All India Coordinated Research Project of Micro- and Secondary-Nutrients and Pollutant Elements in Soils and Plants

I. Historical background

During the initial years of introduction of the modem crop varieties, micronutrient deficiency disorders were discovered as an obstacle to obtain higher yields. In order to delineate the micronutrient deficient areas and to alleviate the nutrition stresses, the Indian Council of Agricultural Research initiated the All India Coordinated Scheme of Micronutrient in Soils and Plants in 1967 with its National Headquarter at the Punjab Agricultural University, Hisar (subsequently shifted to Punjab Agricultural University, Ludhiana in 1970) and 6 Coordinating centre located at Lucknow, Hisar, Jabalpur, Ranchi, Anand and Coimbatore. Later Ludhiana and Hyderabad centres were also created. Realizing the need for micronutrient researches three centres viz. Akola for Maharashtra, Bhubaneswar for Orissa and Pantnagar for Uttar Pradesh were established in the year 1996. The deficiencies of secondary nutrients and toxicities of heavy metal elements were subsequent noticed in many parts of the country. In view of this, the project mandate was expanded and its objectives were enlarged to include researches on these aspects in the project. The name of the project was changed to All India Coordinated Scheme of Micro- and Secondary- Nutrients and Pollutant Elements in Soils and Plants. Currently the Coordinating unit of the scheme is functioning w.e.f. 28.4.1988 at Indian Institute of Soil Science, Bhopal and has eight Cooperating centre. In VIIIth Five Year Plan three new centres at GBPUAT, Pantnagar, OUAT, Bhubaneswar and PDKV, Akola were created to develop technology for Uttar Pradesh and Maharashtra. These centre become functional in the year 1996. Of these, the centre at Lucknow is involved mainly in physiological research on micronutrient nutrition of plants while the remaining 10 centres concentrate their researches on the micro- and secondary- nutrients and pollutant elements in soils and plants.

Introduction of high yielding crop varieties in mid sixties brought a stirring green revolution that remarkably enhanced the agricultural production and made country self sufficient in food grain production. But in the process, it caused a greater depletion of soil fertility and soon deficiency of micronutrients especially that of zinc, cropped up in many areas. In the quest of further enhancing crop production to feed millions of people, more and more marginal lands were brought under intensive cultivation by extensive use of micronutrients free high analysis fertilizers which further aggravated the deficiencies of micronutrients all over the country. These deficiencies became a serious obstacle in achieving higher crop yields. In order to ensure correct diagnosis, proper delineation of micronutrient deficient areas and develop suitable amelioration practices in soils and plants, ICAR initiated "All India Coordinated Research Project of Micronutrient in Soils and Plants" in the year 1967 with six Cooperative centres. Later, two more new centres at Ludhiana and Hyderabad were added in the year 1975. Initially the project was functioning with its head quarter at HAU, Hisar which was subsequently shifted to PAU, Ludhiana during the year 1975.

Realizing the adverse effect of emerging sulphur deficiencies on crop yields and increased incidences of heavy metal pollution in agricultural soils, water and plants, the mandate of project was subsequently enlarged and its name was changed to “All India Coordinated Scheme of Micro- and Secondary- Nutrients and Pollutant Elements in Soils and Plants from 1988 onwards.

The post green revolution scenario of Indian agriculture is characterized by the problems, often referred to as second generation problems, of stagnation or even decline in productivity growth rates of major crops, deterioration in soil fertility and decline in factor productivity. Among these, emergence of multi micronutrient deficiencies in soils, plant, animal and human chain are increasingly reported and are posing threat to the nutritional security of the country.

Presently, coordinating unit of the project is functioning at IISS, Bhopal w.e.f. 28.4.1988. Three more cooperative centres were added in the year 1996, five new out sourcing centres were added in the year 2009, thus our project remain dynamic to serve current issues and problems of micronutrients nutrition and minimizing heavy metal pollution. Now project is functioning at 16 cooperative centres (Table 1 a & b).

Of these 16 centres, one centre at Lucknow University, Lucknow is involved mainly in physiological research on micronutrient nutrition of plants while the remaining 15 centres are conducting research on micro- and secondary- nutrients and pollutant elements in soils and plants.

Table 1 a. Location of the Project Head quarter and Cooperative centers

Location	**Date of start**	**State**	**Agro-ecological region**	**Soil type**
Project Coordinating Unit				
IISS, Bhopal	24.4.1988	Madhya Pradesh	Central high land (Malwa and Bundelkhand) hot sub-humid, Grid Northern Plain and Alluvial central hot semi-arid region	Medium and deep black alluvial soil
Cooperative Centres				
CCSHAU, Hisar	01.01.1967	Haryana	Western plain and Kutch peninsula hot arid	Desert & saline soils, silty-alluvial soils
RAU, Pusa	01.12.1967	Bihar	Eastern plain, hot sub-humid	Alluvial, clayey, red and lateritic
TNAU, Coimbatore	14.08.1967	Tamil Nadu	Eastern Ghats T.N. upland) & Deccan Plateau, hot semi-arid and hill soils	Red loamy soil black clay and red & lateritic soils
AAU, Anand	01.01.1967	Gujarat	Central (Malwa) high lands and Kathiawar	Medium and deep black, alluvial soils
Lucknow University	01.04.1967	Uttar Pradesh	Northern plain, hot sub-humid (Plant physiological research)	Alluvium derived and Tarai soils
JNKVV, Jabalpur	01.01.1967	Madhya Pradesh	Central high lands (Malwa & Bundel khand hot sub-humid)	Medium and deep black soil, red and black, alluvial
PAU, Ludhiana	10.10.1970	Punjab	Northern plain and Central highland hot semi-arid	Alluvium derived (Alluvial, sand to sand loam soils)

ANGAU, Hyderabad	01.08.1975	Andhra Pradesh	Deccan plateau & Eastern Ghats, hot semi-arid	Red and black soils
GBPUAT, Pantnagar	01.04.1996	Uttaranchal	Hill and tarai region, hot sub-humid	Alluvium derived and Tarai soils
PDKV, Akola	01.04.1996	Maharashtra	Deccan Plateau , Hot semi-arid	Medium & Shallow black soil
OUAT, Bhubneshwar	01.04.1996	Orissa	Eastern Ghat hot sub-humid	Red loam, red and lateritic soils

Table 1 b. Location of the new adhoc centres

Location	Date	State	Agro-eco. region	Soil type
CSKHPKV Palampur, H.P.	1-4-2009	Himachal Pradesh	Hill, sub humid	Hill & mountaneous soils , alfisol
CSUAT, Kanpur.U.P.	1-4-2009	Uttar Pradesh	Northern plain , hot semi-arid	Alluvium derived Indo Gangatic alluvial soil
Assam Agril. Univ. Johrat, Assam	1-4-2009	Assam	Hot sub-humid	Alluvium, hill, red, lateritic soils
BAU, Ranchi, Jharkhand	1-4-2009	Jharkhand	Eastern Santhal pargana hot semi-arid,	Red loam, red and laterite soils
BCKV,Mohan-pur, West Bengal	1-4-2009	West Bengal	Hot sub-humid	Alluvium, hill, red and lateritic soils

II. Project mandate and Objectives

The mandate of the Project to provide scientific basis for enhancing and sustaining productivity of soil resources with minimal environmental degradation with special reference to micro- and secondary nutrients and pollutant elements with following objectives.

1. To delineate micro and secondary nutrient deficient areas using GPS/GIS in the states so far remained uncovered.
2. Reassessment of micro- and secondary- nutrients (MSN) deficient/toxic areas by soil and plant analysis as well as through biological responses of crop in different soils.
3. Micronutrient indexing for forecasting emerging micro- and secondary- nutrients disorders and developing decision support system under different soil-cropping-management systems.
4. Standardize suitable soil test methods and establish critical levels for micro and secondary nutrient deficiencies and heavy metal toxicities in different soils and crops.
5. Developing suitable techniques for increasing fertilizer-use-efficiency including organic manures, sewage, sludge added for ameliorating the MSN deficiencies in crops and soils.
6. Monitoring heavy metal pollution and trace element toxicities in soils, plant and animal health.
7. Inducing deficiency/ toxicity symptoms for diagnosing micro- and secondary- nutrient deficiencies in field crops.

8. Identifying mechanism of micronutrient interactions in soils and their role in reproductive physiology of plants.
9. Screening of crop species and genotypes tolerant to micronutrient stress and heavy metal toxicities.

III. Thrust areas

- Development of GPS/GIS based soil fertility maps for five elements zinc, iron, manganese, copper and boron for eight states of country. Total approximately 100 districts soil fertility data will be made available.
- Total 10 – 12 agro ecological regions micronutrient deficiencies data will be made available.
- Delineation of micro and secondary nutrient deficient areas will be undertaken for two districts per year per centre for assessing micronutrient deficiencies in soil and crops, thus 75-80 districts additional district will be covered.
- Reassessment of micro- and secondary- nutrients (MSN) deficient/toxic areas by soil and plant analysis as well as by crop response will be carried out for 14-18 districts to know periodic changes in micronutrient deficiency.
- Amelioration techniques will be developed for increasing fertilizer-use-efficiency including organic manures, Sewage, sludge for ameliorating the MSN deficiencies in major (six) cropping systems.
- Studies will be planned to monitor health hazards from heavy metal pollution and trace element toxicities on soils, plant and animal health at some selected sites.
- Studies will be planned to characterize visual deficiency symptoms in crops, interaction among nutrients and their role in metabolism in plants and reproductive physiology for improving better diagnosis and understanding mechanisms of seed setting.
- Screening of crops and germ plasms tolerant to micronutrient stress and heavy metal toxicities will be carried out in major crops like wheat, rice, maize, pigeon pea, green gram for zinc, manganese, copper, etc.
- Newer technologies generated by the project will be demonstrated among the farmers, researchers, educationist, common people and literature will be published.

IV. Major Research Achievements of AICRP Micronutrients

1. Diagnosis of Micronutrient Disorders in Plants and Soils

- Proper diagnosis is the key for suggesting suitable corrective measures. Therefore characteristic visual deficiency symptoms of zinc, copper, iron, manganese and boron in major cereals, oilseed, and pulses crops have been characterized. Zinc, copper, iron boron and molybdenum deficiency symptoms in major vegetable and horticultural crops like potato, tomato, cauliflower, coriander, mango, citrus, french bean, brinjal, onion and of sulphur deficiency symptoms in oilseed, pulses and in cereals crops have also been characterized for precise diagnosis of nature of deficiency.

- Toxicity symptoms and their impact of growth, grain, shoot and root development was studied in refined sand culture.

2. Changes in plant metabolic and enzymatic activities from micronutrient supply

- Micronutrient supply influences the metabolic and enzymatic changes in plants and their quality. Studies were carried out to evaluate such changes due to differential nutrient supply in several crops. Owing to zinc deficiency in onion, the activity of peroxidase, carbonic anhydrase and acid phosphatase decreased in leaves and that of ribounuclease increased significantly at low levels of zinc supply. Similarly copper deficiency in rapeseed developed chlorosis from base to apex that influenced the activity of catalase and polyphenol oxidase in rapeseed leaves. With an increase in Cu supply from low to excess, the activity of peroxidase, ribonuclease and acid phosphatase decreased.

3. Critical concentration of micronutrients in plants

- The critical concentration for deficiency, threshold of deficiency, threshold of toxicity and toxicity were established under refined sand culture for crops like oilseeds, pulses and vegetables on which information was lacking. Critical limits of micronutrients in groundnut, horse gram, rapeseed, mustard and brinjal crops were established for various micronutrients.

4. Critical limits of micronutrient in soil

- Field and green house experiments were conducted to establish critical level of micro and secondary nutrient for various soils and crops.

5. Delineation of Micro and Secondary Nutrients deficient areas

- In collaboration with NBSSLUP Nagpur, total 55 GIS based soil fertility maps has been prepared at taluka/ district, state level/ national level and agro ecological zone wise. These have been given to the Secretary (Fertilizer), Ministry of Chemicals and Fertilizer for developing strategies for micronutrient manufacturing and supply under Prime minister mission on agricultural. Development. These maps are given to ICAR and Agriculture commissioner, Govt. of India for developing suitable strategies for correction of micronutrient deficiencies.
- Average deficiency of zinc, iron, copper, manganese was found in 48. 12, 5, and 4 percent soils, respectively in India. The deficiency of zinc was more in soils having low organic carbon, high soil pH, High calcium carbonate etc. Zinc deficiency is most wide spared. Its deficiency was recorded less than 40% in AEZ 1, 2, 5, 15, 16, 18, 19; 4050% in AEZ 9, II, 12; 50-55% in AEZ 4, 7, 13 and > 55% in remaining zones of country.
- Analysis of 90419 surface soil samples from AEZ 4, 9, 13, 16 mainly *for* Indo-Gangetic alluvial plain (IGAP) showed 55, 47 and 36% deficiency of zinc in Trans-northern, Central and Eastern parts of IGAP. Reverse trend was found for boron deficiency showing 8, 37, 68% deficient soils, respectively.
- Most of soils have tested to be adequate in available iron; but its deficiency in all AEZ as well as toxicity in some coastal, sub-montane and red lateritic soils is quite common. Studies summarize the occurrence of micronutrient deficiencies amongst and within Agro-ecological zones and magnitude of crop response for formulating

suitable micronutrient management strategies for specific AEZ, soil types and cropping systems for maximizing crop production. Deficiency of boron was found in 33% soil samples tested all over the country.

- Deficiency of boron is reported in several areas. Its deficiency is found wide spread in acidic soil and highly calcareous soils of Bihar, Saurashtra, parts of central India too. Boron deficiency varied from 2% in AER 2; 24-48% in highly calcareous soils of AEZ 2, 9 and 14 but most widespread (39-68%) in red and lateritic soils of AEZ 6, 13, 16, 17, 19. Over all 33% soil samples out of 50,000 soil samples.
- Deficiencies of Cu and Mn are not widespread and response of crops was found sporadic. Iron deficiency accounts 12% soils of the country which needs attention. Deficiency of Mn has been found wide spread in sandy alkaline soils having low organic matter under rice-wheat cropping system in Punjab. So wheat crop suffer badly from manganese malnutrition.
- Molybdenum deficiency is found sporadic and as such 13% soils are suffering with molybdenum deficiency.
- With continuous use of sulphur free high analysis fertilizer and lesser use of organic manure sulphur deficiency has appeared in many Indian soils. As such 41 percent soils are suffering with low sulphur status in the country. Oilseed and pulses growing areas in different states are more prone to its deficiency. Map showing sulphur deficiency has been prepared and published for the benefit of various user agencies.
- The knowledge about micronutrient deficiencies and its impact on crop yields was well visualized by the farmers so in several state use of micronutrients, mainly zinc sulphate, became a common practice. With the results status of zinc is improving and deficiency of zinc is declining in several soil-crop-management systems. On the other hand, deficiency of multi micronutrients surfaced in several areas due to continuous of depletion of micronutrient reserve of the soils.
- Nutrient indexing for micro- and secondary- nutrients in low and high productivity areas of different AER has been initiated in different soil-crop-management system. The programme has been initiated at all 11 centres with respect to monitoring of 20 bench mark sites for emerging micronutrient deficiencies at 2-3 sites representing different soil-crop-management systems.. Data of periodic survey is in initial years revealed that more and more area is suffering with multi nutrient deficiencies.

6. Amelioration of micronutrient deficiencies in cropping system

- Several field experiments were conducted to evaluate optimum rate, better source and method of application so as to enhance nutrient use efficiency. New products like Teprosyn zinc phosphate, Granubor II and Gromor sulphur bentonite were tested and found useful in correcting their deficiencies more efficiently. Integrated nutrient management and zinc enrichment to organic manure was tested. Zinc enrichment found better in enhancing zinc use efficiency by 25-50% over inorganic zinc application alone. Details of these experiments are given below.
- Amelioration of micronutrient is becoming a costly affair. The use efficiency of micronutrient is very low. So seed treatment is one of the promising techniques to enhance use efficiency of micronutrient. Total 22 field experiments were conducted at various centres. Micronutrient Teprosyn formulations having composition of Teprosyn F-2498 (600 g ZnL^{-1}), Teprosyn ZnP F-3090 (300 g Zn + 200 g P_2O_5 L^{-1})

, Teprosyn Mn F-2157 (500 g Mn L^{-1}) and Teprosyn Mo F-1837 (250 g Mo L^{-1}) were tested. High quantity of micronutrients is partially dissolved in acid and slurry is prepared to get desired concentration level of micronutrients such as Zn 300-600 g L^{-1}, Mn 500 g L^{-1} and Mo 250 g L^{-1} for seed coating .Result showed that seed treatment with Teprosyn Zn+P at the recommended level (8ml/ kg seed) increased the yields of several crops having bigger seed size and found beneficial. It is not suitable for small seed crops.

- Thus, considering the benefits accrued from seed coating treatments with above micronutrient formulations, the zinc phosphate (suspension) has been notified in the Fertilizer (Control) Order (FCO) 1985 vide amendment order notification under section 3 of the Essential Commodity Act, 1955 of Govt. of India with following specifications in respect to provisional fertilizer mentioned at sl.no. 3 in the FCO order dated New Delhi 12th May, 2003 with specification as zincated phosphate (suspension), specification under FCO for agricultural use:

Total phosphate as P_2O_5) percent by weight, minimum	300 g Zn L^{-1}
Total zinc (as Zn) percent by weight, minimum	200 g P_20_5 L^{-1}
Neutral Ammonium citrate sulphate phosphate	3.9 % as P_2O_5
Lead (as Pb) percent by weight, maximum	0.0038 +- 1.0

- Sulphur deficiency is commonly corrected though gypsum, SSP or ammonium sulphate. There is no sulphur fertilizer to correct its deficiency. A research net work was therefore initiated to study the efficiency of new source as Gromor sulphur bentonite having 90% S in elemental form. Field studies showed that direct use of S bentonite to improve the grain yield of crops. The effect was significantly superior or at par to SSP and gypsum but better over S control. Among the levels, all the three levels of Bentonite – S significantly increased the yield over S control and response was at par to gypsum and SSP. Highest grain yield was found under the treatment of 40-60 kg S ha^{-1} applied through Bentonite-S. In case of residual effect of S in maize-mustard sequence, application of S through different sources increased mustard seed yield over the S control and superior over 20 kg S/ha. Application of gypsum gave low residual effect than SSP and bentonite.

- Information is limited on Mo deficiency and its correction. So field experiment was initiated at RARS, Chintapalli in a Mo deficient acid soil to know the direct and residual effects of Mo in maize-niger cropping system at high altitude zone. Results indicated that foliar spray of 0.1 per cent sodium molybdate after applying lime to soil initially proved to be better in increasing in the yields of maize (37%), while in rabi soil application of 0.25 kg ha^{-1} sodium molybdate to maize and niger after liming the soil was found beneficial in niger and showed a yield response of 40 percent. Significant difference in Mo content and built up of Mo in the soils was recorded with Mo levels.
- In Ustipsamment of Badaun, the optimum dose of Zn fertilizer rice (cv. PD-10) was found 5.83 kg Zn/ha. Application of Zn improved yield attributes, seed yield and oil content in following mustard (cv. Kranti). Application of Zn increased the grain yield of rice and also increased protein and amylose content of milled rice. In Pearlmillet - wheat

rotation, application of 2.5 kg Zn +5 tonnes FYM ha^{-1} gave highest yields. Applications of zinc (2.5 kg Zn ha^{-1}) together with 5 tonnes FYM ha^{-1} were much effective in increasing grain yields in Pearl millet-wheat system. Under rice-wheat rotation, application of 2.5 kg Zn + 5 t FYM ha^{-1} after two crop cycles was found optimum.

- In a 3 year study, fertilizer use efficiency of Zn-using low doses of organics in rice-wheat rotation in Mollisol of Tarai indicated that application of Zn @ 1.25, 2.5 and 5.0 kg Zn enriched to 200 kg cow dung ha^{-l} increased the pooled grain yield of rice significantly by 17.62, 26.06 and 24.32 per cent over NPK control, respectively. No significant response of Zn application was recorded on the subsequent wheat crop**.**
- Field studies to develop IPNS technology for ameliorating zinc deficiency in sugarcane ratoon system at Bareilly showed that total millable cane yield of both main and ratoon crop was significantly higher on application of 2.5 tonnes PMC along with 5.5 kg Zn ha^{-1} . The yield was statistically at par with the highest millable cane yield recorded for treatment receiving 10 tonnes PMC + 11 kg Zn ha^{-1}.
- Rate and frequency of boron application was studied in different cropping systems. Soil application of borax at 0.25 to 1.0 kg B ha^{-1} to maize significantly increased the grain yield in over NPK. Significant influence of boron was seen on the residual crop of groundnut. Application of 1.0 kg B ha^{-1} to each of maize and groundnut crops gave significantly higher yield and showed higher buildup in the available boron in the soil.
- Ludhiana center observed a significant seed yield increase of Holea sarson from 140-220 kg ha-I (10.9 15.6%) to the application of 20-40 kg S ha^{-1}. Lentil also showed significant response to sulphur in sandy loam soils and gave 92 to 119 kg ha^{-1} (11-15%) extra grain yield with the application of 20-40 kg S ha^{-1}. Similarly in Haryana chickpea showed response to S application, in Hisar and gave 147 to 197 kg ha^{-1} (10-14%) extra grain yield. In medium black soils of Kheda districts chickpea gave 80-458 kg ha^{-1} (11-26) extra grain yield with the application of 20-40 kg S ha^{-1}.
- In Coimbatore application of FYM @ 12.5 t ha^{-1} recorded the highest grain yield of 5483 kg ha^{-1} and it was on par with the addition of sewage sludge @ 2.5 t ha-1+ FYM @ 12.5 t ha^{-1} and sewage sludge @ 2.5 t ha^{-1} + raw coirpith @ 12.5 t ha^{-1}. The micronutrient availability ranged in the order of Mn > Fe > Cu > Zn. Deficiency of Zn was noticed in all the treatments. The heavy metal availability in the post harvest soil showed non-toxic level irrespective of metals analyzed**.**
- Root and seed yield of Ashwagandha increased from 363 kg ha^{-1} in control to 595 and 517 kg ha^{-1} respectively with soil application of 5.5 kg Zn ha^{-1}. Minimum seed yield of 232 kg ha^{-1} was recorded in the control plots. Root yield increased significantly with the application of zinc either through soil or foliar sprays over the control. Increase in yield was recorded up to 63.9 % with the soil application and 23.69 % with foliar spray of zinc. Foliar application of 0.2% $ZnSO_4$ had increased the root yield but it was on par with the soil application of zinc by 10 kg ha^{-1}. Soil application of zinc resulted in higher seed yield compared to foliar application of zinc.
- Mentha (*Tagetes minuta*) is an important medicinal plant. Application of B and Zn significantly increased the dry matter yield of mentha but effect of S application alone was statistically not significant. The conjoint application of two nutrients together or all three nutrients also resulted a significant increase in the dry matter yield over the control..
- Zinc application (5 kg Zn ha^{-1}) increased the oil yield of *Tagetes minuta* significantly by 45.0 and 41.6 per cent over control. Oil yield was highest (78.7 to 84.8 kg ha^{-1}) in

treatment receiving or Zn + B. Oil yield is related to Zn./B ratio in plant tissue but no significant relationship was noted with either Zn/S or B/S. This indicated that the balance of Zn and B in the plant tissue of *Tagetes minuta* played a determining role in governing oil yield and Zn/B value around 1.09 to 1.23 resulted in the highest oil yield.

7. Efficacy of Multi Micronutrient Mixture in Improving Crop Production

- Multi micronutrient mixture grades for foliar and soil application was prepared in the laboratory equivalent to Govt. recognized grades for their testing in important crops under different agro-climatic situation of the Gujarat. Network studies in general indicated the superiority of different grades in increasing crop yields. Amongst the foliar grades, Grade – II (for Fe deficient soils) and Grade – IV (For Zn and Fe deficient soils) were found more effective in most of the crops of various groups viz., cereals (maize, sorghum, bajri and wheat), vegetables (potato, cabbage okra) and pulse like pigeon pea. The soil application Grade–V was also found more useful in oilseed like castor and mustard and found equally effective with foliar Grades–II and IV to cereals crops. Further, the general foliar grade (Grade – I) was also found effective in paddy and summer groundnut.
- Amongst the cereals, the maximum improvement in *kharif* paddy grain was recorded up to 766 kg ha^{-1} over control due to general foliar grade–I. In case of vegetables, potato tuber yield was increased by 8190 kg ha^{-1} equivalent to 22.6 % increase over control (362.5 q ha^{-1}) due to foliar grade–III .The multi micronutrient grades have also been found beneficial in increasing yield of oilseeds. The maximum increase was due to soil application of grade- V to the tune of 579 kg ha^{-1} over control (2091kg ha^{-1}) in castor .The increase in pigeon pea grain yield was by 436 kg ha^{-1} due to grade – IV over control (1250 kg ha^{-1}). These grades were also found effective in fodder crops viz. maize and sorghum .Thus, the use of multi micronutrient mixture foliar grade-IV at the rate of 1 % and soil application Grade–V @ 20 kg ha^{-1} have shown their usefulness in increasing yield of different crops in soils of Gujarat.

8. Monitoring health hazards from heavy metals and trace element pollution

- Survey in and around the Adilabad district, where pollution is caused mainly due to ginning mills, cement industries etc. revealed that the water samples are neutral to alkaline in reaction with normal soluble salt status. Micro nutrients and heavy metal status is within the permissible range. Soils are slightly alkaline in reaction and non-saline. Soils are polluted with cadmium (46%), cobalt (50%), lead and manganese (7%). Water and soil samples collected near cement factories are more polluted compared to other industries. Pollution hazard decreased both in soils and waters as the distance away from the factory is increased

9. Remediation of heavy metals and critical toxic concentrations in soil and plant tissues

- Studies to evaluate efficacy of different crop species for phytoremediation of cadmium contaminated soil .indicated that spinach and marigold showed higher tolerance to Cd accumulation as compared to fenugreek and ladyfinger. Among the crop species tested, spinach appears to be the best for remediation of Cd contaminated soils although marigold merits attention because of its non-consumable nature. Considering 25% dry matter yield decrement was encountered, approximately around 15, 16, 14 and 13 mg kg-1 DTPA-extractable cadmium level was found critical for fenugreek, spinach, marigold and ladyfinger, respectively. A decrease of 25% in dry matter yield was recorded approximately around 20.41, 63.62, 72.09 and 24.82 mg kg^{-1} Cd content in plant tissue for fenugreek, spinach, marigold and lady finger, respectively.

- Bioremediation measure is now a day adopted to reduce the heavy metal load in agricultural field. Keeping in view, a laboratory experiment was also conducted to know the bio-sorption capacity of heavy metals (cadmium and chromium) by different fungi viz. *Pleurotus florida*, *Fussirum oxiporum*, *Penicillium* sp. and *Aspergillus awamorii* to mitigate the problem of heavy metals accumulation in soils and crops irrigated with sewage water. Growth of those fungi was studied with the graded doses of Cd (2.5, 5, 10, 15 and 20 mg/L) and Cr (2.5, 5, 10, 15 and 20 mg/L). It was found that amongst the fungi, *Pleurotus florida* sorbed highest amount of heavy metals and can survive at higher levels of heavy metals. So *Pleurotus florida* can be used as a bio-filter to remove the heavy metals from sewage water.

10. Front line demonstration

- More than 120 FLDs were conducted to show responses of zinc, iron, boron, manganese on oilseeds, pulses and major cereal crops in different agro-ecological zones. Application of 5-10 kg zinc/ha, 1.0-1.5 kg boron /ha and 20-40 kg sulphur/ha was found optimum and is widely recommended to the farmers.
- Spectacular response of cereals, pulses, oilseeds and cash crops to B application (0.5-2.5 kg/ha) have largely been observed on B-deficient soils of Bihar, Orissa, West Bengal, Assam and Punjab (Table 10). The rates of B application for achieving optimum yield varied with crops, season, type of soil. Mustard, maize, sunflower, onion and lentil gave optimum yields at 1.5 kg/ha. of B application and that of *kharif* (summer) crops groundnut, maize, onion, yam bean and black gram gave the best yield at 2.0-2.5 kg B/ha. Application of 2.5 kg B/ha causes reduction in yield due to boron injury.

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