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Enhancing water use efficiency and yield of chickpea (*Cicer arietinum* L.) through optimal irrigation frequencies and sustainable mulching practices

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Abstract
Chickpea (*Cicer arietinum* L.) stands as a crucial rabi pulse crop within India, playing a significant role in bolstering food security and meeting nutritional requirements. Nevertheless, the challenge of water scarcity during critical growth phases poses a notable obstacle to chickpea cultivation, especially in rainfed regions. To tackle this concern, we executed a field study during the rabi season to explore the influence of varying irrigation frequencies and mulching methods on the growth and yield aspects of chickpea.

The research involved eight distinct treatment combinations, encompassing two irrigation frequencies: a single instance of irrigation during the pre-sowing and flowering stage, and a double irrigation approach covering pre-sowing, flowering, and pod-filling stages. These irrigation strategies were coupled with four different mulching techniques: absence of mulch, utilization of black poly mulch, deployment of non-woven mulch, and application of biodegradable mulch.

The results of our investigation underscore that the employment of biodegradable mulch in conjunction with a single irrigation event produced the most favorable outcomes. This specific treatment exhibited superior characteristics such as maximum plant height, primary branches per plant, pod count per plant, seed weight per pod, and yield per hectare. Moreover, this treatment approach demonstrated the highest levels of water use efficiency.

This study accentuates the importance of embracing sustainable irrigation practices that conserve water, along with implementing effective mulching methods. By doing so, chickpea production can be optimized, water use efficiency enhanced, and the overarching goal of ensuring food security can be upheld.

Keywords: Chickpea, biodegradable mulch, irrigation, production, water use efficiency

1. Introduction
Chickpea (*Cicer arietinum* L.) stands as a pivotal rabi pulse crop in India, serving a crucial role in fulfilling the protein needs of the population's diet. Nonetheless, the cultivation of pulses, chickpea included, confronts difficulties in rainfed regions due to water scarcity during critical growth stages like flowering and pod filling. In response, sustainable water-conservation technologies, encompassing pressurized irrigation approaches and mulching techniques, have emerged as potential remedies to enhance water utilization in agriculture and elevate crop productivity. The present study is dedicated to investigating the repercussions of varied irrigation frequencies and diverse mulching methods on the growth and yield variables of chickpea. This endeavor offers valuable insights into facilitating sustainable chickpea cultivation practices.

2. Materials and Methods
2.1 Research Location
The field trial took place at the technology park situated within the premises of MPUAT Udaipur, Rajasthan. The investigation spanned the rabi season from November 2019 to March 2020. The geographical coordinates of the site are 24° 35' N latitude and 73° 44' E longitude, with an elevation of 582.17 meters above sea level. This region experiences a sub-humid climate, receiving an annual average rainfall of 662.5 mm, primarily concentrated during the south-west monsoon period from June 16th to September 15th**.**

2.2 Experimental Setup
A factorial randomized block design (FRBD) was employed for the experiment, with each

treatment replicated three times. The individual plot dimension was 15×1 square meters, and the spacing between plants was maintained at 30 cm×10 cm. The investigation encompassed eight distinct treatment combinations:

I_1: Single irrigation during pre-sowing + flowering stage
I_2: Double irrigation covering pre-sowing + flowering stage + pod filling stage
M_0: Absence of mulch (NM)
M_1: Application of black poly mulch (BPM)
M_2: Implementation of non-woven mulch (NWM)
M_3: Utilization of biodegradable mulch (BDM)

2.3 Data Gathering

Throughout the growth period, parameters related to growth were recorded, including plant height, number of primary branches per plant, and the time taken for 50% flowering. Upon harvest, parameters related to yield, such as the count of pods per plant, average pod weight, number of seeds per pod, and yield per hectare, were measured. In assessing the impact of mulching and irrigation frequencies on chickpea's growth and yield attributes, ANOVA was conducted with a significance level set at 5%.

3. Results and Discussion

The research delved into the influence of irrigation frequencies and mulching on the growth and yield characteristics of chickpeas. Table 1 encompassed a comprehensive summary of the consequences of diverse mulching techniques and irrigation frequencies on various parameters tied to growth and yield. Furthermore, Figures 1 through 5 visually depicted how the interplay between mulching and irrigation frequencies impacted these attributes.

The study brought to light the water demands of chickpea crops. It was found that pre-sowing irrigation alone required 70 mm of water, while a solitary irrigation event during pre-sowing and flowering necessitated 145 mm. In contrast, the double irrigation strategy spanning pre-sowing, flowering, and pod filling stages mandated 218 mm of water.

Upon harvest, the most favorable results were observed with treatment T_7, which entailed the combination of M_3 (biodegradable mulch) and irrigation frequencies I_1 (pre-sowing + flowering stage). This approach yielded the highest plant height (73.27 cm), the most primary branches per plant (30.20), the greatest pod count per plant (138.13), the heaviest seed weight per pod (0.232 gm), and the highest yield per hectare (26.49 q).

Conversely, the lowest values for growth and yield attributes were noted with treatment T_1, encompassing the combination of M_0 (no mulch) and irrigation frequencies I_1 (pre-sowing + flowering stage).

These findings aligned with prior research, as observed in the work of Awal *et al*. (2016) [1]. Mulching techniques involving PPWM and BPM demonstrated superiority over the absence of mulch, leading to increased plant height and a greater number of primary branches per plant.

In conclusion, the research underscored the importance of appropriate irrigation and mulching practices in optimizing chickpea growth and yield characteristics. The combination of M*3* (Biodegradable mulch) and irrigation frequencies I_1 (pre-sowing + flowering stage) emerged as the most efficacious approach for achieving maximum crop productivity. This study provides valuable insights to the agricultural community, offering guidance to farmers for informed decisions aimed at enhancing chickpea production.

Table 1: Effect of mulching, irrigation frequencies and their interaction on growth and yield attributes of chickpea

	Yield parameters			
Treatments	**No. of pods/plant**	**Average weight of pod (gm)**	**No. of seeds/pod**	**Seed weight/pod (gm)**
Mulch (M)				
M_0 (NM)	80.83	0.41	1.44	0.158
M_1 (BPM)	99.05	0.46	1.61	0.189
M_2 (NWM)	112.55	0.46	1.70	0.195
M_3 (BDM)	120.87	0.48	1.80	0.223
S.Em±	3.431	0.006	0.011	0.002
C.D.5%	10.407	0.018	0.033	0.006
Irrigation (I)				
I_1	112.78	0.47	1.66	0.194
I_2	93.87	0.44	1.62	0.189
S.Em±	2.426	0.004	0.008	0.001
C.D.5%	7.359	0.013	0.023	0.004
Interaction (M×I)				
M_0I_1 (T_1)	75.80	0.41	1.43	0.151
M_0I_2 (T_2)	85.87	0.41	1.46	0.165
M_1I_1(T_3)	111.20	0.48	1.65	0.191
M_1I_2 (T_4)	86.90	0.43	1.58	0.186
M_2I_1 (T_5)	126.00	0.47	1.73	0.201
M_2I_2 (T_6)	99.10	0.46	1.68	0.189
M_3I_1 (T_7)	138.13	0.50	1.84	0.232
M_3I_2 (T_8)	103.60	0.45	1.77	0.214
S.Em±	4.852	0.009	0.015	0.003
C.D.5%	14.717	0.026	0.046	0.008

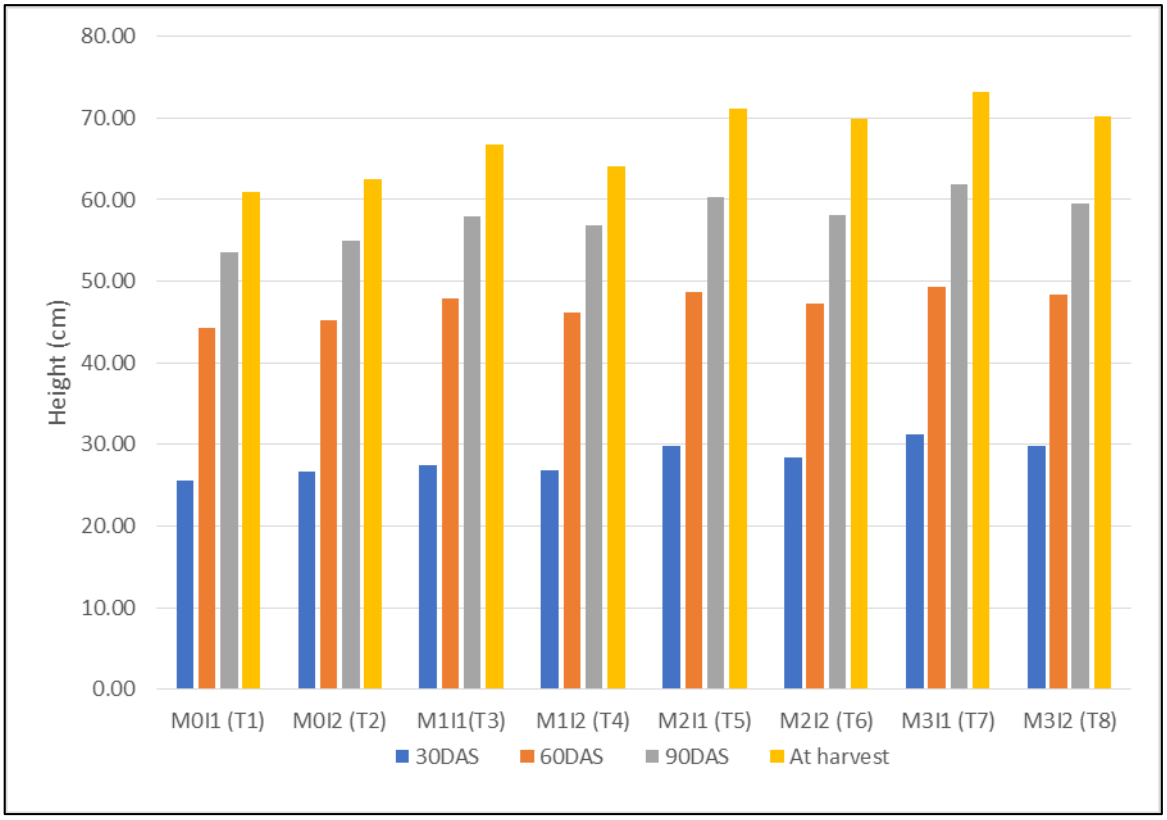

Fig 1: Interaction effect of mulching and irrigation frequencies on plant height

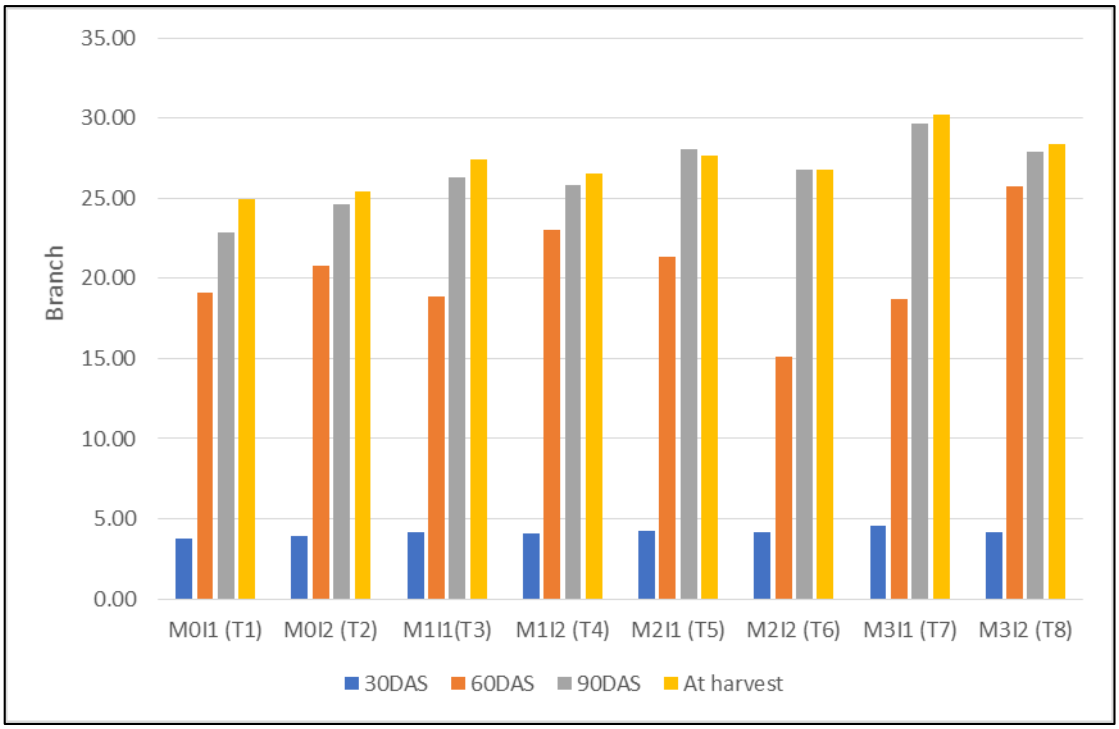

Fig 2: Interaction effect of mulching and irrigation frequencies number of Primary branches per plant

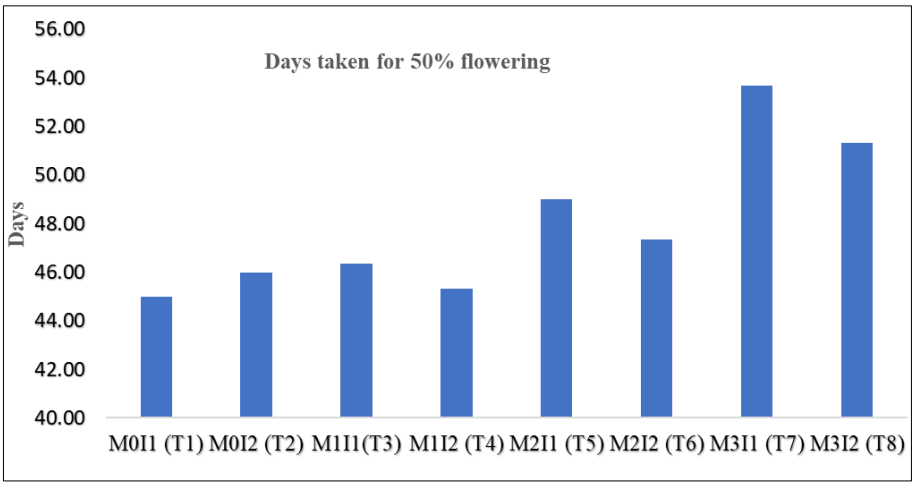

Fig 3: Interaction effect of mulching and irrigation frequencies on days taken for 50% flowering

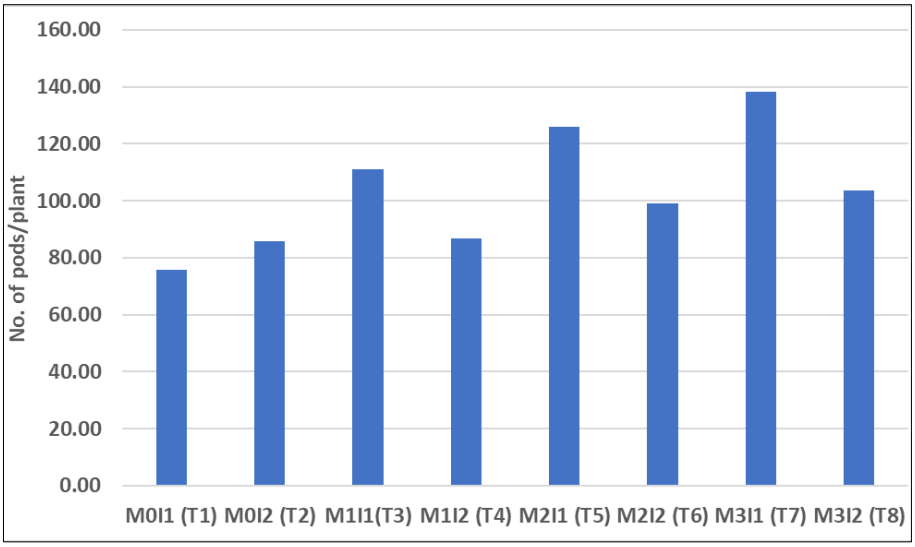

Fig 4: Interaction effect of mulching and irrigation frequencies on number of pods per plant

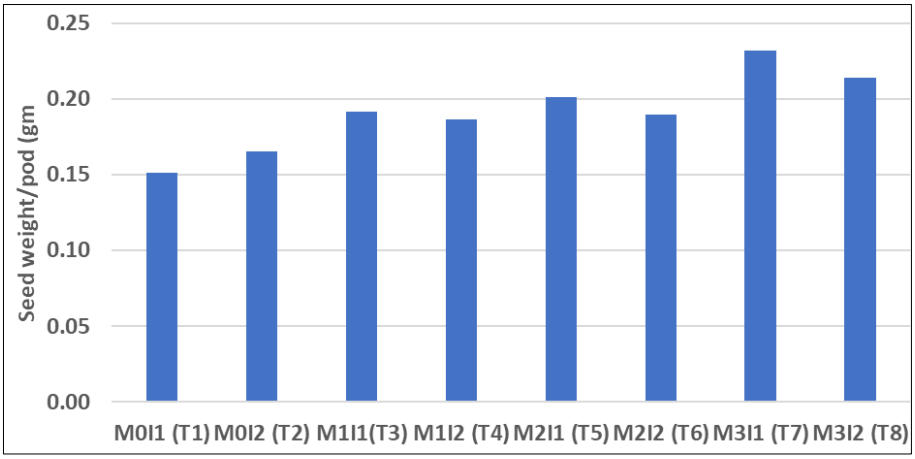

Fig 5: Interaction effect of mulching and irrigation frequencies on seed weight per pod (gm)

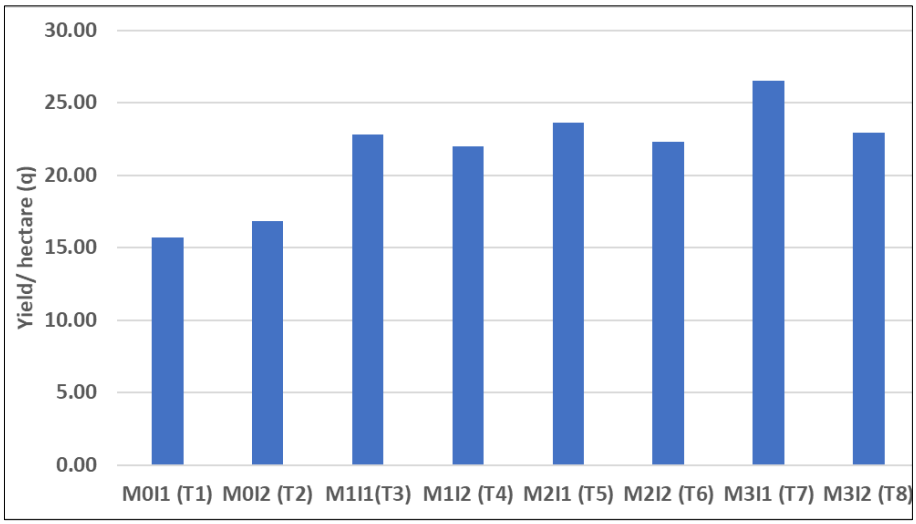

Fig 6: Interaction effect of mulching and irrigation frequencies on yield per hectare

The study's outcomes highlighted that the application of a single irrigation treatment yielded notably greater plant height and a higher count of primary branches per plant when compared to the double irrigation regimen. These results are in line with the prior investigation conducted by Krishnamurthy and Steeramula in 2007 [3], wherein it was also noted that the peak grain yield was attained when crops were irrigated during the flowering and pod formation stages.

Furthermore, Birbal *et al*. 2013 [2] findings showcased an intriguing interplay between drip irrigation and mulching, leading to augmented growth and yield attributes. Notably, the treatment combination of M_3 (biodegradable mulch) and irrigation frequencies I_1 (pre-sowing + flowering stage), identified as treatment T_7, as well as NWM and BPM, displayed superior performance compared to the M_0 (no mulch) + I_1 (pre-sowing + flowering stage) combination, denoted as treatment T_1.

In the present study, an evaluation of growth and yield attributes favored the treatment blend of M_3 (biodegradable mulch) and irrigation frequencies I_1 (pre-sowing + flowering stage). The recorded values for distinct attributes were as follows: plant height attained 73.27 cm, the count of primary branches per plant reached 30.20, the pod count per plant was 138.13, the seed weight per pod measured 0.232 grams, and the yield per hectare amounted to 26.49 quintals.

In conclusion, these findings underscore the substantial enhancement in crop growth and yield when employing drip irrigation in conjunction with mulching, especially at the pre-sowing + flowering stage (T_7). This insight offers valuable guidance for optimizing irrigation methodologies and enhancing agricultural productivity.

Conclusion

The study offered valuable insights into the water requirements and growth as well as yield characteristics of chickpea across various treatment combinations. Notably, the research unveiled the fluctuating net water demand contingent upon irrigation frequency. For pre-sowing exclusively, the chickpea crop necessitated 70 mm of water, whereas a solitary irrigation event encompassing pre-sowing and flowering stages demanded 145 mm. The peak water requirement was evidenced in the treatment amalgamation involving dual irrigation during pre-sowing, flowering, and pod-filling stages, summing up to 218 mm.

Furthermore, the investigation pinpointed specific treatment synergies that yielded favorable growth and yield attributes. Particularly, treatment T_7, involving the combination of M_3 (biodegradable mulch) + I_1 (pre-sowing and at flowering stage), exhibited notable outcomes. It showcased elevated values across various parameters including maximum plant height, primary branch count, duration for 50% flowering, pod count per plant, average pod weight, seeds per pod, seed weight per pod, and yield per hectare at harvest.

Beyond the spectrum of growth and yield attributes, the study extended its purview to encompass water use efficiency, a pivotal facet in sustainable agriculture. Treatment T_7, featuring the pairing of BDM (biodegradable mulch) with a single irrigation event, demonstrated the highest water use efficiency at 1.827 q/ha-cm. This underscored that this particular treatment achieved amplified yield output with a judicious consumption of water. Conversely, treatment T_1, which involved NM (no mulch) with double irrigation, exhibited the lowest water use efficiency at 0.771 q/ha-cm, implying that despite heightened water inputs, the yield attained was comparatively diminished.

Collectively, these findings underscore the imperative of meticulously selecting appropriate treatment blends to optimize water allocation and realize superior growth and yield attributes during chickpea cultivation. This research equips farmers with insights to make educated choices regarding irrigation practices, ultimately culminating in amplified crop productivity and prudent water conservation.

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