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Impact of Soil Salinity on Growth and Yield of Different Millet Crops

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***Abstract*— *Millets are a diverse group of small-seeded cereal crops that have been cultivated for thousands of years. Millets are rich in essential nutrients such as dietary fiber, proteins, vitamins and minerals.With the rising challenges of climate change and food security, millets are being promoted globally as nutri-cereals for their adaptability, nutritional value, and role in sustainable agriculture. Excessive accumulation of soluble salts in the root zone adversely affects plant growth and yield. Crops grown under saline conditions often exhibit reduced germination, stunted growth and poor yield. Millets can also tolerate salinity to some extent but are sensitive to high levels of soil salinity. High salt levels can reduce the grain yield. The experiment was laid out in factorial RBD consists of three main treatments (pearl millet, finger millet and foxtail millet) and five sub treatments (2,3,4,5 dS m^{-1} and control). The salinity of respective pots was developed with addition of salt water prepared by additions of NaCl, $NaSO_4$ and $CaSO_4$ in 2:2:1 ratio. Data on yield attribute (panicle/ear head length) and grain yield were recorded the results revealed that panicle length decreased with increasing salinity. Pearl millet recorded the highest panicle length (21 cm), followed by foxtail millet (18 cm), while finger millet exhibited the lowest mean panicle length (9 cm) . Among the salinity levels, the highest panicle length (19 cm) was observed under control while the lowest panicle length (13 cm) occurred at the highest salinity level 5 dS m^{-1}. A significant reduction in grain yield with increasing salinity. Among the millets, finger millet recorded the highest average grain yield (288 g pot^{-1}) across salinity levels, followed by pearl millet with 213 g pot^{-1}, and foxtail millet with the lowest at 194 g pot^{-1}. Among the salinity levels, the highest yield was observed under control with 257 g pot^{-1}, while the lowest yield occurred at the highest salinity level 5 dS m^{-1} with of 200 g pot^{-1} Grain yield decreased progressively with increasing salinity across all three millets, indicating the negative impact of salt stress on reproductive performance.*

***Keywords*— Millets, nutrients, salinity, panicle length, grain and straw yield.**

I. INTRODUCTION

The changes foreseen under climate change scenarios are the changes in the pattern of rainfall, rather than the quantum, leading to long spells of drought and spells of water-logging of the soils as well as salinity. Salinity is the main abiotic factor influencing crop development, productivity and germination (Sairam *et al.*, 2002). Salinity is the process of accumulation of soluble salts, it affects plant productivity in arid and semi-arid regions of the world where evapo-transpiration is high and the rain is not enough for leaching the salt out of the root zone (Al-Hilal, 1999).

Millets have been cultivated for thousands of years and because of their substantial advantages in terms of nutrition and easy adaptable to environment, they are currently receiving more attention. Pearl millet (*Pennisetum glaucum* L) is well acclaimed for its great tolerance to various forms of adversity, especially its capacity to endure high concentrations of salinity and one of the most important economic crops to face climate change and maintain food security. It has an advantage due to its promising dual purpose (grain and fodder), short duration and quick growing nature. Foxtail millet (*Setaria italica* L.), a member of the Paniceae family is extensively grown for grain and forage throughout Asia, Europe, North America, Australia and North Africa. It's an environment-friendly crop with high drought-stress resistance, short life cycle, dual grain and forage use, wide adaptability, and low water consumption, making it the prospective model crop for investigating the effects of salinity plants.

Finger millet (*Eleusine coracana)* is a staple crop grown in different agronomical regions of the world. It's renowned for its exceptional nutritional profile, containing minerals such as calcium and phosphorus, essential amino acids like methionine, tryptophan and cysteine, dietary fibers and high-quality protein, anti-diabetic, antioxidant and antimicrobial effects. Despite its resilience to multiple stresses, salinity poses major impacts on finger millet growth and development by reducing water content, leaf expansion, plant height, grain weight and delaying flowering. Keeping this in view, the present study was taken up to know the effect of variable salinity levels on yield attributes and yield of millet crops.

II. MATERIAL AND METHODS

The experiment was conducted during *Kharif* 2024 at Agricultural Research Station, Perumallapalle, Tirupati, Acharya N.G. Ranga Agricultural University, which is geographically situated at 13° 36' 761" N latitude and 79° 20' 704" E longitude with an altitude of 182.9 m above the mean sea level, which falls under Southern Agro Climatic Zone of Andhra Pradesh. Three Millets (pearl millet, finger millet and foxtail millet) using five salinity levels (EC of 2, 3, 4, 5 dS m^{-1} and control) by following factorial randomized block design with 3 replications. Cement pots of 1m radius × 1 m height microplot were filled with soil. The soil salinity of different levels were developed by addition of salt water (prepared with dissolving of NaCl, Na_2SO_4 and $CaSO_4$ in the ratio of 2:2:1). The recommended dose of fertilizer for pearl millet (80:40:30 kg NPK ha^{-1}), finger millet (60:30:20 kg NPK ha^{-1}), foxtail millet (40:20:20 kg NPK ha^{-1}) was applied through inorganic fertilizers (urea, single super phosphate and muriate of potash, respectively). Nitrogen fertilizer was applied in two splits (half at basal and half at 30 days after sowing). Entire dose of phosphorus and potassium were applied as basal at the time of sowing. The data on length of ear head or panicle was measured and their average length was reported as per ear head or panicle basis. Total number of tillers $plant^{-1}$ was counted from each pot and average was reported as number of tillers $plant^{-1}$. The air dried ear heads from each pot were threshed, cleaned and weight of the grain was recorded on the basis of grain yield per pot. The weight of straw from each pot was recorded after complete sun drying until a constant weight.

III. RESULTS AND DISCUSSION

Number of Tillers $plant^{-1}$

The data demonstrated on yield attributes such as number of tillers $plant^{-1}$ of different millet crops under varying salinity levels is presented in Table 1. The results indicated that these attributes were significantly influenced by millets, salinity levels and their interaction, Among the millets, finger millet (M_2) recorded the highest number of tillers (5), followed by pearl millet (M_1) of (4), while the lowest (3) was observed in foxtail millet (M_3). Across salinity treatments, the highest number of tillers (5) was recorded in at control. The lowest number of tillers per plant (3) was observed at highest salinity of 5 dS m^{-1}(S_4). The interaction between millets and salinity was found to be significantly highest. The maximum number of tillers per plant (6) was found in the treatment combination M_2S_5, M_2S_1 and M_1S_3.The lowest number of tillers (4) was recorded by the combination M_3S_4.

The superior tillering ability of finger millet may be attributed to its better physiological adaptability and genetic potential for shoot proliferation. The number of tiller per plant decreases with increasing of salinity due to osmotic stress and ion toxicity caused by excess sodium ions in saline condition, which hinders cell division and tiller emergence. These findings align with those of Kumar *et al.* (2018), who reported similar reductions in tillering under salinity. Accumulation of Na^+ and Cl^- ions in shoot tissues causes ion imbalance and toxicity. This affects meristematic activity, especially in basal nodes where tillers initiate. (Parida *et al.*2005).

Panicle length or ear head length

The data displayed on panicle length of different millet crops as influenced by salinity levels is presented in Table 1. A significant effect of millets, salinity levels and their interaction was observed. In the group of millets, pearl millet (M_1) recorded the highest panicle length of 21 cm, which was at par with foxtail millet (M_3) (18 cm), while finger millet (M_2) registered the lowest panicle length of 9 cm.

With respect to salinity levels, the control (S_5) reported the maximum panicle length (19 cm). The panicle lengths under S_1 (17 cm) and S_2 (17 cm) regarded the same mean values. The shortest panicle length under high salinity S_4 (13 cm).

The interaction between two factors showed significant effect on panicle length. highest. The highest panicle length (26 cm) was recorded by the treatment combination M_1S_5.The treatment M_1S_2 (23 cm) which was at par with M_1S_3 (21 cm) and M_1S_2 (20 cm).The lowest ear head length (5 cm) was recorded by the combination M_2S_4.

The higher panicle length in pearl millet is a result of its inherent genetic characteristics, efficient resource use, and moderate salinity tolerance, which allow it to maintain reproductive development even under stress. salinity stress reduces panicle development by impairing reproductive growth. Salinity interferes with flowering and grain formation, leading to reduced ear head elongation. High Na^+ and Cl^- concentrations cause ion toxicity, damaging meristematic tissues responsible for panicle development or earhead development (Parida *et al.*2005).

Table 1. Effect of salinity levels on yield attributes by different millet crops

Millets	Number of tillers plant $^{-1}$						Panicle length (or) ear head length (cm)					
	Salinity levels						Salinity levels					
	S_1 (2dS m^{-1})	S_2 (3dS m^{-1})	S_3 (4dSm-^{1})	S_4 (5dS m^{-1})	S_5 (control)	Mean	S_1 (2 dS m^{-1})	S_2 (3dS m^{-1})	S_3 (4dS m^{-1})	S_4 (5dS m^{-1})	S_5 (control)	Mean
M_1(Pearl millet)	5	5	4	4	5	4	23	21	20	17	26	21
M_2(Finger millet)	6	5	6	5	6	5	10	10	6	5	13	9
M_3(Foxtail millet)	4	4	4	3	4	3	20	19	18	16	18	18
Mean	5	4	4	3	5		17	17	15	13	19	

	SEm±	CD (P=0.05)	SEm±	CD (P=0.05)
Millets(M)	0.053	0.156	0.42	1.22
Salinity levels(S)	0.069	0.201	0.54	1.58
M×S	0.120	0.348	0.94	2.74

Grain Yield

The data pertaining to grain yield (g pot^{-1}) was found to be significantly influenced by salinity levels, different millets and also their interaction which was illustrated in the Table 2. Among the three millets, finger millet (M_2) produced the significantly the highest grain yield of 269 g pot^{-1} trailed by pearl millet (M_1)(211 g pot^{-1}) whereas, the declined grain yield of 195 g pot^{-1} was recorded by foxtail millet (M_1). The highest grain yield of 251 g pot $^{-1}$ was recorded at control which was significant over the remaining salinity levels. The lowest grain yield of 200 g pot $^{-1}$was observed at the superior salinity level of 5 dS m^{-1}(S_4). The percent reduction in grain yield from the lowest to the highest salinity level was 74 per cent.

The interaction between the varieties and salinity levels indicated that, the maximum grain yield of 292 g pot $^{-1}$ was noticed in the combination of M_2S_5, which was on par with M_2S_1(285 g pot^{-1}) whereas, the minimum grain yield (176 g pot^{-1}) was obtained in combination of M_3S_4. Among the millets, finger millet (M_2) records the highest grain yield across salinity levels, indicating its superior adaptability. Its combination of physiological resilience, efficient resource use and stress-tolerant traits makes it the best performer under saline conditions. Finger millet has been genetically reported to have higher yield stability across environments, including under stress conditions like salinity.

The reduction in yield per pot might be due to shrinkage of cell contents, specific ion toxicity, restriction of photosynthesis, ion exclusion and growth limitations originating from nutritional imbalances. Similar findings were reported by Ali *et al.* (2014). Grain yield was greatly influenced by soil salinity. The significant and gradual reduction in grain yield with progressive increase in soil salinity could mainly due to cumulative effect of decrease in plant height, less weight per ear head due its size reduction and less number of filled grains per ear head.

Table 2. Effect of salinity levels on grain and straw yield (g pot^{-1}) by different millet crops

Millets	Grain Yield (g pot^{-1})						Straw yield (g pot^{-1})					
	Salinity levels						Salinity levels					
	S_1 (2dS m^{-1})	S_2 (3dS m^{-1})	S_3 (4dSm-^{1})	S_4 (5dS m^{-1})	S_5 (control)	Mean	S_1 (2dS m^{-1})	S_2 (3dS m^{-1})	S_3 (4dSm-^{1})	S_4 (5dS m^{-1})	S_5 (control)	Mean
M_1(Pearl millet)	221	213	204	183	244	211	533	491	446	379	578	485
M_2(Finger millet)	285	273	255	242	292	269	612	578	542	416	673	564
M_3(Foxtail millet)	205	191	185	175	216	195	391	341	302	286	436	352
Mean	233	226	215	200	251		512	470	430	360	562	
	SEm±			**CD (P=0.05)**			**SEm±**			**CD (P=0.05)**		
Millets (M)	2.09			4.82			3.48			10.14		
Salinity levels (S)	2.70			6.21			4.50			13.10		
M×S	4.69			10.8			7.79			22.69		

Straw Yield

The data on straw yield (g pot^{-1}) of different millet crops under various salinity levels is presented in Table 2. Data pertaining to straw yield (g pot^{-1}) was significantly influenced by salinity levels, different millets and also by their interaction. Within the three millets, finger millet (M_2) produced the highest straw yield (564 g pot $^{-1}$) succeeded by pearl millet (M_1) (485 g pot^{-1}) whereas the lowest grain yield of 352 g pot^{-1} was observed by foxtail millet (M_3). The highest straw yield of 562 g pot^{-1} was noticed at control followed by 512 g pot^{-1} S_1(2 dS m^{-1}). The lowest straw yield 360 g pot^{-1} was observed at the superior salinity level of 5 dS m^{-1}(S_4).

The interaction between varieties and salinity levels indicated that the maximum straw yield of (673 g pot^{-1}) was attained in the combination of M_2S_5 followed by M_2S_1(612 g pot^{-1}) whereas, the minimum straw yield (286 g pot $^{-1}$) was obtained in the combination of M_3S_4.

The superior performance of finger millet may be attributed to its vigorous vegetative growth, greater dry matter accumulation, and relatively higher salt tolerance, allowing it to sustain biomass production even under moderate saline conditions. Salinity was one of the major environmental factors limiting plant growth and yield (Parida and Das, 2005) reported that salinity of soil decreases number of grain per panicle and harvest index. The reduction in yield per pot might be due to excess of soluble salts in the root zone negatively affects plant growth and yield through osmotic effects, nutritional imbalances, and specific ion toxicities (Tahir et *al.*2006).

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