Micronutrient Status in Different Agro-climatic Zones of Haryana, India

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Abstract

Indian Agriculture has undergone a revolution in the last 40 years and self-sufficiency in food-grain production has been attained. The increase in food-grain production has simultaneously created a problem of nutrient imbalance in soils due to extra mining of macro- and micronutrients. These imbalances have not only adversely affected the growth of agricultural production but also affected the chemical and physical conditions of soils. In addition the deficiency of micronutrients in soils has also resulted in food of poor nutritive quality. A widespread incidence of iron deficiency anaemia among young children and pregnant women in India has been reported in many studies. A number of authors revealed that 49% of Indian soils are deficient in Zn, 12% in Fe, 5% in Mn and 3% in Cu.

In India, Haryana is the second most important state contributing to the central food grain pool. A case study was carried out on mining of micronutrients from soils in the two agro-climatic zones of the state: the southwestern (SW) zone and the northeastern (NE) zone. The main crops in the SW zone are pear millet, cotton, gram, raya, and wheat, and in the NE zone rice, wheat, and sugar cane. The food-grain production in Haryana increased from 2.59t in 1966/67 to 13.30t in 2001/02, with projected estimates of 14.15t and 15.60t in 2005 and 2010, respectively. This increase has led to extra mining of nutrients from the soil. Farmers in Haryana generally apply fertilisers containing major nutrients only, as a result of which every year more areas are becoming deficient in micronutrients such as zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu). The soils in the SW zone are more deficient in micronutrients than the soils in the NE zone. Zn deficiency in SW-zone soils varied from 32 to 88% and in NE-zone soils from 30 to 78%. Fe deficiency in SW-zone soils ranged from 12 to 57%, and in NE zone soils from 7 to 29%. Manganese deficiency was only found in the SW zone (3 to 19%). Cu deficiency was not serious. Overall, 54% soils of soils in the state were deficient in Zn, 21% in Fe, 4.4% in Mn, and 2.6% in Cu. The negative balance was greater in the NE zone than in the SW zone, as a result of intensive cropping of high-yielding varieties of rice and wheat. Among micronutrients, the maximum negative balance in both zones was of Fe, followed by Mn, Cu, and Zn. Future research should be oriented towards improving soil fertility and arresting further mining of micronutrients.

Introduction

Soil is an exhaustible storehouse of plant nutrients. In a tropical country like India, the inherent soil fertility is low because of the loss of nutrients for climatic reasons. Before the green revolution, pressure to produce food was far less than it is today. In 1951/52, food-grain production was a mere 52 million tonnes with a fertiliser consumption of only 70 thousand tonnes; food-grain production increased to 212 million tonnes in 2001/02 with a fertiliser consumption of about 18 million tonnes – to feed a billion people. Use of chemically pure fertilisers together with intensive cropping accelerated the exhaustion of finite available micronutrient reserves in the soils. As a result, the deficiencies of these nutrients in presentday exploitative agricultural practices have assumed an alarming importance. It has become imperative to use matching doses of required micronutrients together with nitrogen (N), phosphorous (P), and potassium (K) to sustain high and profitable crop production. A hidden deficit of micronutrients has now emanated from many factors including interaction among nutrients, sub-optimal levels of particular nutrients, and irrigation water quality among others.

Haryana is an agriculturally important state in India. With only about 1.33% of the nation's geographical area, the state contributes 6.27% of the national food-grain production and about 30% of the food grain in the national food pool. It is considered to be the granary of the country. Food-grain production in Haryana rose from 2.6 million tonnes in 1966-67, to 13.3 million tonnes in 2001/02 (Figure 1; Table 1); fertiliser consumption rose from 13.4 to 984 thousand tonnes in the same period (Table 2). Rice and wheat crops accounted for a share of 49% in 1966/67 and 91% in 2001/2002 of the total food-grain production of the state. The area under these crops was 3.6 times more in 2001/02 than in the 1960s and their average yields had risen more than 2.6 times (Table 1). Apart from rice and wheat, average yield and production of other crops, such as pearl millet, maize, barley, cotton, sugar cane, and oilseeds, also increased, in spite of the fact that the area under some of these crops decreased (Table 1). Overall the average annual increase in food grain production was 0.297 million tonnes (Figure 2). It is estimated that total production will reach 14.2 million tonnes by 2005 and 15.6 million tonnes by 2010, requiring 980 and 1130 thousand tonnes of fertiliser, respectively (Antil et al. 2001).

The five-fold increase in food-grain production in the state over the last 36 years was mainly due to the diversion of areas from low productivity crops to rice and wheat which have higher productivity. This shift in cropping pattern was accompanied by increased nutrient mining from the soil at an alarming rate. In Haryana, only N, P, and Zn are usually applied, and this has led to widespread deficiency in nutrients like P, K, sulphur (S), Fe, Mn, and Cu. During the last few years, widespread deficiencies in S and Fe have been found in crops like pearl

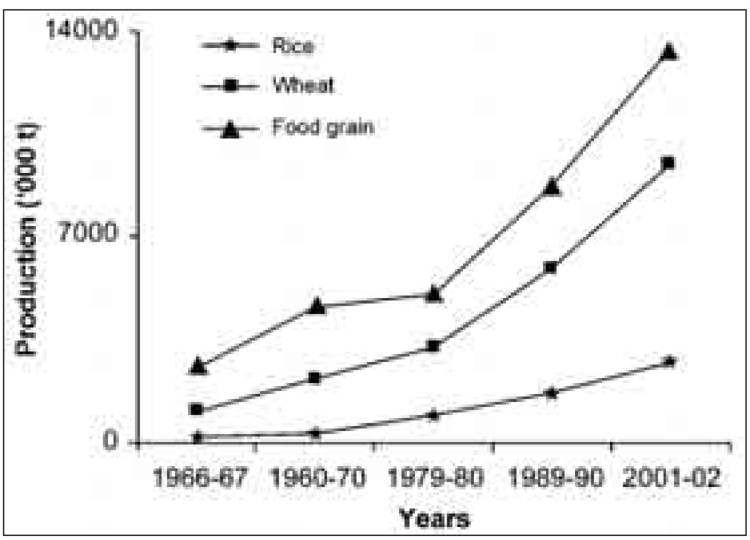

Figure 1: **Production of rice, wheat, and food grain in Haryana**

Table 1: **Area, production and average yield of different crops in Haryana**						
Crops	**Area ('000 ha)**		**Production ('000 t)**		**Average yield (kg ha $^{-1}$)**	
	1966/67	**2001/02**	**1966/67**	**2001/02**	**1966/67**	**2001/02**
Rice	192	1027	223	2724	1161	2652
Sorghum	270	104	49	22	181	212
Pearl millet	893	586	373	834	418	1423
Maize	87	18	86	47	989	2611
Wheat	743	2300	1059	9437	1425	4103
Barley	182	30	239	87	1313	2900
Cereals (T)	*2370*	*4065*	*2029*	*13151*	*856*	*3235*
Pulses (T)	1150	189	563	150	490	796
Food grain crops (pulses+cereals)	*3520*	*4254*	*2592*	*13301*	*1346*	*3127*
Cotton (L)	183	630	288	722	1572	2397
Sugarcane (G)	150	162	510	933	3400	5759
Oilseed (T)	212	546	92	807	434	1477

L = lint (in thousand bales of 170 kg each), G = gur, T = total
Source: Government of Haryana (2003)

Table 2: **Fertiliser consumption in Haryana ('000 t)**					
Nutrients	**Years**				
	1966-67	**1969-70**	**1979-80**	**1989-90**	**2001/02**
N	12.63	47.00	174.54	402.59	742.05
P_2O_5	0.57	5.12	30.24	129.07	232.16
K_2O	0.15	1.80	10.66	3.82	9.74
S	1.28	1.92	0.55	10.20	7.59
Zn	0.0	0.0	0.065	1.05	1.80
Mn	0.0	0.0	0.0	0.0	0.0
Fe	0.0	0.0	0.0	0.0	0.0
Cu	0.0	0.0	0.0	0.0	0.0
$N+P_2O_5+K_2O$	13.35	53.92	215.44	535.48	983.95

Source: Government of Haryana (2003)

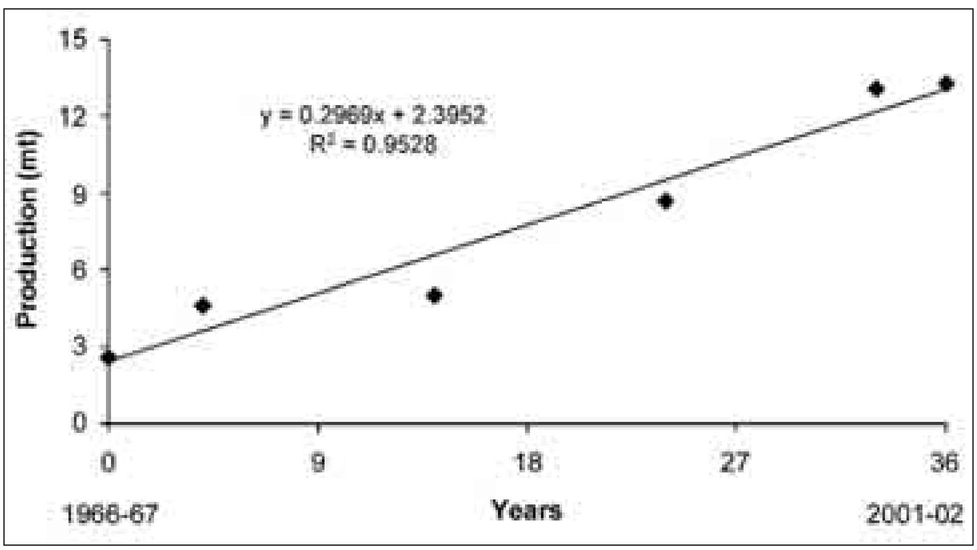

Figure 2: **Trend of food grain production in Haryana**

millet, sugar cane, wheat, and legumes. If this trend of nutrient depletion continues, then in future more areas will become deficient in nutrients like P, K, S, Fe, and Mn. Therefore, it is essential to limit extra mining of those nutrients which are either not being applied today, or are being applied in very limited quantities, in order to check further decline in soil fertility. The gap in nutrient removal and addition needs to be bridged.

The aim of this paper is to assess nutrient mining and addition through fertilisers and organic manure in different agro-climatic zones, and to construct a balance sheet for micronutrients in Haryana. This micronutrient balance sheet will be helpful for future planning of nutrient management strategies to maintain crop productivity for different cropping systems in different zones.

Agroclimatic Zones

Haryana State has nineteen administrative districts and is situated between 27°39' and 30°55'N and 74°27'8" and 77°36'5"E. It occupies a total geographical area of about 44,212 sq. km. The state slopes imperceptibly from north to south with heights ranging from 200 to 900 masl, but the slopes reverse further south and southwest due to the presence of the Aravalli hills in the south. The normal annual rainfall is about 300 mm in the southwest and this increases towards the north and eastern areas up to 600 to 1100 mm, with about a 25 to 45% coefficient of variation. The annual potential evapotranspiration in the region is quite high, exceeding 1200 mm all over the state. The mean temperature in the kharif (rainy) season is 32°C in the southwestern part, decreasing to 20-28°C in the northeastern part. The soils are light to medium textured.

The state can be divided into two main agro-climatic zones: namely, the southwestern (SW) zone and the northeastern (NE) zone.

The northeastern zone

The northeastern zone covers the semi-arid and sub-humid areas of Ambala, Yamuna, Nagar, Panchkula, Kaithal, Karnal, Panipat, Sonipat, Gurgaon, Faridabad, Jhajjar, Rohtak, and Jind districts. It lies between 30° and 31°N and 76°50' to 77°30'E. It receives more than 800 mm of annual rainfall with a coefficient of variation of 25%. Mean seasonal temperatures are around 29 to 16°C during the kharif and rabi (winter) seasons, respectively. The mean maximum temperature ranges from 37 to 47°C and the minimum temperature ranges from 3 to 25°C. This region has an average annual potential evapotranspiration of 1482 mm. The main crops are rice, wheat, and sugar cane with small areas of other crops like pearl millet, oilseeds, pulses, maize, and cotton. In general, the quality of water is good except in the central and southern parts of the zone. The soils are Typic Hapllustrept, Uchani, and loamy to clay loam.

The southwestern zone

The southwestern zone mainly consists of arid tracts. It lies between 27°50' and 30°N and 74°30' and 76°45'E. This zone covers the Sirsa, Fatehabad, Hisar, Bhiwani, Rewari, and Mohindergarh districts. Annual rainfall ranges from 200 to 500 mm during less than 25 rainy days with a coefficient of variation of more than 45%. Mean seasonal temperatures during the kharif and rabi seasons vary from 31 to 32°C and 11 to 16.5°C, respectively. Mean relative humidity is 60 and 50% during the kharif and rabi seasons, respectively.

Temperature variations are quite high, touching 47 to 48°C during the kharif and occasionally dropping below 0°C in the rabi season. Annual potential evapotranspiration is 1600 to 1700 mm. Most of the underground waters are brackish. The main crops are pearl millet, cotton, gram, raya, and wheat. The soils are sandy to sandy loam and classified as Typic Hapllustrept, Ladwa.

Micronutrient Status in the Agroclimatic Zones

The soil is a reservoir for the supply of all essential micronutrients to plants. This reservoir is depleted continuously and has been under stress since the introduction of high-yielding varieties. On average, 54% of the soils in Haryana were found to be deficient in Zn, 21% in Fe, 4.4% in Mn, and 2.6% in Cu (Gupta and Dahiya 2003).

In the northeastern zone, 65 to 84% of samples in Jind, Faridabad, Gurgaon, Rohtak, and Sonepat districts were deficient in available Zn, and less than 42% in other districts. The highest rate of Fe deficiency was found in Sonepat (29% of samples), followed by Faridabad, Ambala, Karnal, Kurukshetra, and Rohtak districts (Table 3). There was almost no deficiency of either Mn or Cu.

In the southwestern zone, Zn deficiency rates were highest in Bhiwani district (88% of samples), followed by Rewari and Mohindergarh (77%) (Table 3). About 12 to 57% of samples were deficient in available Fe with the highest rates in Bhiwani district, followed by Sirsa and Hisar. In Bhiwani district, 12 and 19% of samples were deficient in available Cu and Mn, respectively. But Cu and Mn deficiency was not serious in other districts.

Table 3: **Extent of micronutrient deficiency (% samples deficient) in soils of different districts of Haryana**

District	Zn	Fe	Mn	Cu
Northeastern zone				
Ambala	35	17	0	2
Panchkula	35	17	0	2
Yamunanagar	35	17	0	2
Kurukshetra	30	8	0	0
Kaithal	30	8	0	0
Karnal	42	17	0	0
Panipat	42	17	0	0
Sonepat	65	29	0	0
Rohtak	71	7	0	2
Jhajjar	71	7	0	2
Gurgoan	78	17	3	5
Faridabad	70	17	0	1
Jind	84	10	0	0
Southwestern zone				
Sirsa	32	29	3	0
Fatehabad	55	25	10	3
Hisar	55	25	10	3
Bhiwani	88	57	19	12
Mohindergarh	77	12	0	1
Rewari	77	12	3	1
Overall	54	21	4.4	2.6

Source: Gupta and Dahiya (2003)

Calculation of Nutrient Mining

Nutrient mining and balance in soils were calculated in different agro-climatic zones of Haryana for the micronutrients Zn, Mn, Fe, and Cu as reported by Antil et al. (2001) taking into account the following.

- Production of different crops
- Per ton nutrient requirement of crops
- Fertiliser consumption
- Contribution of dung
- Gross cropped area in different years
- Efficiency in nutrient use

Crop removal of nutrients

The removal of Zn, Cu, Fe, and Mn was calculated by multiplying the total crop production of different crops in different zones by the per tonne requirement for these nutrients as reported by FAO (1982) and Singh (1984). Nutrient removal by different crops was calculated for different years for each zone to give the total removal of nutrients.

Fertiliser consumption

Micronutrient fertiliser (Zn, Mn, Fe and Cu) consumption for the districts in each zone was calculated. The crops covered by this study occupied about 89% of the gross cropped area of the state during different years. The remaining area (11%) is used to grow vegetables, fruit, and forage crops which were not taken into consideration due to the lack of date on their yields and requirements. It was assumed that 11% of fertiliser nutrients were used by these crops, and this amount was subtracted from total fertiliser consumption. The value obtained was used to calculate nutrient removal and balance in kg ha^{-1}. Total dung production in Haryana in each year was calculated from livestock population figures and multiplied by the nutrient contents of dung to arrive at the potential contribution of dung to nutrient recycling in soils. It was estimated that only one third of dung is recycled in soil, the rest being burned as fuel or drained off during the rainy season and this value (one-third of total produced) was used in the calculations. The nutrients supplied through dung and fertilisers were added together to arrive at the total input of nutrients in each zone.

Nutrient balance

The nutrients obtained through fertiliser application and dung were multiplied by the efficiency factors of different nutrients. The efficiency of all the micronutrients (Zn, Mn, Fe and Cu) was taken as 20%. The amount of nutrients obtained after multiplying by nutrient efficiency factors was subtracted from total crop removal figures, and this gave a plus or minus nutrient balance for different nutrients in different years. The amount of nutrients obtained was divided by actual crop area occupied by these crops to give a nutrient balance in kg ha^{-1} in each zone.

Nutrient removal by different crops

The removal of micronutrients for each zone was calculated for different crops in different years (Table 4) by multiplying the total production of different crops with the per tonne requirement of the crops.

Table 4: Micronutrient removal in Haryana				
Micronutrient	1966/67		2001/02	
	Total removal tonnes	Average removal g ha^{-1}	Total removal tonnes	Average removal g ha^{-1}
Haryana state				
Zn	79.5	20.0	428.2	76.6
Mn	271.8	70.0	2217.7	396.9
Fe	851.8	210.0	4002.3	716.2
Cu	35.9	10.0	159.3	28.5
Northeastern zone				
Zn	57.8	20.0	264.4	80.0
Mn	218.9	90.0	1806.4	550.0
Fe	594.7	240.0	2268.9	640.0
Cu	27.0	10.0	107.7	30.0
Southwestern zone				
Zn	21.8	10.0	163.8	64.7
Mn	52.9	30.0	411.3	162.5
Fe	257.1	60.0	1733.4	684.9
Cu	8.9	10.0	51.6	20.4

The total calculated removal of micronutrients was much higher in the northeastern zone than in the southwestern zone (Table 4). In the northeastern zone, total Zn removal increased from 57.8 to 264.4 tonnes between 1966/67 and 2001/02, and in the southwestern zone from 21.8 tonnes to 163.8 tonnes. In terms of g ha^{-1} the rates increased from 20 to 76.6g ha^{-1} in the northeastern zone and from 10 to 64.7g ha^{-1} in the southwestern zone (Table 4). In Haryana overall, the rate of removal of Zn increased from 20 to 76.6g ha^{-1} and of Fe from 210 to 716.2g ha^{-1}. Cu had the lowest rates of removal of all the micronutrients studied in all years in both zones.

The share of each crop in micronutrient removal was calculated. In 1966/67, cereals removed 60% of total Zn removed, 73% of Mn, 54% of Fe, and 57% of Cu, the proportion increased to 77% of Zn, 95% of Mn, 71% of Fe, and 84% of Cu in 2001/02 (Table 5). Among the cereals, rice and wheat removed the maximum amounts. The share in nutrient removal by pulses, oilseeds, cotton, and sugar cane decreased over the years, as a result of the increase in yields of rice and wheat crops resulting from the increase in their area and average yields.

Nutrient balance in soils

In both zones, there was a negative balance of Zn, Fe, Mn, and Cu in all years, except for 2001/02, when Zn balance (7.4 g ha^{-1}) was positive in the northeastern zone (Table 6). The negative balance of Fe, Mn, and Cu was greater in the northeastern zone than in the southwestern zone (Table 6). In Haryana State, the negative balance of Zn, Fe, Mn, and Cu in 1966/67 was -66.7, -265.5, -504.1, and -30.6 tonnes which increased to -59.4, -2205.2, -3307.8 and -148.6 tonnes in 2001/02 (Table 6). The negative balance of all micronutrients increased in both zones separately except for Zn in the northeastern zone, where the balance became positive as a result of the application of Zn to rice and wheat crops.

Table 5: **Percentage micronutrient removal by different crops in Haryana**				
Crop	**Micronutrient**			
	Zn	**Mn**	**Fe**	**Cu**
1966/67				
Cereals	60.37	73.43	54.09	56.56
Cotton	5.79	1.48	3.68	6.40
Sugarcane	9.62	3.19	11.98	14.19
Pulses	12.03	18.44	17.19	17.23
Oilseed	11.57	3.22	12.13	4.22
2001/02				
Cereals	76.90	95.17	71.48	84.20
Cotton	0.46	0.08	0.33	0.62
Sugarcane	3.25	0.71	4.63	5.82
Pulses	0.59	0.60	0.96	1.02
Oilseed	18.81	3.45	22.60	8.34

Table 6: **Micronutrient balance in Haryana**				
Micronutrient	**1966/67**		**2001/2**	
	Total balance tonnes	**Average balance g ha^{-1}**	**Total balance tonnes**	**Average balance g ha^{-1}**
Haryana state				
Zn	-66.7	-16.4	-59.4	-10.6
Mn	-265.5	-65.3	-2205.2	-394.6
Fe	-504.1	-123.9	-3307.8	-592.0
Cu	-30.6	-7.52	-148.6	-26.6
Northeastern zone				
Zn	-49.0	-19.9	22.5	7.4
Mn	-214.7	-87.1	-1798.4	-588.2
Fe	-357.4	-145.0	-1826.8	-597.6
Cu	-23.4	-9.5	-100.9	-33.0
Southwestern zone				
Zn	-17.7	-11.1	-81.9	-32.3
Mn	-50.9	-31.7	-406.8	-160.7
Fe	-146.7	-91.5	-1481.0	-585.2
Cu	-7.2	-4.5	-47.7	-18.9

These studies indicate that the negative balance of nutrients such as Fe, Mn, and Cu will continue to increase in future. In the case of Zn, the situation is almost satisfactory. The more serious threat is for Fe, Mn, and Cu the deficiency of which has increased during the last two decades.

Suggestions to Limit Nutrient Mining from Soils

The increase in food-grain production in the state has led to a simultaneous increase in the removal of nutrients from soils. Except for Zn, there is more mining of all micronutrients from soils in both zones. The gap between nutrient addition and nutrient removal is increasing every year for nutrients like Mn, Fe, and Cu. Although it is not possible to replenish 100% of nutrients removed by crops every year, attempts should be made to maximise recycling of those nutrients likely to be deficient in future. The only way to check further nutrient mining and narrow the gap between nutrient removal and fertiliser consumption is through strategies such as:

- integrated nutrient management (INM),
- balanced use of fertilisers,
- emphasis on the use of organic manure, crop residues, and industrial waste,
- use of green manure, and
- crop diversification.

Conclusions and Future Research Needs

- Food-grain production in Haryana increased about five-fold between 1966/67 and 2001/02. Rice and wheat crops contributed the maximum in terms of grain production with annual rice production increasing from 223 to 2724 thousand tonnes and annual wheat production from 1094 to 9437 thousand tonnes. This was mainly due to the increases in area and average yields of these crops. In spite of a decrease in the cultivated area of pearl millet in the same period, the production of pearl millet also increased. There was an increase in average yields of sorghum, pearl millet, barley, cotton, sugar cane, pulses, and oilseeds.
- On average, 54% of soils in the state were deficient in available Zn and 21% in available Fe, whereas only 4.4 were deficient in Mn and 2.4% in Cu.
- Nutrients added through dung also increased over the same period in the state, as did micronutrient addition: Zn addition increased from 64 to 128 tonnes, Mn from 31.4 to 62.7 tonnes, Fe from 1738.3 to 3472.1 tonnes, and Cu from 26.8 to 53.5 tonnes.
- Nutrient removal by all crops increased from 1966/67 onwards. In 2001/02, rice and wheat crops removed the maximum nutrients. The average removal of Zn, Cu, Mn, and Fe increased over the years in both zones. The removal of all nutrients was greater in the northeastern zone than the southwestern zone.
- In Haryana overall there was a negative balance of micronutrients; the maximum negative balance overall and in both zones separately was of Fe followed by Mn, Cu, and Zn. In the northeastern zone there was a positive balance of Zn (7.4 g ha^{-1}). The negative balance of Fe, Mn, and Cu increased from 1966/67 onwards in both zones.

Future research should be oriented towards improving soil fertility and arresting further mining of nutrients like Fe, Mn, and Cu. Research emphasis should be on the following.

- Research on the balanced use of fertilisers should be carried out on important crops such as rice, wheat, oilseeds, pulses, cotton, and sugar cane.
- The critical levels of available Zn, Cu, Fe, and Mn for cereals, oilseeds, pulses, and other crops should be worked out for different zones.
- The highest priority should be given to research on integrated nutrient management in cropping systems based on rice, wheat, cotton, oilseeds, and sugar cane. The contribution of organic manure and crop rotation should be studied for various cropping systems.
- Emphasis should be given to safe use of industrial and farm wastes to assess their contribution to crop production.

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