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IRRIGATION AND MOISTURE CONSERVATION PRACTICES FOR ENHANCING THE GROWTH OF FODDER SORGHUM DURING SUMMER SEASON IN SEMI-ARID ECOSYSTEM

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SUMMARY

A field experiment was conducted during summer season of 2022 and 2023 at Hisar, Haryana to evaluate the effect of irrigation intervals and moisture conservation practices in fodder sorghum. Two irrigation levels (10 and 15 days interval) were tested with ten moisture conservation practices in split plot design with three replications. Among irrigation levels, sorghum irrigated at 10 days interval recorded the maximum plant height, number of leaves per plant, leaf stem ratio (L:S), leaf area index (LAI) and dry matter accumulation (DMA) at all the growth stages. Among moisture conservation practices, application of hydrogel @ 5.0 kg/ha + mulching @ 4.0 t/ha (M_8) recorded the best results in terms of growth parameters but was found statistically at par with the application of *gond katira* @ 10.0 kg/ha + mulching @ 4.0 t/ha (M_{10}) during both the years. So, it can be concluded that with application of hydrogel @ 5.0 kg/ha + mulching @ 4.0 t/ha along with irrigation at 10 days interval was the most suitable practice to achieve maximum growth of fodder sorghum in summer season under semi-arid conditions of Haryana.

Key words: Fodder sorghum, *gond katira*, hydrogel, leaf stem ratio, LAI, mulch and summer

Sorghum [(*Sorghum bicolor* L.) Moench] is the most widely grown forage crop of India (2.6 m ha) with single and multi-cut sorghums accounting for 0.6 and 2.0 m ha acreage, respectively (Prabhakar Babu, 2018). With climate resilience, sorghum and pearl millet are seen as alternative to maize in rainfed areas (Bhattarai *et al*., 2019). In a country like India that is home to 536 million livestock (Anonymous, 2020) facing a green and dry fodder shortage of 11.23 and 23.40 per cent, respectively (Roy *et al*., 2019). Under such scenario, a drought-tolerant crop like sorghum contribute very significantly towards the fodder security of the country. Summer season may be tapped for cultivation of fodder sorghum as it is a drought-tolerant crop and could provide fodder during the months of acute fodder shortage (Anil *et al*., 2023). Although sorghum has significant production potential, its cultivation is hindered by challenges such as poor soil fertility, limited water availability and pest and disease pressures (Aydinsakir *et al*., 2021). Overcoming these obstacles through improved crop management is crucial to harness its potential as a dependable fodder crop. By choosing location-specific variety and appropriate fertilizer dose, sorghum growth can be further enhanced (Kanika *et al*., 2025). Recent research indicates that excluding irrigation from management practices for single-cut forage sorghum during the *kharif* season could reduce green fodder yield by 22.06 per cent (Satpal *et al*., 2021). Single cut fodder sorghum is generally harvested during 65 DAS to 90 DAS on the attainment of 50% flowering stage or at 80 DAS (days after sowing) when flowering stage is delayed (Satpal *et al*., 2025). Sorghum generally requires 450 to 650 mm of water throughout its growing period. Further, efficient water management not only boosts yield and quality but also minimizes environmental impact. Due to its low water requirement and high water-use efficiency, sorghum is particularly well-suited for cultivation in water-scarce regions (FAO, 2023).

Efficient moisture management is vital for summer fodder production like sorghum, especially under semi-arid and high-temperature conditions. Low organic matter worsens drought stress, making proper irrigation crucial for enhancing nutritional quality, including protein and fiber content. A proper irrigation schedule tailored to the crop needs during different growth stages can improve sorghum's nutritional profile, making it a more reliable and nutritious fodder crop. Mulching conserves soil moisture, regulates temperature and improves water-use efficiency by reducing evaporation and runoff, especially during critical growth stages (Patel *et al*., 2024). Hydrogels, both synthetic and natural (e.g. *Tragacanth* gum) improve seed germination, soil water retention and structure by absorbing and slowly releasing water. These hydrogels contain hydrophilic groups, including amino, carboxyl and hydroxyl, which enhance the soil's water-holding capacity, thereby improving crop performance under drought conditions (Kumar *et al*., 2024). They can hold up to 400 times their weight in water and improve fertilizer retention (Kalhapure *et al*., 2016). Combining mulching, hydrogels and efficient irrigation practices significantly boosts crop yield and nutritional value, particularly in water-limited environments. Keeping this in view, the field investigation was carried out to evaluate the growth parameters of single-cut variety of forage sorghum under different irrigation levels and moisture conservation practices.

MATERIALS AND METHODS

The field experiment was carried out at the Research Farm, Department of Agronomy, CCS HAU, Hisar, during the summer season of 2022 and 2023. The site is situated at 29° 10' N latitude and 75° 46' E longitude, with an elevation of 215.2 meters above mean sea level, in the state of Haryana, India. It has a semi-arid and sub-tropical climate with hot dry summer with severe cold winters. Weekly weather parameters *i.e*. temperature (°C), relative humidity (%) and rainfall (mm) during the crop duration are given in Fig. 1 and 2. The soil texture was sandy loam with pH of 7.8 during both the years. Available N, P and K were 137.2 and 132.2, 13 and 12, 283.5 and 280.5 kg/ha during 2022 and 2023, respectively. The experiment was laid out in split plot design that consists of 10 treatment combinations comprising of two irrigation levels (10 and 15 days interval) in main plot and seven moisture conservation practices in sub plot [M_1: Control, M_2: Mulching @ 4 t/ha (Mustard residue), M_3: Hydrogel @ 2.5 kg/ha, M_4: Hydrogel @ 5.0 kg/ha, M_5: *Gond katira* @ 5.0 kg/ha, M_6: *Gond katira* @ 10.0 kg/ha, M_7: Hydrogel @ 2.5 kg/ha + Mulching @ 4 t/ha, M_8: Hydrogel @ 5.0 kg/ha + Mulching @ 4 t/ha, M_9: *Gond katira* @ 5.0 kg/ha + Mulching @ 4 t/ha and M_{10}: *Gond katira* @ 10.0 kg/ha + Mulching @ 4 t/ha]. These treatments were replicated thrice.

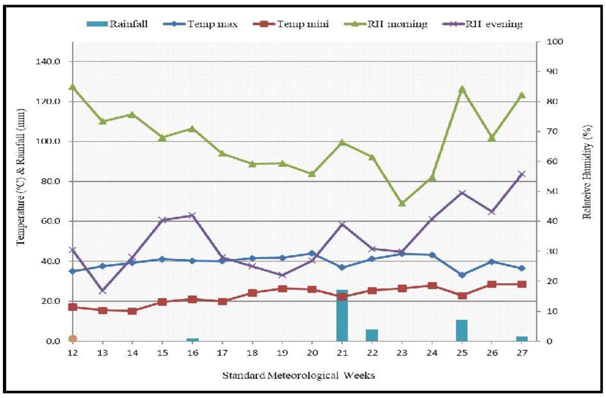

Fig. 1. Mean weekly meteorological data during summer season (2022).

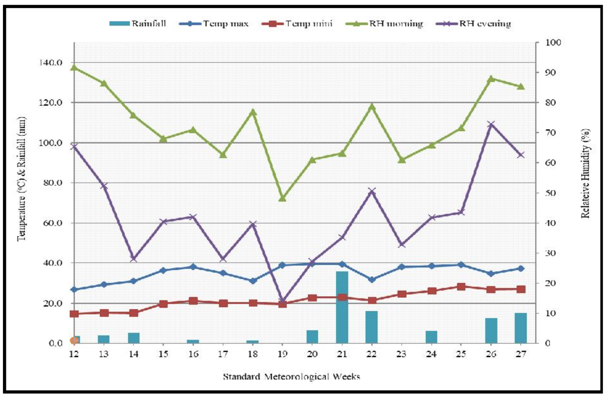

Fig. 2. Mean weekly meteorological data during summer season (2023).

Recommended dose of fertiliser (RDF) was 75 kg N + 15 kg P_2O_5 per ha and its application was: full dose of phosphorus + 50 kg N/ha was applied as basal dose and 25 kg N/ha was top dressed at 30 days after sowing (DAS). Forage sorghum variety (HJ 541) was sown manually on April 9 during 2022 and 2023 (standard week 15) on a well prepared seed bed with row spacing of 25 cm apart and using seed rate of 50 kg/ha. Mulching was carried out as per treatments with mustard straw @ 4 t/ha, spread manually on the soil surface after sowing. Pusa hydrogel and *gond katira* were mixed with soils and applied during sowing as per treatments. Irrigation was scheduled at 10 days and 15 days and the amount of irrigation water was applied to the plots as per the treatments. The source of irrigation water was canal and tube well. All the other standard agronomic practices were followed as per the package of practices for *kharif* crops of CCS Haryana Agricultural University, Hisar (Anonymous, 2021). Data was analyzed by using OPSTAT software available at CCS Haryana Agricultural University website (Sheoran *et al*., 1998). The results are presented at five per cent level of significance (p=0.05) for making comparison between the treatments.

RESULTS AND DISCUSSION

Irrigation levels

Perusal of the data from Table 3 depicts that irrigation levels had significant influence on plant height in fodder sorghum during summer seasons 2022 and 2023. The data related to the plant height were collected periodically at different growth stage *i.e.*, at 60 DAS and at harvest of crop (at 50% flowering stage). In general, the plant height increased linearly with increasing duration of the crop growth stages and reached maximum at harvest (flowering) stage during both the years. The maximum plant height was recorded in summer forage sorghum when irrigated at 10 days interval during 2022 (159.7 and 259.0 cm) as well as 2023 (166.0 and 270.0 cm) at 60 DAS and at harvest, respectively as compared to that irrigated at 15 days interval. This might be due to the availability of adequate moisture for plant growth. Shivakumar *et al.* (2019) revealed that forage sorghum crop grew taller when five to six irrigations were applied as compared to three to four irrigations.

The data in Table 1 represent the variation in number of leaves per plant due to different irrigation scheduling in sorghum during the summer season of 2022 and 2023. In general, the number of leaves increased with growth stages and recorded maximum at harvest (flowering) stage during both the years. The maximum number of leaves per plant at all the observation stages *viz.* 60 DAS and at harvest (10.2 and 11.8) in 2022 and (10.1 and 11.5) in 2023, respectively when irrigated at 10 days interval as compared to that irrigated at 15 days interval. Bhattarai *et al.* (2020) reported that application of 350 mm irrigation level resulted in higher number of leaves per plant in sorghum as compared to 200 mm and 50 mm of irrigation levels. The data related to Leaf stem ratio (L:S) recorded at 60 DAS and at harvest have been presented in Table 1, which depicts that there was significant variation in L:S due to different irrigation scheduling during both the seasons. The L:S recorded in summer fodder sorghum was higher when irrigated at 10 days interval (0.373 and 0.311 during 2022 and 0.403 and 0.327 during 2023) at 60 DAS and at harvest, respectively as compared to that irrigated at 15 days interval. Under water stress conditions due to limited irrigation, the leaf becomes smaller and thicker and thus L:S decreases. There was a positive and significant correlation between leaf to stem ratio and WUE also (Zooleh *et al.*, 2011).

The data presented in Table 2 represent the effects of irrigation levels on the leaf area index (LAI) of fodder sorghum at 60 DAS and at harvest for the summer season 2022 and 2023. The general glance at data indicated that the LAI at harvest was higher than that at 60 DAS for all the treatments during both the years. Among the irrigation levels, summer fodder sorghum crop irrigated at 10 days interval have exhibited higher LAI (5.74 and 7.93 in 2022 and 5.86 and 8.43 in 2023) at 60 DAS and at harvest, respectively as compared to that irrigated at 15 days interval. Ray *et al.* (2021) reported that different

TABLE 1

Effect of irrigation levels and moisture conservation practices on number of leaves per plant and L:S in summer fodder sorghum

Treatments	Number of leaves per plant				Leaf to stem ratio (L:S)			
	2022		2023		2022		2023	
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
Irrigation levels								
I : Irrigation at 10 days interval	10.2	11.8	10.1	11.5	0.373	0.311	0.403	0.327
I^1: Irrigation at 15 days interval	8.5	9.7	8.3	9.6	0.347	0.289	0.373	0.304
C.D. (p = 0.05)	1.2	1.2	1.1	1.3	0.010	0.008	0.011	0.009
Moisture conservation practices								
M_1: Control	8.1	9.2	7.9	9.0	0.337	0.281	0.362	0.294
M_2: Mulching @ 4 t/ha (Mustard residue)	9.5	11.0	9.7	11.1	0.358	0.298	0.386	0.314
M_3: Hydrogel @ 2.5 kg/ha	8.7	10.0	8.3	9.5	0.337	0.281	0.362	0.295
M_4: Hydrogel @ 5.0 kg/ha	9.1	10.3	8.6	9.8	0.357	0.297	0.385	0.313
M_5: *Gond katira* @ 5.0 kg/ha	8.4	9.6	7.9	9.0	0.342	0.285	0.367	0.299
M_6: *Gond katira* @ 10.0 kg/ha	8.8	10.0	8.4	9.6	0.348	0.290	0.374	0.304
M_7: Hydrogel @ 2.5 kg/ha + Mulching @ 4 t/ha	9.8	11.4	10.2	11.5	0.377	0.314	0.407	0.331
M_8: Hydrogel @ 5.0 kg/ha + Mulching @ 4 t/ha	10.7	12.5	10.6	12.4	0.390	0.325	0.422	0.343
M_9: *Gond katira* @ 5.0 kg/ha + Mulching @ 4 t/ha	9.9	11.4	9.8	11.4	0.367	0.306	0.396	0.322
M_{10}: *Gond katira* @ 10.0 kg/ha + Mulching @ 4 t/ha	10.5	12.1	10.5	12.3	0.387	0.322	0.419	0.340
C.D. (p = 0.05)	0.8	0.9	0.9	0.8	0.029	0.025	0.034	0.027

irrigation levels have significant effect on the growth of pearl millet.

The data presented in Table 3 illustrate the effect of irrigation levels on the dry matter accumulation (DMA) of forage summer sorghum in summer season 2022 and 2023. The results demonstrate that among the irrigation levels irrigation at 10 days interval accumulated higher dry matter (63.0 and 110.8 g/plant in 2022 and 80.7 and 123.4 g/plant in 2023) at 60 DAS and harvest, respectively in fodder sorghum as compared to 15 days interval during both the years. Ahmed *et al.* (2019) reported that shorter irrigation intervals led to increased plant height and biomass accumulation. Their study highlights the importance of timely water availability, especially during critical growth stages, for maximizing yield potential.

Moisture conservation practices

The data presented in Table 3 provides insight of forage sorghum under different moisture conservation practices during summer seasons 2022 and 2023. The moisture conservation practices significantly influenced plant height at various stages. Among the moisture conservation practices, maximum plant height was recorded by sorghum crop with the application of hydrogel @ 5.0 kg/ha + mulching @ 4.0 t/ha (M_8) in 2022 (165 and 268.5 cm) and in 2023 (172.4 and 283.3 cm) at 60 DAS and at harvest, respectively which was statistically at par with application of *gond katira* @ 10.0 kg/ha + mulching @ 4.0 t/ha (M_{10}) and significantly higher than other treatments during both the years. The control treatment (M_1- No moisture conservation practice) recorded the lowest plant heights across all stages during both the years. The main reason for increase in plant height with the application of hydrogel might be attributed to water availability and indirectly nutrients provided by superabsorbent polymer, which have been reported to increase the activity of cell division, cell expansion and cell elongation, ultimately leading to an increased plant height (Saini and Malve, 2023). Islam *et al.* (2011) have also reported that plant height of maize and pearl millet increased with hydrogel application from 2.5 to 5 kg/ha.

Perusal of data in Table 1 revealed that moisture conservation practices had a significant impact on the number of leaves per plant. Significant differences were revealed in the number of leaves per plant at 60 DAS and at harvest for both years 2022 and 2023. The maximum number of leaves per plant (12.5 and 12.4 in 2022 and 2023, respectively) was recorded at harvest (flowering) stage with application hydrogel @ 5.0 kg/ha + mulching @ 4 t/ha (M_8), which was statistically at par with M_{10}-*gond katira* @ 10.0 kg/ha + mulching @ 4 t/ha (12.1 in 2022 and 12.3 in 2023 at harvest, respectively) and significantly superior to other treatments. Natalia *et al.* (2024) reported that hydrogel improved the availability of soil water and nutrients which favored the leaf growth in terms of leaf number, size and chlorophyll content. Using hydrogels in conjunction with mulching promoted sorghum growth, as it enhanced both water

TABLE 2

Effect of irrigation levels and moisture conservation practices on LAI of summer fodder sorghum

Treatment Leaf area index (LAI)	2022		2023	
	60 DAS	At harvest	60 DAS	At harvest
Irrigation levels				
I_1 : Irrigation at 10 days interval	5.74	7.93	5.86	8.43
I_2: Irrigation at 15 days interval	4.73	6.90	4.79	7.34
C.D. (p = 0.05)	0.18	0.24	0.23	0.29
Moisture conservation practices				
M_1: Control	4.22	6.39	4.27	6.80
M_2: Mulching @ 4 t/ha (Mustard residue)	5.36	7.49	5.54	7.97
M_3: Hydrogel @ 2.5 kg/ha	4.68	6.94	4.74	7.38
M_4: Hydrogel @ 5.0 kg/ha	5.03	7.27	5.10	7.74
M_5: *Gond katira* @ 5.0 kg/ha	4.46	6.71	4.52	7.13
M_6: *Gond katira* @ 10.0 kg/ha	4.92	7.11	4.99	7.56
M_7: Hydrogel @ 2.5 kg/ha + Mulching @ 4 t/ha	5.77	7.91	5.80	8.36
M_8: Hydrogel @ 5.0 kg/ha + Mulching @ 4 t/ha	6.20	8.42	6.44	8.95
M_9: *Gond katira* @ 5.0 kg/ha + Mulching @ 4 t/ha	5.68	7.72	5.76	8.21
M_{10}: *Gond katira* @ 10.0 kg/ha + Mulching @ 4 t/ha	5.98	8.22	6.06	8.75
C.D. (p = 0.05)	0.40	0.37	0.40	0.39

retention and nutrient availability. The data presented in Table 1 depicts that moisture conservation practices significantly impacted the leaf to stem ratio (L:S) at 60 DAS and as well as at harvest. The maximum L:S was (0.390 and 0.325 in summer 2022 and 0.422 and 0.343 in 2023 at 60 DAS and at harvest, respectively) was recorded with application hydrogel @ 5.0 kg/ha + mulching @ 4 t/ha (M_8), which was statistically at par with M_7, M_9 and M_{10} treatments and significantly superior to other treatments. This could be attributed due to the combined effect of hydrogel and mulching that significantly improved soil moisture retention, reduced evaporation losses and promoted balanced nutrient uptake, favoring leaf growth over stem growth. Also, the L:S was higher in 2023 as compared to 2022. This increase in L:S values in 2023 could be attributed to more favorable environmental conditions, such as better rainfall distribution or temperature regimes, which enhanced leaf growth relative to stems.

The data presented in Table 2 revealed that moisture conservation practices were able to exert significant effect on the LAI at 60 DAS and at harvest during both the years. The highest LAI of fodder sorghum was observed with the application of hydrogel @ 5.0 kg/ha + mulching @ 4 t/ha (M_8) during summer 2022 (6.20 and 8.42) as well as summer 2023 (6.44 and 8.95) at 60 DAS and at harvest, respectively, being statistically at par with application of *gond katira* @ 10.0 kg/ha + mulching @ 4 t/ha (M_{10}) and significantly superior to all other treatments. Saini *et al.* (2018) also reported that by use of hydrogel there was significant increase in growth parameters in pearl millet and maize.

Perusal of data in Table 3 depicts that in general, the DMA increased linearly with increasing duration of the crop and reached maximum at harvest (flowering) stage during both the years. Moisture conservation practices showed significant effects on DMA at various growth stages of fodder sorghum. Mulching @ 4 t/ha increased the dry matter accumulation, which was further enhanced with its combination with application of hydrogel and *gond katira*. The maximum dry matter accumulation at harvest (124.1 g/plant in 2022 and 130.3 g/ plant in 2023) was recorded with the application of hydrogel @ 5.0 kg/ha + mulching @ 4 t/ha (M_8), which was statistically at par with *gond katira* @ 10.0 kg/ha + mulching @ 4 t/ha (M_{10}). In contrast, the control treatment (M_1) consistently recorded the lowest dry matter accumulation across all growth stages and years (74.6 and 88.8 g/plant at harvest during 2022 and 2023, respectively). The enhanced DMA could be attributed to improved soil moisture retention, reduced evaporation losses and better nutrient availability that collectively promoted sustained growth and biomass accumulation throughout the crop growth stages. The results were in conformity with Thejesh *et al.* (2024).

TABLE 3

Effect of irrigation levels and moisture conservation practices on plant height and dry matter accumulation in summer fodder sorghum

Treatments	Plant height (cm)				Dry matter accumulation (g/plant)			
	2022		2023		2022		2023	
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
Irrigation levels								
I_1: Irrigation at 10 days interval	159.7	259.0	166.0	270.0	63.0	110.8	80.7	123.4
I_2: Irrigation at 15 days interval	134.1	219.6	140.8	232.7	50.6	89.0	68.5	104.5
C.D. (p = 0.05)	8.0	6.2	8.4	6.8	5.1	9.0	4.1	6.5
Moisture conservation practices								
M_1: Control	131.5	216.9	137.3	222.2	42.3	74.6	58.1	88.8
M_2: Mulching @ 4 t/ha (Mustard residue)	149.7	246.9	156.4	264.4	59.1	105.7	77.2	115.6
M_3: Hydrogel @ 2.5 kg/ha	139.7	223.0	145.9	233.9	49.5	87.2	70.3	107.6
M_4: Hydrogel @ 5.0 kg/ha	141.3	225.5	147.6	236.6	51.1	90.0	74.1	113.4
M_5: *Gond katira* @ 5.0 kg/ha	136.1	217.2	142.1	227.8	48.1	84.7	68.2	104.4
M_6: *Gond katira* @ 10.0 kg/ha	138.6	221.3	144.8	232.1	49.8	87.8	72.0	110.2
M_7: Hydrogel @ 2.5 kg/ha + Mulching @ 4 t/ha	155.1	256.6	162.0	272.5	64.5	110.6	77.9	121.5
M_8: Hydrogel @ 5.0 kg/ha + Mulching @ 4 t/ha	165.0	268.5	172.4	283.3	70.4	124.1	85.2	130.3
M_9: *Gond katira* @ 5.0 kg/ha + Mulching @ 4 t/ha	151.5	251.7	158.3	264.7	64.2	113.2	79.7	120.5
M_{10}: *Gond katira* @ 10.0 kg/ha + Mulching @ 4 t/ha	160.0	265.6	167.1	276.1	68.8	121.2	83.0	127.0
C.D. (p = 0.05)	11.1	11.0	11.6	16.1	4.2	8.2	4.2	6.6

TABLE 4
Dry matter accumulation of fodder sorghum as influenced by moisture conservation practices under different irrigation levels

	Dry matter accumulation (g/plant)							
Year	2022				2023			
Crop stage	60 DAS		At harvest		60 DAS		At harvest	
Treatments	I_1	I_2	I_1	I_2	I_1	I_2	I_1	I_2
M_1	53.8	30.8	94.9	54.4	70.47	45.67	107.8	69.9
M_2	63.4	54.8	114.8	96.6	84.37	69.98	125.1	106.2
M_3	57.3	41.7	100.9	73.6	76.36	64.34	116.8	98.4
M_4	58.3	43.8	102.8	77.2	80.49	67.81	123.1	103.7
M_5	56.9	39.3	100.2	69.3	73.19	63.28	112.0	96.8
M_6	57.6	42.1	101.5	74.1	79.11	64.97	121.0	99.4
M_7	68.2	60.9	115.4	105.8	82.37	73.44	129.6	113.4
M_8	73.6	67.3	129.7	118.6	89.01	81.34	136.2	124.4
M_9	68.4	60.1	120.6	105.8	85.35	74.15	130.6	110.4
M_{10}	72.4	65.2	127.6	114.9	86.26	79.80	132.0	122.1
Mean	63.0	50.6	110.8	89.0	80.70	68.48	123.4	104.5
	CD (I)	CD (M)	CD (I)	CD (M)	CD (I)	CD (M)	CD (I)	CD (M)
	5.1	4.2	9.0	8.2	4.1	4.2	6.5	6.6
CD I*M (a)	6.0		11.6		5.9		9.4	
CD I*M (b)	9.9		17.8		8.4		13.2	

CD (I) for comparing irrigation levels, CD (M) for comparing moisture conservation practices.
CD I*M (a) for moisture conservation practices at same or different level of irrigation.
CD I*M (b) for irrigation levels at same or different moisture conservation practice.

Interaction

The interaction effect between irrigation levels and moisture conservation practices was found to be non-significant for the above growth parameters except for dry matter accumulation. The interaction effect of irrigation levels and moisture conservation practices was found to be significant at 60 DAS and at harvest during both the years and the same has been depicted in Table 4. Application of mustard straw mulch @ 4.0 t/ha (M_2) in the crop irrigated at 15 days interval was able to accumulate statistically at par dry matter to that irrigated at 10 days interval without mulch application. Application of hydrogel @ 5.0 kg/ha or *gond katira* @ 10.0 kg/ha along with mulching @ 4 t/ha (mustard residue) further enhanced the dry matter accumulation significantly. Application of hydrogel @ 5.0 kg/ha + mulching @ 4 t/ha (M_8) with irrigation at 10 days interval resulted in maximum dry matter accumulation.

CONCLUSION

Based on results of the study, it may be concluded that summer fodder sorghum crop should be irrigated at 10 days interval along with application of mustard straw mulching @ 4.0 t/ha + hydrogel @ 5.0 kg/ha or *gond katira* @ 10.0 kg/ha at sowing for better growth in terms of plant height, number of leaves per plant, leaf area index, L:S and dry matter accumulation in semi-arid ecosystem. However, application of mustard straw mulch @ 4.0 t/ha in the crop irrigated at 15 days interval was able to accumulate statistically at par dry matter to that irrigated at 10 days interval without mulch application.

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