Guidelines for use of micronutrients, soil ameliorants and integrated nutrient management practices in NFSM States

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National Food Security Mission

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Department of Agriculture and Cooperation
Ministry of Agriculture
Government of India
Krishi Bhawan, New Delhi-110001

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PREFACE

Micronutrient deficiency in Indian soils has emerged as one of the major constraints to crop productivity. While zinc, iron, boron and manganese deficient areas are vast, copper and molybdenum deficiency has also been observed in many districts of the country. The problem has been compounded by soil acidity affecting large area in eastern and southern states and soil alkalinity commonly observed in north-western states as crops grown on such soils encounter nutritional disorders and toxicities. National Food Security Mission—a strategic initiative of Ministry of Agriculture, Govt. of India, has endeavored to address these constraints by creating awareness among farmers and promoting use of soil ameliorants and micronutrients in major rice, wheat and pulse crops growing States of the country.

This document outlines guiding principles for scientific use of soil ameliorants and plant micronutrients for restoring soil fertility and enhancing productivity of rice, wheat and pulses. It is hoped that the document will be of immense use for farmers, and agricultural extension workers engaged in dissemination of improved crop production practices in general and execution of National Food Security Mission programme in particular.

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1. Introduction:

Indian soils have become deficient not only in major plant nutrients like nitrogen, phosphorus and in some cases, potash but also in secondary nutrients, like sulphur, calcium, and magnesium. Micronutrients such as zinc, boron and to a limited extent iron, manganese, copper and molybdenum have also been reported to be deficient. Deficiency of micronutrients during the last three decades has grown in both, magnitude and extent because of increased use of high analysis fertilizers, use of high yielding crop varieties and increase in cropping intensity. This has become a major constraint to production and productivity of rice, wheat and pulses. Thus, there is an urgent need for correction of individual nutrient deficiency and for arresting its further spread. Accordingly, it has been planned to address micronutrient deficiency in major rice, wheat and pulses growing States of India through National Food Security Mission programme. It is further intended to support and popularize use of gypsum and lime or dolomite as sources of sulphur and calcium, respectively, in areas planted to *kharif* and *rabi* pulses in selected States, as deficiency of calcium in acid soils and that of sulphur in pulse growing areas has been increasing due to continued mining by crops and use of S-free fertilizers.

Availability of plant nutrients to crops has a strong bearing on physico-chemical nature of soils. India has a vast area under acid soils as well as sodic soils. Productivity of such soils can be restored through well established ameliorative techniques. Use of lime or liming materials in acid soils and that of gypsum/phosphogypsum in sodic soils has been advocated by Soil Scientists for correction of soil pH and improving physico-chemical nature of these soils. It is intended to support and popularize use of these abundantly available ameliorants in NFSM districts with large area covered by such soils.

The approach being adopted for supporting and popularizing use of micronutrients, integrated nutrient management practices and soil ameliorants involves laying out crop demonstrations on use of micronutrients, promoting use of micronutrients and soil ameliorants through financial incentives and encouraging use of lime and gypsum as co-fertilizers for pulses, imparting training and distribution of extension literature to farmers through FFS, etc. In order to facilitate efficient and scientific use of these inputs, easy-to-follow guidelines have been developed for use by field extension functionaries and farmers.

2. Plant Micronutrients:

Out of 17 nutrients established as essential for plant growth, 6 are required in small quantities and therefore called micronutrients. They are zinc, boron, iron, manganese, molybdenum and copper. General guidelines for ensuring optimum crop response to micronutrient application are narrated below.

2.1 Distribution and Extent of Micronutrient deficiency:

As depicted in Table 1a deficiency of zinc covers the largest area in NFSM States whereas deficiency of boron and molybdenum is common to coarse textured, low organic matter soils occurring in high rainfall regions. Area under iron deficiency is also quite large in Haryana, Maharashtra, Karnataka, Punjab and Tamil Nadu which cannot be ignored as the responses of rice, wheat and pulses to iron application are as high as or higher than that to zinc. Copper deficiency has assumed serious dimensions in Gujarat and Kerala. Cropped area within targetted districts deficient in micronutrients needs to be delineated and treated so that soil fertility is improved leading to commensurate crop productivity gains.

Districts of NFSM states with major area under micronutrient deficiency are listed in Table 1b. As noticed zinc deficiency is prevalent in a large number of districts followed by boron and iron. These micronutrients need immediate attention.

Table 1a. Extent of micronutrient deficiency in NFSM States

Name of State	Percent samples deficient					
	Zn	Cu	Fe	Mn	B	Mo
Andhra Pradesh	49.4	<1	3	1	-	-
Assam	34	<1	2	20	-	-
Bihar & Jharkhand	54	3	6	2	38	-
Gujarat	24	40	8	4	2	10
Haryana	60	2	20	4	0	28
Karnataka	72.8	5	35	17	32	-
Kerala	34	31	<1	0	-	-
Madhya Pradesh & Chhattisgarh	44	<1	>	1	22	18
Maharashtra	86	0	24	0	-	-
Orissa	54	-	0	0	60	80
Punjab	48	1	14	-	13	-
Rajasthan	21	-	-	-	-	-
Tamil Nadu	58.4	6	17	6	21	-
Uttar Pradesh	45.7	1	6	3	24	-
West Bengal	36	0	0	3	68	-

Source: Indian Institute of soil science, Bhopal, M.P.

Table 1b Districts of NFSM States affected by deficiency of micronutrients

State	Micronutrient deficient districts			
	Zinc (Zn)	Boron (B)	Copper (Cu)	Iron (Fe)
1. Andhra Pradesh	Anantpur, Guntur, Krishna, Kurnool, Nizamabad, Nalgonda, Nellore, Prakasam.	–	Anantpur East Godavari Prakasam	Cuddapah Kurnool
2. Bihar	Araria, Bhojpur, Bhabhua,Bhagalpur, Banka, East Champaran, West Champaran, Darbhanga, Jamui, Kishanganj, Khagaria, Muzaffarpur, Nawada,Nalanda, Patna, Purnea, Rohtas, Siwan, Saran, Samastipur, Saharsa, Sekhpura.	Araria, Darbhanga Nalanda, Muzaffarpur Madhubani Samastipur Supaul, Siwan Kishanganj, Katihar, Khagaria	Araria , East Champaran, West Champaran Supaul, Kishanganj,	Darbhanga, Madhubani, Muzaffarpur, Samastipur Siwan
3. Chhattisgarh	Bilaspur, Durg, Jashpur, Koriya, Raipur, Raigarh, Sarguja,	Deficiency not reported	Deficiency not reported	Deficiency not reported
4. Gujarat	Ahemdabad, Banaskantha, Bharuch, Jamnagar, Kachchh, Narmada, Panchmahal.	–	Deficiency not reported	Jamnagar Mehsana
5. Haryana	Bhiwani, Gurgaon, Jhajjar, Mahendragarh, Rohtak, Sonipat, Yamunanagar.	–	Deficiency not reported	Bhiwani Hisar Sirsa
6. Jharkhand	Not deficient	Simdega, Hazaribagh, Ranchi, Gumla, Singhbhum (West)	Simdega, Hazaribagh, Ranchi, Gumla, Singhbhum (West)	Simdega, Hazaribagh, Ranchi, Gumla, Singhbhum (West)
7. Maharashtra	Ahmednagar,Aurangabad, Amravati, Akola, Bhandara, Buldhana, Chandrapur, Dhule, Gadchiroli, Gondia, Hingoli, Jalna, Jalgaon, Latur, Nashik, Nagpur, Nanded Osmanabad, Pune, Parbhani, Solapur, Wardha, Washim, Yaotmal	Deficiency not reported	Deficiency not reported	Ahmednagar,Aurangabad, Amravati, Akola, Buldhana, Chandrapur, Hingoli, Jalna, Jalgaon, Latur, Nashik, Nagpur, Nanded Osmanabad, Parbhani, Wardha, Washim, Yaotmal

8. Madhya Pradesh	Bhind , Balaghat, Bhopal, Chhatarpur, Chindwada, Dewas, Dhar, Guna, Indore, Jabalpur,Jhabua, Mandla,Panna, Rajgarh, Raisen, Rewa, Sagar,Sahdol Satna, Seoni, Sehore, Shivpur, Shajapur,Sidhi Tikamgarh, Vidisha.	_	Deficiency not reported	Betul
9. Orissa	Balangir, Boudh, Kalahandi, Nawrangpur, Keonjhargarh.	Bolangir, Baragarh, Cuttack, Ganjam, Jajpur	Kalahandi	Deficiency not reported
10. Punjab	Bhatinda , Firozpur, Gurdaspur, Hoshiarpur, Ludhiana, Rupnagar, Sangrur	_	Deficiency not reported	Bhatinda ,Firozpur Ludhiana,Rupnagar, Sangrur
11. Tamil Nadu	Coimbatore, Nagapattinam Pudukkottai, Ramnathpuram, Triuvalur, Tiruvannamalai, Villupuram	_	Deficiency not reported	Cuddalore, Coimbatore, Namakkal Ramnathpuram Triuvalur, Tiruvannamalai,
12. Uttar Pradesh	Saharanpur, Rampur, Mathura, Bareily, Badaun, Mainpuri, Hardoi, Sitapur, Bahraich, Barabanki, Lucknow, unnao, Kanpur(dehat),Balramp ur, Siddharthnagar, Jalaun, Hamirpur, Mahoba, Banda, Fatehpur, Raibareili, Basti, Ambedkarnagar, Sultanpur, Maharajganj, Azamgarh, Santkabirnagar, Gorakhpur, Deoria, Ballia, Jaunpur, Ravidasnagar, Varanasi, Chitrakut, Pratapgarh, Kausambi, Allahabad, Mirzapur, Sonbhadra, Chandauli.	_	Badaun, Bareilly, Bahraich, Gonda, Mainpuri, Mathura, Saharanpur	Bareilly,Sitapur, Kanpur (Dehat), Hamirpur, Mahoba

2.2 Zinc (Zn)

Zinc deficiency is most widely spread in Indian soils followed by iron, boron and copper. It is common in high pH, calcareous and low organic matter- content soils.

2.2.1. Role:

- ☐ It is required in protein synthesis and for ensuring seed quality and uniform maturity.

2.2.2. Deficiency symptoms:

- ☐ **Rice:** Appearance of rusty-brown spots and discoloration of older leaves beginning 2-3 weeks after transplanting is noticed. Under acute conditions leaf margins of older leaves dry up. New leaves are smaller in size. Crop maturity is non-uniform and delayed.

- ☐ **Wheat:** Plants become stunted and bushy. Interveinal chlorosis of new leaves is seen. In severe cases, leaves turn white and die.

- ☐ **Pulses:** Stunted growth, development of light green, yellowish, bleached spots, little leaf condition, shortening of internodes and delayed reproductive phase are commonly noticed.

2.2.3. Sources:

- ☐ Zinc –EDTA chelate ; Zn content -12 %
- ☐ Zinc sulphate monohydrate; Zn content-33 %
- ☐ Zinc sulphate heptahydrate; Zn content-21 %; included in the Fertilizer Control Order, 1985.

2.2.4. Dose and Application method:

- ☐ Zinc sulphate heptahydrate (Zn-21%) is recommended for soil application at the rate prescribed by the State Agricultural Universities/Soil Testing Laboratories. The dose varies across the states from 25 to 60 kg/ha depending on soil type, cropping intensity and crop productivity levels, to be applied once in two years.

Use of 10 kg/ha zinc sulphate every year has also been recommended in some States.

- ☐ It should not be mixed or applied with phosphate fertilizers, as water soluble zinc is transformed to relatively insoluble zinc phosphate.
- ☐ Drilling, band placement or broadcasting of zinc sulphate are popular application methods. However band placement is most effective.
- ☐ Basal (soil) application is always preferred. However, in the absence of basal application, foliar spray of 0.5 % solution of zinc sulphate heptahydrate 15 days after transplanting of rice and 30 days after planting of wheat should be practiced. The foliar application should be repeated after 15 days. One kg zinc sulphate plus 0.5 kg unslaked lime dissolved in 200 l water will give 0.5 % zinc sulphate solution. About 500 l of solution will be adequate for one foliar spray of 1 hectare cropped area.
- ☐ The material should conform to FCO/BIS specifications.

2.2.5. Crop Response:

Crop response to applied zinc varies depending on soil type, crop and its variety, available nutrient status etc. Average crop yield advantage due to zinc application is depicted in Table- 2.

Table 2. Average crop yield advantage due to application of zinc sulphate at recommended level with full dose of NPK

State	Crop	No. of trials	Yield increase (kg/ha)
Bihar	Rice as paddy	958	510
	Wheat	394	339
Haryana	Rice as paddy	75	580
	Wheat	456	350
Punjab	Rice as paddy	250	950
	Wheat	686	360
Madhya Pradesh	Rice as paddy	-	500
	Wheat	-	450

Response of pulse crops (pigeonpea, chickpea, black gram, green gram, lentil to zinc sulphate application ranges from 160 to 200 kg/ha.

2.2.6. Economics:

Cost of zinc sulphate @ Rs 40/kg for an average dose of 25 kg/ha once in two years works out to be Rs 500/ ha per year. Crop yield increase required to pay for the cost of zinc sulphate will be only 56 kg of paddy @ Rs 9/kg and 50 kg of wheat @ Rs 10/kg. These quantities of produce are much less than the mean yield advantage recorded. The average value-to-cost ratio may be more than 8 in case of paddy and more than 6 in case of wheat.

2.3. Boron (B)

Boron deficiency is most common in Bihar, West Bengal, Orissa, Assam and Jharkhand. However, it has also been observed in Gujarat, Karnataka Madhya Pradesh, Chhattisgarh and Uttar Pradesh.

2.3.1. Role:

- ☐ Boron is required for cell division and extension. It is essential for pollen tube growth which affects seed/fruit set and hence yield.

2.3.2. Deficiency symptoms:

- ☐ **Rice:** Young leaves are deformed and growing points undergo drying and withering.

- ☐ **Wheat:** Boron deficiency causes thickening of stems and leaves, shortened internodes and reduced flowering and seed formation.

- ☐ **Pulses:** Stem thickens, growing points die, leaves become slightly chlorotic and mottled, seed setting is reduced.

2.3.3. Sources:

- ☐ Borax (sodium tetraborate); contains 10.5 % boron.
- ☐ Boric acid; contains 17.0 % boron.
- ☐ Di-sodium octaborate tetrahydrate; contains 20 % boron.

2.3.4. Dose and application method:

- ☐ Boron should be applied to a deficient soil as borax @ 10 kg/ha through broadcasting at the time of planting rice, wheat or pulses.

- ☐ It can also be applied through foliar spray as 0.5 % solution of borax 15 days after planting and at flower initiation stage.

- ☐ The material used should conform to FCO/BIS specifications.

2.3.5. Crop Response:

Boron application to deficient soils leads to significant increase in crops yields. Table 3. depicts average yield increases in rice, wheat and pulses crops recorded in Bihar. Response of hybrid rice to boron is much higher than that of high yielding varieties.

Table 3. Increase in crop yield due to boron application in Bihar

Crop	No. of trials	Yield advantage (kg/ha)
Rice (paddy)	58	310
Wheat	36	370
Chickpea	11	430
Pigeonpea	3	340
Lentil	4	250
Black gram	2	270

2.4. Iron (Fe)

Deficiency of iron has been observed in north Bihar, Andhra Pradesh, Gujarat, Rajasthan, Uttar Pradesh, Haryana, Karnataka, Maharashtra, Tamil Nadu, and Punjab. Iron deficiency is generally noticed in calcareous and alkaline soils.

2.4.1. Role:

- ☐ Iron plays an important role in synthesis of chlorophyll which is essential for photosynthetic activity. It is also required for chemical reduction of nitrate and sulphate and in nitrogen assimilation.

2.4.2. Deficiency symptoms:

- ☐ **Rice:** Interveinal chlorosis in streaks is noticed. Drying of leaves starts from tips and margins. Under severe conditions, leaves become white and die.

- ☐ **Wheat:** Deficiency of iron is manifested as interveinal chlorosis of upper most leaves. As deficiency intensifies, leaves turn almost white and die.

- ☐ **Pulses:** Yellowing of interveinal areas of young leaves is commonly noticed in iron deficient plants. Severity leads to pale-white discoloration of leaves.

2.4.3. Sources:

- ☐ Ferrous sulphate ($FeSO_4$. $7H_2O$); contains 20 % iron.
- ☐ Fe-EDTA chelate; contains 12% iron.

2.4.4. Dose and application method:

- ☐ Ferrous sulphate is most commonly used source of iron. Soil application @ 50 kg/ha to rice, wheat or pulses every 3 years or 15 kg/ha every year is recommended. However, it is more effective when applied as foliar spray of 1 % solution, 2-3 times at weekly interval in rice, wheat or pulse crops.

2.4.5. Crop Response: Crop responses to iron application are comparable to or higher than those to zinc. Average yield increases due to iron (Ferrous sulphate) application have been recorded as 450 kg/ha in chickpea, 780 kg/ha in wheat and upto 1500 kg in paddy.

2.5. Manganese (Mn)

Manganese deficiency is prevalent in Assam, Karnataka, Tamil Nadu, Punjab, Haryana and Gujarat.

2.5.1. Role:

- ☐ It is important for normal functioning of many enzymes, nitrogen metabolism and carbon dioxide assimilation.

2.5.2. Deficiency symptoms:

- ☐ **Rice:** Chlorotic patches between veins are first noticed on younger leaves.
- ☐ **Wheat:** Leaves show interveinal chlorosis with grayish yellow to pinkish brown specks of variable size confined largely to lower portion. At later stage, specks coalesce forming streaks or bands in-between the veins which remain green. Acute deficiency may lead to drying of whole plant.
- ☐ **Pulses:** Interveinal chlorosis and mottling in young leaves is noticed. Brown lesions in cotyledons are commonly noticed.

2.5.3. Sources:

- ☐ Manganese sulphate; contains 30.5 % Mn.
- ☐ Mn-EDTA chelate; contains 5-12 % Mn.
- ☐ Manganese chloride; contains 17 % Mn.

2.5.4. Dose and application method:

- ☐ Foliar spray of 0.5 % manganese sulphate solution at tillering in rice and crown root initiation in wheat is recommended.

2.5.5. Crop Response:

Data base on crops response to manganese is very limited. Average yield increases in paddy and wheat recorded in Punjab are 360 kg/ha and 560 kg/ha, respectively. Intervarietal differences in response of wheat crop to applied manganese have been observed.

2.6. Molybdenum (Mo)

The states affected by Mo deficiency include Orissa, Jharkhand, and West Bengal Gujarat, Madhya Pradesh and Haryana.

2.6.1. Role:

- ☐ Molybdenum is involved in symbiotic N-fixation and protein synthesis in crops.

2.6.2. Deficiency symptoms:

- ☐ Marginal scorching and rolling or cupping of leaves are indicative of Mo deficiency.

- ☐ Acid and coarse textured soils with low organic matter content are usually deficient in molybdenum.

2.6.3. Sources:

- ☐ Ammonium Molybdate; contains 52 % Mo.
- ☐ Sodium Molybdate; contains 39 % Mo.

2.6.4. Dose and application method:

- ☐ Apply 2-4 kg/ha sodium molybdate or 2-3 kg of ammonium molybdate at the time of planting or treat seed with 10-20 g sodium molybdate per 25 kg of seed.

- ☐ Alternatively, 0.1- 0.3 % ammonium molybdate solution may be foliar sprayed 2-3 times at 10 days interval.

2.6.5. Crop Response:

Wheat crop has shown significant increase in yield (440 kg/ha) due to foliar application of molybdenum. Green gram productivity improved by 40 % in laterite soils of Bhubaneshwar when seed was treated with @ 12g Mo / 25 kg seed.

2.7. Copper (Cu)

The states of Gujarat and Kerala are worst affected by copper deficiency. However, Tamil Nadu, Karnataka and Jharkhand have also reported copper deficiency. Deficiency is usually noticed in strongly acidic, alkaline, poorly drained and low organic matter soils.

2.7.1. Role:

- ☐ Copper is involved in chlorophyll formation and is a part of several enzymes. It is also required for symbiotic nitrogen fixation.

2.7.2. Deficiency symptoms:

- ☐ Leaves become light green and develop twisted tips. Panicles are poorly filled and may even remain empty if the deficiency is severe.

2.7.3. Sources:

- ☐ Copper sulphate pentahydrate; contains 24 % copper.
- ☐ Copper sulphate monohydrate; contains 35 % copper.

2.7.4. Dose and application method:

- ☐ Foliar spray of 0.025 % solution of copper sulphate (pentahydrate) at appearance of symptoms or soaking of seeds in 0.25 % copper sulphate solution in case of rice or soil application of 1.5-2 kg copper sulphate / ha once in 4-8 years is recommended.

2.7.5. Crop Response:

On an average, wheat yield improves by 380 kg/ha and paddy yield increase is about 460 kg/ha.

2.8. General Precautions:

- ☐ Never mix zinc, iron or copper micronutrient fertilizers with phosphatic fertilizers as these elements are rendered less soluble.
- ☐ Avoid excessive use of phosphorous as it adversely affects utilization of zinc, iron and copper.

- ☐ Excess of iron adversely affects utilization of zinc and manganese; conversely excess of zinc, manganese and copper induces iron deficiency in crops. Thus mixing of iron containing fertilizers with zinc, manganese and copper fertilizers should be avoided. Further, over-use of micro-nutrients should also be avoided.
- ☐ Excess of sulphur and copper induces molybdenum deficiency in crops. Thus application of sulphur and copper should be within recommended doses.
- ☐ Excessive use of lime or liming material should be avoided as it induces zinc, iron, and manganese and boron deficiency.

3. Management of acid soils:

Acid soils occupy vast area in high rainfall, mountains and coastal regions of India. The soils are highly leached, have poor fertility and water-holding capacity. Acid soils are deficient in phosphorus, calcium, magnesium and molybdenum. Severe acidity often causes iron and aluminum toxicity to crops. Acid soils are low in organic carbon, water retention and prone to run off-induced erosion. These constraints lead to sub optimal productivity of crops raised in acid soils.

3.1. Distribution and extent of acid soils in NFSM States:

Acid soils are widely spread in eastern, north eastern and peninsular region. Table 4 depicts statewise area affected by soil acidity. Total area under acid soils in NFSM states is estimated to be 66 m ha, major part of which falls in targeted districts. However, area with soil pH <5.5 is only about 15.6 m ha and needs to be treated on priority.

Table: 4. Extent of acid soils in NFSM States (m ha)

States	pH <5.5	pH 5.5-6.5	Total
Andhra Pradesh	-	0.40	0.40
Assam	2.33	2.33	4.66
Bihar	0.04	2.32	2.36
Chhattisgarh	6.45	4.39	10.84
Jharkhand	1.0	5.77	6.77
Karnataka	0.06	3.25	3.31
Kerala	3.01	0.75	3.76
M.P	1.12	10.60	11.72
Maharashtra	0.21	4.33	4.54
Orissa	0.26	8.41	8.67
Tamil Nadu	0.56	4.29	4.85
West Bengal	56	1.20	4.76
Total	15.6	51.04	66.64

3.2. Amelioration of acid soils:

Liming of acid soils has been advocated by soil scientists. However the lime requirement based on laboratory tests is usually too high for most of the farmers to afford. Besides, high transport cost of large quantity of lime and inadequate storage facilities at consumption sites have discouraged large scale use of the ameliorant. Now, it has been established that band placement/incorporation of lime @ 1/10 of lime requirement alongwith recommended level of fertilizers every year is economical, practicable and effective.

3.3. Commonly available liming materials:

Carbonates, oxides and hydroxides of calcium and magnesium are referred to as agricultural lime. Liming materials such as calcite, dolomite are naturally occurring ameliorants. Although, they are available in abundance, their use may not always be cost-effective. Industrial by-products such as basic slag (steel industry), lime sludges from paper mills, etc are rich and relatively cheap sources of calcium. Liming materials available in different States are depicted in Table 5. The material should have at least 25 % calcium oxide and be ground to less than 80 mesh size.

Table 5. Liming materials available in NFSM states in India

Acid soil region/state	Liming material	Quantity available (mt)
Assam	Limestone	15
Jharkhand	Basic slag	1
Kerala	Lime shells	4
Maharashtra	Lime	0.2
Orissa	Paper mill sludge	0.2
West Bengal	Basic slag, paper mill sludge	0.3
Others	Basic slag	3.0

3.4. Dose, schedule and method of application:

- The ground material conforming to BIS specifications (80 mesh size) should be broadcast /applied in furrows at the rate of 10% of Lime Requirement (LR) , (usually 2-4 q/ha) at the time of planting of an upland crop preceding rice. It may also be applied to rice crop during puddling (2-4 q/ha) if the soil is highly acidic (soil pH < 5.5).

- The quantity of lime equivalent to 10% of Lime Requirement (LR) is usually about 2-4 q / ha depending on soil type and pH. However, soil should be tested for LR by nearby Soil Testing Laboratory and the dose should be decided accordingly. Generalised LR is depicted in Table 6.

Table: 6. Generalized lime requirement (t/ha)

Soil Texture	**Targeted soil pH change**	
	From 4.5 to 5.5	**From 5.5 to 6.5**
Sand and Loamy Sand	0.6	0.9
Sandy Loam	1.1	1.5
Loam	1.7	2.2
Silt Loam	2.6	3.2
Clay Loam	3.4	4.3

3.5. Crop response to liming and economics:

Yield advantage attributable to liming in case of pigeonpea grown in acidic soil of Jharkhand has been 34 % under farmer's practice and 105 % under 100 % NPK application. Corresponding figures for Orissa are 44 % and 92 %. Productivity gain in wheat grown on acid soils of West Bengal has been 52 % under farmers practice and 86 % under 100 % NPK application. Rice crop grown in submerged acid soils may witness moderate yield advantage which could be increased significantly provided recommended dose of NPK is applied. Thus, liming improves crop response to fertilizers applied to the crop. Productivity of wheat, cowpea, blackgram, pigeopea in States like Assam, Jharkhand, Orissa, West Bengal and Kerala with 50 % NPK plus lime have been equal to or more than with 100 % NPK application.

Benefit: Cost ratio (B:C) of liming alongwith fertilization in case of wheat ranges from 2.78 to 3 in West Bengal. In case of pigeonpea B:C ratio ranges from 1.48 to 1.8 in Orissa. Green gram in Assam recorded B:C ratio of 2.6 to 3.19. B:C ratio for rice has been observed to be more than 2.

4. Management of moderately sodic soils:

Salt affected soils cover more than 7 m ha area most of which occurs in indogangetic plane in the States of Punjab, Haryana, U.P., Bihar and parts of Rajasthan. Arid tracts of Gujarat and Rajasthan and semi-arid tracts of Gujarat, Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh also have large area affected by salinity/alkalinity. Crops grown on saline soils suffer on account of high osmotic stress whereas nutritional disorders, toxicities and poor soil physical conditions reduce crop productivity in alkali soils. Soils with pH >8 and exchangeable sodium more than 12-15 % need to be treated with suitable ameliorant.

4.1. Distribution and extent of salt affected soils in NFSM states:

Table 7. depicts area affected by salinity and alkalinity in NFSM-wheat States. The area includes saline soils which can be reclaimed through leaching with good quality water. However a major area cropped to wheat has moderately alkaline pH which adversely affects nutrient use efficiency and wheat productivity. In order to achieve targetted wheat production, it is necessary that exchangeable sodium and subsequently soil pH are reduced to optimum levels through appropriate interventions.

Table 7 Area of salt affected soils in NFSM-Wheat states

State	Area (000,ha)
Bihar	85
Gujarat	1649
Haryana	555
Punjab	480
Madhya Pradesh	242
Maharashtra	127
Rajasthan	1138
Uttar Pradesh	958
Total	**5234**

4.2. Amelioration of alkali soils:

Amelioration of alkali soils involves replacement of exchangeable sodium from soil-exchange complex and leaching out of soluble salts from root zone. This is accomplished through application of chemical ameliorants (which furnish calcium for replacement of sodium from the exchange complex of the soil) followed by leaching.

Soil of affected area should be tested for gypsum requirement (GR). However, generalized GR based on soil type and degree of sodicity is depicted in Table 8. Agricultural grade gypsum or phosphogypsum should be incorporated into soil @ 75 % of GR at least 15-30 days before planting of a *kharif* crop. The treated field should be kept submerged with good quality water for facilitating reaction and subsequent leaching of by-product salts. Treated field should be planted to rice during *kharif* season followed by wheat during *rabi*.

Fields with marginally alkaline pH can support a wheat crop even without treatment. However, the productivity of the crop and nutrient use efficiency will improve significantly if soil is treated with gypsum or phosphogypsum at moderate (1-1.5 t/ha) rates either in *kharif* season or before planting irrigated wheat crop.

Table 8: Generalized gypsum requirement (t/ha) for reclamation of sodic soils

Soil type	Initial exchangeable sodium (%)					
	15	**20**	**25**	**30**	**40**	**50**
Loam	0.50	1.5	2.0	3.0	5.0	6.5
Clay Loam	0.75	2.0	3.35	4.5	7.0	10
Clay	1.0	2.75	4.5	6.0	9.5	13.0

4.3. Chemical ameliorants:

Amendments used for chemical amelioration are either soluble calcium salts like gypsum, phosphogypsum or acid formers like pyrites, sulphuric acid, aluminum sulphate, sulphur etc. However, gypsum and phosphogypsum are easily available and are most economical ameliorants. Thus they have been included for financial assistance under NFSM programme for wheat crop.

4.4. Crop response and economics:

Soils with high alkalinity can be used to grow highly tolerant crops such as paddy. Productivity of even tolerant crops grown in such soils remains suboptimal. Reclamation of sodic soils requires fairly high quantity of gypsum (5-15 t/ha). Districts selected under NFSM-Wheat, however, exhibit respectable wheat yield levels and soil pH ranging from 7.5 to 8.5 thereby suggesting existence of moderate alkalinity. Application of gypsum to such soils at moderate rates (1-1.5 t/ha) is bound to improve nutrient use efficiency and crop productivity. Although yield gains attributable to gypsum application depend on many factors (existing level of sodicity, soil type, quality of irrigation water, nutrient management practices followed etc.) yield advantage of about 20 % in each crop of rice-wheat sequence due to gypsum application has been observed in field studies. This amounts to additional yield of about 500-600 kg/ha of each crop. The additional annual monetary gain is therefore Rs 9000 to 10,000 in the very first year. The advantage will continue for 4-5 years with progressive decline in magnitude which can be reversed by repeating the treatment. Thus cumulative monetary gains are much higher compared to the cost of gypsum (Rs 2000 to 3000 ha) incurred. Benefit: cost ratio will remain greater than 3:0. Fields being irrigated with poor quality (high residual sodium carbonate) irrigation water should be treated with moderate doses of gypsum annually for guarding against likely sodification of the soil. Underground irrigation waters in parts of Haryana, Uttar Pradesh, Rajasthan, Gujarat and Madhya Pradesh have been observed to be sodic. Their regular use for irrigation in many cases has caused soil degradation.

5. Integrated Nutrient Management (INM) in Pulses:

The basic purpose of INM is to restore soil fertility, improve nutrient use efficiency, maintain soil quality in terms of physical, chemical and biological properties and improve productivity and sustainability of production systems. Accordingly, INM in pulses component of NFSM has been included with a view to enhance productivity of pulses or pulses-based production systems on sustainable basis. The interventions include use of gypsum and lime as a source of secondary nutrients-sulphur and calcium, respectively and micronutrients.

5.1. Use of NPK in pulses:

Requirement of major nutrients such as NPK per ha is much less for pulses than for cereal crops. Nutrient recommendation should be obtained from the State Agricultural University or a Soil Testing Laboratory for pulses crops proposed to be planted. Basal application of nitrogen, phosphorus and potash should be made through drilling fertilizers just below seed. Bullock drawn or tractor drawn seed-cum-ferti-drills can be used for the purpose.

5.2. Use of gypsum/lime in pulses:

Agricultural grade gypsum and phosphogypsum are used as source of sulphur—a secondary nutrient which has become widely deficient in oilseeds and pulses growing areas in NFSM States. It usually contains 18-20 % of sulphur. Recommendation for gypsum varies from 100 kg/ha to 200 kg/ha depending on crop and plant available-S status of the soil. Full quantity of the material should be applied and mixed with soil prior to crop planting. Yield gains of 20 to 30 % in pulses grown in S-deficient soils attributable to gypsum application are commonly observed.

Agricultural grade lime is the most commonly available source of calcium which is often deficient in acid soils. Lime or other liming materials such as dolomite, basic slag, paper mill sludge etc. can also be used if easily available. They are applied in powder form (particle size below 80 mesh) in furrows @ 2-4 q/ha before planting a crop. Pulse crops such as pigeonpea, black gram, cowpea grown in acid soils have recorded yield advantage of 40-100 % due to liming.

5.3. Use of micronutrients:

Zinc deficiency is commonly observed in most NFSM-Pulses districts whereas boron deficiency is noticed in high rainfall areas. Deficiency of molybdenum is wide spread in north eastern and eastern states. Symptoms of deficiency, sources of these nutrients and application methods described in section 2 may be followed

5.4. Use of biofertilizers:

Pulse crops meet a major portion of their nitrogen requirement through biological fixation of atmospheric nitrogen. Seed treatment with crop specific strain of Rhizobium bacteria promotes N-fixation and improves crop yields by 10 to 20 %. Use of Rhizobium inoculants in pulse crops is an integral part of improved package of practices for pulses. Use of phosphorus solublizing bacteria (PSB) is recommended for improving phosphorus availability particularly in calcareous soils. Rhizobium and PSB inoculants are manufactured by SAUs, State Departments of Agriculture and State Agro-Industries Corporations, State Cooperative Marketing Federations, KRIBHCO, IFFCO and many organizations in private sector. In order to ensure optimum crop response, biofertilizers should be applied as follows.

Jaggary or sugar solution is prepared by dissolving 120 g of jaggary or sugar in 1 litre of water. Rhizobium culture is dissolved in clean water which is mixed with jaggary solution. The solution thus prepared is used to wet the seed surface. The quantity of culture required is usually 10 g/kg seed. The treated seed should be dried in shade for an hour and sown within 2 days. Application method and precautions to be taken are printed on packing of the inoculant.

PSB culture should be mixed with sand or farm yard manure, broadcast and mixed with soil at the time of planting. Alternatively, seed should be treated with PSB inoculants @ 10 g/kg seed in the manner recommended for Rhizobium inoculant above.

The guidelines mentioned above are generalized and may need refinements according to local situations. Precise dose and detailed methodology on use of micronutrients and ameliorants in rice, wheat or pulses grown on different soil types should be obtained from the State Agriculture University/ICAR Institute or Krishi Vigyan Kendra located in the area.