Research Article

Impact of Different Irrigation Regimes on Growth, Yield and Nodulation of Mung Bean

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Abstract | A field study at the Arid Zone Research Center in D.I Khan, Pakistan, assessed the impact of varied irrigation methods on mung bean growth, yield, and nodulation. Results showed superior performance in raised beds compared to flatbed systems, indicating their positive influence on mung bean outcomes. The study highlighted that a three-day irrigation schedule positively affected growth and nodulation, while a six-day interval was optimal for maximizing seed yield. Balancing vegetative growth and seed yield is crucial for overall productivity in arid regions of Pakistan. This study underscores the importance of adopting appropriate irrigation schedules for mung beans in such environments.

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Introduction

Mung bean (*Vigna radiata* L.) is a significant source of calories (347-Kcal food energy) and protein (22-24%) in South Asia, particularly for vegetarian populations. In Pakistan, mung bean cultivation covers an extensive area of 183.3 thousand hectares, contributing 118.7 thousand tonnes to the country's agricultural production (Anonymous, 2010). In Dera Ismail Khan District, approximately 6.6 thousand hectares of land are dedicated to mung bean cultivation annually, resulting in a total production of approximately 4.27 thousand tonnes. This highlights the importance of mung bean cultivation in the region, contributing significantly to the local food supply and economy.

The cultivation of mung bean offers numerous advantages, including its nutritional superiority and nitrogen-fixing properties, making it a valuable crop to meet food demands in developing countries. In regions where cereal crops like gram or wheat are traditionally grown in rotation with fallow, replacing fallow with mung bean cultivation can be beneficial due to its ability to fix nitrogen through biological nitrogen fixation (Haque and Sattar, 2010). This reduces the reliance on synthetic nitrogen fertilizers and improves soil structure, particularly in areas where affordable nitrogen fertilizers are limited (Malik, 1990).

Despite its potential, the average yield of mung bean at the farmer level remains low, mainly due to a lack of knowledge about proper production techniques (Bakhsh *et al*., 1999). Among the various factors influencing crop production, irrigation is significant and profoundly affects yield. Applying an adequate amount of water at the appropriate growth stages of the crop is crucial for achieving higher yields in irrigated areas.

Understanding the water requirements of mung bean plants throughout their growth stages is essential. Different stages of growth exhibit varying sensitivities to moisture deficiency. The period from emergence to flowering is generally less sensitive to water scarcity, while irrigation during pod and seed development stages becomes critical for optimizing yield. Adequate moisture supply during these stages positively affects the number of pods and the weight of 1,000 seeds, both crucial components of yield (Assaduzaman *et al*., 2008).

To address this issue, research trials were conducted examining the effects of various irrigation regimes on the growth, yield, and nodulation of mung bean in Dera Ismail Khan. These trials aimed to determine the most effective irrigation practices for maximizing mung bean productivity in the region.

The study highlights the significant role of mung bean cultivation in South Asia, particularly in Pakistan's Dera Ismail Khan District, emphasizing its nutritional value and nitrogen-fixing properties. It addresses the challenge of low yields at the farmer level due to a lack of knowledge about production techniques, focusing on the crucial role of irrigation in influencing yield. Research trials assessing irrigation regimes aim to provide valuable insights for optimizing mung bean production in the region and similar agricultural areas.

Table 1: *Agro-meteorological data recorded for the months of March-July 2015 and March-July 2016 at Arid Zone Research Center, PARC, D.I. Khan.*

Month/Year		Temperature °C		Humidity %		Screen pan evaporation (mm/day)	Wind speed (km/day)	Rainfall (mm)
		Max	Min	0800 hours	1400 hours			
March 2015	Average	38	-	75	56	3.90	3.88	Total 95
	Maximum	32	-	76	68	3.30	2.34	
April 2015	Average	38	-	75	56	3.90	3.88	Total 00
	Maximum	-	06	36	26	2.35	1.70	
May 2015	Average	41	12	39	27	6.00	4.50	Total 17
	Maximum	45	-	57	36	7.50	16.58	
June 2015	Average	42	22	48	33	6.30	3.43	Total 06
	Maximum	45	-	62	50	7.50	7.13	
July 2015	Average	40	24	49	32	3.88	3.27	Total 126
	Maximum	45	-	73	42	6.40	5.08	
March 2016	Average	39	-	75	56	3.95	3.90	Total 75
	Maximum	32	-	76	68	3.32	2.35	
April 2016	Average	38	-	75	56	3.90	3.88	Total 00
	Maximum	-	06	36	26	2.35	1.70	
May 2016	Average	41	12	39	27	6.00	4.50	Total 20
	Maximum	45	-	57	36	7.50	16.58	
June 2016	Average	42	22	48	33	6.30	3.43	Total 07
	Maximum	45	-	62	50	7.50	7.13	
July 2016	Average	40	24	49	32	3.88	3.27	Total 112
	Maximum	45	-	73	42	6.40	5.08	

Material and Methods

Description of the study site

This study was conducted at the Arid Zone Research Centre (AZRC), Dera Ismail Khan, in 2015 and 2016 to investigate the optimal irrigation dosage for controlling water supply to the mung bean crop under rainout shelter conditions. The research also aimed to assess the impacts of various irrigation levels in the region. The area experiences a climate ranging from arid to semi-arid, with an annual precipitation of approximately 300mm. The monsoon season accounts for about 70% of the total precipitation, whereas the average wheat season receives less than 100mm of rainfall. The agro-meteorological data for the experimental site is given in Table 1.

Before the experiment, soil samples were randomly collected from the experimental site. Each sample was taken to a depth of 105cm, with a constant 15cm increment in depth. Consolidated samples were prepared by combining individual soil samples with the same depth. To determine the field capacity and permanent wilting point of each soil layer, a pressure plate apparatus was employed. This apparatus applies various pressures to the soil samples to mimic the soil moisture conditions at which plants can easily extract water (field capacity) and the point at which plants can no longer draw water from the soil (permanent wilting point). The pressures used for these measurements were 33 kPa for field capacity and 1500 kPa for permanent wilting point. The composition of soil particles, namely sand, silt, and clay, was determined through the Bouyoucos hydrometer technique, which involves dispersing soil particles in water and using a hydrometer to measure their settling velocity. This allows the determination of the proportions of different soil particle sizes. Standard procedures were employed to assess soil chemical properties, including analyses for soil pH, organic matter content, nutrient levels (such as nitrogen, phosphorus, and potassium), cat-ion exchange capacity, and other relevant chemical parameters. The specific methods used varied based on the desired information and the laboratory's standard protocols. Soil chemical and physical properties are described in Tables 2 and 3, respectively.

The study was conducted as a two-factor factorial design, involving two bed types (Raised Bed and Flat beds) and four different irrigation schedules: treatment one (T_1) with three days irrigation intervals, treatment two (T_2) with six days irrigation interval, treatment three (T_3) with nine days irrigation interval, and treatment four (T_4) with zero irrigation. The experiment consisted of four replicates, and each plot measured 4 X 4 m. Soil moisture content was determined by collecting soil samples at two depths: 0-15 cm and 15-30 cm. Throughout the study, samples were gathered at three-day intervals.

Table 2: *Chemical properties of soil.*

S/No.	Parameter	Depth (0-15cm)		Depth (15-30cm)	
1	Soil pH	7.6	7.2	7.5	7.4
2	Available P	7.1 ppm	8.3 ppm	6.2 ppm	6.6ppm
3	Available K	120ppm	128ppm	120ppm	122ppm
4	Soil OM	1.6%	1.8%	1.15%	1.12%
5	Nitrogen	0.04%	0.03%	0.02%	0.02%

Table 3: *Physical properties of soil.*

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	[1]FC (cm^3/cm^3)	[2]PWP (cm^3/cm^3)	Bulk density (g/cm^3)
15	56	24	19	0.232	0.114	1.51
30	67	18	15	0.206	0.109	1.55
45	72	15	13	0.191	0.099	1.55
60	68	18	15	0.206	0.109	1.55
75	68	15	18	0.214	0.120	1.56
90	68	20	13	0.199	0.099	1.52
105	70	15	15	0.203	0.109	1.56

[1]Field capacity, [2]Permanent wilting point.

Numerous growth and nodulation parameters were measured, including leaf area; shoot dry weight, root dry weight, and effective nodulation. Additionally, yield-related measurements were taken, such as days to flowering, number of pods per plant, number of seeds per pod, 100 seeds weight, and overall yield. The data was analyzed using an F-test through analysis of variance (ANOVA) to assess the effects of bed type and irrigation schedule on the measured parameters. Post hoc Tukey's test was conducted at a significance level of 5% to compare the means of the different treatments.

Results and Discussion

Effect of irrigation regimes and land preparation on plant growth

The results indicate that the correlation between the planting technique and the frequency of irrigation did not have a significant impact on these growth

Table 4: *Leaf and shoot growth of mung bean as affected by planting method and irrigation frequency.*

Bed type	Irrigation schedules	Leaf area at flowering stage (cm²)	Leaf area at harvesting stage (cm²)	Shoot dry wt. at flowering stage (g)	Shoot dry wt. at harvesting stage (g)
Raised bed	T_1	406.87	259.25	3.14	4.01
	T_2	392.12	263.50	2.75	3.41
	T_3	390.62	313.50	2.99	3.74
	T_4	355.00	230.25	1.82	2.35
Flat bed	T_1	373.62	249.75	2.55	2.57
	T_2	311.37	278.25	2.12	2.44
	T_3	277.50	216.25	1.84	2.35
	T_4	329.12	196.50	1.92	2.11

Table 5: *Root growth of mung bean as affected by planting method and irrigation frequency.*

Bed type	Irrigation schedules	Root length at flowering stage (cm)	Root length at harvesting stage (cm)	Root dry wt. at flowering stage (g)	Root dry wt. at harvesting stage (g)
Raised bed	T_1	72.58	43.80	0.48	0.49
	T_2	45.47	52.64	0.40	0.43
	T_3	50.38	41.44	0.49	0.54
	T_4	38.79	48.32	0.21	0.28
Flat bed	T_1	50.38	29.66	0.42	0.35
	T_2	35.94	52.64	0.27	0.35
	T_3	45.96	24.35	0.31	0.38
	T_4	32.80	38.45	0.22	0.28

parameters (Table 4). Among the plants grown on raised beds, those irrigated with an occurrence of intervals every three days (T_1) showed the highest leaf area and shoot dry weights. This implies that the combination of raised beds and an irrigation frequency of three-day intervals provided optimal conditions for shoot growth in mung bean plants in the distinct agro-ecological characteristics of Dera Ismail Khan.

Effect of irrigation regimes and land preparation on root growth

The interaction between planting method (raised beds vs. flat bed) and irrigation frequency (Table 5) did not have a significant impact on the growth and formation of roots and nodules in mung bean. This suggests that the type of land preparation did not affect the growth of mung bean roots, but the irrigation schedules did have a similar influence on root growth.

At the flowering stage, there were significant differences in root length and root dry weight between the different planting methods and irrigation frequencies. Nevertheless, during the harvest stage, these parameters remained unaffected. This suggests that the variations in root growth due to planting method and irrigation frequency diminished as the plants approached maturity.

Furthermore, the study found that the raised beds exhibited the most significant root growth in comparison to the flat beds. This indicates that raised beds have an advantage, particularly in dry seasons, as they help conserve moisture and provide a better growing environment for mung beans

Effect of irrigation regimes and land preparation on nodulation

Table 6 indicates that the interaction between irrigation regimes (frequency and schedule of irrigation) and bed types (raised beds) had a significant effect on the flowering stage of mung bean plants. However, no significant difference was observed during the harvesting stage. One possible explanation for this lack of difference could be the insufficient substrate available for nodules to develop properly.

Additionally, the formation of nodules in mung bean plants was impacted by both the irrigation frequency and the bed type. Specifically, mung bean plants grown in raised beds with a three-day irrigation schedule showed a higher number of nodules. This indicates that the frequency of irrigation plays a significant role in the nodulation process of mung bean plants.

Table 6: *Nodulation of mung bean as affected by planting method and irrigation frequency.*

Bed type	Irrigation schedules	Root length at flowering stage (cm)
Raised bed	T_1	68.50
	T_2	17.12
	T_3	9.12
	T_4	8.12
Flat bed	T_1	24.75
	T_2	8.50
	T_3	15.5
	T_4	9.75

Table 7: *Means of yield parameters as affected by irrigation frequency.*

Irrigation schedules	Number of pods per plant	Number of seeds per pod	100 seeds weight (g)	Yield per pod (g)
T_1	7.75a	9.62a	6.24a	308.98ab
T_2	7.87a	10.00a	6.55ab	424.42a
T_3	7.37a	10.12a	6.51bc	315.75ab
T_4	6.62a	9.37a	6.23c	267.46b

Means in a column followed by the same letter are not significantly different at p=0.05

Effect of irrigation regimes and land preparation on yield

The findings of the study (Table 7) indicate that different irrigation regimes had a significant impact on two important parameters: 100 seeds weight and seed yield. It suggests that the amount and timing of irrigation directly affected the growth and productivity of mung bean crops.

The research emphasizes the significance of soil moisture in the growth and pod filling of mung beans. Soil moisture represents the quantity of water in the soil, which is vital for plant growth and nutrient absorption. Insufficient or excessive soil moisture can negatively impact crop development and yield.

Based on the results, the study recommends an irrigation frequency of six days intervals as the optimal regime for mung bean cultivation on raised beds in the arid climate of D.I. Khan. This means that the crops should be irrigated every six days, providing a sufficient amount of water to maintain adequate soil moisture levels.

By implementing this irrigation regime, farmers in the arid climate of D.I. Khan can potentially maximize the growth and yield of mung bean crops. Adequate soil moisture levels will support optimal crop development, ensuring healthy pod filling and ultimately increasing the seed yield

Conclusions and Recommendations

The study conducted at AZRC D.I. Khan, Pakistan comparing raised beds and flat bed systems of land preparation for mung bean cultivation. The investigation revealed that mung bean's growth, nodulation, and yield were more pronounced in raised beds. This suggests that raised beds provide a favorable growing environment for mung bean plants, leading to better overall performance.

Furthermore, the research also investigated the impact of irrigation schedules on the growth and yield of mung beans. The results showed that the six-day irrigation schedule resulted in significantly higher growth and nodulation parameters compared to other schedules. This indicates that providing water at regular intervals of three days promotes better growth and nodulation in mung bean plants.

Interestingly, although the three-day irrigation schedule resulted in superior growth and nodulation, the maximum yield of mung bean was obtained with a six-day irrigation schedule. This suggests that a slightly longer interval between irrigation events allows for optimal resource utilization and yield production in mung bean crops.

For optimal mung bean cultivation, end users are recommended to adopt raised beds over flat bed systems, as the study at AZRC D.I. Khan, Pakistan, indicates their significant positive impact on growth, nodulation, and yield. Additionally, implementing a six-day irrigation schedule is advised to promote higher growth and nodulation parameters, emphasizing the importance of regular watering. Although a three-day interval showed superior growth and nodulation, the study suggests that the maximum yield is obtained with a slightly longer, six-day irrigation schedule. Therefore, end users should consider this interval to optimize resource utilization and enhance overall mung bean yields.

Novelty Statement

As far as the authors are aware, there is no similar research work carried out related, "Impact of Different Irrigation Regimes on Growth, Yield and Nodulation of Mung Bean".

Author's Contribution

Shahid Hameed Khalil: Writing - review and editing.
Muhammad Arshad Khan: Conceptualization, writing - original draft, Writing - review and editing.
Muhammad Mansoor: Supervision.
Muhammad Shahzad Khattak: Methodology.
Ghani Akbar: Data curation.
Rana Naveed Mustafa: Formal analysis.
Salah ud Din: Software.

Conflict of interest

The authors have declared no conflict of interest.

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