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Growth, Yield and Water Productivity of Sorghum Influenced by Saline Water Irrigation and Management Practices

Korla Aditya Chowdary
Student, Water Technology Centre, College of Agriculture, Rajendranagar, Hyderabad, AP, India
Makam Umadevi
Director, Water Technology Centre, College of Agriculture, Rajendranagar, Hyderabad, AP, India
Veeramalla Ramulu
Principal Scientist, Water Technology Centre, College of Agriculture, Rajendranagar, Hyderabad, AP, India
Kodary Avil Kumar
Principal scientist, Water Technology Centre, College of Agriculture, Rajendranagar, Hyderabad, AP, India

Abstract:
The progressive decrease of fresh water resources is leading towards the inevitable use of saline water for irrigation purpose. With the use of saline waters for irrigation, there is need to undertake appropriate management practices to prevent the development of excessive soil salination for crop production. A field experiment was carried out to investigate the effect of saline water irrigation and management practices on growth and yield of sorghum. The crop showed significant response to quality of irrigation water and management practices. It was noticed that during early stages of growth (30 DAS) all main treatments, sub treatments and their interactions were found to be significant. At 60 DAS the main treatment effect was not significant. At 90 DAS only management practices had significant effect on dry matter production. At harvest the interaction effect were found to be not significant. The yield of sorghum was significantly influenced by water quality levels, management practices and their interaction. The highest grain and stover yield was recorded in C_2-FYM followed by C_3-FYM and C_3/C_4-FYM treatments. The water productivity was highest in C_2-FYM followed by C_3-FYM and C_3/C_4-FYM.

Keywords: *Saline water, management practices, dry matter, grain yield, water productivity*

1. Introduction

World growth in population demands more food and fiber. The need for food and fiber production necessitates water to be used more efficiently in irrigated agriculture. However, the scarcity of fresh water is limiting irrigation development. The scarcity of fresh water restricts sustainable agricultural development in arid regions. At the same time, the quality of irrigation water has also deteriorated. As a result, deficit irrigation and saline water irrigation have been used more prevalently in agriculture to overcome drought and sustain crop yields (Oron *et al.,* 1999). Salt stress in arid and semi-arid regions is one of the major stresses that can severely limit plant growth and productivity (Sharma and Rao, 1998).

Overcoming salt stress is a main issue in these regions to ensure agricultural sustainability and crop production. With the use of saline waters for irrigation, there is need to undertake appropriate practices to prevent the development of excessive soil salination for crop production. Management practices for the control of salinity include: selection of crops or crop varieties that will produce satisfactory yields under the resulting conditions of salinity (Francois *et al.,* 1984), use of land-preparation and planting methods that aid in the control of salinity (Bezborodov *et al.,* 2010); (Ghane *et al.,* 2009), irrigation procedures (Wan *et al.,* 2007) that maintain a relatively high soil-moisture regime and that periodically leach accumulated salts from the soil and maintenance of water conveyance and drainage systems and cultural practices like application of organic manures (Kahlown and Azam, 2003). The crop type, the water quality and the soil properties determine, to a large degree, the management practices required to optimize production.

Sorghum is moderately salt tolerant, and is a C_4 grass that is well adapted to semi-arid and arid regions where salinity is the major problem. Moreover, this grain crop is the fifth most important cereal grown worldwide, due in large parts to its unusual tolerance to adverse environmental conditions. So here an attempt has been made to determine the effect of saline water irrigation in conjunction with different management practices on sorghum growth, yield and water productivity.

2. Material and Methods

The experiment was carried out at the Water Technology Centre, College Farm, College of Agriculture, Rajendranagar, Hyderabad (Latitude $17^0 19'$ 19.2" N, Longitude $78^0 24'$ 39.2" E during winter (*rabi*) season, 2012-2013. During the crop growth period (26-10-2012 to 26-02-2013) the mean weekly maximum temperature ranged from 24 to 34 ºC with an average of 29.7 ºC and the mean weekly minimum temperature ranged from 11 to 19 ºC with an average of 15.7 ºC. The soil of experimental site was sandy clay loam in texture, medium alkaline in reaction (pH: 8.24) and non-saline (EC: 0.22 dS m^{-1}) with SAR value of 0.82. The experiment was laid out in strip plot design with four main treatments, four sub treatments and three replications. The main treatments comprised of M_1: irrigation with C_2 quality (good) water, M_2: irrigation with C_3 quality (marginal) water, M_3: irrigation with C_4 quality (poor) water and M_4: alternate irrigations with C_3 followed by C_4. The sub treatments comprised of – S_1: control (no organic manure and magnetic treatment), S_2: FYM @ 10 t ha^{-1}, S_3: green manuring (Sunnhemp) *in situ* and S_4: magnetic treatment to irrigation water. The source of C_3 water for irrigating the crop was from an open well No. 2 and C_4 water from an open well No. 5 of College Farm, Rajendranagar and C_2 water obtained from *Hyderabad Metropolitan Water* Supply and Sewerage Board (HMWSSB), Budvel. The farym yard manure was applied fifteen before date of sowing of crop and green manure was grown upto flowering and incorporated twenty days before date of sowing of crop.Sorghum variety CSV-216 R was sown on 26^{th} October adopting a spacing of 40 x 15 cm.

Dry matter production was recorded at 30, 60, 90 DAS and harvest. Five plants harvested from each net plot for estimation of dry matter accumulation. The roots were clipped off from each selected plant, remainder and along with leaves transferred to properly labeled brown paper bags and partially dried in sun, later subjected to oven drying at 60 ^{0}C to constant weight. Ear heads from net plot was harvested at maturity, air dried, threshed, cleaned, weighed, grain yield $ha^{-}1$ was worked out and expressed in t ha^{-1}. Stover yield of sorghum was recorded after complete sun drying of the stalks harvested from net plot area and expressed in t ha^{-1}. The amount of water applied under each irrigation treatment was measured through water meters. The effective rainfall received in the crop growth period was added to this and expressed as total depth of water applied in m^3. A total amount 431.5 mm of water was consumed by crop consisting 360.5 mm applied water and effective rainfall was 70.6 mm received during crop growth period. Water productivity is the ratio of economic yield (grain) that can be produced to the unit quantity of water.

3. Results and Discussion

3.1. Total Dry Matter Production

At 30 DAS, among water quality levels the highest dry matter production was recorded by irrigation with C_2 (good) quality water (4.35 g $plant^{-1}$) which has on par with irrigation with C_3 (marginal) quality water (4.16 g $plant^{-1}$) and both were significantly higher over alternate irrigation C_3 followed by C_4 (poor) quality (3.8 g $plant^{-1}$) and irrigation with C_4 quality (3.64 g $plant^{-1}$). It was noticed that irrigation with C_2, C_3 and C_3/C_4 resulted in 19, 14 and 4 % increase in dry matter production when compared to irrigation with C_4 quality. Among management practices, application of FYM @ 10 t ha^{-1} has recorded significantly the highest dry matter (5.06 g $plant^{-1}$). It was followed by green manuring *in situ* (sunnhemp) (4.17 g $plant^{-1}$) which were on par with magnetic treatment (3.69 g $plant^{-1}$) and significantly higher over control (3.02 g $plant^{-1}$) where no management practices were followed. The magnetic treatment was on par with control. Among the interactions, higher dry matter was recorded by C_2-FYM (5.81 g $plant^{-1}$) followed by C_3-FYM (5.40 g $plant^{-1}$) which were on par with each other and significantly higher over other interactions. The lowest dry matter was observed in C_4-Control (2.62 g $plant^{-1}$). The data pertaining to dry matter was given in Table 1.

At 60 DAS, effect of water quality was found to be non significant and it ranges from 25.31 to 26.50 g $plant^{-1}$. It was noticed that the irrigation with C_2, C_3 and C_3/C_4 resulted in 8, 3 and 2 % increase in dry matter when compared to irrigation with C_4 quality. Among management practices, the highest dry matter was recorded by FYM @ 10 t ha^{-1} (28.78 g $plant^{-1}$) which was significantly higher over GM, MT and control. The other treatments GM and MT were also significantly higher over control (21.87 g $plant^{-1}$). Among the interactions, the highest dry matter was recorded by C_2-FYM (29.91 g $plant^{-1}$) which was significantly higher over other treatments. It was followed by C_4-FYM (28.76 g $plant^{-1}$). Significantly lower dry matter was recorded by C_4- control (20.50 g $plant^{-1}$). The data pertaining to dry matter was given in Table 1.

At 90 DAS, only the management practices showed significant influence, where as the water quality and their interaction effects were found to be non significant. It ranges from 34.50 to 36.13. It was noticed that the irrigation with C_2, C_3 and C_3/C_4 resulted in 5, 3 and 1 % increase in dry matter when compared to irrigation with C_4 quality. Among management practices, the highest dry matter was recorded by FYM @ 10 t ha^{-1} (38.53 g $plant^{-1}$) and was significantly higher over GM, MT and control. GM and MT treatments also recorded significantly higher dry matter over control (31.87 g $plant^{-1}$). The interaction effect was found to be non significant. It ranges from 30.76 to 39.53 g $plant^{-1}$. The highest dry matter was recorded by C_3-FYM and the lowest dry matter recorded by C_4- control. The data pertaining to dry matter was given in Table 1.

At harvest, among water quality levels the highest dry matter was recorded by irrigation with C_2 quality (62.37 g $plant^{-1}$) which was on par with C_3 quality (61.12 g $plant^{-1}$). It was noticed that the irrigation with C_2, C_3 and C_3/C_4 resulted in 6, 3 and 1 % increase in dry matter when compared to irrigation with C_4 quality. Among management practices, the highest dry matter was recorded by FYM @ 10 t ha^{-1} (66.89 g $plant^{-1}$) which was significantly higher over GM, MT and control. The other treatments GM and MT were also significantly higher over control (53.98 g $plant^{-1}$). The interaction effect was found to be non significant. It ranges from 52.63 to 69.20 g $plant^{-1}$. The data pertaining to dry matter was given in Table 1. The application of saline water resulted in decreased dry matter production when compared to good quality water which might be due to excess salt accumulation in the root zone. Similar results were also obtained by Katerji *et al.* (1996) in maize and sunflower, Irshad *et al.* (2002) and Kang *et al.* (2010) in waxy maize crop.

The combined application of less saline water and FYM resulted in increased dry matter production. This could be due to less ion toxicity and more photosynthetic rate in turn resulting in more dry matter production. Materials like organic manures such as FYM and green manure *in situ* can absorb a part of soluble salts are known to improve the soil physical conditions, because of their exchange capacities, decrease the pH due to release of organic acids, and promote aggregation of soil might have resulted in higher dry matter production in these treatments.

3.2. Stover Yield

The effect of main treatments, sub treatments and their interactions were found to be significant. Among water quality levels, it was noticed that the irrigation with C_2, C_3 and C_3/C_4 resulted in 6, 5 and 2 % increase in stover yield when compared to irrigation with C_4 quality. Among management practices, application of FYM @ 10 t ha^{-1}, green manuring *insitu* (sunn hemp) and magnetic treatment to irrigation water resulted in 30, 24 and 12 % increase in stover yield when compared to no management practices. Among the interactions, the highest stover yield was recorded by C_2-FYM (5.85 t ha^{-1}) which was significantly higher over other treatments and on par with C_3-FYM (5.75 t ha^{-1}). The lowest stover yield was recorded by C_4- control (4.33 t ha^{-1}). Application of FYM along with good quality water, might have recorded higher yields, because of better supply of nutrients to crop under congenial environment leading to better root activity and higher nutrient absorption. The stover yield of crop reduced as the salinity of water was increased. Application of mulch material or manures increased the stover yield when compared to control. This was mainly might be due to decreased salinity in the root zone which resulted in higher stover yields. Similar trend was observed by Hamed *et al.* (2010) in sorghum. The lower stover yields in treatment with poor quality water could be due to existence of high salt concentration near root zone in poor quality irrigation. The similar results were obtained by De Pascale *et al*. (2003) in vegetables and Amer (2010) in corn. The data was given in Table 2 and figure 1.

3.3. Grain Yield

The effect of main treatments, sub treatments and their interactions were found to be significant. Among water quality levels, significantly the highest grain yield was recorded by irrigation with C_2 quality (1.67 t ha^{-1}) which was followed by irrigation with C_3 quality water (1.56 t ha^{-1}). The lowest grain yield was observed in irrigation with C_4 quality (1.35 t ha^{-1}). It was noticed that the irrigation with C_2, C_3 and C_3/C_4 resulted in 24, 16 and 8 % increase in grain yield when compared to irrigation with C_4 quality. Among management practices, the highest grain yield was recorded by FYM @ 10 t ha^{-1} (2.13 t ha^{-1}) which was significantly higher over GM, MT and control. The other treatments GM and MT were also significantly higher over control (0.93 t ha^{-1}). Among the interactions, the highest grain yield was recorded by C_2-FYM (2.35 t ha^{-1}) which was significantly higher over other treatments and followed by C_3-FYM (2.19 t ha^{-1}). The lowest grain yield recorded by C_4- control (0.82 t ha^{-1}). Grain yield can be increased by using different amendments which control the root zone salinity. Higher grain yield can be obtained by using FYM as a management practice. Khan *et al.* (2010) in wheat crop also obtained the same result by using FYM as a management practice. The yield of cyclic irrigation was better than C_4 quality might be due to the stress exerted by saline water was relieved for some time. The same results were obtained by Phogat *et al.* (2011) in wheat and pearl millet. Salinity in the manured plots was relatively less than control plot, which caused less osmotic stress on the crop and assisted in improving growth and yield. This coincides with Bezborodov *et al.* (2010) in cotton crop. The data was given in Table 2 and figure 1.

3.4. Water Productivity

The effect of main treatments, sub treatments and their interactions were found to be significant. Among water quality levels, the significantly the highest water productivity of sorghum grain was recorded by irrigation with C_2 quality (0.410 kg m^{-3}) which was followed by C_3 quality (0.361 kg m^{-3}). The lowest water productivity was observed in C_4 (0.301 kg m^{-3}). Among management practices, the highest water productivity was recorded by FYM @ 10 t ha^{-1} (0.495 kg m^{-3}) which was significantly higher over GM, MT and control. The other treatments GM and MT were also significantly higher over control (0.216 kg m^{-3}). Among the interactions, the highest water productivity was recorded by C_2-FYM (0.576 kg m^{-3}) which was followed by C_3-FYM (0.503 kg m^{-3}). The lowest water productivity was recorded by C_4- control (0.183 kg m^{-3}). Therefore, in addition to increase in crop yield, application of organic manures decreases the amount of water used in the production process and increases crop water productivity substantially (Bezborodov *et al.,* 2010). The data was given in Table 2 and figure 1.

	30 DAS					**60 DAS**				
Treatments	Control	FYM	GM	MT	Mean	Control	FYM	GM	MT	Mean
C_2	3.35	5.81 (73)*	4.31 (29)	3.92 (17)	4.35 (19)	23.12	29.91 (29) *	27.57 (19)	25.78 (12)	26.60 (8)
C_3	3.27	5.40 (65)	4.17 (28)	3.79 (16)	4.16 (14)	22.36	27.86 (25)	26.66 (19)	25.25 (13)	25.53 (3)
C_4	2.62	4.43 (69)	4.05 (55)	3.45 (32)	3.64	20.50	28.76 (40)	26.54 (29)	23.14 (13)	24.74
C_3/C_4	2.83	4.60 (63)	4.13 (46)	3.62 (28)	3.80 (4)	21.48	28.58 (33)	27.22 (27)	23.94 (11)	25.31 (2)

Mean	3.02	5.06 (67)	4.17 (38)	3.69 (22)		21.87	28.78 (32)	27.00 (23)	24.53 (12)	
	S.Em (±)		C.D (P=0.05)			S.Em (±)		C.D (P=0.05)		
W	0.06		0.22			0.41		NS		
M	0.22		0.75			0.23		0.79		
W at same M	0.14		0.43			0.39		1.16		
M at same W	0.14		0.43			0.53		1.73		
90 DAS						**Harvest**				
C_2	33.03	39.38 (19)*	37.00 (12)	35.11 (6)	36.13 (5)	55.33	69.20 (25)*	64.88 (17)	60.05 (9)	62.37 (6)
C_3	32.06	39.53 (23)	36.04 (12)	34.53 (8)	35.54 (3)	54.58	66.81 (22)	63.10 (16)	59.98 (10)	61.12 (3)
C_4	30.76	37.95 (23)	36.07 (17)	33.21 (8)	34.50	52.63	65.74 (25)	61.32 (17)	56.60 (8)	59.07
C_3/C_4	31.61	37.25 (18)	36.11 (14)	34.07 (8)	34.76 (1)	53.39	65.82 (23)	62.33 (17)	57.94 (9)	59.87 (1)
Mean	31.87	38.53 (21)	36.31 (14)	34.23 (7)		53.98	66.89 (24)	62.91 (17)	58.64 (9)	
	S.Em (±)		C.D (P=0.05)			S.Em (±)		C.D (P=0.05)		
W	0.39		NS			0.41		1.44		
M	0.34		1.18			0.19		0.67		
W at same M	0.53		NS			0.43		NS		
M at same W	0.61		NS			0.56		NS		

Table 1: Effect of saline water irrigation and management practices on dry matter (g plant $^{-1}$) of rabi Jowar at 30, 60, 90 DAS and at harvest

* Figures in parenthesis indicate the percent of increase over control

W: Water quality (Main Treatments)
C_2: Irrigation with C_2 quality (good) water
C_3: Irrigation with C_3 quality (marginal) water
C_4: Irrigation with C_4 quality (poor) water
C_3/ C_4: Alternate irrigations with C_3 followed by C_4

M: Management practices (Sub Treatments)
M_1: Control (No organic manure and magnetic treatment)
M_2: FYM @ 10 t ha^{-1}
M_3: GM: Green manuring *in situ*. (Sunnhemp)
M_4: MT: Magnetic treatment to irrigation water

	Yield (t ha^{-1})										Water productivity (kg m^{-3})				
	Stover					Grain									
Treatments	Control	FYM	GM	MT	Mean	Control	FYM	GM	MT	Mean	Control	FYM	GM	MT	Mean
C_2	4.56	5.85 (28)*	5.67 (24)	5.21 (14)	5.32 (6)	1.04	2.35 (2.3)*	1.86 (79)	1.44 (39)	1.67 (24)	0.253	0.576 (2.2)*	0.456 (1.8)	0.353 (1.4)	0.410 (1.4)
C_3	4.51	5.75 (27)	5.57 (23)	5.20 (15)	5.26 (5)	0.97	2.19 (2.3)	1.77 (83)	1.33 (38)	1.56 (16)	0.223	0.503 (2.3)	0.410 (1.8)	0.306 (1.4)	0.361 (1.2)
C_4	4.33	5.73 (32)	5.36 (24)	4.66 (8)	5.02	0.82	1.92 (2.3)	1.54 (88)	1.13 (38)	1.35	0.183	0.430 (2.4)	0.340 (1.8)	0.250 (1.4)	0.301
C_3/C_4	4.41	5.74 (30)	5.48 (24)	4.82 (9)	5.11 (2)	0.90	2.06 (2.3)	1.63 (82)	1.24 (38)	1.46 (8)	0.206	0.470 (2.3)	0.373 (1.8)	0.280 (1.4)	0.332 (1.1)
Mean	4.45	5.77 (30)	5.52 (24)	4.97 (12)		0.93	2.13 (2.3)	1.70 (83)	1.28 (38)		0.216	0.495 (2.3)	0.395 (1.8)	0.297 (1.4)	
	S.Em (±)		C.D (P=0.05)			S.Em (±)		C.D (P=0.05)			S.Em (±)		C.D (P=0.05)		
W	0.04		0.13			0.01		0.04			0.003		0.011		
M	0.02		0.06			0.01		0.05			0.003		0.011		
W at same M	0.03		0.10			0.02		0.06			0.004		0.013		
M at same W	0.05		0.15			0.02		0.06			0.005		0.016		

Table 2: Effect of saline water irrigation and management practices on stover, grain yield (t ha^{-1}) and water productivity (kg m^{-3}) at harvest of rabi Jowar

* Figures in parenthesis indicate the percent of increase over control

W: Water quality (Main Treatments)
C_2: Irrigation with C_2 quality (good) water
C_3: Irrigation with C_3 quality (marginal) water
C_4: Irrigation with C_4 quality (poor) water
C_3/C_4: Alternate irrigations with C_3 followed by C_4

M: Management practices (Sub Treatments)
M_1: Control (No organic manure and magnetic treatment)
M_2: FYM @ 10 t ha^{-1}
M_3: GM: Green manuring *in situ*. (Sunnhemp)
M_4: MT: Magnetic treatment to irrigation water

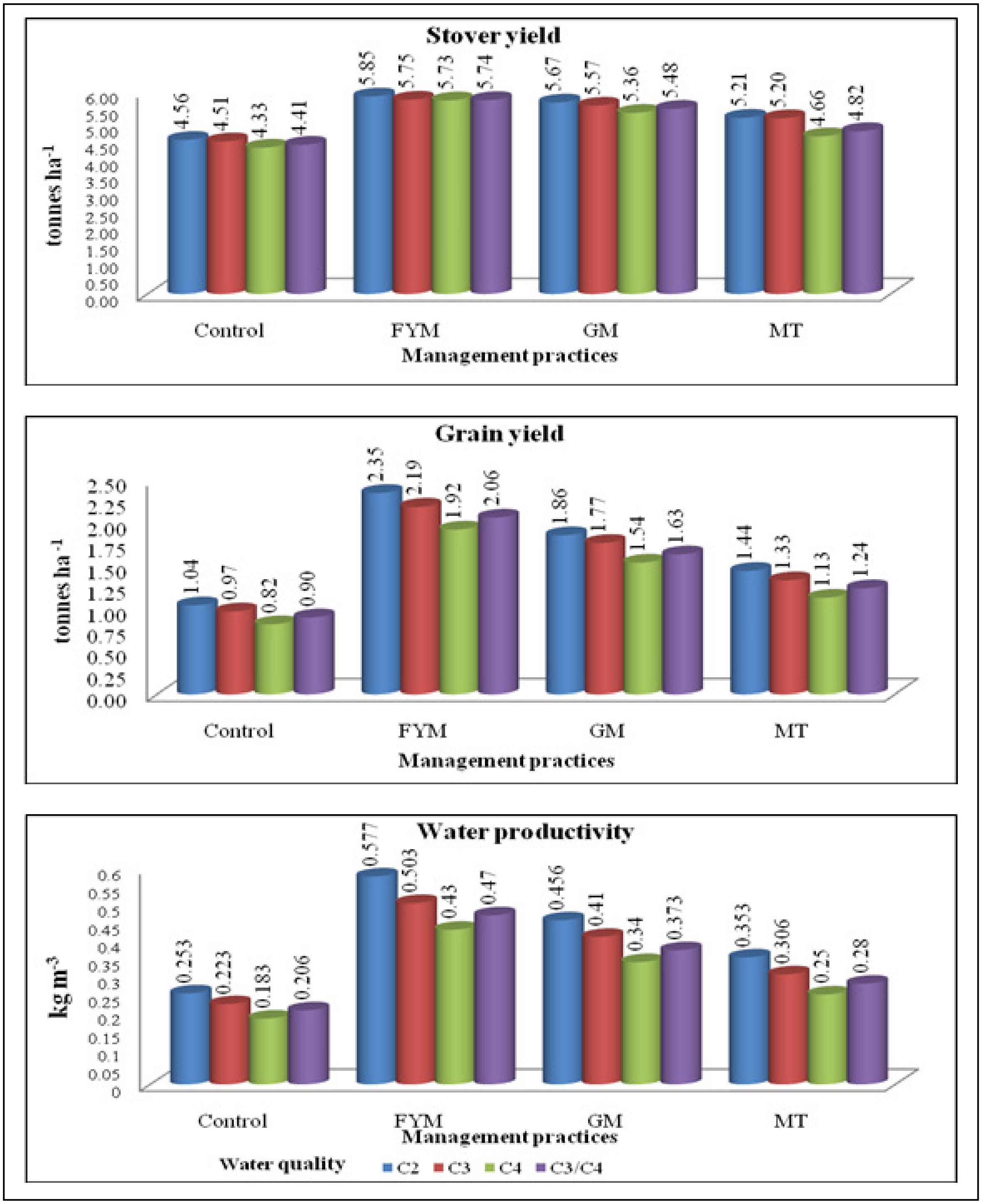

Figure 1: Effect of saline water irrigation and management practices on stover yield, grain yield (t ha^{-1}) and water productivity (kg m^{-3}) of rabi Sorghum

W: Water quality (Main Treatments):
C_2: Irrigation with C_2 quality (good) water
C_3: Irrigation with C_3 quality (marginal) water
C_4: Irrigation with C_4 quality (poor) water
C_3/C_4: Alternate irrigations with C_3 followed by C_4

M: Management practices (Sub Treatments):
M_1: Control (No organic manure and magnetic treatment)
M_2: FYM @ 10 t ha^{-1}
M_3: GM: Green manuring *in situ*. (Sunnhemp)
M_4: MT: Magnetic treatment to irrigation water

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