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Influence of drip irrigation scheduling and nutrient management on growth and yield of summer black gram (*Vigna mungo* L. Hepper)

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Abstract

A field experiment was conducted during the summer of 2025 at the Regional Research Station, Anand Agricultural University, Anand, to evaluate the influence of drip irrigation scheduling and nutrient management on the growth and yield of summer black gram (*Vigna mungo* L. Hepper). The experiment was laid out in a split-plot design with three replications, comprising twelve treatment combinations involving four irrigation schedules (drip irrigation at 0.50, 0.75, and 1.00 Pan Evaporation Fraction, and flood irrigation) assigned to the main plots and three nutrient management practices (100% RDF, 75% RDF + PSB + *Rhizobium*, and 75% RDF + VAM + *Rhizobium*) assigned to the sub-plots. The results revealed that among the irrigation scheduling treatments, drip irrigation at 1.00 PEF (I3) recorded significantly higher growth, yield attributes and yield, including plant height at 60 DAS and at harvest (42.95 and 51.41 cm, respectively), number of branches per plant (6.73), dry weight of root nodules at 40 DAS (42.53 mg/plant), number of pods per plant (33.23), number of seeds per pod (6.93), seed yield (1194 kg/ha), and stover yield (2756 kg/ha), though it remained statistically at par with 0.75 PEF (I2) for most of these parameters. However, water use efficiency was significantly higher under drip irrigation at 0.75 PEF (I2) and was statistically at par with drip irrigation at 0.50 PEF (I1). Regarding nutrient management, 100% RDF (N1) recorded the higher number of pods per plant (32.40), number of seeds per pod (6.50), seed yield (1028 kg/ha) and stover yield (2400 kg/ha), but remained statistically at par with 75% RDF + PSB + *Rhizobium* (N2). However, significantly higher dry weight of root nodule (41.75 mg/plant) was recorded by 75% RDF + PSB + *Rhizobium* (N2) and it was statistically at par with N3 (75% RDF + VAM + *Rhizobium*). The interaction effect of drip irrigation at 0.75 PEF combined with 75% RDF + PSB + *Rhizobium* (I2N2) recorded higher number of pods per plant (34.60), number of seeds per pod (7.20), seed yield (1316 kg/ha), stover yield (3192 kg/ha) and water use efficiency (7.03 kg/ha-mm). Based on the results of the present investigation, drip irrigation scheduled at 0.75 PEF along with 75% RDF supplemented with PSB and *Rhizobium* was found to be the most suitable for achieving higher growth, yield attributes, yield and water use efficiency in summer black gram.

Keywords: Irrigation scheduling, nutrient management, yield, black gram

Introduction

Pulses play a crucial role in sustainable agriculture due to their natural ability to fix atmospheric nitrogen, thereby improving soil fertility and health. They also contribute to reducing greenhouse gas emissions and promoting environmentally sustainable farming systems. Among pulse crops, black gram is of particular importance because of its high nutritional value. It is an excellent source of dietary protein and fibre and forms an integral part of nutritious diets in many regions of the world (FAO, 2016) [8]. Pulses generally contain 17- 25% protein, substantially higher than cereals (6-10%), and are rich in fibre, potassium, magnesium, zinc, iron, and other essential nutrients (Mudryj *et al.*, 2014) [20]. Regular consumption of pulses is associated with reduced risks of obesity, diabetes, cardiovascular diseases, and certain cancers. Black gram is recognized as one of the most important pulse crops (Gade *et al.*, 2022) [10].

Black gram [*Vigna mungo* (L.) Hepper], commonly known as urdbean, belongs to the family *Fabaceae* (Singh *et al.*, 2017) [29]. Originating in South Asia, it contains 25-30% protein and is widely cultivated due to its adaptability to diverse soil types and moderate drought tolerance (Gopalan *et al.*, 2012; Reddy, 2016) [11, 26]. India is the largest producer and consumer of black gram, contributing nearly 70% of global production (ANGRAU Black gram outlook report - June

to May 2023-24) ^[3]. During 2022, India produced 2.78 million tonnes from 4.63 million hectares, with a productivity of 600 kg/ha (Agricultural Statistics Division, DES, MoAF & W, 2022) ^[2].

Irrigation is a critical factor influencing black gram growth, yield, and quality, particularly during flowering and pod-filling stages. Drip irrigation offers an efficient means of water application by delivering water directly to the root zone, reducing evaporation losses and improving water use efficiency. In addition, balanced nutrient management is essential for achieving higher productivity. Integrated nutrient management (INM), which combines organic, inorganic, and biological nutrient sources, helps maintain soil fertility, improve crop performance, reduce environmental impacts, and enhance economic returns (Agegnehu *et al.*, 2016) ^[1]. Furthermore, blanket fertilizer recommendations often fail to address field-specific nutrient requirements, resulting in inefficient nutrient utilization (Singh *et al.*, 2018) ^[30]. Sustainable agricultural practices such as drip irrigation and efficient nutrient management contribute to resource conservation, improved productivity, and higher profitability (FAO, 2017; Pretty *et al.*, 2018) ^[9,23]. In view of these considerations, the present study entitled “Influence of drip irrigation scheduling and nutrient management on growth and yield of summer black gram (*Vigna mungo* L. Hepper)” was undertaken.

Materials and Methods

A field experiment entitled “Influence of drip irrigation scheduling and nutrient management on growth and yield of summer black gram (*Vigna mungo* L. Hepper)” was carried out during the summer season of 2025 at the Regional Research Station, Anand Agricultural University, Anand, Gujarat, India. Geographically, Anand lies at 22°35' N latitude and 72°55' E longitude and is situated at an elevation of 45.1 m above mean sea level. The experimental site was characterized by a loamy sand texture and alluvial soil, which was very deep, possessed high moisture-holding capacity, and responded well to both fertilization and irrigation. The soil of the experimental site was low in organic carbon (0.32%) and available nitrogen (221.15 kg/ha), but medium in available phosphorus (35.83 kg/ha) and potassium g/ha).

The experiment was conducted in a split-plot design with twelve treatment combinations replicated thrice. Four irrigation schedules (drip irrigation at 0.50, 0.75, and 1.00 PEF, and flood irrigation) were allotted to the main plots, whereas three nutrient management practices (100% RDF, 75% RDF + PSB + *Rhizobium*, and 75% RDF + VAM + *Rhizobium*) were allotted to the sub-plots. The black gram variety GAU-4 (Shyamal) was sown on 12 February 2025 at a seed rate of 20 kg/ha with a spacing of 30 cm × 10 cm. In drip irrigation treatments, irrigation was scheduled on alternate days as per the respective pan evaporation fraction (PEF) levels, whereas in flood irrigation treatment, irrigation was applied at 50 mm depth at an interval of 10 days. An inline drip irrigation system was used for the drip irrigation scheduling treatments, with a lateral spacing of 60 cm, an emitter spacing of 50 cm, and an emitter discharge rate of 4 lph. The recommended dose of fertilizers (RDF) was applied as a basal dose before sowing, while the biofertilizers were applied as seed treatments 24 hours before sowing, and the treated seeds were shade-dried before sowing.

Observations on growth and yield parameters were recorded from five randomly selected and tagged plants in each net plot. The growth parameters recorded included plant population at 30 DAS,

plant height at 30, 60 DAS, and at harvest, number of branches per plant at harvest, dry weight of root nodules at 40 DAS and days to 50% flowering. The yield attributes recorded were the number of pods per plant, number of seeds per pod, test weight, and harvest index, along with seed yield and stover yield.

Results and Discussion

Growth Parameters

The irrigation schedules did not significantly affect plant population at 30 DAS, plant height at 30 DAS and days to 50% flowering. However, 1.00 PEF (I₃) recorded significantly higher plant height at 60 DAS and at harvest (42.95 and 51.41 cm, respectively), number of branches per plant at harvest (6.73), dry weight of root nodules (42.53 mg/plant) and remained statistically at par with 0.75 PEF (Table 1). This might be due to the fact that adequate moisture provided through 1.00 PEF and 0.75 PEF resulted in improved soil moisture availability in the root zone, which maintained cell turgidity, enhanced nutrient uptake and promoted cell elongation, thereby resulting in better vegetative growth. The results were in accordance with that of Hussien *et al.* (2019) ^[13], Fanish and Pannerselvam (2023) ^[7], and Priya *et al.* (2025) ^[24].

The different nutrient management practices did not significantly influence plant population at 30 DAS, plant height at 30, 60 DAS, and at harvest, number of branches per plant at harvest and days to 50% flowering. However, significantly higher dry weight of root nodules at 40 DAS (41.75 mg/plant) was recorded by 75% RDF + PSB + *Rhizobium* (N₂) and it was statistically at par with 75% RDF + VAM + *Rhizobium* (N₃) (Table 1). The significant impact of nutrient management on nodule dry weight may be due to the synergistic effect of chemical fertilizers and biofertilizers on plant-microbial interactions. Whereas, the non-significant effect of nutrient management on growth parameters may be attributed to adequate soil fertility and the compensatory role of biofertilizers, which ensured sufficient nutrient availability across treatments, resulting in comparable plant growth. The results were in close conformity with that of Divyavani *et al.* (2020) ^[6], Meera *et al.* (2022) ^[18] and Gupta *et al.* (2025) ^[12]. The interaction effect of irrigation scheduling and nutrient management on all the growth parameters was found to be non-significant (Table 1).

Yield Attributes and Yield

The yield attributes, viz., number of pods per plant and number of seeds per pod, were significantly influenced by the irrigation schedules (Table 2). However, the effect of irrigation schedules on test weight and harvest index was found to be non-significant. Irrigation scheduled at 1.00 PEF (I₃) recorded significantly higher number of pods per plant (33.23) and number of seeds per pod (6.93). However, I₃ was statistically at par with 0.75 PEF (I₂) and flood irrigation (I₄) for number of pods per plant, while for number of seeds per pod it remained at par only with 0.75 PEF (I₂). The significant influence of irrigation scheduling on the yield attributes can be attributed to differences in moisture availability affecting plant growth and reproductive development. Sufficient moisture under 1.00 PEF (I₃) likely promoted better flowering and pod setting, while limited moisture under 0.50 PEF (I₁) may have caused stress, leading to reduced pod formation. The results were also supported by the findings of Ayyadurai *et al.* (2017) ^[4], Vishnu *et al.* (2021) ^[33], and Marimuthu *et al.* (2024) ^[15].

Various nutrient management practices significantly influenced the number of pods per plant and number of seeds per pod. However, their effect on test weight and harvest index was found to be non-significant (Table 2). Significantly higher number of pods per plant and seeds per pod (32.40 and 6.93, respectively)

was reported under 100% RDF (N₁) and it was found to be statistically at par with 75% RDF + PSB + *Rhizobium* (N₂). The significant influence of nutrient management on the number of pods per plant and seeds per pod may be attributed to variations in nutrient availability and their uptake. Sufficient nutrient supply under 100% RDF (N₁) promoted better flowering and pod development, whereas reduced availability under N₃ led to fewer pods. The similar performance of N₂ could be due to enhanced nutrient availability through the action of biofertilizers. The results were in accordance with that of Meena *et al.* (2021) [17], Reddy and Kumar (2023) [25] and Yuganthra *et al.* (2023) [34].

The interaction effect of irrigation scheduling and nutrient management on number of pods per plant and number of seeds per pod was found to be significant (Table 3). Significantly higher number of pods per plant (34.60) was observed under the treatment combination I₂N₂ which was found to be statistically comparable with I₃N₁, I₃N₂, I₃N₃ and I₂N₁. Significantly lower number of pods per plant (26.08) was obtained under treatment combination I₁N₃ and it was at par with I₁N₂. Significantly higher number of seeds per pod (7.20) was reported under the treatment combination I₂N₂ which was found to be statistically comparable with I₃N₁, I₃N₂ and I₃N₃. The higher number of pods per plant and seeds per pod under I₂N₂ could be due to adequate irrigation along with balanced nutrient supply, which promoted better nutrient uptake and efficient pod and seed formation. The findings are in agreement with those of Mondal *et al.* (2018) [19] and Patra *et al.* (2024) [21].

Seed and stover yields of black gram were significantly influenced by the different irrigation schedules (Table 2). The irrigation schedule 1.00 PEF (I₃) recorded significantly higher seed and stover yield (1194 and 2756 kg/ha, respectively), which remained statistically at par with 0.75 PEF (I₂). The significantly lower seed yield and stover yield (749 and 1623 kg/ha, respectively) were recorded under 0.50 PEF (I₁). This result was mainly due to the cumulative effect of growth and yield attributes such as number of branches per plant, number of pods per plant and number of seeds per pod. The differences in seed and stover yield among irrigation schedules might be due to variations in soil moisture levels, nutrient uptake, and plant physiological behaviour. It was also observed that adequate soil moisture under higher irrigation frequency through drip irrigation enhanced the availability of nutrients, particularly N, P and K, which may have facilitated their translocation and resulted in greater dry matter production. These results are in conformity with the results of Senthil Kumar *et al.* (2017) [27], Kaviti *et al.* (2018) [14], Vishnu *et al.* (2021) [33], Marimuthu *et al.* (2024) [15], and Sujatha *et al.* (2024) [32].

Different nutrient management practices significantly affected the seed and stover yields of black gram (Table 2). Higher seed yield and stover yield (1028 and 2400 kg/ha, respectively) were obtained under 100% RDF (N₁), which remained statistically at par with 75% RDF + PSB + *Rhizobium* (N₂). Lower seed yield and stover yield (923 and 2080 kg/ha, respectively) were recorded under 75% RDF + VAM + *Rhizobium* (N₃). The higher yield observed under 100% RDF (N₁) could be attributed to the readily

available and sufficient supply of essential nutrients, which promotes better growth and yield. Moreover, balanced fertilization under RDF may have promoted better root growth, increased chlorophyll content and enhanced photosynthetic activity, thereby improving dry matter accumulation and its allocation to pods. The similar performance of 75% RDF + PSB + *Rhizobium* (N₂) may be explained by the role of biofertilizers in nitrogen fixation and enhancing phosphorus availability, thereby making up for the reduced fertilizer dose. The results are consistent with those reported by Shekhawat *et al.* (2018) [28], Danga *et al.* (2022) [5], Meera *et al.* (2022) [18], and Yuganthra *et al.* (2023) [34].

The interaction between irrigation scheduling and nutrient management practices significantly influenced the seed and stover yields of black gram (Table 3). Higher seed yield and stover yield (1316 and 3192 kg/ha, respectively) were recorded under the treatment combination I₂N₂, which remained statistically at par with I₃N₁. Lower seed yield and stover yield (702 and 1361 kg/ha, respectively) were observed under I₁N₃, while the lower seed yield under I₁N₃ was statistically comparable with I₁N₁ and I₁N₂. The significantly higher seed and stover yield under the treatment combination I₂N₂ may be attributed to adequate moisture availability at I₂ (0.75 PEF) along with improved nitrogen fixation and phosphorus solubilization under N₂ (75% RDF + PSB + *Rhizobium*), which enhanced nutrient availability, uptake, and translocation, ultimately resulting in better pod development. The results were in close agreement with that of Sodavadiya *et al.* (2017) [31], Mondal *et al.* (2018) [19], Maurya *et al.* (2019) [16] and Patra *et al.* (2024) [21].

Water Use Efficiency (WUE)

Water use efficiency was significantly influenced by different irrigation schedules (Table 2). Significantly higher water use efficiency (6.04 kg/ha-mm) was recorded under 0.75 PEF (I₂), which was found to be statistically at par with 0.50 PEF (I₁). Significantly lower water use efficiency (2.05 kg/ha-mm) was obtained under flood irrigation (I₄). These results were also supported by the findings of Senthil Kumar *et al.* (2017) [27], Hussien *et al.* (2019) [13], Marimuthu *et al.* (2024) [15].

Different nutrient management practices had a significant impact on water use efficiency (Table 2). Higher water use efficiency (4.91 kg/ha-mm) was observed under 100% RDF (N₁), which was found to be statistically at par with 75% RDF + PSB + *Rhizobium* (N₂). Lower water use efficiency (4.37 kg/ha-mm) was recorded under 75% RDF + VAM + *Rhizobium* (N₃). The results aligned with the findings of Porpavai and Nagarajan (2022) [22].

The interaction between irrigation scheduling and nutrient management had a significant influence on water use efficiency (Table 3). Higher water use efficiency (7.03 kg/ha-mm) was recorded under the treatment combination I₂N₂, which was found to be statistically at par with I₁N₁. Lower water use efficiency (1.94 kg/ha-mm) was observed under I₄N₃, which was statistically comparable with I₄N₁ and I₄N₂. The results were in conformity with the findings of Sodavadiya *et al.* (2017) [31].

Table 1: Effect of different treatments as influenced by irrigation scheduling and nutrient management practices on growth parameters

Treatments		Plant population at 30 DAS	Plant height (cm)			No. of branches per plant at harvest	Dry weight of root nodules at 40 DAS (mg/plant)	Days to 50% flowering
			At 30 DAS	At 60 DAS	At harvest			
Main plot: Irrigation scheduling (I)								
I1	0.50 PEF	10.03	21.25	36.07	44.78	5.16	37.87	42.52
I2	0.75 PEF	10.67	23.74	42.40	51.24	6.62	40.85	47.21
I3	1.00 PEF	10.79	24.00	42.95	51.41	6.73	42.53	47.50

I4	Flood irrigation	10.27	22.45	38.24	48.80	5.74	38.98	45.82
	S.Em. $\pm$	0.41	0.83	1.47	1.35	0.19	0.94	1.50
	CD at 5%	NS	NS	5.08	4.65	0.64	3.26	NS
Sub-plot: Nutrient management (N)								
N1	100% RDF	10.53	23.20	41.09	50.16	6.27	37.88	46.77
N2	75% RDF + PSB + <i>Rhizobium</i>	10.49	23.00	40.42	49.58	6.05	41.75	45.82
N3	75% RDF + VAM + <i>Rhizobium</i>	10.30	22.42	38.23	47.42	5.86	40.54	44.70
	S.Em. $\pm$	0.27	0.52	0.92	1.09	0.12	0.66	0.91
	CD at 5%	NS	NS	NS	NS	NS	1.98	NS
	I $\times$ N Interaction	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of different treatments as influenced by irrigation scheduling and nutrient management practices on yield attributes, yield and water use efficiency

Treatments		No. of pods per plant	No. of seeds per pod	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Water use efficiency (kg/ha-mm)
Main plot: Irrigation scheduling (I)								
I1	0.50 PEF	28.19	5.29	46.20	749	1623	31.82	6.01
I2	0.75 PEF	32.86	6.69	48.11	1130	2668	29.81	6.04
I3	1.00 PEF	33.23	6.93	48.62	1194	2756	30.26	4.79
I4	Flood irrigation	31.51	6.14	46.75	882	2117	29.38	2.05
	S.Em. $\pm$	1.00	0.20	1.28	37.59	93.61	0.81	0.20
	CD at 5%	3.47	0.70	NS	130.08	323.93	NS	0.70
Sub-plot: Nutrient management (N)								
N1	100% RDF	32.40	6.50	47.67	1028	2400	30.01	4.91
N2	75% RDF + PSB + <i>Rhizobium</i>	31.57	6.38	47.57	1016	2393	29.97	4.87
N3	75% RDF + VAM + <i>Rhizobium</i>	30.38	5.92	47.02	923	2080	30.97	4.37
	S.Em. $\pm$	0.43	0.11	0.89	20.42	56.69	0.54	0.12
	CD at 5%	1.29	0.33	NS	61.22	169.97	NS	0.35
	I $\times$ N Interaction	S	S	NS	S	S	NS	S

Table 3: Interaction effect of irrigation scheduling and nutrient management practices on yield attributes, yield and water use efficiency

Treatments	No. of pods per plant	No. of seeds per pod	Seed yield (kg/ha)	Stover yield (kg/ha)	Water use efficiency (kg/ha-mm)
I1N1	31.07	5.98	831	1972	6.66
I1N2	27.44	5.35	716	1536	5.74
I1N3	26.08	4.55	702	1361	5.62
I2N1	32.04	6.50	1102	2504	5.89
I2N2	34.60	7.20	1316	3192	7.03
I2N3	31.96	6.37	973	2307	5.20
I3N1	34.53	7.18	1219	2951	4.89
I3N2	32.83	6.87	1182	2710	4.74
I3N3	32.33	6.75	1181	2609	4.73
I4N1	31.95	6.33	958	2173	2.23
I4N2	31.40	6.10	851	2133	1.98
I4N3	31.17	6.00	836	2045	1.94
S.Em. $\pm$	0.86	0.22	40.84	113.39	0.23
CD at 5%	2.58	0.66	122.45	339.94	0.70

Conclusion

The present investigation demonstrated that both irrigation scheduling and nutrient management play a crucial role in improving the productivity of summer black gram under drip irrigation. Irrigation scheduling at 1.00 PEF promoted superior vegetative growth, yield attributes, seed and stover yield, although most of these parameters remained statistically at par with 0.75 PEF. Among the nutrient management practices, application of 100% RDF recorded high seed and stover yields, while 75% RDF supplemented with PSB and *Rhizobium* produced comparable yields. The interaction between irrigation scheduling and nutrient management significantly influenced yield attributes, yield and water use efficiency. This indicates that efficient irrigation scheduling combined with integrated nutrient management can optimize crop performance while reducing fertilizer use by 25%.

Overall, the study conducted during the summer season of 2025 concludes that drip irrigation scheduled at 0.75 PEF along with 75% RDF supplemented with PSB and *Rhizobium* is an efficient and viable production strategy for summer black gram (GAU-4).

This combination ensures high productivity, better resource-use efficiency, enhanced soil biological activity, making it a sustainable nutrient and water management practice for irrigated black gram cultivation.

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Conflicts of Interest

The authors declare no competing financial interests or personal relationships that could have influenced the findings reported in this paper.

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