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Research Article

Screening of finger millet genotypes for sodicity tolerance using the Na^+/K^+ ratio as a major physiological trait

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Abstract
Sodicity affects a larger area than salinity, but research on the sodicity tolerance mechanism is limited. The study was carried out to screen 120 finger millet genotypes under sodic soil conditions and identify sodicity-tolerant genotypes. The experimental field soil conditions were sandy clay loam with pH 8.9, electrical conductivity (EC) 0.94 dSm^{-1} and exchangeable sodium percentage (ESP) 21.5, which was naturally sodic. Grain yield per plant and Na^+/K^+ ratio were recorded for each genotype to screen sodicity tolerance among the genotypes. A significantly higher grain yield per plant than that of the sodicity-tolerant check variety TRY 1 (23.10 g) was observed in 30 finger millet genotypes. The analysis of sodium and potassium revealed that these 30 finger millet genotypes also recorded a significantly lower Na^+/K^+ ratio, which is comparatively lower than that of the sodicity-tolerant check variety TRY 1 (0.23 Na^+/K^+ ratio). The genotypes (FIN 3045, FIN 2875, FIN 3077, FIN 3015, FIN 3063, FIN 2861, FIN 3028, FIN 2867, FIN 2854, FIN 2860, FIN 2872, FIN 2896, FIN 4268, FIN 3034, FIN 3928, FIN 3104, FIN 3965, FIN 3091, FIN 2960, FIN 3994, FIN 4198, FIN 3174, FIN 3078, FIN 4288, FIN 4202, FIN 4238, FIN 3089, FIN 4205, FIN 3966 and FIN 3182) that recorded higher grain yield per plant and lower Na^+/K^+ ratio can be considered sodicity tolerant. These genotypes with a high grain yield per plant and a low Na+/K+ ratio could be utilized in stress breeding programs to develop sodicity-tolerant finger millet varieties.

Keywords: Finger millet, Grain yield, Na^+/K^+ ratio, Sodicity

INTRODUCTION

Finger millet (*Eleusine coracana* (L.) Gaertn.) is a drought-hardy crop majorly cultivated and consumed by resource-poor farmers in the developing countries of Asia and Africa. The crop is mainly grown for grain purposes in semiarid and subtropical regions of the world under rainfed conditions. It is an exceptional crop with high nutritional content, being especially rich in calcium and contains the amino acids methionine and tryptophan, which are not present in other starch-based foods such as rice and wheat (Bhatt *et al.,* 2011). This crop also has a high degree of pest resistance and long-term storability, which makes the cultivation of finger millet a “famine reserve” (Reddy *et al.,* 2011; Sood *et al*., 2019).

Sodic soils are characterized by extravagantly higher concentrations of sodium (Na) in their cation exchange capacity. These soils tend to have poor physical and chemical properties leading to soil instability, which can have a significant impact on plant growth compared with saline soils (Tran *et al*., 2015). Sodicity affects a larger area than salinity, but research on the sodicity tolerance mechanism is limited. This is because screening for sodicity tolerance has to be done using a large number of accessions under controlled field experiments, as screening in glasshouses or laboratories was proven to be difficult (Genc *et al*., 2019). Hence, this research was carried out with the aim of screening 120 finger millet genotypes under sodic soil conditions and identifying sodicity-tolerant genotypes.

MATERIALS AND METHODS

A total of 120 finger millet genotypes were screened for their tolerance/susceptibility to sodicity under sodic soil conditions along with the sodicity-tolerant check variety TRY 1. The genotypes were obtained from the Indian Institute of Millets Research, Hyderabad, Telangana. The experimental field soil conditions were sandy clay loam with pH 8.9, electrical conductivity (EC) 0.94 dSm^{-1} and exchangeable sodium percentage (ESP) 21.5 The Soil samples were analyzed in Soil Science and Agricultural Chemistry Laboratory at ADAC&RI, Tamil Naidu Agriculture University, Trichy. Grain yield was recorded from each genotype, and the plant samples were analysed for sodium (Na^+) and potassium (K^+). Grain yield was calculated by recording the weight of each earhead after threshing, and an average of five plants for each genotype was taken. Total sodium and potassium were estimated from the individual plant sample for each genotype, and the Na^+/K^+ ratio was calculated by dividing sodium values by potassium values. Estimation of sodium and potassium was performed according to the procedure of Jackson (1973) using a Flame photometer.

RESULTS AND DISCUSSION

The mean performances of all 120 finger millet genotypes along with checks for the Na^+/K^+ ratio and grain yield per plant traits, are presented in Table 1. A significantly higher grain yield per plant (significant at 1% level) than the sodicity tolerant check variety TRY 1 (23.10 g) was observed in 30 finger millet genotypes viz., FIN 3045, FIN 2875, FIN 3077, FIN 3015, FIN 3063, FIN 2861, FIN 3028, FIN 2867, FIN 2854, FIN 2860, FIN 2872, FIN 2896, FIN 4268, FIN 3034, FIN 3928, FIN 3104, FIN 3965, FIN 3091, FIN 2960, FIN 3994, FIN 4198, FIN 3174, FIN 3078, FIN 4288, FIN 4202, FIN 4238, FIN 3089, FIN 4205, FIN 3966 and FIN 3182. This may be due to the capacity of these genotypes to eliminate excess sodium ion intake from the soil.

The analysis of sodium and potassium revealed that these 30 finger millet genotypes also recorded a significantly lower Na^+/K^+ ratio, which was comparatively lower than that of the sodicity-tolerant check variety TRY 1. Similarly, the low-yield genotypes, such as FIN 3071 and FIN 2881, seemed to contain higher Na^+/K^+ ratios. Fig. 1 clearly depicts the relationship between grain yield per plant and Na^+/K^+ ratio. These results were in accordance with Vijayalakshmi *et al*. (2014) in finger millet genotypes and Vieira *et al*. (2018) in soybean cultivars which were screened for salt stress under greenhouse condition.

The genotypes that recorded higher grain yield per plant and lower Na^+/K^+ ratio can be considered sodicity tolerant, as the Na^+/K^+ ratio has a significant negative correlation (-0.8128) with grain yield (Keerthana *et al*., 2019). These tolerant genotypes have the ability to maintain the level of K and lower Na accumulation in their shoots (Sharma *et al*., 1986). Even though other traits, such as days to 50% flowering, days to maturity,

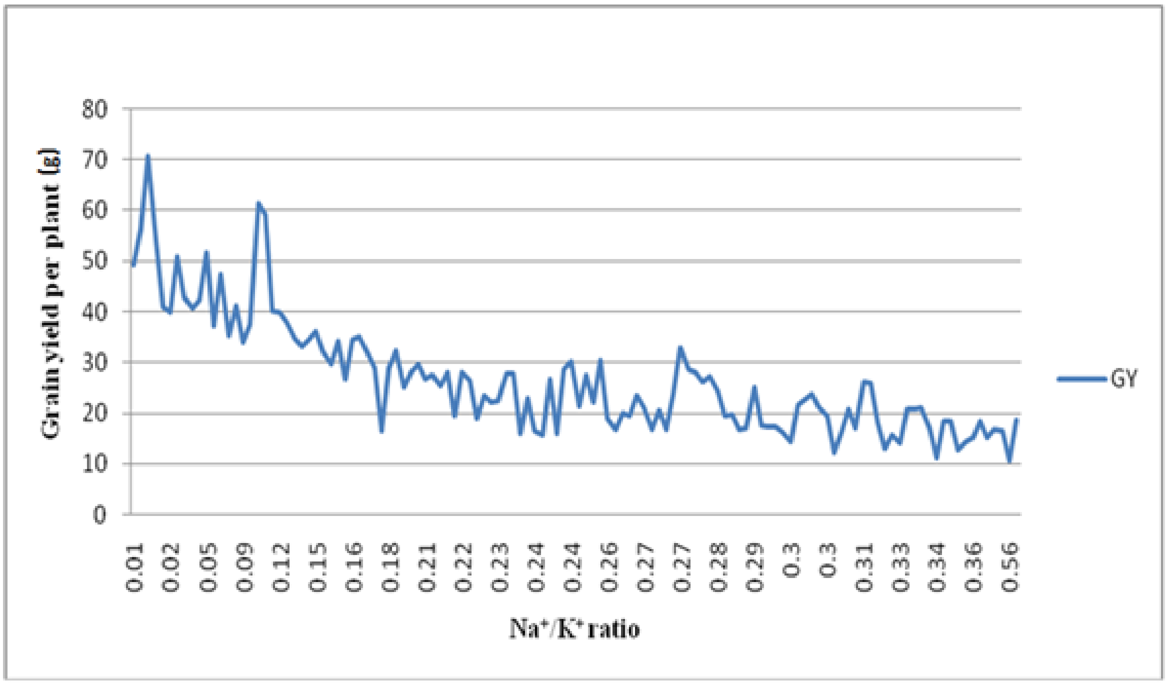

Fig. 1. *Relationship between Grain yield per plant and Na^+/K^+ ratio*

Table 1. Mean comparison of Na^+/K^+ ratio and grain yield per plant among 120 finger millet genotypes

S. No.	Genotypes	Na^+/K^+ ratio	Grain Yield per plant (g)	S. No.	Genotypes	Na^+/K^+ ratio	Grain Yield per plant (g)
1	FIN 2882	0.23	26.45	61	FIN 4605	0.27	28.69
2	FIN 3039	0.18*	16.61	62	FIN 2857	0.17**	31.81*
3	FIN 3027	0.22	27.59	63	FIN 2852	0.34	18.44
4	FIN 3055	0.34	11.07	64	FIN 2860	0.12**	39.93**
5	FIN 2886	0.30	17.29	65	FIN 2855	0.26	20.07
6	FIN 3045	0.12**	40.24**	66	FIN 2871	0.21	29.76
7	FIN 3053	0.25	21.28	67	FIN 2870	0.27	27.97
8	FIN 3042	0.23	19.05	68	FIN 2873	0.30	22.66
9	FIN 3041	0.27	19.49	69	FIN 2872	0.09**	35.32**
10	FIN 3050	0.16**	29.67	70	FIN 2869	0.20	28.07
11	FIN 3036	0.26	19.01	71	FIN 2896	0.14**	33.17**
12	FIN 2890	0.27	23.49	72	FIN 2864	0.30	23.68
13	FIN 3064	0.31	16.20	73	FIN 2848	0.23	22.52
14	FIN 2850	0.23	23.40	74	FIN 4268	0.12**	38.03**
15	FIN 3056	0.27	21.15	75	FIN 2856	0.33	20.74
16	FIN 2887	0.22	25.41	76	FIN 2859	0.31	25.94
17	FIN 3019	0.33	18.07	77	FIN 4219	0.27	26.31
18	FIN 2885	0.25	27.55	78	FIN 3033	0.36	18.33
19	FIN 2851	0.37	15.14	79	FIN 4119	0.38	16.74
20	FIN 3061	0.28	24.32	80	FIN 3034	0.01**	70.69**
21	FIN 2875	0.16**	34.20**	81	FIN 3928	0.05**	42.34**
22	FIN 3029	0.30	17.44	82	FIN 4048	0.24	26.60
23	FIN 2874	0.31	20.78	83	FIN 3062	0.33	20.92
24	FIN 3074	0.27	16.91	84	FIN 3104	0.09**	41.22**
25	FIN 3037	0.33	12.93	85	FIN 3968	0.28	19.81
26	FIN 3044	0.29	25.11	86	FIN 3965	0.16**	34.49**
27	FIN 3060	0.30	16.25	87	FIN 4135	0.33	20.99
28	FIN 3075	0.22	28.11	88	FIN 3873	0.28	16.69
29	FIN 2889	0.30	14.30	89	FIN 3091	0.09**	33.92**
30	FIN 3049	0.26	16.73	90	FIN 4183	0.21	26.70
31	FIN 3077	0.01**	49.27**	91	FIN 3076	0.33	17.20
32	FIN 3079	0.18*	28.85	92	FIN 3144	0.30	21.15
33	FIN 3032	0.24	16.58	93	FIN 2960	0.05**	51.74**
34	FIN 3030	0.30	21.50	94	FIN 3171	0.22	19.61
35	FIN 3015	0.10**	61.35**	95	FIN 3173	0.15**	32.11*
36	FIN 3040	0.31	16.99	96	FIN 3155	0.28	17.20
37	FIN 2881	0.77	18.55	97	FIN 3907	0.24	16.03
38	FIN 3048	0.39	16.62	98	FIN 3994	0.10**	59.06**
39	FIN 3017	0.56	10.64	99	FIN 3088	0.25	22.15
40	FIN 3046	0.33	15.76	100	FIN 4198	0.01**	53.95**
41	FIN 3063	0.15**	36.01**	101	FIN 4035	0.30	19.44
42	FIN 3057	0.24	15.72	102	FIN 3154	0.24	28.66
43	FIN 2876	0.27	20.62	103	FIN 4109	0.25	30.49
44	FIN 3066	0.29	17.63	104	FIN 3966	0.18**	32.29**
45	FIN 3014	0.20	25.09	105	FIN 3174	0.02**	50.88**
46	FIN 2849	0.23	22.10	106	FIN 3078	0.07**	37.12**
47	FIN 3047	0.27	16.87	107	FIN 4288	0.09**	37.53**
48	FIN 2992	0.34	18.40	108	FIN 4202	0.01**	40.96**
49	FIN 3025	0.27	23.83	109	FIN 4238	0.12**	34.65**
50	FIN 2861	0.02**	39.94**	110	FIN 3089	0.14**	34.43**
51	FIN 2899	0.31	26.14	111	FIN 4401	0.24	30.18
52	FIN 3038	0.35	12.80	112	FIN 3067	0.23	27.80
53	FIN 3065	0.16**	26.67	113	FIN 4166	0.35	14.39
54	FIN 3021	0.33	14.11	114	FIN 3022	0.27	27.19
55	FIN 3016	0.28	19.49	115	FIN 4205	0.02**	42.71**
56	FIN 3028	0.03**	40.71**	116	FIN 3068	0.23	27.84
57	FIN 3026	0.36	15.13	117	FIN 4218	0.17**	28.9
58	FIN 2858	0.27	32.88**	118	FIN 3182	0.16**	34.97**
59	FIN 2867	0.01**	56.34**	119	FIN 4487	0.22	27.97
60	FIN 2854	0.09**	47.40**	120	FIN 4270	0.23	15.88
				121	#TRY 1	0.23	23.10

*significant at 5% level; **significant at 1% level; #sodicity-tolerant check variety plant height, earhead length, number of fingers, finger length, number of tillers and number of productive tillers, could affect grain yield, sodium and potassium accumulation in shoots has a major impact on grain yield per plant. Therefore, it was confirmed that the Na^+/K^+ ratio was the key physiological characteristic for sodicity screening experiments.

Conclusion

The study concluded that sodium and potassium levels in plant samples contribute primarily to sodicity tolerance in finger millet. The selected 30 finger millet genotypes with high grain yield per plant and a low Na^+/K^+ ratio could be utilized in stress breeding programs to develop sodicity-tolerant finger millet varieties.

Conflict of interest

The authors declare that they have no conflict of interest.

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