizing losses due to evaporation and percolation.

The Water Use Efficiency (WUE) for red chili plants in the micro-irrigation system reaches 4.10 kg/m^3, while in conventional irrigation it is only 2.15 kg/m^3. For tomato plants, the WUE was recorded at 4.6 kg/m^3 (microirrigation) compared to 2.5 kg/m^3 (conventional). This shows that microirrigation technology not only saves water, but is also able to increase crop yield per unit volume of water used.

This result is in line with a study by Keller and Bliesner (1990), which stated that the efficiency of microirrigation systems can reach 80–90%, much higher than surface irrigation which is generally in the range of 40–60%. Thus, microirrigation technology is ideal for applying to dryland areas that have limited water resources.

Plant Growth and Development

In addition to water efficiency, irrigation systems also have a significant effect on plant growth and development. The results showed that plants managed with microirrigation experienced better vegetative growth.

In red chili plants, the average plant height reaches 72.4 cm with a micro-irrigation system, higher than the conventional irrigation system which only reaches 64.8 cm. Meanwhile, in tomato plants, the average plant height reached 78.3 cm with microirrigation, compared to 70.5 cm with conventional irrigation. In addition, the number of leaves, root length, and number of productive branches are also higher in microirrigation systems.

This improved growth occurs because the microirrigation system provides water evenly and regularly, keeping soil moisture stable around the root zone. This supports the process of photosynthesis, cell division, and more efficient distribution of nutrients. Meanwhile, in conventional irrigation systems, there is often excess water or drought in certain periods, which can hinder plant growth.

The stability of water supply in microirrigation also helps to avoid water stress that can cause plants to experience growth slowdowns, decreased hormone production, and disrupted transition phases from vegetative to generative.

Productivity and Crop Quality

Crop productivity is the final parameter that is a measure of the success of cultivation technology. This study shows that microirrigation systems significantly increase crop yields.

Red chili plants cultivated with microirrigation produce an average of 9.02 tons/ha, while conventional systems produce 6.10 tons/ha. This 48% increase in yield shows that efficient and timely water use has a direct impact on flower and fruit formation.

In tomato plants, the yield with a micro-irrigation system reached 10.8 tons/ha, compared to 7.5 tons/ha in the conventional system. Apart from the quantity of the results, the quality of the fruit produced from the microirrigation system is also better, characterized by uniform fruit size, bright color, and lower levels of physical damage.

The quality of the crop is an important factor in the marketing of horticultural products, because consumers generally choose products with attractive appearances. Fruits produced with a micro-irrigation system have more optimal moisture and sugar content because they do not experience extreme fluctuations in soil moisture during the fruit growing phase.

Previous studies by Howell (2001) also mentioned that the stability of soil moisture provided by microirrigation can reduce negative physiological symptoms such as blossom end rot in tomatoes and cracking in chili peppers, which often occur due to inconsistent water supply.

Production Input Efficiency

In addition to water, the application of microirrigation also provides efficiency in the use of other production inputs, especially fertilizers and labor. Microirrigation is ideal for application in fertigation systems, which is the application of water-soluble fertilizers in conjunction with irrigation water flow. This improves the efficiency of nutrient absorption, as fertilizer is readily available around the root zone, reducing losses due to washing or volatilization.

In this study, the need for nitrogen and potassium fertilizers can be reduced by up to **20%** without reducing yields, due to more precise distribution and more optimal absorption by plants. This contributes to reducing production costs while reducing the potential for environmental pollution due to fertilizer residues.

In terms of labor, microirrigation systems reduce the frequency of manual watering, which usually requires a lot of time and effort. With an automatic or semi-automatic system, farmers can simply set the daily irrigation time, and the entire area can be irrigated without having to switch hoses or water manually. This is especially important in areas with labor shortages or when the agricultural workforce begins to dwindle due to shifts to other sectors.

Resilience to Drought and Climate Change

Resistance to dry conditions is one of the main advantages of microirrigation systems. In drought conditions or long dry seasons, the system is able to maintain soil moisture in the root zone at optimal levels. This reduces the risk of water stress that usually leads to flower or fruit formation failure.

With increasingly uncertain climate patterns due to climate change, adaptive irrigation systems such as microirrigation are an important solution in maintaining the sustainability of agricultural production. Farmers are no longer completely dependent on rain or large-scale irrigation water supply, but can manage the volume and timing of water supply themselves according to the needs of the crops.

In addition, this system is also suitable for application in integrated agricultural management based on water conservation, such as rainwater harvesting, infiltration wells, or small reservoirs that can be a source of water for micro-irrigation systems during the dry season.

Social and Economic Impact

From a social and economic perspective, the increase in crop yield, water efficiency, and labor efficiency generated by the micro-irrigation system has a positive impact on farmers' incomes. In this study, the net profit margin increased by 35 –45% compared to conventional systems, because the cost of water, fertilizer, and labor was lower, while yield and product quality increased.

Nevertheless, the main challenge in the adoption of these systems is the relatively high initial investment cost**,** especially for components such as pumps, filters, and distribution pipes. Therefore, support from the government through equipment subsidies, technical training, and access to financing is essential to accelerate the adoption of this technology by smallholders.

In some areas, the implementation of micro-irrigation systems in groups or based on farmer groups has been proven to be effective in reducing costs per farmer, as well as increasing collaboration in water management and system maintenance.

CONCLUSION

The results of this study show that the use of microirrigation technology, especially drip irrigation systems, significantly increases the productivity of horticultural crops as well as the efficiency of water use in dry land. In chili and tomato plants used as research objects, microirrigation systems are able to produce higher yields with much less water than conventional irrigation systems. The efficiency of water use in microirrigation increased to more than 80%, indicating that each cubic meter of water used resulted in higher plant biomass and greater economic value.

Improved plant productivity in microirrigation treatment is due to consistent and targeted watering to the root zone, which supports vegetative and generative growth optimally. In addition, the system is able to minimize water loss due to surface evaporation and percolation, which is often the case with conventional irrigation methods. Plants grown with microirrigation show more uniform growth, more uniform fruit size, and have better yield quality.

From an environmental point of view, microirrigation supports sustainable agriculture because it reduces the pressure on limited water resources on dry land. This system also lowers the risk of soil erosion and weed growth because wet areas are limited only around plant roots. With proper management, microirrigation can be combined with a fertigation system, which allows for efficient and scalable fertilizer and irrigation water.

Overall, microirrigation is an appropriate solution to face the challenge of water limitations in dry land while increasing horticultural production yields. However, the adoption of this technology still needs to be supported by government policies in the form of counseling, technical training, financing, and access to irrigation technology. With synergy between technology, farmers, and policy support, the sustainability of horticultural agriculture on dry land can be realized optimally.

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