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Ashoka KR
Assistant Professor, Department of Soil Science & Agricultural Chemistry, College of Agriculture, V.C. Farm, Mandya UAS (B), Karnataka, India

Srinivasamurthy CA
Central Agricultural University, Impal, Manipur, India

Prakash SS
Department of Soil Science & Agricultural Chemistry, College of Agriculture, V.C. Farm, Mandya UAS (B), Karnataka, India

Ramakrishna Parama VR
UAS, G.K.V.K., Bangalore, Karnataka, India

Atheefa Munawery
ICAR-KVK, V.C. Farm, Mandya UAS (B), Karnataka, India

Corresponding Author:
Ashoka KR
Assistant Professor, Department of Soil Science & Agricultural Chemistry, College of Agriculture, V.C. Farm, Mandya UAS (B), Karnataka, India

Validation of sulphur requirement for finger millet (*Eleusine coracana* (L.), Karnataka, India

Ashoka KR, Srinivasamurthy CA, Prakash SS, Ramakrishna Parama VR and Atheefa Munawery

Abstract
One hundred and fifty eight (158) soil samples were collected from different agro-ecological situations (AES) in Eastern Dry Zone of Karnataka (EDZ) and were analysed for available sulphur and categorized soil to five classes as very low, low, medium, high & very high. The critical limit for soil available and plant sulphur and ratings for soil available sulphur were determined by conducting pot culture experiment in 24 soils collected from six different locations from each category. The results reveal that, response of finger millet was higher in very low and low S fertility soils as compared to medium and high status. Critical limit for available soil sulphur (SO_4^{2-}) was 5 mg kg^{-1} whereas, for finger millet plant the critical concentration was 0.23 per cent. Fertility ratings for available sulphur were proposed as very low (VL) <5.00 mg kg^{-1}, low (L) 5.10 to 14.00 mg kg^{-1}, medium (M) 14.10 to 24.00 mg kg^{-1}, high (H) >24.00 mg kg^{-1}. The available sulphur status of soils four AES varied from 3.32 to 37.15 mg kg^{-1}. Further, finger millet was grown in different S fertility soils at farmer's field for 7 years found to be promising for S critical limit in plant & soil.

Keywords: AES, critical limit, plant sulphur, categories, available sulphur, pot culture, fertility ratings

Introduction
The "Sulphur" is considered as a forgotten nutrient element (DCA 2010) [7], imbalanced application of fertilizers might have played a role in lowering the yield of crops through reduction in fertilizer use efficiency thereby increase the cost of cultivation. Due to higher demand for sulphur and its higher requirement by different crops it is recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium (TSI 2020) [28-29]. Functionally, S significantly influences yield and quality of crops, improves odour and flavours, imparts resistance against cold and hence, it is generally considered as ‘‘quality nutrient.’’ (TSI 2020) [28-29].

Insufficient supply of sulphur can affect yield and quality of the crops, because sulphur required for synthesis of the three amino acids cysteine, cystine and methionine and in the formation of various enzyme and proteins (Kertesz *et al*., 2007) [15]. Sulphur deficiency in crops is gradually increasing in various soils across the states in India due to (a) continued application of sulphur free fertilizers. (b) reduced application of organic manures (c) reduced application sulphur containing pesticides and (c) intensive cultivation leading higher removal of sulphur form soils (e) growing high yielding varieties of crops and (f) wide spread soil erosion (TSI 2020) [28-29]. It is estimated that about one million tonnes of sulphur is taken up from soil every year, whereas its addition through fertilizers is around 0.34 million tonne, this gap is expected to be widened in the coming years unless proper measures are taken. Sulphur deficiency could develop into a serious constraint in the crop production, since it is required in quantities almost same as that of phosphorus. (Lavanya *et al*., 2019) [17].

Sulphur availability to crops is influenced by numerous soil factors *viz*., available S storage, soil texture, soil pH (Germida & Janzen - 1993) [9]. The status and distribution of different forms of sulphur in soils varies with soil conditions and soil types. Originally sulphur is present in rocks as sulphide of metals. During weathering these sulphides are broken down through oxidation to furnish sulphate and other forms through the action of microbes, vegetation and water. Part of the S is incorporated into organic forms and part will remain as inorganic sulphate. Organic S is the major form of S, comprising 87 per cent of total S, followed by extractable SO_4-S (13%) (Ye *et al*., 2011) [30].

Development of modern agricultural technology has attracted the attention of scientists on sulphur nutrition owing to cultivation of high yielding varieties, adoption of intensive cropping systems particularly involving oil seeds and pulses, use of high analysis fertilizers and decreased usage of organic manures (Jaggi, 2008) [13].

Finger millet (*Eleusine coracana* (L.) Gaertn.) [F: Poaceae] also known as ragi or African millet ranks fourth in importance among millets in the world after sorghum (*Sorghum* bicolor), pearl millet (Pennisetum glaucum) and foxtail millet (*Setaria italica*) (Dinesh *et al*., 2016) [8]. Of the total area of 2.70 m ha under millets, ragi alone accounts for 1.60 mha of the area and 75 per cent of total production in the country. India is the world's largest producer of finger millet with annual production of 2.1 mt and productivity of around 1300 kg ha-1. In India, ragi ranks fourth among the grain crops in productivity after wheat, rice and maize (O'Kennedy *et al*. 2006) [20]. Under irrigated conditions, the crop has a yield potential of 3 to 4 t ha-^{1} (Anon., 2009) [1].

In the light of the above facts, this study was carried out with the objectives *viz*., to study the effect of graded levels of sulphur application to soils of different sulphur fertility gradient then to revalidate the soil fertility ratings for sulphur with a test crop as finger millet and to study the status of available sulphur in EDZ of Karnataka.

Materials and Methods

To know the available sulphur status of soils of Eastern Dry Zone of Karnataka (EDZ), five to ten true representative soils were collected from four Agro-Ecological systems (AES) of EDZ of Karnataka covering three district *viz*., Tumkur, Bangalore Rural and Kolar. The details of the sampling areas are presented in below Table 1. The soil samples collected were air dried, crushed, and passed through a 2-mm sieve before chemical characterization. pH (1:2.5) was determined by glass membrane electrode (Rayment & Higginson 1992) [24]. Electrical conductivity (EC) was measured by using a conductivity meter (Rhoades, 1996) [25]. Organic carbon (OC) by Wet oxidation method (Jackson 1973) [12] and available nitrogen (N) were analysed by Micro kjeldahl distillation method (Subbiah and Asija 1956) [27] and Olsen-extractable or Bray's extractable phosphorus (depending on Soil pH) was done by spectroscopy (Jackson 1973) [12]. Further, available sulphur done by turbidity method (Jackson 1973) [12]. The DTPA extractable (Fe,Zn, Cu & Mn) analysis were done using atomic absorption spectroscopy (AAS) All determinations were done to samples from three replications.

Pot experiment: to study the critical limits of sulphur a pot culture experiment was conducted. Collection of soil sample for pot experiment was done as per above mentioned procedure. Subsequently the soils were categorized into different categories based on available sulphur content of soil as detailed below Very Low, Low, Medium, High & Very high if the soil contains < 5 mg kg^{-1}, 6 to15 mg kg^{-1}, 16 to 25 mg kg^{-1}, 26 to 35 mg kg^{-1} and > 35 mg kg^{-1} in available sulphur content, respectively. The details of the bulk samples collected are presented in Table 1. Based on the initial soil available sulphur, 6 soil samples from each category *viz*., very low, low, medium and high (24) were filled into (24x7x3) 504 individual pots. The experimental details are given below.

Experimental details

Sulphur fertility levels: 4 (very low, low, medium and high)
Number of soils in each category: 6

Treatment Details

T_1: Absolute control
T_2: Recommended NPK through DAP, urea and MOP (no sulphur)
T_3: Recommended NPK + FYM as per package of practice (PoP)
T_4: 20 kg S ha^{-1} as elemental S + Rec. NPK + Rec. FYM
T_5: 20 kg S ha^{-1} as elemental S + Rec. NPK + no FYM
T_6: 40 kg S ha^{-1} as elemental S + Rec. NPK. + Rec. FYM
T_7: 40 kg S ha^{-1} as elemental S + Rec. NPK. + no. FYM

Crop details

Crop: Finger millet (GPU-28)
Season: Summer
Date of sowing: 05-04-2012 & Date of harvest: 06-06-2012
Design & layout: CRD
RDF: 100: 50: 50 Kg N: P_2O_5: K_2O ha^{-1}
Recommended dose of FYM: 7.5 t ha^{-1}

Ten kg of soil was taken in each plastic pot. Calculated quantity of FYM equivalent to 7.5 t ha-^{1} was mixed in each pot as per the treatment details 5 days before sowing. At the time of transplanting 50 per cent of recommended N was applied through urea & DAP and entire dose of P and K were applied through DAP and Mop, respectively for all the plots. Calculated quantity of sulphur was applied through elemental sulphur as per the treatments, the N content of DAP was taken into consideration while calculating the quantity of urea to be applied. Sowing of ragi seeds was done & moisture content of soil in pots was maintained at field capacity. Thinning was done after a week and two plants were maintained per pot. Weed management and plant protection measures were taken up as per the package of practices. Irrigation was given regularly whenever crop needed. At 60 days after sowing, finger millet plants were harvested separately from each pot and dry matter yield was calculated and were analysed for the nutrients content *viz*., total N by Kjeldahl digestion distillation method, total P by diacid digestion and vanadomolybdate yellow colour method, total K by diacid digestion and flame photometer method, total Ca & Mg by diacid digestion with versenate titration method, total S by diacid digestion with turbidometry (Piper, 1966).

Critical level of available sulphur for higher dry matter production was calculated by adopting the Cate and Nelson (1965 and 1971) [5, 6] procedure by plotting relative yield against sulphur levels in soils and fitting regression curve (Korndorfer *et al*., 2001) [32] and categorization of soil test values in to very low, low, medium and high categories was made by adopting the procedure given by Cope and Rouse (1973) [33]

The critical limit of available sulphur was calculated by plotting (Cate and Nelson, 1971) [6]. The available sulphur was plotted on X – axis and relative yield on Y- axis. However, the FYM treated pots also taken in to consideration to determine the critical limits and revalidate soil available sulphur.

Relative yield = [{1- (maximum yield – check yield/check yield)} X 100]

The critical limits of soil and plants for higher yields were calculated in a graphical method by plotting the soil available sulphur in different sulphur fertility levels on X-axis and relative yield on the Y-axis. A transparent overlay with a vertical line and an intersecting horizontal line so as to maximize the number of points in the first and third quadrants and minimum number of points in the second and fourth quadrants. The soil test value corresponding to the location was taken as critical value for sulphur (Cate and Nelson, 1965 and 1971) [5, 6].

To confirm this research results, farm trails were conducted in different locations using finger millet as test crop at EDZ of Karnataka from 2013 to 2019. Five finger millet crop was grown in each soil sulphur fertility (VL, L, M & H) under protected irrigation condition and pooled finger millet grain yield data.

Results and Discussion

Data pertaining to changes in pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium and sulphur content of soil after the harvest of finger millet (60 DAS) crop are presented from Table 3 to 11.

Changes in chemical properties of soil in pot experiment

Irrespective of treatments, the changes in pH (1:25), electrical conductivity (dS m^{-1}) and organic carbon (mg kg^{-1}) (Table 3 to 5) were found non-significant for all the soils. However, due to sulphur and FYM application a slight decrease in pH, a slight increase in electrical conductivity and decrease in organic carbon content of soil at 60 days after sowing (DAS) of finger millet was observed.

Generally, the pH of soil was found to be lower in T_6 (100% NPK + 40 kg S + FYM) in all the fertility levels, but the electrical conductivity was found to be higher in treatment which received inorganic fertilizers. Higher organic carbon content of soil was observed in the treatment which received FYM (farm yard manure) and also in T_6 (100% NPK + 40 kg S + FYM) in the soils at all the fertility levels, which might be due to use of FYM & higher buffering capacity of soil used in pot experiment from different locations of EDZ of Karnataka, India (Paul & Ninghu, 2010) [10].

Application of 100% NPK + 40 kg S + FYM (T_6) recorded significantly higher available nitrogen (Table 6) in soils of very low fertility (124.01, 133.67, 160.32, 169.63, 175.09 and 227.85 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil$_5$ and soil $_6$ respectively). The values for low fertility level soils were 163.91, 160.77, 165.11, 180.86, 170.01 and 188.56 kg ha^{-1} soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively and in medium fertility level soils the values were 228.66, 253.49, 271.67, 287.46, 348.87 and 339.00 kg ha^{-1} soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively). The high fertility soil recorded higher available N content 370.17, 378.66, 365.59, 395.91, 409.01 and 395.52 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively) followed by T_7 (100% NPK + 40 kg S) in all six soils. These results are corroborated with the findings of Skwierawska *et al.* (2008) [26] observed & concluded it might be due to application of sulphur (N & S are synergetic) to soil.

However, lower available nitrogen content was recorded in control (T_1) of very low fertility level (79.15, 92.67, 110.51, 117.67, 122.25 and 168.94 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively). The low fertility soil recorded 116.78, 116.93, 122.26, 132.62, 127.73 and 141.41 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively). In the medium fertility level soil, the values were 171.52, 182.47, 196.16, 196.16, 244.51 and 237.48 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively. In high fertility soil the values were 260.93, 264.58, 255.46, 281.46, 290.58 and 288.30 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively. Higher mean available nitrogen was noticed in soil $_6$ (198.80 kg ha^{-1}) of very low fertility level, soil $_6$ of (168.63 kg ha^{-1}) low, soil $_5$ of (306.08 kg ha^{-1}) of medium fertility and soil $_5$ (356.84 kg ha^{-1}) of high fertility level respectively and lower mean available nitrogen was observed in soil$_1$ of all sulphur levels. It could be due to nature of soil as well as treatment difference.

The available references contain diverse interpretation of the influence of sulphur on the dynamics of available phosphorus in soil, significant difference in the available phosphorus (Table 7) content of soil after harvest of finger millet (at 60 DAS) was observed, there was increase in phosphorus content with increased sulphur application along with FYM. Significantly lower available phosphorus content was recorded in control (T_1) of very low fertility level (12.55, 13.61, 14.03, 16.76, 17.91 and 13.13 kg ha^{-1} in soil$_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively). In low fertility soil the values were 18.66, 15.68, 15.36, 17.06, 18.20 and 20.56 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively. The medium fertility soils recorded 15.84, 21.78, 27.14, 29.74, 27.16 and 21.16 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively. In soils of high fertility the values were 16.25, 25.19, 14.63, 21.21, 18.20 and 24.09 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively.

Higher available phosphorus was recorded with application of 100% NPK + 40 kg S+ FYM (T_6) in very low fertility soils (17.22, 18.13, 19.03, 23.00, 24.81 and 18.01 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively) and low fertility soil (25.60, 21.61, 21.39, 23.79, 25.38 and 28.66 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively). The available phosphorus content of medium fertility soils were 22.09, 30.63, 37.84, 40.76, 38.18 and 32.18 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively. The high fertility soils recorded with 23.79, 35.12, 20.39, 29.57, 25.38 and 33.36 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively followed by T_7 in all soils with different sulphur levels.

However, the initial available phosphorus content of different soils of different fertility levels has influence on its availability at harvest of finger millet (at 60 DAS). Among six soils of different levels, higher mean available phosphorus was observed in soil $_5$ (21.62 kg ha^{-1}) of very low fertility level. In low fertility level soils, 25.00 kg ha^{-1} of higher available P recorded in soil $_5$, whereas in medium fertility soils the value was 35.87 kg ha^{-1} (soil $_4$) and in high fertility soils, soil $_2$ recorded 30.47 kg ha^{-1} of higher mean available phosphorus content respectively. The effect produced by elementary sulphur depended on the rate of its oxygenation in soil and its dose which is confirmed by Skwierawska *et al.* (2008) [26], Our findings are confirmed by Germida and Janzen (1993) [9] as well as by Watkinson and Lee (1994) [34]. Lindemann *et al.* (1991) [18] found no increase in available phosphorus in soil following fertilization treatments with elementary sulphur, even though the soil pH was lowered and the amount of the sulphate form in soil increased. According to Jaggi *et al.* (2005) [31], addition of elementary sulphur improves the availability of phosphorus in cultivated soils, irrespective of the soil initial pH.

Application of sulphur, FYM and inorganic nutrients significantly increased the available potassium content of soil (Table 8). Among different treatments, T_6 (100% NPK + 40 kg S+ FYM) recorded significantly higher available potassium in very low fertility soils (84.09, 99.67, 112.44, 89.69, 125.57 and 121.09 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively), low fertility soils (262.35, 444.95, 75.79, 236.56, 405.86 and 188.35 kg ha^{-1} in soil$_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively), in medium fertility soils (283.65, 706.33, 206.29, 174.90, 218.63 and 455.86 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively) and in high fertility soils (315.05, 269.08, 246.65, 313.92, 300.50 and 497.56 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil$_6$ respectively) and this was followed by treatment T_7 which received 100% NPK+ 40 kg S in all fertility level soils. However, little difference was noticed between T_6 and T_7 treatments.

Lower available potassium content of soils was observed in control (T_1) in very low fertility soils (57.94, 68.43, 74.85, 66.79, 88.19 and 85.15 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively), in low fertility soils (190.07, 320.08, 57.02, 167.26, 275.22 and 133.05 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively), in medium fertility soils (195.44, 555.00, 139.89, 121.64, 152.06 and 325.70 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil$_6$ respectively) and high sulphur fertility soils (228.08, 187.03, 182.47, 227.05, 212.88 and 369.50 kg ha^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively) in all six soils of their respective fertility levels. Among different soils high mean values of available potassium was found in soil$_5$ (109.23 kg ha^{-1}) of very low fertility level, soil$_3$ (390.01 kg ha^{-1}) of low fertility level, soil$_2$ (629.36 kg ha^{-1}) of medium sulphur level and soil$_6$ (436.98 kg ha^{-1}) of high sulphur level respectively. There was a very clear tendency towards decreasing potassium concentrations in soil after the application of higher rates of either form of sulphur Skwierawska *et al*., 2008) [26].

The availability of sulphur increased with increased application of sulphur with or without FYM and sulphur gradients (Table.9). Due to application of 100% NPK + 40 kg S + FYM (T_6) significantly higher available sulphur found in very low fertility soils (2.46, 2.77, 3.56, 4.84, 4.76 and 6.07 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively), in low S fertility soils (9.15, 10.12, 10.30, 12.61, 14.85 and 16.40 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil$_4$, soil $_5$ and soil $_6$ respectively), in medium S fertility soils (21.60, 21.16, 24.03, 24.35, 25.18 and 28.97 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively) and in high S fertility soils (31.64, 36.18, 36.42, 34.65, 41.60 and 42.47 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$respectively). This was followed by T_7 (100% NPK + 40 kg S) in very low S fertility soils (2.21, 2.51, 3.20, 4.44, 4.14 and 5.44 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively), in low S fertility soils (8.79, 9.76, 10.03, 12.09, 14.58 and 16.12 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively), in medium S fertility soils (20.59, 20.64, 22.91, 23.75, 24.71 and 27.63 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively) and in high S fertility level soils (30.39, 33.14, 33.36, 33.53, 40.25 and 41.27 mg kg^{-1} soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil$_6$ respectively).

However, treatment T_7 and T_4 were found on par with each other in all the soils of all sulphur fertility levels. Control (T_1) recorded lower available sulphur content of 1.46, 1.86, 2.33, 3.35, 3.41 and 4.13 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil$_4$, soil $_5$ and soil $_6$ respectively in soils of very low sulphur level, 7.17, 8.23, 8.38, 10.48, 12.49 and 13.67 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively in soils of low sulphur level, 17.27, 17.65, 19.21, 20.29, 21.16 and 23.17 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively in soils of medium sulphur level and 24.81, 25.05, 25.22, 27.51, 33.59 and 34.50 mg kg^{-1} in soil $_1$, soil $_2$, soil $_3$, soil $_4$, soil $_5$ and soil $_6$ respectively of high sulphur fertility level soils respectively.

Higher mean available sulphur content of individual soil was found to be higher in soil $_6$ of all the fertility levels 4.96 mg kg^{-1} of very low, 15.12 mg kg^{-1} of low, 25.93 mg kg^{-1} of medium and 38.43 mg kg^{-1} of high sulphur fertility level respectively and lower mean value (1.90, 8.08, 19.33 and 28.07 mg kg^{-1} in very low, low, medium and high S fertility level soils respectively) was found in soil $_1$ of all sulphur levels.

Critical limit of available sulphur, plant sulphur content and revalidation of sulphur fertility ratings for finger millet in eastern dry zone (EDZ) of Karnataka

Soil test value below which an economic crop response to the added nutrient is expected called critical level of that nutrient and the percentage of yield obtained in the unfertilized control soil relative to the maximum yield achieved in the sulphur fertilized soil called per cent relative yield has been computed and presented in Table 15.

The relative per cent yield plotted against available soil sulphur as shown in Fig. 1 and 2 (Cate and Nelson, 1965 graphical representation) [5] represents critical limit of available soil sulphur, revalidation of available soil sulphur fertility rating and critical limit of plant sulphur content for finger millet in EDZ of Karnataka.

The dry matter yield of finger millet was influenced by application of graded levels of sulphur with/without FYM and initial available sulphur for maximum yield and check yield of finger millet grown in pot which ranged from 19.41 to 28.01 g pot^{-1} and due to treatment effect the maximum yield ranged from 30.00 to 33.50 g pot^{-1}.

The increased yield (YI) computed difference between maximum yield and check yield decreased as the available sulphur increased which ranged from 2.64 to 12.47 g pot^{-1} and the dependent variable per cent relative yield (PRY) increased with increased sulphur level and sulphur availability and the average PRY was found lower (38.32%) in low sulphur level and was found higher (85.99%) in high sulphur level respectively which ranged 35.75 to 41.36 per cent in very low (<5 mg kg^{-1}), 53.40 to 74.58 mg kg^{-1} in low (6 to 15 mg kg^{-1}), 66.49 to 79.25 per cent in medium (16 to 25 mg kg^{-1}) and 80.21 to 90.41 per cent in high sulphur level (>25 mg kg^{-1}) respectively (Table 15).

The sulphur content in check pot increased with increased sulphur level which ranged from 0.19 to 0.22 per cent in very low, 0.22 to 0.23 per cent in low, 0.26 to 0.33 per cent in medium and 0.35 to 0.40 per cent in high sulphur level respectively (Fig.3). The results are in accordance with Brajendra *et al*. (2012) [3] and Huda *et al*. (2014) [11]. The critical concentration of sulphur in 60 days old musturd plant tissue was found to be 0.51 per cent on dry weight basis (Pandey and Girish, 2006) [21].

The revalidation of sulphur fertility ratings based on the per cent relative yield (PRY) for soils with different S fertility levels in Eastern Dry Zone of Karnataka was done using Cope and Rouse (1973) [33] continuous calibration curve method. PRY below 55 per cent was considered as very low in available sulphur, 55 to 75 per cent was considered as low available sulphur 75 to 95 per cent as medium available sulphur and above 95 per cent was categorized as high in available sulphur content of soil, the corresponding fertility ratings for available sulphur in soil and the range of values (Fig. 22) are as follows.

Fertility ratings			Available sulphur (SO_4) mg kg^{-1}
Very low	(VL)	:	< 5.00
Low	(L)	:	5.10 to 14.00
Medium	(M)	:	14.10 to 24.00
High	(H)	:	>24.00

The results are in corroboration with Huda *et al*. (2004) [11], who determined the critical limits of sulphur to rice plant and soil by graphical and statistical methods. Brajendra *et al*. (2012) [3] and Kumar Rakesh *et al*. (2002) [23] also found similar observations.

Table 1: Details of soil sampled in soils of Eastern Dry Zone of Karnataka, India

Agro climatic zone – 5			
Agro ecological situations			
AES 1	AES 2	AES 3	AES 4
Red sandy loam	Red loamy soils	Red laterite soil	Irrigated
Low rainfall	Medium rainfall	Medium rainfall	
Taluks (Samples number)			
Gouribidanur (17)	Nelamangala (10)	Kolar (10)	Scattered in all AES
Parts of Doddaballapur (19)	Tumkur (9)	Hosakote (6)	
Parts of Mulabagalu	Gubbi (10)	Devanahalli (13)	
	Parts of Chikkaballapur (15)	Parts of Chikkaballapur	
	Parts of Mulabaglu (10)		
Total number of soil sample = 158			
Major crops grown Ragi, maize, red gram, vegetables: (Gouribidanur, Mulabaglu, Kolar, Chikkaballapur) Maize, ragi, red gram, vegetables: (Devanahalli, Parts of Doddaballapur, Hosakote, Nelamangala) Paddy, ragi, red gram: (Gubbi & Tumkur)			

Table 2: Soil available sulphur status (mg kg^{-1}) in Eastern Dry Zone of Karnataka, India

Place & AES	***SO_4^{2-}***	***Place & AES***	***SO_4^{2-}***	***Place & AES***	***SO_4^{2-}***
Huskuru, Doddaballapura, AES1	22.3	Kempaganahalli, Chikkaballapura, AES2	9.56	Sonnahallipura Hoskote AES3	11.12
Kuntanahalli, Doddaballapur AES1	14.53	Hegunda, Nelamangala AES2	7.04	Jadigenahalli, hoskote AES3	8.06
Kamanagrahara, Doddaballapura AES1	21.42	Narashipura, Nelamanagala AES2	6.84	Jadigenahalli, hoskote AES3	8.15
Saslu, Doddaballapura AES1	15.84	Bugudihalli, Nelamangala AES4	11.58	Haraluru, Hoskote AES3	15.65
Saslu, Doddaballapura AES1	28.93	Makenahalli, Nelamangala AES2	8.21	Haraluru, Hoskote AES3	13.75
Thodalabande, Doddaballapura AES1	8.80	Enchenahalli, Nelamanagala AES2	4.50	Cheemasandra Hoskote AES3	18.75
Kanakenahalli, Doddaballapura AES1	10.53	Manne, Nelamanagala AES2	12.63	Chikkamaralli, Devanahalli AES3	18.95
Adakavalla, Doddaballapura AES1	9.38	Thyamagondlu, Nelamangala AES2	3.98	Chikkamaralli, Devanahalli AES3	14.56
Kadathippuru, Doddaballapura AES1	10.56	Kalghatta, Nelamangala AES2	7.33	Chikkamaralli, Devanahalli AES3	9.68
Akkathamanahalli, Doddaballapura AES1	8.41	Mallunugallihattu, Nelamangala AES2	15.54	Settarahalli, Devanahalli AES3	22.56
Kattivasahalli, Doddaballapura AES1	8.02	Basavanahalli, Nelamangala AES2	5.60	Chikkagollahalli, Devanahalli, AES3	19.65
Doddabelavangala, Doddaballapura AES1	17.99	Mylanahalli, Nelamangala AES2	7.71	Byadarahalli, Devanahalli AEs3	14.12
Sonnenahalli, Doddaballapura AES1	9.19	Varadagunahalli, Mulabagalu AES2	7.43	Jalige, Devanahalli AES3	6.84
Tubinakere, Doddaballapura AES1	11.93	Avani Mulabagalu AES2	12.71	Thindlu, Devanahalli AES3	11.53
Lakkasandra, Doddaballapura AES1	12.32	Kurudumalai, Mulabagalu AES2	14.66	Neraganahalli, Devanahalli AES3	6.65
Tubegere, Doddaballapura AES1	9.19	Kadaripura, Mulabagalu AES2	8.60	Koramangala, Devanahalli AES3	6.26
Hadonahalli, Doddaballapura AES1	8.02	Kurubarahalli, Mulabagalu AES2	12.51	Koramangala, Devanahalli AES3	24.24
Kanasavadi, Doddaballapura AES1	7.43	Puttarahalli, Mulabagalu, AES2	6.84	Vijayapura, Devanahalli AES3	23.26
Honnavara, Doddaballapura AES1	9.19	Puttarahalli, Mulabagalu, AES2	8.80	Channarayapatna, Devanahalli AES3	28.64
T. Bommasandra, Gowribidanur, AES1	16.44	Gummakal, Mulabagalu AEs2	5.47	Malleshwarnagar, Kolar AES3	3.91
Kenkere, Gowribidanur, AES1	10.78	Varadagunahalli, Mulabagalu AES2	3.71	Vakkaleri Kolar AES3	33.63
Vedalveni, Gowribidanur, AES1	17.98	Mulabagalu, Kolar AES2	8.02	Chinnapura, Kolar AEs3	4.30
Bandaralahalli, Gowribidanur, AES1	10.56	Suthapete, Chikkaballapura, AEs2	7.62	Dandigonahalli, Kolar, AES3	11.73
Benchippanahalli, Gowribidanur, AES1	8.21	Katenahalli, Chikkaballapura AES2	13.88	Beglibeneganahalli, kolar AES3	8.21
Alkapura, Gowribidanur, AES1	7.82	Bichaganahalli, Chikkaballapura AES2	3.32	Ammerhalli, kolar AES3	6.84
Gidaganahalli, Gowribidanur, AES1	3.65	Yerahalli, Chikkaballapura, AES2	5.47	Beglibeneganahalli, Kolar AES3	4.89
Kachamachanahalli, Gowribidanur, AES1	19.56	Iddolu, Chikkaballapura, AES2	9.78	Mediyalla, Kolar AES3	12.51
Hale upparhalli, Gowribidanur, AES1	14.65	Chipaganahalli, Chikkaballapura, AES2	7.82	Veemagal, Kolar AES3	6.26
Kotaldinne, Gowribidanur, AES1	18.65	Chipaganahalli, Chikkaballapura, AES2	6.06	Kurugal, KolarAES3	9.58
Kadaluveri, Gowribidanur, AES1	11.93	Chikathekahalli, Chikkaballapura AES2	11.73	Byagadralli, Tumkur, AEs2	37.15
Herebindu, Gowribidanur, AES1	7.82	Nandi, Chikkaballapura AES2	6.26	Sorekunte, Tumkur, AES2	8.98
Sigadigere, Gowribidanur, AES1	8.41	Kondavanahalli, Chikkaballapura AES2	4.89	Tubgunte, Doddaballapura AES4	7.04
Nulugumanahalli, Gowribidanur, AES1	9.97	Gandhipura, Chikkaballapura AEs2	14.27	Hambalgere, Doddaballapura AES4	7.43
Heggenahalli, Gowribidanur, AES1	10.17	Bandamanahalli, Chikkaballapura, AES2	3.32	Neralaghatta, Doddaballapura AES4	7.82
Demgattanahalli, Gowribidanur, AES1	10.17	Kuduthi, Chikkaballapura, AES2	6.65	Purushanahalli, Doddaballapura AES4	8.21
Basavapura, Gowribidanur, AES1	12.42	Erenahalli, Chikkaballapura AES2	12.90	Kamanagrahara, Doddaballapura AES4	17.01
Gubbi, AES2	16.23	Kanganakoppa, Gowribidanur, AES4	28.68	Neralaghatta, Doddaballapura AES4	19.65
Ammanghatta, Gubbi, AES2	16.62	Rampura, Hoskote AES4	6.91	Adivasahalli, Nelamangala AES4	12.57
Doddagini, Gubbi, AES2	7.82	Sulibele, Hoskote AES4	13.96	Mallarabanavadi, Nelamagala AES4	9.50
Doddagini, Gubbi, AES2	4.89	Chikkalagere, Hoskote AES4	8.08	Lakshmipura, Chikkaballapura AES4	8.60
Mattighatta, Gubbi, AEs2	5.67	Theneyur, Hoskote AES4	17.99	Mittemari, Chikkaballapura AES4	6.65
Channashettyhalli, Gubbi, AES2	14.08	Nandagudi, Hoskote AES4	6.06	Pottavarahalli, Chikkaballapura AES4	8.60

M.H.Patna, Gubbi, AES2	3.71	Tandaga, Tumkur AES4	18.56	Avathi, Devanahalli AES4	4.89
Kundernahalli, Gubbi, AES2	18.38	Ranganahalli, Tumkur AES4	15.65	Avathi, Devanahalli AES4	4.69
Kundernahalli, Gubbi, AES2	9.58	Nagarakatte, Tumkur AES4	16.81	Honnavara, Devanahalli AES4	6.98
Nittur, Gubbi, AES2	5.28	Nagarhole, Tumkur, AES4	7.62	Channarayapatna, Devanahalli, AES4	23.97
Nijagahalli, Tumkur, AES2	6.06	Brahmadevarahalli, Tumkur, AES4	7.98	Channarayapatna, Devanahalli, AES4	21.44
Linganahalli, Tumkur, AES2	11.14	Honnapanahalli, Gowribidanur AES4	30.68	Chatrakodihalli, Kolar AES4	8.99
Dodderi, Tumkur, AES2	7.82	Hosur, Gowribidanur, AES4	31.42	Naganala, Kolar AES4	6.06
G.G.Palya, Tumkur, AES2	7.62	Henumanthapura, Gowribidanur, AES4	9.86	Busunahalli, Kolar AEs4	9.19
Sorekunte, Tumkur, AES2	9.58	Kalludi, Gowribidanur AES4	16.03	Marenahalli, Kolar AES4	31.28
Helenijoglu, Tumkur, AES2	14.27	Nagaragere, Gowribidanur AES4	5.67	Mudiyanur, Mulabagalu AES4	13.49
Ballapura, Tumkur, AES2	9.78			Nangali, Mulabagalu AES4	17.01
Over all Mean	11.70	Maximum sulphur	37.15	Minimum sulphur	3.32

Table 3: Finger millet post-harvest soil pH (1:2.5) at different soil S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	Very low sulphur level							Low sulphur level						
	Soil$_1$	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**	**Soil$_1$**	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**
T_1:Control	6.92	7.79	7.12	7.41	7.90	6.87	6.55	6.63	6.63	6.67	6.47	6.50	6.36	6.55
T_2:100% NPK (No FYM)	6.87	7.78	7.07	7.37	7.84	6.81	6.50	6.57	6.59	6.62	6.42	6.45	6.31	6.50
T_3:100% NPK +FYM	6.83	7.73	7.02	7.31	7.80	6.78	6.46	6.54	6.54	6.59	6.41	6.42	6.28	6.46
T_4:100% NPK +FYM + 20kg S	6.81	7.70	7.00	7.28	7.79	6.77	6.45	6.53	6.53	6.57	6.38	6.41	6.27	6.45
T_5:100% NPK +20kg S	6.86	7.75	7.05	7.35	7.84	6.82	6.49	6.58	6.57	6.62	6.40	6.46	6.32	6.49
T_6:100% NPK +FYM+40kg S	6.77	7.68	6.97	7.26	7.68	6.73	6.41	6.46	6.49	6.53	6.38	6.38	6.24	6.41
T_7:100% NPK +40 kg S	6.80	7.67	7.00	7.28	7.76	6.76	6.44	6.51	6.52	6.54	6.38	6.40	6.26	6.44
Mean	6.84	7.73	7.03	7.32	7.80	6.79	7.25	6.55	6.55	6.59	6.40	6.43	6.29	6.47
Initial	6.94	7.84	7.14	7.44	7.94	6.90	7.37	6.68	6.86	6.77	6.56	6.60	6.46	6.66
F	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*		*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	Soil$_1$	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**	**Soil$_1$**	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**
T_1:Control	6.14	6.24	6.05	6.15	6.08	6.04	6.11	6.02	6.04	5.92	5.91	5.82	6.23	5.99
T_2:100% NPK (No FYM)	6.10	6.21	6.00	6.10	6.03	5.99	6.07	5.98	6.00	5.87	5.87	5.78	6.19	5.95
T_3:100% NPK +FYM	6.06	6.16	5.97	6.07	6.00	5.96	6.04	5.95	5.97	5.84	5.82	5.75	6.16	5.92
T_4:100% NPK +FYM + 20kg S	6.04	6.15	5.96	6.06	5.99	5.95	6.02	5.94	5.96	5.83	5.81	5.74	6.13	5.90
T_5:100% NPK +20kg S	6.09	6.19	5.99	6.10	6.03	5.99	6.07	5.98	5.99	5.87	5.86	5.78	6.17	5.94
T_6:100% NPK +FYM+40kg S	6.01	6.12	5.90	6.03	5.96	5.90	5.99	5.91	5.93	5.77	5.78	5.71	6.10	5.87
T_7:100% NPK +40 kg S	6.04	6.14	5.96	6.05	5.98	5.92	6.02	5.93	5.95	5.83	5.80	5.73	6.12	5.89
Mean	6.07	6.17	5.98	6.08	6.01	5.96	6.05	5.96	5.98	5.85	5.84	5.76	6.16	5.93
Initial	6.35	6.29	6.17	6.28	6.24	6.20	6.26	6.22	6.09	6.11	6.01	6.05	6.34	6.14
F	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*		*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	

Table 4: Finger millet post-harvest soil EC (1:2.5) at different soil S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	Very low sulphur level							Low sulphur level						
	Soil$_1$	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**	**Soil$_1$**	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**
T_1:Control	0.10	0.12	0.09	0.13	0.11	0.15	0.12	0.14	0.15	0.15	0.17	0.18	0.15	0.16
T_2:100% NPK (No FYM)	0.11	0.13	0.10	0.14	0.13	0.16	0.13	0.15	0.17	0.16	0.19	0.19	0.16	0.17
T_3:100% NPK +FYM	0.10	0.12	0.09	0.13	0.12	0.15	0.12	0.14	0.16	0.15	0.18	0.18	0.15	0.16
T_4:100% NPK +FYM + 20kg S	0.11	0.12	0.10	0.13	0.12	0.15	0.12	0.14	0.15	0.15	0.18	0.18	0.15	0.16
T_5:100% NPK +20kg S	0.11	0.13	0.10	0.14	0.13	0.16	0.12	0.15	0.16	0.16	0.18	0.18	0.16	0.17
T_6:100% NPK +FYM+40kg S	0.12	0.13	0.10	0.13	0.13	0.16	0.13	0.14	0.17	0.16	0.17	0.19	0.15	0.16
T_7:100% NPK +40 kg S	0.12	0.14	0.11	0.14	0.13	0.17	0.13	0.16	0.16	0.16	0.19	0.19	0.16	0.17
Mean	0.11	0.13	0.10	0.13	0.12	0.15	0.12	0.14	0.16	0.16	0.18	0.18	0.15	0.16
Initial	0.11	0.13	0.10	0.14	0.13	0.16	0.13	0.15	0.17	0.16	0.19	0.19	0.16	0.17
F	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*		*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	Soil$_1$	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**	**Soil$_1$**	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**
T_1:Control	0.17	0.17	0.19	0.15	0.20	0.19	0.18	0.17	0.16	0.19	0.19	0.19	0.15	0.17
T_2:100% NPK (No FYM)	0.18	0.18	0.20	0.16	0.21	0.20	0.19	0.18	0.16	0.21	0.19	0.20	0.16	0.18
T_3:100% NPK +FYM	0.17	0.17	0.18	0.16	0.19	0.18	0.17	0.17	0.15	0.20	0.18	0.18	0.15	0.17
T_4:100% NPK +FYM + 20kg S	0.17	0.16	0.19	0.16	0.19	0.19	0.18	0.18	0.15	0.19	0.19	0.19	0.15	0.18
T_5:100% NPK +20kg S	0.18	0.18	0.19	0.17	0.21	0.20	0.19	0.18	0.16	0.21	0.19	0.20	0.15	0.18
T_6:100% NPK +FYM+40kg S	0.17	0.16	0.19	0.15	0.20	0.18	0.17	0.16	0.15	0.19	0.18	0.19	0.15	0.17
T_7:100% NPK +40 kg S	0.18	0.18	0.20	0.17	0.21	0.19	0.19	0.18	0.16	0.21	0.20	0.20	0.16	0.18
Mean	0.17	0.17	0.19	0.16	0.20	0.19	0.18	0.17	0.16	0.20	0.19	0.19	0.15	0.18
Initial	0.18	0.18	0.20	0.17	0.21	0.20	0.19	0.18	0.16	0.21	0.20	0.20	0.16	0.19
F	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*		*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	

Table 5: Finger millet post-harvest soil OC (mg kg^{-1}) at different soil S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	Very low sulphur level							Low sulphur level						
	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean
T$_1$:Control	3.27	3.65	3.94	3.87	4.43	3.67	3.81	4.07	4.10	4.64	4.73	5.03	5.64	4.70
T$_2$:100% NPK (No FYM)	3.30	3.63	3.98	3.88	4.50	3.69	3.83	4.13	4.10	4.66	4.61	5.03	5.65	4.70
T$_3$:100% NPK +FYM	3.37	3.76	4.17	3.96	4.60	3.76	3.94	4.17	4.17	4.75	4.75	5.20	5.74	4.80
T$_4$:100% NPK +FYM + 20kg S	3.37	3.76	4.15	3.97	4.57	3.84	3.94	4.17	4.17	4.76	4.80	5.16	5.73	4.80
T$_5$:100% NPK +20kg S	3.30	3.69	3.98	3.88	4.40	3.69	3.82	4.00	4.10	4.66	4.66	5.06	5.63	4.69
T$_6$:100% NPK +FYM+40kg S	3.43	3.77	4.27	4.13	4.73	3.93	4.04	4.17	4.20	4.87	4.87	5.27	5.80	4.86
T$_7$:100% NPK +40 kg S	3.27	3.65	3.94	4.19	4.60	3.82	3.91	4.07	4.17	4.77	4.79	5.18	5.71	4.78
Mean	3.33	3.70	4.06	3.98	4.55	3.77	3.90	4.11	4.14	4.73	4.74	5.13	5.70	4.76
Initial	3.42	3.81	4.13	4.0	4.56	3.79	3.95	4.22	4.20	4.81	4.78	5.23	5.84	4.85
F	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*		*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean
T$_1$:Control	6.00	6.49	4.74	5.41	6.19	5.90	5.79	6.19	6.38	5.61	5.41	6.09	6.00	5.95
T$_2$:100% NPK (No FYM)	6.02	6.44	4.76	5.44	6.21	5.82	5.78	6.21	6.41	5.63	5.51	6.21	5.92	5.98
T$_3$:100% NPK +FYM	6.14	6.54	4.82	5.55	6.34	5.94	5.89	6.34	6.54	5.74	5.55	6.24	6.04	6.07
T$_4$:100% NPK +FYM + 20kg S	6.15	6.55	4.86	5.55	6.35	5.95	5.90	6.35	6.55	5.75	5.55	6.25	6.05	6.08
T$_5$:100% NPK +20kg S	6.02	6.41	4.76	5.56	6.21	5.82	5.80	6.21	6.41	5.69	5.56	6.11	5.92	5.98
T$_6$:100% NPK +FYM+40kg S	6.13	6.70	5.00	5.67	6.37	6.10	5.99	6.37	6.73	5.97	5.67	6.30	6.17	6.20
T$_7$:100% NPK +40 kg S	5.97	6.47	4.87	5.57	6.07	6.01	5.83	6.30	6.56	5.67	5.57	6.10	6.04	6.04
Mean	6.06	6.51	4.83	5.53	6.25	5.93	5.85	6.28	6.51	5.72	5.55	6.19	6.02	6.04
Initial	6.43	6.61	5.83	5.57	6.33	6.12	6.15	6.38	6.60	5.81	5.58	6.32	6.12	6.14
F	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*		*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	

Table 6: Finger millet post-harvest soil available N (kg ha^{-1}) content at different soil S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	Very low sulphur level							Low sulphur level						
	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean
T$_1$:Control	79.15	92.67	110.51	117.67	122.25	168.94	115.20	116.78	116.93	122.26	132.62	127.73	141.41	126.29
T$_2$:100% NPK (No FYM)	88.41	103.33	123.23	131.31	135.35	180.62	127.04	129.29	129.17	130.82	147.47	141.41	156.56	139.12
T$_3$:100% NPK +FYM	101.40	115.54	136.67	146.83	151.34	192.36	140.69	143.26	145.30	148.41	163.13	158.12	172.71	155.15
T$_4$:100% NPK +FYM + 20kg S	112.72	122.21	145.74	155.30	157.53	211.49	150.83	149.52	151.33	157.53	170.62	159.38	178.11	161.08
T$_5$:100% NPK +20kg S	97.47	104.03	124.07	137.02	138.02	198.03	133.11	131.84	135.78	138.02	153.82	144.20	161.68	144.22
T$_6$:100% NPK +FYM+40kg S	124.01	133.67	160.32	169.63	175.09	227.85	165.10	163.91	160.77	165.11	180.86	170.01	188.56	171.54
T$_7$:100% NPK +40 kg S	114.96	125.06	145.77	159.12	163.82	212.29	153.50	156.48	153.90	160.18	173.00	163.63	181.38	164.76
Mean	102.59	113.79	135.19	145.27	149.06	198.80	140.78	141.58	141.88	146.05	160.22	152.07	168.63	151.74
Initial	99.80	102.33	122.00	130.34	134.63	188.71	129.62	128.81	130.33	133.22	147.91	145.54	159.83	140.92
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	2.54	3.24	2.89	3.43	4.22	4.46		3.59	2.98	3.91	4.33	3.89	4.13	
CD (*p=0.05*)	7.83	9.97	8.89	10.56	13.02	13.75		11.06	9.19	12.04	13.36	11.99	12.72	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean
T$_1$:Control	171.52	182.47	196.16	196.16	244.51	237.48	204.72	260.93	264.58	255.46	281.46	290.58	288.30	273.55
T$_2$:100% NPK (No FYM)	181.82	189.90	212.12	222.22	282.83	278.18	227.85	297.78	304.34	293.94	320.51	330.61	318.99	311.03
T$_3$:100% NPK +FYM	202.17	210.07	237.18	254.12	316.24	310.82	255.10	333.86	341.09	329.79	355.77	363.22	350.91	345.77
T$_4$:100% NPK +FYM + 20kg S	206.91	230.42	245.70	264.51	329.17	323.76	266.74	347.15	352.68	340.92	368.43	374.31	363.26	357.79
T$_5$:100% NPK +20kg S	183.34	203.94	221.44	236.89	288.39	283.86	236.31	304.77	312.08	299.72	327.53	345.04	337.83	321.16
T$_6$:100% NPK +FYM+40kg S	228.66	253.49	271.67	287.46	348.87	339.00	288.19	370.17	378.66	365.59	395.91	409.01	395.52	385.81
T$_7$:100% NPK +40 kg S	210.27	232.28	263.56	268.95	332.52	317.12	270.78	343.16	350.86	338.63	372.86	385.09	372.62	360.54
Mean	197.81	214.65	235.40	247.19	306.08	298.60	249.96	322.55	329.18	317.72	346.07	356.84	346.78	336.52
Initial	188.92	201.54	228.51	240.63	283.44	280.50	237.23	302.41	310.11	300.33	320.52	343.22	333.10	318.27
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	5.56	6.10	5.77	6.98	7.11	7.48		7.52	7.63	7.34	9.73	8.89	8.32	
CD (*p=0.05*)	17.13	18.79	17.76	21.52	21.92	23.03		23.17	23.51	22.63	29.99	27.39	25.63	

Table 7: Finger millet post-harvest soil available P_2O_5 (kg ha^{-1}) content at different soil S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	Very low sulphur level							Low sulphur level						
	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean	Soil$_1$	Soil$_2$	Soil$_3$	Soil$_4$	Soil$_5$	Soil$_6$	Mean
T$_1$:Control	12.55	13.61	14.03	16.76	17.91	13.13	14.66	18.66	15.68	15.36	17.06	18.20	20.56	17.59
T$_2$:100% NPK (No FYM)	12.43	13.90	14.15	17.01	18.08	13.41	14.83	18.81	15.95	15.78	17.55	18.73	21.15	17.99
T$_3$:100% NPK +FYM	14.74	15.52	16.30	19.69	21.24	15.42	17.15	21.92	18.51	18.31	20.37	21.73	24.54	20.90
T$_4$:100% NPK +FYM + 20kg S	16.13	16.98	17.83	21.54	23.24	16.87	18.76	23.98	20.25	20.04	22.29	23.77	26.85	22.86
T$_5$:100% NPK +20kg S	15.14	15.94	16.73	20.22	21.81	15.84	17.61	22.51	19.01	18.81	20.92	22.31	25.20	21.46
T$_6$:100% NPK +FYM+40kg S	17.22	18.13	19.03	23.00	24.81	18.01	20.03	25.60	21.61	21.39	23.79	25.38	28.66	24.41

T_7:100% NPK +40 kg S	16.84	17.73	18.62	22.49	24.27	17.62	19.59	23.93	21.14	20.92	23.27	24.82	28.03	23.69
Mean	15.01	15.97	16.67	20.10	21.62	15.76	17.52	22.20	18.88	18.66	20.75	22.13	25.00	21.27
Initial	15.23	16.00	16.81	20.30	21.90	15.90	17.68	22.60	19.08	18.84	21.02	22.40	25.61	21.59
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.44	0.44	0.46	0.50	0.52	0.37		0.58	0.59	0.49	0.67	0.62	0.78	
CD (*p=0.05*)	1.37	1.34	1.41	1.53	1.61	1.14		1.79	1.82	1.52	2.07	1.92	2.41	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	$Soil_1$	**$Soil_2$**	**$Soil_3$**	**$Soil_4$**	**$Soil_5$**	**$Soil_6$**	**Mean**	**$Soil_1$**	**$Soil_2$**	**$Soil_3$**	**$Soil_4$**	**$Soil_5$**	**$Soil_6$**	**Mean**
T_1:Control	15.84	21.78	27.14	29.74	27.16	21.16	23.80	16.25	25.19	14.63	21.21	18.20	24.09	19.93
T_2:100% NPK (No FYM)	16.44	22.40	27.92	30.60	27.61	21.61	24.43	17.55	26.58	15.05	21.82	18.73	25.08	20.80
T_3:100% NPK +FYM	18.92	26.00	32.40	35.50	32.39	26.39	28.60	19.40	30.07	17.46	25.52	22.15	29.10	23.95
T_4:100% NPK +FYM + 20kg S	20.80	28.44	35.44	38.51	35.76	29.76	31.45	21.75	32.37	19.10	28.12	23.98	31.57	26.15
T_5:100% NPK +20kg S	19.42	26.70	33.85	36.46	33.57	27.57	29.60	19.92	29.88	17.93	26.05	22.46	29.98	24.37
T_6:100% NPK +FYM+40kg S	22.09	30.36	37.84	40.76	38.18	32.18	33.57	23.79	35.12	20.39	29.57	25.38	33.36	27.93
T_7:100% NPK +40 kg S	21.61	29.64	36.69	39.56	37.34	31.38	32.70	22.72	33.80	19.95	29.03	24.88	32.75	27.19
Mean	19.30	26.47	33.04	35.87	33.14	27.15	29.16	20.20	30.43	17.79	25.90	22.25	29.42	24.33
Initial	19.50	26.80	33.45	36.62	33.76	27.61	29.62	20.88	31.18	18.34	26.10	22.39	29.63	24.75
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.57	0.73	0.88	0.98	0.77	0.79		0.63	0.63	0.50	0.64	0.65	0.73	
CD (*p=0.05*)	1.75	2.24	2.71	3.03	2.37	2.43		1.95	1.93	1.55	1.97	1.99	2.25	

Table 8: Finger millet post-harvest soil available K_2O (kg ha^{-1}) content at different soil S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	**Very low sulphur level**							**Low sulphur level**						
	$Soil_1$	**$Soil_2$**	**$Soil_3$**	**$Soil_4$**	**$Soil_5$**	**$Soil_6$**	**Mean**	**$Soil_1$**	**$Soil_2$**	**$Soil_3$**	**$Soil_4$**	**$Soil_5$**	**$Soil_6$**	**Mean**
T_1:Control	57.94	68.43	74.85	66.79	88.19	85.15	73.56	190.07	320.08	57.02	167.26	275.22	133.05	190.45
T_2:100% NPK (No FYM)	64.57	76.53	79.38	71.76	96.42	92.97	80.27	201.44	344.35	58.20	181.65	311.64	146.35	207.27
T_3:100% NPK +FYM	70.46	83.52	86.66	75.98	105.67	103.20	87.58	219.84	375.81	63.51	198.24	340.11	161.60	226.52
T_4:100% NPK +FYM + 20kg S	78.82	93.42	100.69	84.07	117.70	113.50	98.03	245.91	419.31	71.04	221.74	380.43	177.60	252.67
T_5:100% NPK +20kg S	73.83	87.52	88.73	78.75	110.26	108.21	91.22	230.36	394.76	66.55	207.71	356.36	165.38	236.85
T_6:100% NPK +FYM+40kg S	84.09	99.67	112.44	89.69	125.57	121.09	105.43	262.35	444.95	75.79	236.56	405.86	188.35	268.98
T_7:100% NPK +40 kg S	80.88	95.87	107.59	86.28	120.79	116.47	101.31	249.67	430.81	72.90	227.55	390.40	181.18	258.75
Mean	72.94	86.42	92.91	79.05	109.23	105.80	91.06	228.52	390.01	66.43	205.82	351.43	164.79	234.50
Initial	75.40	88.90	96.73	80.20	112.30	108.60	93.69	234.5	401.46	66.54	211.60	362.88	170.69	241.28
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	2.01	3.18	2.98	2.60	3.32	3.00		5.74	10.59	2.12	6.06	9.14	4.45	
CD (*p=0.05*)	6.20	9.79	9.17	8.02	10.23	9.24		17.68	32.65	6.54	18.68	28.15	13.72	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	$Soil_1$	**$Soil_2$**	**$Soil_3$**	**$Soil_4$**	**$Soil_5$**	**$Soil_6$**	**Mean**	**$Soil_1$**	**$Soil_2$**	**$Soil_3$**	**$Soil_4$**	**$Soil_5$**	**$Soil_6$**	**Mean**
T_1:Control	195.44	555.00	139.89	121.64	152.06	325.70	248.29	228.08	187.03	182.47	227.05	212.88	369.50	234.50
T_2:100% NPK (No FYM)	217.80	576.79	158.05	134.30	167.54	350.03	267.42	241.05	206.61	191.39	241.05	230.72	383.95	249.13
T_3:100% NPK +FYM	237.70	601.29	172.87	146.57	183.20	382.67	287.38	264.01	225.49	206.69	264.90	251.79	418.84	271.95
T_4:100% NPK +FYM + 20kg S	265.88	662.06	193.37	163.94	204.93	429.61	319.96	296.35	253.27	233.30	300.53	277.44	468.96	304.97
T_5:100% NPK +20kg S	249.06	630.03	181.14	153.57	191.96	404.01	301.63	281.55	238.23	217.56	278.59	263.83	439.06	286.47
T_6:100% NPK +FYM+40kg S	283.65	706.33	206.29	174.90	218.63	455.86	340.94	315.05	269.08	246.65	313.92	300.50	497.56	323.79
T_7:100% NPK +40 kg S	272.85	674.03	198.43	168.24	210.30	436.66	326.75	303.91	259.90	239.41	300.89	289.02	480.99	312.35
Mean	246.05	629.36	178.58	151.88	189.8	397.79	298.91	275.71	234.23	216.78	275.28	260.88	436.98	283.31
Initial	253.00	643.78	184.60	156.40	198.50	426.00	310.38	283.30	240.60	223.50	289.60	268.60	456.00	293.60
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	7.99	15.73	6.06	3.69	5.07	10.96		8.38	5.74	5.53	8.06	7.29	11.39	
CD (*p=0.05*)	24.61	48.47	18.67	11.38	15.61	33.77		25.81	17.67	17.04	24.83	22.46	35.08	

Table 9: Finger millet post-harvest soil available sulphur (mg kg^{-1}) content at different soil S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	**Very low sulphur level**							**Low sulphur level**						
	$Soil_1$	**$Soil_2$**	**$Soil_3$**	**$Soil_4$**	**$Soil_5$**	**$Soil_6$**	**Mean**	**$Soil_1$**	**$Soil_2$**	**$Soil_3$**	**$Soil_4$**	**$Soil_5$**	**$Soil_6$**	**Mean**
T_1:Control	1.46	1.86	2.33	3.35	3.41	4.13	2.76	7.17	8.23	8.38	10.48	12.49	13.67	10.07
T_2:100% NPK (No FYM)	1.52	1.91	2.42	3.56	3.60	4.23	2.87	7.28	8.22	8.51	10.61	12.62	13.89	10.19
T_3:100% NPK +FYM	1.74	2.28	2.77	3.96	4.03	4.91	3.28	8.09	9.28	9.62	11.93	14.15	15.61	11.45
T_4:100% NPK +FYM + 20kg S	2.07	2.37	3.05	4.18	4.50	5.18	3.56	8.43	9.57	9.94	12.34	14.25	15.76	11.71
T_5:100% NPK +20kg S	1.84	2.20	2.73	3.84	3.90	4.74	3.21	7.67	8.57	8.90	11.00	13.03	14.41	10.60
T_6:100% NPK +FYM+40kg S	2.46	2.77	3.56	4.84	4.76	6.07	4.08	9.15	10.12	10.30	12.61	14.85	16.40	12.24
T_7:100% NPK +40 kg S	2.21	2.51	3.20	4.44	4.14	5.44	3.66	8.79	9.76	10.03	12.09	14.58	16.12	11.89
Mean	1.90	2.27	2.87	4.02	4.05	4.96	3.35	8.08	9.11	9.38	11.58	13.71	15.12	11.16
Initial	1.56	1.95	2.40	3.60	3.65	4.46	2.94	7.43	8.45	8.60	10.66	12.57	13.88	10.27
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.05	0.06	0.08	0.10	0.10	0.12		0.20	0.22	0.30	0.28	0.41	0.45	

CD ($p=0.05$)	0.14	0.19	0.24	0.30	0.30	0.36		0.62	0.69	0.92	0.86	1.26	1.38	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	Soil$_1$	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**	**Soil$_1$**	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**
T_1:Control	17.27	17.63	19.21	20.29	21.16	23.17	19.79	24.81	25.05	25.22	27.51	33.59	34.50	28.45
T_2:100% NPK (No FYM)	17.41	17.85	19.37	20.54	21.39	23.33	19.98	25.15	26.57	26.74	27.82	33.79	34.50	29.10
T_3:100% NPK +FYM	19.45	19.99	21.64	22.99	23.99	26.10	22.36	27.98	29.61	29.80	30.88	37.29	38.07	32.27
T_4:100% NPK +FYM + 20kg S	20.62	20.31	22.94	23.37	24.16	27.67	23.18	29.98	33.38	33.60	33.53	40.25	41.10	35.31
T_5:100% NPK +20kg S	18.37	18.44	20.44	21.21	22.08	24.65	20.86	26.53	28.68	28.87	30.27	36.34	37.10	31.30
T_6:100% NPK +FYM+40kg S	21.60	21.16	24.03	24.35	25.18	28.97	24.21	31.64	36.18	36.42	34.65	41.60	42.47	37.16
T_7:100% NPK +40 kg S	20.59	20.64	22.91	23.75	24.71	27.63	23.37	30.39	33.14	33.36	33.53	40.25	41.27	35.32
Mean	19.33	19.43	21.51	22.36	23.24	25.93	21.97	28.07	30.37	30.58	31.17	37.59	38.43	32.70
Initial	17.39	17.99	19.35	20.70	21.31	23.34	20.01	25.70	26.89	27.07	28.18	33.83	34.54	29.37
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.52	0.45	0.64	0.65	0.55	0.82		0.83	0.85	0.85	0.95	0.93	0.98	
CD ($p=0.05$)	1.59	1.39	1.97	2.02	1.69	2.54		2.55	2.61	2.62	2.93	2.88	3.02	

Table 10: Dry matter yield (g pot^{-1}) at harvest (60 DAS) of finger millet grown on soils of different S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	**Very low sulphur level**							**Low sulphur level**						
	Soil$_1$	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**	**Soil$_1$**	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**
T_1:Control	9.90	9.70	9.93	9.24	9.85	9.42	9.68	10.43	10.60	9.96	10.79	10.98	11.01	10.63
T_2:100% NPK (No FYM)	19.65	19.58	19.41	19.72	19.63	19.60	19.60	20.84	21.71	22.00	22.62	22.96	21.78	21.98
T_3:100% NPK +FYM	23.08	24.97	23.56	23.41	23.77	24.02	23.80	25.21	26.97	26.19	26.81	26.69	27.16	26.51
T_4:100% NPK +FYM + 20kg S	27.59	29.02	28.68	28.73	27.84	27.67	28.25	28.25	29.55	27.18	29.72	29.59	29.35	28.94
T_5:100% NPK +20kg S	24.39	26.90	25.14	24.37	24.87	24.37	25.01	26.22	28.54	27.72	27.43	27.59	28.31	27.64
T_6:100% NPK +FYM+40kg S	31.37	31.00	31.88	31.50	32.00	31.77	31.59	32.01	31.68	31.15	32.32	31.61	31.55	31.72
T_7:100% NPK +40 kg S	29.35	28.97	29.86	29.81	30.25	29.72	29.66	28.66	30.10	29.95	30.00	30.29	30.33	29.89
Mean	23.62	24.31	24.07	23.83	24.03	23.79	23.94	24.52	25.59	24.88	25.67	25.67	25.64	25.33
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.590	0.709	0.610	0.635	0.558	0.572		0.624	0.519	0.906	0.706	0.607	0.725	
CD ($p=0.05$)	1.82	2.19	1.88	1.96	1.72	1.76		1.92	1.60	2.79	2.18	1.87	2.23	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	Soil$_1$	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**	**Soil$_1$**	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**
T_1:Control	11.16	10.83	10.32	10.38	10.91	10.42	10.67	10.49	10.61	11.00	10.53	10.91	10.65	10.70
T_2:100% NPK (No FYM)	25.09	24.67	24.84	25.13	25.27	24.67	24.95	27.20	26.48	27.52	28.01	27.20	26.88	27.22
T_3:100% NPK +FYM	27.36	27.00	26.58	26.34	26.58	26.85	26.79	27.95	28.26	29.07	28.37	28.24	28.32	28.37
T_4:100% NPK +FYM + 20kg S	30.62	29.63	28.59	29.44	29.35	29.04	29.44	31.39	31.73	31.39	31.15	31.18	32.13	31.49
T_5:100% NPK +20kg S	26.61	27.19	26.58	27.24	27.06	26.78	26.91	28.75	29.69	29.93	29.67	29.34	29.54	29.49
T_6:100% NPK +FYM+40kg S	33.50	32.37	31.08	31.25	31.66	32.35	32.04	29.93	29.64	28.96	28.99	27.42	28.06	28.83
T_7:100% NPK +40 kg S	31.25	29.82	29.46	29.71	30.11	30.01	30.06	28.92	29.25	28.48	28.57	29.11	27.95	28.71
Mean	26.51	25.93	25.35	25.64	25.85	25.73	25.84	26.38	26.52	26.62	26.47	26.20	26.22	26.40
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.719	0.528	0.477	0.533	0.526	0.551		0.43	0.58	0.55	0.63	0.54	0.52	
CD ($p=0.05$)	2.22	1.63	1.47	1.64	1.62	1.70		1.33	1.78	1.70	1.95	1.67	1.59	

Table 11: Finger millet plant nitrogen concentration (%) at harvest (60 DAS) grown on soils of different S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	**Very low sulphur level**							**Low sulphur level**						
	Soil$_1$	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**	**Soil$_1$**	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**
T_1:Control	0.69	0.70	0.68	0.70	0.69	0.71	0.70	0.92	0.94	0.95	0.98	1.00	1.02	0.97
T_2:100% NPK (No FYM)	0.83	0.84	0.85	0.86	0.83	0.86	0.85	1.07	1.09	1.09	1.13	1.16	1.17	1.12
T_3:100% NPK +FYM	1.00	1.02	1.03	1.04	1.00	1.04	1.02	1.28	1.31	1.32	1.36	1.38	1.41	1.34
T_4:100% NPK +FYM + 20kg S	1.37	1.39	1.42	1.43	1.39	1.46	1.41	1.42	1.45	1.46	1.51	1.57	1.56	1.49
T_5:100% NPK +20kg S	1.15	1.16	1.17	1.20	1.22	1.20	1.18	1.35	1.38	1.39	1.44	1.49	1.48	1.42
T_6:100% NPK +FYM+40kg S	1.49	1.54	1.54	1.61	1.61	1.61	1.57	1.58	1.61	1.61	1.67	1.72	1.73	1.65
T_7:100% NPK +40 kg S	1.43	1.44	1.44	1.48	1.49	1.48	1.46	1.50	1.53	1.54	1.59	1.65	1.65	1.58
Mean	1.14	1.16	1.16	1.19	1.18	1.20	1.17	1.30	1.33	1.34	1.38	1.42	1.43	1.37
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.036	0.032	0.029	0.034	0.035	0.034		0.034	0.038	0.037	0.046	0.044	0.038	
CD ($p=0.05$)	0.111	0.099	0.091	0.106	0.106	0.106		0.104	0.119	0.113	0.143	0.135	0.118	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	Soil$_1$	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**	**Soil$_1$**	**Soil$_2$**	**Soil$_3$**	**Soil$_4$**	**Soil$_5$**	**Soil$_6$**	**Mean**
T_1:Control	1.04	1.05	1.08	1.07	1.09	1.08	1.07	1.11	1.23	1.25	1.27	1.87	1.91	1.44
T_2:100% NPK (No FYM)	1.25	1.21	1.24	1.28	1.25	1.28	1.25	1.40	1.58	1.61	1.83	1.88	1.92	1.70
T_3:100% NPK +FYM	1.44	1.45	1.49	1.46	1.48	1.53	1.47	1.67	1.79	1.83	1.85	1.89	1.93	1.83
T_4:100% NPK +FYM + 20kg S	1.62	1.62	1.65	1.63	1.63	1.66	1.64	1.78	1.81	1.89	1.91	1.96	2.11	1.91

T5:100% NPK +20kg S	1.55	1.54	1.57	1.55	1.56	1.60	1.56	1.72	1.84	1.89	1.91	1.96	2.11	1.90
T6:100% NPK +FYM+40kg S	1.74	1.78	1.83	1.84	1.83	1.88	1.81	2.04	2.01	2.05	2.09	2.11	2.16	2.08
T7:100% NPK +40 kg S	1.69	1.71	1.75	1.73	1.73	1.76	1.73	1.86	1.97	2.04	2.08	2.10	2.16	2.03
Mean	1.48	1.48	1.52	1.51	1.51	1.54	1.51	1.65	1.75	1.79	1.85	1.97	2.04	1.84
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.041	0.043	0.045	0.043	0.051	0.040		0.043	0.048	0.027	0.040	0.046	0.054	
CD (*p=0.05*)	0.126	0.131	0.140	0.132	0.158	0.123		0.133	0.149	0.084	0.124	0.142	0.166	

Table 12: Finger millet plant phosphorous concentration (%) at harvest (60 DAS) grown on soils of different S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	Very low sulphur level							Low sulphur level						
	Soil1	Soil2	Soil3	Soil4	Soil5	Soil6	Mean	Soil1	Soil2	Soil3	Soil4	Soil5	Soil6	Mean
T1:Control	0.16	0.17	0.19	0.18	0.25	0.18	0.19	0.18	0.19	0.20	0.19	0.21	0.22	0.20
T2:100% NPK (No FYM)	0.21	0.22	0.26	0.25	0.32	0.26	0.26	0.26	0.27	0.28	0.28	0.29	0.31	0.28
T3:100% NPK +FYM	0.27	0.26	0.29	0.29	0.35	0.28	0.29	0.30	0.32	0.31	0.32	0.34	0.36	0.32
T4:100% NPK +FYM + 20kg S	0.31	0.32	0.34	0.34	0.40	0.34	0.34	0.35	0.35	0.37	0.39	0.41	0.43	0.38
T5:100% NPK +20kg S	0.28	0.29	0.31	0.31	0.37	0.30	0.31	0.32	0.33	0.33	0.35	0.37	0.39	0.35
T6:100% NPK +FYM+40kg S	0.39	0.41	0.43	0.44	0.49	0.40	0.43	0.44	0.45	0.47	0.48	0.50	0.53	0.48
T7:100% NPK +40 kg S	0.33	0.33	0.39	0.38	0.45	0.37	0.38	0.40	0.41	0.42	0.44	0.45	0.47	0.43
Mean	0.28	0.29	0.32	0.31	0.38	0.31	0.32	0.32	0.33	0.34	0.35	0.37	0.39	0.35
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.007	0.008	0.009	0.008	0.009	0.008		0.008	0.010	0.009	0.011	0.009	0.009	
CD (*p=0.05*)	0.021	0.023	0.028	0.026	0.029	0.026		0.025	0.030	0.028	0.035	0.028	0.029	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	Soil1	Soil2	Soil3	Soil4	Soil5	Soil6	Mean	Soil1	Soil2	Soil3	Soil4	Soil5	Soil6	Mean
T1:Control	0.27	0.26	0.29	0.31	0.32	0.32	0.30	0.33	0.34	0.33	0.35	0.35	0.36	0.34
T2:100% NPK (No FYM)	0.35	0.36	0.37	0.38	0.41	0.41	0.38	0.45	0.46	0.44	0.48	0.46	0.49	0.47
T3:100% NPK +FYM	0.39	0.40	0.40	0.43	0.45	0.44	0.42	0.50	0.51	0.49	0.53	0.50	0.53	0.51
T4:100% NPK +FYM + 20kg S	0.44	0.44	0.46	0.48	0.52	0.51	0.47	0.56	0.57	0.54	0.59	0.58	0.61	0.57
T5:100% NPK +20kg S	0.41	0.40	0.42	0.46	0.48	0.46	0.44	0.53	0.55	0.52	0.56	0.55	0.58	0.55
T6:100% NPK + FYM+40kg S	0.56	0.54	0.56	0.60	0.63	0.62	0.58	0.65	0.67	0.64	0.68	0.67	0.69	0.67
T7:100% NPK +40 kg S	0.49	0.50	0.51	0.54	0.56	0.56	0.53	0.60	0.62	0.59	0.64	0.62	0.66	0.62
Mean	0.42	0.41	0.43	0.46	0.48	0.47	0.45	0.52	0.53	0.51	0.55	0.53	0.56	0.53
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.011	0.012	0.012	0.012	0.013	0.012		0.015	0.010	0.005	0.009	0.013	0.012	
CD (*p=0.05*)	0.035	0.036	0.038	0.037	0.040	0.038		0.046	0.031	0.015	0.028	0.040	0.037	

Table 13: Finger millet plant potassium concentration (%) at harvest (60 DAS) grown on soils of different S fertility status applied with graded levels of sulphur

Sulphur level/Treatments	Very low sulphur level							Low sulphur level						
	Soil1	Soil2	Soil3	Soil4	Soil5	Soil6	Mean	Soil1	Soil2	Soil3	Soil4	Soil5	Soil6	Mean
T1:Control	0.54	0.56	0.56	0.58	0.59	0.61	0.57	0.66	0.68	0.71	0.73	0.72	0.75	0.71
T2:100% NPK (No FYM)	0.70	0.71	0.73	0.74	0.76	0.78	0.74	0.84	0.87	0.90	0.92	0.90	0.95	0.89
T3:100% NPK +FYM	0.93	0.95	0.97	0.99	1.01	1.04	0.98	1.01	1.03	1.09	1.13	1.09	1.17	1.09
T4:100% NPK +FYM + 20kg S	1.19	1.22	1.24	1.26	1.28	1.32	1.25	1.27	1.32	1.36	1.41	1.37	1.43	1.36
T5:100% NPK +20kg S	1.03	1.06	1.09	1.09	1.12	1.14	1.09	1.18	1.23	1.28	1.32	1.30	1.35	1.28
T6:100% NPK +FYM+40kg S	1.28	1.32	1.35	1.37	1.39	1.44	1.36	1.40	1.44	1.48	1.51	1.52	1.56	1.48
T7:100% NPK +40 kg S	1.21	1.24	1.25	1.31	1.31	1.34	1.28	1.33	1.35	1.37	1.40	1.42	1.46	1.39
Mean	0.98	1.01	1.03	1.05	1.07	1.10	1.04	1.10	1.13	1.17	1.20	1.19	1.24	1.17
F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.024	0.026	0.028	0.028	0.028	0.028		0.028	0.025	0.027	0.030	0.028	0.033	
CD (*p=0.05*)	0.073	0.079	0.087	0.087	0.085	0.085		0.086	0.078	0.083	0.092	0.086	0.101	
Sulphur level/Treatments	**Medium sulphur level**							**High sulphur level**						
	Soil1	Soil2	Soil3	Soil4	Soil5	Soil6	Mean	Soil1	Soil2	Soil3	Soil4	Soil5	Soil6	Mean
T1:Control	0.84	1.24	0.88	0.87	0.89	0.98	0.95	1.03	1.04	1.04	1.08	1.08	1.11	1.06
T2:100% NPK (No FYM)	0.95	1.37	0.98	0.99	1.01	1.08	1.06	1.18	1.17	1.18	1.20	1.30	1.29	1.22
T3:100% NPK +FYM	1.07	1.54	1.09	1.11	1.13	1.22	1.19	1.33	1.29	1.29	1.33	1.39	1.38	1.34
T4:100% NPK +FYM + 20kg S	1.38	2.01	1.42	1.42	1.46	1.59	1.55	1.66	1.62	1.62	1.67	1.64	1.64	1.64
T5:100% NPK +20kg S	1.29	1.88	1.33	1.35	1.37	1.49	1.45	1.60	1.60	1.61	1.62	1.51	1.48	1.57
T6:100% NPK +FYM+40kg S	1.53	2.22	1.58	1.57	1.62	1.76	1.71	2.04	2.05	2.05	2.06	2.05	2.27	2.09
T7:100% NPK +40 kg S	1.46	2.08	1.49	1.47	1.54	1.65	1.62	1.74	1.79	1.78	1.74	1.85	1.87	1.79
Mean	1.22	1.76	1.25	1.25	1.29	1.40	1.36	1.51	1.51	1.51	1.53	1.54	1.58	1.53

F	S	S	S	S	S	S		S	S	S	S	S	S	
SEm±	0.036	0.037	0.034	0.031	0.036	0.033		0.039	0.038	0.040	0.049	0.037	0.042	
CD (*p=0.05*)	0.110	0.113	0.105	0.095	0.110	0.103		0.121	0.119	0.123	0.152	0.114	0.129	

Table 15: Initial available sulphur content in soil (AS), PSC (Plant Sulphur Content) in check pot, CY (Yield in Check pot), YI (Yield Increase), PRY (Per cent Relative Yield) and MY (Maximum Yield) at harvest(60 DAS) of finger millet grown on different sulphur fertility status soils of EDZ of Karnataka, India as influenced by graded levels of applied sulphur

Sl No.	Categorization (mg kg^{-1})	Soils	Avail. S (mg kg^{-1})	PSC in check pot (%)	CY (g pot^{-1})	MY (g pot^{-1})	YI*(g pot^{-1})	PRY**(Per cent)	Avg. PRY
1	Very low (< 5)	Soil$_1$	1.56	0.20	19.65	31.37	11.72	40.36	38.82
2		Soil$_2$	1.95	0.20	19.58	31.00	11.42	41.68	
3		Soil$_3$	2.40	0.19	19.41	31.88	12.47	35.75	
4		Soil$_4$	3.60	0.21	19.72	31.50	11.78	40.26	
5		Soil$_5$	3.65	0.20	19.63	32.00	12.37	36.98	
6		Soil$_6$	4.46	0.22	19.60	31.77	12.17	37.91	
7	Low (6 to 15)	Soil$_1$	7.43	0.23	21.83	32.01	10.17	53.40	68.84
8		Soil$_2$	8.45	0.23	24.21	31.68	7.48	69.12	
9		Soil$_3$	8.60	0.22	24.84	31.15	6.31	74.58	
10		Soil$_4$	10.66	0.24	25.07	32.32	7.26	71.06	
11		Soil$_5$	12.57	0.23	24.51	31.61	7.10	71.03	
12		Soil$_6$	13.88	0.24	24.50	31.55	7.05	71.21	
13	Medium (16 to 25)	Soil$_1$	17.39	0.26	25.09	33.50	8.41	66.49	73.47
14		Soil$_2$	17.99	0.26	24.67	30.63	5.95	75.88	
15		Soil$_3$	19.35	0.33	24.84	30.00	5.16	79.25	
16		Soil$_4$	20.70	0.28	25.13	31.25	6.12	75.63	
17		Soil$_5$	21.31	0.28	25.27	31.66	6.40	74.68	
18		Soil$_6$	23.34	0.28	24.67	32.35	7.68	68.85	
19	High (>25)	Soil$_1$	25.70	0.35	27.20	31.39	4.19	84.60	85.99
20		Soil$_2$	26.89	0.38	26.48	31.73	5.24	80.21	
21		Soil$_3$	27.07	0.36	27.52	30.16	2.64	90.41	
22		Soil$_4$	28.18	0.39	28.01	31.05	3.04	89.15	
23		Soil$_5$	33.83	0.40	27.20	30.71	3.51	87.09	
24		Soil$_6$	34.54	0.40	26.88	31.05	4.17	84.49	

* YI = (MY-CY) **PRY=[{1-(YI÷CY)} x 100]

Table 16: Categorization of available soil sulphur status based on pot culture experiment in EDZ of Karnataka, India

Agro Ecological System	Very low (<5 mg kg^{-1})	Low (5.10 to 14.10 mg kg^{-1})	Medium (14.20 to 23.90 mg kg^{-1})	High (> 24 mg kg^{-1})	Total
AES1	1	24	10	1	36
AES2	8	39	7	1	55
AES3	3	15	8	3	29
AES4	2	22	10	4	38
Total	14	100	35	9	158
Per cent	8.86	63.29	22.16	5.69	100

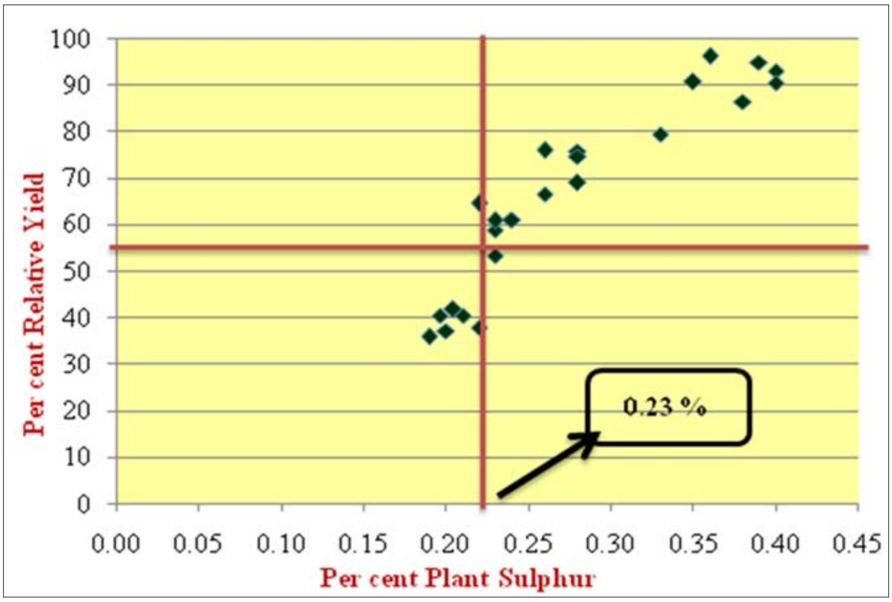

Fig 1: Critical limit for Plant sulphur content (%) for finger millet crop

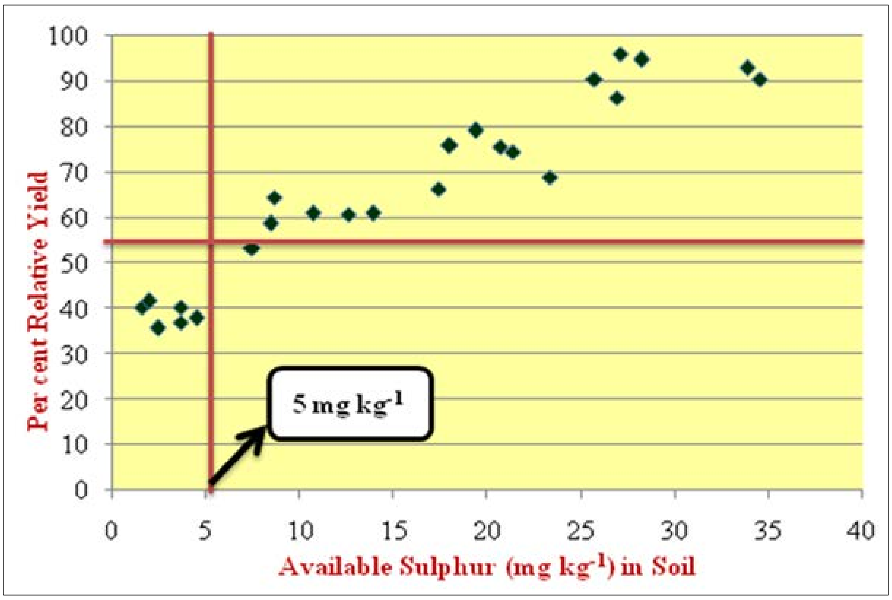

Fig 2: Critical limit for available soil sulphur (mg kg^{-1})

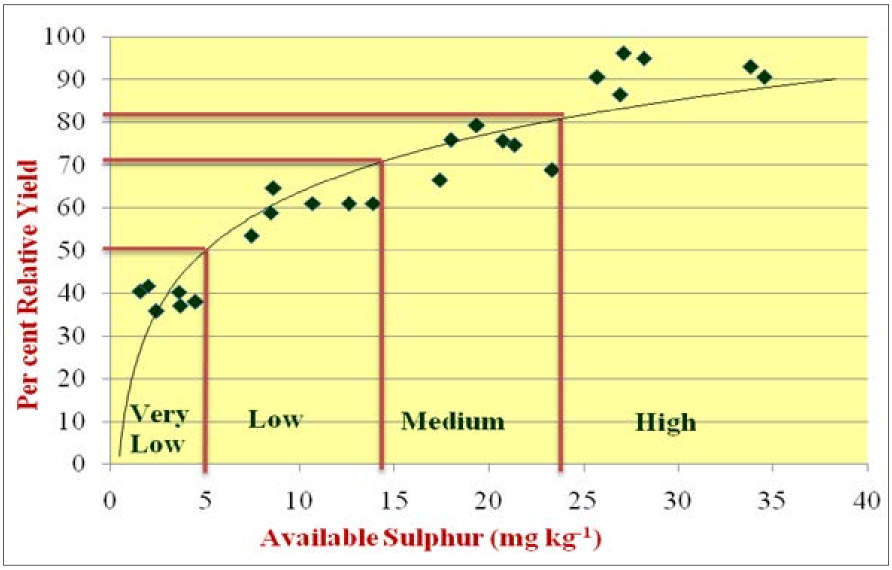

Fig 3: Categorization of soil sulphur (mg kg^{-1})

Conclusion

The above findings enlighten the importance of sulphur even in cereal crop (ragi). Further, being 4th major nutrient after NPK, sulphur is required as high as 30 kg ha^{-1} for finger millet

References

1. Anonymous. Results of front line demonstrations (2000-2007) and technologies for increasing small millet production in India, Project coordinating unit (small millets), ICAR, Bangalore; c2009.
2. Arnulv Stabursvik, Ola M Heide. Protein content and amino acid spectrum of finger millet [*Eleusine coracana* (L.)] as influenced by nitrogen and sulphur fertilizers, Pl. Soil. 1974;41(3):549-571.
3. Brajendra LM, Shukla BS, Kherawat Andmunna Lal. Critical limit of sulphur for safflower in Alfisols and Ultisols of Jharkhand, An Asian J Soil Sci. 2012;**7**(2):223-225.
4. Bray RH, Kurtz LT. Determination of total, organic, and available forms of phosphorus in soils. Soil Science. 1945;59:39-45.
5. Cate RB, Nelson LA. A rapid method for correlation of soil test analysis with plant response data. International soil testing series technical Bulletin No. I North Caroline. State University, Agricultural Experiment Statistics, Releigh (USA); c1965. p. 135-136.
6. Cate RB, Nelson LA. A simple statistical procedure for partitioning soil test correlation data into two classes. Soil Sci. Soc. Am. Proc. 1971;35:658-666.
7. DCA-Danish Centre for Food & Agriculture; c2010. https://dca.au.dk/en/current-news/news/show/artikel/sulphur-the-forgotten-nutrient/
8. Dinesh Chandra, Satish Chandra, Pallavi, Sharma AK. Review of Finger millet (*Eleusine coracana* (L.) Gaertn): A power house of health benefiting nutrients, Food Science and Human Wellness. 2016;5(3)149-155.
9. Germida JJ, Janzen HH. Factors affecting the oxidation

of elemental sulfur in soils, Fertilizer research. 1993;35:101-114

10. Girish BH, Venkata Reddy P. Sulphur requirement and its use efficiency by soybean, *Glycine max* (L) Merill with different sources on an Alfisol. J Oilseeds Res. 2005;22(2):293-297.
11. Huda MN, Islam MR, Jahiruddin M. Evaluation of extractants and critical limits of sulphur in soils of Bangladesh, Asian J.Pl. Sci. 2004;3(4):480-483.
12. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 1973;498:151-154.
13. Jaggi RC, Raina SK. Direct, residual and direct + residual effects of sulphur in garlic (*Allium sativum*)-maize (*Zea mays*) cropping sequence. J Environ Biol. 2008;29(1):85-8.
14. Kertesz MA, Mirleau P. The role of soil microbes in plant sulphur nutrition. J Exper. Bot. 2004;55:1939-1945.
15. Kertesz MA, Fellows E, Schmalenberger A. Rhizobacteria and plant sulfur supply. Adv. Appl. Microbiol. 2007;62:235-268.
16. Korndörfer GH, Snyder GH, Ulloa M, Powell G, Datnoff LE. Calibration of soil and plant silicon analysis for rice production, J Plant Nutrition. 2006;24(7):1071-1084
17. Lavanya KR, Kadalli GG, Siddaram Patil, Jayanthi T, Naveen DV, Channabasavegowda R. Sulphur Fractionation Studies in Soils of Long Term Fertilizer Experiment under Finger Millet – Maize Cropping Sequence Int. J Curr. Microbiol. App. Sci. 2019;8(9):1334-1345.
18. Lindemann WC, Aburto JJ, Haffner WM, Bono AA. Effect of sulfur source on sulfur oxidation. Soil Sci. Soc. Am. J. 1991;55:85-90.
19. Naveen Saviour, Raghupathy B, Poonkodi P, Angayarkanni A. Effect of gypsum & lignite fly ash as sources of sulphur on ragi, Agric. Sci. Digest. 2001;21(1):5-8.
20. O'kennedy MM, Grootboom A, Shewry PR. Harnessing sorghum and millet biotechnology for food and health, J Cereal Sci. 2006;44(3):224-235
21. Pandey RN, Girish BH. Extractants and critical limits of available soil sulphur for mustard (*Brassica campestris* var. toria), Ann. Agric. Res. New Series. 2006;27(4): 360-364.
22. Paul N, Nelson, Ninghu Su. Soil pH buffering capacity: a descriptive function and its application to some acidic tropical soils, Australian Journal of Soil Research. 2010;48:201-207.
23. Rakesh Kumar, Singh KP, Singh S. Vertical distribution of sulphur fractions and their relationships among carbon, nitrogen and sulphur in acidic soil of Jharkhand. J Indian Soc. Soil Sci. 2002;50(3):502-505.
24. Rayment GE, Higginson FR. Australian laboratory handbook of soil and water chemical methods. Melbourne: Inkata Press; c1992. p. 330.
25. Rhoades JD. Salinity: electrical conductivity and total dissolved solids. In: Sparks DL, editor. Methods of soil analysis, Part 3. Chemical methods. Madison (WI): *Soil* Science Society of America. 1996;5:417-435.
26. Skwierawska M, zawartka L, Zawadzki B. The effect of different rates and forms of sulphur applied on changes of soil agrochemical properties, plant soil environ. 2008;54(4):171-177.
27. Subbiah BV, ASIJA GL. A rapid procedure for the determination of available nitrogen in soil, Curr. Sci. 1956;25:259-260.
28. TSI: The Sulphur Institute; c2020. https://www.sulphurinstitute.org/about-sulphur/india/status-of-indian-soils/
29. TSI-The Sulphur Institute; c2020. https://www.sulphurinstitute.org/about-sulphur/sulphur-the-fourth-major-plant-nutrient/
30. YE R, Wright AL, Mccray JM. Seasonal changes in nutrient availability for sulfur -amended everglades soils under sugarcane. J Plant Nutr. 2011;34(14):2095-2113.
31. Jaggi S, Sanders P, Chou PA, Effros M, Egner S, Jain K, *et al*. Polynomial time algorithms for multicast network code construction. IEEE Transactions on Information Theory. 2005 May 31;51(6):1973-82.
32. Korndörfer GH, Lepsch I. Effect of silicon on plant growth and crop yield. InStudies in plant science. Elsevier. 2001 Jan 1;8:133-147.
33. Cope JT, Rouse RD, Walsh LM, Beaton JD. Interpretation of soil test results. Soil testing and plant analysis. 1973:35-54.
34. Watkinson JH, Lee A. Kinetics of field oxidation of elemental sulfur in New Zealand pastoral soils and the effects of soil temperature and moisture. Fertilizer research. 1994 Feb;37(1):59-68.