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Research Article

Characterization of Zeolite and Its Influence on Growth and Yield of Finger Millet (*Eleusine coracana* L.) in Eastern Dry Zone of Karnataka

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ABSTRACT

A field experiment was conducted at Zonal Agricultural Research Station, GKVK, Bengaluru during kharif-2017 to characterize the chemical and physical properties of zeolite and to study its influence on growth and yield of finger millet. The pH of zeolite recorded 7.41 and it has higher water holding capacity of 89.5%, electrical conductivity was 0.61 dS m^{-1}. The nitrogen, phosphorus and potassium content of zeolite were 0.14, 0.18 and 0.77 per cent, respectively. The cation exchange capacity of zeolite was 184 cmol (p+) kg^{-1}. The bulk density and particle density of zeolite were 0.54 and 0.64 g cc^{-1}, respectively. Field experiment consists of 20 treatment combinations comprising five levels of zeolite and four levels of graded fertilizers, laid out in RCBD design with factorial concept and replicated thrice on sandy loam soil having slightly acidic soil pH (5.52). The treatment received zeolite at 50 kg ha^{-1} recorded significantly higher plant height (15.95, 51.70 70.34 and 76.17 cm at 30, 60, 90 DAS and at harvest stage, respectively). Number of tillers per hill (7.70), total dry matter production (40.36 g hill^{-1}), number of fingers per ear head (5.97), straw yield (46.22 q ha^{-1}) and grain yield (34.84). Significantly higher plant height was recorded in treatment received 125 per cent RDF (14.89, 47.02, 66.55 and 72.85 cm, respectively) and 100 per cent RDF (14.87, 46.32, 66.38, 72.28 cm, respectively) in 30, 60, 90 DAS and at harvest stage, respectively. Significantly higher grain (33.88 q ha^{-1}) and straw yield (44.08 q ha^{-1}) was recorded in 125% RDF. The dry matter production (41.89 g per hill) straw yield (48.30 q ha^{-1}), grain yield (36.32 q ha^{-1}) and number of fingers per ear head (5.94) were recorded significantly higher in treatment received 50 kg zeolite ha^{-1}+ 125% RDF.

Keywords: *Zeolite, Finger Millet, Nutrient content, Growth, Yield*

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INTRODUCTION

Zeolites are microporous, aluminosilicate minerals commonly used as commercial adsorbents and catalysts (Yapparov et al., 1988; Mumpton, 1999). Zeolites occur naturally and are also produced synthetically on large scale. Zeolites have been classified on the basis of their morphological characteristics, crystal structure, chemical composition, effective pore diameter, natural occurrence etc. The unique ion exchange, dehydration–rehydration and adsorption properties of zeolite are the reason for its use in agricultural and aquaculture technologies. Zeolite applications are suitable for water-efficient agricultural uses (Xiubin & Zhanbin, 2001). Clinoptilolite is the most common natural zeolite used agriculture (Mumpton, 1999; Ramesh et al., 2010). Zeolite contains some macronutrients and micronutrients such as N, K, Ca, Mg, Zn, Mn, and Cu (Navrotsky et al., 1995; Mumpton, 1999). Zeolite has been used on a variety of soil types and a number of crops such as potatoes, maize, rice, tomatoes, eggplant, and carrots, and an increase in the yield of these crops have been observed (Burriesci et al., 1984; Yapparov et al., 1988).

Finger millet is one of the important cereal which occupies the highest area under cultivation among the small millets. A predominant food crop of the southern Karnataka, mainly grown under rainfed conditions. In India it is grown in an area of 1.19 m ha with a production of 1.98 m t with an average productivity of 1661 kg ha^{-1}. Karnataka is the largest producer of finger millet grown in an area of 1.05 m ha with a production of 1.57 m t with an average productivity of 1889 kg ha^{-1} (Anon., 2015).

Intensification of production and increasing yield on limited arable land are important in securing an adequate food supply apart from extending the area under rainfed situation with suitable package of practices. Erratic distribution of rainfall severely affects the crop yield; in order to conserve the moisture for longer period during the cropping season, absorbents like zeolite can be applied to soil. The research findings on application of zeolite for finger millet in drylands are very scanty. Hence an experiment was conducted to study the effects of different levels of zeolite and fertilizer applications on finger millet growth, yield and soil properties under rainfed conditions.

MATERIALS AND METHODS

Characterization of zeolite

The natural zeolite used in this study was procured from Agrotech chemicals, India. The properties of zeolite were analyzed using standard protocols *viz*., pH (Jackson, 1973), EC Jackson (1973), CEC (Jackson, 1973), Al (Jackson et al., 1986) , Si (Haysom & Chapman, 1975), Na (Piper, 1966), Ca (Piper, 1966), K (Piper, 1966), Mg (Piper, 1966), N (Piper, 1966), P (Piper, 1966), S (Bradsley & Lancester, 1965), Fe, Mn, Zn and Cu (Lindsay & Norvell,1978) , B (Page et al., 1982) and physical properties like bulk density, particle density, and porosity (Gupta and Dhakshinamurthi, 1980), maximum water holding capacity (Keen and Raczkowski, 1921) and colour of zeolite (Pendleton & Nickelson, 1951).

Site and experimental details

A field experiment was conducted during *Kharif*, 2017 at the Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru.

The soil of the experimental site was sandy clay loam in texture, acidic pH (5.52), electrical conductivity (0.032 dS m^{-1}), medium organic carbon (0.42%), nitrogen, phosphorus and potassium contents of the soil were 207.29, 56.28 and 128.67 kg ha^{-1}, respectively. Iron, manganese, copper and zinc content of soil were 3.28, 11.20, 0.72 and 0.58 mg $kg,^{-1}$ respectively.

The experiment consists of 5 different levels of zeolite (0, 20, 30, 40 and 50 kg ha^{-1}) and 4 different levels of fertilizer NPK (50, 75, 100 and 125% RDF) were tried in factorial RCBD with 3 replications. Finger millet (GPU-28) was taken up as a test crop and recommended dose of fertilizer is 50: 40: 37.5 kg of N, P_2O_5 and K_2O per ha. Calculated quantities of nitrogen, phosphorus and potassium were applied treatment wise, in the form of urea, SSP and muriate of potash respectively. Nitrogen was applied in two split doses, that is 50 per cent nitrogen at initial and another 50 per cent at tillering stage, whereas P_2O_5 and K_2O was applied as basal dose. Zeolite was applied along with fertilizers initially. Manual weeding was done at 30 days after sowing and since there was no pest and disease incidence, no plant protection chemical was sprayed. Since the research was taken in rainfed situation, no protective irrigation was given.

Details of observation for growth, yield and yield attributes of finger millet

The plant height of five randomly selected plants was measured, from base of the plant to fully emerged leaf. After emergence of panicle, the height was measured from base of plant to tip of the panicle during 30, 60, and 90 days after sowing (DAS) and at harvest stage. Total numbers of tillers hill^{-1} were counted in tagged hills manually and averaged to get number of tillers per hill^{-1} at harvest stage. Five randomly selected hills from sampling area of a plot were used to record the dry matter production. The sampled hills were separated into leaves, stem and reproductive parts. The samples were dried at 65°C until they attained constant dry weight. Dry weight of straw was recorded separately. The dry weights of all the parts were summed up to obtain the total dry matter production which was expressed as g hill^{-1}. Total number of fingers and number of ear heads in five tagged hills were counted manually and averaged to get the finger number ear^{-1}. Thousand (1000) grain samples were drawn from net plot produce of each treatment for recording test weight and expressed in gram.

RESULTS AND DISCUSSION

Zeolite characterization:

The data on the characteristics of zeolite used in the experiment are presented in Table 1. The zeolite was characterized for physical properties like bulk density, particle density, colour, water holding capacity. The bulk density and particle density of zeolite was 0.54 and 0.64 Mg m^{-3} respectively. The water holding capacity was 89.5 per cent. Zeolite had pH of 6.8 that is slightly acidic in nature and electrical conductivity of 0.61 dS m^{-1}. The nitrogen, phosphorus and potassium content of zeolite were 0.14, 0.18 and 0.77 per cent, respectively. The higher water holding capacity of zeolite was due to lower bulk density and finer in particle size which resulted in higher surface area thereby greater moisture holding capacity. Similar, results were observed by Junrungreang et al. (2002).

The secondary nutrients like calcium, magnesium and sulphur content of zeolite were 1.24, 0.19 and 0.28 per cent, respectively. The micronutrients like iron, manganese, copper and zinc content were 22.91, 0.92, 0.79 and 0.94 per cent, respectively. The boron content found below detectable limit. Among micronutrients, iron recorded higher concentration compared to other treatments might be due to the nature of origin of zeolite mineral, since zeolites were generally originated from volcanic ash that contains higher concentrations of acidic materials containing iron (Mohammadi & Shadparvar, 2013).

The silicon content of zeolite was 33.60 per cent, whereas sodium and aluminum content was 12.5 and 3.96 per cent, respectively. The cation exchange capacity of zeolite was 184 cmol (p^{+}) kg^{-1}. The dry sample of zeolite recorded 7.5YR 7/2 and the wet sample of zeolite recorded 10YR 7/3 in munsell colour chart. The silica content of zeolite was higher due to its microporous, aluminosilicate forms obtained from volcanic ash and zeolites are tectosilicates exhibiting an open, three-dimensional structure containing cations needed to balance the electrostatic charge of the framework of silica and alumina tetrahedra and containing water (Hemingway & Robie, 1984).

Growth and yield parameters of finger millet as influenced by different levels of zeolite and fertilizers

Data on growth and yield parameters as influenced by zeolite and fertilizer levels on finger millet was presented in Table 2.

The crop growth rate increased progressively from 30-60 to 60-90 DAS and then gradually decreased between 90 DAS to till maturity in all the treatments. The application of zeolite at different levels showed significant difference in plant height. The treatment Z_4 (zeolite 50 kg ha^{-1}) recorded significantly higher plant height (15.95, 51.70, 70.34 and 76.17 cm at 30, 60, 90 DAS and at harvest stage, respectively) compared to all other zeolite applications (0, 20, 30 and 40 kg ha^{-1} zeolite, respectively).

Fertilizer application significantly influenced the plant height. Significantly higher plant height was recorded in treatment which received 125 per cent RDF (F_4) (14.89, 47.02, 66.55 and 72.85 cm) which was at par with the treatment which received 100 per cent RDF (F_3) (14.87, 46.32, 66.38 and 72.28 cm) during 30, 60, 90 DAS and at harvest stage of the crop, respectively. Significant difference in plant height was observed due to interaction of zeolite and fertilizer levels. The treatment which received 50 kg zeolite ha^{-1} +125 per cent RDF (Z_4F_4) showed significantly higher plant height (16.79 and 53.75 cm) which was on par with the treatment which received zeolite 50 kg ha^{-1} +100 per cent RDF (Z_4F_3) (16.43 and 52.64 cm) and 50 kg ha^{-1} +75 per cent RDF (Z_4F_2) (15.87 and 51.78 cm), however lower plant height was recorded in treatment which received 50 per cent RDF with no zeolite (Z_0F_1) (10.44 cm) during 30 and 60 DAS. The significantly higher plant height was recorded in the treatment received zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) (73.18 and 77.65 cm) which was at par with treatment received zeolite 50 kg ha^{-1} +100 per cent RDF (Z_4F_3) (72.80 and 76.88 cm) during 60 DAS and at harvest stage.

Zeolite incorporated with chemical fertilizer gave positive effect for plant growth (Valente, 1982). Zeolite increased the plant height significantly regardless of growth stages. Plants were significantly taller than conventional fertilized plants irrespective of levels of application this could be due to enhanced availability and uptake of nutrients in these treatments. The result revealed that increased levels of fertilizer and zeolite which was significantly increased plant height and also interaction effect of fertilizer and zeolite showed significant effects. Similar result for plant height was also obtained by Taotao et al. (2017). With respect to fertilizer levels plant height was higher in the treatment received 125 per cent RDF at 90 DAS and harvest stage might be due to higher application of fertilizer along with the zeolite at its maximum level of 50 kg ha^{-1} could have held these nutrients for longer period compare to the normal levels of fertilizer application, this results were also noticed by Mumpton (1999). Saha et al. (2017) also concluded that more plant height might be due to more availability of nitrogen which has released slowly from zeolite pores as well as simultaneous reduction in loss of nitrogen. As nitrogen is an important element required for cell division, increased availability of nitrogen has positively affected plant height which was probably due to higher uptake of applied nitrogen and greater availability of soil nutrients *i.e.* N, P and K.

The treatment received 50 kg ha^{-1} zeolite (Z_4) recorded significantly higher number of tillers per hill (4.70) which was on par with Z_4 (4.60) compared to rest of the zeolite treatments. Significantly higher number of tillers per hill was recorded in treatment which received 125 per cent RDF (F_4) (4.69) which were on par with the treatment which received 100 per cent RDF (F_3) (4.62), respectively. However lower number of tillers per hill was recorded in the treatment which received 50 per cent RDF (F_1) (3.16). The result revealed that increased levels of fertilizer and zeolite which was significantly increased number of tillers $hill^{-1}$ and also interaction effect of fertilizer and zeolite showed significant effect on number of tillers $hill^{-1}$. Similar result for number of tillers $hill^{-1}$ was also obtained by Taotao et al. (2017). More number of tillers observed might be due to more availability of nitrogen which has released slowly from zeolite canal or pores as well as simultaneous reduction in loss of nitrogen. Nitrogen is an important element required for cell division, increased availability of nitrogen might positively influenced number of tillers which was probably due to higher uptake of applied nitrogen and greater availability of soil nutrients (Saha et al., 2017).

The treatment received 50 kg ha^{-1} zeolite (Z_4) recorded significantly higher number of fingers ear head (597) compared to rest of the treatments. Significantly higher number of fingers per ear head was recorded in treatment which received 125 per cent RDF (F_4) (5.79) which was par with 100 per cent RDF (F_3) (5.64), respectively. The treatment which received zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) showed significantly higher number of fingers per ear head (5.94) which was par with treatment received zeolite 50 kg ha^{-1} +100 per cent RDF (Z_4F_3) (5.86), respectively

Application of zeolite at different levels showed significant differences in total dry matter production. The treatment received 50 kg ha^{-1} zeolite (Z_4) recorded significantly higher total dry matter production (40.36g $hill^{-1}$) compared to rest of the treatments. Whereas the lower Total dry matter production was recorded in control (Z_0) (34.16 g $hill^{-1}$). Significantly higher total dry matter production was recorded in treatment which received 125 per cent RDF (F_4) (38.49 g $hill^{-1}$) which was par with 100 per cent RDF (F_3) (37.85 g $hill^{-1}$), respectively. Whereas, lower total dry matter production was recorded in the treatment which received 50 per cent RDF (F_1) (36.04 g $hill^{-1}$). The treatment which received zeolite @50 kg ha^{-1} +125 per cent RDF (Z_4F_4) showed significantly higher total dry matter production (41.89 g $hill^{-1}$) which was on par with treatment received zeolite @50 kg ha^{-1} +100 per cent RDF (Z_4F_3) (41.17g $hill^{-1}$), respectively. Whereas, lower total dry matter production was recorded in the treatment which received 50 per cent RDF with no zeolite (Z_0F_1) (32.36 g $hill^{-1}$). The significant increase in the plant yield parameters like number of tillers per hill, dry matter production and number of fingers per head might be due to the combination of chemical fertilizers with zeolite, since zeolite assists water infiltration and retention in the soil and acts as a natural wetting agent due to its very porous property and the capillary suction it exerts. In order to assist water distribution through soils, zeolites act as excellent amendment and also the availability of nutrients might have increased at optimum soil moisture (Ferguson et al., 1989; Huang & Petrivic, 1995).

Nutrient and zeolite levels showed significant effect on increasing dry matter production. The dry matter production was increased with increasing nutrient and zeolite application might be due to more use of nitrogen in photosynthetic activity, enhancing the carbohydrate metabolism and ultimately increasing the dry matter accumulation. Highest dry matter production was recorded in Z_4F_4 (50 kg ha^{-1} +125 per cent RDF) compared to other treatments due to that increased nutrient availability and uptake which might be responsible for profuse tillering and higher growth rate. Similar result related to dry matter production in sunflower were obtained by Gholamhoseini et al. (2013). Qi Wu et al. (2016) reported that higher dose of nitrogen and zeolite showed significant effect on dry matter of root, stem, leaf and spike.

There was no significant difference was found among the different treatments includes different fertilizer and zeolite levels with respect to test weight (1000 seeds).

The treatment received 50 kg ha^{-1} zeolite (Z_4) recorded significantly higher grain yield (34.84 q ha^{-1}), whereas the lower grain yield was recorded in control (Z_0) (30.59 q ha^{-1} in pooled). Significantly higher total grain yield was recorded in treatment which received 125 per cent RDF (F_4) (33.88 q ha^{-1}) which was par with the treatment which received 100 per cent RDF (F_3) (33.71 q ha^{-1}), respectively. Whereas lower grain yield was recorded in the treatment which received 50 per cent RDF (F_1) (31.26 q ha^{-1}). The treatment which received zeolite @50 kg ha^{-1} +125 per cent RDF (Z_4F_4) showed significantly higher grain yield (36.32 q ha^{-1}) which was on par with treatment received zeolite @50 kg ha^{-1} +100 per cent RDF (Z_4F_3) (35.89 q ha^{-1}), respectively. Whereas lower grain yield was recorded in the treatment which received 50 per cent RDF with no zeolite (Z_0F_1) (29.46 q ha^{-1}).

The treatment received 50 kg ha^{-1} zeolite (Z_4) recorded significantly higher straw yield (46.22 q ha^{-1}) compared to rest of the treatments. The lower straw yield was recorded in control (Z_0) (38.89 q ha^{-1}). Significantly higher straw yield was recorded in treatment which received 125 per cent RDF

(F_4) (44.08q ha^{-1}) which was on par with the treatment which received 100 per cent RDF (F_3) (43.72 q ha^{-1}), respectively. Whereas, lower straw yield was recorded in the treatment which received 50 per cent RDF (F_1) (40.30 q ha^{-1}in pooled data). Significant difference in straw yield was observed due to interaction of zeolite and fertilizer levels. The treatment which received zeolite @50 kg ha^{-1} +125 per cent RDF (Z_4F_4) showed significantly higher straw yield (48.30 q ha^{-1}) which was on par with treatment received zeolite @50 kg ha^{-1} +100 per cent RDF (Z_4F_3) (47.73q ha^{-1}), respectively. However lower straw yield was recorded in the treatment which received 50 per cent RDF with no zeolite (Z_0F_1) (37.46 q ha^{-1}).

Grain yield depend upon growth and yield parameter *viz*., number of tillers, number of fingers per ear head and other parameters, which were superior at higher levels of fertilizer and zeolite application. The result of present study agrees with Taotao et al. (2017) who reported that grain yield increases consistently by increasing application rate of zeolite and fertilizers. It also influenced significant effect on straw yield and their interaction also showed significant effect on straw yield. Kavoosi (2007) reported that grain yield was increased significantly by the application of zeolite and nitrogen. The increased grain yield in treatment combination of Z_4F_4 (36.07 q ha^{-1} in pooled) might be due to sorption capability of zeolite and its ability towards uniform release of nutrients into the soil along with its ion exchange ability prevents against their quick elution. The controlled release and unique properties of zeolites allow a gradual and controlled introduction of necessary nutrients *i.e.* potassium, ammonium or phosphates into the soil (Perry & Keeling-Tucker, 2000) thus enhances the growth and yield parameters of finger millet. The straw yield of finger millet was significantly increased with the combination of chemical fertilizer with zeolite, might be due to the slow release of nutrients which are imbibed in the zeolite, so that plants get the nutrients sufficiently for longer period leads to the increased grain and straw yield similar results were reported by Valente (1982), Mazur et al. (1986) and Ferguson (1989).

Table 1: Characterization of zeolite for physical and chemical properties

Zeolite characterization	
Parameters	**Values**
MWHC (%)	89.50
pH (1: 2.5)	7.41
EC (dS m^{-1})	0.61
N **(%)**	0.14
P **(%)**	0.18
K **(%)**	0.77
Ca (%)	1.24
Mg (%)	0.19
S (%)	0.28
Fe (mg kg^{-1})	22.91
Mn (mg kg^{-1})	0.92
Cu (mg kg^{-1})	0.79
Zn (mg kg^{-1})	0.94
B (mg kg^{-1})	nil
Si (%)	33.60
Na (%)	12.50
Al (%)	3.96
CEC (cmol (p+) kg)	184
Bulk density (Mg m^{-3})	0.54
Porosity (%)	66.24
Particle density (Mg m^{-3})	0.64
Zeolite colour (dry)	7.5YR 7/2 (munsell colour chart)
Zeolite colour (wet)	10YR 7/3 (munsell colour chart)

Table 2: Plant height and tiller numbers in finger millet crop as influenced by different levels of zeolite and fertilizer application

Treatments	Plant height (cm)				Number of tillers per hill
Zeolite levels	**30 DAS**	**60 DAS**	**90 DAS**	**At Harvest**	
Z_0 : Control	12.73	34.73	60.77	67.54	3.68
Z_1 : Zeolite @ 20 kg ha^{-1}	13.10	43.36	64.87	69.25	3.77
Z_2 :Zeolite @ 30 kg ha^{-1}	14.25	45.73	65.36	72.02	4.27
Z_3 :Zeolite @ 40 kg ha^{-1}	14.57	46.67	66.54	74.50	4.60
Z_4 : Zeolite @ 50 kg ha^{-1}	15.95	51.70	70.34	76.17	4.70
S.Em±	0.20	0.47	0.26	0.23	0.04
CD (P=0.05)	0.62	1.34	0.74	0.66	0.11
Fertilizer levels					
F_1: 50% RDF	13.00	41.26	64.37	67.54	3.69
F_2: 75% RDF	13.72	43.15	64.99	69.25	4.08
F_3: 100% RDF	14.87	46.32	66.38	72.02	4.62
F_4: 125% RDF	14.89	47.02	66.55	74.50	4.69
S.Em±	0.18	0.42	0.23	76.17	0.03
CD (P=0.05)	0.52	1.20	0.66	0.23	0.10
Zeolite levels X Fertilizer levels					
Z_0F_1: Control + 50% RDF	10.44	29.90	60.11	67.28	3.16
Z_0F_2: Control + 75% RDF	11.76	33.02	60.00	67.37	3.48
Z_0F_3: Control + 100% RDF	12.10	37.37	60.33	67.42	3.79
Z_0F_4: Control + 125% RDF	12.18	38.62	62.63	68.45	4.27
Z_1F_1: Zeolite @ 20 kg ha^{-1}+ 50% RDF	11.77	39.97	64.00	67.76	3.37
Z_1F_2: Zeolite @ 20 kg ha^{-1}+ 75% RDF	12.15	42.31	65.39	67.69	3.74
Z_1F_3: Zeolite @ 20 kg ha^{-1} +100% RDF	13.23	45.46	65.70	70.30	3.81
Z_1F_4: Zeolite @ 20 kg ha^{-1} +125% RDF	13.78	45.68	64.38	71.25	4.48
Z_2F_1: Zeolite @ 30 kg ha^{-1} + 50%RDF	11.85	42.99	64.99	68.40	4.10
Z_2F_{12}:Zeolite @ 30 kg ha^{-1} + 75% RDF	14.36	44.60	64.03	69.73	4.25
Z_2F_3: Zeolite @ 30 kg ha^{-1} + 100% RDF	14.36	47.22	66.37	72.73	4.21
Z_2F_4: Zeolite @ 30 kg ha^{-1} + 125% RDF	14.44	48.12	66.04	72.86	4.54
Z_3F_1: Zeolite @ 40 kg ha^{-1} + 50% RDF	14.24	44.81	65.34	70.85	4.14
Z_3F_2: Zeolite @ 40 kg ha^{-1} + 75% RDF	14.46	44.05	66.84	71.68	4.35
Z_3F_3: Zeolite @ 40 kg ha^{-1} + 100% RDF	15.25	48.90	67.44	74.40	4.94
Z_3F_4: Zeolite @ 40 kg ha^{-1} + 125% RDF	15.34	48.93	66.54	74.68	5.21
Z_4F_1: Zeolite @ 50 kg ha^{-1} + 50% RDF	14.69	48.62	67.43	73.25	3.93
Z_4F_2: Zeolite @ 50 kg ha^{-1} + 75% RDF	15.87	51.78	68.70	74.62	4.59
Z_4F_3: Zeolite @ 50 kg ha^{-1} + 100% RDF	16.43	52.64	72.80	76.88	5.22
Z_4F_4: Zeolite @ 50 kg ha^{-1} + 125% RDF	16.79	53.75	73.18	77.65	5.27
S.Em±	0.41	0.94	0.52	0.46	0.07
CD (P=0.05)	1.17	2.68	1.49	1.32	0.21

Table 3: Yield and yield attributes of finger millet crop as influenced by different levels of zeolite and fertilizer application

Treatments	Total dry matter production (g hill^{-1})	Straw yield (q ha^{-1})	Grain yield (q ha^{-1})	Test weight (1000 Seeds)	Number of fingers per ear head
Zeolite levels					
Z_0 : Control	34.16	38.89	30.59	3.36	5.31
Z_1 : Zeolite @ 20 kg ha^{-1}	36.25	40.82	31.80	3.46	5.67
Z_2 :Zeolite @ 30 kg ha^{-1}	37.33	42.36	32.74	3.37	5.63
Z_3 :Zeolite @ 40 kg ha^{-1}	37.90	43.92	33.51	3.42	5.73
Z_4 : Zeolite @ 50 kg ha^{-1}	40.36	46.22	34.84	3.42	5.98
S.Em±	0.30	0.15	0.11	0.028	0.028
CD (P=0.05)	0.87	0.42	0.32	NS	0.081
Fertilizer levels					
F_1: 50% RDF	36.04	40.30	31.26	3.42	5.50
F_2: 75% RDF	37.02	41.77	32.11	3.38	5.73
F_3: 100% RDF	37.85	43.72	33.71	3.43	5.64
F_4: 125% RDF	38.49	44.08	33.88	3.39	5.79
S.Em±	0.27	0.13	0.10	0.02	0.02
CD (P=0.05)	0.78	0.38	0.29	NS	0.07
Zeolite levels X Fertilizer levels					
Z_0F_1: Control + 50% RDF	32.36	37.46	29.46	3.31	4.55
Z_0F_2: Control + 75% RDF	33.02	38.29	30.11	3.34	5.58
Z_0F_3: Control + 100% RDF	35.13	39.63	31.17	3.39	5.49
Z_0F_4: Control + 125% RDF	36.11	40.18	31.60	3.38	5.64
Z_1F_1: Zeolite @ 20 kg ha^{-1}+ 50% RDF	34.68	38.49	30.27	3.55	5.52
Z_1F_2: Zeolite @ 20 kg ha^{-1}+ 75% RDF	36.27	40.18	31.21	3.34	5.71
Z_1F_3: Zeolite @ 20 kg ha^{-1} +100% RDF	36.24	42.11	32.70	3.56	5.74
Z_1F_4: Zeolite @ 20 kg ha^{-1} +125% RDF	37.82	42.50	33.01	3.38	5.76
Z_2F_1: Zeolite @ 30 kg ha^{-1} + 50%RDF	36.82	39.98	31.05	3.38	5.58
Z_2F_{12}:Zeolite @ 30 kg ha^{-1} + 75% RDF	38.27	42.10	32.49	3.39	5.74
Z_2F_3: Zeolite @ 30 kg ha^{-1} + 100% RDF	38.43	43.53	33.60	3.37	5.79
Z_2F_4: Zeolite @ 30 kg ha^{-1} + 125% RDF	38.65	43.84	33.84	3.36	5.67
Z_3F_1: Zeolite @ 40 kg ha^{-1} + 50% RDF	37.18	41.75	32.22	3.42	5.68
Z_3F_2: Zeolite @ 40 kg ha^{-1} + 75% RDF	38.30	43.27	32.89	3.44	5.78
Z_3F_3: Zeolite @ 40 kg ha^{-1} + 100% RDF	38.56	45.12	34.29	3.42	5.79
Z_3F_4: Zeolite @ 40 kg ha^{-1} + 125% RDF	38.67	45.56	34.63	3.41	5.82
Z_4F_1: Zeolite @ 50 kg ha^{-1} + 50% RDF	39.15	43.81	33.30	3.42	5.77
Z_4F_2: Zeolite @ 50 kg ha^{-1} + 75% RDF	39.22	45.02	33.85	3.41	5.82
Z_4F_3: Zeolite @ 50 kg ha^{-1} + 100% RDF	41.17	47.73	35.89	3.42	5.86
Z_4F_4: Zeolite @ 50 kg ha^{-1} + 125% RDF	41.89	48.30	36.32	3.44	5.94
S.Em+	0.61	0.30	0.23	0.06	0.03
CD (P=0.05)	1.74	0.85	0.65	NS	0.08

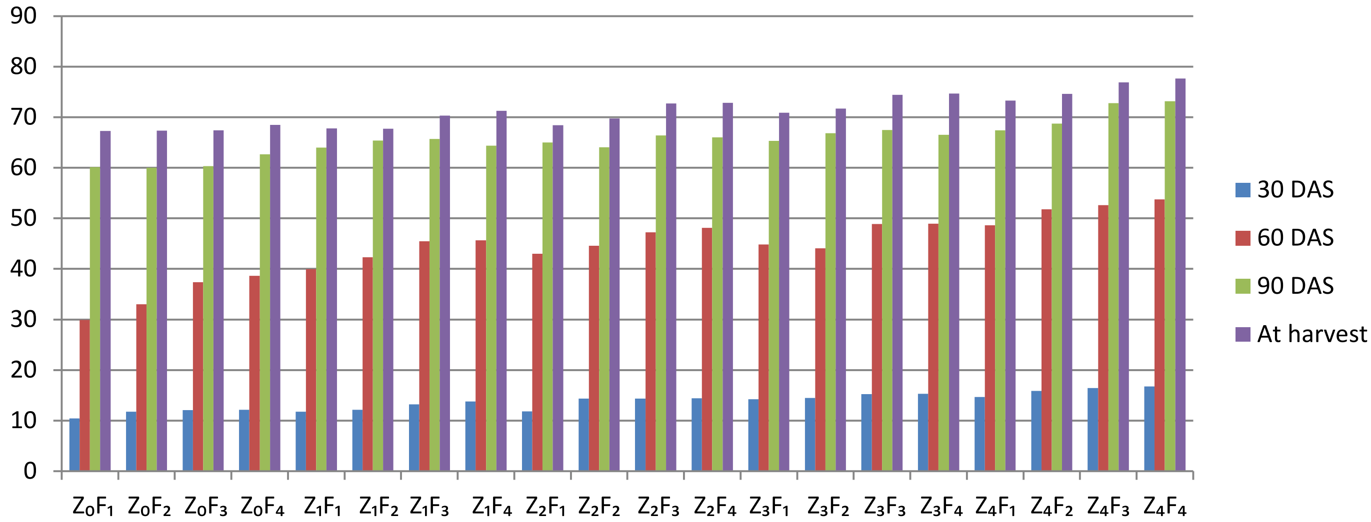

Fig. 1: Plant height and in finger millet crop as influenced by the zeolite and different levels of nutrient application

Factor I: Zeolite levels	**Factor II: Fertilizer levels**
Z_0 : Control	F_1: 50% RDF
Z_1 : Zeolite @ 20 kg ha^{-1}	F_2: 75% RDF
Z_2 :Zeolite @ 30 kg ha^{-1}	F_3: 100% RDF
Z_3 :Zeolite @ 40 kg ha^{-1}	F_4: 125% RDF
Z_4 : Zeolite @ 50 kg ha^{-1}	

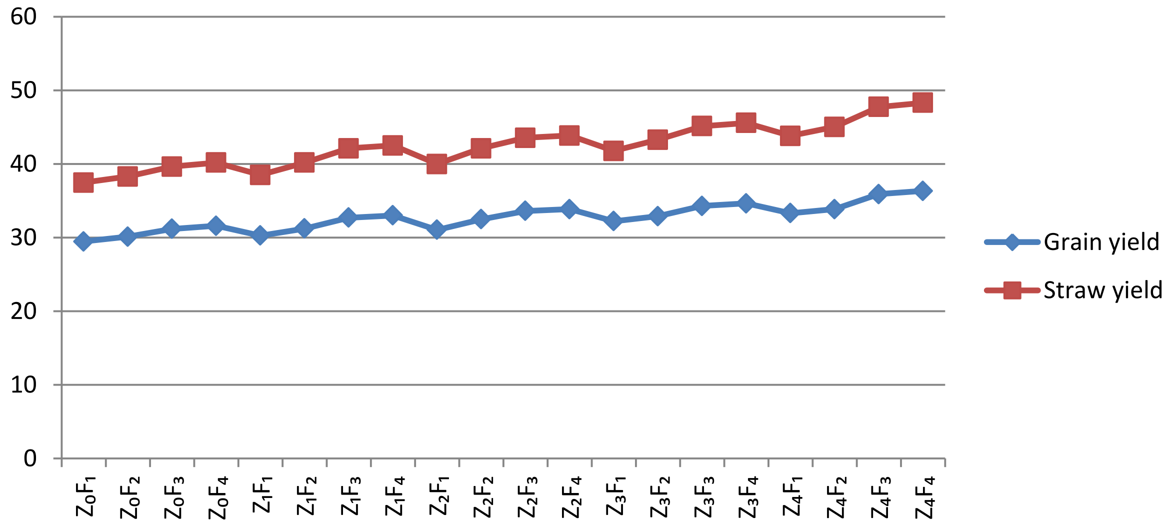

Fig. 2: Grain and straw yield of finger millet crop as influenced by different levels of zeolite and fertilizer application

Factor I: Zeolite levels	**Factor II: Fertilizer levels**
Z_0 : Control	F_1: 50% RDF
Z_1 : Zeolite @ 20 kg ha^{-1}	F_2: 75% RDF
Z_2 :Zeolite @ 30 kg ha^{-1}	F_3: 100% RDF
Z_3 :Zeolite @ 40 kg ha^{-1}	F_4: 125% RDF
Z_4 : Zeolite @ 50 kg ha^{-1}	

CONCLUSION

Zeolites are hydrated crystalline aluminosilicates, naturally occurring mineral having the favorable properties required for the better crop growth by making higher availability of nutrients and water for longer period. Zeolite application @ 50 kg ha^{-1} along with the recommended dose (100% RDF) of fertilizer and 125% RDF showed higher growth attributes like plant height, number of tillers per hill and total dry matter production. Similarly yield and yield parameters also recorded in the treatment which received zeolite @ 50 kg ha^{-1} along with 125 % and 100 % recommended dose of fertilizer.

The above study clearly emphasis the goodness of zeolite inclusion in nutrient management practices. Thus in the future year's inclusion of zeolite with fertilizer application would be an important component in nutrient management. Application of zeolite along with recommended dose of fertilizer enhances growth, yield and yield attributes of finger millet.

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