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Agronomic biofortification of finger millet with calcium and iron by using different sources in lateritic soils of konkan

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Abstract
A field study on biofortification of finger millet with calcium and iron by using different sources in lateritic soils of Konkan was conducted at farm of Department of Agronomy, College of Agriculture, Dapoli, Dist. Ratnagiri during *Kharif* 2015, where lime and basic slag were applied as a source of Ca, foliar application of Ca through $CaCl_2$ and Fe through $FeSO_4$ as well as Ca + Fe fortified Urea-DAP briquette were applied to finger millet Cv. Dapoli-1 to enhance Ca and Fe content in grain especially as well as its effect on yield of finger millet. The data revealed that the application of recommended dose of fertilizer (80:40:00 kg ha^{-1}) with $CaCO_3$ or basic slag (@ 1/5th LR) either alone or with the foliar spray of Fe through $FeSO_4$ @1% recorded the higher grain yield and straw yield of finger millet. Further, the quality of finger millet grain specially calcium and iron content as well as protein, crude fibre, phosphorus, potassium, magnesium sulphur, manganese, zinc and copper content in grain were also higher in treatment RDF with $CaCO_3$ or basic slag either alone or with the foliar spray of Fe. Thus, the application of recommended dose of fertilizer (80:40:00 kg ha^{-1}) with $CaCO_3$ or basic slag (@ 1/5th LR) either alone or with the foliar spray of Fe through $FeSO_4$ @1% indicating thereby that liming of soil with $CaCO_3$ or basic slag (@ 1/5th LR) and application of recommended dose of fertilizer (80:40:00 kg ha^{-1}) and/or foliar application of Fe through $FeSO_4$ @1% was beneficial in lateritic soils of Konkan from the view point of biofortification of Ca and Fe as well as getting higher yield.

Keywords: Biofortification, finger millet, yield, quality

Introduction

Finger millet is small-seeded minor cereal with light brown to brick red coloured or dark brown seed coat, which is mainly rich in phyto-chemicals such as a polyphenol and dietary fibers. Finger millet is a good source of nutrients especially fiber, antioxidant properties, photochemical which makes it easily and slowly digestible. Finger millet efficiently helps in controlling the blood glucose level in diabetic patients. Therefore, finger millet is considered to be ideal food for diabetic individual due to its low sugar content and slow release of sugar/glucose in the body (Kang *et at*. 2008) [7]. Finger millet plays an important role in our diet as it is the richest source of calcium and iron, finger millet helps to overcome the calcium deficiency and iron deficiency. Finger millet flour can be used for the preparation of various nutrient rich or dense recipes which can be used for supplement feeding. Finger millet flour provide many health benefits like finger millet for losing weight, bone health, lowering blood cholesterol, for anaemia and other health conditions.

In Maharashtra, finger millet occupies an area of about 120 thousand hectares with an annual grain production of 109 thousand tonnes with productivity 908 kg per ha (Bhagat *et al*. 2019) [3]. It is mainly cultivated in Thane, Raigad, Ratnagiri, Sindhudurga, Dhule, Jalgaon, Nashik, Ahmednagar, Pune, Satara and Kolhapur districts. The largest acreage of *ragi* is in Konkan region. In Konkan region, finger millet plays an important role in agriculture with an area of 38488 hectares of Maharashtra comprising with an annual production 41136 tonnes. However, the productivity in Thane, Palghar, Raigad, Ratnagiri and Sindhudurg is very low 1167 kg ha^{-1} (Mane *et al*. 2019) [8]. The high rainfall of Konkan region during *Kharif* season does not permit farmers cultivation of any other millet on slopy soils except finger millet. Thus, finger millet is cultivated during *Kharif* on hill slopes and uplands, which are less fertile land. Such no work on agronomic biofortification of calcium and iron has been done under Konkan condition on finger millet, hence the present investigation was proposed to undertake.

Material and Methods

The field study was conducted at farm of Department of Agronomy, College of Agriculture, Dapoli, Dist. Ratnagiri during *Kharif* 2015. Soil application of lime and basic slag as a source of Ca, foliar application of Ca through $CaCl_2$ and Fe through $FeSO_4$ as well as Ca + Fe fortified Urea-DAP briquette were applied to finger millet Cv. Dapoli-1. The experiment was laid out in randomized block design comprising nine treatments replicated thrice. The variety 'Dapoli-1' is released by Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli in 1985, the grain is red or brown in colour and crop duration is 125 to 135 days with yield potential of 15 to 20 q ha^{-1}.

Lime requirement of the initial composite soil sample was determined by Shoemaker *et al*. (1961) [11] method in t ha^{-1} and $1/5^{th}$ lime requirement per gross plot was worked out. Lime requirement determined to bring soil pH to 6.8. Similar to lime, calculated quantity of basic slag based on $1/5^{th}$ lime requirement was applied to the gross plot and mixed thoroughly in 0-30 cm of surface soil manually with pick-axe. The calcium chloride @ 2% and $FeSO_4$ @ 1% solution for foliar application were prepared by dissolving the respective weight of chemical fertilizers in respective quantity of water by continuous stirring and were given in the pertinent treatments at maximum tillering and panicle initiation stage. The Urea-DAP briquettes fortified with calcium and iron were prepared as per the ratio of fertilizers combination (i.e. 1.5**:**1.0 Urea**:**DAP) by adding calculated quantity of Ca as $CaCO_3$ i.e. 500 g and Fe as $FeSO_4$ i.e. 90 g with the help of Briquetter and were applied through deep point placement method at about 7 to 10 cm @ one briquette for every four hills of finger millet immediately after transplanting.

Nitrogen @ 80 kg ha^{-1} was applied in two splits *viz.*, first dose of 50 per cent N (40 kg N ha^{-1}) at the time of sowing and second dose of 50 per cent (40 kg N ha^{-1}) at maximum tillering stage; while phosphorus @ 40 kg ha^{-1} was applied as a basal dose at the time of sowing in the pertinent treatments (T_2 to T_8). After the preparation of plots, FYM was added @ 5 t ha^{-1} as common to all treatments except the treatment absolute control (T_1).

Protein and crude fibre in finger millet grains were determined by the procedure outlined by AOAC (1980) [1]. P, K, Ca and Mg content in finger millet grains were determined by the procedure outlined by Chopra and Kanwar (1978) [6]. S content in finger millet grains was measured spectrophotometrically at 340 nm wavelength (Chesnin and Yein, 1950) [5]. Micronutrients *viz*., Fe, Mn, Zn and Cu content were estimated by using Atomic Absorption Spectrophotometer (Mclaren and Crawford, 1950) [9].

Results and Discussion

Yield of finger millet

Grain yield is the ultimate end product of many yield contributing components, physiological and morphological processes took place in plants during growth and development. The conjunctive use of RDF and ameliorants had a beneficial effect on the physiological process of plant metabolism and growth, thereby leading to higher grain yield. In general, the higher grain yield were reported with the application of $CaCO_3$ (T_3 and T_7) and Basic Slag (T_4 and T_8) either alone or in combination with foliar Fe (Table 1). The highest grain yield (31.03 q ha^{-1}) was observed in the treatment T_4 (RDF+BS), which was at par with the treatments T_3 (RDF+$CaCO_3$), T_7 (RDF+ $CaCO_3$+Fe foliar), T_8 (RDF+BS+Fe foliar) and T_9 (UB-DAP Briquette fortified with Ca and Fe). These results indicate that combined use of inorganic fertilizer with FYM and ameliorants are essential for better yield. In case of straw yield, treatments T_3, T_4, T_5, T_6, T_7, T_8 and T_9.

Table 1: Yield and quality of finger millet as influenced by soil and foliar application of Ca and Fe

Tr.	Treatments	Grain Yield	Straw Yield
		(q ha^{-1})	
T_1	Control	12.05	13.80
T_2	RDF	23.55	31.86
T_3	RDF + $CaCO_3$	29.69	40.30
T_4	RDF + Basic Slag (BS)	31.03	41.08
T_5	RDF + Ca foliar	23.28	33.53
T_6	RDF + Fe foliar	23.06	33.25
T_7	RDF + $CaCO_3$ + Fe foliar	29.97	40.89
T_8	RDF+BS+ Fe foliar	30.72	41.28
T_9	Ca + Fe fortified Urea-DAP Briquette	27.64	40.97
	S.Em.±	1.54	3.04
	C.D.(P=0.05)	4.62	9.11

Quality of finger millet

In general, the higher protein and crude fibre content were reported with the application of $CaCO_3$ (T_3 and T_7) and Basic Slag (T_4 and T_8) either alone or in combination with foliar Fe (Table 1). The significant increase in protein content due to addition of liming materials may be attributed to the better use of atmospheric nitrogen in limed soil, which in term enhanced the protein content (Chatterjee 2002) [4].

The higher and at par values of phosphorus, potassium, calcium and magnesium content of finger millet grain were reported with the application of $CaCO_3$ (T_3 and T_7) and Basic Slag (T_4 and T_8) either alone or in combination with foliar Fe (Table 2). Liming increased the soil pH to neutrality and restricted the fixation of phosphorus which helped in enhancing the P availability of crop by resulting in higher uptake of P (Agarwal *et al*. 2007) [2]. Application of Ca + Fe fortified Urea-DAP briquettes were also found to be beneficial in enhancing the phosphorus, calcium and magnesium content of finger millet grain. Liming may serve as means for Ca delivery and the fortification of cereals plant, providing then significant amount of Ca. Further, foliar application of Ca significantly increased the calcium content in grain. In this connection, Reddy *et al*. (2018) [10] explained that the pores within the leaf cuticles can take up the nutrients as these pores are lined with negatively charged molecules. Therefore, the uptake of such cations is comparatively faster than anions. Thus, absorption of nutrients and other positively charged particles are rapid and efficient when applied as foliar spray. It is evident from the data that soil or foliar application of Ca or Fe by using different sources did not significantly change sulphur content of finger millet.

Table 2: Quality of finger millet as influenced by soil and foliar application of Ca and Fe to finger millet

Tr.	Treatments	Protein	Crude Fibre	P content	K content	Ca	Mg	S
		($g\ 100g^{-1}$)		($mg\ 100g^{-1}$)				
T_1	Control	6.42	2.82	126	283	297	123	0.09
T_2	RDF	6.84	3.00	142	298	308	132	0.10
T_3	RDF + $CaCO_3$	7.28	3.21	162	341	337	153	0.12
T_4	RDF + Basic Slag (BS)	7.36	3.20	164	338	341	157	0.12
T_5	RDF + Ca foliar	6.96	3.01	140	302	340	130	0.10
T_6	RDF + Fe foliar	6.92	2.98	141	306	312	134	0.10
T_7	RDF + $CaCO_3$ + Fe foliar	7.32	3.21	163	342	342	151	0.12
T_8	RDF+BS+ Fe foliar	7.30	3.20	164	340	343	153	0.12
T_9	Ca + Fe fortified Urea-DAP Briquette	7.16	3.08	152	314	326	141	0.10
	S.Em.±	0.101	0.032	4.73	4.93	8.66	5.82	0.012
	C.D.(P=0.05)	0.303	0.098	14.18	14.77	25.96	17.45	NS

Application of RDF+BS+Fe foliar (T_8) recorded the highest mean iron content in finger millet grain (15.08 mg $100g^{-1}$) thereby depicting the role of foliar application of Fe in increasing the content in grain (Table 3). Treatment T_3 (RDF+$CaCO_3$), T_4 (RDF+BS), T_6 (RDF+Fe foliar), T_7 (RDF+ $CaCO_3$+Fe foliar), T_8 (RDF+BS+Fe foliar) and T_9 (Ca & Fe fortified Urea-DAP Briquette) were at par with each other. It indicates that foliar application of Fe may serve as means for Fe delivery and the fortification of cereals plant, providing then significant amount of Fe. Thus, foliar application at critical growth stages has the potential to improve the nutrient concentration. In this connection, Reddy *et al*. (2018) [10] explained that the pores within the leaf cuticles can take up the nutrients as these pores are lined with negatively charged molecules. Therefore, the uptake of such cations is comparatively faster than anions. Thus, absorption of nutrients and other positively charged particles are rapid and efficient when applied as foliar spray. Further, it is evident from the data that soil or foliar application of Ca or Fe by using different sources did not significantly change Mn, Zn and Cu content of finger millet grain (Table 3).

Table 3: Micro-nutrient content of finger millet as influenced by soil and foliar application of Ca and Fe to finger millet

Tr.	Treatments	Fe	Mn	Zn	Cu
		($mg\ 100g^{-1}$)			
T_1	Control	10.02	31.02	3.14	1.13
T_2	RDF	11.56	33.32	3.24	1.15
T_3	RDF + $CaCO_3$	14.52	35.12	3.36	1.22
T_4	RDF + Basic Slag (BS)	14.06	35.24	3.34	1.23
T_5	RDF + Ca foliar	11.42	33.12	3.23	1.14
T_6	RDF + Fe foliar	14.86	33.18	3.24	1.15
T_7	RDF + $CaCO_3$ + Fe foliar	15.08	35.32	3.37	1.24
T_8	RDF+BS+ Fe foliar	14.96	35.42	3.35	1.23
T_9	Ca + Fe fortified Urea-DAP Briquette	13.02	34.08	3.31	1.19
	S.Em.±	0.86	1.07	0.054	0.053
	C.D.(P=0.05)	2.59	NS	NS	NS

Thus, application $CaCO_3$ or basic slag @ 1/5th LR along with recommended dose of fertilizer (80:40:00 N:P_2O_5:K_2O kg ha^{-1}) and/or foliar application of Fe through $FeSO_4$ @1% were found to increase Ca and Fe content in grain from the view point of biofortification, as well as getting significantly higher finger millet grain yield in lateritic soils of Konkan.

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