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Karanam Navya Jyothi
Ph.D Scholar, Department of Agronomy, S.V. Agricultural College, Tirupati, Andhra Pradesh, India

V Sumathi
Professor of Agronomy, Programme Coordinator, Krishi Vigyan Kendra, Nellore, Andhra Pradesh, India

D Subramanyam
Professor, Department of Agronomy, S.V. Agricultural College, Tirupati, Andhra Pradesh, India

P Sudhakar
Controller of Examinations, Acharya N. G. Ranga Agricultural University, Lam, Guntur, Andhra Pradesh, India

T Giridhar Krishna
Registrar, Acharya N. G. Ranga Agricultural University, Lam, Guntur, Andhra Pradesh, India

G Karuna Sagar
Professor and Head, Department of Agronomy, S.V. Agricultural College, Tirupati, Andhra Pradesh, India

Corresponding Author:
Karanam Navya Jyothi
Ph. D Scholar, Department of Agronomy, S.V. Agricultural College, Tirupati, Andhra Pradesh, India

Productivity and profitability of foxtail millet (*Setaria italica* L.) as influenced by varied agro techniques under Southern agro-climatic Zone of Andhra Pradesh

Karanam Navya Jyothi, V Sumathi, D Subramanyam, P Sudhakar, T Giridhar Krishna and G Karuna Sagar

Abstract
A field experiment was conducted during *kharif*, 2016 and 2017 at S.V. Agricultural College farm, Tirupati to study the effect of spacing, nutrient and weed nutrient management practices on productivity and profitability of foxtail millet. Significant influence was noticed on the growth, yield and economics of foxtail millet. Among the spacings, closer spacing of 20 cm x10 cm resulted in taller plants, higher dry matter accumulation, maximum number of panicles m^{-2}, higher grain and straw yield and maximum monetary returns and B: C ratio. Foliar application of $ZnSO_4$@ 0.5 % twice at the time of flowering and 20 days after flowering along with 100% RDF resulted in higher growth stature, yields as well as monetary returns. Further, hand weeding at 20 DAS and 30 DAS in foxtail millet resulted in higher stature of growth and yield attributes, yield and monetary returns. The study concluded that the spacing of 20 cm x 10 cm, 100% RDF +foliar application of $ZnSO_4$ at the time of flowering and 20 days after flowering and hand weeding twice at 20 DAS and 30 DAS resulted in higher productivity and profitability of foxtail millet.

Keywords: Foxtail millet, spacing, zinc foliar application, weed management practices, yield, economics

Introduction
Millets are known to be 'crops of the future as they can be well adapted and cultivated under the harsh environment of the arid and semi-arid region (RESMISA, 2012) [9]. Foxtail millet ranks second in the world's total millet production. It is an elite drought-tolerant crop due to its high water use efficiency and short life cycle (Zhang *et al*., 2012) [14]. Due to its low glycemic index and excellent nutritional profile in terms of dietary fibre (6.7%), protein (11%) and low fat (4%), there is an increasing demand for foxtail millet particularly by the people suffering from diabetes in recent years. The productivity of foxtail millet is very low compared to its potentially achievable yield owing to a lack of suitable crop management practices. Spacing is one of the major agronomic practices which requires due attention as it is being broadcasted by the farmers. Micronutrients are as important as macronutrients and are involved in vital metabolic events in plants. The deficiency of even a single essential micronutrient may disturb the plant developmental cascades and cause a substantial reduction in crop yield (Tripathi *et al*., 2015) [13]. In global human nutrition, zinc deficiency is one of the major widespread mineral deficiencies. Foxtail millet, being less expensive than cereals and being the staple food for weaker sections of the population makes it an important crop that deserves attention for fortification with micronutrients. Further, the Slow initial growth of foxtail millet results in heavy weed infestation. It was reported that the loss of grain yield due to uncontrolled weed growth in foxtail millet was as high as 55-60 % (Zhou *et al*, 2012) [15]. Therefore, an appropriate weed management strategy would help to increase productivity and profitability. The above facts necessitate generating information on the optimum spacing, zinc fortification and weed management practices in foxtail millet for higher productivity and profitability. The present investigation was therefore taken up to study the effect of spacing, zinc fertilization and weed management practices on the productivity and profitability of foxtail millet

Material 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 a split-split plot design with three replications. 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). Spacings were allotted to main plots, nutrient management practices in subplots while weed management practices to sub-sub plots 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 a knapsack sprayer. The data obtained on various parameters during the study were statistically analyzed by following the analysis of variance for Randomized Block Design with factorial concept as suggested by Panse and Sukhatme (1985) [8]. Statistical significance was tested by 'F' test at a five per cent level of probability. Critical difference for the significant source of variation was calculated at five per cent level of significance. Treatmental differences that were not significant were denoted by NS.

Results And Discussion

Effect of spacing

Among the three spacings tested, spacing of 20 cm x 10 cm (S_1) resulted in significantly taller plants with higher drymatter accumulation followed by the spacing of 25 cm x 10 cm (S_2) with a significant difference between them. While the spacing of 30 cm x 10 cm (S_3) resulted in significantly shorter plants with lower dry matter accumulation tried during both the years of research and pooled mean (Table 1). Taller plants at closer spacing 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, further, more number of plants unit $area^{-1}$ intercepting more sunlight leading to higher photosynthesis and accumulation of more photosynthates resulting in increased drymatter production. The results are in conformity with the findings of Hugar and Halikatti (2001) [3] in foxtail millet and Korir *et al.* (2018) [6].

The significantly higher number of panicles m^{-2} were recorded with the spacing of 20 cm x 10 cm; while the spacing of 30 cm x 10 cm (S_3) resulted in a significantly lower number of panicles m^{-2} which might be due to higher number of plants per unit area at the closer spacing (Table 2).

Spacing of 20 cm x 10 cm (S_1) recorded significantly higher grain and straw yield followed by the spacing of 25 cm x 10 cm (S_2). The lowest grain yield was recorded in the widest spacing of 30 cm x 10 cm (S_3) (Table 2).The higher grain yield at closer spacing might be due to the accommodation of more plants per unit area. The results are in line with the findings of Nandini and Sridhara (2019) [7] in foxtail millet and Siddiqui *et al.* (2020) [12] in browntop millet.

As regards the economics, the highest gross, net returns as well as B:C ratio were realized with the planting pattern of 20 x 10 cm (S_1) which was however at par with the planting pattern of 25 cm x 10 cm (S_2).The lowest monetary returns and B: C ratio were realized with the planting pattern of 30 cm x 10 cm (S_3) during both the years of study and pooled mean(Table 3) This might be due to the higher productivity of foxtail millet recorded at closer spacing. The results are in conformity with the findings of Hebbal *et al.* (2018) [2] in finger millet.

Effect of zinc foliar application

Significantly higher plant height and drymatter production 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). It might be attributed to the fact that zinc facilitates catalytic reactions of various physiological processes and auxin synthesis in plants resulting in increased plant height and leaf area as well as dry matter production. While all these parameters were at their lowest value in the control (N_1) without any foliar sprays. However, the number of panicles m^{-2} was found to be nonsignificant with nutrient management practices.

Significant increase 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 2). Enhanced stature of growth and yield attributes, as well as yield with foliar nutrition, might be presumably due to supplementing of 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 growth, yield attributes and yield of foxtail millet. Similar findings were also reported by Shekawat and Kumawat (2017) [11] and Sandyarani *et al*. (2017) [10].

With regard to the economics, foliar application of $ZnSO_4$ @ 0.5% twice at flowering and 20 days after flowering along with 100% RDF (N_3) fetched significantly higher returns and B: C ratio. The next best treatment in this regard was the foliar application of $ZnSO_4$ @ 0.5% only at flowering, however, it was maintained parity with N_1 (100 % RDF without any application) which fetched the lowest returns and B: C ratio during both years of research and pooled mean. Higher returns associated with N_3 might be due to higher grain yield and straw yield. Similar results were also reported by Shekawat and Kumawat (2017) [11] in pearl millet.

Effect of weed management practices

Significantly taller plants and maximum drymatter accumulation were observed in the 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 effective control of all the categories of weeds leading to reduced weed competition and increased growth components *viz.*, the plant height and leaf area, which in turn increased the dry matter production. These findings are in agreement with those of Kitawat (2007) [5] in foxtail millet and Jawahar *et al.*(2019) [4] in kodo millet. The lowest dry matter production of foxtail millet obtained with the unweeded check (W_1) might be due to severe weed competition for growth resources, resulting in reduced plant height, size and number of the leaves which inturn decreased the dry matter production.

Number of panicles m^{-2} was 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 a large number of tillers and their conversion to ear bearing tillers by a liberal supply of nutrients in balanced proportions. Whereas the weedy check (W_1) resulted in the lowest number of panicles m^{-2}. 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.

Significantly higher grain and straw yield of foxtail millet were 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). A relatively weed free environment maintained during the 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 Fufa and Mariam (2016) [1] in finger millet and Jawahar *et al.* (2019) [4] in kodo millet.

As regards economics, hand weeding twice at 20 DAS and 30 DAS (W_2) registered significantly higher monetary returns and B:C ratio during both the years of study and pooled mean. The next best treatment in realizing higher returns 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 the statistically perceptible difference between them. Significantly lower monetary returns and B:C ratio was obtained as usual due to weedy check (W_1) in foxtail millet. This might be due to a drastic reduction in the grain and straw yield realized with this treatment due to unchecked weed growth throughout the life cycle of foxtail millet. Higher monetary returns and B: C ratio associated with W_2 could be attributed to significantly higher grain and straw yield obtained with this treatment by the effective control of weeds in this treatment compared to any other weed management practices tried in the present study. Jawahar *et al.* (2019) [4] in kodo millet in barnyard mill*et al*so reported similar findings.

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

Table 1: Plant height (cm) at harvest and drymatter production (kg ha^{-1}) of foxtail millet as influenced by spacing, nutrient and weed management practices

Treatments	Plant height			Drymatter production (kg ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled
Spacings						
S_1: 20 cm x 10 cm	100	102	101	4347	4569	4458
S_2 :25 cm x 10 cm	96	99	97	4033	4273	4153
S_3: 30 cm x 10 cm	93	97	95	3638	3908	3773
SEm ±	0.7	0.4	0.5	61.8	52.5	57.1
CD (P=0.05)	3	2	2	252	252	241
Nutrient management practices						
N_1: 100%RDF	95	97	96	3781	3985	3883
N_2: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering	97	99	98	4010	4251	4131
N_3: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering and 20 DAF	98	100	99	4227	4514	4371
SEm ±	0.3	0.4	0.3	28.3	39.4	33.1
CD (P=0.05)	1	1	1	87.3	121	102
weed management practices						
W_1: Control (weedy check)	70	73	71	2267	2109	2188
W_2 : Two HWs at 20 and 30 DAS	109	111	110	5160	5569	5364
W_3: PE application of butachlor @ 1 kg *a.i* ha^{-1} + 1HW at 30DAS	106	108	107	4598	4958	4778
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	3999	4363	4181
SEm ±	0.4	0.5	0.4	45.4	51.2	47.3
CD (P=0.05)	2	1	1	129	145	134
Interaction						
S x N						
SEm ±	0.6	0.7	0.6	49.1	68.2	57.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SxW						
SEm ±	0.7	1.0	0.7	78.5	88.7	81.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS
NxW						

SEm ±	0.7	1.0	0.7	78.5	88.7	81.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SxNxW						
SEm ±	1.2	1.7	1.3	136.1	153.7	141.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 2: Number of panicles m^{-2}, Grain yield (kg ha^{-1}) and Straw yield (kg ha^{-1}) of foxtail millet as influenced by spacing, nutrient and weed management practices

Treatments	Number of panicles m^{-2}			Grain yield(kg ha^{-1})			Straw yield (kg ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Spacings									
S_1: 20 cm x 10 cm	85	89	87	1460	1574	1517	2407	2588	2499
S_2 :25 cm x 10 cm	78	80	79	1351	1481	1416	2252	2456	2355
S_3: 30 cm x 10 cm	74	76	75	1205	1353	1279	2047	2279	2163
SEm ±	0.6	0.9	0.3	28.0	22.4	24.2	39.4	31.7	34.2
CD (P=0.05)	2	4	1	109	87	94	154	124	135
Nutrient management practices									
N_1: 100%RDF	79	81	80	1257	1345	1301	2121	2265	2194
N_2: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering	80	81	81	1325	1473	1390	2215	2466	2331
N_3: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering and 20 DAF	79	82	80	1434	1591	1512	2369	2611	2491
SEm ±	0.8	0.6	0.6	18.2	19.2	18.2	25.8	26.7	25.9
CD (P=0.05)	NS	NS	NS	56	59	56	80	83	77
Weed management practices									
W_1: Control (weedy check)	52	51	52	769	821	795	1202	1343	1283
W_2 : Two HWs at 20 and 30 DAS	95	100	97	1784	1949	1867	2960	3187	3077
W_3: PE application of butachlor @ 1 kg *a.i* ha^{-1} + 1HW at 30DAS	88	91	89	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	81	85	83	1279	1442	1360	2211	2456	2324
SEm ±	0.7	0.7	0.6	24.0	25.2	22.8	34.0	31.6	31.4
CD (P=0.05)	2	2	2	68	72	65	96	90	89
Interaction									
S x N									
SEm ±	1.3	1.0	1.1	31.5	33.2	31.6	44.7	46.6	44.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x W									
SEm ±	1.3	1.1	1.0	41.6	43.7	39.6	58.8	54.8	54.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x W									
SEm ±	1.3	1.1	1.0	41.6	43.7	39.6	58.8	54.8	54.3
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x N x W									
SEm ±	2.2	2.0	1.8	72.1	71.5	68.5	101.9	94.9	94.0
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Gross returns (₹ ha^{-1}), Net returns (₹ ha^{-1}) and Benefit: Cost ratio of foxtail millet as influenced by spacing, nutrient and weed management practices

Treatments	Gross returns (₹ ha^{-1})			Net returns (₹ ha^{-1})			B: C ratio		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Spacings									
S_1: 20 cm x 10 cm	30402	32783	31592	13317	16438	14877	1.75	1.96	1.86
S_2 :25 cm x 10 cm	28150	30836	29493	11065	14491	12778	1.61	1.85	1.73
S_3: 30 cm x 10 cm	25115	28207	26661	8030	11862	9946	1.43	1.68	1.55
SEm ±	578.7	463.6	500.44	579	464	501	0.033	0.027	0.028
CD (P=0.05)	2260	1810	1954	2260	1810	1956	0.13	0.11	0.11
Nutrient management practices									
N_1: 100%RDF	26197	28024	27110	9512	12138	10855	1.54	1.73	1.64
N_2: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering	27605	30686	29145	10520	14341	12430	1.58	1.84	1.71
N_3: 100%RDF + foliar application of $ZnSO_4$ @ 0.5% at flowering and 20 DAF	29865	33117	31491	12320	16312	14316	1.67	1.93	1.79
SEm ±	376	396.4	377.6	376	396	378	0.019	0.023	0.020
CD (P=0.05)	1159	1221	1163	1159	1221	1164	0.06	0.07	0.06
Weed management practices									
W_1: Control (weedy check)	15989	17081	16535	2479	4311	3395	1.18	1.34	1.26
W_2 : Two HWs at 20 and 30 DAS	37165	40579	38872	17255	21049	19332	1.86	2.11	1.99
W_3: PE application of butachlor @ 1 kg *a.i* ha^{-1} + 1HW at 30DAS	31724	34710	33217	13514	17240	15377	1.74	1.99	1.86
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	26679	30065	28372	9969	14095	12032	1.60	1.88	1.74
SEm ±	497	519	472.1	498	519	472	0.027	0.032	0.026

CD (P=0.05)	1412	1472	1339	1412	1472	1339	0.08	0.09	0.07
Interaction									
S x N									
SEm ±	651.7	686.7	654.1	652	687	654	0.034	0.039	0.035
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x W									
SEm ±	862.1	898.9	817.8	862	899	818	0.047	0.055	0.045
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x W									
SEm ±	862.1	898.9	817.8	862	899	818	0.047	0.055	0.045
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x N x W									
SEm ±	1493.2	1557.0	1416.4	1493	1557	1416	0.082	0.095	0.079
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Conclusion

From the present study, it was revealed 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 promising and economically viable package under southern Agro-climatic zone of Andhra Pradesh.

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