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Productivity Enhancement of Foxtail Millet (*Setaria italica* L.) through Critical Agronomic Interventions under Southern Agro-Climatic Zone of Andhra Pradesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *kharif*, 2016 and 2017 at S.V. Agricultural College farm, Tirupati to study the influence of spacing, nutrient and weed nutrient management practices on growth and yield of foxtail millet. Significant effects were noticed on growth and yield components *viz*., plant height, number of panicles m^{-2}, weight of the panicle, grain weight $panicle^{-1}$, grain and straw yield of foxtail millet. Among different plant geometries tried, closer spacing of 20 cm x10 cm registered taller plants, higher number of panicles m^{-2}, higher grain and straw yield, where as the weight of the panicle, grain weight $panicle^{-1}$ were found to be highest with 30 cm x10 cm. Among the micronutrient management practices, foliar application of $ZnSO_4$@ 0.5% twice at the time of flowering and at grain filling stage along with 100% RDF registered taller plants as well as higher grain yields.Hand weeding at 20 DAS and 30 DAS outperformed other weed management practices. This was followed by pre-emergence application of butachlor @ 1 kg *a.i* ha^{-1} with one

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hand weeding at 30DAS.The study concluded that the closer spacing of 20cmx 10cm, foliar application of $ZnSO_4$ at the time of flowering and 20 days after flowering along with RDF and hand weeding twice at 20 DAS and 30 DAS resulted in higher productivity of foxtail millet.

Keywords: Foxtail millet; spacing; zinc foliar application; weed management practices; yield.

1. INTRODUCTION

Foxtail millet ranks second in the world's total millet production. It is cultivated in more than 23 countries of Africa, Asia and America and it has a prominent place in world agriculture in providing food for millions of people in arid and semiarid regions. It is an elite drought tolerant crop due to its high water use efficiency and short life cycle [1]. Nutritionally, foxtail millet is superior to rice, wheat and other prominent cereal crops [2]. It is rich in proteins (11.2%), dietary fiber (6.7%) and low in fat (4%) and also highly suitable for diabetic patients due to its lower glycemic index. In recent years, there is an increasing demand for foxtail millet as consumption of foxtail millet is increasing day by day particularly by the people suffering from diabetes. The productivity of foxtail milletis very low compared to its potentially achievable yield owing to a lack of suitable crop management practices. The potential yield of the variety could be realized only when backed up by good management practices. Spacing is one of the major agronomic practices which requires due attention. Optimum spacing provides ideal conditions for maximum light interception by providing uniformly distributed photosynthetic surfaces with complete ground cover.Micronutrients are as important as macronutrients and are involved in vital metabolic events in the plants. Deficiency of even a single essential micronutrient may disturb the plant developmental cascades and cause substantial reduction in crop yield [3]. Foxtail Millet, being less expensive than cereals and being the staple food for weaker sections of the population makes it as an important crop that deserves attention for fortification with micronutrients. Fortification especially with zinc is a better option to tackle the global zinc malnutrition problem and further it has attained a greater significance in today's intensive and exploitive agriculture practices which aims to enhance productivity.Further, heavy weed infestation is one of the serious limitations in production of foxtail millet due to its slow initial growth. It was reported that the loss of grain yield due to uncontrolled weed growth in foxtail millet was as high as 55-56% [4]. Therefore, an appropriate weed management strategy would help to enhance productivity and input use-efficiency. When improved agrotechnologies are adopted, efficient weed management becomes even more crucial, otherwise the expensive inputs will benefit weeds rather than the crops. Despite the crop's importance, information pertaining to the optimum spacing, zinc fortification and weed management practices was limited.Hence, this study was aimed at determining the influence of spacing, micronutrients and weed management practices and their interactions on growth and yield of foxtail millet.

2. MATERIALS AND METHODS

A field experiment was carried out during *kharif*, 2016 and 2017 at S.V. Agricultural College farm, Tirupati, situated at an altitude of 182.9 m above mean sea level, 13°N latitude and 79°E longitude. The soil of the experimental site was sandy clay loam in texture, neutral in soil reaction, low in organic carbon and available nitrogen, high in phosphorus, medium in potassium and deficient in zinc.The experiment was laid out in split-split plot design with three replications. Spacings were allotted to main plots, nutrient management practices in sub plots while, weed management practices to sub-sub plots. The experiment was comprised of three spacings (S_1: 20 cm x 10 cm; S_2:25 cm x 10 cm and S_3:30 cm x 10 cm), three nutrient management practices (N_1 : 100% RDF, N_2:100% RDF + foliar application of $ZnSO_4$ @ 0.5% at the time of flowering and N_3:100% RDF + foliar application of $ZnSO_4$ @ 0.5% at the time of flowering and 20 days after flowering and four weed management practices(W_1:Control (weedy check); W_2:Two Hand weedings at 20 and 30 DAS; W_3: Pre-emergence application of butachlor @ 1 kg *a.i* ha + 1 Hand weeding at 30DAS and W_4: Pre-emergence application of butachlor @ 1 kg *a.i*ha + Post-emergence application of bispyribac sodium @ 20 g a.i ha^{-1} at 2-4 leaf stage of weed). SiA 3085 variety of foxtail millet was used for field study. Seeds @ 5 kg ha^{-1} were sown by mixing with sand in the open furrows made with the help of hand hoe at different spacings as per the treatments i.e., 20 cm x 10 cm, 25 cm x 10 cm and 30 cm x 10 cm.

The recommended dose of fertilizer was 50:30:20 kg N, P_2O_5 and K_2O ha^{-1} . The entire dose of phosphorous @ 30 kg ha^{-1} and potassium @ 20 kg ha^{-1} was applied basally. Nitrogen @ 50 kg ha^{-1} was applied in two equal splits *viz.,* first half at the time of sowing as basal and remaining half as top dressing at 30 DAS. Hand weedings were carried out at the scheduled time according to the treatments. The required quantity of pre-emergence and post-emergence herbicides as well as zinc was sprayed as per treatments with the help of knap sack sprayer. The total rainfall received during crop season was 134.1 mm and 807.2 mm during first and second year, respectively.

3. RESULTS AND DISCUSSION

3.1 Effect of Spacing

Among the three spacings evaluated, the closer spacing of 20 cm x 10 cm (S_1) resulted in significantly taller plants followed by the spacing of 25 cm x 10 cm (S_2) with significant disparity between them. Whilethe spacing of 30 cm x 10 cm (S_3) resulted in shorter plants which were significantly inferior to the other spacings tried during both the years of study and pooled mean. This might be due to mutual shading and increased competition for light among the plants at closer spacing, resulting in longer internodes and more terminal growth. While at the spacing of 30 cm x 10 cm (S_3), plants did not struggle for radiant energy leading to more lateral growth.

Significantly higher number of panicles m^{-2} was recorded with the spacing of 20 cm x 10 cm; while, the spacing of 30 cm x 10 cm (S_3) resulted in significantly lower number of panicles m^{-2} which might be due to more number of plants per unit area at the closer spacing. The other yield attributing parameters *viz*., weight of the panicle, weight of the filled grains per panicle were found to be significantly higher with the spacing of 30 cm x 10 cm (S_3).This might be attributed to the efficient translocation of photosynthates to sink supported by the increased vegetative growth at wider spacing due to maximum utilization of the growth resources and minimum competition for the growth resources between the plants. Closer spacing of 20 cm x 10 cm (S_1) resulted in the significantly lower weight of the panicle andweight of the filled grains per panicle (Table 2).

Significantly higher grain yield was recorded with the closer spacing of 20 cm x 10 cm (S_1) followed by the wider spacing of 25 cm x 10 cm (S_2). The lowest grain yield was recorded in widest spacing of 30 cm x 10 cm (S_3). The higher grain yield at closer spacing might be due to accommodation of more number of plants per unit area.In the present study, though individual weight of the panicle was lower at closer spacing of 20 cm x 10 cm (S_1), higher number of panicles per unit area at closer spacing resulted in maximum grain yield ha^{-1}. The results are in accordance with the findings of Nandini and Sridhara [5] in foxtail millet and Siddiqui et al. [6] in browntop millet.

3.2 Effect of Zinc Fertilization

The highest expression of all the growth parameters and yield attributes were observed with the foliar application of$ZnSO_4$ @ 0.5% at the time of flowering and 20 days after flowering along with RDF (N_3). While all these parameters were at their lowest value in the control (N_1) without any foliar sprays. (Table 1 and 2). However, the number of panicles m^{-2} was found to be nonsignificant with nutrient management practices.

Significantincrease in grain and straw yields were observed with foliar application of $ZnSO_4$ @ 0.5% at the time of flowering and 20 days after flowering along with RDF (N_3) followed by foliar feeding of $ZnSO_4$ @ 0.5% only once at the time of flowering (N_2) and it was found to be the lowest in the RDF (N_1) (Table 3).The improvement in yield with foliar nutrition might be attributed to the fact that the foliar application coincides with the peak nutrient demand of the crop. Supplementing nutrients through the foliage during the flowering and grain filling stages might have resulted in a better nutrient balance, which improved the plant's photosynthetic efficiency during the post-anthesis period, resulting in increased yield attributes and yield of foxtail millet. Similar findings were also reported by Shekawat and Kumawat [7] and Sandhyarani et al. [8].

3.3 Effect of Weed Management Practices

Significantly taller plants were observed in plots with hand weeding twice at 20 and 30 DAS of foxtail millet in both the years and the pooled means. This might be due to the creation of weed free environment with reduced crop-weed competition during critical stages of crop growth associated withcomplete removal of weeds which results in rapid cell multiplication and cell elongation. The shortest plants were noticed in the plots which were unweeded throughout the crop growing period which was obviously due to severe competition offered by the weeds for growth resources right from the seedling emergence, leading to stunted growth of crop plants. The results are in accordance with the findings of Ullah et al. [9].

The yield attributes *viz*., number of panicles m^{-2}, weight of the panicle and weight of the filled grains per panicle were found to be significantly higher with hand weeding twice (W_2) during both the years of study and pooled mean. This might be due to the efficient suppression of weeds due to which a favorable situation was created for sustaining the large number of tillers and their conversion to ear bearing tillers by liberal supply of nutrients in balanced proportions. Further, effective translocation of photosynthates to sink resulted in the higher weight of the panicle. Whereas the weedy check (W_1) resulted in the lowest values of all the yield attributes. Continuous and heavy robbing of nutrients by weeds in weedy check plots (W_1) might have resulted in reduced vegetative growth and subsequent reproductive growth.

Table 1. Plant height (cm) at harvest and number of panicles m^{-2} of foxtail millet as influenced by spacing, nutrient and weed management practices

Treatments	Plant height			No. of Panicles m^{-2}		
	2016	2017	Pooled	2016	2017	Pooled
Spacings						
S_1: 20 cm x 10 cm	100	102	101	85	89	87
S_2 :25 cm x 10 cm	96	99	97	78	80	79
S_3: 30 cm x 10 cm	93	97	95	74	76	75
SEm ±	0.7	0.4	0.5	0.6	0.9	0.3
CD (P=0.05)	3	2	2	2	4	1
Nutrient management practices						
N_1: 100%RDF	95	97	96	79	81	80
N_2: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering	97	99	98	80	81	81
N_3: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering and 20 DAF	98	100	99	79	82	80
SEm ±	0.3	0.4	0.3	0.8	0.6	0.6
CD (P=0.05)	1	1	1	NS	NS	NS
Weed management practices						
W_1: Control (weedy check)	70	73	71	52	51	52
W_2 : Two HWs at 20 and 30 DAS	109	111	110	95	100	97
W_3: PE application of Butachlor @ 1 kg *a.i* ha^{-1} + 1HW at 30DAS	106	108	107	88	91	89
W_4: PE application of Butachlor @1 kg *a.i*ha^{-1} + PoE application of Bispyribac sodium @ 20 g*a.i* ha^{-1} at 2-4 leaf stage of weed	102	104	103	81	85	83
SEm ±	0.4	0.5	0.4	0.7	0.7	0.6
CD (P=0.05)	2	1	1	2	2	2
Interaction						
S x N						
SEm ±	0.6	0.7	0.6	1.3	1.0	1.1
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SxW						
SEm ±	0.7	1.0	0.7	1.3	1.1	1.0
CD (P=0.05)	NS	NS	NS	NS	NS	NS
NxW						
SEm ±	0.7	1.0	0.7	1.3	1.1	1.0
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SxNxW						
SEm ±	1.2	1.7	1.3	2.2	2.0	1.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 2. Weight of the panicle (g) and Weight of the filled grains panicle^{-1} (g) of foxtail millet as influenced by spacing, nutrient and weed management practices

Treatments	Weight of the panicle			Weight of the filled grains panicle^{-1}		
	2016	2017	Pooled	2016	2017	Pooled
Spacings						
S_1: 20 cm x 10 cm	4.59	4.84	4.71	2.70	2.84	2.77
S_2 :25 cm x 10 cm	4.99	5.28	5.13	2.87	3.15	3.01
S_3: 30 cm x 10 cm	5.30	5.69	5.50	3.10	3.36	3.23
SEm ±	0.030	0.032	0.032	0.028	0.034	0.032
CD (P=0.05)	0.12	0.13	0.13	0.11	0.13	0.12
Nutrient management practices						
N_1: 100%RDF	4.61	4.92	4.72	2.63	2.86	2.75
N_2: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering	4.97	5.28	5.13	2.89	3.12	3.01
N_3: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering and 20 DAF	5.30	5.70	5.50	3.15	3.37	3.26
SEm ±	0.029	0.032	0.031	0.027	0.026	0.026
CD (P=0.05)	0.09	0.10	0.09	0.08	0.08	0.08
Weed management practices						
W_1: Control (weedy check)	2.02	1.74	1.88	1.43	1.25	1.34
W_2 : Two HWs at 20 and 30 DAS	6.39	6.97	6.68	3.79	4.16	3.98
W_3: PE application of Butachlor @ 1 kg *a.i* ha^{-1} + 1HW at 30DAS	5.81	6.33	6.07	3.28	3.65	3.46
W_4: PE application of Butachlor @1 kg *a.i*ha^{-1} + PoE application of Bispyribac sodium @ 20 g*a.i* ha^{-1} at 2-4 leaf stage of weed	5.62	6.04	5.83	3.07	3.41	3.24
SEm ±	0.050	0.057	0.054	0.048	0.046	0.045
CD (P=0.05)	0.14	0.16	0.15	0.14	0.13	0.13
Interaction						
S x N						
SEm ±	0.050	0.056	0.053	0.046	0.046	0.044
CD (P=0.05)	NS	NS	NS	NS	NS	NS
S x W						
SEm ±	0.087	0.099	0.093	0.083	0.079	0.080
CD (P=0.05)	NS	NS	NS	NS	NS	NS
N x W						
SEm ±	0.087	0.099	0.093	0.083	0.079	0.080
CD (P=0.05)	NS	NS	NS	NS	NS	NS
S x N x W						
SEm ±	0.151	0.171	0.161	0.144	0.137	0.139
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Significant disparities in the weight of the filled grains panicle^{-1}, grain and straw yield of foxtail millet followed by pre-emergence application of butachlor @ 1 kg *a.i* ha^{-1} with one hand weeding at 30DAS (W_3) and pre-emergence application of butachlor @ 1 kg *a.i* ha^{-1}+ post emergence application of bisypyribac sodium @20 g *a.i* ha^{-1} at 2-4 leaf stage of weed (W_4) with statistically significant difference between any two of them for all the parameters except the panicle length for which they have maintained parity with each other. While the weedy check (W_1) resulted in lowest values of growth, yield attributes and yield.

Significantly higher grain and straw yield of foxtail millet was recorded in the plots with hand weeding twice at 20 DAS and 30 DAS (W_2) over the other weed management practices tried during both the years of study and in pooled means. The next best treatment was pre emergence application of butachlor @ 1 kg *a.i* ha^{-1} + one hand weeding at 30DAS (W_3) followed by pre emergence application of butachlor @ 1 kg *a.i* ha^{-1} + Post emergence application of bispyribac sodium @20 g *a.i* ha^{-1} at 2-4 leaf stage of weed (W_4) with significant difference between them. The grain yield of foxtail millet was found to be the lowest in the plots where, weed management was not done throughout the crop growth (W_1). Uncontrolled weed growth in foxtail millet was found to reduce the mean grain and straw yield to the tune of 57.48% and 58.30% across both the years of study indicating the adverse impact of weed flora on yield of foxtail millet. A relatively weed free environment maintained during critical period of crop weed competition in the weed control treatments might have enabled the crop plants to absorb larger amounts of nutrients to produce higher growth stature, yield attributes and ultimately yield. Similar findings were documented by Kitawat [10] in foxtail millet, Fufa and Mariam [11] in finger millet and Jawahar et al. [12] in kodo millet.

In none of the parameters, the interaction effects among main plots, sub plots and sub-sub plots treatments was found significant during both the years of investigation and in pooled means.

Table 3. Grain and straw yield (kg ha^{-1}) of foxtail millet as influenced by spacing, nutrient and weed management practices

Treatments	Grain yield			Straw yield		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
Spacings						
S_1: 20 cm x 10 cm	1460	1574	1517	2407	2588	2499
S_2 :25 cm x 10 cm	1351	1481	1416	2252	2456	2355
S_3: 30 cm x 10 cm	1205	1353	1279	2047	2279	2163
SEm ±	28.0	22.4	24.2	39.4	31.7	34.2
CD (P=0.05)	109	87	94	154	124	135
Nutrient management practices						
N_1: 100%RDF	1257	1345	1301	2121	2265	2194
N_2: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering	1325	1473	1390	2215	2466	2331
N_3: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering and 20 DAF	1434	1591	1512	2369	2611	2491
SEm ±	18.2	19.2	18.2	25.8	26.7	25.9
CD (P=0.05)	56	59	56	80	83	77
Weed management practices						
W_1: Control (weedy check)	769	821	795	1202	1343	1283
W_2 : Two HWs at 20 and 30 DAS	1784	1949	1867	2960	3187	3077
W_3: PE application of Butachlor @ 1 kg *a.i* ha^{-1} + 1HW at 30DAS	1522	1666	1594	2569	2779	2671
W_4: PE application of Butachlor @1 kg *a.i*ha^{-1} + PoE application of Bispyribac sodium @ 20 g*a.i* ha^{-1} at 2-4 leaf stage of weed	1279	1442	1360	2211	2456	2324
SEm ±	24.0	25.2	22.8	34.0	31.6	31.4
CD (P=0.05)	68	72	65	96	90	89
Interaction						
S x N						
SEm ±	31.5	33.2	31.6	44.7	46.6	44.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SxW						
SEm ±	41.6	43.7	39.6	58.8	54.8	54.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS
NxW						
SEm ±	41.6	43.7	39.6	58.8	54.8	54.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SxNxW						
SEm ±	72.1	71.5	68.5	101.9	94.9	94.0
CD (P=0.05)	NS	NS	NS	NS	NS	NS

4. CONCLUSION

From the present investigation, it could be concluded that the closer spacing of 20 cm x 10cm with foliar application of 0.5% $ZnSO_4$ at the time of flowering and 20 days after flowering along with RDF and hand weeding twice at 20 DAS and 30 DAS in foxtail millet was found to be the best package of practices for realization of higher yield under southern Agro-climatic zone of Andhra Pradesh.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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