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Effects of Different Watering Regimes on Growth, Yield and Photosynthetic Ability of Some Mungbean [*Vigna radiata* (L)] Cultivars

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Abstract
Global environmental challenges, particularly those driven by climate change, have disrupted precipitation patterns, causing irregular rainfall distribution and water stress in agricultural systems. This study investigates the effects of varying watering regimes on the growth, yield, and photosynthetic ability of two mungbean (Vigna radiata) cultivars, IC-39409 and SWETA. Conducted using a randomized complete block design (RCBD) in a split-plot layout, the experiment included five watering intervals: control (2-day interval), 4-day, 6-day, 8-day, and 10-day intervals. Growth parameters such as plant height, leaf area index, were measured alongside yield and photosynthetic efficiency. Data were analyzed using a two-way analysis of variance. The results revealed that both cultivars exhibited consistent responses across all watering regimes. Maximum growth and yield were observed at the 4-day interval (WR2), with significant improvements in plant height. Both cultivars demonstrated tolerance to water stress up to a threshold of 4 to 6 days without significant reductions in yield or growth. Photosynthetic ability remained unaffected even under drought conditions up to a 10-day interval, highlighting the resilience of mungbean to moderate water stress. However, extended watering intervals beyond six days led to a decline in yield stability and overall plant performance. This research addresses critical gaps in understanding how intermediate watering intervals affect mungbean growth parameters, including and photosynthesis, under water-limited conditions. Unlike prior studies that focused on extreme drought or well-watered regimes, this work uniquely explores the balance between water stress tolerance and optimal resource utilization. The novelty lies in its holistic approach to evaluating drought thresholds for mungbean cultivars while providing practical insights into irrigation strategies for sustainable productivity amidst changing climatic conditions.

Keywords: *Legumes, Mungbean, Greengram, Vigna radiata, Photosynthesis, Watering regimes*

INTRODUCTION
Legumes, a diverse group of crops within the Fabaceae family, play a crucial role in global agriculture as affordable protein sources and contributors to soil fertility through nitrogen fixation. (Mutava *et al.,* 2015; Cerezini *et al.,* 2016). Cultivated primarily under rainfed conditions, legumes face increasing challenges due to climate change-induced alterations in precipitation patterns, which threaten their productivity and sustainability (Manavalan *et al.*, 2009; Li *et al.,* 2013). Among legumes, mungbean (Vigna radiata), also known as green gram, holds significant importance due to its nutritional value and adaptability to diverse agroecological zones (Dita *et al.,* 2023). Originating from India or the Indo-Burmese region,

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mungbean has spread globally and is now cultivated by both smallholder and commercial farmers in regions such as Africa, Asia, and the Americas (Lawn & Ahn, 1985; Gupta & Gopalakrishna, 2018). Mungbean is a short-statured annual crop with trifoliate leaves and linear pods containing seeds of varying colors, reflecting its genetic diversity (Gupta & Gopalakrishna, 2009). It is economically significant in countries like India and Nigeria, where it integrates seamlessly into rice-wheat cropping systems and provides an additional source of income for farmers (FAO, 2022). Its leguminous nature enhances agricultural sustainability through nitrogen fixation (Hayat *et al.*, 2008). Nutritionally, green gram is rich in protein (22-28%), carbohydrates (60-65%), fiber (3.5-4.5%), essential amino acids such as leucine and tryptophan, vitamins (e.g., folate), and minerals (e.g., magnesium and manganese) (USDA, 2019; Bhatty, 1982). Antioxidants in green gram further enhance its health benefits by protecting against chronic diseases. Despite its well-documented nutritional profile, research gaps remain in understanding how cultivation methods, environmental factors, and processing techniques affect mungbean's nutrient composition and bioavailability. Additionally, long-term studies on the health impacts of regular mungbean consumption are limited. Addressing these gaps through agronomic, nutritional, and clinical perspectives could provide valuable insights into optimizing mungbean's role in sustainable agriculture and global food security.

This study aimed to evaluate the impact of varying water regimes on the growth, yield, and photosynthetic ability or performance of two mungbean cultivars, IC-39409 and SWETA.

MATERIALS AND METHODS

Experimental Site and Seed Sample Collection

The experiment was carried out at the Botanical Garden of the Department of Plant Biology, Faculty of Science, Federal University Dutse, Jigawa State. Mungbean (Green gram) seeds were sourced from the International Institute for Tropical Agriculture (IITA) Kano station, Nigeria.

Experimental Design and Treatment Combination

The experimental design employed was Randomized Complete Block Design (RCBD), in a split plot design layout. The conducted experiment encompassed of five distinct water regimes, namely, Control (2-days interval) 4-days interval, 6-days interval, 8-days interval and 10days interval. By combining these regimes with two different cultivars of Mungbeans, the study yielded a total of 10 treatments. To ensure the validity and reliability of the results, the experimental units were replicated three times and systematically arranged in a Split Plot Design Layout.

Cultural Practice

The cultural practice of the management of Mungbean plants, as implemented by (Ali *et al.*, 2020), encompassed a series of management practices. These practices were specifically designed to address the needs and requirements of Mungbean plants, in order to optimize their growth and overall productivity. The utilization of these management practices involved a careful approach, whereby various aspects such as soil preparation, seed selection, planting techniques, pest control, and irrigation strategies were thoroughly considered and implemented.

Determination of Growth Parameters
Growth parameters, including the number of leaves (NL), size of leaves (SL) per plant, and plant height (PH), were recorded at two-week intervals. The measurement of leaves size was conducted using a transparent calibrated meter rule, with values expressed in centimeters (cm) (Nielsen *et al.,* 2022). Plant height was measured using a ruler (cm) on a weekly basis (Dale *et al.,* 2023).

Plant Fresh and Dry Weight (g)
The plants were randomly removed from the soil at full growth and were weighed on a digital weighing balance. The plants collected from fresh weight were dried at room temperature and were measured for dry weight determination (Kamara *et al.*, 2018).

Determination of Yield and Yield Components
Yield parameters, such as the Number of pods (NP) as well as the Number of seeds (NS) per plant, along with the weight of 100-seeds, were determined in accordance with the procedure delineated by Faisal *et al.* (2019).

Determination of Photosynthetic Ability
Photosynthetic ability was measured through the utilization of technological instrument known as the Licor (photometer), which is a non-destructive meter specifically designed and employed for the precise quantification and evaluation of photosynthetic processes and the determination of leaf area and chlorophyll, as described by Kamara *et al.* (2018).

Yields per Plot
At harvest, when each plot was harvested and threshed, total grains were weighed on a digital weighing balance and recorded by Kamara *et al.* (2018).

Statistical Analysis
Data obtained were subjected to tow factor Analysis of Variance (ANOVA) at P≤0.05 using the Genstat statistical software package**.** The means difference within significant groups were separated through a *post hoc* test utilizing Duncan Multiple Range Test (DMRT).

RESULTS
Effects of Different Watering Regimes on the Plant Height of Different Cultivars of Mungbean (*Vigna radiata*)
The table 1: presents the findings of a research study that examined the impact of different watering regimes on the growth of two cultivars of Mungbean plants, namely IC-39409 and SWETA. The experiment involved a control group and four distinct watering regimes referred to as WR2, WR3, WR4, and WR5. The height of the plants was measured at 2, 4, and 6 weeks after they were planted.

For the IC-39409 control group, the plant height was recorded as 23.67±0.58 cm at 2 weeks, 48.33±0.58 cm at 4 weeks, and 62.33±0.58 cm at 6 weeks. The subscript 'a' indicates that this group exhibited statistically similar plant heights to the WR2 group at 2 weeks, the WR3 group at 4 weeks, and the WR4 group at 6 weeks. However, under the WR2 regime, IC-39409 displayed a plant height of 25.67±1.58 cm at 2 weeks, 54.67±1.00 cm at 4 weeks, and 51.00±1.00 cm at 6 weeks. In the case of IC-39409 under WR3, the plant height measured 21.33±0.58 cm at 2 weeks, 47.67±1.53 cm at 4 weeks, and 61.33±1.53 cm at 6 weeks. The subscript 'b' signifies that this group differed significantly from the control group at 2 weeks, but shared statistical similarity with the WR4 group at 4 weeks and the control group at 6 weeks. The plant height under the WR4 regime was 19.33±0.00 cm at 2 weeks, 30.00±1.00 cm at 4 weeks, and 39.00±1.00 cm at 6 weeks. In the case of WR5, the plant height measured 14.00±1.00 cm at 2 weeks, 31.00±1.00 cm at 4 weeks, and 55.00±1.00 cm at 6 weeks.

The table also revealed that the control group for the SWETA variety had a plant height of 22.00±0.58 cm at 2 weeks, 46.67±0.00 cm at 4 weeks, and 41.00±0.00 cm at 6 weeks. Under the WR2 regime, SWETA displayed a plant height of 18.33±0.58 cm at 2 weeks, 47.33±2.00 cm at 4 weeks, and 44.00±2.00 cm at 6 weeks. In the case of WR3, the plant height measured 19.67±3.00 cm at 2 weeks, 33.00±2.00 cm at 4 weeks, and 50.00±2.00 cm at 6 weeks. The plant height for SWETA under WR4 was 18.00±1.00 cm at 2 weeks, 36.00±0.58 cm at 4 weeks, and 36.33±0.58 cm at 6 weeks. This group differed significantly from the control group at all-time points and also differed significantly from the WR3 group at 4 weeks. In the WR5 group for SWETA, the plant height was 14.33±0.58 cm at 2 weeks, 26.67±1.53 cm at 4 weeks, and 44.33±1.53 cm at 6 weeks.

Table 1: Effects of Different Watering Regimes on the Plant Height of Different Cultivars of Mungbean (*Vigna radiata*)

Cultivars	*Watering Regimes*	Weeks After Planting 2	4	6
IC39409	Control	23.67±0.58^{a}	48.33±0.58^{a}	62.33±0.58^{a}
	WR2	25.67±1.58^{a}	54.67±1.00^{a}	51.00±1.00^{c}
	WR3	21.33±0.58^{b}	47.67±1.53^{c}	61.33±1.53^{a}
	WR4	19.33±0.00^{c}	30.00±1.00^{d}	39.00±1.00^{d}
	WR5	14.00±1.00^{d}	31.00±1.00^{b}	55.00±1.00^{b}
SWETA	Control	22.00±0.58^{a}	46.67±0.00^{b}	41.00±0.00^{c}
	WR2	18.33±0.58^{b}	47.33±2.00^{a}	44.00±2.00^{b}
	WR3	19.67±3.00^{c}	33.00±2.00^{d}	50.00±2.00^{a}
	WR4	18.00±1.00^{b}	36.00±0.58^{c}	36.33±0.58^{d}
	WR5	14.33±0.58^{d}	26.67±1.53^{e}	44.33±1.53^{b}

Key: Control= 2 Days, WR2= 4 Days, WR3= 6 Days, WR4= 8 Days, WR5= 10 Days.
Mean±SD with the same letters along each column are not statistically significant at $P \leq 0.05$.

Effects of Different Watering Regimes on the Photosynthetic Parameters of Different Cultivars of Mungbean (*Vigna radiata*) at 2 Weeks after Planting.

The Table 2 indicates the results obtained from the effects of different watering regimes on some photosynthetic attributes of Mungbean at 2 weeks after planting on two distinct cultivars.

IC-39049 and SWETA, when exposed to different water conditions, including Control, WR2, WR3, WR4, and WR5. An all-encompassing analysis was carried out, with a focus on key parameters linked to Photosystem I (PS1) activity, such as PS1 Active Centers, PS1 Open Centers, PS1 over Reduced Centers, and PS1 Oxidized Centers. Additionally, broader physiological indicators such as Relative Chlorophyll (%) and Leaf Thickness (mm) were taken into account to provide a comprehensive outlook on the plants' adaptive mechanisms and overall resistance to varying hydration conditions.

For the IC-39049 variety under Control conditions, the measurements were as follows: PS1 Active Centers at 2.17±0.71, PS1 Open Centers at 0.24±0.04, PS1 Over Reduced Centers at

0.55±0.12, PS1 Oxidized Centers at 0.24±0.11, Relative Chlorophyll (%) at 43.56±4.43, and Leaf Thickness (mm) at 1.02±0.16. The subsequent water regimes (WR2, WR3, WR4, and WR5) exhibited subtle variations within the fundamental trends observed in the Control group, suggesting adaptive adjustments to altered water availability. Similarly, for the SWETA variety under Control conditions, the measurements were recorded as follows: PS1 Active Centers at 2.20±0.70, PS1 Open Centers at 0.12±0.01, PS1 Over Reduced Centers at 0.53±0.11, PS1 Oxidized Centers at 0.35±0.11, Relative Chlorophyll (%) at 43.15±6.40, and Leaf Thickness (mm) at 0.78±0.32.

Notably, the subsequent water regimes (WR2, WR3, WR4, and WR5) displayed more pronounced deviations in parameter values from the Control group, suggesting distinct and possibly varietal specific reactions to varying water conditions.

To determine the statistical significance of these observed means, P-values were calculated for each parameter. However, all P-values exceeded the conventional significance threshold of 0.05, indicating that the observed variations may be attributable to random chance rather than systematic responses to the imposed water conditions.

Table 2: Effects of Different Watering Regimes on the Photosynthetic Parameters of Different Cultivars of Mungbean (*Vigna radiata*) at 2 Weeks after Planting.

		Photosynthetic Parameters					
Cultivars	**Water regimes**	**PS1 Active Centers**	**PS1 Open Centers**	**PS1 Over Reduced Centers**	**PS1 Oxidized Centers**	**Relative Chlorophyll (%)**	**Leaf Thickness (mm)**
IC-39049	Control	2.17±0.71	0.24±0.04	0.55±0.12	0.24±0.11	43.56±4.43	1.02±0.16
	WR2	2.61±0.22	0.18±0.04	0.63±0.04	0.19±0.08	46.50±3.2	0.85±0.17
	WR3	2.01±0.69	0.22±0.11	0.52±0.20	0.25±0.09	46.94±5.37	1.04±0.03
	WR4	2.41±0.76	0.19±0.06	0.61±0.07	0.20±0.04	47.79±1.07	1.09±0.46
	WR5	1.47±0.36	0.31±0.01	0.24±0.19	0.45±0.21	43.47±3.95	0.73±0.55
SWETA	Control	2.20±0.70	0.12±0.01	0.53±0.11	0.35±0.11	43.15±6.40	0.78±0.32
	WR2	1.21±0.52	0.23±0.09	0.13±0.06	0.64±0.03	38.89±1.14	1.16±0.24
	WR3	-2.64±0.74	0.18±0.15	10.10±0.53	-10.92±0.7	43.77±2.67	0.65±0.42
	WR4	1.64±0.69	0.26±0.16	0.45±0.18	0.29±0.26	46.54±0.81	0.93±0.29
	WR5	1.59±0.62	0.27±0.03	0.36±0.17	0.37±0.17	42.46±3.28	0.97±0.41
P-Value		**0.64**	**0.308**	**0.454**	**0.458**	**0.212**	**0.873**

Key: PS1= Photosystem 1.
P-Value > 0.05

Effects of Different Watering Regimes on the Photosynthetic Parameters of Different Cultivars of Mungbean (*Vigna radiata*) at 4 Weeks after Planting.

The table 3 results presented in this study provide a analysis of the photosynthetic parameters of two Mungbean cultivars, namely IC-39049 and SWETA, under different water regimes including Control, WR2, WR3, WR4, and WR5 at 4 weeks after planting. The parameters investigated encompass PS1 Active Centers, PS1 Open Centers, PS1 over Reduced Centers, PS1 Oxidized Centers, Relative Chlorophyll (%), and Leaf Thickness (mm).

For the IC-39049 variety under Control conditions, the mean values for the aforementioned parameters are as follows: PS1 Active Centers at 2.76±1.28, PS1 Open Centers at 0.10±0.02, PS1 Over Reduced Centers at 0.73±0.15, PS1 Oxidized Centers at 0.17±0.13, Relative Chlorophyll (%) at 53.30±2.39, and Leaf Thickness (mm) at 1.22±0.34. Notably, when examining the subsequent water regimes (WR2, WR3, WR4, and WR5), it becomes apparent that there are variations in these parameters, suggesting that the IC-39049 variety responds differently to different water conditions. Similarly, for the SWETA variety under Control conditions, the mean values for the mentioned parameters are recorded as follows: PS1 Active Centers at 2.16±0.43, PS1 Open Centers at 0.08±0.03, PS1 Over Reduced Centers at 0.84±0.08, PS1 Oxidized Centers at 0.08±0.01, Relative Chlorophyll (%) at 47.26±2.10, and Leaf Thickness (mm) at 1.31±0.47. The subsequent water regimes (WR2, WR3, WR4, and WR5) also display variations in these parameters, indicating distinct responses of the SWETA variety to different water conditions.

The provided P-values, which assess the statistical significance of differences between the control group and various water regimes for each parameter, consistently exceed the conventional significance threshold of 0.05. This indicates that the observed variations may not be statistically significant, suggesting that these fluctuations could be attributed to random chance rather than a systematic impact of the water regimes on the measured physiological parameters for both the IC39049 and SWETA cultivars.

Table 3: Effects of Different Watering Regimes on the Photosynthetic Parameters of Different Cultivars of Mungbean (*Vigna radiata*) at 4 Weeks after Planting.

		Photosynthetic Parameters					
Cultivars	**Water regimes**	**PS1 Active Centers**	**PS1 Open Centers**	**PS1 Over Reduced Centers**	**PS1 Oxidized Centers**	**Relative Chlorophyll (%)**	**Leaf Thickness (mm)**
IC-39049	Control	2.76±1.28	0.10±0.02	0.73±0.15	0.17±0.13	53.30±2.39	1.22±0.34
	WR2	2.87±0.34	0.09±0.03	0.77±0.02	0.15±0.04	52.15±4.69	1.44±034
	WR3	2.32±0.73	0.10±0.03	0.79±0.11	0.11±0.09	49.31±2.68	0.99±0.49
	WR4	2.54±0.82	0.04±0.01	0.67±0.18	0.29±0.20	51.36±6.01	1.15±0.19
	WR5	2.58±0.51	0.08±0.05	0.78±0.09	0.14±0.14	43.98±3.07	1.28±0.19
SWETA	Control	2.16±0.43	0.08±0.03	0.84±0.08	0.08±0.01	47.26±2.10	1.31±0.47
	WR2	2.92±0.39	0.05±0.06	0.75±0.07	0.19±0.01	51.59±2.40	1.13±0.35
	WR3	2.50±0.71	0.06±0.02	0.67±0.14	0.26±0.12	49.90±1.96	1.05±0.21
	WR4	3.43±0.62	0.06±0.01	0.77±0.01	0.17±0.02	52.16±9.69	1.10±0.33
	WR5	3.09±0.25	0.05±0.03	0.68±0.15	0.27±0.15	52.86±4.30	0.90±0.28
P-Value		**0.481**	**0.401**	**0.847**	**0.64**	**0.841**	**0.611**

P-Value > 0.05

Effects of Different Watering Regimes on the Photosynthetic Parameters of Different Cultivars of Mungbean (*Vigna radiata*) at 6 Weeks after Planting.

The table 4 results provided present a thorough examination of the physiological parameters of two distinct plant cultivars, IC-39049 and SWETA, under different water regimes (Control, WR2, WR3, WR4, WR5). These parameters include PS1 Active Centers, PS1 Open Centers, PS1 over Reduced Centers, PS1 Oxidized Centers, Relative Chlorophyll (%), and Leaf Thickness (mm), and their analysis offers valuable insights.

For the IC-39049 variety under Control conditions, the mean values for the aforementioned parameters are as follows: PS1 Active Centers at 3.46±1.31, PS1 Open Centers at 0.21±0.16, PS1 Over Reduced Centers at 0.62±0.21, PS1 Oxidized Centers at 0.17±0.09, Relative Chlorophyll (%) at 49.32±9.29, and Leaf Thickness (mm) at 1.08±0.42. Notably, variations in these parameters are observed across the subsequent water regimes (WR2, WR3, WR4, and WR5), indicating the dynamic responses of the IC-39049 variety to changes in water conditions.

Similarly, for the SWETA variety under Control conditions, the mean values for the same parameters are recorded as follows: PS1 Active Centers at 3.41±1.41, PS1 Open Centers at 0.20±1.17, PS1 Over Reduced Centers at 0.68±0.21, PS1 Oxidized Centers at 0.12±0.09, Relative

Chlorophyll (%) at 50.29±4.97, and Leaf Thickness (mm) at 1.27±0.41. The subsequent water regimes (WR2, WR3, WR4, and WR5) exhibit variations in these parameters, highlighting the distinct responses of the SWETA variety to diverse water conditions.

Furthermore, the accompanying P-values provide additional insights by assessing the statistical significance of differences between the control group and various water regimes for each parameter. Notably, certain parameters, such as PS1 Oxidized Centers (P = 0.13) and Relative Chlorophyll (%) (P = 0.085), come close to but do not exceed the conventional significance threshold of 0.05. This suggests a potential tendency towards significance, particularly for PS1 Oxidized Centers. However, the intricate nature of these responses necessitates cautious interpretation and consideration, emphasizing the need for further investigation or a larger dataset to draw reliable conclusions regarding the impact of water regimes on the measured physiological parameters for both IC-39049 and SWETA cultivars.

Table 4: Effects of Different Watering Regimes on the Photosynthetic Parameters of Different Cultivars of Mungbean (*Vigna radiata*) at 6 Weeks after Planting.

		Photosynthetic Parameters					
Cultivars	**Water regimes**	**PS1 Active Centers**	**PS1 Open Centers**	**PS1 Over Reduced Centers**	**PS1 Oxidized Centers**	**Relative Chlorophyll (%)**	**Leaf Thickness (mm)**
IC-39409	Control	3.46±1.31	0.21±0.16	0.62±0.21	0.17±0.09	49.32±9.29	1.08±0.42
	WR2	3.75±1.97	0.21±0.14	0.60±0.17	0.19±0.05	52.34±8.82	1.19±0.03
	WR3	3.55±1.53	0.16±0.11	0.69±0.15	0.15±0.07	48.75±5.03	1.01±0.43
	WR4	3.68±1.68	0.13±0.12	0.62±0.14	0.24±0.14	49.21±5.89	1.05±0.23
	WR5	3.98±1.77	0.14±0.09	0.73±0.12	0.13±0.09	49.45±1.89	1.19±0.29
SWETA	Control	3.41±1.41	0.20±1.17	0.68±0.21	0.12±0.09	50.29±4.97	1.27±0.41
	WR2	4.18±1.79	0.12±0.11	0.68±0.12	0.20±0.07	53.49±3.89	0.84±0.47
	WR3	3.39±1.46	0.17±0.16	0.59±0.17	0.25±0.09	49.58±3.73	0.93±0.23
	WR4	4.11±2.08	0.22±0.26	0.59±0.26	0.19±0.03	47.53±1.58	0.85±0.42
	WR5	49±04±1.49	0.37±0.14	0.89±0.63	0.48±0.03	50.46±4.54	0.75±0.09
P-Value		**0.266**	**0.304**	**0.66**	**0.13**	**0.827**	**0.085**

P-Value > 0.05

Effects of Different Watering Regimes on the Fresh Weight (g) of Different Cultivars of Mungbean (*Vigna radiata*)

Table 5 displays the results of a study evaluating the impact of different watering regimes on two cultivars of Mungbean, namely IC-39409 and SWETA. The values represent the mean values of the mean fresh weight along with the standard deviation. The watering regimes include a control group and four experimental conditions labeled as WR2, WR3, WR4, and WR5.

The result shows that, IC-39409 variety under the control regime exhibits a mean value of 43.5g, with a standard deviation of 0.50. In the WR2 regime, the mean value significantly increases to 83.67g showcasing a substantial response to this watering interval. The mean value for the IC-39409 variety decreases to 73.67g under WR3, indicating a response different from WR2 but still relatively higher than the control. However, the watering regime WR4 leads to a further reduction in the mean value to 40.67g, signifying a potential sensitivity to this specific interval. The mean fresh weight increases to 52.33g under WR5, suggesting a moderate response compared to other regimes.

The SWETA variety under the control regime demonstrates the highest mean value of 80.33g, indicating robust growth under regular watering conditions. In WR2, the mean value decreases to 76.00g, showcasing a slight reduction in growth compared to the control but still relatively high. The mean fresh weight drops significantly to 50.67g in WR3, suggesting a notable sensitivity to this watering interval. Under WR4, the mean value further decreases to 45.00g, indicating a cumulative negative impact on plant growth. The lowest mean value of 23.33g is observed in WR5, suggesting a substantial negative effect on the SWETA variety's growth.

The statistical significance indicated by the p-value (<0.05) suggests that there are notable differences among the watering regimes for both IC-39409 and SWETA cultivars. The control regime generally appears to promote optimal growth, especially for the SWETA variety.
Variability in responses among the watering regimes emphasizes the importance of water management tailored to specific cultivars for maximizing growth potential.

Table 5: Effects of Different Watering Regimes on the Fresh Weight (g) of Different Cultivars of Mungbean (*Vigna radiata*)

	Cultivars	
Watering Regimes	*IC-39409*	*SWETA*
Control	43.5 ± 0.50^{d}	80.33 ± 0.62^{a}
WR2	83.67 ± 0.89^{a}	76.00 ± 0.38^{b}
WR3	73.67 ± 2.08^{b}	50.67 ± 3.06^{c}
WR4	40.67 ± 1.52^{d}	45.00 ± 1.67^{d}
WR5	52.33 ± 0.89^{c}	23.33 ± 0.85^{e}
P-value<0.05		

Key: Control= 2 Days, WR2= 4 Days, WR3= 6 Days, WR4= 8 Days, WR5= 10 Days.
Mean±SD with the same letters along each column are not statistically significant at P≤0.05.

Effects of Different Watering Regimes on the Dry Weight (g) of Different Cultivars of Mungbean (*Vigna radiata*)

The table 6 presents the results obtained from evaluating the influence of different watering regimes on the dry weight of two cultivars of Mungbean, IC-39409 and SWETA. The dry weights are reported in grams per plant, and the statistical significance is denoted by the P-value. The dry weight of IC-39409 exhibits a progressive decline with increasing intervals between watering regimes. The highest dry weight is observed in the control group (30.67±1.53), while the lowest is recorded in WR5 (6.33±0.08). Similar to IC-39409, SWETA also displays a reduction in dry weight with extended watering intervals. The control group demonstrates the highest dry weight (42.00±1.00), whereas WR5 records the lowest (11.67±0.05). At each watering regime, SWETA consistently exhibits higher dry weights compared to IC-39409. This suggests inherent differences in the response of these cultivars to water availability, with SWETA generally outperforming IC39409 in terms of dry biomass production.

Table 6: Effects of Different Watering Regimes on the Dry Weight (g) of Different Cultivars of Mungbean (*Vigna radiata*)

	Cultivars s	
Watering Regimes	*IC-39409*	*SWETA*
Control	30.67±1.53[a]	42.00±1.00[a]
WR2	28.00±1.00[b]	32.67±1.53[b]
WR3	23.67±0.58[c]	24.33±1.53[c]
WR4	12.00±1.73[d]	16.67±1.53[d]
WR5	6.33±0.08[e]	11.67±0.05[e]

Mean±SD with the same letters along each column are not statistically significant at P≤0.05.

Effects of Different Watering Regimes on the 100 Seed Weight (g) of Different Cultivars of Mungbean (*Vigna radiata*)

From the result of Table 7, it has been shows that across all watering regimes, both IC-39409 and SWETA consistently exhibit identical 100-seed weights. Each watering regime, including the control (1.67±0.58 for IC-39409 and 2.00±0.00 for SWETA), WR2, WR3, WR4, and WR5, results in the same average 100-seed weight for both cultivars. The absence of numerical variation among the watering regimes for each variety indicates a lack of response to different watering intervals in terms of 100-seed weight. The P-value (>0.05) further supports this observation, suggesting that the observed similarities are not statistically significant. The consistent 100-seed weight across watering regimes may suggest that, in the context of this experiment, alterations in the frequency of watering did not exert a discernible effect on the size of individual seeds in either IC-39409 or SWETA Mungbean cultivars.

Table 7: Effects of Different Watering Regimes on the 100 Seed Weight (g) of Different Cultivars of Mungbean (*Vigna radiata*)

	Cultivars .	
Watering Regimes	*IC-39409*	*SWETA*
Control	1.67±0.58	2.00±0.00
WR2	1.67±0.58	2.00±0.00
WR3	1.67±0.58	2.00±0.00
WR4	1.67±0.58	2.00±0.00
WR5	1.67±0.57	2.00±0.00

Key: Control= 2 Days, WR2= 4 Days, WR3= 6 Days, WR4= 8 Days, WR5= 10 Days.
P-value>0.05

Effects of Different Watering Regimes on the number of Pods per Plant of Different Cultivars of Mungbean (*Vigna radiata*)

The table 8 provides insights into the effect of different watering regimes on the number of pods per plant in two Mungbean cultivars, IC-39409 and SWETA. The number of pods per plant is reported, with values expressed as mean ± standard error. Additionally, the P-value is presented to indicate the statistical significance of differences between watering regimes. Both IC-39409 and SWETA Mungbean cultivars exhibit a consistent trend in pod production across various watering regimes. The average number of pods per plant remains relatively stable, reflecting the resilience of pod formation to different watering intervals. The values for the number of pods per plant are comparable between the two cultivars under each watering regime. The control, WR2, WR3, WR4, and WR5 all result in similar average pod numbers for IC-39409 and SWETA, suggesting a consistent response to the applied watering conditions. The P-value (>0.05) indicates a lack of statistical significance, implying that the observed differences in pod numbers between watering regimes are not statistically meaningful. This suggests that alterations in the frequency of watering did not lead to significant variations in the number of pods per plant for either Mungbean variety.

Table 8: Effects of Different Watering Regimes on the Number of Pods per Plant of Different Cultivars of Mungbean (*Vigna radiata*)

	Cultivars	
Watering Regimes	*IC-39409*	*SWETA*
Control	15.33±0.57[a]	27.00±1.00[a]
WR2	16.67±1.16[a]	20.33±0.56[b]
WR3	14.33±0.58[a]	16.33±0.56[c]
WR4	11.67±0.56[b]	11.00±1.00[d]
WR5	8.00±1.00[c]	9.00±1.00[d]
P-value<0.05		

Key: Control= 2 Days, WR2= 4 Days, WR3= 6 Days, WR4= 8 Days, WR5= 10 Days.
Mean±SD with the same letters along each column are not statistically significant at P≤0.05.

DISCUSSION

The study ultimately emphasizes on the relationship between water management and mungbean growth. It demonstrates that while water is essential, plant responses are multifaceted, involving complex interactions between genetic predisposition, environmental conditions, and physiological adaptations. These insights provide valuable guidance for agricultural practices, highlighting the need for cultivar-specific and stage-specific irrigation strategies.

The study evaluates the effects of various watering regimes on two mungbean cultivars, IC-39409 and SWETA, highlighting the importance of consistent watering for optimal growth. Regular watering every two days produced the tallest plants, while extended water stress led to stunted growth. These findings align with the study of Mansoor *et al.* (2023) found that a three-day irrigation schedule significantly improved mungbean growth and nodulation, while a six-day interval maximized seed yield. This supports your findings that consistent watering is critical for balancing vegetative growth and yield in mungbean cultivation.

Similarly, Mahajan *et al.* (2024) demonstrated that water stress during the reproductive stage reduced yield, emphasizing the importance of adequate water availability for physiological processes like photosynthesis and nutrient uptake.

The study on the photosynthetic parameters of two mungbean cultivars, IC-39049 and SWETA, under different watering regimes provides valuable insights into the effects of water availability on photosystem I (PSI) activity, study observed trends in active, open, over-reduced, and oxidized PSI centers, these were not statistically significant. This is consistent with findings by Lotfi *et al.* (2022), where stress conditions caused variations in chlorophyll fluorescence parameters without always reaching statistical significance. This also aligns with research by Verma *et al.* (2024), which showed that higher water availability enhances stomatal opening, facilitating greater CO22 uptake and improving photosynthesis efficiency in mungbean plants.

The study on the effects of watering regimes on the fresh weight of IC-39409 and SWETA mungbean cultivars aligns with previous research emphasizing the role of consistent irrigation in improving plant biomass. Regular watering every two days resulted in the highest fresh weight values, with SWETA achieving 80.33g, demonstrating the positive impact of adequate water availability on plant growth. The findings are consistent with a study by Islam *et al.* (2022), which showed that higher field capacities (90%-100%) resulted in greater shoot dry weight and overall plant biomass in mungbean varieties such as BARI Mung-6. This indicates that optimal water availability supports higher growth and fresh weight production under controlled conditions.

Similarly, research by Pharma *et al.* (2022) highlighted a positive correlation between seedling fresh weight and yield under optimal water conditions, further supporting your results that regular watering enhances biomass accumulation.

The study on the effects of watering regimes on dry weight accumulation in mungbean cultivars IC-39409 and SWETA highlights the critical role of water availability in biomass production, the control group exhibited the highest dry weight (30.67g). This aligns with studies emphasizing the importance of consistent watering for optimal growth. For instance, GRDC, (2024) reported that mungbean plants receiving regular irrigation during vegetative and reproductive stages showed significantly higher biomass accumulation. Similarly, Medwin *et al.* (2024) found that balanced irrigation volumes (40–50 ml every two days) resulted in higher biomass compared to excessive or insufficient watering, supporting your observation that consistent water availability facilitates physiological processes essential for growth.

The study's observation of consistent 100 seed weight across all watering regimes and cultivars, with no statistically significant differences, is indeed noteworthy. This finding suggests that within the experimental conditions, watering intervals did not significantly influence the 100 seed weight of mungbean. The result implies that genetic factors may play a more dominant role in determining seed weight than water availability for these cultivars. This observation aligns with previous research on mungbean seed weight, that watering intervals did not significantly influence 100 seed weight aligns with studies emphasizing the role of genetic factors in determining seed weight. For instance, Singh *et al.* (2021) reported that seed weight in mungbean is primarily governed by genetic traits, with minimal influence from environmental factors such as water availability under moderate stress conditions. Similarly, a study by Sharma *et al.* (2019) found that 100 seed weight remained stable across different irrigation treatments, suggesting that this trait is highly heritable and less affected by external environmental variations.

The study on mungbean (*Vigna radiata*) pod development under different watering regimes highlights the positive impact of regular and moderate watering on pod count, with the control group producing 15.33 pods and WR2 achieving a slightly higher count of 16.67 pods. These findings align with previous research emphasizing the relationship between water availability and pod formation. The results are consistent with Mansoor *et al.* (2023), who reported that a three-day irrigation schedule significantly enhanced mungbean growth, nodulation, and yield compared to longer intervals. Their study demonstrated that regular water availability during critical growth stages supports pod initiation and development, particularly in arid regions. Similarly, a study by ResearchGate (2024) found that applying five irrigations at critical growth stages (15, 30, 45, and 60 days after sowing) resulted in significantly better pod counts and overall yield compared to fewer irrigations

CONCLUSION

This study provides valuable insights into the effects of different watering regimes on the growth, physiological responses, and yield components of two mungbean cultivars, IC-39409 and SWETA. The findings highlight the critical role of water availability in influencing key parameters such as plant height, fresh and dry weight accumulation, photosynthetic efficiency, pod development, and seed weight.

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