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Uptake of primary and secondary nutrients of sorghum under irrigation with different qualities of water

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ABSTRACT

The gradual decrease of fresh water resources is leading towards the inevitable use of saline water for irrigation. Using saline waters for irrigation, there is needed to take management practices to prevent the development of excessive soil salinisation for crop production. A field experiment was carried out to investigate the effect of saline water irrigation and management practices on uptake of primary and secondary nutrients. At harvest, the significantly highest total N, K, S and Mg uptake was recorded by C_2-FYM, followed by C_3-FYM and C_3/C_4-FYM. Regarding P and Ca total uptake, among water quality levels, the significantly highest uptake was recorded by C_2 water followed by C_3 water and alternate irrigation with C_3/C_4 water. Among management practices, significantly the highest total P and Ca uptake was recorded by FYM application, followed by green manure treatment. However, the interaction effect was found to be non significant in case of P and Ca uptake.

Key words: *saline water; water quality; management practices; nutrient uptake*

INTRODUCTION

One of the major problems confronting irrigated agriculture nowadays throughout the world is the decreasing availability of fresh water. In many countries and regions, fresh water is relatively scarce, but there are considerable resources of saline water, which could be utilized for irrigation if proper crops, soil and water management practices were established. That soluble Ca, Mg and Na increased with increasing salinity level of irrigation water, while soluble K decreased with increasing salinity levels[1]. But soluble Ca and Na increased with decreasing irrigation frequency, while increasing salinity levels and irrigation frequency decreased the hazardous effects. The combined effects of salinity and sodicity were greater than salinity alone. Ragab *et al.*[12] concluded that the lowest N and P uptake were found in sandy soil with salinity levels (8.86 dS m^{-1}) and substantial decrease of K: Na ratio of wheat was found with increasing water salinity levels. The Na and Cl concentrations increased in salinized plants where as nitrogen content, K Ca and Mg concentrations decreased upon salinization[4]. Uptake of N, P, K, Ca, Mg, Zn, Mn, Cu and Fe were reduced by salinity and/or sodicity of soil and irrigation water**.** The saline irrigation water has a tremendous impact on the yield potential of crops. When the crop was irrigated with saline water, the roots contained the highest Na content; Ca and Mg were higher in the leaves, whereas K and Cl were highest in the stalk.

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Application of organic manures like farmyard manure or green manuring is one of the easiest methods to mitigate the adverse effects of use of poor quality water especially for small farmers who do not have resources to implement more costly corrective measures. The applied inorganic and organic chemical ameliorants achieved better nutrient uptake by plant, which may be ascribed to its role in improving soil physical properties[11]. Keeping in view the present study was conducted to evaluate uptake of primary (N, P and K) and secondary (S, Ca and Mg) nutrients of sorghum under irrigation with different water qualities.

MATERIAL AND METHODS

The experiment was carried out at the Water Technology Centre, College Farm, College of Agriculture, Rajendranagar, Hyderabad, India 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 following main treatments comprised based on different levels of water qualities according to their electrical conductivity (dS m^{-1}), M_1: irrigation with C_2 (good) quality (0.4 dS m^{-1}) water, M_2: irrigation with C_3 (marginal) quality (1.7 dS m^{-1}) water, M_3: irrigation with C_4 (poor) quality (3.5 dS m^{-1}) 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: Farmyard manure @ 10 t ha^{-1}, S_3: green manuring (Sunnhemp) *in situ* and S_4: magnetic treatment to irrigation water. Magnetic treatment to irrigation water means the irrigation water was passed through a device called magnetic pipe. Magnetic field, when applied to normal water restructures the water molecules into very small water molecule clusters, each made up of six symmetrically organized molecules. This miniscule cluster is recognized by the cell as "bio-friendly" due to its hexagonal structure and because the toxins cannot travel within the cluster, and easily enters the passage ways in plant. The result provides maximum, healthy hydration with less water (Magnetic Technologies, L. L. C., Dubai). The FYM 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 26th October adopting a spacing of 40 x 15 cm. An amount of 360.5 mm water given through irrigation and effective rainfall of 70.6 mm was received during crop growth period. Thus a total 431.5 mm of water was used by the crop.

Plant samples were collected at 60 Days after sowing and harvest was oven dried. The dried samples were powdered and analyzed for total N, P, K, S, Ca and Mg contents by adopting the standard procedures[5]. Corresponding uptake at 60 DAS and harvest were estimated. The data of parameters studied during the course of study were statistically analysed, applying the technique of analysis of variance described by Gomez and Gomez[6]. The uptake of N, P, K, S, Ca and Mg nutrients were calculated using the following formula and expressed in kg ha^{-1}.

$$\text{Uptake of nutrient (kg ha}^{-1}) = \frac{\text{Nutrient content (\%)} \times \text{dry matter production (kg ha}^{-1})}{100}$$

RESULTS AND DISCUSSION

Uptake of primary nutrients

Nitrogen uptake (kg ha^{-1})

The data regarding nitrogen uptake was given in Table 1. At 60 DAS, the effect of main treatments, sub treatments found to be significant but their interactions were found to be non significant. Among water quality levels, significantly the highest nitrogen uptake was recorded by the treatment C_2 quality (22.12 kg N ha^{-1}) which was on par with irrigation with C_3 quality water (21.21 kg N ha^{-1}). The lowest nitrogen uptake was observed in irrigation with C_4 quality (20.06 kg N ha^{-1}).Among management practices, the highest nitrogen uptake was recorded by FYM @ 10 t ha^{-1} (24.94 kg N ha^{-1}) which was significantly higher over GM (22.99 kg N ha^{-1}), MT (19.66 kg N ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (16.52 kg N ha^{-1}).

At harvest, among water quality levels, significantly the highest nitrogen uptake was recorded by the treatment C_2 quality (73.98 kg N ha^{-1}) which was followed by irrigation with C_3 quality water (69.97 kg N ha^{-1}). The lowest nitrogen uptake was observed in irrigation with C_4 quality (62.62 kg N ha^{-1}). Among management practices, the highest nitrogen uptake was recorded by FYM @ 10 t ha^{-1} (90.19 kg N ha^{-1}) which was significantly higher over GM (75.09 kg N ha^{-1}), MT (60.28 kg N ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (47.02 kg N ha^{-1}). Among the interactions, the highest nitrogen uptake was recorded by C_2-FYM (96.81 kg N ha^{-1}) which was significantly higher over other treatments and followed by C_3-FYM (91.56 kg N ha^{-1}). The lowest nitrogen uptake was recorded by C_4- control (43.80 kg N ha^{-1}). The maximum nitrogen uptake was recorded by C_2-FYM may be due to higher nitrogen absorption when good quality water was used. When poor quality water (C_4) was used, it might have affected metabolic processes such as protein synthesis and resulted in lower uptake of N. The higher concentrations of soluble salts through their high osmotic pressures affect the plant growth by restricting the uptake of water by plant roots. High saline water can also cause nutrient imbalances increasing salinity and reduced the content of free amino acids in wheat as a result of decreasing nitrate reducatase activity that plays an important role in conversion of nitrate to ammonium[12]. Nutrients uptake by plants is decreased under stress conditions due to impaired active transport and membrane permeability, resulting in reduced root absorbing power. This process may inhibit water and nutrient uptake, consequently causing adverse effects on crop growth and yield[7].

Phosphorus uptake (kg ha^{-1})

The data regarding phosphorus uptake was given in Table 1. At 60 DAS among water quality levels, significantly the highest phosphorus uptake was recorded by the treatment C_2 quality (4.26 kg P ha^{-1}) which was on par with irrigation with C_3 quality water (4.02 kg P ha^{-1}). The lowest phosphorus uptake was observed in irrigation with C_4 quality (3.76 kg P ha^{-1}). Among management practices, the highest phosphorus uptake was recorded by FYM @ 10 t ha^{-1} (5.11 kg P ha^{-1}) which was significantly higher over GM (4.48 kg P ha^{-1}), MT (3.62 kg P ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (2.73 kg P ha^{-1}). Among the interactions, the highest phosphorus uptake was recorded by C_2-FYM (5.33 kg P ha^{-1}) which was on par with C_4-FYM (5.08 kg P ha^{-1}). The lowest phosphorus uptake was recorded by C_4- control (2.47 kg P ha^{-1}).

At harvest, among water quality levels, significantly the highest phosphorus uptake was recorded by the treatment C_2 quality (17.77 kg P ha^{-1}) which was followed by irrigation with C_3 quality water (16.91 kg P ha^{-1}). The lowest phosphorus uptake was observed in irrigation with C_4 quality (15.27 kg P ha^{-1}). Among management practices, the highest phosphorus uptake was recorded by FYM @ 10 t ha^{-1} (21.78 kg P ha^{-1}) which was significantly higher over GM (18.37 kg P ha^{-1}), MT (14.59 kg P ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (11.15 kg P ha^{-1}). The interaction effect was found to be non significant. It ranges from 10.29 to 23.22 kg P ha^{-1}. When the poor quality water (C_4) was used, the excessive salts appear to restrict nutrients uptake. It is also possible that plants irrigated with saline water may utilize energy for osmotic adjustment process at the expense of growth and the most important factor which is the high soil water potential, hence the water flow from soil to plant is very much limited under saline conditions[12]. The ionic strength effects that reduce the activity of phosphate, sorption processes that control phosphate concentrations in soil solution and low solubility of Ca–P minerals are the usual explanations for salinity–induced reduction in P availability[9].

Potassium uptake (kg ha^{-1})

The data regarding potassium uptake was given in Table 2. At 60 DAS, among water quality levels, significantly the highest potassium uptake was recorded by the treatment C_2 quality (21.97 kg K ha^{-1}) which was on par with irrigation with C_3 quality water (21.05 kg K ha^{-1}). The lowest potassium uptake was observed in irrigation with C_4 quality (19.99 kg K ha^{-1}). Among management practices, the highest potassium uptake was recorded by FYM @ 10 t ha^{-1} (24.61 kg K ha^{-1}) which was significantly higher over GM (22.79 kg K ha^{-1}), MT (19.65 kg K ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (16.66 kg K ha^{-1}). Among the interactions, significantly the highest potassium uptake was recorded by C_2-FYM (25.52 kg K ha^{-1}) which was on par with C_3/C_4 -FYM (24.59 kg K ha^{-1}). The lowest potassium uptake was recorded by C_4- control (15.40 kg K ha^{-1}).

At harvest, among water quality levels significantly the highest phosphorus uptake was recorded by the treatment C_2 quality (76.35 kg K ha^{-1}) which was followed by irrigation with C_3 quality water (74.13 kg K ha^{-1}). The lowest phosphorus uptake was observed in irrigation with C_4 quality (68.85 kg K ha^{-1}). Among management practices, the highest phosphorus uptake was recorded by FYM @ 10 t ha^{-1} (87.41 kg K ha^{-1}) which was significantly higher over GM (78.67 kg K ha^{-1}), MT (67.40 kg K ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (57.21 kg K ha^{-1}). Among the interactions, the highest phosphorus uptake was recorded by C_2-FYM (91.47 kg K ha^{-1}) which was significantly higher over other treatments and followed by C_3-FYM (87.74 kg K ha^{-1}). The lowest phosphorus uptake was recorded by C_4- control (54.36 kg K ha^{-1}). Probably the negative effect of saline water on plants provoked osmotic potential by salts in the soil and the root cells might not obtained required which might have restricted the uptake of potassium[3]. High sodium concentration in the rhizosphere may disrupt the integrity and selectivity of root membranes. As a result, imbalance in the availability of different ions may occur, affecting mineral uptake by roots. In addition, high soil Na content may interfere with K uptake by the roots[9].

Uptake of secondary nutrients

Sulphur uptake (kg ha^{-1})

The data pertaining to sulphur was given in Table 2. At 60 DAS, among water quality levels, significantly the highest sulphur uptake was recorded by the treatment C_2 quality (4.32 kg S ha^{-1}) which was followed by irrigation with C_3 quality water (3.95 kg S ha^{-1}) and this was on par with C_3/C_4 quality water (3.72 kg S ha^{-1}). The lowest sulphur uptake was observed in irrigation with C_4 quality (3.48 kg S ha^{-1}). Among management practices, the highest sulphur uptake was recorded by FYM @ 10 t ha^{-1} (5.71 kg S ha^{-1}) which was significantly higher over GM (4.38 kg S ha^{-1}), MT (3.21 kg S ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (2.16 kg S ha^{-1}). The interaction effect was found to be non significant and it ranges from 1.89 to 6.28 kg S ha^{-1}.

At harvest, among water quality levels, significantly the highest total sulphur uptake was recorded by the treatment C_2 quality (15.63 kg S ha^{-1}) which was followed by irrigation with C_3 quality water (14.64 kg S ha^{-1}). The lowest total sulphur uptake was observed in irrigation with C_4 quality (12.71 kg S ha^{-1}). Among management practices, the highest total sulphur uptake was recorded by FYM @ 10 t ha^{-1} (20.43 kg S ha^{-1}) which was significantly higher over GM, MT and control. The other treatments GM (15.75 kg S ha^{-1}) and MT (11.86 kg S ha^{-1}) were also significantly higher over control (8.52 kg S ha^{-1}). Among the interactions, the highest total sulphur uptake was recorded by C_2-FYM (22.47 kg S ha^{-1}) which was significantly higher over other treatments and followed by C_3-FYM (20.87 kg S ha^{-1}). The lowest sulphur uptake was recorded by C_4- control (7.76 kg S ha^{-1}). It is possible that higher dry matter production in farm yard manure applied treatments resulted in higher total uptake of sulphur in the treatments which received farm yard manure.

Calcium uptake (kg ha^{-1})

The data pertaining to calcium was given in Table 3. At 60 DAS, among water quality levels, significantly the highest calcium uptake was recorded by the treatment C_2 quality (14.77 kg Ca ha^{-1}) which was followed by irrigation with C_3 quality water (13.79 kg Ca ha^{-1}) and this was on par with C_3/C_4 quality water (13.21 kg Ca ha^{-1}). The lowest calcium uptake was observed in irrigation with C_4 quality (12.49 kg Ca ha^{-1}). Among management practices, the highest calcium uptake was recorded by FYM @ 10 t ha^{-1} (18.10 kg Ca ha^{-1}) which was significantly higher over GM (15.46 kg Ca ha^{-1}), MT (11.85 kg Ca ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (8.84 kg Ca ha^{-1}). The interaction effect was found to be non significant and it ranges from 7.66 to 19.32 kg Ca ha^{1}.

At harvest, among water quality levels, significantly the highest total calcium uptake was recorded by the treatment C_2 quality (54.77 kg Ca ha^{-1}) which was followed by irrigation with C_3 quality water (52.05 kg Ca ha^{-1}). The lowest total calcium uptake was observed in irrigation with C_4 quality (46.29 kg Ca ha^{-1}). Among management practices, the highest total calcium uptake was recorded by FYM @ 10 t ha^{-1} (67.50 kg Ca ha^{-1}) which was significantly higher over GM (56.59 kg Ca ha^{-1}), MT (44.08 kg

Ca ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (33.86 kg Ca ha^{-1}). Among the interactions, the highest total calcium uptake was recorded by C_2-FYM (72.51 kg Ca ha^{-1}) which was significantly higher over other treatments and followed by C_3-FYM (68.79 kg Ca ha^{-1}). The lowest total calcium uptake was recorded by C_4- control (30.69 kg Ca ha^{-1}). Higher concentrations of ions in poor quality water can hinder the uptake of nutrients and break down in ion balance. Saline water reduces the root growth, uptake as well as transpiration and respiration which results in perished hormonal balance, altered photosynthesis and cell growth. The main response of the plant to salt stress is a change in Ca^{2+} homeostasis and attributed that the salt tolerance of plants is their ability to avoid Na toxicity and to maintain Ca^{2+} concentration. Ca^{2+} contents in leaf decreased with increased salinity Levels (Patel *et al*., 2010).

Magnesium uptake (kg ha^{-1})

The data pertaining to magnesium was given in Table 3. At 60 DAS, among water quality levels, significantly the highest magnesium uptake was recorded by the treatment C_2 quality (9.31 kg Mg ha^{-1}) which was followed by irrigation with C_3 quality water (8.63 kg Mg ha^{-1}) and this was on par with C_3/C_4 quality water (8.22 kg Mg ha^{-1}). The lowest magnesium uptake was observed in irrigation with C_4 quality (7.71 kg Mg ha^{-1}). Among management practices, the highest magnesium uptake was recorded by FYM @ 10 t ha^{-1} (11.84 kg Mg ha^{-1}) which was significantly higher over GM (9.72 kg Mg ha^{-1}), MT (7.25 kg Mg ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (5.06 kg Mg ha^{-1}). The interaction effect was found to be non significant and it ranges from 4.31 to 12.73 kg Mg ha^{-1}.

At harvest, among water quality levels, significantly the highest magnesium uptake was recorded by the treatment C_2 quality (37.14 kg Mg ha^{-1}) which was followed by irrigation with C_3 quality water (35.17 kg Mg ha^{-1}). The lowest magnesium uptake was observed in irrigation with C_4 quality (31.03 kg Mg ha^{-1}). Among management practices, the highest magnesium uptake was recorded by FYM @ 10 t ha^{-1} (46.78 kg Mg ha^{-1}) which was significantly higher over GM (38.25 kg Mg ha^{-1}), MT (29.42 kg Mg ha^{-1}) and control. The other treatments GM and MT were also significantly higher over control (21.85 kg Mg ha^{-1}). Among the interactions, the highest magnesium uptake was recorded by C_2-FYM (50.47 kg Mg ha^{-1}) which was significantly higher over other treatments and followed by C_3-FYM (47.63 kg Mg ha^{-1}). The lowest magnesium uptake was recorded by C_4- control (19.67 kg Mg ha^{-1}). Salt stress effects to a decreased Mg ion absorption and thus detrimental effects on photosynthetic capacity (Balliu *et al*., 2015).

Table 1: Effect of saline water irrigation and management practices on uptake of nitrogen and phosphorus (kg ha^{-1}) at 60 DAS and at harvest of *rabi* Sorghum

Nitrogen uptake (kg ha^{-1})										
	60DAS					**Harvest**				
Treatments	Control	FYM	GM	MT	**Mean**	Control	FYM	GM	MT	**Mean**
C_2	17.68	25.81 (46)*	23.65 (34)	21.32 (21)	**22.12 [10]****	50.29	96.81 (92)	80.73 (60)	68.07 (35)	**73.97 [18]**
C_3	17.01	24.14 (42)	22.91 (35)	20.77 (22)	**21.21 [6]**	48.22	91.57 (89)	77.22 (60)	62.86 (30)	**69.97 [11]**
C_4	15.27	24.93 (36)	22.27 (46)	17.78 (16)	**20.06**	43.80	84.34 (92)	69.33 (58)	53.14 (21)	**62.65**
C_3/C_4	16.13	24.88 (54)	23.12 (43)	18.76 (16)	**20.72 [3]**	45.75	88.07 (92)	73.07 (59)	57.05 (24)	**65.99 [5]**
Mean	**16.52**	**24.94 (51)**	**22.99 (39)**	**19.66 (19)**		**47.01**	**90.20 (91)**	**75.09 (59)**	**60.28 (28)**	
	S.Em (±)		C.D (P=0.05)			S.Em (±)		C.D (P=0.05)		
W	0.36		1.25			0.56		1.94		
M	0.17		0.58			0.35		1.22		
W X M	0.40		NS			0.84		2.49		
M X W	0.50		NS			0.91		2.89		

Phosphorus uptake (kg ha^{-1})										
	60DAS					**Harvest**				
Treatments	Control	FYM	GM	MT	**Mean**	Control	FYM	GM	MT	**Mean**
C_2	3.01	5.33 (77)*	4.69 (56)	4.02 (34)	**4.26 [13]****	12.06	23.22 (92)	19.69 (63)	16.11 (33)	**17.77 [16]**
C_3	2.85	4.96 (74)	4.49 (58)	3.77 (32)	**4.02 [7]**	11.53	22.05 (91)	18.88 (63)	15.20 (31)	**16.91 [10]**
C_4	2.47	5.08 (2.1)	4.26 (73)	3.24 (31)	**3.76**	10.29	20.62 (100)	17.02 (65)	13.17 (27)	**15.27**
C_3/C_4	2.59	5.05 (95)	4.48 (73)	3.37 (30)	**3.87 [3]**	10.74	21.24 (97)	17.90 (66)	13.90 (29)	**15.94 [4]**
Mean	**2.73**	**5.11 (87)**	**4.48 (64)**	**3.60 (32)**		**11.15**	**21.78 (95)**	**18.37 (64)**	**14.59 (30)**	
	S.Em (±)		C.D (P=0.05)			S.Em (±)		C.D (P=0.05)		
W	0.08		0.27			0.17		0.59		
M	0.06		0.20			0.16		0.55		
W X M	0.09		0.28			0.18		NS		
M X W	0.11		0.36			0.23		NS		

*** Figures in parentheses ( ) indicate the percentage of increase over control**

****Figures in parentheses [ ] indicate the percentage of increase over C_4 quality**

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

Table 2: Effect of saline water irrigation and management practices on uptake of potassium and sulphur (kg ha^{-1}) at 60 DAS and at harvest of *rabi* Sorghum

Potassium uptake (kg ha^{-1})										
	60DAS					**Harvest**				
Treatments	Control	FYM	GM	MT	**Mean**	Control	FYM	GM	MT	**Mean**
C_2	17.83	25.52 (43)*	23.29 (31)	21.24 (19)	**21.97 [10]****	59.91	91.47 (52)	82.10 (37)	71.93 (20)	**76.35 [11]**
C_3	17.09	23.77 (39)	22.74 (33)	20.61 (21)	**21.05 [5]**	58.24	87.74 (50)	80.19 (37)	70.35 (20)	**74.13 [8]**
C_4	15.40	24.54 (59)	22.08 (43)	17.93 (16)	**19.99**	54.36	84.23 (54)	74.71 (37)	62.10 (14)	**68.85**
C_3/C_4	16.33	24.59 (51)	23.04 (41)	18.84 (15)	**20.70 [4]**	56.35	86.19 (52)	77.66 (37)	65.20 (15)	**71.35 [4]**
Mean	**16.66**	**24.61 (48)**	**22.79 (37)**	**19.65 (18)**		**57.22**	**87.41 (52)**	**78.67 (37)**	**67.40 (17)**	
	S.Em (±)		C.D (P=0.05)			S.Em (±)		C.D (P=0.05)		
W	0.36		1.24			0.53		1.82		
M	0.18		0.63			0.34		1.18		
W X M	0.38		1.14			0.36		1.07		
M X W	0.49		1.58			0.61		2.04		

Sulphur uptake (kg ha^{-1})	
60DAS	**Harvest**

Treatments	Control	FYM	GM	MT	Mean	Control	FYM	GM	MT	Mean
C_2	2.49	6.28 (152)*	4.77 (91)	3.72 (49)	**4.32 [24]****	9.41	22.47 (138)	17.29 (83)	13.36 (41)	**15.63 [23]**
C_3	2.23	5.64 (152)	4.48 (100)	3.45 (54)	**3.95 [14]**	8.73	20.87 (139)	16.37 (87)	12.60 (44)	**14.64 [15]**
C_4	1.89	5.36 (183)	3.97 (110)	2.68 (42)	**3.48**	7.76	18.65 (140)	14.19 (82)	10.25 (32)	**12.71**
C_3/C_4	2.04	5.57 (162)	4.29 (110)	2.98 (46)	**3.72 [7]**	8.16	19.71 (141)	15.15 (85)	11.22 (45)	**13.56 [6]**
Mean	**2.16**	**5.71 (164)**	**4.38 (102)**	**3.21 (49)**		**8.52**	**20.43 (139)**	**15.75 (85)**	**11.86 (39)**	
	S.Em (±)		C.D (P=0.05)			S.Em (±)		C.D (P=0.05)		
W	0.07		0.24			0.10		0.36		
M	0.04		0.13			0.07		0.24		
W X M	0.08		NS			0.09		0.28		
M X W	0.10		NS			0.13		0.43		

*** Figures in parentheses ( ) indicate the percentage of increase over control**

****Figures in parentheses [ ] indicate the percentage of increase over C_4 quality**

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

Table 3: Effect of saline water irrigation and management practices on uptake of calcium and magnesium (kg ha^{-1}) at 60 DAS and at harvest of *rabi* Sorghum

Calcium uptake (kg ha^{-1})										
	60DAS					**Harvest**				
Treatments	Control	FYM	GM	MT	**Mean**	Control	FYM	GM	MT	**Mean**
C_2	9.83	19.32 (97)*	16.39 (67)	13.53 (38)	**14.77 [18]****	36.56	72.51 (98)	60.87 (66)	49.12 (34)	**54.77 [18]**
C_3	9.33	17.81 (91)	15.46 (66)	12.56 (35)	**13.79 [10]**	35.19	68.79 (95)	57.86 (64)	46.35 (31)	**52.05 [12]**
C_4	7.66	17.45 (127)	14.54 (90)	10.29 (34)	**12.49**	30.69	63.01 (105)	52.36 (70)	39.10 (27)	**46.29**
C_3/C_4	8.55	17.82 (108)	15.45 (81)	11.03 (29)	**13.21 [6]**	32.99	65.70 (99)	55.25 (67)	41.75 (26)	**48.92 [5]**
Mean	**8.84**	**18.10 (104)**	**15.46 (75)**	**11.85 (34)**		**33.86**	**67.50 (99)**	**56.59 (67)**	**44.08 (30)**	
	S.Em (±)		C.D (P=0.05)			S.Em (±)		C.D (P=0.05)		
W	0.25		0.87			0.41		1.43		
M	0.14		0.48			0.19		0.66		
W X M	0.29		NS			0.35		1.03		
M X W	0.36		NS			0.51		1.68		
Magnesium uptake (kg ha^{-1})										
	60DAS					**Harvest**				
Treatments	Control	FYM	GM	MT	**Mean**	Control	FYM	GM	MT	**Mean**
C_2	5.77	12.73 (120)*	10.45 (81)	8.28 (43)	**9.31 [21]****	23.90	50.47 (111)	41.49 (73)	32.70 (36)	**37.14 [19]**
C_3	5.36	11.65 (117)	9.80 (83)	7.72 (44)	**8.63 [12]**	22.73	47.63 (109)	39.33 (73)	31.01 (36)	**35.17 [13]**
C_4	4.31	11.36 (163)	8.97 (108)	6.19 (44)	**7.71**	19.67	43.56 (121)	34.98 (77)	25.90 (31)	**31.03**
C_3/C_4	4.80	11.62 (142)	9.66 (101)	6.80 (42)	**8.22 [7]**	21.08	45.44 (121)	37.22 (81)	28.07 (39)	**32.95 [6]**

Mean	**5.06**	**11.84 (133)**	**9.72 (92)**	**7.25 (41)**	**21.85**	**46.78 (114)**	**38.25 (75)**	**29.42 (34)**

	S.Em (±)	C.D (P=0.05)	S.Em (±)	C.D (P=0.05)
W	0.18	0.62	0.33	1.14
M	0.07	0.26	0.11	0.41
W X M	0.17	NS	0.24	0.71
M X W	0.23	NS	0.39	1.30

*** Figures in parentheses ( ) indicate the percentage of increase over control**

****Figures in parentheses [ ] indicate the percentage of increase over C_4 quality**

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

CONCLUSION

It was observed that, good quality water (C_2) along with application of FYM @ 10 t ha^{-1} was found to be better among the all treatments tested. Sorghum crop was found to tolerate the marginal quality (C_3) water. Hence, in situations where C_3 water is available for irrigation, it can be recommended to apply FYM @ 10 t ha^{-1}, to get higher yields. In situations where both C_3 and C_4 water is available, alternate irrigation with C_3 water and C_4 water along with application of FYM @ 10 t ha^{-1} can be recommended. When use of C_4 class of irrigation water is the only available option, application of FYM @ 10 t ha^{-1} or green manuring is essential to mitigate the adverse effect of poor quality water so as to obtain fairly good yields and for maintenance of soil health. Magnetic treatment effect on water quality improvement did not show a consistent trend. However it was found to be better than no management practices. Furthermore investigations need to be done to test its performance. Its effect in combination of different organic manures and their long term effect on soil properties also need to be tested.

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