Nutrients removed from the soil decide the nutritional security of a nation: the case of iron and zinc in India

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National iron (Fe) and zinc (Zn) balance were computed using theoretical mean daily per capita dietary Fe and Zn requirement and composition of Fe and Zn in foods in agriculture, horticulture, animal husbandry and fisheries sectors. The analyses imply a satisfactory situation that the intake of Fe and Zn through food sources by the Indian population is adequate. Despite sufficient availability of Fe and Zn through food, there is widespread Zn and Fe deficiency in our population. Ours is a vegetarian-dominant society. The phytate content of our foods is relatively high as the phytate content of vegetarian diets is high. This may be the main cause of the low absorption of Zn and Fe from the foods we eat. A sector-wise contribution indicated a major share of the agriculture sector, followed by the animal husbandry sector. Surprisingly, horticulture sector contributed a small portion (9.1% Zn and 12.9% Fe). The fisheries sector contributed the least. Given the multiple sources of uncertainty in following this method, caution must be exercised in interpreting the estimated figures for prevalence. Since our food sources are supplying enough Fe and Zn, our research efforts should therefore be diverted towards bioavailability rather than bio-fortification.

Keywords: Bioavailability, food sources, iron, micronutrient deficiency, vegetarian diet, zinc.

THE intellect and physical endowment of human beings decide the economic capacity or potential of an individual. Human brawn and brain are the prime movers behind such success. In the final analysis, it is seen that brawn develops the brain. The brawn is attributable to soil and air. Therefore, the continuum: soil–plant/animal–human chain. Our food production is sufficient to make it easy for us to get calories, but this is not always high in quality, nor are we sure that it is nutrient-dense. It may not be an exaggeration to state that India is a country of malnourished people. The reason is unknown. Emergence of lifestyle diseases has drained the exchequer in the health sector. Work efficiency of the population is on a drastic decline owing to chronic fatigue in youngsters eating junk food. Despite the Green Revolution which resulted in increased food production, we inherited a legacy of an inherently leaky and unsustainable agricultural system. We mined excessive nutrients from the soil. We ignored the other ecosystem services and food quality, particularly nutrients in the food. Micronutrient deficiency in our diet is an issue we cannot afford to ignore. It demands our attention not only because of the importance of optimal nutrition, but also due to its impact on healthcare cost.

With improvement in economic status and market globalization, a nutrition transition is taking place leading to rapid changes in lifestyles and dietary habits[1] and intake of energy-dense foods not containing adequate amounts of vitamins and minerals is on the increase[2]. As a consequence, grossly inadequate micronutrient uptake in the populace is leading medically to poor growth/development and cognitive performance, and in increased susceptibility to infections[3,4]. Micronutrient deficiencies are prevalent even among the non-obese, well-nourished children[4,5]. Evidence is mounting on the importance of micronutrients for immune function, capacity for physical work and cognitive development, including learning ability in children. Cereal and tuber-based diets are relatively low in minerals such as iron (Fe) and zinc (Zn), but inclusion of legumes in food can improve Fe content slightly in these diets. However, due to high phytate content the absorption of these nutrients by the body from such non-heme Fe is low. Hence there is practical difficulty in meeting the daily requirement of Fe and Zn through staple diets. To overcome this problem we need to include some fruits, meat, poultry or fish in our diet. It has already been shown that a small portion (25 g) of a fruit like guava or aonla, or 50 g of meat, poultry or fish can increase total Fe content and enhance the absorption of Fe from food. Similarly, inclusion of a small portion (50 g) of meat, poultry or fish can secure Zn in most staple diets.

Efficiency of absorption apart, it is high time we looked at a national level if our food sources are removing sufficient amount of minerals from the soil, manures or fertilizers to meet the daily requirement of micronutrients in our population. Are we removing less, leading to malnutrition in our population? Or, are we removing more than required, ending up in exporting these to other nations? There is an urgent need to arrest the current rate of soil-nutrient stripping to produce quality food and to enhance the use efficiency of synthetic fertilizers that we employ.

We have examined agricultural sustainability (in the case of Fe and Zn) that considers nutritional quality of food holistically, nutrient removal from the soil, export/recycling, and societal needs to socially and environmentally re-engineer our agricultural systems at all levels. We suggest that this can be best realized by taking initiatives at the national level. Failure to do so will inevitably lead to an explosion in health problems, particularly in the younger generation, and cause a rapid decline in the delivery of provisioning services within our

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Table 1. Percentage distribution of population by broad age-groups to total population by sex and residence based on the 2011 census

		Broad age-group (years)							
Residence (location)	Sex	0–4	5–9	10–14	0–14	15–59	60+	15–64	65+
Overall total	Total	9.7	9.2	10.5	29.5	62.5	8.0	65.2	5.3
	Male	9.9	9.4	10.7	30.0	62.2	7.7	65.0	5.0
	Female	9.5	9.0	10.3	28.8	62.8	8.4	65.5	5.7
Rural	Total	10.3	9.5	11.0	30.9	61.0	8.1	63.7	5.4
	Male	10.5	9.7	11.3	31.5	60.7	7.8	63.4	5.1
	Female	10.1	9.4	10.8	30.3	61.3	8.4	63.9	5.8
Urban	Total	8.2	8.3	9.0	25.5	66.6	7.9	69.4	5.1
	Male	8.3	8.6	9.2	26.1	66.2	7.6	69.1	4.8
	Female	8.0	8.1	8.8	24.9	66.9	8.2	69.7	5.5

Figures for the total may not add up to exactly 100 on account of rounding-off in broad age-groups (source: www.censusindia.gov.in).

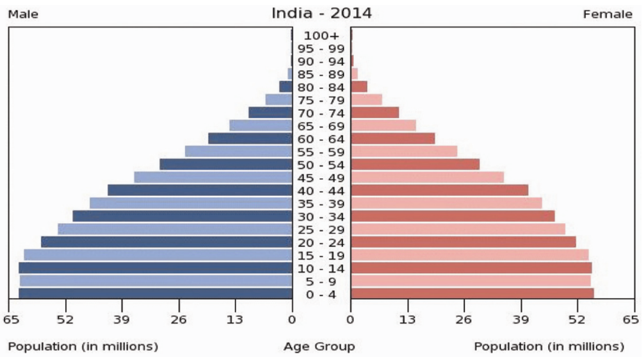

Figure 1. The Indian population pyramid (source: www.censusindia.gov.in).

agricultural system. Correcting this malady without any further delay can lead to a healthy nation, enhance work efficiency of our people, and reduce expenses in our health sector.

Age–sex structure is one of the most important characteristics of the composition of a population for understanding the nutritional requirements of a nation. According to the 2011 census, India has a total population of 1210.19 million, comprising 623.72 million males and 586.47 million females. Figure 1 shows the structure of the population pyramid in India.

Usefulness of data on age is better noticed when they are cross-classified by variables like specifics on children, adolescents, adults, etc. for nutritional requirement which varies with age, in different patterns. Table 1 presents the distribution of population into broad age-groups vis-à-vis the total population by sex and location (urban/rural). This forms the basis for calculating national requirement of Fe and Zn, to help understand nutritional security of the country.

In human beings the optimum total-body Fe is estimated at ~3.8 g in men and ~2.3 g in women. All the Fe is not used by the body, but only ~30–40 mg/kg is functional Fe and ~0–20 mg/kg is storage Fe (European Food Safety Authority, 2015). However, Fe requirement is elastic and depends upon age, sex, phase of life and increased periodic physiological needs. Anaemia is the primary symptom of Fe deficiency in humans. However, it is a late indicator of Fe deficiency. It is estimated that prevalence of Fe deficiency is 2.5 times that of the anaemia prevalent. It is 39% among children of <5 years, 48% in children of 5–14 years, 42% in women of 15–59 years, 30% in men of 15–59 years and 45% in adults of >60 years. These staggering figures have important economic and health consequences for low- and middle-income people[6]. Anaemia and Fe deficiency lead to substantial losses in physical productivity in adults. Fe deficiency during pregnancy is associated with maternal mortality, pre-term labour, low birth weight and infant mortality. In children, Fe deficiency affects cognitive and motor development and increases susceptibility to infections[7,8]. Highest prevalence of anaemia is seen in children of <10 years, followed by women and older adults. A vast majority of the cases of anaemia are microcytic, suggesting that Fe deficiency is the main cause of this condition.

Anaemia is prevalent in all age groups and all segments of the population in our country. Pregnant women, adolescent boys and girls, and young children are most affected. However, females are more vulnerable to this malady.

The human body generally contains 2 g of Zn of which 60% is stored in skeletal muscle and bone mass. The body mass contains about 30 mg/g of Zn. But the plasma Zn which accounts for only about 0.1% of the total body Zn has a rapid turnover rate. The eye choroids have the high concentration of Zn (274 μg/g) followed by the prostatic fluids (300–500 mg/l)[9].

Zn is responsible for the activation of several enzyme systems in the body. Some of the most important systems include enzymes involved in cell division, immunity, gene expression and reproduction[10]. Linear growth in young children is directly influenced by the dietary intake of Zn. Further complicated pregnancy, non-healing leg ulcers and infants' neurobehavioural disturbances are among important expressions of Zn deficiency. These problems are common in developing countries due to low dietary-Zn intake and are responsible for about 4% of child mortality[11,12]. Studies demonstrated that 49.4% of adolescent girls in Delhi[13] and 52% of non-pregnant women in central India[14,15] suffered from Zn deficiency. As the Indian soils are Zn-deficient, so are Indians. The link between Zn-deficient soils and Zn deficiency in humans is especially prevalent in India that relies on cereal grains as the main source of calorie intake. Twenty-six per cent of the population (312 million people) in India is at risk for Zn deficiency.

Absorption of Fe from various Indian diets was studied by Apte and Iyengar[16]. Their chemical-balance studies reported the absorption to vary from 7% to 20% with a mean of 10%. The same varied from 7% to 30% during pregnancy, and 33% at gestational weeks 8–16, 27–32 and 36–39 respectively. The National Nutrition Monitoring Bureau (NNMB) diet surveys form the basis for calculating the intake of Fe. It has been found that the magnitude of differences in Fe content when it is chemically analysed or computed fairly match with each other. This confirms that the estimates from diet surveys reflect actual intakes. We need an accurate measure of Fe content as well as its bio-availability from the Indian diets, to calculate recommended daily allowance (RDA). The NNMB committee critically reviewed all the data available from India on Fe absorption and its utilization from different dietary sources.

Fe absorption is inversely related to body Fe-stores, but Indians have lower Fe-stores compared to their peers in the developed world. In this situation a realistic estimate of Fe absorption would be 5% for all physiological groups, except for adult women (where it can be in the 8–10%) range. Though the World Health Organization (WHO)/Food and Agriculture Organization (FAO) list three bio-availability levels of 5%, 10% and 15%, the present committee recommends the use of only two tiers: 5% (men and children) and 8% (all women). Recent stable-isotope studies[17] have shown that in infants aged 6–12 months, the absorption of Fe is 15%. In the Indian context, absorption of Fe from a cereal–pulse-based diet in an adult male is 5%, and a conservative figure of 8% is considered for women (who are expected to have better absorption due to Fe-deficient store).

The International Zn Nutrition Consultative Group (IZiNCG) has reviewed the recommendations of WHO, Institute of Medicine (IOM), Food and Nutrition Board of United States of America (FNB) and IZiNCG. Information on dietary Zn content in India is scanty. The present dietary intake of Zn in India appears to range from 7 to 12 mg/day. This is lower than those of the Western countries. Apart from this, the absorption of Zn from the phytate-rich Indian vegetarian (mixed cereal/pulse) diets is expected to be poor. The Indian diets generally have a Zn–phytate molar ratio of >15. This leads to low bio-availability of less than 15% as against 20–25% seen with low phytate/animal food-rich diets.

The Indian population seems to be exposed to only a marginal risk of inadequate Zn at the intake of 9–11 mg/day, as indicated above. Further studies conducted in India on regional diets showed positive balance at their intake of Zn as high as 25 mg. However, based on data generated on the Western populations consuming low phytate foods, expert committees' reviews showed low absorption. These recommendations only lead to higher recommendations of RDA. Hence the NNMB recommended that up to the computation of requirements, criteria set by IZiNCG be followed, and any correction for bio-availability should be based on the actual data obtained in the Indian population of 20–25% absorption at habitual levels of intake. We used the upper limit of 25% to calculate Zn requirement from the average diet, including vegetarian and non-vegetarian foods[17].

The national needs for Fe and Zn are computed by averaging the requirements of different population groups specified by age, sex, weight and physical activity. This again depends upon the size of each age–sex group and is computed by averaging the requirements of representatives of the population. For generalized national requirement we considered pregnant and lactating women as normal adults. Table 2 presents the generalized age- and sex-wise requirements of Fe and Zn. This has provided the basis for calculating the national-level annual requirement of Fe and Zn in the country.

The total annual requirement of Zn and Fe in the population of India was computed using age- and sex-wise RDA, in population figures according to the 2011 census (Table 3). The country as a whole requires 8170.525 tonnes of Fe and 4412.485 tonnes of Zn in the food to meet nutritional Fe and Zn requirement.

Sources of Fe and Zn to human beings are the minerals present in the food, apart from dietary supplements of Fe and Zn in the form of tablets and fortification. We have made an assumption that intake of sufficient quantity and variety of foods will meet the nutritional needs of individuals. The nutritional value of food is assessed based on protein and energy requirements alone. But these assessments must invariably include the mineral nutrition also. For example, cereals and tubers are low in mineral density compared to pulses, fruits and vegetables. Similarly, the bio-availability of minerals also depends upon the sources. Bio-availability of Fe and Zn is better with intake of non-vegetarian foods. For example, adding a small portion of fruits, meat, poultry or fish can increase the total Fe content as well as the amount of bio-available Fe. For Zn, presence of a small portion of meat, poultry or fish can secure dietary sufficiency in most staple diets.

Foods originating from plants are classified and grouped in various ways. For example, it can be grouped into field crops, plantation crops, commercial crops,

Table 2. Age-wise and gender-wise requirement of iron (Fe) and zinc (Zn) in humans

Group	Age	Sex	Fe (mg/person/day)	Zn (mg/person/day)
Children	(0–4)	Male and female	9	5
	(5–9)	Male and female	14.5	7.5
Pre-adolescents	(10–14)	Male and female	27.5	10
Adults	>14	Male	17	12
		Female	21	10

Source: Reconstructed from ref. 17.

Table 3. Total Fe and Zn requirement (tonnes/year) for the Indian population

Group	Age (years)	Sex	Population (crores)	Fe (mg/d)	Fe (tonnes/day)	Fe (tonnes/year)	Zn (mg/day)	Total Zn Req (tonnes/day)	Zn req (tonnes/year)
Children	(0–4)	Male and female	11.737	9	1.056	385.44	5	0.587	214.255
	(5–9)	Male and female	11.132	14.5	1.614	589.11	7.5	0.85	310.25
Pre-adolescents	(10–14)	Male and female	12.705	27.5	3.494	1275.3	10	1.27	463.55
Adults	>14	Male	42.35	17	7.2	2628.0	12	5.082	1854.93
		Female	42.955	21	9.021	3292.665	10	4.3	1569.50
		Total	85.305						
Total			120.879	17.8	22.385	8170.525	8.9	12.07	4412.485

horticultural crops, forage crops and grasses or cereals, roots and tubers, nuts and seeds, fruits and vegetables, or food from trees and food from annuals, etc. However, there is overlap between these groups, and a particular plant may appear in more than one group. In nutrition, several ways of grouping foods have been tested; but, grouping based on commercial value, e.g. cereals, roots and tubers, nuts and seeds, fruits and vegetables is considered for working out Fe and Zn content obtained through food crops.

Foods from animal sources (eggs, milk, fish, chicken, mutton, beef and pork) are dealt with separately to calculate Fe and Zn supply through food crops. These calculations were made on the basis of mean Fe and Zn content in different foods (various published sources). Table 4 presents the total Zn and Fe availability calculated from different food sources in India. Availability of Zn from food sources is estimated at 6335.20 tonnes/year, and that of Fe at 10,939.30 tonnes/year.

Table 5 gives the national balance between availability and requirement of Fe and Zn. The present analyses suggest a sufficiency in supply, rather a little excess, of Fe and Zn through food sources in the country. Per cent excess supply of Fe and Zn from various food sources produced from Indian soils was found to be 33.9 and 43.6, respectively. These analyses also imply a satisfactory situation that the intake of Fe and Zn through food sources by the Indian population is adequate. In estimates of the adequacy of Fe and Zn intake, since there are multiple sources of uncertainty, considerable caution needs to be exercised in interpreting prevalence figures; these should not be considered as numeric absolutes. Further bifurcation of Table 5 into state-wise balance sheet is required for preparing an area-specific action plan. Thus, interstate inferences can be drawn on the relative availability of Fe and Zn through food using the information of rank orders. With the emergence of this scenario, four questions may be raised: (1) Why is such widespread Fe and Zn deficiency reported in the country? (2) Is the prevalence of Fe and Zn deficiency in the population related to poor bioavailability? (3) Does the RDA of Fe and Zn need revisiting? (4) What needs to be done to overcome these problems?

Relative contribution of different food sources and broad food sectors was computed based on the total national requirement. Within a given sector individual sub-sector data were also computed (Table 6). The agriculture sector, including cereals, pulses, oilseeds and sugars, contributes a major share of 78.6% Zn and 82.8% Fe requirement. This is followed by 11.7% and 3.9% respectively, from the animal husbandry sector, including milk and milk products, meat, mutton, beef, pork, chicken and eggs. Horticultural sector (including fruits, vegetables and nuts) which was surmised to contribute a major portion to mineral nutrition of humans, contributes only a small portion of 9.1% Zn and 12.9% Fe to national production. The least, i.e. 0.62% Zn and 0.42% Fe comes from the fisheries sector.

Concentration of Zn in blood or tissue does not give any indication of the Zn status in the human body. It is the prevalence of stunting; dietary Zn intake and plasma Zn concentration are the best indicators of population risk of Zn deficiency[18]. This is the unanimous recommendation of WHO, UNICEF, International Atomic Energy Agency and IZiNCG. However, in the Indian context we do not have relevant data from a representative sample of

Table 4. Total Zn and Fe available to Indian population from various foods

Food source	Zn (mg/100 g)	Fe (mg/100 g)	Production (MT; 2013–14)	Zn (g/tonnes of food)	Fe (g/tonnes of food)	Total Zn availability (tonnes)	Total Fe availability (tonnes)
Cereals							
Rice	1.08	1.32	106.65	10.8	13.2	1151.82	1407.78
Wheat	1.62	3.89	95.85	16.2	38.9	1552.77	3728.565
Sorghum	2.24	6.51	5.54	22.4	65.1	124.096	360.654
Maize	1.48	3.21	24.26	14.8	32.1	359.048	778.746
Bajra	3.8	6.5	9.25	38	65	351.5	601.25
Finger millet	1.73	2.13	1.98	17.3	21.3	34.254	42.174
Pulses				0	0	0	0
Chickpea	2.03	4.95	9.53	20.3	49.5	193.459	471.735
Green gram	2.4	4.55	1.61	24	45.5	38.64	73.255
Red gram	2.35	4.93	3.17	23.5	49.3	74.495	156.281
Black gram	2.3	6.46	1.7	23	64.6	39.1	109.82
Cowpea	2.57	4.79	0.35	25.7	47.9	8.995	16.765
Oilseeds							
Groundnut	3.27	4.58	9.71	32.7	45.8	317.517	444.718
Soybean	4.89	4.5	11.86	48.9	45	579.954	533.7
Sunflower	5	5.25	0.504	50	52.5	25.2	26.46
Rapeseed and mustard	1.6	3.8	7.877	16	38	126.032	299.326
Fruits							
Apple	0.04	0.12	2.585	0.4	1.2	1.034	3.102
Banana	0.15	0.26	29.725	1.5	2.6	44.5875	77.285
Grapes	0.07	0.36	1.737	0.7	3.6	1.2159	6.2532
Guava	0.23	0.26	3.668	2.3	2.6	8.4364	9.5368
Citrus	0.07	0.4	11.147	0.7	4	7.8029	44.588
Mango	0.04	0.13	18.431	0.4	1.3	7.3724	23.9603
Pineapple	0.12	0.29	2.498	1.2	2.9	2.9976	7.2442
Papaya	0.07	0.1	5.639	0.7	1	3.9473	5.639
Sapota	0.1	0.8	1.744	1	8	1.744	13.952
Pomegranate	0.35	0.3	1.346	3.5	3	4.711	4.038
Jackfruit	0.42	0.6	1.572	4.2	6	6.6024	9.432
Aonla	0.12	0.31	1.225	1.2	3.1	1.47	3.7975
Vegetables							
Brinjal	0.16	0.24	13.558	1.6	2.4	21.6928	32.5392
Cabbage	0.18	0.47	9.039	1.8	4.7	16.2702	42.4833
Cauliflower	0.27	0.42	8.573	2.7	4.2	23.1471	36.0066
Okra	0.6	0.8	6.346	6	8	38.076	50.768
Onion	0.17	0.21	18.736	1.7	2.1	31.8512	39.3456
Peas	1.24	1.47	3.869	12.4	14.7	47.9756	56.8743
Tomato	0.17	0.3	19.402	1.7	3	32.9834	58.206
Potato	0.33	0.73	41.555	3.3	7.3	137.1315	303.3515
Sweet potato	0.3	0.61	1.088	3	6.1	3.264	6.6368
Leafy vegetables	0.2	7	2.92	2	70	5.84	204.4
Beans	1.8	3.6	1.37	18	36	24.66	49.32
Chilli	0.26	1.2	1.687	2.6	12	4.3862	20.244
Tapioca	0.2	2.1	8.139	2	21	16.278	170.919
Radish	0.28	0.34	2.484	2.8	3.4	6.9552	8.4456
Others							
Nuts	3.5	5.6	2.1	35	56	73.5	117.6
Sugar (white)	0.01	0.03	27.7	0.1	0.3	2.77	8.31
Eggs	1.1	2	1.8	11	20	19.8	36
Milk	0.4	0.2	132.4	4	2	529.6	264.8
Fish	0.6	0.7	6.57	6	7	39.42	45.99
Chicken	1.2	0.7	2.6	12	7	31.2	18.2
Mutton	3.3	2.5	0.8	33	25	26.4	20
Beef	3.3	2.4	3.4	33	24	112.2	81.6
Pork	3.5	1.2	0.6	35	12	21	7.2
Total availability from various foods						6335.20	10939.30

Table 5. Total requirement and availability (tonnes) of Zn and Fe from different foods

Mineral	Total availability through food sources	Annual requirement	Net balance of nutrients at national level	% deficit supply through food
Fe	10,939.3	8,170.53	+2,768.77	Nil
Zn	6,335.2	4,412.49	+1,922.71	Nil

Table 6. Food sector-wise availability of Zn and Fe

Sector	Zn availability (tonnes)	Fe availability (tonnes)	% Zn contribution	% Fe contribution
Agriculture				
Cereals	3,573.488	6,919.169	56.41	63.25
Pulses	354.689	827.856	5.60	7.57
Oilseeds	1,048.703	1,304.204	16.55	11.92
Sugar	2.77	8.31	0.04	0.08
Total agriculture	4,979.65	9,059.54	78.6	82.8
Horticulture				
Fruits	91.9214	208.828	1.45	1.91
Vegetables	410.5112	1,079.5399	6.48	9.87
Nuts	73.5	117.6	1.16	1.08
Total horticulture	575.93	1,405.97	9.1	12.9
Animal husbandry				
Milk and milk products	529.6	264.8	8.36	2.42
Others (meat, mutton, beef, pork, chicken and eggs)	210.6	163	3.32	1.49
Total Animal husbandry	740.2	427.8	11.7	3.91
Fisheries				
Fish	39.42	45.99	0.62	0.42
Total	39.42	45.99	0.62	0.42
Grand total	6,335.2	10,939.3		

the national population. The existing rough estimates suggest that Fe and Zn deficiency may be fairly common. For this reason only the national food balance sheets can help in estimating the quantities of total and absorbable Fe and Zn in national food supplies. These results may provide useful information regarding the estimated prevalence of inadequate Zn and Fe intake in the population compared to the theoretical requirements for Zn and Fe in the respective population.

Ours is a vegetarian-dominant society having relatively high phytate – the main cause of low bio-availability of Zn and Fe by Indians. Conflicting arguments are made that phytate has beneficial roles as an antioxidant and anti-carcinogen. But this argument is shadowing the absolute necessity to improve the bio-availability of essential minerals in our foods. Several methods are available to reduce the phytic acid content of Indian foods and improve the bio-availability of minerals. Especially South Indian foods have the process of fermentation, soaking and germination which reduces phytate leading to enhanced bio-availability. Other methods like minimal milling, vitamin C intake, heating, enzymatic treatment of grains with phytase enzyme and maintaining a low pH in the gut through gut floral manipulation, as well as genetic improvement of food crops may enhance bio-availability.

This basic information cautions us that our efforts and directions in tackling nutritional security need a review. The mineral content of the food per se is not the cause of Fe and Zn deficiency in the country and the quantity of intake appears satisfactory. It is the bio-availability that needs focus rather than the intake of minerals. Methods available for reducing the phytic acid content of Indian foods for improving the bio-availability of minerals should find prime place in nutritional programmes and extension activities. Further efforts are needed to find easier methods to reduce phytate in Indian foods. Plant and animal breeders need to re-orient their programmes to assure adequate supply of bio-available forms of minerals from food rather than total mineral content. Institute/State/national-level variety release committees must take into account bio-available nutritional status of the product per se and production technology for each variety before its release for cultivation. Biotechnological efforts must divert the attention towards bio-availability rather than bio-fortification of minerals to enhance absorption of Fe and Zn consumed through plant food. Further, we must do all we can to ensure a healthy soil and a healthy production environment, with good agricultural practices.

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Status of zinc fractions in soils of Cooch Behar district, West Bengal, India

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A study was conducted on the distribution of different forms of zinc (Zn) in soils (0–20 and 20–40 cm depths) in different blocks of Cooch Behar district, West Bengal, India. The soils of the selected areas were acidic in reaction (pH) at both the depths, ranging from 4.23 to 6.96 (0–20 cm) and 3.89 to 6.45 (20–40 cm) and having sandy to sandy loam texture. The different fractions of Zn varied among the soils of all locations. The order of different zinc fractions was: exchangeable zinc (Ex-Zn) < organic matter-bound zinc (OM-Zn) < manganese oxide-bound zinc (Mn-Ox-Zn) < crystalline oxide-bound zinc (Cry-Ox-Zn) < amorphous iron oxide-bound zinc (Am-Ox-Zn). Am-Ox-Zn was relatively higher in the soils of Mekhliganj, i.e. 1.56 kg ha^{-1} at 0–20 cm depth and 0.92 kg ha^{-1} in the soils of Tufanganj-II at 20–40 cm depth respectively. Exch-Zn, OM-Zn, Mn-Ox-Zn and Am-Ox-Zn were positively correlated with CEC ($r = 0.088$, $r = 0.105$, $r = 0.137$, $r = 0.103$) at 0–20 cm depth, while at 20–40 cm depth, Exch-Zn, OM-Zn, Mn-Ox-Zn, Am-Ox Zn and Cry-Ox-Zn were positively correlated with CEC ($r = 0.204$, $r = 0.168$, $r = 0.342$, $r = 0.123$, $r = 0.278$). The influence of different soil properties on the distribution of Zn-fractions in the soils was apparent from this study.

Keywords: Acid soil, cation exchange capacity, terai region, zinc fractions.

THERE is continuous mining of not only the major plant nutrients like nitrogen, phosphorus and in some cases potash, but also secondary nutrients like sulphur, calcium and magnesium from the soils. In some regions of West Bengal (WB), India, the deficiency of micronutrients like zinc (Zn), boron and to a limited extent iron, manganese, copper and molybdenum in soils have been reported. This also occurs due to the use of high analysis fertilizers, increasing areas with high-yielding crop varieties or by increasing the cropping intensity which in turn affects the production and productivity of crops. Zn is essential for plant growth and development[1]. In sandy soil, the deficiency of micronutrients is prominent due to the low organic matter content and other available plant nutrients[2]. The different forms of zinc in soils are: primary and

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