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Soil available nutrients status and their indexing in cotton growing areas of South Gujarat

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Abstract
Available soil nutrients status (N, P_2O_5, K_2O, S and Zn) of irrigated and rainfed cotton growing surface soils (0-22.5 cm) from 11 talukas of South Gujarat comprising Bharuch, Surat and Narmada districts. Total 110 nos. samples were subjected to determination above nutrients with a view to better future management of these soils in achieving higher cotton yield. The results revealed available N, P_2O_5, K_2O, S and Zn ranged from 171.2 to 386.0 kg ha^{-1}, 12.4 to 53.4 kg ha^{-1}, 282 to 1180 kg ha^{-1}, 4.9 to 26.9 ppm and 0.25 to 0.91 mg kg^{-1}, respectively in irrigated soils with mean values of 241.3 kg ha^{-1}, 31.1 kg ha^{-1}, 637 kg ha^{-1}, 14.8 ppm and 0.51 mg kg^{-1}, respectively. However, for rainfed soils, the corresponding values were 127.9 to 298.8 kg ha^{-1}, 7.4 to 42.2 kg ha^{-1}, 281 to 812 kg ha^{-1}, 5.4 to 15.8 ppm and 0.20 to 0.59 mg kg^{-1}, respectively, with mean values of 216.5 kg ha^{-1}, 25.0 kg ha^{-1}, 497 kg ha^{-1}, 9.9 ppm and 0.39 mg kg^{-1}, respectively. With respect to available N, 85.5 and 14.5 per cent soils were 'low' and 'medium', respectively while, the corresponding values for rainfed soils were 98.2 and 1.8 per cent, respectively. In case of available P_2O_5 in irrigated areas, 60 and 22 per cent soils exhibited 'low' and 'medium' status, respectively and in rainfed soils values were 72.7 and 27.3 per cent, respectively. Available K_2O status in respective of irrigated and rainfed situations was 'high'. 20, 72.7 and 7.3 per cent irrigated soils were rated under 'low', 'medium' and 'high' status, respectively in respect to available S and the corresponding data for rainfed soils were 63.6, 36.4 and 0.0 per cent soils respectively. DTPA-Zn in irrigated areas showed 52.7 and 47.3 per cent soils under 'low' and 'medium' status and in rainfed soils 96.4 per cent under 'low' Zn status. Nutrients index for all the nutrients followed the same trends of 'low', 'medium' and 'high' as those of available nutrients status.

Keywords: Soil, irrigated, rainfed, available nutrients, nutrient index, cotton, South Gujarat

Introduction
Cotton is most important fiber crop ('queen of fibres') which plays very important role in economic and social affairs of people, especially in India. This 'white gold' (cotton) is one of the most important cash crops of Gujarat state whereby, out of 99.66 lakh hectares cultivable land about 30 lakh hectares area is under cotton on various types of soils producing 125 lakh bales of lint, about 50 lakh tonnes of cotton seed and 60-65 lakh tonnes of stalks. However, the cotton crop in Gujarat is grown under variable annual rainfall situations ranging from 250 mm in the North West to > 1500 mm in South Gujarat (*Annon*. 2016) [1]. Any research work towards enhancement of cotton crop productivity or soil quality on which it survives would be of paramount importance. A research topic, thus, was chosen on cotton growing soils of South Gujarat. Cotton cultivation in Gujarat is done on various soils right from sandy soil of Kutch, the alluvial soil of Ahmedabad and Kheda districts to the black and black cotton soils of Central, Southern and Saurashtra regions. As productivity of both rainfed and irrigated cotton crops largely depends on the soil characteristics under a specific set of climate, ignorance of soil-site requirement of a particular crop leads to the sub-optimal yield or complete failure of the crop. Due to continuous cotton cultivation, soils under irrigated and rainfed system may differ/ or affect soil properties which may modify nutrients content and their availability to crops, so analysis of soil properties may have significant importance in understanding proper nutrient management practices. Under these contexts, an attempt has been made to generate information on soil nutrients status in irrigated and rainfed situations in cotton growing areas of South Gujarat in order to future management of these soils for higher cotton yield.

Materials and Methods
Overview of study area: Cotton is an important cash crop of South Gujarat. It is cultivated in 11 talukas of South Gujarat and the area of cotton comes under subtropical climate with semi

arid conditions, where the annual rainfall varies in these talukas from 700 to 950 mm. However, Surat city receives little more rainfall *i.e.* about 1200 mm. Distribution of rainfall is not uniform. Soils of the major areas are *Vertisols* and *Inceptisols* in order. Cotton is grown in about 100 lakh hectares in South Gujarat encompassing 11 talukas namely, Bharuch, Jhagadia, Jambusar, Amod, Vagra, Hansot, Surat, Narmada, Dediapada, Tilakwada and Sagbara. These eleven talukas are distributed in three districts of South Gujarat namely Bharuch (21.3^0 to 22.0^0 N, 72.45^0 to 73.15^0 E), Surat (20° 10' 596" N, 072° 52' 638"E) and Narmada (21° 52' 028"N, 073° 30' 035"E). Major soils are clayey in texture. Moreover, soils fertility status is also medium to poor and a result, yield of cotton (desi or hybrid or *Bt*) crop is not optimum and varies widely from talukas to talukas. Thus, it is essential to analyze the soil samples chemically so as to have analytical results on parameters like N, P_2O_5, K_2O, S and Zn in order to take appropriate management practices for improving cotton yield.

Soil sampling and analysis: Total 110 numbers (55 irrigated and 55 rainfed) of representative surface soil samples (0 - 22.5 cm) encompassing eleven talukas of South Gujarat were collected by using GPS. All the collected soil samples were air dried, processed and analyzed for above available nutrients following standard methods (Jackson, 1973). Soil N was determined by using alkaline potassium permanganate method (Subbiah and Asija, 1956) [25], phosphorus were determined by extracting soil with 0.5 M $NaHCO_3$ at pH 8.5 and determining P from the filtrate by spectrometric method (Olsen *et al*. 1954) [11], potassium was determined by flame photometer by using normal neutral ammonium acetate (1N NH_4OAc adjusting pH 7.0 as extractant) as described by Jackson (1973) and available sulphur was estimated by using 0.15 per cent $CaCl_2$ solution as extractant following the method as narrated by Willams and Steinbergs (1959) [28]. DTPA- Zn was determined by using Atomic Absorption Spectrophotometer as per the procedure described by Lindsay and Norvell (1978) [9]. Results of all the chemical analysis *viz.* soil available N, P_2O_5, K_2O, S and Zn were rated as per Subbiah and Asija, (1956) [25], Olsen *et al*. (1954) [11], Hanway and Heidel, (1952) [6], Hariram and Dwivedi, (1994) [7] and Lindsay and Norvell, (1978) [9], for available N, P_2O_5, K_2O, S and Zn respectively. Further apart from rating, N, P_2O_5, K_2O, S and Zn were also subjected to nutrient indexing as described by Ramamoorthy and Bajaj (1969) [20] and Parker *et al*. (1951) [14] based on their index <1.67 as low, 1.67 to 2.33 as medium and >2.33 as high. The equation is given as under:

$$NI = [(NL \times 1) + (NM \times 2) + (NH \times 3)] / NT$$

Where: NL, NM and NH are the number of soil samples falling in low, medium and high categories for nutrient status and are given weightage of 1, 2 and 3, respectively. NT is the total number of samples. At last, results of both the ratings and nutrient index of each and every parameter were interpreted and discussed thoroughly.

Results and Discussion

Available nitrogen (N)

Available N status along with ratings of surface soil (0-22.5 cm) from irrigated and rainfed cotton growing areas are presented in Table 1. Irrigated soils of six talukas of Bharuch district revealed that N varied widely from 185.9 - 386.0 kg ha^{-1} ('low' to 'medium') with a mean value of 258.7 kg ha^{-1} depicting 80 per cent soils with 'low' available N status. In Surat city taluka, available N varied from low to medium status ranging from 222.5 - 297.3 kg ha^{-1} with a mean value of 270.3 kg ha^{-1}, whereby 60 per cent soils came under 'low' available N status. But all the soils of four talukas of Narmada district came under low status showing its variation from 171.2 - 243.4 kg ha^{-1} with a mean value of 209.2 kg ha^{-1}. When all the irrigated soils of 11 talukas were considered together, it was found that soil available N varied from low to medium status ranging from 171.2 - 386.0 kg ha^{-1} with 85.5 and 14.5 per cent soils belonging to 'low' and 'medium' available N status, respectively. Thus it is imperative that major irrigated soils urgently need improvement in available N status through the proper N-management system for enhancement of N uptake by cotton crop and yield as well, especially for hybrid and or *Bt* cotton under irrigated conditions. N status of all the rainfed soils of six talukas of Bharuch district were 'low' (145.1 - 279.8 kg ha^{-1}) with mean value of 226.4 kg ha^{-1}. Coming to soils of Surat city taluka, available N ranged from 186.5 - 298.8 kg ha^{-1} with mean value of 235.4 kg ha^{-1} depicting 80 per cent soils under 'low' available N status. Similarly, all the soils of four talukas of Narmada district were 'low' in available N status and the values ranged from 127.9 - 223.3 kg ha^{-1} with mean value of 187.6 kg ha^{-1}. When all the rainfed soils of 11 talukas were considered together, it was found that soil available N varied from 127.9 - 298.8 kg ha^{-1} with 98.2 per cent soils under 'low' category. The reason for low available N status in almost all the soils might be ascribed to low organic matter content of these soils along with low inorganic inputs and rapid loss of applied N. Similar reason was put forwarded by Vineetha and Malewar (2009) [27]. Results of low available N status were supported by Prabhavati *et al.* (2015) [18] and Dhamak *et al.* (2014) [5]. As SOC plays a major role in generating native available N through decomposition /mineralization process by the activity of microbes, to tide over problems of low to medium available N status, addition of more organic matter /manures/compost/ biocomposts/ pressmud as suggested by Patel and Das (2009) [15] would be of prime importance. Further, stimulation of the activity of soil microbes in both irrigated and rainfed soils would be judicious measures in combination with regular inorganic N-fertilizer schedule (preferably in splits as per recommendations) in order to achieve higher available soil N, higher uptake and assimilation of N by plants and as a consequence higher yield of cotton. However, mean available N of irrigated soils (241.3 kg ha^{-1}) was higher as compared to that of rainfed soils (216.5 kg ha^{-1}). This might be due to higher organic matter content in irrigated soils as compared to rainfed soils as a result of higher mineralization of N from native and applied organic matter apart from better crop management practices. Similar reports were made by Padekar *et al.* (2014) [12], Negash and Mohammed (2014) [10], Paramasivan and Jawahar (2014) [13] for soils of cotton growing areas.

Available phosphorus (P_2O_5)

Available P_2O_5 status along with ratings of surface soil from irrigated and rainfed cotton growing area of 6 talukas of Bharuch district, 1 taluka of Surat district and 4 talukas of Narmada district are presented in Table 1. Irrigated soils of six talukas of Bharuch district revealed that soil available P_2O_5 ranged from 14.9 - 53.4 kg ha^{-1} ('low' to 'medium') with a mean of 33.9 kg ha^{-1} showing 53.3 and 46.7 per cent soils under 'low' and 'medium' available P_2O_5 category, respectively. Coming to Surat city taluka, available P_2O_5 ranged from 24.3 - 52.1 kg ha^{-1} (mean 36.4 kg ha^{-1}) depicting

40 and 60 per cent soils respectively under 'low' and 'medium' available P_2O_5 status. In case of soils from four talukas of Narmada district, the available P_2O_5 ranged from 12.4 - 42.2 kg ha^{-1} (mean 23.1 kg ha^{-1}) whereby 75 and 25 per cent soils came under low and medium status, respectively. It was further found that soil available P_2O_5 varied from 12.4 - 53.4 kg ha^{-1} (mean 31.1 kg ha^{-1}) in irrigated soils with 60 and 22 per cent soils under 'low' and 'medium' status of P_2O_5, respectively. In the similar way, soil available P_2O_5 in all the rainfed soils varied from 'low' to 'medium' status and that in Bharuch district ranged from 12.4 - 42.2 kg ha^{-1} (mean 27.7 kg ha^{-1}), in Surat city taluka 13.7 - 37.2 kg ha^{-1} (mean 27.9 kg ha^{-1}) and in four talukas of Narmada district 7.4 - 36.0 kg ha^{-1} (mean 19.4 kg ha^{-1}). Soils from six taluka of Bharuch district, one taluka of Surat district and four talukas of Narmada district exhibited 63.3, 40 and 95 per cent 'low' status of available P_2O_5, respectively and rest of the soils from these districts belong to 'medium' status of available P_2O_5. Further, available P_2O_5 in soils from the entire rainfed cotton growing areas varied from 7.4 - 42.2 kg ha^{-1} (mean 25.0 kg ha^{-1}) *i.e.* 'very low' to 'medium'. However, 72.7 per cent soils from the entire rainfed areas belong to 'low' available P_2O_5 status and the rest came under 'medium' available P_2O_5 status. The variations in available P_2O_5 both in irrigated and rainfed soils might be attributable to pH, organic matter content, soil texture and various management and practices followed by the farmers. Thus, in soils with low or lower medium status of P_2O_5 depending upon the type cotton crop *i.e.* desi or hybrid or *Bt* and their P requirement, improvement of available phosphorus is of immense importance in soils under both the situation (irrigated / rainfed) through application of inorganic phosphorus with proper placement (Patel and Patel 2012) [16], organic sources like, vermicompost, organic matter in-combination with PSB (Yadav *et al*. 2013) [29]. Singh and Mishra (2012) [8, 22] also obtained available P_2O_5 in the similar range *i.e.* 8.2-25.0 kg ha^{-1} (average 12.8 kg ha^{-1}). Mean available P_2O_5 of irrigated soils was found slightly higher (31.1 kg ha^{-1}) as compared to that of rainfed soils (24.68 kg ha^{-1}) which might be due to higher organic matter content coupled with application of more inorganic P-fertilizers in irrigated soils as compared to rainfed soils. Higher available P in irrigated system was also observed by Negash and Mohammed (2014) [10] than rainfed system.

Available potassium (K_2O)

Available K_2O status along with ratings of surface soil from irrigated and rainfed cotton growing areas are presented in Table 1. All the soils samples from 11 talukas both from irrigated and rainfed areas were 'high' in available K_2O status. However, in irrigated soils of six talukas of Bharuch, one taluka of Surat and four talukas of Narmada districts available K_2O ranged from 332 to 1180, 645 to 1050 and 282 to 664 kg ha^{-1}, respectively with the corresponding mean values of 646, 796 and 637 kg ha^{-1}, respectively. In case of rainfed soils available K_2O was also high ranging from 325 to 812, 539 to 739 and 281 to 554 kg ha^{-1}, respectively in chronological order as above. Higher ranged of available K_2O (212.8 to 680.0 kg ha^{-1}) as reported by Chaudhary *et al.* (2006) [2] and ranged of 134-573 kg ha^{-1} in cotton growing soils by Devraj *et al.* (2008) [4]. Wide range of available K_2O both in irrigated and rainfed situations in these cotton growing soils might be ascribed to soil pH, soil texture, clay content and type (including potassium- rich minerals like, feldspar and mica), SOC, degree of irrigation and management practices by farmers including inorganic K application based on cotton crop (hybrid / *desi* /*Bt*). Further, mean available K_2O of all irrigated soils of 11 talukas was higher (637 kg ha^{-1}) as compared to that of rainfed soil (497 kg ha^{-1}) which might be due to higher solublization of potassium under irrigated condition from mineral lattice. Thus, the high status of soil available K_2O is quite sufficient to fulfill the requirement of cotton crops of South Gujarat.

Available sulphur (S)

Available S status along with ratings of surface soil from irrigated and rainfed area of 6 talukas of Bharuch district, 1 taluka of Surat district and 4 talukas of Narmada district are presented in Table 1. Result revealed that in irrigated soils from six talukas of Bharuch district available S varied widely from 'low' to 'high' (8.9 - 26.9 ppm) with mean value of 16 ppm. In Surat city taluka available S ranged from 15.0 - 23.9 ppm (mean 18.6 ppm) and in soils of four talukas of Narmada district the same varied from 4.9-13.1 ppm (mean 9.9 ppm). Major soils of Bharuch district (83.3 %), Surat city taluka (80 %) and Narmada district (72.7 %) came under 'medium' status of available S. However, in soils of the above area in chronological order, the percentages of available S under 'low' category were 6.7, 0.0 and 45 per cent, respectively and under 'high' category 10.0, 20 and 7.3 percent, respectively. When all the irrigated soils of 11 talukas were considered together, it was found that soil available S widely varied from 4.9 - 26.9 ppm *i.e.* very 'low' to 'high' with 20, 72.7 and 7.3 per cent soils under 'low', 'medium' and 'high' available S status, respectively. However, in rainfed soils of six talukas of Bharuch district soil available S ranged from 6.2 - 15.8 ppm (mean 9.8 ppm) *i.e.* 'low' to 'medium' having 53.3 per cent under low category and the rest belonged to 'medium' available S status. Similarly, for Surat city taluka, S ranged from 9.7 - 13.1 ppm with a mean value of 11.2 ppm, whereby 20 and 80 per cent soils belonged to 'low' and 'medium' available S status, respectively. In case of soils from four talukas of Narmada district, the same ranged from 5.4 - 12.7 ppm (mean 8.7 ppm) with 90 per cent soils under 'low' category. Varaprasad Rao *et al*. (2008) [26] found that available S content varied from 3.42 to 9.82 mg kg^{-1} soil in black soils. Low status of available S both in irrigated and rainfed soils was perhaps due to low organic carbon content in soils coupled with its low mineralization rate. Thus, soils having sulphur status below critical level (< 10 ppm) are required to be replenished / improved to meet the demand of S in cotton crop. To overcome the low or medium available S status (or alternately low to medium crop productivity potential), sulphur management through addition of either inorganic S, organic manures or sulphonated compost and biocomposts or gypsum and sulphur - solubilising microbes, are some of suggested measures in order sustain soil quality and for possible improvement in cotton crop. Results further revealed that overall available S of irrigated soils was higher (14.8 ppm) as compared to that of rainfed (9.9 ppm). The reason might be the higher organic matter content along with mineralization rate in irrigated soils as compared to rainfed soils. Similar result was obtained by Shrvan Kumar *et al.* (2016) investigated available S ranged from 3.8 to 74.8 and 4.5 to 26.2 ppm, respectively in irrigated and rainfed soils of cotton system in Bharuch, Gujarat.

DTPA-Zn

DTPA- Zn (available Zn) status along with ratings of surface soils from irrigated and rainfed cotton growing areas are presented in Table 2. Irrigated soils of six talukas of Bharuch

district revealed that DTPA-Zn ranged from 0.25- 0.91 mg kg^{-1} *i.e.* 'low to medium' with mean of 0.55 mg kg^{-1} showing 46.7 and 53.3 per cent soils under 'low' and 'medium' DTPA-Zn status, respectively. In case soils of Surat city taluka, DTPA-Zn ranged from 0.38-0.80 mg kg^{-1} (mean 0.58 mg kg^{-1}), showing 40 and 60 per cent soils under 'low' and 'medium' status, respectively. In soils of Narmada district, the same ranged from 0.29 - 0.67 mg kg^{-1} (mean 0.44 mg kg^{-1}) depicting 65 and 35 per cent soils under 'low' and 'medium' status, respectively. All the irrigated soils when considered together, it was found that soil DTPA-Zn widely varied from 0.25 - 0.91 mg kg^{-1} with 52.7 and 47.3 per cent soils under 'low' (< 0.5 mg kg^{-1}) and 'medium' (0.5 - 1.0 mg kg^{-1}) status of DTPA-Zn, respectively. Rainfed soils of six talukas of Bharuch district revealed that DTPA-Zn ranged from 0.21 - 0.52 mg kg^{-1} (mean 0.38 mg kg^{-1}) with 96.7 and 3.3 per cent soils under 'low' and 'medium' Zn status, respectively. Coming to Surat city taluka, DTPA-Zn ranged from 0.41-0.60 mg kg^{-1} (mean 0.48 mg kg^{-1}) where, 80 and 20 per cent soils exhibited 'low' and 'medium' DTPA- Zn status, respectively. In case of soils of Narmada district, DTPA-Zn ranged from 0.20 - 0.45 mg kg^{-1} (mean 0.32 mg kg^{-1}) showing all the soils with 'low' DTPA-Zn status. When all the rainfed soils were considered together, it was found that lower value of soil DTPA-Zn was 0.20 mg kg^{-1} and showed as high as 0.59 mg kg^{-1} showing major soils (96.4%) under 'low' (<0.5 mg kg^{-1}) DTPA-Zn status. Chouhan *et al.* (2012) [3] observed that DTPA- Zn varied from 0.04 to 4.9 mg kg^{-1} (mean 0.49 mg kg^{-1}) in soil whereby 72.7 percent soil was deficient. Similar result was also obtained by Pathiar *et al.* (2015) [17] and Singh *et al.* (2014) [23]. In general, DTPA-Zn in both irrigated and rainfed soils were found to increase with the increase in organic matter content in soil. About 53 per cent irrigated and rainfed soils 96 per cent rainfed soils were low/ deficient in available Zn, thus, the uptake of Zn in requisite quantity by plants would be problem which might affect flowering, boll formation, synthesis of growth hormones *etc.* and ultimately crop yield. Thus, soils with low DTPA-Zn can be considered as soils with low cotton crop productivity potential. To overcome such Zn deficiency problem and to improve possible yield of cotton as well as soil health, addition of more organic manures, organic residues/ organic matter, green manuring and addition of inorganic Zn ($ZnSO_4$ / Zn chelates / Zn frit / NA-Zn-EDTA *etc.*) of soils would be some prime corrective measures for almost all rainfed soils as well as about 53 per cent irrigated soils. Prabhavati *et al.* (2015) [18] reported that 100% black soils were deficient in DTPA-Zn content based on critical value of 0.6 mg kg^{-1}. Mean DTPA-Zn of irrigated soils was higher (0.51 mg kg^{-1}) as compared to that of rainfed soils (0.39 mg kg^{-1}). The reason might be the presence of higher organic matter content and reduced soil pH in irrigated soils as compared to rainfed soils. The results were in good agreement with the findings of Negash and Mohammed (2014) [10] and Paramasivan and Jawahar (2014) [13].

Nutrient Index

These scales provide a general indication of the likely crop response as shown here. In the present study, nutrient index of different parameters in soils of irrigated and rainfed cotton growing areas of 11 talukas are presented in Table 4. For the irrigated soils, rainfed soils and for the irrigated and rainfed soils jointly nutrient index value of available N was also 'low' *i.e.* 1.15, 1.02 and 1.08, respectively. The reason for low nutrient index for available N could be the semi arid climatic condition, low organic matter and total N reserve along with low mineralization rate in these soils. Thus, soils of these talukas are expected to respond to the added N fertilizers to a greater magnitude. In case of available P_2O_5, nutrient index value of irrigated, rainfed as well as irrigated + rainfed soils was 'low' and *i.e.* 1.40, 1.27 and 1.34, respectively. As the nutrient index for available P_2O_5 was low it is likely that application of phosphorus through organic and inorganic sources might give a good response of cotton crop. In respect of K, however, all the soils of irrigated and rainfed situations as well as from irrigated and rainfed jointly exhibited 'high' status showing index value of 3.00 which indicated no external addition of potassium would be needed. Available nutrient index of S in irrigated, rainfed as well as irrigated and rainfed soils together, depicted 'medium' (1.87), 'low' (1.36) and 'low' (1.62) respectively, just showing the same as obtained for available S status under irrigated, rainfed and irrigated + rainfed soils together *i.e.* 'medium', 'low' and 'low', respectively. Observations of the present study are in accordance with the results of Jatav, G. K. (2010), Srinivas *et al.* (1998) [24] and Prasuna Rani *et al.* (1992) [19]. In case of available Zn, nutrient index value of irrigated, rainfed as well as irrigated + rainfed soils was 'low' and *i.e.* 1.47, 1.04 and 1.25, respectively. Thus, 'low' status of available Zn / deficiency, requires to be corrected by application of Zn in soil through organic or inorganic means by Zn-Chelates/ Na-Zn-EDTA *etc.*

Conclusion

Application of organic manure, sulphonated compost/ biocomposts along with decomposing / mineralizing microbes would be judicious measures for major soils having low available N, P_2O_5, S and Zn. This apart, in soils with 'low' N status or index, addition of regular schedule of inorganic fertilizer, soils with low status or index of P_2O_5, application of inorganic-P with proper placement, soils with 'low' S status or index application of gypsum, soils with low status or index of Zn application of Zn either in soil or through foliar spray in sulphate form or as Zn-Chelates/ Na-Zn-EDTA *etc* would be worth in order improve available nutrients status thereby to sustain soil quality and yield of cotton.

Table 1: Soil available nutrients and its rating of surface soils from irrigated and rainfed cotton growing talukas of South Gujarat

	No. of samples	N (kg ha^{-1})	Nitrogen status			P (kg ha^{-1})	Phosphorus status			K (kg ha^{-1})	Potassium status			S (ppm)	Sulphur status		
		Range & mean	Low (<280)	Medium (280-560)	High (>560)	Range & mean	Low (<28)	Medium (28-56)	High (>56)	Range & mean	Low (<140)	Medium (140-280)	High (>280)	Range & mean	Low (<.10)	Medium (10-20)	High (>20)
Bharuch District	**Irrigated soils**																
Talukas																	
Bharuch	**5**	253.0-386.0 (321.0)	**2** (40)	**3** (60)	**0** (0)	25.2-52.1 (39.3)	**1** (20)	**4** (80)	**0** (0)	510-642 (588)	**0** (0)	**0** (0)	**5** (100)	16.9-21.8 (19.7)	**0** (0)	**4** (80)	**1** (20)
Jhagadia	**5**	208.9-232.7 (223.4)	**5** (100)	**0** (0)	**0** (0)	24.8-32.3 (27.8)	**4** (80)	**1** (20)	**0** (0)	418-668 (506)	**0** (0)	**0** (0)	**5** (100)	12.7-26.9 (17.8)	**0** (0)	**3** (60)	**2** (40)
Jambusar	**5**	204.5-250.3 (227.2)	**5** (100)	**0** (0)	**0** (0)	23.6-39.7 (31.7)	**2** (40)	**3** (60)	**0** (0)	332-568 (498)	**0** (0)	**0** (0)	**5** (100)	9.6-14.6 (13.4)	**1** (20)	**4** (80)	**0** (0)
Amod	**5**	185.9-284.8 (247.3)	**4** (80)	**1** (20)	**0** (0)	14.9-39.7 (28.8)	**3** (60)	**2** (40)	**0** (0)	386-687 (469)	**0** (0)	**0** (0)	**5** (100)	10.5-19.2 (14.7)	**0** (0)	**5** (100)	**0** (0)
Vagra	**5**	238.3-298.7 (261.5)	**4** (80)	**1** (20)	**0** (0)	23.6-53.4 (39.5)	**3** (60)	**2** (40)	**0** (0)	541-1176 (853)	**0** (0)	**0** (0)	**5** (100)	12.3-20.0 (16.9)	**0** (0)	**5** (100)	**0** (0)
Hansot	**5**	249.9-324.1 (271.9)	**4** (80)	**1** (20)	**0** (0)	24.8-52.1 (36.5)	**3** (60)	**2** (40)	**0** (0)	767-1180 (961)	**0** (0)	**0** (0)	**5** (100)	8.9-16.9 (13.3)	**1** (20)	**4** (80)	**0** (0)
Overall	**30**	185.9-386.0 (258.7)	**24** (80.0)	**6** (20.0)	**0** (0)	14.9-53.4 (33.9)	**16** (53.3)	**14** (46.7)	**0** (0)	332-1180 (646)	**0** (0)	**0** (0)	**30** (100)	8.9-26.9 (16.0)	**2** (6.7)	**25** (83.3)	**3** (10.0)
Surat																	
Surat city	**5**	222.5-297.3 (270.3)	**3** (60)	**2** (40)	**0** (0)	24.3-52.1 (36.4)	**2** (40)	**3** (60)	**0** (0)	645-1050 (796)	**0** (0)	**0** (0)	**5** (100)	15.0-23.9 (18.6)	**0** (0)	**4** (80)	**1** (20)
Narmada																	
Talukas																	
Narmada	**5**	217.0-243.4 (232.6)	**5** (100)	**0** (0)	**0** (0)	12.4-29.5 (20.6)	**4** (80)	**1** (20)	**0** (0)	436-512 (552)	**0** (0)	**0** (0)	**5** (100)	9.6-11.2 (10.2)	**2** (40)	**3** (60)	**0** (0)
Dadiapada	**5**	196.3-220.8 (211.4)	**5** (100)	**0** (0)	**0** (0)	16.6-32.3 (23.7)	**4** (80)	**1** (20)	**0** (0)	285-551 (391)	**0** (0)	**0** (0)	**5** (100)	4.9-13.1 (9.9)	**3** (60)	**2** (40)	**0** (0)
Tilakwada	**5**	171.2-213.2 (195.9)	**5** (100)	**0** (0)	**0** (0)	15.9-29.8 (22.3)	**3** (60)	**2** (40)	**0** (0)	282-519 (398)	**0** (0)	**0** (0)	**5** (100)	8.5-12.7 (10.6)	**2** (40)	**3** (60)	**0** (0)
Sagbara	**5**	175.6-207.0 (196.9)	**5** (100)	**0** (0)	**0** (0)	13.7-42.2 (25.6)	**4** (80)	**1** (20)	**0** (0)	383-664 (530)	**0** (0)	**0** (0)	**5** (100)	6.2-11.2 (9.0)	**2** (40)	**3** (60)	**0** (0)
Overall	**20**	171.2-243.4 (209.2)	**20** (100)	**0** (0)	**0** (0)	12.4-42.2 (23.1)	**15** (75.0)	**5** (25.0)	**0** (0)	282-664 (468)	**0** (0)	**0** (0)	**20** (100)	4.9-13.1 (9.9)	**9** (45.0)	**11** (55.0)	**0** (0)
Overall-11 Talukas	**55**	171.2-386.0 (241.3)	**47** (85.5)	**8** (14.5)	**0** (0)	12.4-53.4 (31.1)	**33** (60.0)	**22** (40.0)	**0** (0)	282-1180 (637)	**0** (0)	**0** (0)	**55** (100)	4.9-26.9 (14.8)	**11** (20.0)	**40** (72.7)	**4** (7.3)

Continue…..

	No. of samples	N (kg ha^{-1})	Nitrogen status			P (kg ha^{-1})	Phosphorus status			K (kg ha^{-1})	Potassium status			S (ppm)	Sulphur status		
		Range & mean	Low (<280)	Medium (280-560)	High (>560)	Range & mean	Low (<28)	Medium (28-56)	High (>56)	Range & mean	Low (<140)	Medium (140-280)	High (>280)	Range & mean	Low (<.10)	Medium (10-20)	High (>20)
Bharuch District																	
Talukas	**Rainfed soils**																
Bharuch	**5**	211.4-275.1 (259.3)	**5** (100)	**0** (0)	**0** (0)	26.1-34.5 (29.6)	**2** (40)	**3** (60)	**0** (0)	329-570 (416)	**0** (0)	**0** (0)	**5** (100)	9.6-12.7 (10.9)	**2** (40)	**3** (60)	**0** (0)
Jhagadia	**5**	183.8-233.9 (211.9)	**5** (100)	**0** (0)	**0** (0)	13.7-39.7 (24.8)	**4** (80)	**1** (20)	**0** (0)	327-495 (414)	**0** (0)	**0** (0)	**5** (100)	8.1-11.3 (9.9)	**2** (40)	**3** (60)	**0** (0)
Jambusar	**5**	172.5-260.3 (201.7)	**5** (100)	**0** (0)	**0** (0)	19.9-37.2 (26.0)	**4** (80)	**1** (20)	**0** (0)	373-562 (467)	**0** (0)	**0** (0)	**5** (100)	6.2-11.6 (8.8)	**4** (80)	**1** (20)	**0** (0)
Amod	**5**	145.1-269.9 (210.8)	**5** (100)	**0** (0)	**0** (0)	12.4-36.0 (21.3)	**4** (80)	**1** (20)	**0** (0)	325-552 (453)	**0** (0)	**0** (0)	**5** (100)	6.9-12.3 (9.7)	**3** (60)	**2** (40)	**0** (0)
Vagra	**5**	146.7-275.9 (209.4)	**5** (100)	**0** (0)	**0** (0)	24.8-41.0 (32.9)	**2** (40)	**3** (60)	**0** (0)	406-742 (535)	**0** (0)	**0** (0)	**5** (100)	8.0-11.2 (9.8)	**2** (40)	**3** (60)	**0** (0)
Hansot	**5**	242.6-279.8 (265.0)	**5** (100)	**0** (0)	**0** (0)	23.6-42.2 (31.3)	**3** (60)	**2** (40)	**0** (0)	629-812 (695)	**0** (0)	**0** (0)	**5** (100)	7.1-11.9 (9.6)	**3** (60)	**2** (40)	**0** (0)
Overall	**30**	145.1-279.8 (226.4)	**30** (100)	**0** (0)	**0** (0)	12.4-42.2 (27.7)	**19** (63.3)	**11** (36.7)	**0** (0)	325-812 (497)	**0** (0)	**0** (0)	**30** (100)	6.2-15.8 (9.8)	**16** (53.3)	**14** (46.7)	**0** (0)
Surat																	
Surat city	**5**	186.5-298.8 (235.4)	**4** (80)	**1** (20)	**0** (0)	13.7-37.2 (27.9)	**2** (40)	**3** (60)	**0** (0)	539-739 (633)	**0** (0)	**0** (0)	**5** (100)	9.7-13.1 (11.2)	**1** (20)	**4** (80)	**0** (0)
Narmada																	
Talukas																	
Narmada	**5**	152.9-223.3 (194.0)	**5** (100)	**0** (0)	**0** (0)	11.2-19.9 (15.9)	**5** (100)	**0** (0)	**0** (0)	284-389 (337)	**0** (0)	**0** (0)	**5** (100)	5.4-12.7 (8.9)	**4** (80)	**1** (20)	**0** (0)
Dadiapada	**5**	178.6-218.3 (196.7)	**5** (100)	**0** (0)	**0** (0)	12.9-27.3 (19.1)	**5** (100)	**0** (0)	**0** (0)	281-521 (373)	**0** (0)	**0** (0)	**5** (100)	8.2-9.7 (9.0)	**5** (100)	**0** (0)	**0** (0)
Tilakwada	**5**	127.9-215.8 ss(182.0)	**5** (100)	**0** (0)	**0** (0)	12.4-26.1 (20.9)	**5** (100)	**0** (0)	**0** (0)	281-409 (354)	**0** (0)	**0** (0)	**5** (100)	5.8-10.4 (8.5)	**4** (80)	**1** (20)	**0** (0)
Sagbara	**5**	165.6-188.2 (177.5)	**5** (100)	**0** (0)	**0** (0)	7.4-36.0 (21.8)	**4** (80)	**1** (20)	**0** (0)	306-554 (381)	**0** (0)	**0** (0)	**5** (100)	5.8-9.7 (8.4)	**5** (100)	**0** (0)	**0** (0)
Overall	**20**	127.9-223.3 (187.6)	**20** (100)	**0** (0)	**0** (0)	7.4-36.0 (19.4)	**19** (95.0)	**1** (5.0)	**0** (0)	281-554 (362)	**0** (0)	**0** (0)	**20** (100)	5.4-12.7 (8.7)	**18** (90.0)	**2** (10.0)	**0** (0)
Overall-11 Talukas	**55**	127.9-298.8 (216.5)	**54** (98.2)	**1** (1.8)	**0** (0)	7.4-42.2 (25.0)	**40** (72.7)	**15** (27.3)	**0** (0)	281-812 (497)	**0** (0)	**0** (0)	**55** (100)	5.4-15.8 (9.9)	**35** (63.6)	**20** (36.4)	**0** (0)

Values in bold are numbers of samples and values in parenthesis ( ) are per cent of samples.

Table 2: DTPA-Zn and its rating of surface soils from irrigated and rainfed cotton growing areas of South Gujarat

	DTPA-Zn (mg kg^{-1})		DTPA-Zn rating		
	Range	**Mean**	**Low (<0.5)**	**Medium (0.5-1.0)**	**High (>1.0)**
Bharuch District	**Irrigated**				
Talukas					
Bharuch	0.45-0.54 (0.50)	0.50	**3** (60)	**2** (40)	**0** (0)
Jhagadia	0.25-0.79 (0.55)	0.55	**2** (40)	**3** (60)	**0** (0)
Jambusar	0.42-0.91 (0.60)	0.60	**3** (60)	**2** (40)	**0** (0)
Amod	0.35-0.68 (0.51)	0.51	**3** (60)	**2** (40)	**0** (0)
Vagra	0.45-0.61 (0.53)	0.53	**2** (40)	**3** (60)	**0** (0)
Hansot	0.42-0.72 (0.60)	0.60	**1** (20)	**4** (80)	**0** (0)
Overall	0.25-0.91 (0.55)	0.55	**14** (46.7)	**16** (53.3)	**0** (0.0)
Surat					
Surat city	0.38-0.80 (0.58)	0.58	**2** (40)	**3** (60)	**0** (0)
Narmada					
Talukas					
Narmada	0.34-0.52 (0.42)	0.42	**4** (80)	**1** (20)	**0** (0)
Dadiapada	0.29-0.67 (0.45)	0.45	**3** (60)	**2** (40)	**0** (0)
Tilakwada	0.34-0.62 (0.51)	0.51	**2** (40)	**3** (60)	**0** (0)
Sagbara	0.32-0.50 (0.40)	0.40	**4** (80)	**1** (20)	**0** (0)
Overall	0.29-0.67 (0.44)	0.44	**13** (65.0)	**7** (35.0)	**0 (0)**
Overall-11 Talukas	0.25-0.91 (0.51)	0.51	**29** (52.7)	**26** (47.3)	**0** (0)
Bharuch District	**Rainfed**				
Talukas					
Bharuch	0.45-0.54 (0.50)	0.50	**3** (60)	**2** (40)	**0** (0)
Jhagadia	0.25-0.79 (0.55)	0.55	**2** (40)	**3** (60)	**0** (0)
Jambusar	0.42-0.91 (0.60)	0.60	**3** (60)	**2** (40)	**0** (0)
Amod	0.35-0.68 (0.51)	0.51	**3** (60)	**2** (40)	**0** (0)
Vagra	0.45-0.61 (0.53)	0.53	**2** (40)	**3** (60)	**0** (0)
Hansot	0.42-0.72 (0.60)	0.60	**1** (20)	**4** (80)	**0** (0)
Overall	0.25-0.91 (0.55)	0.55	**14** (46.7)	**16** (53.3)	**0** (0.0)
Surat					
Surat city	0.38-0.80 (0.58)	0.58	**2** (40)	**3** (60)	**0** (0)
Narmada					
Talukas					
Narmada	0.34-0.52 (0.42)	0.42	**4** (80)	**1** (20)	**0** (0)
Dadiapada	0.29-0.67 (0.45)	0.45	**3** (60)	**2** (40)	**0** (0)
Tilakwada	0.34-0.62 (0.51)	0.51	**2** (40)	**3** (60)	**0** (0)
Sagbara	0.32-0.50 (0.40)	0.40	**4** (80)	**1** (20)	**0** (0)
Overall	0.29-0.67 (0.44)	0.44	**13** (65.0)	**7** (35.0)	**0 (0)**
Overall-11 Talukas	0.25-0.91 (0.51)	0.51	**29** (52.7)	**26** (47.3)	**0** (0)

Values in bold are numbers of samples and values in parenthesis ( ) are per cent of samples.

Table 3: Nutrient index of available nutrients in soils of irrigated and rainfed cotton growing areas of South Gujarat

Talukas	**Irrigated soils**									
	N		**P_2O_5**		**K_2O**		**S**		**Zn**	
	NI	**Fertility status**	**NI**	**Fertility status**	**NI**	**Fertility status**	**NI**	**Fertility status**	**NI**	**Fertility status**
Bharuch	1.60	Low	1.80	Medium	3.00	High	2.20	High	1.40	Low
Jhagadia	1.00	Low	1.20	Low	3.00	High	2.40	High	1.60	Low
Jambusar	1.00	Low	1.60	Low	3.00	High	1.80	Medium	1.40	Low
Amod	1.20	Low	1.40	Low	3.00	High	2.00	Medium	1.40	Low
Vagra	1.20	Low	1.40	Low	3.00	High	2.00	Medium	1.60	Low
Hansot	1.20	Low	1.40	Low	3.00	High	1.80	Medium	1.80	Low
Surat city	1.40	Low	1.60	Low	3.00	High	2.20	Medium	1.60	Low
Narmada	1.00	Low	1.20	Low	3.00	High	1.60	Low	1.20	Low
Dadiapada	1.00	Low	1.20	Low	3.00	High	1.40	Low	1.40	Low
Tilakwada	1.00	Low	1.40	Low	3.00	High	1.60	Low	1.60	Low
Sagbara	1.00	Low	1.20	Low	3.00	High	1.60	Low	1.20	Low
	Rainfed soils									
Bharuch	1.00	Low	1.60	Low	3.00	High	1.60	Low	1.00	Low
Jhagadia	1.00	Low	1.20	Low	3.00	High	1.60	Low	1.00	Low
Jambusar	1.00	Low	1.20	Low	3.00	High	1.20	Low	1.00	Low
Amod	1.00	Low	1.20	Low	3.00	High	1.40	Low	1.00	Low
Vagra	1.00	Low	1.60	Low	3.00	High	1.60	Low	1.00	Low
Hansot	1.00	Low	1.40	Low	3.00	High	1.40	Low	1.20	Low

Surat city	1.20	Low	1.60	Low	3.00	High	1.80	Medium	1.20	Low
Narmada	1.00	Low	1.00	Low	3.00	High	1.20	Low	1.00	Low
Dadiapada	1.00	Low	1.00	Low	3.00	High	1.00	Low	1.00	Low
Tilakwada	1.00	Low	1.00	Low	3.00	High	1.20	Low	1.00	Low
Sagbara	1.00	Low	1.20	Low	3.00	High	1.00	Low	1.00	Low
Irrigated	1.15	Low	1.40	Low	3.00	High	1.87	Medium	1.47	Low
Rainfed	1.02	Low	1.27	Low	3.00	High	1.36	Low	1.04	Low
Total	1.08	Low	1.34	Low	3.00	High	1.62	Low	1.25	Low

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