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Evaluation of fingermillet varieties under varying levels of irrigation water salinity

P Prasuna Rani , P Venkata Subbaiah and K A Mrudhula
AICRP on Management of Salt affected Soils and Use of Saline Water in Agriculture,
Acharya N G Ranga Agricultural University, Bapatla-522 101, Andhra Pradesh, India

ABSTRACT

Finding alternative means for better use of poor qualityirrigationwatercould significantly help in alleviating pressure on limited fresh-water resources. Identification of salt tolerant crops and varieties is one of the viableoptions for enhancing the productivity under saline irrigation systems. Keeping this in view apot culture experiment was conducted at Saline Water Scheme, Bapatla to evaluate the performance of finger millet varieties Vakula and Tirumala with varying levels of groundwater salinity (up to 12 dS m^{-1})during*rabi*2021-22 and 2022-23. The highest plant height, number of tillers per hill and fingers per earhead in variety Vakula were recorded with the best available water(BAW).There was no significant variation in plant height up to 6 dS m^{-1}but a significant difference was observed with tillers per hill and fingers per ear headat 4 dS m^{-1}.The stover yield was influenced by irrigation water salinity levels. The highest grain yield was recorded by the best available water, which is on a par with 2 dS m^{-1} water and significantly superior to others.Tirumala variety recorded comparable plant height, fingers per earhead and stover yield up to 2 dS m^{-1} when related to BAW. A significant variation was observed in tillers/hill and grain yield between BAW and all other salinity levels. A grain yield level of around 85 per cent was observed at a salinity level of 4 and 2 dS m^{-1}, respectively in Vakula and Tirumala indicating higher tolerance of Vakula variety to irrigation water salinity.

Key words: *Finger millet, Irrigation water, Salinity Soil and water salinity*

Crop production is under setback due to dwindling resources and declinein the quality of soil and irrigation water because of global climate change and human intervention.Soil and irrigation water salinity poses a significant challenge for agriculture, particularly impacting the most fertile crop regions worldwide. These areas, predominantly found in arid and semiarid regions where irrigation is common, constitute approximately 15% of the world's arable land. Yet, despite their relatively small area, they contribute over 40% of the world's food supply (Munns and Tester, 2008). The combination of water scarcity and elevated salinity presents a significant obstacle to plant growth in these saline environments. Soil and water salinity induce various physiological abnormalities in plants due to the altered concentration of ions in the rhizospheric environment. In agricultural point of view, the final effect of salinity is the reduction of quality and yield of crops (Yadav *et al.,* 2004). Inadequate supply of water for irrigation is a major factor limiting crop production in arid and semi-arid regions of our country. Given the concerning state of freshwater availability and the imperative to sustain food security for the growing global population, the agriculture sector finds itself compelled to resort to utilizing low-quality water sources to supplement irrigation needs. Research findings reveal that across various states in India, the utilization of substandard groundwater constitutes a significant portion, ranging from 32% to 84% of total groundwater utilization. This prevalence is primarily attributable to the saline nature of groundwater in arid regions and its sodic composition in semi-arid areas. Subbaiah *et al.* (2022a) documented that nearly 50 per cent of the groundwater used for irrigation in the region is of poor quality. The pursuit of enhanced crop yields in arid and semi-arid zones is frequently impeded by the scarcity of suitable irrigation water. Moreover, diminishing freshwater reservoirs coupled with traditional agricultural irrigation practices are contributing to a gradual escalation in soil salinity.Subbaiah *et al.* (2022b) reported that long term use of saline irrigation water may cause salinity in soil due to upward movement of saline groundwater via capillary action and minimal leaching due to arid or semi-arid climates. Such trends forecast a future marked by desertification in affected regions, accompanied by diminished crop yields for both human and animal consumption. Consequently, it is imperative to explore alternative crop varieties/ genotypes and develop ecologically sustainable and economically viable production systems capable of utilizing substandard water sources and withstanding drought conditions on saline lands. Finger millet is grown on 1.00 million hectares in India, with a total yield of 1.76 million tons and average productivity of 1747 kg per ha. It comes in third place among millets, behind pearl millet and sorghum, and sixth place among Indian cereals, behind rice, wheat, maize, sorghum, and bajra (www.https://apeda.gov.in,2022). Finger millet is mostly grown in areas with poor quality water.Selection of crops or tolerant varieties that will produce satisfactory yields under the prevailing conditions of salinity is the need of the hour (Prasanthi *et al.,* 2020). Among the abiotic stresses constraining finger millet production is salinity, which is a devastating environmental stress factor that has a substantial negative impact on crop quality and production (Hema *et al.,* 2014). In general, salinity causes osmotic stress which leads to physiological changes including membranes interruption, nutrient imbalance, decrease in photosynthetic activity, decrease in stomatal aperture, and changes in the antioxidant enzymes (Shahzad *et al.,* 2021).Although there is limited information available on yield loss of in large-scale producing areas, pot studies have reported genotypic variability in the grain yield loss among different multiple varieties (Krishnamurthy *et al.,* 2014). In this context a research study was formulated with an objective to assess the performance of finger millet varieties under varying levels of irrigation water salinity

MATERIAL AND METHODS

A pot culture study was carried out at AICRP-SAS&USW,Saline Water Scheme,Agricultural CollegeFarm, Bapatla. The experimental farm is located at 15°542 163 N latitude and 80°282 33 E longitude at an altitude of 8 m and 10km away from the coast of Bay of Bengal.The climate of the area is semi-aridwith a mean annual rainfall of 854 mm (70-80% of which received during July-September)and most affected by cyclonic storms that occur on the east coast. The soil of experimental site is sandy loam in texture with pH and EC values of6.0and 0.41dS m^{-1}, respectively.

The experiment was conducted for two years(2021-22 and 2022-23) during *rabi* season to evaluate the performance of finger millet varieties *viz*., Vakula and Tirumala under various irrigation water salinity levels. The treatments include T_1: Best available Water(0.4),T_2- 2 dSm^{-1},T_3- 4 dSm^{-1},T_4- 6 dSm^{-1},T_5- 8 dSm^{-1},T_6-10 dSm^{-1},T_7-12 dSm^{-1} and were laid incompletely randomized design with four replications. The pots were filled with 10 kg soil.The irrigation water with varying levels of salinity was prepared by dilutingsea water. Irrigation, fertilizer application and plant protection measures were taken up as per the requirement of the crop. The yield attributes *viz*., plant height, number of tillers per hill, number of fingers per ear headand yield (stover yield (g pot^{-1}) and grain yield (g pot^{-1})) were recordedas per the standard procedures. The soil samples collected after harvest were dried and pounded to pass through 2 mm sieve for determination of soil pH and EC parameters. Allthe data recorded were analyzed with the help of analysis of variance(ANOVA) technique (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

The phenotypic parameters of finger millet variety Vakula*viz*. plant height, tillers per hill and fingers per ear head were significantly affected by different salinity levels of irrigation water (Table 1). The highest plant height (64.80 cm), tillers per hill (8.22) and fingers per ear head (9.17) were observed with best available water. The plant height was not statistically influenced up to an EC level of 6 dS m^{-1}. A significant variation was observed in tillers /plant and fingers per year beyond 2 dS $m^{-1}$of irrigation water salinity. Both the parameters recorded comparable values at EC levels of 2 and 4 dSm^{-1}. This could be due to the high concentration of soluble salts in root zone, which through their high osmotic pressures reduce plant growth as result of restricted uptake of water by the roots (Tester and Davenport, 2003). The maximum grain yield (95.24 g pot^{-1}) and stover yield (137 g pot^{-1}) were observed with the BAW (0.4 dS m^{-1}), which is on par with 2 dS m^{-1} water. The

Table: 1 Influence of irrigation water salinity levels on growth and yield of finger millet Variety Vakula

Salinity level (dS m^{-1})	Finger millet (Vakula)				
	Plant height (cm)	Tillers / Hill	Fingers / earhead	Stover yield (g/pot)	Grain yield (g / pot)
BAW(0.4)	64.8	8.22	9.17	137	95.24
2	64.63	7.44	8.5	123	92.92
4	62.5	7.11	7.83	118	88.03
6	62.51	5.78	7.4	117	73.61
8	58.73	5	6.33	112	68.29
10	56.74	5	6.5	116	69.6
12	54.03	4.67	5.83	109	66.16
Sem±	1.07	0.27	0.29	3	2.22
CD(0.05%)	3.23	0.81	0.89	9	6.73
CV(%)	3.07	7.45	6.91	4.5	4.86

irrigation water EC of 4 dSm^{-1} resulted in the grin and stover yield like 2 dSm^{-1} but significantly lower when compared to BAW. Similar observations of reduced plant growth in terms of plant height, stem diameter, number of branches and leaves and leaf area were observed when irrigated with saline water in *Calendula officinalis* L, a flowering plant (Elhindi *et al.*, 2020). The effects of drip irrigation with salinewater on maize revealed that assalinity of irrigation water increased, seedling biomassdecreased, and the plant height, fresh and dry weight of maize decreased by 2 per cent for every 1 dS m^{-1} increase in salinity of irrigated water (Kang *et al.,* 2010).

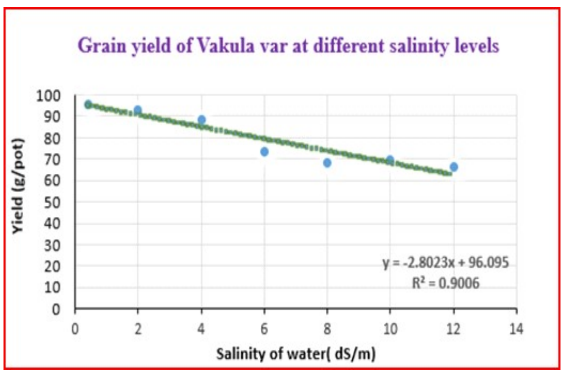
The varietyTirumalarecorded the highest plant height (69.67 cm), fingers per earhead (8.33) andstover yield (150 g pot^{-1}) with BAW (0.4 dSm^{-1}) and were on a par with the EC level of 2 dS m^{-1} but statistically superior to other EC levels. The maximum tillers per hill (8.73) and grain yield (79.9 g pot^{-1}) observed with BAW were found to be significantly higher than the salinity levels of irrigation water tested. Adilakshmi *et al.*(2017) recorded 67.68 per cent decrease in drymatter accumulation in sorghum with an increase in salinity from 1.5 dS m^{-1} to 12 dS m^{-1} and attributed it to the disruption of normal growth and development of plants with increase in salinity. Subbaiah *et al*.(2020) also reported 25 - 60 per cent reduction in yields of major crops of Chittoor district irrigated with poor quality water.

The adverse effects of saline irrigation water may be due to obstruction in the absorption or permeability of some essential nutrients which in turn leads to the toxicity of certain elements instigating metabolic changes causing reduction in most of the vegetative growth characteristics of plants (Hilal and Hilal, 2000). The negative effect of high saline water could also be due ionic toxicity that causes disruption of enzymes and rupture of plasma membrane, which in turn slows down main metabolic processes like photosynthesis, respiration, and protein synthesis (Ferrante *et al*., 2011). Govind Makarana *et al.* (2019) mentioned that higher load of salt with increased level of salinity of irrigation water restricted the root growth of plants that in turn reduced the uptake of nutrients leading to leaf chlorosis that reduces the photosynthetic potential of crops which ultimately leads to lower drymatter yield.

The production function derived between yield and irrigation water salinity indicated a strong relation between the two with R^2 values of more than 0.9 (Fig 1). The present study indicated that, Vakula variety resulted in higher fingers per panicle and grain yield compared to Tirumala variety at all salinity levels. Further, Vakula variety resulted in comparable grain yield up to 2 dS m^{-1}. The per cent reduction in grain yield was less than 10 in Vakula up to irrigation water salinity of 4 dS m^{-1} while, it was nearly 10 % with Tirumala even at 2 dS m^{-1}(Table 3). The overall results of the experiments carried out for two years (Table 4 &5) indicated that the mean per cent reduction was high in grain than stover except at 2 and 4 dSm^{-1} in Vakula. In Tirumala the mean per cent reduction in grain was higher than stover at all salinity levels. A

Table: 2: Effect of irrigation water salinity levels on growth of finger millet Variety *Tirumala*

Salinity level (dS m^{-1})	Finger millet (Tirumala)				
	Plant height (cm)	Tillers / Hill	Fingers / earhead	Stover (g pot-1)	Grain (g pot^{-1})
BAW(0.4)	69.67	8.73	8.33	150	79.9
2	69.5	7.89	7.67	142	72
4	63.5	7	7.5	129	66.4
6	61.5	5.44	7.5	115	66.3
8	58.75	5.22	7	112	59.2
10	58.92	4.89	6.67	111	57.2
12	58.5	4.11	6.5	97	53.5
Sem±	1.58	0.27	0.27	3	2.2
CD(0.05%)	4.79	0.83	0.81	9	6.6
CV(%)	4.35	7.67	6.33	4.4	5.8



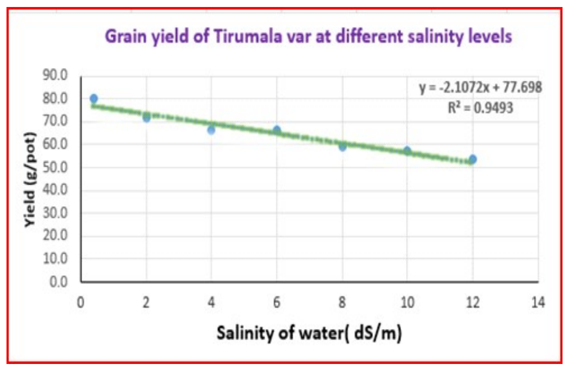


Fig: 1. Production functions for Vakula and Tirumala varieties Showing the relation between grain yield and salinity

Table. 3: Comparison of per cent reduction in yield among the two varieties tested

Salinity level (dS m^{-1})	Vakula 22-23		Tirumala 22-23	
BAW(0.4)	% Reduction in stover over BAW	% Reduction in grain over BAW	% Reduction in stover over BAW	% Reduction in grain over BAW
2	10	2.4	5.2	9.9
4	14.2	7.6	13.9	16.9
6	14.3	22.7	23.1	17.1
8	18.4	28.3	25.3	26
10	15.7	26.9	25.8	28.4
12	20.5	30.5	35.1	33

Table 4 : Per cent reduction in stover and grain yield of finger millet variety Vakula during 2021-22 and 2022-23 at different salinity levels

Salinity level (dS m-1)	% Reduction in stover 2021-22	% Reduction in stover 2022-23	**Mean % reduction in stover**	% Reduction in grain 2021-22	% Reduction grain 2022-23	**Mean % reduction in grain**
2	13.3	9.96	**11.63**	22.07	2.43	**12.25**
4	30.89	14.16	**22.53**	24.96	7.56	**16.26**
6	36.53	14.26	**25.39**	28.31	22.71	**25.51**
8	39.57	18.38	**28.97**	33.94	28.3	**31.12**
10	41.04	15.71	**28.37**	44.44	26.92	**35.68**
12	51.18	20.51	**35.85**	46.42	30.53	**38.48**

Table 5 : Influence of salinity level of irrigation water on stover and grain yield levels of finger millet variety Tirumala during 2021-22 and 2022-23

Salinity level (dS m^{-1})	% Reduction in stover 2021-22	% Reduction in stover 2022-23	**Mean % reduction in stover**	% Reduction in grain 2021-22	% Reduction grain 2022-23	**Mean % reduction in grain**
BAW(0.4)						
2	6.43	5.16	**5.8**	21.78	9.88	**15.83**
4	11.83	13.91	**12.87**	30.37	16.89	**23.63**
6	23.52	23.11	**23.32**	22.81	17.08	**19.95**
8	25.96	25.32	**25.64**	26.67	25.96	**26.31**
10	32.32	25.8	**29.06**	45.78	28.44	**37.11**
12	32.77	35.15	**33.96**	47.56	33.02	**40.29**

Table. 6 Soil pH and EC at harvest of finger millet at different salinity levels

Salinity level	**Vakula**		**Tirumala**	
(dS m^{-1})	**pH**	**EC (dS m^{-1})**	**pH**	**EC (dS m^{-1})**
BAW(0.4)	5.5	0.5	5.6	0.5
2	5.5	1.4	5.7	1.1
4	5.7	2.6	5.6	2
6	5.9	3.3	5.8	2.2
8	5.6	3.8	5.7	3
10	5.8	4.5	5.4	3.1
12	6	4.9	5.9	3.5
Sem$\pm$		0.1		0.8
CD(0.05%)	NS	0.3	NS	0.2
CV(%)	5.1	5.5	4.2	6.3

grain yield level of around 85 per cent was observed at a salinity level of 4 and 2 dS m^{-1}, respectively in Vakula and Tirumala indicating higher tolerance of Vakula variety to irrigation water salinity. The high tolerance could be due to an increase in osmotic potential of plants by accumulating organic solutes such as organic acids, carbohydrates and quaternary ammonium compounds such as glycine betadine and proline (Asaf and Foolad, 2007). The endurance of plants at high salinity could also be due to the protection form oxidative damage due to reactive oxygen species through non-enzymatic and enzymatic defence mechanisms (Misra and Gupta, 2005).

The data presented in table 6 indicated that the pH of the soil was not significantly influenced by the salinity levels while, the EC of soil was found to be influenced significantly in both the varieties. Relatively higher EC values were recorded in Vakula at all salinity levels. Prolonged use of poor quality irrigation water might have resulted in accumulation of ions in higher concentration at the root zone of crop (Subbaiah *et al*., 2020).

CONCLUSION

The study indicated that the performance of both the varieties of finger millet (Vakula and Tirumala) were influenced by the salinity of irrigation water. Among the observed parameters, number of tillers per hill and grain yield were found to be most affected than plant height, fingers per ear head and stover yield in both the varieties. Overall the Vakula variety performed better than Tirumala variety showing its high tolerance to irrigation water salinity.

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