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Influence of Various Methods of Zinc Fertilization on Growth and Yield of Finger Millet (*Eleusine coracana*) Varieties

G. Mrudula[1], P. Sandhya Rani[2], B. Sreekanth[3], K.V. Naga Madhuri[4], M. Martin Luther[5]

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ABSTRACT

Background: Zn deficiency was predominant in soils of Chittoor district of Andhra Pradesh, which causes yield reduction in most of the crops especially in finger millet. Zinc has important role in enzyme activation *viz.,* oxidoreductase, transferases, hydrolases, lyases, isomerases and ligases. The deficient soil gives us the zinc deficient food which is said to be the major root cause for malnutrition among the children. Hence present study was intended to find out most appropriate method and time of zinc fertilization for higher productivity, grain quality and zinc fortification with two major finger millet varieties *viz.,* vakula and tirumala.

Methods: The field experiment was laid out in split plot design with three replications and two varieties *viz.,* vakula (V_1) and tirumala (V_2) with seven zinc application treatments which includes: control (T_1); NPK (30-30-20) + FYM @ 10t ha^{-1} (T_2); T_2 + soil application (SA) of $ZnSO_4$ @ 25 kg ha^{-1} as basal (T_3); T_2 + SA of chelated zinc sulphate @ 5 kg ha^{-1} as basal (T_4); T_2 + FA of 0.2% $ZnSO_4$ at ear head emergence stage (T_5); T_2 + foliar application (FA) of 0.2% $ZnSO_4$ at grain filling stage (T_6); T_2 + FA of 0.2% $ZnSO_4$ at ear head emergence and grain filling stages (T_7).

Result: Foliar application of 0.2% $ZnSO_4$ at ear head emergence and grain filling stages registered significantly highest grain and straw yield of 3150 kg ha^{-1} and 7364 kg ha^{-1}, respectively compared to control and other zinc fertilization treatments. Between the two tested varieties tirumala variety recorded higher grain yield (2298 kg ha^{-1}) compared to vakula variety (2230 kg ha^{-1}).

Key words: Chelated zinc, Dry mater production, Ear head emergence, Grain filling stages.

INTRODUCTION

Finger millet commonly known as ragi and grown in both *kharif* and *rabi* seasons. It is short duration (<120 days) day-neutral crop and thus can be grown more than once a year in certain regions. Finger millet grains have long storability even under normal conditions and have made them "famine reserves". This aspect is at most important as Indian agriculture suffers from vagaries of monsoon (Michaelraj and Shanmugam, 2013). These features have made finger millet an important cereal in low rainfall areas, affordable for the poor.

Finger millet is known for several health benefits and some of the health benefits are attributed to its polyphenol and dietary fiber contents. Finger millet contains about 5-8% protein, 1-2% ether extractives, 65-75% carbohydrates, 15-20% dietary fiber and 2.5-3.5% minerals and it has 30 times more calcium content than rice (344 mg/100 g). They are also recognized for their health beneficial effects, such as anti-diabetic, anti-tumerogenic, atherosclerogenic effects, antioxidant and antimicrobial properties (Chethan and Malleshi, 2007a). Apart from calcium content, grains are also rich in iron, phosphorus and vitamin content. The iodine content is said to be highest among all the food grains (Sandhya Rani, 2017). However, zinc content of finger millet grain is low (2.3 mg/100g).

Zinc (Zn) is considered as one of the essential micronutrient which limit the crop production. Almost 40 per cent of cultivated soils in India facing the problem of zinc deficiency and it strongly correlates to zinc deficiency in humans hence, zinc recognized as one of the most widespread mineral deficiencies in global human nutrition. Zinc deficiency is 5[th] leading cause of death and disease in the developing world and 8,00,000 people die annually due to zinc deficiency (WHO), of which 4,50,000 are children under the age of five years old. As most of the soils of Andhra Pradesh (AP) are also deficient in Zn and there is a dietary need to increase grain Zn content of finger millet.

[1]Department of Crop Physiology, Agricultural College, Acharya NG Ranga Agricultural University, Bapatla-522 101, Andhra Pradesh, India.
[2]Departmeny of Crop Physiology, Sri Venkateswara Agricultural College, Tirupati-517 502, Andhra Pradesh, India.
[3]Regional Agricultural Research Station, Lam-522 034, Andhra Pradesh, India.
[4]Regional Agricultural Research Station, Tirupati-517 502, Andhra Pradesh, India.
[5]Acharya N.G. Ranga Agricultural University, Guntur-522 034, Andhra Pradesh, India.

Corresponding Author: G. Mrudula, Department of Crop Physiology, Agricultural College, Acharya N.G. Ranga Agricultural University, Bapatla-522 101, Andhra Pradesh, India.
Email: gmrudu16@gmail.com

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MATERIAL AND METHODS

Description of experimental site

The experiment was carried out during *kharif,* 2019 and 2020 at College Farm, S.V. Agricultural College, Tirupati, ANGRAU. The experimental site is geographically located at 13.5°N latitude and 79.5°E longitude with an altitude of 182.9 m from mean sea level. The soil of the experimental site was sandy clay loam in texture which is medium in organic carbon (0.5-0.75%) and available nitrogen (<280 kg ha^{-1}), high in available phosphorus (>56 kg ha^{-1}) and potassium (>300 kg ha^{-1}) and sufficient in available zinc (>0.6 ppm).

Treatments and experimental design

The experiment was laid out in split plot design with two finger millet varieties as main treatments *viz.,* Vakula and Tirumala varieties released from Agricultural Research Station, Perumallapalli and zinc fertilization at different methods of application at various crop stages as sub treatments *viz.,* T_1: Control (No fertilizers and manures), T_2: 30-30-20 kg N-P-K + FYM @ 10 t ha^{-1}, T_3: T_2 + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} as basal, T_4: T_2 + Soil application of chelated zinc sulphate @ 5 kg ha^{-1}, T_5: T_2 + Foliar application of 0.2% $ZnSO_4$ at ear head emergence stage, T_6: T_2 + Foliar application of 0.2% $ZnSO_4$ at grain filling stage and T_7: T_2 + Foliar application of 0.2% $ZnSO_4$ at ear head emergence and grain filling stages. The treatments were randomized in split plot design with three replications. The recommended dose of 30 kg N, 30 kg P_2O_5 and 20 kg K_2O ha^{-1} applied through urea, SSP and MOP, respectively. Nitrogen fertilizer was applied in two equal splits as first half dose at the time of transplanting and second half at 30 DAT and the full dose of FYM @ 10 t ha^{-1}, phosphorus and potassium applied at the time of transplanting.

Estimation of growth parameters

The growth parameters like plant height, number of tillers per plant, leaf area and total dry matter were recorded at 20, 40 and 60 days after transplanting (DAT) and at harvest. The crop was harvested with the help of a sickle. The yield attributes [number of productive tillers per plant, number of fingers per plant and test weight (g)] and yield [grain yield (kg ha^{-1}), straw yield (kg ha^{-1})] were recorded at harvest. From each plot, five plants were randomly selected for observations and value of each parameters was averaged to get mean value.

Statistical analysis

The experimental data were analyzed statistically by following standard procedure outlined by (Panse and Sukhatme,1985). Significant difference was tested by comparing 'F' value at 5 per cent level of probability. Treatmental differences that were non-significant were denoted as NS and the data analysed by OPSTAT.

RESULTS AND DISCUSSION

Experiment was conducted two years (2019 and 2020). The response was almost similar among main, sub plots and

Table 1: Effect of sources of zinc application on plant height, number of tillers per plant and leaf area of finger millet varieties

Treatments	Plant height (cm)				Number of tillers per plant				Leaf area (cm^2 plant^{-1})			
	20 DAT	40 DAT	60 DAT	H	20 DAT	40 DAT	60 DAT	H	20 DAT	40 DAT	60 DAT	H
Varieties (V)												
(V_1) : Vakula	19.43	50.84	92.37	95.69	0.85	1.26	1.86	1.94	377.84	506.27	980.46	875.06
(V_2) : Tirumala	26.99	53.76	97.78	101.69	1.18	1.87	2.18	2.28	501.01	638.35	995.23	899.87
S.E (m)	0.71	1.38	1.29	1.51	0.10	0.08	0.15	0.18	11.25	5.74	22.82	22.20
C.D (p=0.05)	4.68	NS	NS	NS	NS	0.52	NS	NS	73.73	37.65	NS	NS
Method and stage of Zn application												
T_1: Control	20.33	45.37	85.47	89.15	0.40	0.80	1.53	1.62	283.03	414.51	697.17	621.72
T_2: NPK+FYM	22.13	50.28	92.13	95.22	0.75	1.47	1.88	1.97	358.70	495.69	880.00	789.08
T_3: T_2+ SA of $ZnSO_4$	25.47	57.98	95.20	99.04	1.57	1.97	2.02	2.05	626.36	739.67	950.58	841.62
T_4: T_2+ SA of chelated Zn	24.05	56.52	96.27	99.78	1.35	1.82	2.10	2.18	528.11	728.44	976.59	886.94
T_5: T_2+ FA of Zn at ear head emergence	23.68	53.62	98.45	100.86	1.03	1.67	2.20	2.33	438.32	548.38	1,143.76	928.33
T_6: T_2+ + FA of Zn at grain filling stage	23.05	50.92	95.08	100.34	1.07	1.63	2.10	2.23	428.01	552.96	1,046.82	1,023.64
T_7: T_2+ FA of Zn at ear head emergence and grain filling	23.75	51.42	102.92	106.43	0.93	1.62	2.32	2.40	413.45	526.52	1,220.02	1,120.95
S.E (m)	0.93	1.30	2.12	1.98	0.11	0.10	0.17	0.19	17.49	14.07	23.44	23.02
C.D (p=0.05)	2.74	3.79	6.24	5.82	0.34	0.30	NS	NS	51.35	41.31	68.82	68.12
Interaction (M x S)	NS	NS	NS	NS	NS	NS	NS	NS	90.02	64.80	NS	NS

SA- Soil application; FA- Foliar application; NS- Non significant at 0.05%.

Table 2: Effect of sources of zinc application on total dry matter (g pl^{-1}) (leaf, stem and grain) in finger millet varieties.

Treatments	Leaf dry weight (g $plant^{-1}$)				Stem dry weight (g $plant^{-1}$)				Grain dry weight (g pl^{-1})		Total dry matter (g $plant^{-1}$)			
	20 DAT	40 DAT	60 DAT	H	20 DAT	40 DAT	60 DAT	H	60 DAT	H	20 DAT	40 DAT	60 DAT	H
Varieties (V)														
(V_1) : Vakula	2.35	3.33	8.16	6.01	1.16	3.34	9.82	10.13	3.49	12.28	3.51	6.67	21.47	28.42
(V_2): Tirumala	3.20	4.28	8.18	6.52	1.53	3.75	11.91	10.91	4.68	12.63	4.73	8.03	24.77	30.06
S.E (m)	0.10	0.11	0.67	0.12	0.08	0.12	0.10	0.44	0.26	0.57	0.32	0.15	0.19	0.11
C.D (p=0.05)	0.62	0.66	NS	NS	NS	NS	0.63	NS	NS	NS	NS	0.90	1.14	0.67
Method and stage of Zn application (T)														
T_1: Control	1.57	2.46	5.15	3.68	0.89	2.13	5.45	6.66	1.57	7.67	2.46	4.59	12.17	18.01
T_2: NPK+FYM	1.84	2.86	6.02	5.30	1.02	2.76	7.12	7.62	2.35	9.07	2.86	5.62	15.49	21.99
T_3: T_2+ SA of $ZnSO_4$	4.48	5.68	8.02	5.58	1.70	5.08	11.33	10.74	4.02	13.04	6.18	10.76	23.37	29.37
T_4: T_2+ SA of chelated Zn	3.68	4.85	7.42	6.32	1.79	4.95	10.01	9.30	3.57	11.88	5.47	9.80	21.00	27.50
T_5: T_2+ FA of Zn at ear head emergence	2.79	3.63	9.23	7.14	1.44	3.57	14.30	11.79	5.90	13.50	4.23	7.20	29.43	32.43
T_6: T_2+ + FA of Zn at grain filling stage	2.35	3.37	8.78	7.45	1.27	2.80	12.53	13.11	4.62	15.37	3.62	6.17	25.93	35.93
T_7: T_2+ FA of Zn at ear head emergence and grain filling	2.56	3.78	12.32	8.84	1.48	3.52	15.28	14.41	6.85	16.22	4.04	7.30	34.45	39.45
S.E (m)	0.19	0.18	0.59	0.52	0.15	0.23	0.21	0.66	0.35	0.85	0.23	0.34	0.44	0.38
C.D (p=0.05)	0.55	0.52	1.72	1.51	0.6	0.95	0.62	1.94	1.04	2.48	0.67	0.99	1.28	1.11
Interaction (M x S)	NS	0.73	NS	NS	NS	NS	0.88	0.94	NS	NS	NS	NS	1.81	1.57

SA- Soil application; FA- Foliar application; NS- Non significant at 0.05 %.

interactions in two years of research and hence only pooled date was presented.

Growth parameters

There was no significant variation between the two varieties with respect to the growth parameters. The effect of zinc on growth parameters at 20 days interval of crop was found significant between the zinc application treatments and non-significant between the varieties. Significantly higher plant height and more number of tillers per plant (25.47 and 57.98 cm) and (1.57 and 1.97) respectively at 20 and 40 DAT was recorded with T_3 *i.e.,* T_2 + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} as basal, (102.92 and 106.43 cm) however, at 60 DAT and at harvest it was recorded in T_7 *i.e.,* T_2 + Foliar application of 0.2% $ZnSO_4$ at ear head emergence and grain filling stages (2.32 and 2.40, respectively) compared to control (T_1). Higher plant height may be due to better availability of nutrients resulting in improved crop establishment with better development. With the change in levels and methods of application of Zn from soil application to foliar application, the plant height gradually increased, which might be attributable to greater photosynthetic activity and chlorophyll synthesis due to Zn fertilization resulted into better vegetative growth. Jakhar *et al.* (2006) also observed higher plant height with the application of zinc. The pooled data was given in the Table 1.

The influence of zinc application on leaf area at 20 days interval in finger millet was found to be significant. Among the treatments, at 20 and 40 DAT, T_3 *i.e.,* T_2 + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} as basal registered significantly higher leaf area (626.36 and 739.67 cm^2 $plant^{-1}$ respectively) and at 60 DAT and at harvest, T_7 *i.e.,* T_2 + Foliar application of

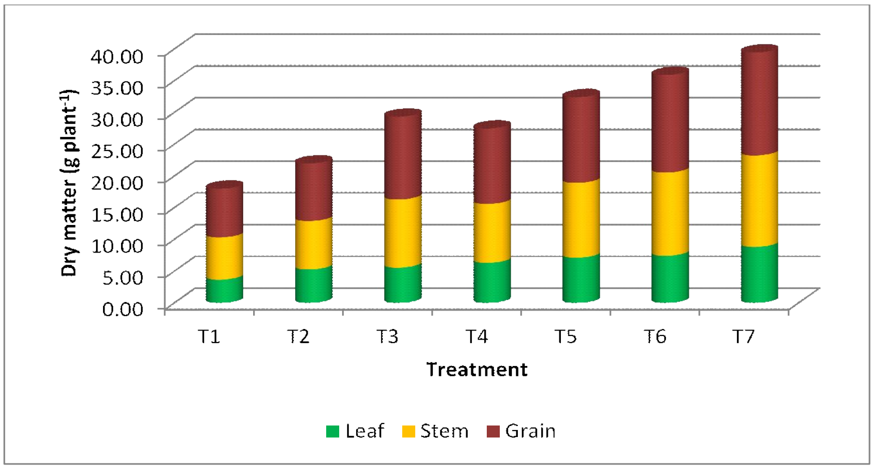

Fig 1: Effect of sources of zinc application on leaf, stem and grain (g $plant^{-1}$) in finger millet.

Table 3: Effect of sources of zinc application on yield and yield attributing parameters in finger millet varieties.

Treatment	Grain (kg ha^{-1})	Straw (kg ha^{-1})	1000 grain weight (g)	No. of productive tillers per plant	No. of fingers per plant
Varieties (V)					
(V_1) : Vakula	2230	5423	2.86	1.43	15.98
(V_2) : Tirumala	2298	5531	2.94	1.61	18.35
S.E (m)	6.03	146.4	0.025	0.062	1.048
C.D (p=0.05)	40.2	NS	NS	NS	NS
Method and stage of Zn application					
T_1: Control	1452	4018	2.72	1.17	12.82
T_2: NPK+FYM	2003	4858	2.86	1.30	14.22
T_3: T_2+ SA of $ZnSO_4$	2201	5089	2.89	1.53	17.33
T_4: T_2+ SA of chelated Zn	2143	4979	2.85	1.47	16.63
T_5: T_2+ FA of Zn at ear head emergence	2297	5779	2.95	1.62	18.17
T_6: T_2+ + FA of Zn at grain filling stage	2603	6252	2.98	1.68	19.40
T_7: T_2+ FA of Zn at ear head emergence and grain filling	3150	7364	3.05	1.88	21.58
S.E (m)	40.5	190.8	0.037	0.125	0.915
C.D (p=0.05)	119.0	560.2	0.109	0.366	2.686
Interaction (M x S)	171.1	NS	NS	NS	NS

SA- Soil application; FA- Foliar application; NS- Non significant at 0.05%.

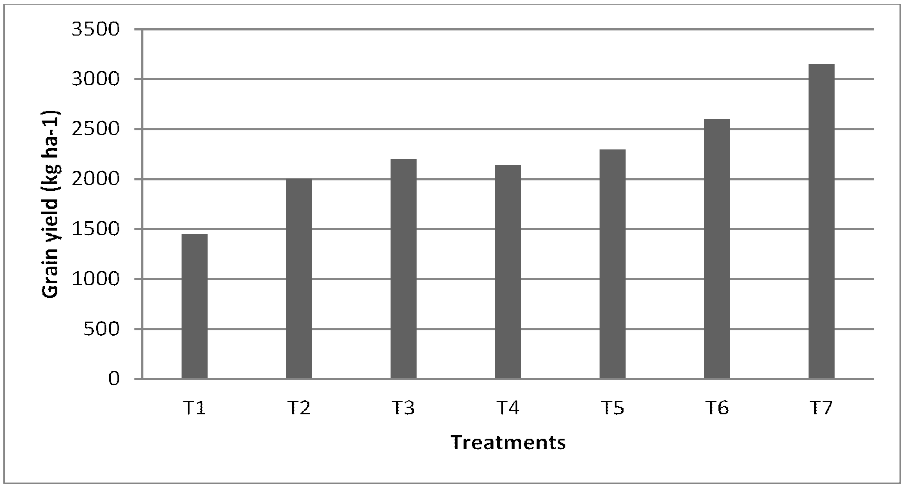

Fig 2: Effect of sources of zinc application on grain yield (kg ha^{-1}) in finger millet.

0.2% $ZnSO_4$ at ear head emergence and grain filling stages (1220 and 1120 cm^2 $plant^{-1}$ respectively) was depicted maximum leaf area compared to other treatments. The increase in the leaf area might be due to foliar application at two critical stages of finger millet which helps to quick absorption of zinc through leaf and this helps in increase in cell division and elongation and photosynthesis. Foliar application of zinc might increase the translocation of photosynthesis from source to sink. Similar findings were observed by Chand, 2017.

Dry matter accumulation

Total dry matter per plant was recorded at 20 days interval. The pooled data was given in the Table 2 and Fig 1. Significantly higher total dry matter per plant was recorded at 20 and 40 DAT by T_3 *i.e.,* T_2 + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} as basal (6.18 and 10.76 g $plant^{-1}$) respectively and at 60 and at harvest by T_7 *i.e.,* T_2 + Foliar application of 0.2% $ZnSO_4$ at ear head emergence and grain filling stages (34.45 and 39.45 g $plant^{-1}$) respectively compared to other treatments. The increase in dry matter accumulation may be due to increased leaf area and biomass. Application of Zn was found to have significantly positive influence on growth of finger millet compared to control (Shankar *et al.,* 2015).

Yield and yield attributes

The pooled data was given in the Table 3. The significant difference was observed in grain yield among the two varieties *i.e.,* tirumala yielded better compared to vakula variety with the application of zinc. The influence of zinc on yield and yield attributes was found to be significant. Among the treatments, T_7 *i.e.,* T_2 + Foliar application of 0.2% $ZnSO_4$ at ear head emergence and grain filling stages registered higher grain (3150 kg ha^{-1}) as shown in Fig 2, straw (7364 kg ha^{-1}) yield, 1000 seed weight (3.05 g), number of productive tillers per plant (1.88) and number of finger per plant (21.58) compared to control. Whereas, higher grain yield was recorded in soil application rather than foliar application in rice (Venkatesh *et al.,* 2018) and maize (Ariraman *et al.,* 2020).The favorable influence of applied zinc on yield may be due to its catalytic or stimulatory effect on most of the physiological and metabolic process of plants (Mandal *et al.,* 2009) participation of Zn in biosynthesis of indole acetic acid (IAA) and its role in initiation of primordial reproductive parts and partitioning of photosynthates towards them are responsible for increased yield.

CONCLUSION

The result of the above study indicates that application of zinc along with FYM and RDF increased dry matter accumulation and grain yield as compared to control. The favorable influence of applied zinc on yield may be due to its catalytic or stimulatory effect on most of the physiological and metabolic process of plants. Among the zinc application treatments, during early stages *i.e.,* up to ear head emergence stage, the T_3 (T_2 + soil application of $ZnSO_4$ @ 25 kg ha^{-1} was applied as basal) increased the growth parameters compared to other treatments. After ear head emergence stage, the T_7 (T_2 + foliar spray of 0.2% $ZnSO_4$ at ear head emergence and grain filling stages) treatment proved to be the best.

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