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EFFECT OF IRRIGATION SCHEDULES OF DOMESTIC WASTE WATER ON GROWTH AND YIELD OF FODDER SORGHUM

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ABSTRACT

An experiment was conducted to evaluate the effect of irrigation schedules of domestic wastewater on growth and yield of fodder sorghum (*Sorghum bicolor* L. Moench) during kharif season (May to September, 2013) in micro-plots at ICAR - Central Soil Salinity Research Institute, Karnal (Haryana). The experiment was laid out in factorial randomized block design consisting of nine treatment combinations of three irrigation water quality levels (tube well water, cyclic use of tube well water : sewage water, sewage water) and three irrigation schedules based on ID (irrigation depth) / CPE (cumulative pan evaporation) ratio levels (0.8, 1.0, 1.2) with four replications. Irrigation with sewage water and scheduling at 1.2 ID/CPE ratio resulted significant ($P<0.05$) increase in plant height, number of leaves per plant, leaf area index, leaf to stem (green and dry) biomass and green fodder yield. A significant ($P<0.05$) decrease was observed in dry matter content in sewage water as compared to tube well water and 0.8 ID/CPE ratio, respectively. The green fodder yield in sewage water was 14.4% and 25.0% higher as compared to tube well water at 1st and 2nd cut, respectively. The increment in green fodder yield observed at 1.2 ID/CPE ratio as compared to 0.8 was 15.3% at 1st cut ($P<0.001$) and 20.7% at 2nd cut ($P<0.001$). Continuous use of sewage water for irrigation tended to increase soil electrical conductivity (EC) and decreased soil pH. The findings indicated that sorghum can be profitably grown for quality fodder with use of sewage for irrigation scheduled at ID/CPE ratio up to 1.2.

Key words: Irrigation schedule**,** Sewage water, Soil health, Sorghum, Yield

India is facing a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% feeds for livestock (Anon, 2011). Most of the deficient regions lie in the arid and semi-arid agro-ecological zones. India supports more than 16% of the world's population with only 4% of the world's fresh water resources (Singh, 2003). Although agriculture sector in India has been major user of water, share of water allocated to irrigation is likely to decrease by 10–15% in next two decades (CWC, 2000). Agriculture sector uses around 79% of the available fresh water supply. It is estimated that 38000 MLD (Million litres per day) of wastewater is generated from urban centers out of which only 35% is treated (CPCB, 2009), at the same time 13,500 MLD of industrial wastewater is also generated with a large gap between sewage generated and treatment capacity at present. In this scenario, reuse of domestic and industrial waste water in agriculture for irrigating crops seems to be a sustainable alternative for productive utilization of this resource. Sorghum (*Sorghum bicolor* L. Moench) is widely used for food and fodder all over the world and is considered as fifth most important cereal crop after wheat, maize, rice and barley (Mehmood et al., 2008). So keeping in view the paucity of irrigation water and fodder, the present study was conducted to evaluate the effect of irrigation schedules of domestic wastewater on growth and yield of fodder sorghum and soil health.

MATERIALS AND METHODS

The study was conducted during kharif season (May to September 2013) in micro-plots (36, 2×2 m^2) at ICAR - Central Soil Salinity Research Institute, Karnal, Haryana (29°43'N, 76°58'E, 245 m above the mean sea level). Climate of experimental site is sub-tropical monsoon type and rainfall is received mainly during July to September. To characterize the chemical properties of soil, samples were taken from two soil depths (0-15 and 16-30 cm) before preparing the micro-plots for sowing. Multi-cut forage sorghum hybrid Raseela (MFSH-4, Mahyco Seed Company) was used as test crop in the study. The experiment was conducted in factorial randomized block design consisting of nine treatment combinations of three irrigation water quality levels (tube well water (TW), cyclic use of TW water : sewage water (SW), sewage water) and three irrigation schedules based on ID (irrigation depth) / CPE (cumulative pan evaporation) ratios (0.8, 1.0, 1.2) with four replications. The seeds of sorghum were sown on 7th May by Pora method with 8 rows in each micro-plot at 25 cm distance between the rows. Details of application of irrigation treatments are given in Table 1.

Table 1. Application of waste water scheduled at different ID/CPE ratios

Irrigation schedule	Total evaporation (mm)	Total rainfall (mm)	Irrigation water	No. of irrigation
0.8 (75 mm)	800.8	649.3	151.5	2.02
1.0 (60 mm)	800.8	649.3	151.5	2.52
1.2 (50 mm)	800.8	649.3	151.5	3.03

First cut was taken at 65 days after sowing while second cut was taken at 50 days after first cut. Parameters studied were plant height, number of leaves per plant, leaf area index, leaf to stem green and dry biomass, green fodder yield, dry matter content. Plant height of main shoot and number of leaves per plant were counted from five randomly selected plants in each plot and averaged. Leaf area was recorded by portable leaf area meter CI-202 and LAI (leaf area index) was calculated as:

$$LAI = \frac{\text{Average leaf area (cm}^2\text{) x No. of leaves x No. of plants}}{\text{Plot area}}$$

Fresh and dry weight of leaf and stem were recorded from five randomly selected plants, before separation of leaves and stems and reweighing. Samples were dried at room temperature for initial five days followed by in hot air oven at 60°C till constant weight was attained. Green fodder yield (kg/plot) of the crop was recorded in by harvesting around 8-10 cm above ground level. For dry fodder yield a random sample of 500 g fresh green fodder was taken from each plot at the time of harvesting, chopped and put into the aerated paper bags with small holes. The samples were dried at room temperature for a week and then at 60°C in hot air oven till constant weight was attained (AOAC, 2005). The green fodder yield was converted into dry fodder yield (t/ha), on the basis of dry matter content as below:

Dry matter (%) = (Weight of oven dry sample/ Weight of sample before drying) x 100

Dry fodder yield = (Fresh fodder yield x % Dry matter content) /100

Two-way analysis of variance was applied to assess the effects of treatments using Genstat 13 (GenStat® 13th Edition, VSN International limited) software.

RESULTS AND DISCUSSION

During cropping period the lowest (19.3ºC) and highest (44.2ºC) temperature was recorded in 18th (30 April - 6 May) and 21st week (21 - 27 May). The relative humidity varied from 45% (in 18th week) to 94% (in 32nd week). A total of 64.93 cm rainfall was received during the growing period and remaining water requirement of the crop was met by irrigation. The temperature prevailed during the study period favoured better growth of fodder sorghum (Fig. 1). The results of the soil analysis along with methods used for determination are presented in Table 2. Chemical composition of tube well water and wastewater used for irrigation is presented in Table 3.

The effect of irrigation water quality and schedules applied on the basis of ID/CPE ratio on plant height of sorghum is presented in Table 4. The plant height increased significantly (P<0.05) by using SW followed by TW:SW as compared to TW treatments. The increment in plant height by using SW was 3.1, 1.9 and 2.3% at 30, 45 and 65 DAS (days after sowing), respectively as compared with TW treatments. Plant height increased significantly (P<0.05) under wetter regimes of irrigation scheduled using ID/CPE ratios varying from 0.8 to 1.0 and further to 1.2.

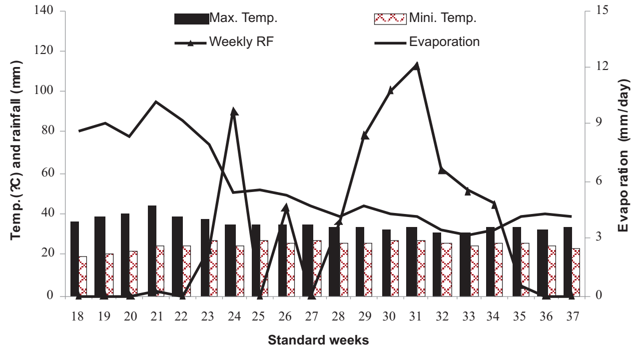

Fig. 1. Weekly rainfall, evaporation and temperature of experimental site (May - September 2013)

Table 2. Initial status of soil fertility, reaction and salinity

Particulars	Soil depth 0-15 cm	Soil depth 15-30 cm	Method used
Available nitrogen (kg/ha)	176.1-230.1	131.6-162.0	Modified alkaline potassium permanganate (Subbia h and Asija, 1956)
Available phosphorus (kg/ha)	30.03-47.56	19.38-30.55	0.5 N sodium bicarbonate extractable P (Olsen et al., 1954)
Available potassium (kg/ha)	234.9-295.3	169.8-217.9	Ammonium acetate extractable K (Jackson, 1967)
pH	8.31-8.45	7.52-8.85	1:2 soil: water suspension (Jackson, 1967)
Electrical conductivity (dS/m)	0.18-0.44	0.19-0.50	1:2 soil: water supernatant solubridge (Jackson, 1967)

Table 3. Quality of tube well and treated waste water

Parameter	Tube well water	Wastewater	Maximum concentration for irrigation
pH(0-14)	7.7	8.2	6.5-8.0
Electrical conductivity (dSm^{-1})	0.6	1.3	<3.0
Residual sodium carbonate (meq L^{-1})	1.6	2.8	2.5
Sodium absorption ratio	1.7	4.6	9.0
Biological oxygen demand (mg L^{-1})	Traces	62	<100
Chemical oxygen demand (mg L^{-1})	Traces	112	-
Nitrogen (mg L^{-1})	Traces	18	-
Phosphorous (mg L^{-1})	0.3	4.3	-
Potassium (mg L^{-1})	3.5	17	-
Cadmium (mg L^{-1})	Traces	0.1	0.01
Chromium (mg L^{-1})	Traces	0.3	0.1
Nickel (mg L^{-1})	Traces	0.3	0.2
Lead (mg L^{-1})	Traces	1.2	5.0

The increments in plant heights with irrigation being scheduled at ID/CPE ratio of 1.2 in comparison to that of ID/CPE ratio of 0.8 were 2.6, 2.1 and 2.7% at 30, 45 and 65 DAS, respectively. Gowri (2005) observed that growth parameters of the crop plants decrease with increasing severity of water stress. It has been also reported that water deficit manifest many anatomical changes in the plant which includes decrease in cell size, cell division and cell elongation, intercellular space and thickening of cell wall and there by limit overall plant growth. In the present study we have also observed decrease in height of sorghum plants at different growth intervals similar under drier irrigation regimes scheduled at decreasing ID/CPE ratio from 1.2 to 0.8.

Table 4. Periodic increase in sorghum plant height of sorghum as affected by irrigation water quality and their schedules based on ID/CPE ratio

Irrigation schedule	Water quality on DAS									Average on DAS		
	TW			TW:SW			SW					
	30	45	65	30	45	65	30	45	65	30	45	65
0.8	138.1	203.3	232.6	141.9	205.6	235.9	143.3	207.1	237.3	141.1[a]	205.3[a]	235.2[a]
1.0	141.3	205.6	235.9	143.5	208.2	238.4	145.6	209.9	240.0	143.4[b]	207.9[b]	238.1[b]
1.2	143.0	207.7	237.7	144.6	209.7	242.5	146.7	211.5	244.8	144.8[b]	209.6[c]	241.7[c]
Average	140.8[a]	205.5[a]	235.4[a]	143.3[b]	207.8[b]	238.9[b]	145.2[b]	209.5[c]	240.7[c]			
LSD (P=0.05)	1.715	0.908	1.313		WQ/IS		2.971	1.572	2.274		WQ*IS	

*WQ*IS - Interaction between water quality and irrigation schedules; Different superscripts represent significant difference among different treatments*

There was an increase in number of leaves per plant at progressive growth periods of the sorghum crop under the influence of irrigation with different treatments of water quality (Table 5). There was no significant difference in the number of leaves at 30 and 45 DAS in all the water quality treatments (TW, TW:SW and SW) however, cyclic use of TW:SW and SW treatments recorded a significant (LSD=0.055) increase in number of leaves per plant as compared to control (TW) at 65 DAS. Irrespective of water quality, wetter irrigation schedule regimes, using increasing ID/CPE ratio from 0.8 to 1.0 and 1.2 increased numbers of leaves per plant. Irrigation scheduled at 1.2 ID/CPE increased number of leaves per plant by 3.3, 1.2 and 1.3% at 30, 45 and 65 DAS, respectively, as compared to the driest irrigation regime scheduled at 0.8 ID/CPE. ID/CPE ratio of 1.0 and 1.2 had no significant difference with each other, although it differed significantly to that of 0.8 at 30 DAS. The observations suggest that there was no significant difference in the number of leaves in all the ID/CPE ratios at 45 DAS, however, the number of leaves increased significantly (LSD = 0.055) from ID/CPE ratio 0.8 to 1.0 and the further to 1.2 at 65 DAS.

Table 5. Changes in number of leaves per plant of sorghum at different growth periods as affected by water quality and irrigation regimes

Irrigation schedule	Water quality on DAS									Average on DAS		
	TW			TW:SW			SW					
	30	45	65	30	45	65	30	45	65	30	45	65
0.8	8.30	10.93	11.44	8.34	11.04	11.50	8.42	11.06	11.55	8.35[a]	11.01[a]	11.49[a]
1	8.55	11.05	11.52	8.60	11.09	11.56	8.68	11.14	11.63	8.61[b]	11.09[a]	11.57[b]
1.2	8.58	11.13	11.59	8.63	11.15	11.65	8.70	11.17	11.70	8.63[b]	11.15[a]	11.65[c]
Average	8.48[a]	11.04[a]	11.51[a]	8.52[a]	11.09[a]	11.57[a]	8.60[a]	11.12[a]	11.62[b]			
LSD (P=0.05)	0.135	0.145	0.055		WQ/IS		0.234	0.252	0.096		WQ*IS	

*WQ*IS - Interaction between water quality and irrigation schedules; Different superscript represents significant difference among different treatment*

The leaf area index of sorghum was affected by different levels of irrigation water quality (Table 6). The leaf area index ranged significantly (P<0.001) from 3.53 (TW irrigation) to 3.98 (SW irrigation) at first cut. The results obtained have also shown that LAI increased significantly in both the treatments where sewage was used for irrigation in comparison to sole tube well water irrigation. Nadia (2005) reported similar observations of significant increase in LAI of sorghum irrigated with sewage water. In various ID/CPE treatments, there was a significant (P<0.001) reduction in LAI when irrigation was scheduled at 1.0 and 0.8 ID/CPE ratios as compared to 1.2 ID/CPE ratio. The highest LAI of 3.9 was achieved when irrigation was scheduled at ID/CPE ratio of 1.2, while the lowest LAI of 3.6 was observed at an ID/CPE ratio of 0.8. The highest LAI under ID/CPE ratio of 1.2 could be due to the adequate availability of water throughout the growth period.

Table 6. Effect of water quality and their irrigation regimes on leaf area index of sorghum

Irrigation schedule	TW	TW:SW	SW	Average
0.8	3.31	3.63	3.90	3.61
1	3.51	3.77	3.99	3.76
1.2	3.79	3.89	4.04	3.90
Average	3.53	3.76	3.98	
LSD (P = 0.05)	0.058	WQ/IS	0.1004	WQ*IS

The effect of irrigation water quality on sorghum green fodder yield becomes evident from increased biomass production at both cuts (Fig. 2a,b). Irrigation with continuous SW produced the highest green fodder yield at 1^{st} (31.31 t/ha) and 2^{nd} cut (21.6 t/ha), whereas, TW irrigation recorded the lowest green fodder yield at 1^{st} (27.37 t/ha) and at 2^{nd} (17.16 t/ha). Alternate irrigations using TW and SW recorded the intermediate fresh fodder yield and at par with TW irrigation. The increase in green fodder yield in SW irrigation was 14.39 % at 1^{st} and 25.0 % at 2^{nd} cut of sorghum as compared to sorghum green fodder yield realized with TW irrigation. Nadia (2005) also reported increase in sorghum yield with use of wastewater for irrigation during whole growth period rather than tube well water and might be due to higher amount of nitrate in municipal treated wastewater. Green fodder yield was highest under irrigation at ID/CPE ratio 1.2 followed by 1.0 and 0.8. The highest green fodder yield observed at ID/CPE ratio 1.2 at 1^{st} and 2^{nd} cut was 31.31 t/ha and 21.64 t/ha, respectively. The lowest green fodder yield of 27.24 and 17.15 t/ha at 1^{st} and 2^{nd} cut, respectively was observed with irrigation schedule of ID/CPE ratio 0.8. The increment in green fodder yield at 1.2 compared to 0.8 was 15.3% at 1st cut (P<0.001) and 20.7% at 2nd cut (P<0.001). Green fodder yield increased significantly both at ID/CPE 1.0 and 1.2 as compared to 0.8. This might be due to better moisture availability at ID/CPE ratios of 1.0. Reduction in yield attributes and yield with drier irrigation regime of ID/CPE ratio 0.6 was reported by Velu and Palaniswamy (2001) which might be due to insufficient moisture availability leading to lower cell elongation and cell division activities.

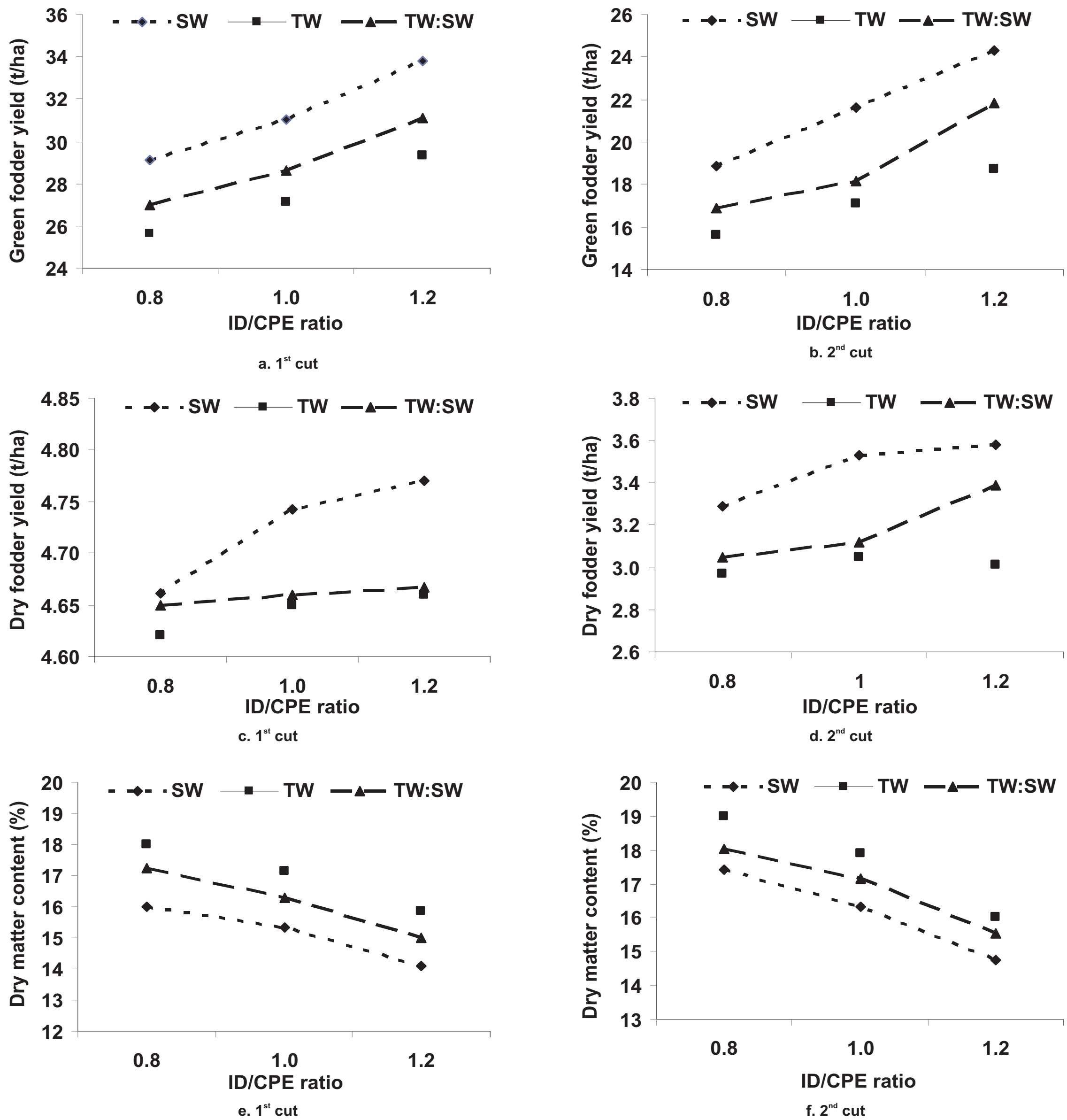

Fig. 2. Fodder yield and dry matter content of sorghum on different schedules and regimes of irrigation using sewage and tube well water

Across the irrigation water quality treatments, dry fodder yield increased with gradual switch over from TW to SW irrigation at both the cuts (Fig. 2c,d). The highest dry fodder yield recorded with SW irrigation at 1st (4.72 t/ha) and at 2nd cut (3.46 t/ha), whereas, the lowest dry fodder yield recorded with TW irrigation at 1st (4.64 t/ha) and 2nd (3.02 t/ha). Irrigation with SW produced 1.72% higher dry fodder yield at 1st cut and 15.14% at 2nd cut compared to TW. Cogger et al. (2001) advocated the application of 30-40% of sewage sludge as it could be mineralized during the 1st year of application and assumed to supply organic nitrogen. Therefore, when sewage sludge applied to soil, it provides nitrogen to crops for more than a year because mineralization will take place for long period and also nitrogen losses will be limited. Dry fodder yield increased with gradual increase in ID/CPE ratio from 0.8 to 1.2 (Fig. 2b). The highest dry fodder yields recoded at ID/CPE ratio 1.2 at 1st and 2nd cut were 4.70 t/ha and 3.32 t/ha, respectively. However, the least dry fodder yields of 4.64 and 3.10 t/ha at 1st and 2nd cut, respectively were found at ID/CPE ratio 0.8. The increase in yield observed at ID/CPE 1.2 compared to 0.8 was 1.20 % at 1st cut and 7.25 % at 2nd cut, respectively. Keskin et al. (2009) also reported the increase in dry matter yield with the application of chemical N fertilizer and sewage sludge as compared to control.

There was a significant reduction in dry matter content at 1st ($P<0.001$) and at 2nd cut under SW irrigation (Figs. 2e,f) and could possibly be due to presence of higher contents of nutrients in SW which leads to luxurious growth and thus decreased in dry matter content. The dry matter content was highest at ID/CPE ratio of 0.8 and was 17.09 % and 18.13 % higher at 1st and 2nd cut, respectively. The dry matter content decreased under wetter irrigation regimes. This reduction was 12.2% at 1st cut ($P<0.001$) and 14.9% at 2nd cut ($P<0.001$) at the wettest irrigation regime scheduled at ID/CPE ratio of 1.2 as compare to .08 ID/CPE ratio. This lower content of dry matter in wetter irrigation regimes could ascribed be to application of higher number of irrigations causing more water uptake with more availability in soil leading to more turgid cells (Saini, 2012).

Economic analysis of cost of cultivation, gross returns, net returns and benefit cost ratio (B: C) in various treatments of water quality are presented in Table 7. Cost of cultivation was considered same for all the waste water treatments because of natural availability of waste water. In case of different schedules of ID/CPE ratios the highest cost of cultivation (Rs. 30238.9/ha) was recorded for 1.2 ID/CPE ratio. Maximum B:C ratio (0.92) was obtained for the fodder grown using the sewage water irrigation and 1.2 ID/CPE ratio and the lowest B: C ratio (0.40) was found for tube well water irrigation and 0.8 ID/CPE and might be due to higher grain yield with higher irrigation level. Sumathi and Koteswara Rao (2007) also reported the higher net returns and B: C ratio when irrigation was scheduled at IW: CPE ratio 1.0, among the various irrigation schedules in sunflower.

Table 7. Economics of cultivation of fodder sorghum with different levels of water quality and different ID/CPE ratio

Treatment Water quality	ID/CPE	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
TW	0.8	29481.4	41300.0	11818.6	0.40
TW	1.0	29856.4	44187.5	14331.1	4.80
TW	1.2	30238.9	48112.5	17873.6	0.59
TW:SW	0.8	29481.4	43880.0	14398.6	0.49
TW:SW	1.0	29856.4	46806.2	16949.8	0.57
TW:SW	1.2	30238.9	52937.5	22698.6	0.75
SW	0.8	29481.4	48003.1	18521.7	0.63
SW	1.0	29856.4	52631.2	22774.8	0.76
SW	1.2	30238.9	58106.2	27867.3	0.92

(TW- Tube well water); SW- Sewage water

The results showed that irrigation with sewage water and scheduling at 1.2 ID/CPE ratio lead to significant increase in plant height, number of leaves per plant, leaf area index, green fodder yield and significant decrease in dry matter content, as compared to tube well water and 0.8 and 1.0 ID/CPE ratios, respectively. Continuous use of sewage for irrigation tended to increase soil EC whereas decreased soil pH. Thus, the use of wastewater can effectively contribute in recycling the nutrients present in the wastewater and also filling the increasing gap between water demand and water availability particularly in semi-arid areas, along with minimizing the side effects on the quality of downstream water resources.

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