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Evaluation of Suitable Smart Irrigation System for Black Gram

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experimental study was conducted during summer season (2023) at Eastern farm of Tamil Nadu Agricultural University, Coimbatore to evaluate suitable irrigation method for black gram. The experiment was laid out in a strip plot design which comprise main plot treatments such as M1 – Drip Irrigation, M2 –Micro sprinkler Irrigation, M3 – Rain hose Irrigation and M4 – Conventional Irrigation and subplot consists of different depths for placement of soil moisture sensor viz., D1 – 5 cm , D2 – 10 cm and D3 – 15 cm. The growth attributes viz., plant height, number of branches per plant, number of leaves per plant were significantly higher in drip irrigation system with sensor depth of 15cm. The root length and root dry weight were significantly greater in Rain hose irrigation with sensor placed at depth of 15 cm. The yield attributes viz., number of pods per plant, number of seeds per pod, number of seeds per plant, pod weight per plant, pod length, test weight, grain yield and haulm yield were significantly higher in drip irrigation with sensor placed at depth of 15 cm. The average grain yield of drip irrigation method is 31.7 per cent higher than the grain yield of conventional irrigation method. Higher grain yield of 1159 kg ha $^{-1}$ was obtained in drip system with sensor placed at the depth of 15 cm.

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1. INTRODUCTION

Pulses are the important source of protein in the human diet. After the cereals , pulses are the chief constituent of diet in India. India is the largest consumer, producer and importer of pulses in the world. Black gram is grown in about 4.63 million ha area with the annual production of 2.78 million tonnes and the average productivity is 599 kg ha $^{-1}$ (India stat, 2021-2022) [1]. Although India stands first in area and production of pulses, but the productivity is low so that the production is not enough to country's requirement. The productivity of black gram is less mainly due to pulses suffers from various constraints including biotic and abiotic stress. Among that water is important abiotic stress that leads to the yield loss [2]. In India mostly farmers follow the surface method of irrigation includes furrow irrigation and check basin method of irrigation. But the surface method of irrigation leads to loss of water through evaporation loss, deep percolation, lateral seepage and poor irrigation water management [3]. Researchers estimated that modern irrigation methods such as drip and micro sprinkler results in significant increase in growth and yield of crops than the surface method of irrigation [4]. Modern irrigation methods saves the water up to 40 – 80 per cent and also saves the fertilizer and labour cost [5]. Some modern irrigation methods such as rain hose irrigation also reduces the cost incurred for establishment of irrigation system [6].

Water scarcity is one of the important problems faced by the world in current era. Agriculture consumes plenty of water, so there is need to develop a system that uses water precisely. Smart irrigation system works based on the available soil moisture and current plant moisture by installing sensor [7]. It saves both water and labour. Soil moisture sensors measures the water potential in soil and gives an indication for irrigation it leads to automation in irrigation. Efficiency of irrigation is influenced by depth for placement of sensor in smart irrigation system [8]. Keeping the above point in view, a study was carried out to identify suitable method of irrigation to improve the growth and productivity of black gram. And also to identify the suitable depth for placement of sensor.

2. MATERIALS AND METHODS

A field experiment was conducted at the Eastern farm of Tamil Nadu Agricultural University, Coimbatore during *summer* season (May 2023 to July 2023). The study area geographically situated in Western Agro- Climatic Zone of Tamil Nadu with the coordinates of 11º N latitude, 76º E longitude and an altitude of 426.7 m above mean sea level. The soil type of experimental site is sandy clay loam in texture, moderately alkaline pH (8.11) and normal in soluble salts (EC 0.47 dsm^{-1}) and with low in available nitrogen (263 kg/ha), but high in available phosphorus (17.6 kgha^{-1}) and available potassium (314 kg/ha).. The black gram variety VBN 11(Vamban11) was used for the experimental study. The recommended cultural practices were carried out. Soil moisture sensor was installed in the field at various depths to monitor soil moisture which is helpful to irrigate the crop at right time and right amount. The observations on growth parameters like plant height, number of branches per plant, number of leaves per plant, root length, root dry weight and yield para meters like number of pods per plant, number of seeds per pod, number of seeds per plant, test weight, grain yield and haulm yield were recorded as per the standard procedures. The experimental trial was laid out in Strip Plot Design with three replications (Table. 1).

Table 1. Treatment details

Main plot (Methods of irrigation)	Sub plot (depth for placement of soil moisture sensors)
M1 – Drip irrigation	D1 : 5 cm depth D2 : 10 cm depth D3 : 15 cm depth
M2- Micro sprinkler	D1 : 5 cm depth D2 : 10 cm depth D3 : 15 cm depth
M3- Rain hose	D1 : 5 cm depth D2 : 10 cm depth D3 : 15 cm depth
M4 - Conventional irrigation	D1 : 5 cm depth D2 : 10 cm depth D3 : 15 cm depth

M – Method of Irrigation; D – Depth for placement of sensor

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

The plant growth characteristics like plant height, number of branches per plant and number of leaves per plant were recorded at 15, 30, 45 and 60 DAS respectively.

Different methods of irrigation and different depths for placement of soil moisture sensor had greatly influenced the plant height and it was shown in Table 2. The highest plant height was recorded in drip irrigation method with sensor depth of 15 cm at all stages. It was on par with the treatments consists of drip irrigation at sensor depth of 10 cm and 5 cm. At 15 DAS, the lowest plant height was obtained in sprinkler irrigation method with sensor depth of 5 cm. but at the later stages, it was obtained in conventional irrigation method with sensor depth of 5 cm. over all the maximum plant height was obtained in drip irrigation method, it was followed by rain hose, sprinkler and conventional method of irrigation. This may be due to very frequent irrigation intervals which helps to maintain soil moisture, this leads to proper nutrient availability and increased microbial action, that results in vigorous growth of the plant. These results were similar to the findings of Vaghasia et al. [9] & Angiras et al. [10].

The different methods of irrigation and different depths of placement of soil moisture sensor significantly influenced the number of branches and it was shown in Table 3. At 15 DAS, there was no significance difference between the treatments. At later stages, the maximum number of branches per plant were recorded in drip irrigation method with sensor depth of 15 cm , it was on par with drip irrigation method with sensor depth of 10 cm and 5 cm. the minimum number of branches were obtained in conventional irrigation method with sensor depth of 5 cm. Increase in soil moisture availability and frequency of irrigation in drip irrigation would have increased number of branches per plant by improving root multiplication and efficient utilization of available nutrient resources. These results were similar to findings of Rao et al. [11].

The number of leaves per plant were highest in drip irrigation method with sensor depth of 15 cm. At 15 DAS and 30 DAS, the lowest number of leaves were obtained in sprinkler irrigation method with sensor depth of 5 cm. but at 45 DAS and 60 DAS, the lowest number of leaves were recorded in conventional irrigation method with sensor depth of 5 cm. the data on number of leaves per plant is shown in Table 4.

Table 2. Effect of different irrigation methods and different depths for placement of soil moisture sensor on plant height (cm) of black gram

	15 DAS					30 DAS			
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	13.9	16.3	16.6	15.6	**M1**	29.8	30.6	32.0	30.8
M2	10.9	12.9	13.7	12.5	**M2**	22.7	24.4	25.4	24.2
M3	13.5	15.0	16.8	15.1	**M3**	24.8	26.4	26.8	26.0
M4	13.0	14.4	14.8	14.1	**M4**	18.5	21.0	22.3	20.6
Mean	12.8	14.7	48.2		**Mean**	24.0	25.6	26.6	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0.88**	**0.51**	**1.19**		**S.Ed**	**1.21**	**0.55**	**2.18**	
CD(p=0.05)	**2.15**	**1.42**	**2.6**		**CD(p=0.05)**	**2.96**	**1.54**	**4.76**	

	45DAS					60 DAS			
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	48.2	51.4	53.6	51.1	**M1**	58.4	61.6	62.7	60.9
M2	36.4	38.1	39.6	38.0	**M2**	38.9	40.2	41.5	40.2
M3	46.7	48.0	48.1	47.6	**M3**	53.2	55.9	57.2	55.4
M4	32.0	34.0	37.6	34.5	**M4**	35.3	37.4	37.9	36.8
Mean	40.8	42.9	44.7		**Mean**	46.5	48.8	49.8	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0.8**	**0.95**	**0.97**		**S.Ed**	**1.11**	**0.61**	**1.12**	
CD(p=0.05)	**2.03**	**2.63**	**2.11**		**CD(p=0.05)**	**2.72**	**1.69**	**2.45**	

Table 3. Effect of different irrigation methods and different depths for placement of soil moisture sensor on number of branches per plant of blackgram

	15 DAS					30 DAS			
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	0.66	1	1	0.89	**M1**	3.66	4.33	4.66	4.22
M2	0.66	0.66	0.66	0.66	**M2**	2.33	2.66	2.66	2.55
M3	0.66	0.66	1	0.77	**M3**	3.33	3.66	4	3.66
M4	0.66	0.66	1	0.77	**M4**	2	2.33	2.66	2.33
Mean	0.66	0.74	0.91		**Mean**	2.83	3.24	3.49	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0.03**	**0.05**	**0.16**		**S.Ed**	0.42	0.32	**0.31**	
CD(p=0.05)	**0.19**	**0.42**	**0.51**		**CD(p=0.05)**	**1.02**	**0.89**	**0.68**	

	45DAS					60 DAS			
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	7.66	8.33	9	8.33	**M1**	10.66	11.33	11.66	11.22
M2	4.33	4.33	5	4.55	**M2**	7.33	7.66	8	7.66
M3	6.33	7	7.33	6.89	**M3**	9.33	10.33	11.66	10.44
M4	3	4	4.66	3.89	**M4**	6.33	7	7.33	6.89
Mean	5.33	5.91	6.49		**Mean**	8.41	9.08	9.66	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0.31**	**0.27**	**0.56**		**S.Ed**	**0.82**	**0.46**	**1.06**	
CD(p=0.05)	**0.76**	**0.76**	**1.21**		**CD(p=0.05)**	**1.99**	**1.28**	**2.31**	

Table 4. Effect of different irrigation methods and different depths for placement of soil moisture sensor on number of leaves per plant of black gram

	15 DAS					30 DAS			
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	7	8	9	8.00	**M1**	30	32	32.66	31.55
M2	4.66	6	6.66	5.77	**M2**	19.66	21.33	27	22.66
M3	6.66	6.66	7	6.77	**M3**	27.66	28.66	30	28.77
M4	6	7	7.33	6.78	**M4**	22.66	26.33	27	25.33
Mean	6.08	6.91	7.49		**Mean**	24.99	27.08	29.16	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0.41**	**0.78**	**1.08**		**S.Ed**	1.51	0.82	**3.28**	
CD(p=0.05)	**1.01**	**2.15**	**2.35**		**CD(p=0.05)**	**3.69**	**2.28**	**7.15**	

45DAS					**60 DAS**				
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	42.33	44.66	45.33	44.11	**M1**	39	42	43.66	41.55
M2	29.33	31	33	31.11	**M2**	27.66	29	30.33	29.00
M3	36	37.33	39.66	37.66	**M3**	33.33	36.33	36.66	35.44
M4	25.33	26,33	28.66	27.00	**M4**	22.66	24.33	24.66	23.88
Mean	33.24	37.66	36.66		**Mean**	30.66	32.91	33.82	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**1.51**	**0.98**	**1.78**		**S.Ed**	**0.94**	**0.96**	**2.14**	
CD(p=0.05)	**3.69**	**2.73**	**3.87**		**CD(p=0.05)**	**2.3**	**2.65**	**4.65**	

3.2 Root Parameters

The different methods of irrigation had greatly influence the root growth. It is shown in Table 5. The maximum root length was obtained in rain hose irrigation with the sensor depth of 15 cm. It was on par with rain hose irrigation with sensor depth of 10 cm and 5 cm and drip irrigation with sensor depth of 15 cm. The minimum root length was recorded in drip irrigation method with sensor depth of 5 cm. it was on par with drip irrigation method with sensor depth of 5 cm and sprinkler irrigation with sensor depth of 5 cm. The root length was highest in rain hose irrigation method and it was followed by drip irrigation, sprinkler irrigation and conventional irrigation. This result is similar to the findings of Palriya [12]. In drip irrigation method nearly 75 per cent of roots were present in upper layer of soil profile with short tap root length due to minimum depth of irrigation and continuous availability of soil moisture, but in conventional irrigation method, the depth of irrigation is more, it leads to long tap root system. This is confirmed by Dasila et al. [13] & Goldberg and Shmueli [14].

The different methods of irrigation and different depths for placement of soil moisture sensor have no significant difference on root dry weight at 15& 30 DAS. But at the later stages. The rain hose irrigation with sensor depth of 15 cm recorded maximum root dry weight. It was on par with rain hose irrigation with sensor depth of 10 cm and 5 cm and conventional irrigation with sensor depth of 15 cm. The drip irrigation with sensor depth of 5 cm had obtained minimum root dry weight. The same trend followed in root length is continued in root weight. This result is similar with findings of Tomar *et al*., [15]. The data on root dry weight per plant is shown in Table 6.

Table 5. Effect of different irrigation methods and different depths for placement of soil moisture sensor on root length (cm) of black gram

	15 DAS					30 DAS			
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	1.88	2.09	2.17	2.05	**M1**	7.2	7.5	7.73	7.48
M2	2.44	2.68	2.73	2.62	**M2**	7.24	8.23	8.54	8.00
M3	3.98	4.09	4.15	4.07	**M3**	12.86	14.23	14.72	13.94
M4	3.36	3.41	3.53	3.43	**M4**	11.34	12.01	13.33	12.23
Mean	2.91	3.06	3.14		**Mean**	9.66	10.49	11.08	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0.16**	**0.09**	**0.25**		**S.Ed**	0.54	0.47	**1.35**	
CD(p=0.05)	**0.38**	**0.25**	**0.53**		**CD(p=0.05)**	**1.32**	**1.3**	**2.94**	

	45DAS					60 DAS			
Treatment	**D1**	**D2**	**D3**	**MEAN**	**Treatment**	**D1**	**D2**	**D3**	**MEAN**
M1	8.93	10.53	11.33	10.26	**M1**	16.73	17.16	18.23	17.37
M2	10.86	12.9	13.7	12.49	**M2**	16.66	17.43	18.26	17.45
M3	17.9	17.93	18.44	18.09	**M3**	22.3	24.6	26.33	24.41
M4	16.56	17.44	17.63	17.21	**M4**	21.8	22.8	23.3	22.63
Mean	13.56	14.7	15.27		**Mean**	19.37	20.49	21.53	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0.61**	**0.17**	**1.44**		**S.Ed**	**1.19**	**0.76**	**1.56**	
CD(p=0.05)	**1.5**	**0.47**	**3.13**		**CD(p=0.05)**	**2.92**	**2.11**	**3.4**	

Table 6. Effect of different irrigation methods and different depths for placement of soil moisture sensor on root dry weight (g plant $^{-1}$) of black gram

	15 DAS					30 DAS			
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	0.007	0.007	0.008	0.01	**M1**	0.086	0.089	0.094	0.09
M2	0.007	0.009	0.009	0.01	**M2**	0.091	0.099	0.103	0.10
M3	0.012	0.013	0.015	0.01	**M3**	0.134	0.149	0.151	0.14
M4	0.011	0.012	0.014	0.01	**M4**	0.107	0.115	0.141	0.12
Mean	0.009	0.0104	0.0116		**Mean**	0.104	0.113	0.122	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0**	**0**	**0**		**S.Ed**	0.01	0.01	**0.01**	
CD(p=0.05)	**0.012**	**0.011**	**0.017**		**CD(p=0.05)**	**0.02**	**0.01**	**0.03**	

45DAS					60 DAS				
Treatment	**D1**	**D2**	**D3**	**MEAN**	**Treatment**	**D1**	**D2**	**D3**	**MEAN**
M1	0.36	0.39	0.43	0.39	**M1**	0.61	0.65	0.71	0.66
M2	0.37	0.4	0.44	0.40	**M2**	0.66	0.67	0.73	0.69
M3	0.65	0.68	0.7	0.68	**M3**	0.93	1.02	1.16	1.04
M4	0.53	0.61	0.63	0.59	**M4**	0.88	0.91	0.94	0.91
	0.47	0.52	0.55			0.77	0.81	0.88	
Mean	**M**	**D**	**M x D**		**Mean**	**M**	**D**	**M x D**	
S.Ed	**0.02**	**0.02**	**0.03**		**S.Ed**	**0.05**	**0.03**	**0.04**	
CD(p=0.05)	**0.04**	**0.05**	**0.08**		**CD(p=0.05)**	**0.12**	**0.08**	**0.09**	

3.3 Yield Parameters

The yield attributes like the average number of pods per plant, Number of seeds per pod, Number of seeds per plant, weight of pods per plant, test weight, grain yield and haulm yield were recorded at the harvest stage.

The different methods of irrigation and different depth for placement of soil moisture sensor significantly influenced the number of pods per plant and it was shown in Table 7. The higher number of pods per plant (78.33) were noticed in drip irrigation with sensor depth of 15 cm. It was on par with drip irrigation with sensor depth of 10 cm and 5 cm. This is due to availability of optimum moisture during vegetative growth period, reduce the excess vegetative growth and enhance the flowering capability. This favourable condition leads to increase in number of pods per plant. The lowest number of pods per plant [18] was noticed in conventional irrigation with sensor depth of 5 cm. It was on par with conventional irrigation with sensor depth of 10 cm and 15 cm. These findings were confirmed by Shree et al. [16].

The different methods of irrigation and different depths for placement of sensor had significantly influence the pod length. It is shown in Table 8. The pod length was noticed to be higher in drip irrigation with sensor depth of 15 cm (6.68 cm). it was on par with drip irrigation with sensor depth of 10 cm and 5 cm. The lower pod length (3.72 cm) was recorded in conventional irrigation with sensor depth of 5 cm and it was on par with conventional irrigation with sensor depth of 10 cm and 5 cm. These results are in accordance with the results obtained by Palriya [12] and Shivakumar et al. [17]. This result was closely related to the findings of Jadhav et al. [18].

Table 7. Effect of different irrigation methods and different depths for placement of soil moisture sensor on number of pods per plant of blackgram

Treatment	**D1**	**D2**	**D3**	**Mean**
M1	70.33	73.33	78.33	74.00
M2	24.66	34.66	45.33	34.88
M3	60.33	66	68.33	64.89
M4	18	18.66	19.66	18.77
Mean	43.33	48.16	52.91	
	M	**D**	**M x D**	
S.Ed	**6.13**	**1.69**	**6.31**	
CD(p=0.05)	**15**	**4.7**	**13.75**	

Table 8. Effect of different irrigation methods and different depths for placement of soil moisture sensor on pod length (cm) of black gram

Treatment	**D1**	**D2**	**D3**	**Mean**
M1	6.32	6.56	6.68	6.52
M2	4.20	4.47	4.61	4.43
M3	4.82	5.04	5.15	5.00
M4	3.72	3.95	4.05	3.91
Mean	4.76	5.00	5.12	
	M	**D**	**M x D**	
S.Ed	**0.09**	**0.12**	**0.30**	
CD(p=0.05)	**0.23**	**0.34**	**0.65**	

Table 9. Effect of different irrigation methods and different depths for placement of soil moisture sensor on Number of seeds pod^{-1} and Number of seeds plant^{-1} of black gram

Number of seeds pod^{-1}					Number of seeds plant^{-1}				
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	6.66	6.66	7	6.77	**M1**	447.54	463.98	489.36	466.96
M2	4.66	5	5.33	5.00	**M2**	144.47	186.15	225.81	185.48
M3	6	6.33	6.33	6.22	**M3**	360.7	407.04	422.48	396.74
M4	3.66	4	4	3.89	**M4**	83.65	94.39	118.46	98.83
Mean	5.24	5.49	5.66			259.09	287.89	314.02	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0.27**	**0.14**	**0.44**		**S.Ed**	**5.52**	**7.9**	**19.98**	
CD(p=0.05)	**0.66**	**0.38**	**0.97**		**CD(p=0.05)**	**13.51**	**21.93**	**43.52**	

The number of seeds per pod was maximum in drip irrigation with sensor depth of 15 cm (7 seeds per pod). It was on par with drip irrigation with sensor depth of 10 cm and 5 cm and rain hose irrigation with sensor depth of 15 cm. The number of seeds per pod was minimum in conventional irrigation with sensor depth of 5 cm (3.66 seeds per pod). The same trend was observed in number of seeds per plant. The data on number of seeds per pod and plant is shown in Table 9.

The different methods of irrigation and different depth for placement of soil moisture sensor significantly influenced the test weight. The highest test weight (5.84 g) was recorded in drip irrigation with sensor depth of 15 cm. It was on par with drip irrigation with sensor depth of 10 cm and 5 cm. The lowest test weight (3.24 g) was obtained in conventional irrigation with sensor depth of 5 cm. it was on par with conventional irrigation with sensor depth of 10 cm and 15 cm.

The pod weight per plant was maximum in drip irrigation with sensor depth of 15 cm (23.65 g plant^{-1}). It was on par with drip irrigation with sensor depth of 10 cm and 5 cm. the minimum pod weight per plant (5.76 g plant^{-1}) was recorded in conventional irrigation with sensor depth of 5 cm. The data on test weight and pod weight per plant is shown in Table 10.

The principal output of the cultivating crops is grain yield. The different methods of irrigation and different depth for placement of sensor had significantly influenced the grain yield. The greatest grain yield (1159.98 kg ha^{-1}) was obtained in drip irrigation with sensor depth of 15 cm. It was on par with drip irrigation with sensor depth of 10 cm and 5 cm. The lowest grain yield (894.40 kg ha $^{-1}$) was recorded in conventional irrigation with sensor depth of 5 cm. it was on par with conventional irrigation with sensor depth of 10 cm and 15 cm. In drip irrigation method, the application of irrigation water directly to the root zone leads to optimum soil moisture condition that results in uniform flowering, it enhances the pod growth and promote favourable condition for pod development [19]. Over all the maximum grain yield was obtained in drip irrigation and it was followed by rain hose irrigation, micro sprinkler irrigation and conventional irrigation. This results were concordance with findings of Kumar et al. [20]. When compared to conventional broadcasting with check basin irrigation, drip and sprinkler methods of irrigation recorded 42.1 and 36.1%, respectively increased yield Vinoth et al. [21]. Conventional irrigation results in lower yield due to availability of higher soil moisture, that increases the vegetative period even after attaining the flowering stage, this leads to greater reduction in grain yield [22].

Table 10. Effect of different irrigation methods and different depths for placement of soil moisture sensor on Test weight (g)and Pod weight (g plant^{-1}) of black gram

Test weight (g)					Pod weight (g plant^{-1})				
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	5.54	5.65	5.84	5.68	**M1**	20.87	21.69	23.65	22.07
M2	4.53	4.72	4.87	4.71	**M2**	9.34	11.57	12.66	11.19
M3	5.09	5.17	5.36	5.21	**M3**	17.75	18.89	19.4	18.68
M4	3.24	3.48	3.67	3.46	**M4**	5.76	6.48	6.92	6.39
Mean	4.6	4.75	4.93		**Mean**	13.43	14.65	15.65	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**0.08**	**0.15**	**0.25**		**S.Ed**	**0.27**	**0.4**	**0.96**	
CD(p=0.05)	**0.21**	**0.42**	**0.55**		**CD(p=0.05)**	**0.65**	**1.12**	**2.09**	

Table 11. Effect of different irrigation methods and different depths for placement of soil moisture sensor on Grain Yield (kgha^{-1}) and Haulm Yield (kgha^{-1}) of black gram

	Grain Yield (kgha^{-1})					Haulm Yield (kgha^{-1})			
Treatment	**D1**	**D2**	**D3**	**Mean**	**Treatment**	**D1**	**D2**	**D3**	**Mean**
M1	1074.23	1117.47	1159.98	1117.23	**M1**	2983.16	3016.62	3110.58	3036.79
M2	833.12	854.76	872.49	853.46	**M2**	2837.51	2874.97	2932.84	2881.77
M3	920.74	953.95	998.42	957.70	**M3**	3129.67	3175.82	3256.35	3187.28
M4	749.53	762.37	794.74	768.88	**M4**	2549.05	2614.42	2674.42	2612.63
Mean	894.40	922.13	956.40		**Mean**	2874.84	2920.45	2993.54	
	M	**D**	**M x D**			**M**	**D**	**M x D**	
S.Ed	**15.22**	**27.51**	**52.68**		**S.Ed**	**48.76**	**92.24**	**159.46**	
CD(p=0.05)	**37.25**	**76.37**	**114.78**		**CD(p=0.05)**	**117.49**	**256.11**	**347.44**	

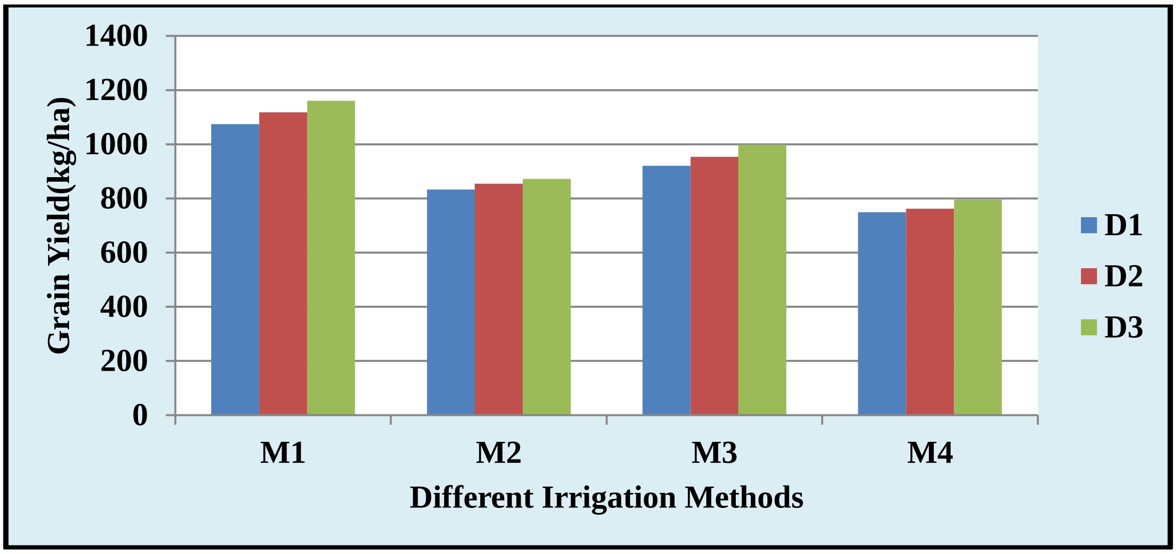

Fig. 1. Effect of different irrigation methods and different depths for placement of soil moisture sensor on Grain Yield (kg ha^{-1}) of black gram

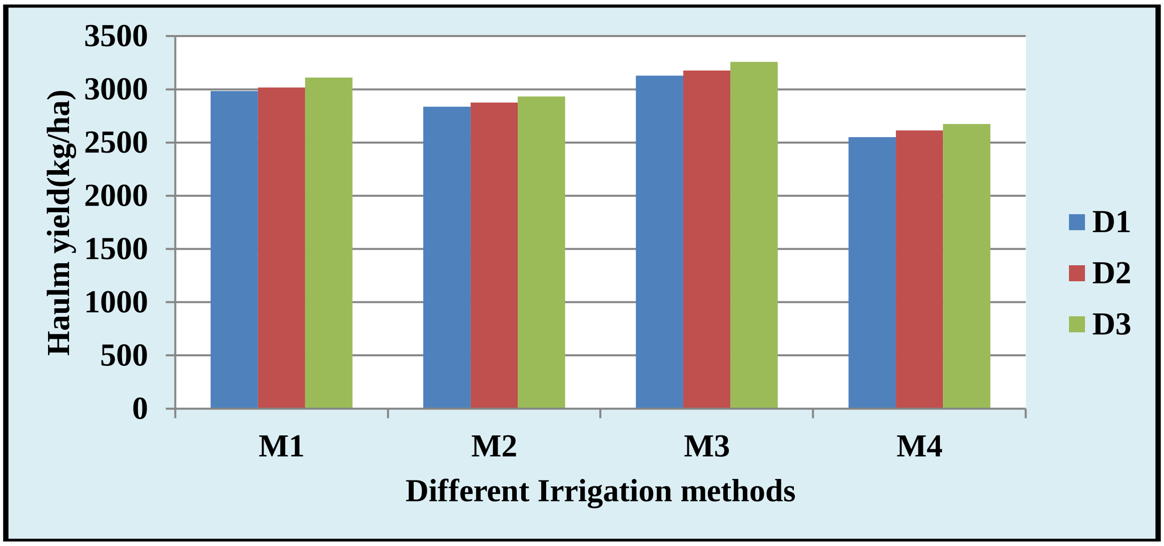

Fig. 2. Effect of different irrigation methods and different depths for placement of soil moisture sensor on Haulm Yield (kg ha^{-1}) of blackgram

The different methods of irrigation and different depth for placement of sensor had significantly influenced the haulm yield .The maximum haulm yield (3256.35 kg ha^{-1}) was obtained in rain hose irrigation with sensor depth of 15 cm. It was on par with rain hose irrigation with sensor depth of 10 cm and 5 cm. It may be due to excess application of water over the foliage at regular intervals leads to vigorous vegetative growth [23]. The minimum haulm yield (2874.84 kg ha^{-1}) was recorded in conventional irrigation with sensor depth of 5 cm. it was on par with conventional irrigation with sensor depth of 10 cm and 15 cm. Similar results on haulm yield was found earlier by Ramanjaneyulu et al. [24] & Soni et al. [25]. The data on Grain yield and Haulm yield is shown in Table 11.

4. CONCLUSION

The main conclusion from this study is that modern irrigation systems like drip irrigation, micro sprinkler irrigation and rain hose irrigation are performing well than the conventional irrigation method. Among various modern irrigation methods, drip irrigation is well suitable and results in better growth and yield. It is mainly due to maintenance of optimum moisture condition which is favourable for better plant growth. Among the various depths for placement of soil moisture sensor, depth of 15cm is performing better than the depth of 5cm and 10 cm. It concludes that drip irrigation method with sensor depth of 15 cm is suitable method with suitable depth to enhance the productivity of black gram.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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