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The Effect of Watering Frequency on Growth, Productivity, and Agribusiness Feasibility of Bali Karet Shallot Variety in Lowland Areas

Ni Ketut Karina Sari[1*], Ni Nyoman Alit Purnami[1], Dicky Marsadi[2]

[1]Agrotechnology Study Program, Faculty of Agriculture and Business, Dwijendra University, Denpasar, Indonesia
[2]Agroecotechnology Study Program, Faculty of Agriculture, Udayana University, Denpasar, Indonesia

*Corresponding author: ketutkarina17@gmail.com

Abstract
This study aimed to evaluate the effect of watering frequency on the growth, productivity, and agribusiness feasibility of the Bali Karet shallot variety cultivated in lowland areas. The experiment was conducted at the Experimental Farm of the Faculty of Agriculture, Udayana University, from January to March 2026 using a Randomized Complete Block Design (RCBD) with four irrigation treatments: P0 (once/day), P1 (twice/day), P2 (three times/day), and P3 (soil moisture-based), each with three replications. Data were analyzed using Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at the 5% significance level. Watering frequency significantly affected plant growth, productivity, water use, and agribusiness feasibility. Treatment P3 showed the best performance, increasing productivity from 7.8 to 11.3 t ha^{-1} (44.9%), farm profit from IDR 17.4 million to IDR 42.6 million ha^{-1} (144.8%), and the R/C ratio from 1.39 to 1.89, while reducing water consumption from 5,850 to 5,100 m^3 ha^{-1} (12.8%) compared with P0. These results demonstrate that soil moisture-based irrigation improves water-use efficiency while maximizing shallot productivity and profitability, making it a promising irrigation strategy for sustainable shallot production in lowland areas.

Keywords: shallot, watering frequency, productivity, agribusiness

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Introduction

The Bali Karet shallot variety is one of the local horticultural commodities with high economic value and plays an important role in supporting the horticultural agribusiness sector in Indonesia. This commodity is widely used as a primary seasoning ingredient in traditional Indonesian cuisine and contains bioactive compounds, including flavonoids and sulfur compounds, that provide health benefits. Due to its high consumption, shallots are recognized as one of Indonesia's strategic food commodities and frequently contribute to food price fluctuations and national inflation [1].

The increasing market demand for shallots has encouraged the expansion of cultivation into lowland areas, creating opportunities for the development of locally adapted varieties such as Bali Karet shallots. Previous studies have shown that successful shallot cultivation in lowland environments depends largely on the use of varieties that are well adapted to local agroecological conditions. Rahman et al. [2] reported that adaptive varieties have better growth and yield performance under lowland conditions, while [3] emphasized that varietal suitability is a major determinant of agribusiness success in shallot production systems.

Despite these opportunities, shallot cultivation in lowland areas is constrained by high temperatures, low relative humidity, intense solar radiation, and irregular water availability. These environmental conditions increase transpiration rates, reduce photosynthetic efficiency, and negatively affect bulb development. Climate change further aggravates these constraints by increasing seasonal variability, pest and disease incidence, and production instability. Yeshiwas et al. [4] demonstrated that climate change significantly affects shallot cultivation through its influence on environmental conditions and plant health, while [5] identified climate variability as one of the major causes of annual fluctuations in shallot production in Indonesia.

Among these environmental factors, irrigation management is considered one of the most critical components determining shallot productivity. Previous studies have consistently shown that appropriate irrigation frequency improves water-use efficiency, plant growth, and bulb yield in shallots. Setiawan et al. [6] reported that optimized irrigation scheduling significantly increased shallot productivity while reducing unnecessary water use. Similarly, [7] found that efficient irrigation management is essential for maintaining horticultural production under dry and hot lowland conditions.

Although the effects of irrigation management on shallot cultivation have been widely investigated, most previous studies focused on commonly cultivated commercial varieties and evaluated irrigation using fixed watering schedules. Information regarding the response of local varieties, particularly the Bali Karet shallot, to different irrigation frequencies remains scarce. Furthermore, little attention has been given to irrigation strategies based on soil moisture conditions, which may improve water-use efficiency while maintaining or increasing yield under lowland environments. In addition, previous studies have primarily emphasized agronomic performance, whereas the economic feasibility of irrigation practices for local shallot varieties has received limited investigation.

In addition to its agronomic importance, irrigation management has direct economic implications because irrigation frequency influences water use, labor requirements, and production costs, which ultimately affect farm profitability. Moreover, improving the productivity of the Bali Karet shallot variety could enhance its market competitiveness and strengthen its potential as a valuable local commodity for sustainable horticultural agribusiness in lowland areas.

Therefore, this study was conducted to evaluate the effects of different irrigation frequencies, including soil moisture-based irrigation, on the growth, productivity, and agribusiness feasibility of the Bali Karet shallot variety cultivated in lowland areas. The findings are expected to address the existing knowledge gap by providing scientific evidence on both agronomic and economic responses of this local variety to irrigation management under lowland conditions and to support the development of sustainable shallot production systems.

Material and Methods

This study was conducted at the Experimental Farm of the Faculty of Agriculture, Udayana University, located in South Denpasar, Bali, at an altitude of approximately 9–10 m above sea level (masl). The site was selected because it represents a lowland area characterized by relatively high air temperatures, high solar radiation intensity, and high evaporation rates, making it suitable for evaluating the effect of irrigation frequency on the growth, productivity, and agribusiness feasibility of the Bali Karet shallot variety.

The study was carried out over a period of three months, from January to March 2026, encompassing land preparation, planting, crop maintenance, observation of growth and yield parameters, harvesting, and data collection for agribusiness analysis.

The tools used in this study included hoes, rulers, digital scales, a 5-L watering can, a soil moisture meter, stationery, a digital camera, and treatment labels. The materials used in this experiment consisted of Bali Karet shallot bulbs as planting material, manure, NPK fertilizer, irrigation water, and pesticides when necessary.

Each experimental unit consisted of a planting bed measuring 1 m × 2 m with a height of 30 cm, while the distance between beds was maintained at 50 cm to ensure proper drainage and air circulation. Each plot contained 20 plants arranged at a spacing of 15 cm × 15 cm, resulting in a total of 240 experimental plants.

This study employed a Randomized Complete Block Design (RCBD) to evaluate the effect of irrigation frequency on the growth, productivity, and agribusiness feasibility of the Bali Karet shallot variety cultivated in lowland areas. The RCBD was selected because field environmental conditions were not homogeneous; therefore, blocking was necessary to minimize the influence of environmental variation on the experimental results.

The experiment was conducted under open-field conditions without shading to ensure that the plants received full sunlight exposure, consistent with the agroclimatic characteristics of lowland areas, which are characterized by high temperatures and high evaporation rates.

The irrigation treatments were as follows:
- P0: irrigation once per day;
- P1: irrigation twice per day;
- P2: irrigation three times per day; and
- P3: irrigation based on soil moisture conditions.

Irrigation was applied manually using a 5-L watering can. At each irrigation event, 5 L of water was applied uniformly to each experimental plot, equivalent to approximately 0.25 L plant^{-1}. Thus, the total amount of water applied varied according to the irrigation frequency of each treatment. For treatment P3 irrigation was applied only when soil moisture reached the predetermined threshold, whereas P0, P1, and P2 followed fixed daily irrigation schedules. Each treatment was replicated three times, resulting in a total of 12 experimental units.

The variables observed in this study of the Bali Karet shallot variety included growth variables, productivity variables, agroclimatic factors, and agribusiness feasibility parameters affected by different irrigation frequency treatments.

1. Growth Variables
   Growth observations were conducted every seven days after planting until the pre-harvest stage and included the following parameters:
   a. Plant height (cm). Plant height was measured from the base of the stem to the tip of the highest leaf using a ruler or measuring tape.
   b. (Number of leaves (leaves plant). The number of leaves was determined by counting fully expanded leaves on each sample plant.
   c. Bulb diameter (cm). Bulb diameter was measured at harvest using a vernier caliper on the largest bulb section.
2. Productivity Variables
   Productivity observations were conducted at harvest and included the following parameters:
   a. Bulb weight per clump (g). Bulb weight per clump was measured using a digital scale after harvesting and cleaning procedures.
   b. Number of bulbs per clump. The number of bulbs was determined by counting the total bulbs formed in each plant clump.
   c. Productivity per hectare (ton ha). Productivity was calculated by converting the yield obtained from each experimental plot into a hectare-scale production value.
3. Agribusiness Feasibility Variables
   These variables were analyzed to evaluate the economic feasibility of Bali Karet shallot farming and included the following parameters:
   a. Production cost (IDR ha). Production costs included expenses for seeds, fertilizers, labor, pesticides, and irrigation water.
   b. Revenue (IDR ha). Revenue was calculated based on total production multiplied by the market price of shallots at the farmer level.
   c. Income/profit (IDR ha). Income or profit was obtained from the difference between total revenue and total production costs.
   d. R/C Ratio (Revenue–Cost Ratio). The R/C ratio was used to determine the economic feasibility of shallot farming using the following formula:

$$R/C = \frac{\text{Total Revenue}}{\text{Total Production Cost}}$$

An R/C ratio greater than 1 indicates that the farming activity is economically feasible and profitable.

The research data were analyzed using Analysis of Variance (ANOVA) at a 5% significance level to determine the effect of irrigation frequency treatments on the observed variables. Data were subjected to analysis of variance (ANOVA). When significant treatment effects were detected ($P < 0.05$), mean comparisons were performed using Duncan's Multiple Range Test (DMRT) at the 5% significance level.

In addition, agribusiness feasibility was analyzed descriptively to evaluate the economic performance of Bali Karet shallot farming under different irrigation frequency treatments. Descriptive analysis was also used to describe the environmental conditions observed during the experimental period.

Results and Discussion

Growth Observation Results

The results showed that irrigation frequency significantly affected the growth of the Bali Karet shallot variety cultivated in lowland areas. Increasing irrigation frequency to match crop water requirements improved vegetative growth, particularly plant height and leaf number. Duncan's Multiple Range Test (DMRT) at the 5% significance level showed that treatment P3 (soil moisture-based) consistently produced the greatest plant height and differed significantly from P0, whereas P1 and P2 exhibited intermediate responses throughout the observation period (Table 1).

Table 1. Average Plant Height of Shallots (cm)

Treatment	14 DAP (cm)	28 DAP (cm)	42 DAP (cm)
P0 (once/day)	15.2a	23.5a	28.1a
P1 (twice/day)	17.8b	27.6b	32.4b
P2 (three times/day)	18.5bc	29.1bc	34.7bc
P3 (soil moisture-based)	19.3c	31.2c	36.5c

The superior performance of P3 (soil moisture-based) suggests that maintaining soil moisture close to the crop water requirement provided more favorable conditions for plant growth than fixed irrigation schedules. Under lowland conditions characterized by high temperatures and high evapotranspiration, maintaining adequate soil moisture may reduce water stress and improve the availability of water for plant development. Although physiological parameters such as photosynthetic rate, chlorophyll content, and stomatal conductance were not measured in this study, previous studies have suggested that appropriate irrigation management can improve physiological performance by maintaining plant water status and enhancing nutrient uptake. These findings are consistent with those of [6], who reported that optimized irrigation scheduling improved shallot growth by enhancing water availability and nutrient absorption. Similarly, [7] found that efficient irrigation management significantly increased vegetative growth and productivity of horticultural crops under dry tropical conditions. However, [3] observed that the response of shallot growth to irrigation management may vary among varieties and environmental conditions, indicating that variety-specific irrigation strategies are required. Therefore, the present study provides additional evidence that soil moisture-based irrigation is an effective strategy for improving the growth performance of the Bali Karet shallot variety cultivated in lowland areas.

The DMRT results also showed that treatment P3 (soil moisture-based) produced the highest number of leaves and differed significantly from P0, whereas P1 and P2 resulted in better performance than P0 but were grouped closely during several growth stages (Table 2). The greater leaf number observed under soil moisture-based irrigation may indicate that maintaining adequate soil moisture created more favorable conditions for vegetative development than fixed irrigation schedules. Although leaf physiological characteristics were not evaluated, this response is consistent with previous reports indicating that irrigation management based on crop water requirements improves water-use efficiency and supports plant growth. Kurniawan and Lestari [8] reported that irrigation adjusted to plant water requirements improved water-use efficiency by up to 25% compared with conventional irrigation systems, while [9] demonstrated that appropriate irrigation management directly influences productivity and profitability of horticultural farming in tropical regions.

Table 2. Average Number of Leaves (leaves)

Treatment	14 DAP	28 DAP	42 DAP
P0 (once/day)	6.2a	10.4a	14.1a
P1 (twice/day)	7.1b	11.8b	16.2b
P2 (three times/day)	7.4bc	12.6bc	17.5bc
P3 (soil moisture-based)	8.0c	13.9c	18.8c

The superior plant height and leaf number obtained under treatment P3 (soil moisture-based) may be associated with more stable soil moisture conditions throughout the growing period. However, because physiological variables were not measured, the underlying mechanisms cannot be confirmed directly in the present study. Previous studies have suggested that irrigation practices that maintain adequate soil moisture may support metabolic activity, nutrient uptake, and vegetative development. Hidayat et al. [10] stated that irrigation management adjusted to crop water requirements can enhance metabolic activity and vegetative growth of horticultural crops. Saputra and Mahendra [11] also reported that plant height and leaf number in shallots are strongly influenced by the balance of water availability in the growing medium. Likewise, [12] found that adequate water supply during the vegetative stage promoted leaf formation and plant height, while [13] explained that sufficient water availability is essential for maintaining cell turgor required for normal plant growth. Therefore, the results of the present study support the use of soil moisture-based irrigation as an effective approach for improving the vegetative growth of Bali Karet shallots under lowland conditions, although further studies including physiological measurements are needed to clarify the underlying mechanisms.

Production Results

Watering frequency also had a significant effect on production parameters, including bulb weight and productivity per hectare. The DMRT test at the 5% level indicated that treatment P3 (soil moisture-based) produced the highest values for all production parameters and differed significantly from P0. Treatments P1 and P2 showed better results than P0; however, several parameters were grouped closely (bc), indicating that some treatments were not significantly different statistically. These findings suggest that water management based on plant requirements improves plant physiological efficiency, particularly in bulb formation and filling processes, thereby directly increasing shallot productivity in lowland areas (Table 3).

Table 3. Average Shallot Production

Treatment	Bulb Weight per Clump (g)	Number of Bulbs per Clump	Productivity (tons ha⁻¹)
P0 (once/day)	42.3a	6.1a	7.8a
P1 (twice/day)	51.6b	7.2b	9.4b
P2 (three times/day)	55.8bc	7.8bc	10.2bc
P3) (soil moisture-based)	61.4c	8.5c	11.3c

The results further demonstrated that watering frequency significantly affected bulb weight, bulb number, and shallot productivity. Treatment P3 (soil moisture-based) produced the highest productivity at 11,3 tons ha, whereas P0 resulted in the lowest productivity at 7,8 tons ha^{-1} (Figure 1). The increase in yield indicates that optimal water availability plays an important role in bulb formation and filling. According to [14], proper water management can enhance photosynthetic efficiency and the translocation of photosynthates to bulbs, thereby significantly increasing shallot yield. Nugraha and Fitriani [15] reported that water stress during the bulb formation stage reduces bulb size and weight due to disruptions in plant metabolic processes. Fauzan et al. [16] also explained that optimal watering frequency can increase shallot productivity by maintaining stable soil moisture during the generative phase. This statement was supported by Gardner et al. [17], who stated that adequate water availability directly affects photosynthate distribution and the development of plant storage organs such as bulbs. Therefore, treatment P3 (soil moisture-based) provided optimal conditions for maximizing the genetic potential of Bali Karet shallots, resulting in the highest production yield.

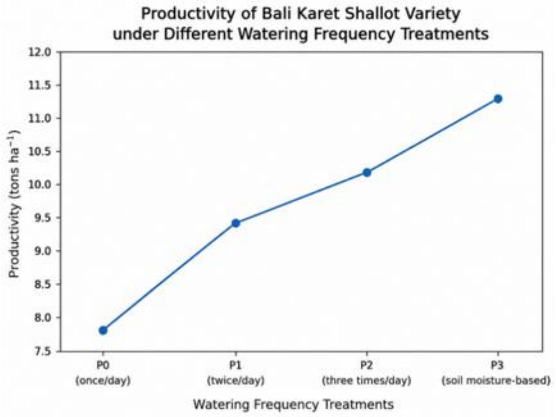

Figure 1. Productivity of Bali Karet Shallot Variety

Agribusiness Feasibility Analysis

Economic analysis showed that all treatments were agribusiness-feasible; however, treatment P3 (soil moisture-based) provided the highest profit. Production costs increased from P0 to P3 (soil moisture-based), with the lowest cost recorded in P0 at IDR 45,000,000 ha and the highest in P3 (soil moisture-based) at IDR 47,800,000 ha. The increase in production costs was presumably due to additional use of production inputs such as seeds, fertilizers, pesticides, labor, and more intensive cultivation practices. Nevertheless, the increase in costs remained efficient because it was followed by higher farm revenues and profits. The difference in production costs between P0 and P3 (soil moisture-based) was IDR 2,800,000 ha, which was relatively small compared with the increase in revenue obtained (Table 4), indicating that the additional input use in higher treatments remained efficient in improving production yields.

Table 4. Agribusiness Feasibility Analysis

Treatment	Production Cost (IDR ha)	Revenue (IDR ha)	Profit (IDR ha)	R/C Ratio	Water Consumption (m^3 ha^{-1})	Irrigation Cost (IDR ha^{-1})
P0 (once/day)	45,000,000	62,400,000	17,400,000	1,39	5,850	2,925,000
P1 (twice/day)	46,500,000	75,200,000	28,700,000	1,62	6,450	3,225,000
P2 (three times/day)	47,000,000	81,600,000	34,600,000	1,74	6,900	3,450,000
P3 (soil moisture-based)	47,800,000	90,400,000	42,600,000	1,89	5,100	2,550,000

Farm revenue increased across all treatments, amounting to IDR 62,400,000 ha in P0, IDR 75,200,000 ha in P1, IDR 81,600,000 ha in P2, and reaching the highest value in P3 (soil moisture-based) at IDR 90,400,000 ha. The increase in revenue indicated that the applied treatments improved both production yield and product quality. Compared with P0, treatment P3 (soil moisture-based) increased revenue by IDR 28,000,000 ha, demonstrating the best response in improving farming outcomes (Table 4). Furthermore, the greater increase in revenue compared with the increase in production costs indicated that the applied treatments remained economically beneficial for farmers.

Farm profit was calculated as the difference between total revenue and total production costs. The highest profit was obtained in treatment P3 (soil moisture-based) at IDR 42,600,000 ha, whereas the lowest profit was recorded in P0 at IDR 17,400,000 ha. Profit increased to IDR 28,700,000 ha in P1 and IDR 34,600,000 ha in P2 (Table 4). Compared with P0, treatment P3 (soil moisture-based) increased profit by IDR 25,200,000 ha, indicating that the use of production inputs in this treatment significantly improved crop productivity and generated higher farmer income. Therefore, treatment P3 (soil moisture-based) is considered more prospective for shallot farming development.

Water consumption also differed among treatments because irrigation frequency was adjusted according to the assigned schedule. Treatment P3 (soil moisture-based) required irrigation only when soil moisture reached the predetermined threshold, thereby reducing unnecessary water application while maintaining optimum soil moisture for plant growth. Consequently, the total water consumption in P3 (soil moisture-based) was lower than that of fixed-interval irrigation treatments, indicating greater water-use efficiency. This finding demonstrates that higher productivity in P3 (soil moisture-based) was achieved not by increasing water input but by improving irrigation precision.

Irrigation cost followed the pattern of water consumption. Although the installation of soil moisture monitoring slightly increased production costs, the operational cost of irrigation, including water pumping and labor, was lower because irrigation was applied only when required. Consequently, treatment P3 (soil moisture-based) achieved lower irrigation cost per kilogram of shallot produced compared with the fixed-interval irrigation treatments. This improvement contributed to higher net farm profit and strengthened the economic feasibility of the soil moisture-based irrigation system.

The R/C Ratio values of all treatments were greater than 1, namely 1,39 in P0, 1,62 in P1, 1.74 in P2, and the highest value of 1,89 in P3 (soil moisture-based). These results indicate that all treatments were economically feasible and profitable. The R/C Ratio value of 1,89 in P3 (soil moisture-based) indicates that every IDR 1,00 of production cost generated IDR 1,89 in revenue, making it the most efficient treatment among all treatments. A higher R/C Ratio reflects greater farming efficiency; therefore, treatment P3 (soil moisture-based) can be recommended as the best treatment. According to [18], farming is considered efficient when the R/C Ratio is greater than one, while [19] stated that farming feasibility is influenced by the farmer's ability to minimize production costs and maximize crop yield. In this study, the increase in R/C Ratio was consistent with the increase in production across treatments.

According to [20], the efficiency of horticultural farming is strongly influenced by crop productivity and efficient use of production inputs, particularly water and fertilizers. Pramono and Yuliana [21] explained that efficient use of production inputs can increase farm profits without excessively increasing production costs. In addition, [22] stated that efficient water use in horticultural cultivation directly contributes to increased farmer income through improved crop productivity. In this study, treatment P3 (soil moisture-based) increased profit up to IDR 42,600,000 ha due to a significant increase in production without disproportionate increases in production costs.

Besides increasing farm profit, the soil moisture-based irrigation system improved water productivity by producing higher shallot yield with lower water consumption. Therefore, the economic advantage of treatment P3 (soil moisture-based) resulted not only from higher production but also from more efficient utilization of irrigation water, making this technology more suitable for sustainable shallot production under lowland conditions where water availability is becoming increasingly limited.

Therefore, from an agribusiness perspective, treatment P3 (soil moisture-based) not only increased production but also generated the highest economic returns, making it highly recommended for the development of shallot farming systems in lowland areas. The results of this study indicate that a soil moisture-based irrigation system is the most effective approach for improving shallot productivity and farm profitability. This system is more adaptive to lowland agroclimatic conditions characterized by high temperature fluctuations and high evaporation rates. In addition, this approach supports the principles of sustainable agriculture by improving water-use efficiency, which is an important consideration given the limited availability of water resources in modern agricultural systems.

Conclusion

The results of this study demonstrate that watering frequency significantly affected the growth, productivity, water use, and agribusiness feasibility of the Bali Karet shallot variety cultivated in lowland areas. Among the irrigation treatments, soil moisture based irrigation (P3) consistently produced the best performance by promoting superior vegetative growth, as reflected in greater plant height and leaf number, and by achieving the highest bulb weight (61.4 g clump^{-1}), bulb number (8.5 bulbs clump^{-1}), and productivity (11.3 t ha^{-1}), representing an increase of approximately 44.9% compared with conventional once daily irrigation (P0). In addition, P3 improved water use efficiency by reducing irrigation water consumption by 12.8% (from 5,850 to 5,100 m^3 ha^{-1}) and lowering irrigation costs from IDR 2,925,000 to IDR 2,550,000 ha^{-1} without compromising yield. Economically, all irrigation treatments were feasible, with R/C ratio values exceeding 1.0; however, P3 generated the highest farm profit (IDR 42,600,000 ha^{-1}), representing an increase of approximately 144.8% over P0, and achieved the highest R/C ratio (1.89). Overall, soil moisture based irrigation proved to be the optimum irrigation strategy for Bali Karet shallot cultivation in lowland environments because it simultaneously enhanced plant growth, bulb productivity, water use efficiency, and farm profitability. Therefore, this irrigation approach has strong potential as a sustainable water management technology for shallot production, particularly in lowland areas experiencing increasing water scarcity and high evaporative demand..

Conflict of Interest

All authors declare no conflicts of interest” in this section.

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