


e-book

Certificate Course on Integrated Nutrient Management (CCINM) for Fertiliser Dealers




National Institute of Agricultural Extension Management (MANAGE)
(An Autonomous Organization of Ministry of Agriculture & Farmers Welfare, Govt. of India)
Rajendranagar, Hyderabad-500030, Telangana, India.

Certificate Course on Integrated Nutrient Management (CCINM) for Fertiliser Dealers

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Foreword

Director General, MANAGE

Fertiliser plays an important role in crop production. However, farmers are applying indiscriminate quantity of fertiliser which affects soil, water and environment, besides, increase in cost of production. Moreover, non-judicious use of fertiliser leads to decrease in soil fertility and decline in crop yield. Fertilizer consumption for India is calculated to be 175 kilograms per hectare. However, Fertilizer consumption of India was only 12.4 kilograms per hectare in 1969. The NSSO 70^{th} round survey indicates that at all India level, average monthly expenditure on crop production per cultivating agricultural household was estimated as ₹ 2192. Of which, about 24 percent on fertilizers and manure.

Both Public extension system and private extension service providers are disseminating advisory services on better fertiliser management and Integrated Nutrient Management (INM) to the farmers. Among the private extension service providers, fertiliser dealers/input dealers are considered to be the first hand information source for the farmers in fertiliser management. However, majority of them do not possess formal degree in agriculture nor have knowledge on scientific management of fertiliser including INM. Considering the importance of capacity building to the fertiliser dealers, Government of India has made 15 days INM program mandatory for fertiliser dealers to obtain and renew the license on fertiliser dealership through the amendments of the Fertiliser (Inorganic, Organic or Mixed) (Control) Order, 1985.

Accordingly, MANAGE being the national level implementing agency, it has initiated a Certificate Course on Integrated Nutrient Management (CCINM) as 15 days course for fertiliser dealers in 2018. The program organised with the help of Nodal Training Institutes such as KVKs, ATMA, FTCs etc., through SAMETI as state level nodal implementing agency. In this context, MANAGE has prepared a comprehensive study material in the form of e-Book covering all the subjects/topics of CCINM with the help the Scientists and Experts from ICAR institutes, SAUs and other reputed institutes.

I appreciate the efforts made by Dr N Balasubramani, Director and Principal Coordinator (CCINM) and Mr Vincent A, Consultant (CCINM), Centre for Sustainable Agriculture & Climate Change and Adaptation (CSA & CCA), MANAGE in bringing out the e-book on Certificate Course on Integrated Nutrient Management.

I believe that this INM book will facilitate NTIs, Coordinators and resource persons of CCINM program to effectively impart training and enhance the knowledge of the fertilizer dealers on INM.

Yours Sincerely,

(Dr Chandra Shekara)

Preface

Director, Centre for Sustainable Agriculture & Climate Change and Adaptation (CSA&CCA), MANAGE

Integrated Nutrient Management (INM) is helping the farmers in restoring the soil fertility, sustaining the crop productivity and minimizing the cost of crop production. Creating awareness among the farmers for judicial application of fertiliser is therefore essential. It can be done through a series of training and other capacity building programmes.

Fertiliser/input dealers play a major role in disseminating appropriate technical knowledge on fertiliser management to the farmers. However, the dealers' have inadequate scientific knowledge and competency on INM. In order to enhance their professional competency on INM, Government of India has amended the Fertiliser (Inorganic, Organic or Mixed) (Control) Order, 1985 under the Essential Commodities Act, 1955, wherein 15 days residential course on INM is mandatory to obtain and renew the fertiliser license.

Accordingly, MANAGE being the Nodal implementing agency at national level, it has launched a Certificate Course on Integrated Nutrient Management (CCINM) for Fertiliser Dealers in the year 2018. The program is implemented with the help of various Nodal Training Institutes (NTIs) such as KVKs, ATMA, FTC etc. across the country.

In order to support the NTIs, facilitator/coordinator/resource persons, the Centre for Sustainable Agriculture & Climate Change and Adaptation (CSA & CCA), MANAGE has prepared a comprehensive e-book on CCINM with the help of the scientists/ experts from ICAR institutes, SAUs and other elite institutes.

The book consists of 11 chapters covering the topics such as CCINM guidelines, information related to inorganic fertiliser and its computation, organic fertiliser production and its use; production of bio fertiliser and its application, importance of agronomic practices such as crop rotation, site specific placement of fertiliser, communication skills and innovative extension tools for fertiliser dealers to reach out to farmers etc. The e-book will help the Nodal Training Institutes and resource persons to systematically cover all the subjects of INM and impart training to the fertilizer dealers to enhance their professional competency on CCINM.

MANAGE also believes that this will serve as a source book for all the stakeholders of agriculture in providing scientific advisory services to farmers in fertiliser management and INM.

Dr N Balasubramani
Director
(CSA&CCA)
MANAGE

Content Pages

Chapter – 1

Guidelines for Operationalization of Certificate Course on Integrated Nutrient Management for Fertiliser Dealers

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Background

Fertiliser is one of the important agri inputs in Agriculture. The fertilisers is mostly marketed by dealers. Most of the farmers are dependent on fertiliser dealers for information related to fertiliser and soil health management. However, majority of the fertiliser dealers do not have formal education in agriculture. It is essential therefore to impart technical knowledge on agriculture with special reference to soil health management and advisory based on scientific recommendations.

In this context, the National Institute of Agricultural Extension Management (MANAGE) has been entrusted to design a 15 days residential certificate course for fertiliser dealers and to equip them to acquire professional competency on plant health management and advisory services thereof. The certificate course may further help the public and private extension systems to utilise these trained candidates as para extension professionals.

Mission

To enhance the professional competency of fertiliser / prospective dealers and to develop them as para extension professionals on soil health management

Objectives

1. To impart the technical knowledge on soil health management to the fertiliser / prospective dealers
2. To provide knowledge about the rules and laws governing the fertilisers
3. To develop the fertiliser / prospective dealers as para extension professional on soil health management

Methodology

The program will be organised continuously for a period of 15 days as a residential program for fertiliser / prospective dealers. The program consists of both Class room session and hands-on experience by the resource persons from the Agricultural University, Research station, free lancers and other experts on the subject and field / exposure visits to nearby agricultural farms / INM plots of Agricultural University/ Research Organisations/ KVKs / innovative farmers field, etc. The field visit may help them to acquire knowledge on recent advancement in soil health management.

Study material is provided to every participant of the certificate course in their local language and multimedia cum interactive videos / instructional devices are to be used in the class rooms.

The course is offered by SAMETIs and other Nodal Training Institutes (NTIs) selected by SAMETIs. The potential agricultural training institutes such as Agricultural Colleges, KVK, FTC, ATMA etc., could be selected as NTIs.

The selected NTI is to ensure the enrolment of 30 fertiliser dealers per batch for a period of 15 days, preferably from the surrounding locality to ensure location specific knowledge. The programme will be implemented and monitored by respective SAMETIs at state level with the overall guidance from MANAGE at National level. The course will be organised under Self-Finance mode.

The Roles and Responsibilities of Stakeholders Role of MANAGE

MANAGE is the implementing agency for conducting Certificate course for fertiliser / prospective dealers at National level

Creating Awareness cum Orientation about the certificate course among various stakeholders.

Role of SAMETIs

- ✓ SAMETI is the State Nodal Implementing agency for organising the Certificate Course to the fertiliser / prospective dealers at the state level under the overall guidance of MANAGE
- ✓ SAMETIs will give publicity of the course among the fertiliser / prospective dealers in the state.
- ✓ SAMETIs themselves can conduct the program with the help of facilitator and also conduct with the help of other potential Nodal Training Institutes.

Role of Nodal Training Institute (NTI)

- ✓ Agricultural Colleges, KVKs, FTC, ATMA, etc., will be NTIs at the regional/district level. The selected NTIs need to publicise the certificate course among the practicing and prospective fertiliser dealers for a wider reach of the program.
- ✓ The concerned NTIs are to collect the course fee i.e. Rs. 12,500 per candidate in the form of Demand Draft, in favour of SAMETI.
- ✓ The NTI has to submit the list of 30 enrolled candidates along with Demand draft of course fee to SAMETI.
- ✓ SAMETI has to retain an amount of Rs 7500/ - (@ Rs 250 / per candidate) towards monitoring charges and an amount of Rs. 7500 has to be sent to MANAGE towards accreditation charges (i.e. 250 per head). The remaining amount of Rs 3,60,000/- has to be transferred to NTIs concerned.
- ✓ NTIs have to utilise the amount as per the cost norms indicated in the Annexure – I in the guidelines.

- ✓ The Nodal Training Institute will get the entire expenditure audited by ta CAG – Empanelled practising Chartered Accountant. After the audit, the NTI will have to submit the UC to SAMETI.
- ✓ NTI is to conduct one midterm exam on the 8th day of the program and final exam on 15th day from the commencement of the program.
- ✓ The Facilitator is responsible for setting the midterm and final question paper and the results of which are to be sent SAMETIs for verification and award of the course certificate to the successful candidates.

Role of Facilitator

- ✓ The Facilitator is responsible for organising the course which includes identifying the relevant resource persons based on the course framework, providing honorarium to the resource person, arrangement of facilities to the participants including food and accommodation, preparation of schedule for 15 days programme with both theory and practical and get it approved by the SAMETI Director, preparation of exams and getting feedback from the participants, settlement of accounts, etc.,.
- ✓ The Facilitator has to send the weekly progress reports about the functioning of programme to the SAMETI i.e. on the 8th day and on 15th day.
- ✓ The Facilitator must ensure uniform and Id cards to the enrolled candidates
- ✓ The Facilitator should ensure practicals and hands - on experiences in the areas such as soil sampling, identification of nutrient disorders in the plants, INM practices, Site Specific Nutrients Management practices, soil, water, leaf analysis, etc

Eligibility Criteria for Candidates for Enrolment

- ✓ The course is open to all the practicing fertiliser dealers and prospective dealers. The candidate with the minimum qualification of 10th pass will be selected for enrolling to the course. The application form is given in Annexure – III.
- ✓ Course fee: The fertiliser / prospective dealer has to pay the entire course fee of Rs. 12,500 per candidate.

Eligibility Criteria for the Program Coordinator

The programme coordinator should have sound knowledge on agriculture with good managerial and administrative capacity. The agricultural professional with good communication and technical knowledge in the subject of soil health and fertiliser management may be given preference.

Curriculum

The curriculum consisting of theory practicals and filed visit are given in Annexure – II. The coverage of content should be based on the local need and relevance. Minimum 30 to 40 % of the content should have local content.

Time Schedule

Pre - lunch : 10.00 A.M. to 1.00 P.M. (with a tea break)

Lunch : 1.00 P.M to 2.00 P.M.

Post- lunch : 2.00 P. M. to 5.00 P. M. (with a tea break)

Maintenance of Attendance

Each candidate is required to fulfil a minimum of 80 % of attendance both in theory and field visit for appearing the final exam.

Evaluation

The performance of the candidate is evaluated based on Midterm Examination, Final Examination, Assignment and Viva – Voce as indicated below.

Distribution of marks

S.No.	Pattern of evaluation	Marks
1.	Midterm exam	30 marks
2.	Final exam	50 marks
3.	Assignment	10 marks
4.	Viva voce	10 marks
	Total	100 Marks

Result

1.	40 and above Marks	Pass
2.	60-80 Marks	First Class
3.	Above 80 Marks	Distinction

Certification

The successful candidates will be awarded certificates jointly by MANAGE and SAMETI.

Cost norms of the program

Sl.No.	Details	Total Amount (Rs.)
1.	Food and Accommodation @ Rs.500 / person / day for 15 days x 30 participants	225000.00
2.	Study Material @ Rs.700 / person for 30 participants including Video films and DVDs	21000.00
3.	Exposure Visit @ Rs.10000 / visit for 5 visits	50000.00
4.	Honorarium to the Facilitators for 15 days	15000.00
5.	Monitoring charges @ Rs.250 / candidate for SAMETI for 30 candidates	7500.00
6.	Accreditation charges @ Rs.250 / candidates for MANAGE for 30 candidates	7500.00
	Sub-Total:	**326000.00**
7.	**Add:** Institutional charges and other Administrative expenditure to SAMETI /NTI (Honorarium to the resource persons, hall rent, TA to the resource persons, group photo, banner, and other miscellaneous expenditure)	**49000.00**
	GRAND TOTAL:	**375000.00**

Note: Course fee is Rs.12500.00 per candidate for 15 days for a batch of 30 candidates under Self-Finance Mode.

Subjects to be covered under CCINM

Sl. No.	THEORY AND PRACTICAL CLASSES
1	Plant, Plant nutrients and Uptake of nutrients by plants Identification of different types of fertilizers, micronutrients, soil amendmentsetc.
2	Agro ecological situation; Soil types and Plant nutrients in soil (Primary,Secondary & Micronutrients)
3	Role / Functions of Primary and Secondary nutrients in plants and theirdeficiency Symptoms
4	Role/ Functions of Micro- nutrients in plants and their deficiency Symptoms
5	Available forms of different plant nutrients and related fertilizers withpercentage of nutrients

6	Inorganic Fertilizer: Types of Fertilizers based on Ingredient (Straight , Complex and Mixed Fertilizers) and based on Physical Form (Solidand Liquid Fertilizers), - Computation of amount of fertilizer, Micronutrients on the basis of percentage of nutrient and doses for different major crops - Hands -On experience on calculation of fertilizer dose through Computer / Apps - Qualitative testing of fertilizers for impurities/ adulteration - Preparation of Fertilizer solution for foliar spray
7	Concept of Soil fertility, Soil Health and Role of Organic ManureEnvironmental impact of excessive use of fertilizer application Preventing measure to avoid the soil fertilizer erosion
8	Different sources of Organic Manure (FYM, Green Manure, Vermicompost, Crop residue)
9	Production procedure of different Organic Manure/ Compost (FYM, Green Manure, Vermicompost), Crop residue management
10	Different Microbial/ Bio-inoculant/ Bio- Fertilizer: Rhizobium, Azotobacter, Phosphate solubilizers, Azospirilum, Blue Green Algae... , Bio-liquid manure (Panchagavya etc)
11	Method of application of different Bio-fertilizer including Doses of bio- fertilizer; Dos and Don's in application of Bio-fertilizer
12	Concept of Acid Soil, Saline Soil, Sodic soil; Soil Toxicity, its effect on plant nutrition uptake; Different Soil Amendments: Lime, Gypsum; their importanceand Reclamation of Soil
13	Importance of Soil / water Testing, Soil / water Sampling techniques, Different simple Soil Testing Kits (Soil Testing Fertilizer Recommendation: STFR meter; Medha Parishak)

Sl. No	FIELD VISITS
1.	Exposure visit to field for Collection and processing of soil / water / leaf samples for testingand Assessing soil fertility status using STFR Meter, and test based inferences. Includingvisit for soil test labs, water and micro nutrients analysis labs.
2.	Field visit for hands – on Experience on Application of fertilizer, Lime, Gypsum forcorrection / reclamation of soil on the basis of soil test result
3.	Visit to Scientific compost / vermicompost / Enriched Vermi compost Units for hands-on experience on preparation of Compost / Bio - inoculum / Vermi wash preparation / Panchgavya etc.
4.	Exposure Visit to Bio Fertilizer Labs and hands on experience of Bio Fertilizers for seedtreatment, root dipping of sapling and soil application etc.

5.	Exposure Visits to INM fields and organic farms.

Perception of CCINM trained candidates about the program

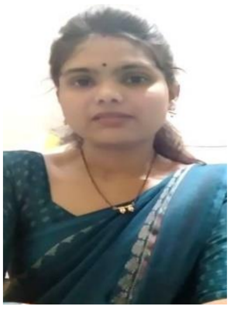
The feedback has been collected from facilitators and also from trained candidates with one-to-one interaction. The perceptions of the program are briefly given below.

- ✓ Majority of the trained candidates have expressed that the Certificate Course on Integrated Nutrient Management (CCINM) has helped them to acquire knowledge and skills related to efficient fertiliser management such as soil test based fertiliser application, Integrated Nutrient Management, crop and soil based fertiliser management, etc.
- ✓ Some of the trained candidates have established bio fertiliser and other organic-based fertiliser units. This may ensure additional income for the trainees and also the availability of organic fertiliser for the farmers.
- ✓ Many prospective dealers are getting benefited from this course as they can get the license for the establishment of fertiliser shops within a short period, which promotes entrepreneurship and livelihood of youth in villages.
- ✓ Moreover, the facilitators who are organizing the classes of CCINM indicated that the field visits inbuilt in the programme curriculum such as the field visits to biofertilizer lab, vermicompost units, soil testing laboratories, organic farms etc., help the trainee to understand the production and management processes of several fertiliser management technologies /techniques.
- ✓ Trainees firmly believe that the adoption of organic fertiliser in the management of crops will improve soil fertility and crop productivity. As most of the fertiliser dealers/youth are farmers themselves, a few of them have adopted organic farming practices in their farms in post training, besides, suggesting the organic technologies to the fellow farmers.
- ✓ Around 4288 candidates have been trained under CCINM from 2018 to 2021.

Details of trained candidates from 2018 to 2021

S.No.	Name of the State	Number of Candidates
1.	Bihar	924
2.	Gujarat	30
3.	Haryana	262
4.	Karnataka	88
5.	Maharashtra	59
6.	Uttar Pradesh	2925
	Total	**4288**

Feedback of the Candidates of CCINM about the program

S.No.	Name of the Candidates, district and state	Feedback	Photo
1.	Mrs Jayshree, Vanamati, Maharashtra	CCINM course has helped me to learn Organic farming, bio-fertilizes, Bio-Pesticides etc., Also, enabled me to know about the fertilizer management methods related to the reduction of the cost of cultivation. After joining the course, my knowledge of fertiliser management has increased. She expressed that the program has motivated her to serve farmers by following business ethics in trading fertilizers.	
2.	Mr Abishek Kashikar, Nagpur Maharashtra	CCINM has enabled him to understand the various concepts of integrated nutrient management. He stated that he was previously unaware of the fertiliser management practices, but after joining the course, he learned various procedures and methods of managing crops, application of fertiliser and reduction of the cost of cultivation. He is certain that his advice now helping the farmers to manage the crops effectively.	
3.	Mr Juber Ahmed, Balarampur, Uttar Pradesh	He indicated that the 15 days CCINM course has changed his perception towards fertiliser management. He believes that adopting INM at farmers' fields will enable farmers to gain more income and safeguard the soil, water, ecosystem.	
4.	Mr Ankit Kumar, Madhepura, Bihar	He expressed that the first thing he has learned from CCINM was how to do farming, the subjects on application methods and procedures of fertiliser have helped him to reduce the inputs and manage crops effectively. Also, CCINM course has further helped him to learn the importance of vermicompost	

		and other organic fertiliser in crop production.	
5.	Sagar Thaygi, Uttar Pradesh	He expressed with happiness that though he did not had chance to get graduated, CCINM course has helped him to study agriculture. He stated that after his higher secondary, he was running a business and earning his livelihood. After joining CCINM, he has gained knowledge on several aspects of fertiliser management, especially on organic farming, vermicompost production and benefits of its application in crop production.	

The success story of Mr Devanshu Kumar from Bhadohi district, Uttar Pradesh-Establishment of Mini soil testing lab for advising farmers

Mr Devanshu Kumar Gupta

Mr Devanshu Kumar Gupta was always helping his father - Mr. Ram Kumar Gupta in the sale of fertilizer during his free time. Their fertiliser shop - Ujhani Khad Bhandar Ujhani was located at Bhadohi district, Uttar Pradesh. However, the sudden death of his father has pushed him into trouble as the fertiliser license was in his father's name. Mr Devanshu Kumar Gupta had left with no idea on what to do to run the fertiliser shop. However, he was fortunate enough to get to know about the Certificate Course on Integrated Nutrient Management (CCINM) due to the wider publicity and awareness created by Laxmi Jan Kalyan Seva Sansthan (LJKSS), an NGO which is organizing CCINM as one of the NTIs under the guidance of MANAGE since 2019. With the help of LJKSS, he has joined the CCINM course in August 2020. After completing the CCINM programme of MANAGE, he could obtain the fertiliser license from the competent authority. The knowledge and skills acquired during the CCINM classes are helping him to provide scientific advice to the farmers on fertiliser management. Further, knowing the importance of soil test-based fertiliser application, he has established a mini soil testing laboratory at his shop and advises his clients to get their soil tested before applying fertiliser. He informed that before CCINM, he and his father were not aware of providing advice to farmers, they sold the fertilizers to the farmers what they asked for. But, today, he is giving advice to farmers on all aspects of fertiliser management. This helps the farmers to reduce the cost of cultivation by applying the required quantity of fertiliser and indirectly helps in protecting soil, water and environment from the fertiliser pollution. Mr Devanshu Kumar Gupta's story is one of the many innovative practices adopted by the trainees of CCINM, there are many such happenings because of the CCINM programme.

Chapter - 2

Agro Ecological Situation; Soil Types and Plant Nutrients in Soil
Agro-Ecological Regions (AER) of India

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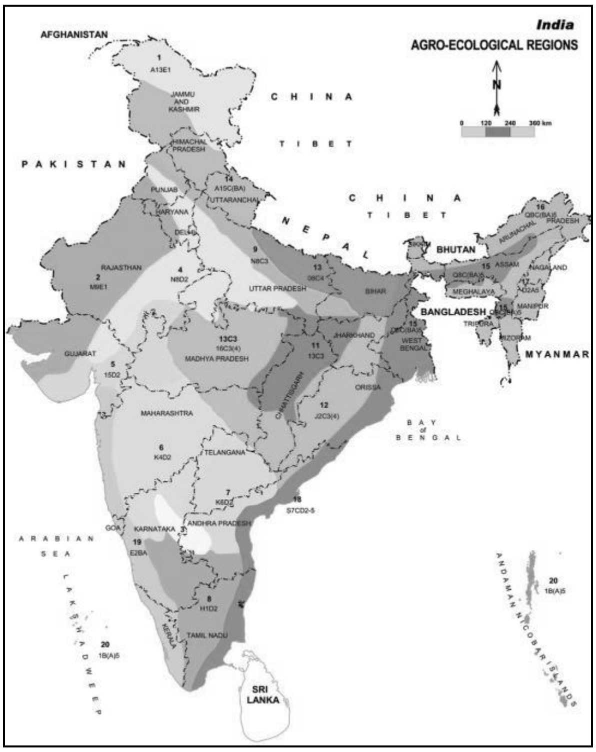
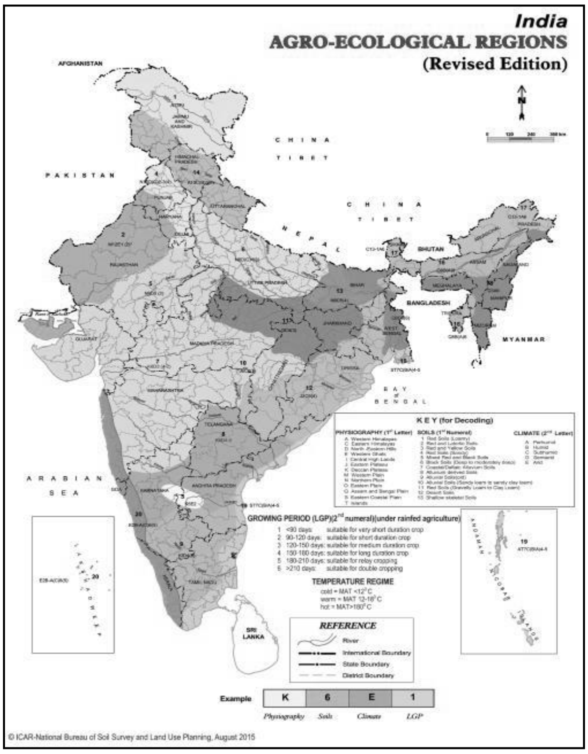
Introduction

Agro-ecology refers to the study of agricultural ecosystems and their components as they function in themselves and as a part of the larger ecosystem. Difference between an agro-climatic zone and an agro-ecological zone is that Agro-climatic zone refers to a land unit based on major climate, superimposed on the length of growing period/moisture availability period, whereas, Agro-ecological region is the land unit derived from agro-climatic zone and superimposed on landform and soils which influences both the climate and length of growing period. LGP is the number of days in one year during which rainfall plus stored soil moisture exceed the half of potential evapotranspiration.

There is a need of systematic investigation of the agro-ecological regions, in terms of soil, climate and physiographic and moisture availability periods (LGP), is important for planning appropriate agricultural land use. The National Bureau of Soil Survey and Land Use Planning (NBSS and LUP) has been instrumental in preparing 20 agro-ecological regions (AER) (NBSS Publ. 35, 1999) based on the climate, growing period, soil groups and physiography. Subsequently, these agro-ecological regions were sub- divided into 60 sub-regions. The AER were further revised in nomenclature and symbols and released in 2015 by ICAR-NBSS and LUP (NBSS Publ. 179, 2015) and is available in BHOOMI Geo-portal.



Agro-ecological regions of India (1999**)**



Revised agro-ecological regions of India (2015)

Agro-ecological regions (AER) and Sub Regions (AESR) in Assam

Agro-ecological region (AER) 15

The AER covers Teesta and Brahmaputra Plains, Assam and North Frontier Parts Bengal Plains, characterized as warm to hot, sub humid moist to per humid region. This has subdivided in following agro-ecological sub regions.

15.2- Middle Brahmaputra Pain, Hot Sub humid To Humid (Inclusion of per Humid) Eco-Region with loamy alluvium derived soils with LGP 240-270 days

15.3- Teesta, Lower Brahmaputra Plain and Barak Valleys, Hot Moist Sub humid To Humid (Inclusion of per Humid) Eco-Region with alluvium derived soils with LGP 270-300 days.

15.4- Upper Brahmaputra Plain, Warm to Hot per Humid Eco Region with alluvial derived soils with LGP more than days.

Agro-ecological region (AER) 16

The AER covers Arunachal Pradesh, Bhutan and Sikkim with fringe areas under Assam bordering to parts of Bhutan and Arunachal Pradesh situated in Eastern Sub duded Himalayas , characterized as warm per humid region.

16.1- Terai, Foot Hills of Eastern Himalayas (Bhutan Foot Hills) Warm to Hot per Humid Eco Region with loamy to clayey Terai soil with LGP 270-300 days.

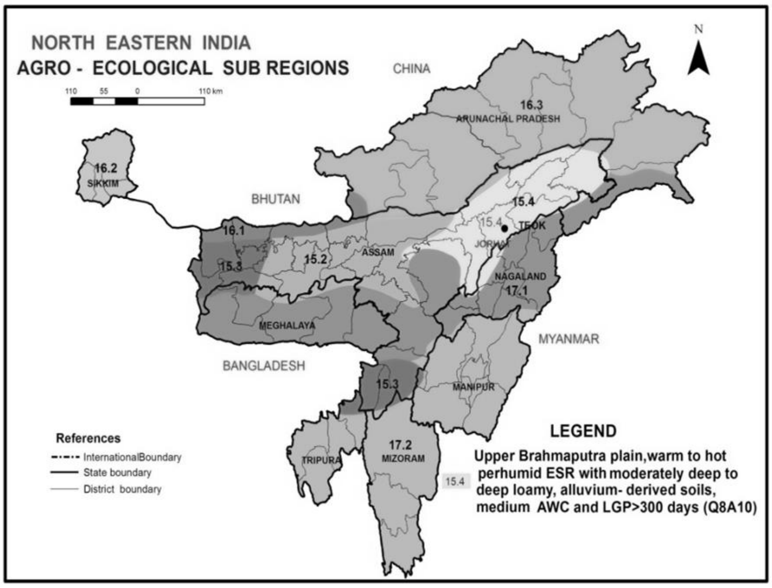
16.3- Sub duded Eastern Himalayas (Foot Hills of Arunachal Pradesh) Warm to Hot per Humid Eco Region with red sandy to red loamy soil with LGP 300 days.

Agro-ecological region (AER) 17

The AER occupies Meghalaya, Nagaland, Tripura, Manipur and Mizoram, situated in Meghalaya plateau and Purvanchal Hills, characterized as warm to hot per humid region.

17.1-Meghalaya Plateau and Nagaland Hills (Purvanchal Hill Ranges), Warm to Hot Moist Humid to per Humid Eco Region with red and lateritic soil with LGP more than 300 days.

17.2- Nagaland, Tripura, Manipur, Mizoram Hills (Purvanchal Hill Ranges), Warm to Hot Moist Humid to per Humid Eco Region with red loamy soil with LGP 270-300 days.



Agro-ecological regions of Assam and NE Regions, India

Different Soil Types in Agro-ecological Regions of Assam

Assam has versatile soil types in various agro ecological regions owing to their formation in varying landforms and parent materials. Broadly, the soils are derived from alluviums of Brahmaputra Plains as major formation and Tertiary Sandstones and Shales of Purvanchal Hill Ranges and pre-Cambian Gneissic parent materials of Meghalaya plateau as minor.

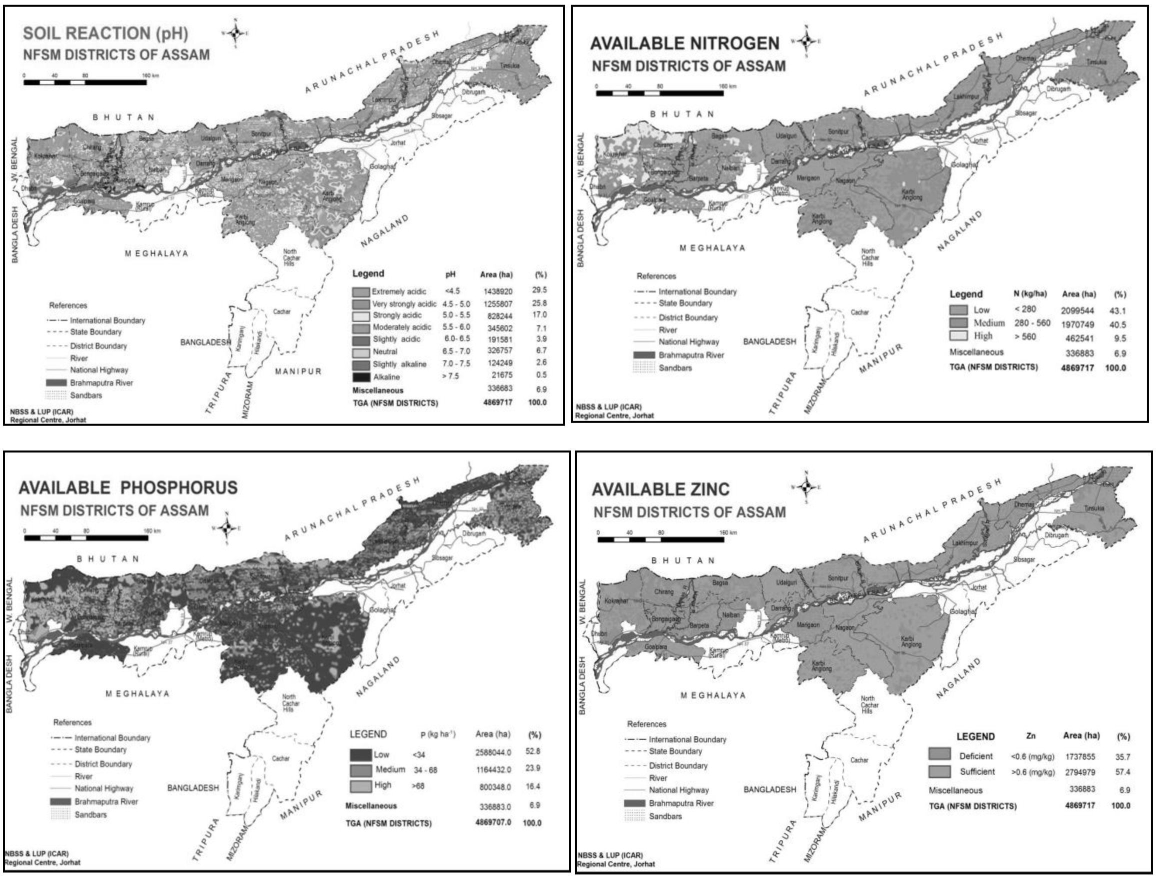
Table Soil types in agro-ecological regions of Assam

AER	Landforms	Soil Types
15 (Major) (Brahmaputra Valley Region)	Piedmonts	Deep, well drained, very strongly acidic sandy clay loam to clay loam soils (fine loamy family)
	Uplands	Very deep, well drained, very strongly to strongly acidic clay loam to silty clay loam and clayey soils (fine to fine loamy family)
	Broad Valleys	Moderately deep to deep, imperfectly drained, moderately to weakly acidic sandy clay loam to loamy soils (fine loamy to coarse loamy family)
	Old Alluvial Plains	Very deep, imperfectly drained, strongly to moderately acidic silty clay loam to silty clay and clayey soils (fine to fine silty family)

	Young Alluvial Plains	Very deep, imperfectly to poorly drained, weakly acidic to neutral, silt loam to loamy soils (coarse loamy to loamy family)
	Active Alluvial Plains	Very deep, moderately well to well drained, weakly acidic to slightly alkaline, loamy sand to silt loam soils (coarse loamy to coarse silty family)
16 and 17 (Minor) (Meghalaya Plateau, Eastern Subdued Himalayas/ Purvanchal Hills)	Low Amplitudinal Hills	Moderately deep to deep, somewhat excessively drained, strongly acidic, loamy to clay loam soils (fine loamy family)
	Piedmonts	Deep to very deep, well drained, very strongly acidic clay loam to clayey loam soils (fine to fine loamy family)
	Uplands	Very deep, well drained, very strongly to strongly acidic clay loam to silty clay and clayey soils (fine to fine loamy family)
	Narrow Valleys	Moderately deep to moderately shallow, gravelly, well drained, moderately to strongly acidic, clay loam to loamy soils (loamy-skeletal to fine loamy)
	Old Alluvial Plains	Very deep, imperfectly to poorly drained, very strongly to strongly acidic silty clay to clayey soils (fine to fine silty family)

Scenario of Soil Nutrient Status in Assam

Soil nutrient mapping (SNM) of 16 national food security mission (NFSM) districts of Assam has been appraised by National Bureau of Soil Survey and Land Use Planning (ICAR-NBSS and LUP) at 1: 50, 000 scale (NBSS Publ. 1041A-P). As per the SNM report and data base, 72.3% of total surveyed area (TSA) under 16 NFSM districts of Assam has been affected by degraded acidic soils with pH less than 5.5, in which, 29.5% of area has been affected by extreme soil acidity (pH < 4.5), being predominant in low hills, uplands and piedmont situations of the state. Soil organic carbon was found low in 11.2% of TSA, whereas, low availability of nitrogen, phosphorus and potassium were found in 43.1%, 52.8% and 42.1% of TSA of the state. Among the micronutrients, available zinc was found deficient in 35.7% of TSA of Assam (Bandyopadhyay et al., 2016).



Soil nutrient mapping of Assam (NFSM districts)

In Assam, deficiency of available Fe prevailed in Karbi-Anglong (15.0% of TSA), Darrang (11.0%), Baksa (10.2%) and Chirang district (10.0%). These districts are tribal dominated by the major clans as Karbi and Bodo. Shifting cultivation, locally known as slash and burn agriculture, is quite popular in this region. The practice is unscientific and is responsible for forest degradation, soil erosion and loss of fertility status of top soils, which may attribute to micronutrient deficiency at many places of the regionAvailable Fe deficiency was maximum in AESR 17.1 (6.1% of TSA). Assam comprises higher Mn deficiency and confined in Tinsukia (23.7% of TSA) and Chirang districts (23.7% of TSA). Mn deficiency was maximum in AESR 15.4 (10.1% of TSA) followed by AESR 15.2 (9.1% of TSA). Mn-deficiency has been observed in both the south and northern banks of Brahmaputra. Soils are occurred in sand casted lands, locally known as ‘‘Char lands’’. The soils are light textured both at surface as well as at sub-surface horizons from loamy sand to sandy loam, which may not retain the micronutrients. This may attribute to loss of Mn by rapid leaching as well as loss of Mn from top soils due to high run-off due to river bank erosion by Brahmaputra. Zn-deficient soils were mostly occurred in Chirang (76.1% of TSA) and Dhemaji (58.1% of TSA) districts. Zn deficiency was maximum area in AESR 15.4 (44.4% of TSA). Available Cu was deficient in 7.2% of TSA in Assam. Its deficiency was maximum in AESR 15.4 (9.1% of TSA). It appears that AESR 15.4 is the most vulnerable zone of soil micronutrient deficiency particularly prevailing in Lakhimpur, Dhemaji and Tinsukia districts of Assam (Bandyopadhyay et al., 2018).

Sub Topic 2: Crops/ Cropping/ Plantation Systems in Assam

Table Major Cropping/Plantation Systems in AESR of Assam

AER	AESR	Districts	Major Cropping/ Plantation Systems
15 (Major)	15.2	Baksa, Nalbari, Barpeta, Kamrup, Sonitpur, Darrang, Udalguri, Nagaon, Morigaon	**Pre-Kharif** (Ahu Rice/ Cucurbit) **Kharif** (Sali Rice/ Jute/ Sesame/ Black gram) **Rabi** (Wheat/ Mustard/ Vegetables) **Other** (Sugarcane) **Plantation** (Banana/ Assam Lemon/ Pineapple/ Arecanut)
	15.3	Kokrakjhar, Chirang, Dhubri, Goalpara, Bongaingaon, Cachar, Hailakandi, Karimganj	**Pre-Kharif** (Ahu Rice/ Cucurbits/ Mesta) **Kharif** (Sali Rice/ Black gram/ Sesamum) **Rabi** (Mustard/ Pea/ Lentil/Wheat/) **Other** (Vegetables-Cole/ Chili) **Plantation** (Papaya/ Jackfruit/ Banana/ Assam Lemon/ Pineapple)
	15.4	Tinsukia, Dibrugarh, Dhemaji, Lakhimpur, Sibsagar, Jorhat, Golaghat	**Pre-Kharif** (Ahu Rice/ Sesame/ Cucurbits) **Kharif** (Sali Rice/ Black gram/ Green gram) **Rabi** (Rice/ Pea/ Lentil/ Wheat/ Mustard/ Potato/ Cole/ Chili)/ **Other** (Sugarcane) **Plantation** (Arecanut/ Banana/ Assam Lemon/ pineapple)
16 (Minor)	16.1	Chirang, Kokrajhar	**Pre-Kharif** (Ahu Rice/ Cucurbits) **Kharif** (Sali Rice/ Sesame/ Black gram/ Jute) **Rabi** (Maize/ Mustard/ Chili/ Lentil/ Pea) **Plantation** (Medicinal / Aromatic/ Citrus/ Banana) **Horticulture** (Ginger/ Turmeric/ Black pepper)
	16.3	Lakhimpur, Tinsukia	**Pre-Kharif** (Ahu Rice/ Jute/ Sugarcane) **Kharif** (Sali Rice/ Black gram/ Sesame)

			Rabi (Wheat/ Mustard) **Plantation** (Banana/ Pineapple/ Orange/ Assam Lemon)
17 (Minor)	17.1 17.2	Karbi-Anglong, Dima Hasao	**Pre-Kharif** (Jhum Paddy-TRC/ Tapioca/ Cucurbits) **Kharif** (Sali Rice/ Sesame/ Black gram/ Pigeonpea/ Cotton/ Jute) **Rabi** (Maize/ Mustard/ Chili/ Potato/ Pea/) **Plantation** (Coconut/ Arecanut/ Banana/ Lichi/ Lemon/ Pineapple/ Swat potato/ Orange) **Other** (Sugarcane) **Horticulture** (Ginger/ Turmeric/ Black pepper)

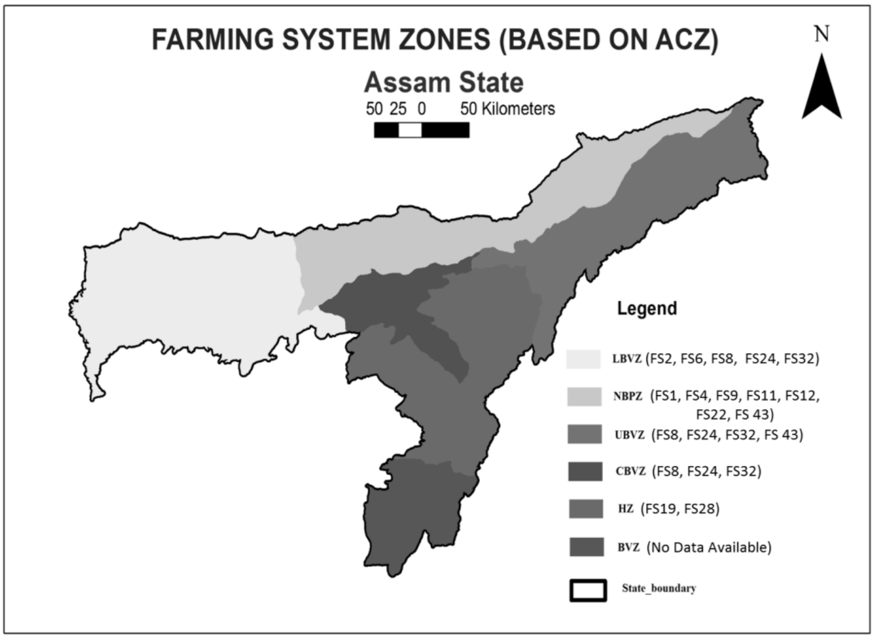
The Farming System Zones of Assam (Agro-climatic Zone Based)

Farming system zones has been developed by Bhowmick et al. (1999) based on agro-climatic zones in Assam. There were 43 farming system zones recognized based on multiple combinations of cropping systems with fishery and livestock components. North Bank plains and Lower Brahmaputra Valley Zones of Assam appear to comprise maximum farming system zones.

Major Farming Systems in ACZs of Assam

Agro-climatic zone (ACZ)	Districts	% of TGA	Major Farming Systems
Lower Brahmaputra Valley Zone (LBVZ)	Kokrajhar, Goalpara, Bangaigaon, Kamrup	26	FS2, FS6, FS8, FS24, FS32
Central Brahmaputra Valley Zone (CBVZ)	Nagaon, Marigaon	7	FS8, FS24, FS32
North Bank Plain Zone (NBPZ)	Lakhimpur, Dhemaji, Sonitpur, Darrang, Udalguri	18	FS1, FS4, FS9, FS11, FS12, FS22, FS 43
Upper Brahmaputra Valley Zone (UBVZ)	Jorhat, Sibsagar, Dibrugarh, Tinsukia, Golaghat	21	FS8, FS24, FS32, FS 43
Barak Valley Zone (BVZ)	Cachar, Hailakandi, Karimganj	8	NA

Hill Zone (HZ)	Karbi Anglong, Dima Hasao	20	FS19, FS28



Farming Systems of Assam (based on ACZ)

Sub Topic 3: Role of Primary, Secondary and Micronutrients and Their Deficiency Symptoms in Plants

Criteria for Essentiality of 16 Elements in Soil and Plant System

1. It must be absolutely necessary for supporting normal growth and reproduction.
2. In the absence of it the plants do not complete their life cycle.
3. The requirement of it must be specific and not replaceable by another element.
4. Deficiency of any one element cannot be met by supplying some other element.
5. The element must be directly involved in the metabolism of the plant.

Macro and Secondary Nutrients

They are generally present in plant tissues in large amounts (> 10 m mole Kg^{-1} of dry matter) and include nitrogen, phosphorous, potassium, sulphur, calcium and magnesium.

Micronutrients

Micronutrients or trace elements are needed in very small amounts (< 10 m mole Kg^{-1} of dry matter). These include iron, manganese, copper, molybdenum, zinc, boron, chlorine and nickel.

Nitrogen

This is the essential nutrient element required by plants in the greatest amount. It is absorbed mainly as NO_3^- though some are also taken up as NO_2^- or NH_4^+. Nitrogen is required by the meristematic tissues and the metabolically active cells. It is one of the major building blocks of proteins, vitamins and and hormones.

Deficiency Symptoms of Nitrogen

1. Stunted growth may occur because of reduction in cell division.
2. Pale green to light yellow color (chlorosis) on older leaves, usually at the tips.
3. The chlorosis could result in the death and/or dropping of the older leaves.
4. This is caused by the translocation of N from the older to the younger tissues.
5. Reduced N lowers the protein content of seeds and vegetative parts.
6. In severe cases, flowering is greatly reduced.
7. N deficiency causes early maturity in crops, resulting in decline in yield.

Phosphorus

Phosphorus is absorbed by plants from soil as phosphate ($H_2PO_4^-$ or HPO_4^{2-}). Phosphorus is a constituent of cell membranes, ADP, ATP, etc. It is also building block of all nucleic acids and nucleotides, it is required for all phosphorylation reactions (ATP synthesis).

Deficiency Symptoms of Phosphorus

1. The initial overall symptom is slow, weak, and stunted growth.
2. It can cause symptoms of dark to blue-green coloration on older leaves of plants.
3. Under severe deficiency, purpling of leaves and stems may appear.
4. Lack of P can cause delayed maturity and stagnated fruit development.

Potassium

It is absorbed as potassium ion (K+) in plant's root zone. It is required in the meristematic tissues, buds, leaves and root tips. Potassium helps to maintain an ion exchange balance in cells. It is involved in opening and closing of stomata and activation of enzymes.

Deficiency Symptoms of Potassium

1. The most common symptom is chlorosis along the edges of leaves
2. This is known as leaf margin scorching.
3. This occurs first in older leaves, because K is very mobile in the plant.
4. Plants lacking K will have slow and stunted growth.
5. The size of seeds and fruits and the quantity of their production is reduced.
6. Its deficiency can cause necrotic spotting in vegetables like tomato.

7. Symptoms occur most frequently in acid soils.

Calcium

Plant absorbs calcium from the soil in the form of calcium ions (Ca^{2+}). Calcium is required by meristematic and differentiating tissues. It is used in the synthesis of cell wall as calcium pectate in the middle lamella. It is also needed during the formation of mitotic spindle. It is involved in the normal functioning of the cell membranes. It plays an important role in regulating metabolic activities.

Deficiency Symptoms of Calcium

1. Deficiency symptoms first appear on the younger leaves and leaf tips.
2. The growing tips of roots and leaves turn brown and die.
3. Without adequate Ca, cell walls of plants may be weakened/ damaged.
4. Newly emerging leaves may stick together at the margins.
5. This may also cause the stem structure to be weakened.
6. Buds and blossoms fall prematurely in some crops.

Magnesium

It is absorbed by plants in the form of divalent magnesium ion (Mg^{2+}). It activates the enzymes of respiration, photosynthesis. It is involved in synthesis of DNA and RNA. Magnesium is a constituent of the ring structure of chlorophyll. It helps to maintain the ribosome structure.

Deficiency Symptoms of Magnesium:

1. The deficiency symptom of interveinal chlorosis first appears in older leaves.
2. Leaf tissue between the veins may be yellowish, bronze, or reddish.
3. Corn leaves appear yellow- striped with green veins.
4. Potatoes, tomatoes and cabbage) show orange-yellow color with green veins.
5. In severe cases, it can cause premature leaf drop in young leaves.
6. Symptoms occur most frequently in acid soils.

Sulphur

Plants obtain sulphur in the form of sulphate (SO_4^{2-}) ion. Sulphur is present in two amino acids – cysteine and methionine. It is the constituent of coenzymes, vitamins (Thiamine, Biotin, Coenzyme A) and ferredoxin.

Deficiency Symptoms of Sulphur

1. Younger leaves are chlorotic with evenly, lightly colored veins.
2. In citrus, the older leaves may show symptoms first.
3. Growth rate is retarded and maturity is delayed. Plant stems are stiff, thin, and woody.
4. Symptoms are most often found in sandy soils that are low in organic matter.

Iron: Plants obtain iron in the form of ferric ions (Fe3+). It is a constituent of proteins like ferredoxin and cytochromes. It activates catalase enzyme, and is essential for the formation of chlorophyll.

Deficiency Symptoms of Iron

Interveinal chlorosis in younger leaves (in high pH soils) is the common symptom.

Manganese

It is absorbed in the form of manganous ions (Mn2+). It activates many enzymes involved in photosynthesis and respiration. It helps in the splitting of water to liberate oxygen during photosynthesis.

Deficiency Symptoms of Manganese

Interveinal chlorosis (yellow leaves with green veins) (Calcareous and alkaline soils) is the common symptom. In legumes, necrosis develops, a symptom known as marsh spots.

Zinc

Plants obtain zinc as Zn^{2+} ions. It activates various enzymes, especially carboxylases. It is also needed in the synthesis of auxin hormone.

Deficiency Symptoms of Zinc

Interveinal chlorosis occurs on younger leaves is the common symptom. Browning of leaves (Khaira disease in cereals) has also been reported in sub humid tropics.

Copper

It is absorbed as cupric ions (Cu2+). It is essential for the overall metabolism in plants. It is associated with certain enzymes involved in redox reactions. It helps in lignin synthesis in plant.

Deficiency Symptoms of Copper

Reduced growth, distortion of the younger leaves and necrosis in the apical meristem has been reported (Shiva and Uchinda, 2000).

Boron

It is absorbed as borate (BO_3^{3-}) or metaborate ($B_4O_7^{2-}$). Boron is required for uptake and utilization of Ca^{2+}. It helps in membrane functioning, pollen germination, cell elongation, cell differentiation and carbohydrate translocation.

Deficiency Symptoms of Boron

Stunted growth on the younger leaves has been reported. Hollow stem in crucifers/ brassica crops and Hollow heart in peanuts/ groundnuts are also common symptoms.

Molybdenum

Plants obtain it in the form of molybdate ions (MoO_2^{2+}). It is a component of enzymes like nitrogenase and nitrate reductase both of which participate in nitrogen metabolism.

Deficiency Symptoms of Molybdenum

Whiptail in cole vegetables (cabbage/cauliflower) (strapped/deformed leaf beds) in humid sub tropics has been anonymously reported. Deficient plants are stunted, and flower formation may be restricted.

Uptake of Nutrients by Plants

Diffusion

Diffusion is the movement of a nutrient ion from an area of high concentration to an area of lower concentration. In soil system, the surface of the root is usually considered to be the area of lower concentration. When cationic macro (K), secondary (Ca, Mg) and micronutrients (Fe, Mn, Zn, Cu) dissolved in the soil-water suspension, the major mechanism of nutrient movement to the root surface is the very slow process of diffusion. The positively charged nutrient ions diffuse from the surface of clays in the soil aggregates to the surface of the root.

Mass flow

It is a plant physiological process driven transpiration mechanism, in which, water moves from the soil pores into the plant root. The soil water contains three negatively charged ions of N (nitrate), S (sulfate) and B (borate). Some of the water and the nutrients contained in this water moves below the root zone. This process is referred to as leaching.

Root interception

Soil aggregates (sand, silt, clay) contain most of the plant nutrients. However, in growth and development, plant roots come in contact with a very limited of soil surface within the aggregates (1% to 2%).

Plant –Soil Interactions

Plants are known to show different responses to different specific nutrient deficiencies and the responses can vary between species. The most common changes are inhibition of primary root growth (often associated with P deficiency), increase in lateral root growth and density (often associated with N, P, Fe, and S deficiency) and increase in root hair growth and density (often associated with P and Fe deficiency). Plant roots exhibit a variety of changes in response to nutrient deficiency, including inhibition of primary root elongation and increased growth and density of lateral roots and root hairs. These responses are species-, genotype-, and nutrient-specific, but they are generalized in this figure to demonstrate all potential effects (Morgan and Connolly, 2013).

Integrated Nutrient Management- Concept and Applications (with Special Reference to Assam)

INM- Concepts

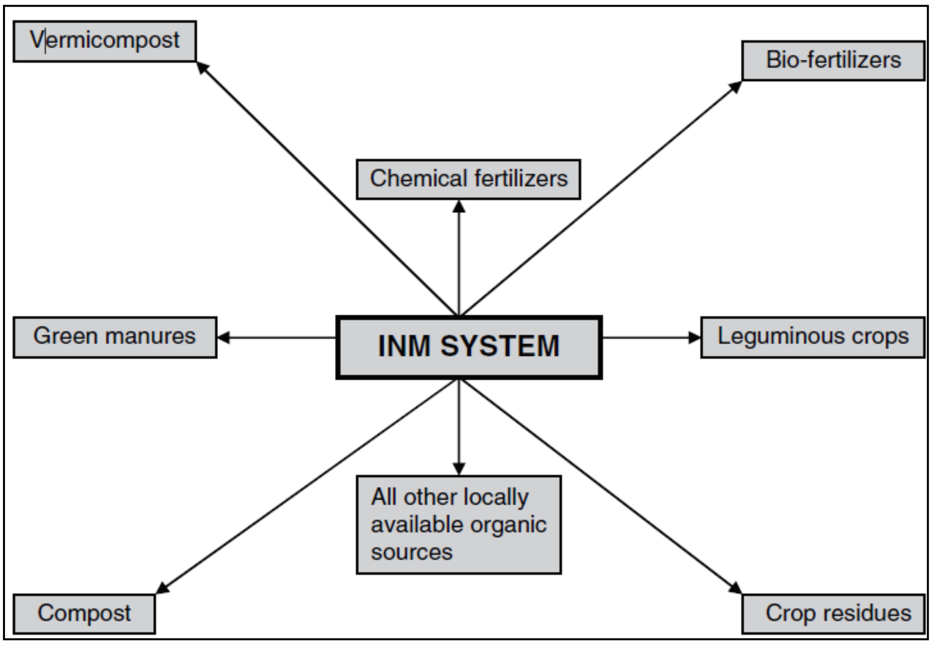
INM is an approach that seeks to both increase quality of production and protect the environment for posterity. It relies on nutrient application and conservation, new technologies to increase nutrient availability to plants and dissemination of knowledge between farmers and researchers (Palm et al., 2001). The basic concept underlying Integrated Nutrient

Management (INM) is the maintenance of soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of benefits from all possible sources of plant nutrients. Continuous application of blanket doses of chemical fertilizers alone to soil has resulted in the deterioration of soil health, thereby culminating in environmental pollution and stagnation in crop productivity (Mahajan and Gupta, 2009). Hence, integrated use of organic manures with optimal levels of NPK fertilizer is the need of the hour, as it will not only improve the nutrient status and soil health, but also prove to be a boon in stabilizing the crop yields in the long run. Therefore, integrated nutrient management (INM) system is an ecologically, socially and economically viable approach, which on the whole is non-hazardous.

External agricultural inputs viz., chemical fertilizers, and pesticides are applied to maximize agricultural productivity and economic returns, often undermining the environmental impacts on soil organisms. Mineral fertilizers have minimum use efficiency (30-40% for N, 15-20% for P and 2-5% for Zn), coupled with hazardous effect on soil acidification and responsible for emissions of GHGs. Organic amendments through crop residue management, on-farm manures, biofertilizers/ bio-inoculants, Vermicomposting and biological pest control can promote sustainable microbial growth and biomass production leading to restore soil quality as well as soil health.

The concept of balanced fertilization was developed more than 150 years ago. Application of balanced fertilization is the key in enhancing nutrient use efficiency of the applied plant nutrients for maintaining soil productivity (Mahajan and Gupta, 2009). Balanced fertilization refers to the application of essential plant nutrients in optimum quantities and proportions. Balanced nutrient supply is a best management practice (BMP) that should also include proper application methods and timing for the specific soil-crop-climate situation. INM approach is one of the most logical solutions of balanced fertilization.

The major objective behind INM system is to manage and sustain the agricultural productivity and improve the farmer's profitability through the judicious and efficient use of chemical fertilizers, and organic amendments. It is a well-considered efficient blend of diverse nutrient sources which can produce desired yields and maintain soil health on long-term basis. INM system helps to restore and sustain crop productivity. It assists in checking the emerging micronutrient deficiencies. Further, it brings economy and efficiency in the use of fertilizers.



Components of INM System (Mahajan and Gupta, 2009)

Requirement of Biofertilizers in India

India is one of the most important countries in bio-fertilizer production and consumption in the world. The present production capacity of different bio-fertilizer production units in the country is more than 10,000 t year−1. At present there are 151 bio-fertilizer production units representing both government and nongovernment agencies in the country that are producing and supplying different bio-fertilizers, out of which, the Government of India has supported 71 units. Based on cultivated areas of the country and treatment of the seed sown at the rate of 200 g bio-fertilizer per 10 kg seed, the National Bio-fertilizer Development Centre (NBDC). The estimated biofertilizer requirement in the country is shown as below (Mahajan and Gupta, 2009).

Bio-fertilizers	Estimated requirement (tonnes)
Rhizobium	34,999
Azotobacter	145,953
Azospirillum	74,342
Blue-green algae	251,378
P solubilizer	25,534

Potential Organic Sources of INM

The nutrient content of various organic resources having the total nutrient potential of 14.85 million tonnes was estimated in 2000, which would become around 16.34 and 32.41 million tonnes by 2010 and 2025, respectively. Out of these organic resources, considerable potential of nutrients (N + P2 O5 + K2 O) from human excreta, livestock dung and crop residues has been worked out to the order of 5.05 million tonnes in 2000, which would be about 6.24 and 7.75 million tonnes by 2010 and 2025, respectively, for the required food grain production of the increased human population (Mahajan and Gupta, 2009).

Constraints in the adoption of INM System

The adoption of INM system by farming communities is limited in rural India because of:

1. Increasing compulsion to use cow dung as a source of fuel.
2. Increasing competitive value of crop residue as animal feed that affects the recycling of agricultural wastes.
3. Crop residue burning issues.
4. Problems in timely preparation of fields and application bulky organic manures to plants.
5. Lacking timely decomposition of agricultural wastes and green manures which require irrigation are the other constraints faced by farmers.
6. Large amounts of insoluble constituents of organic matter like cellulose and lignin which delay the process of composting due to high C/N ratio.
7. This situation helps in development of other worms due to lack of proper air circulation in the container during vermicomposting.
8. Undermined quality bio-fertilizers are ineffective and their marketing becomes difficult because the products contain living or latent organisms.

Applications of INM in different Cropping Systems of Assam

INM on enhancing productivity of Banana

The state level productivity of Banana in Assam is only 13.8 tonnes/ha as compared to national average 33.5 tonnes/ha. There is potential for increasing perspective yield to 40 tonnes/ha with the following interventions

- Replacement of Jahaji with G-9.
- Use of virus-free in-vitro propagated plants.
- Use of pseudo-stem waste for Vermicomposting.
- Integrated nutrient management including zinc, boron and manganese (adopting state implemented PoP).

INM on enhancing productivity of Coconut:

Its productivity is 36 nuts/palm/year, while the potential yield could be achieved as high as 120 nuts/palm/year. Reasons for low productivity are lack of adoption of farming system approach, heavy incidence of crown chocking-nutritional disorder, lack of adoption of soil and moisture conservation measures. The productivity can be increased manifolds by the following technologies.

- Coconut based farming system with Assam Green Tall and hybrid.
- Vermicomposting of coconut biomass.
- High density multispecies cropping system with coconut, pepper, ginger, Assam lemon, banana.

- Integrated nutrient management measures including boron (adopting state implemented PoP).

Application of INM in growing Ahu Rice in Hill Zone of Assam

The highest grain and straw yields (3.64 and 9.49 t/ha, respectively) along with highest benefit cost ratio (7.72) was obtained with 10.0 t FYM/ha+50% N, P and K application in Ahu Rice in Karbi-Anglong district (Dey, 2000).

Impact of INM on enhancing grain yield and SOC in Wheat Growing Soils of NE India

Grain yield was increased 27% due to NPK + Azolla compost application compared to control (NPK). Azolla compost application in soil had noticeable influence on non-labile and recalcitrant carbon fractions. Recalcitrant, humic and fulvic carbon fractions can persist in soil for longer duration and are associated with long term soc sequestration through INM approach (Bharali et al, 2017).

Effect of INM on productivity, nutrient uptake and economics of rape seed in Assam

Results revealed that integration of 50% N through organic manure along with 50% N through chemical fertilizer significantly increased the seed and stover yields, N, P and K uptake in pant and availability in soil with highest net monetary return. The highest value of seed and stover yields of 1.2 t/ha and 4.38 t/ha, respectively. The highest net monetary return was Rs 19000.96/-(Saikia et al., 2013).

INM applications in NE Regions

Application of (FYM) @ 10 t/ ha along with 75% of the recommended dose of fertilizers in rice – french bean system in NER proved to be effective in increasing yield restore soil fertility status (Rathore, 2014) and as well as increased the rice yield and improves the phosphorus use efficiency by 10.6% (Sharma et al., 2006). Green manuring by different short duration legumes is suitable for maintenance of soil quality in terms of adding nitrogen to soil. Nitrogen addition by Sunhemp (150-210 kg/ ha N) and Dhaincha (140-195 kg/ ha N) is highly beneficial for the succeeding crops and even for the subsequent crops too. Besides nitrogen, these legumes also incorporate phosphorus and potassium and other secondary nutrients to soils. In humid sub tropics of North East, these crops are observed to comprise leaf manure with 2.4- 2.9% N, 0.3-0.6%P and 0.8-2.8% K on dry weight basis and can produce 12-15 kg green matter / tree. Crop residues can also produce 2.47 kg N, 0.53 kg P and 8.87 kg K per hectare. Thus, residue incorporation by green manuring is an effective method of restoration of soil health in the region.

Anonymous INM strategies in Assam and NE Regions

Cropping Systems	INM Strategies	Results
Rice-French Bean	75% NPK + 10t/ ha FYM	Phosphorus use efficiency enhances by 10.6% (Sharma et al., 2006)
Mustard/ Rapeseed	75% recommended dose of NPK + FYM @ 5 t/ha + Azotobacter sp. + PSB + 5 kg/ ha Zn	Enhances oil content, improves soil fertility and increases net return (Rs. 82037/- and B: C ratio (2.97) (Bora et al., 2021)
Maize	50% recommended dose of N through chemical fertilizer + 50% N replaced by Enriched compost with DA- 61-A variety of Maize.	Nitrogen, phosphorus and potassium uptake by crop was highest (144.06 kg/ha N, 26.7 kg/ha P, 141.9 kg/ha K) (Bora and Dutta, 2018)

Conclusions

Soil health deterioration is an alarming situation in the NE Regions of India facilitated by severe soil erosion on hills by deforestation and shifting cultivation and flood hazards in Brahmaputra valley regions. The region is by and large rain-fed and mono-cropped in most of its parts, responsible for steady decline in soil fertility status. Strong soil acidity in hill regions coupled with depletion of soil nutrient status (mainly nitrogen, phosphorus and zinc) in valleys is the major soil health concerns. Periodic monitoring of soil health status should be regulated by soil resource inventory at large scales and site specific nutrient management. Land suitability for crops should be evaluated based on critical behavior of soil quality parameters. Appropriate soil conservation measures with integrated nutrient management and integrated farming system approach would be the most logical solutions for sustaining productivity and soil health restoration. Indigenous farming systems may be enriched with scientific interventions with organic farming approaches. Sustainable development in agriculture is the prime mover of prosperity in North Eastern Region of India.

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Chapter – 3

Inorganic Fertilizer: Types of Fertilizers based on Ingredient (Straight, Complex and Mixed Fertilizers) and based on Physical Form (Solid and Liquid Fertilizers) Computation of amount of Fertilizer, Micronutrients on the basis of Percentage of Nutrient and Doses for different Major Crops

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Introduction

Agriculture contributes 17.1% to the country's Gross Value Added. 54.6% of the population is engaged in agriculture and allied activities (Census 2011). Besides, it provides crucial backward and forward linkages to the rest of the economy. Successive five-year plans have laid emphasis on self-sufficiency and self-reliance in food grain production and concerted efforts in this direction have resulted in substantial increase in agriculture production and productivity. Thus, chemical fertilizers played a significant role to fulfill the domestic requirement of food grains.

The goal of nutrient management is to provide an adequate supply of all essential nutrients for a crop throughout the growing season. If the amount of any nutrient is limiting at any time, there is a potential for loss in production. As crop yields increase and as increasing amounts of nutrients are exported from the fields where crops are grown, the nutrient supply in the soil can become depleted unless it is supplemented through application of fertilizers. Fertilizers need to be applied to all types of crop production systems in order to achieve yield levels which make the effort of cropping worthwhile. Modern fertilization practices, first introduced in the last half of the 1800s and based on the chemical concept of plant nutrition, have contributed very widely to the immense increase in agricultural production and have resulted in better quality food and fodder. Furthermore, the farmer's economic returns have increased substantially due to fertilizer use in crop production.

German agronomist, Carl Sprengel (1787-1859) was the first to publish on the *Law of the Minimum* around 1837 which states that plant yield is proportional to the amount available of the most limiting nutrient, and if that nutrient deficiency is corrected, yield will improve to the point of the next most limiting nutrient in the soil. German chemist, Justus von Liebig (1803-1873) is generally credited for promoting this concept, and for developing the first mineral fertilizer to be used as a part of sustainable agriculture production systems.

Why Inorganic Fertilizer

Fertile and productive soils are vital components of stable societies because they ensure growth of plants needed for food, fiber, animal feed and forage, industrial products, energy and for an aesthetically pleasing environment. Soil fertility integrates the basic principles of soil biology, soil chemistry, and soil physics to develop the practices needed to manage nutrients in a profitable and environmentally sound manner. Soils differ widely in their ability to meet nutrient requirements of plants; most have only moderate natural soil fertility. To achieve production objectives, more nutrients are usually required than can be supplied by the soil. High crop yields mean greater depletion of soil nutrient supplies, which eventually must be balanced by increased nutrient input to maintain the fertile soils needed by our societies. Thus a hallmark of high-intensity agriculture is its dependence on mineral fertilizers to restore soil fertility, and in the broader context of soil productivity, soil fertility regulates supply of nutrients inherently available in soils or applied as manures and fertilizers to plants. Soils with a high natural fertility can produce substantial crop yields even without added fertilizer, but can produce even higher yields with an additional supply of the critical nutrients. Good soil fertility provides the basis for successful farming and should not be neglected.

There are a number of ways of making use of soil fertility in farming

- ✓ *Nutrient mining*–farming without any added fertilizer (e.g. in shifting cultivation),
- ✓ *Utilization* of as many components of soil fertility as possible without compensation and yet without negative yield effects (e.g. by applying only moderate amounts of fertilizer N and P),
- ✓ *Maintenance and improvement* of soil fertility to assure consistent high yields (e.g. by compensating for losses due to removal and by soil amendments to improve fertility).

Essential nutrients

Plants contain practically all (92) natural elements, but 17 elements have been identified as *essential nutrients* that are required for plant growth. These must be provided either by the soil or by plant and animal wastes and/or other organic sources or by mineral fertilizers. For an element to be proven essential, it must be demonstrated that a plant cannot complete its life cycle in the absence of the element, and that no other element can substitute for the test element. Three of these, carbon (C), hydrogen (H) and oxygen (O), are used in the greatest quantities and are provided by the air and water. The other 14 nutrients are mineral elements obtained from the soil through the plant roots.

The three *macronutrients* are required by plants in relatively large amounts. Nitrogen as N_2 gas forms 78% of the Earth's atmosphere and is non-reactive. It must be converted to reactive chemical forms (ammonium and nitrate) to be utilized by plants. This conversion is done by micro-organisms in the soil, by symbiotic bacteria living on plants, or by chemical reactions. Phosphorus (P) usually occurs in large quantities in the soil minerals and organic matter, and must be converted to inorganic phosphate ions ($H_2PO_4^-$ or HPO_4^{2-}) to be used by plants. Potassium (K) exists in large quantities in the soil minerals and adsorbed in the ionic form K^+ to soil particles and organic matter. It enters the plant roots as a K^+ ion, often by osmosis through cell walls as a companion to negatively charged ions. Potassium does not form any chemical compounds in plants, but plays a major role in transport of water and other ions across cell membranes.

Sulphur (S), calcium (Ca) and magnesium (Mg), the three *secondary macronutrients,* are no less necessary for plant growth than the macronutrients, but are needed in somewhat smaller amounts. Sulphur is found in soil organic matter, but it also occurs in some clay minerals. Sulphur is taken up by plants as a sulphate ion (SO_4^{2-}). Calcium and Mg are easily available in the soil and taken up as cations by plant roots. Calcium is an important structural component of cell walls and plant tissues while Mg plays a major role in photosynthesis as a central component of the chlorophyll molecule.

The eight essential nutrients needed by plants in small amounts are called the *micronutrients* and these are iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo), chlorine (Cl), boron (B), and nickel (Ni). Cobalt (Co) and silicon (Si) are the two other nutrients that are essential, or at least beneficial, to some plant species, but not required by all.

Common deficiency symptoms of essential nutrients

A first step in diagnosing nutrient deficiencies is to describe what the symptoms look like. Each deficiency symptom must be related to some function of the nutrient in the plant (Havlin et al. 1999). Symptoms caused by nutrient deficiencies are generally grouped into five categories: (1) stunted growth, (2) chlorosis, (3) interveinal chlorosis, (4) purplish-red coloring and (5) necrosis. Stunting is a common symptom for many deficient nutrients due to their varied roles in the plant. Interveinal chlorosis is the yellowing of leaf tissue between veins, with the veins themselves remaining green. Interveinal chlorosis occurs when some nutrients (B, Fe, Mg), Mn, Ni, and Zn) are deficient. Purplish-red discolorations in plant stems and leaves are due to above normal levels of anthocyanin (a purple colored pigment) that can accumulate when plant functions are disrupted or stressed. Necrosis generally happens in later stages of a deficiency and causes the parts of the plant first affected by the deficiency to brown and die. Since a number of nutrient deficiencies can produce similar symptoms, further evaluation of symptoms related to particular leaf patterns or locations on the plant will be needed to diagnose nutrient specific deficiencies.

Fertilizer

Fertilizers are chemical substances supplied to the crops to increase their productivity. These are used by the farmers daily to increase the crop yield. The fertilizers contain the essential nutrients required by the plants, including nitrogen, potassium, and phosphorus. They enhance the water retention capacity of the soil and also increase its fertility.

Inorganic Fertilizers

Inorganic fertilizers are chemical fertilizers that contain nutrient elements for the growth of crops made by chemical means.

Advantages of Fertilizers

The advantages of fertilizers are mentioned below

- ✓ They are easy to transport, store, and apply.
- ✓ For supplying a specific nutrient we can select a specific fertilizer due to its nutrient specific nature.

- ✓ They are water-soluble and can easily dissolve in the soil. Hence, they are easily absorbed by the plants.
- ✓ They have a rapid effect on the crops.
- ✓ They increase the crop yield and provide enough food to feed the large population.
- ✓ They are predictable and reliable.

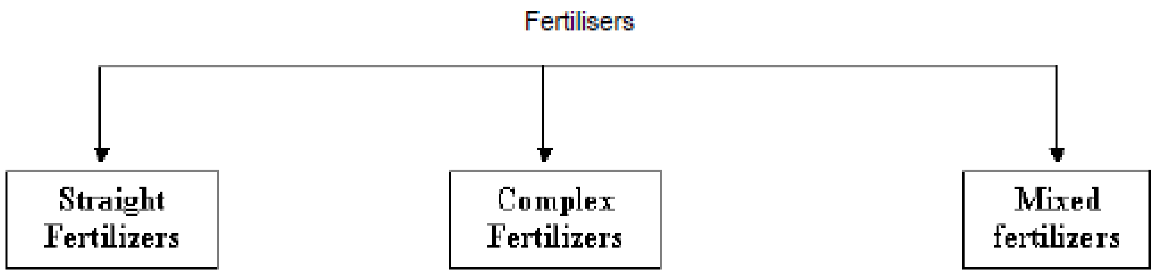
Disadvantages of Fertilizers

Fertilizers have the following disadvantages

- ✓ They are expensive.
- ✓ The ingredients in the fertilizers are toxic to the skin and respiratory system.
- ✓ Excessive use of fertilizers damages the plants and reduces soil fertility.
- ✓ Leaching occurs and the fertilizers reach the rivers causing eutrophication.
- ✓ Long term use reduces the microbial activity and disturbs the pH of the soil.

Classification of fertilizer based on ingredients:

There are three types of fertilizer based on ingredients



Straight fertilizers

Straight fertilizers are those which supply only one primary plant nutrient, namely nitrogen or phosphorus or potassium. eg. Urea, ammonium sulphate, potassium chloride and potassium sulphate.

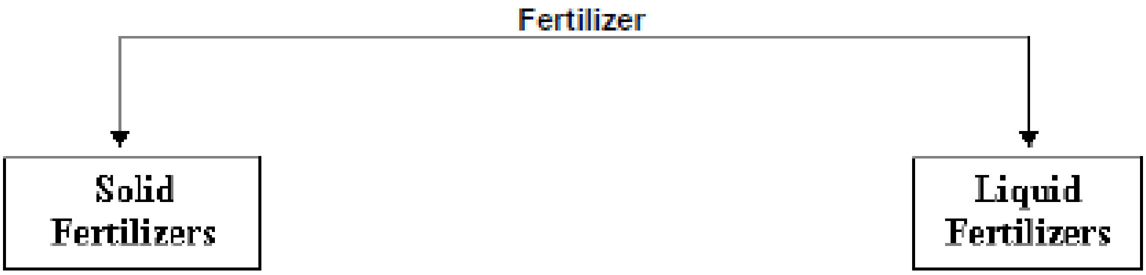
Complex fertilizers

Complex fertilizers contain two or three primary plant nutrients of which two primary nutrients are in chemical combination. These fertilisers are usually produced in granular form. e.g. Diammonium phosphate, nitrophosphates and ammonium phosphate.

Mixed fertilizers

These are physical mixtures of straight fertilisers. They contain two or three primary plant nutrients. Mixed fertilisers are made by thoroughly mixing the ingredients either mechanically or manually.

Classification of fertilizer based on physical forms



There are two types of fertilizer based on physical forms

1. Solid
2. Liquid fertilizers

Solid fertilizers are in several forms viz.

- ✓ Powder (single superphosphate),
- ✓ Crystals (ammonium sulphate),
- ✓ Prills (urea, diammonium phosphate, superphosphate),
- ✓ Granules (Holland granules),
- ✓ Supergranules (urea supergranules) and
- ✓ Briquettes (urea briquettes)

Liquid fertilizers

a. Liquid form fertilizers are applied with irrigation water or for direct application.

b. Ease of handling, less labour requirement and possibility of mixing with herbicides has made the liquid fertilizers more acceptable to farmers.

Fertilizer products in India:

Fertilizer types	**Grade (%)**
Straight nitrogenous	
Urea	46 N
Ammonium sulphate	20.6 N
Ammonium chloride	25 N
Calcium ammonium nitrate	25 N
Straight Phosphatic	
Rock phosphate	12-18 P_2O_5
Single super phosphate	16 P_2O_5
Triple super phosphate	46 P_2O_5
Straight Potassic	
Muriate of potash	60 K_2O
Sulphate of potash	50 K_2O
NP/NPK Complex Fertilizers	
Diammonium Phosphate	18-46-0 $N:P_2O_5:K_2O$
	16-46-0 $N:P_2O_5:K_2O$

Ammonium Phosphate Sulphate	16-20-0 $N:P_2O_5:K_2O$
	20-20-0 $N:P_2O_5:K_2O$
Ammonium Phosphate Sulphate Nitrate	20-20-0 $N:P_2O_5:K_2O$
Nitro Phosphate with Potash	15-15-15 $N:P_2O_5:K_2O$
Urea Ammonium Phosphate	27-28-0 $N:P_2O_5:K_2O$
	14-35-14 $N:P_2O_5:K_2O$
Nitro Phosphate	20-20-0 $N:P_2O_5:K_2O$
	23-23-0 $N:P_2O_5:K_2O$

Micronutrient Fertilizers:

1. The importance of fertilization of crops with micro-nutrients is increasing mainly because of greater removal from the soil, intensive liming of soil, intensive drainage of soil, higher use of nitrogenous, phosphatic and potassic fertilizers etc.
2. There are seven essential micronutrients required by plants. These are iron, manganese, zinc, copper, chlorine, boron and molybdenum.

a. Iron fertilizers

1. These are generally water soluble substances, predominantly sprayed as foliar nutrients on the crops.
2. Plants absorb iron in the form of Fe^{2+}.

Commonly used iron fertilizers are as follows.

Ferrous sulphate ($FeSO_4.7H_2O$)	It is a water soluble fertilizer containing 20% Fe
Fe-Chelates Fe-EDTA Fe-EDDPA	Suitable for application as foliar nutrients

b. Manganese fertilizers

The manganese (Mn) fertilizers are as follows:

Manganous Sulphate ($MnSO_4.7H_2O$)	It is the well known water soluble Mn fertilizer. It is pink salt containing 24% Mn. It dissolves in water and is suitable for foliar application.
Mn-chelates (Mn-DTA)	It contains 13% Mn. It plays an important role in the crop fertilization.

c. Zinc fertilizers

Zinc (Zn) fertilizers play an important role in Zn deficient areas.

Zinc sulphate ($ZnSO_4.7H_2O$)	It is water soluble whitish salt containing 23 % Zn. It is applied as foliar nutrient. Its acidic action causes corrosion damage to plants
Zinc-oxide(ZnO)	It contains 70% Zn. It is slightly soluble in water It is used as slow acting foliar nutrient

d. Copper Fertilizers

Copper fertilizers have been used to correct copper (Cu), deficiencies.

Copper sulphate ($CuSO_4.5H2O$)- 25 % Cu

Copper sulphate ($CuSO_4.H2O$)- 36 % Cu

e. Boron Fertilizers

Borax ($Na_2B_4O.10H_2O$)	It contains 11% B It is water soluble white salt It can be applied as a soil dressing or foliar application
Boric acid (H_3BO_3)	It contains 18% B It is a white crystalline powder It is applied as a foliar nutrient

f. Molybdenum Fertilizers

Sodium molybdate ($Na_2MoO_4.2H_2O$)	It contains 40% Mo
Ammonium molybdate ($(NH_4)6Mo_7O_2.44H_2O$)	It contains 54% Mo

General fertilizer recommendation:

The general fertilizer recommendations are based on multi-locational trials conducted with different doses of N, P and K fertilizers and their economic evaluation obtained at an optimum dose for a particular crop. These recommendations are suitable for medium soil fertility condition irrespective of wide variation that occurs in soil fertility status. Hence, under high or low soil fertility conditions, the applied nutrients prove often a wasteful expenditure and insufficient, respectively.

Package of fertilizer recommendations for different crops in Assam

Crops	**Fertilizer doses (kg ha^{-1})**		
	N	**P_2O_5**	**K_2O**
Rice (direct seeded)	40	20	20
Rice (transplanted)	40	20	20
Rice (Sali or winter)	60	20	40
Maize	60	40	40
Finger millet	40	20	20
Black gram	15	35	15
Green gram	15	35	15
Cow pea	15	35	0
Pigeon pea	15	40	0
Soyabean	20	60	40
Sesamum	30	20	20
Groundnut	20	40	30

Rice bean	20	40	0
Jute	40	25	30
Mesta	40	20	20
Cotton	60	30	30

(Source: Assam Agricultural University, Jorhat & Department of Agriculture, Assam, 2015)

Fertilizer Calculation

Fertilizer recommendations are expressed in kilograms of nutrients per hectare (kg/ha) in the order N-P_20_5-K_20. If only nitrogen is needed, for example, the rate is given in kilograms of nitrogen (N) per hectare.

P_2O_5	×	0.44	=	P
P	×	2.29	=	P_2O_5
K_2O	×	0.83	=	K
K	×	1.20	=	K_2O
CaO	×	0.71	=	Ca
Ca	×	1.40	=	CaO
MgO	×	0.60	=	Mg
Mg	×	1.66	=	MgO
SO_2	×	0.50	=	S
S	×	2.00	=	SO_2

A. Calculation for a single-element fertilizer

Step 1: Select a fertilizer that is available locally, least expensive, suited to the soil conditions (on acidic soil, avoid or minimize use fertilizers with residual acid effect), storable, applicable with available equipment.

Step 2: List necessary data like recommended application rate (R) (kg/ha) and nutrient in fertilizer (C) (%).

Step 3: Calculate amount of fertilizer required per hectare (ha) by dividing application rate (R) by nutrient in fertilizer (C) (%).

Fertilizer required (kg/ha) = [R (kg/ha) / C (%)] x 100

B. Calculation for combinations of single-element fertilizers:

For example, a recommended rate of 80 N-30 P_20_5-30 K_20 kg/ha can be achieved by combining single-nutrient fertilizers, such as urea, triple superphosphate and muriate of potash.
Calculate first the amount of urea (45% N) required, then the amount of triple superphosphate (46% P_20_5) and muriate of potash (60% K_20) to satisfy the recommendation 80-30-30 kg/ha.

Urea = [80 (kg/ha) / 45 (%)] x 100
= 178 kg/ha of urea
TSP = [30 (kg/ha) / 46 (%)] x 100
= 65.2 kg/ha of TSP

$$MOP = [30 (kg/ha) / 60 (\%)] \times 100$$
$$= 50 \text{ kg/ha of MOP}$$

C. Calculation for combinations of single-nutrient and compound fertilizers

Example: An application rate of 80-30-30 kg/ha can also be achieved by combining single-nutrient fertilizers with compound fertilizers.

Assumption:

A 15-15-15 fertilizer and urea (45 % N) are recommended for the 80-30-30 kg/ha fertilizer application.

In the recommended rate 80 N-30 P_20_5-30 K_20 kg/ha, less amounts of phosphorus and potassium are required. Phosphorus and potassium must be calculated first.

$$[30 (kg/ha) / 15 (\%) \times 100 = 200 \text{ kg/ha}$$

200 kg of a 15-15-15 compound fertilizer supplies only 30 kg of N per ha. This means that you must yet supply another 50 kg of N by urea:

$$[50 (kg/ha)/45 (\%)] \times 100 = 111 \text{ kg/ha}$$

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Chapter - 4

Qualitative testing of fertilizers for impurities/ adulteration; Preparation of Fertilizer solution for foliar spray, Concept of Soil fertility, Soil Health and Role of Organic Manure, Identification of different types of fertilizers, micronutrients, soil amendments. Environmental impact of excessive use of fertilizer application and Preventing measure to avoid the soil fertilizer erosion

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Introudction to Qualitative testing of fertilizers for impurities/ adulteration

Chemical analysis of fertilizers is a pre-requisite to identify their composition and quality. The physical analysis includes the moisture and particle size, while chemical analyses include total and different forms of nutrients and the impurities. Sample collection is a critical step in ensuring the accuracy and validity of analytical results. The good sampling is to draw best possible representative sample with minimum contamination and in a best possible natural condition. This requires first sub division of huge big lots into identifiable smaller lots, then selection of specific representative bags without any element of bias and finally drawing samples from the selected bags to make representative samples. single or double tube probe, stainless steel or brass sampling cups/scoops were used for taking composite samples. Spread the composite sample on a clean hard surface and divide into three equal portions of not less than 0.5 kg each and send one sample to State Fertilizer Testing Laboratory. Sieve through 1 mm or No. 20 standard sieves for fertilizer material that form a paste on putting pressure an use No. 40 standard sieve for dry mixtures that tend to segregate while grinding in a porcelain pestle and mortar.

Fertilize Nutrient analysis

Estimation of Nitrogen in Urea (Macro Kjeldahl Distillation Method)

Urea contains nitrogen in organic (amide) form. It is digested with conc. sulphuric acid and the amide nitrogen is converted into ammoniacal nitrogen *(amino group into ammonium sulphate*). The digested material is transferred to distillation flask. In an alkaline medium (*addition of 40%* NaOH) the ammoniacal nitrogen in the digest is liberated through distillation and absorbed in known excess of standard acid (N/10 *sulphuric acid*). The excess acid is back-titrated against standard alkali (N/10 KOH) using methyl red indicator and from the volume of standard acid used for absorbing the liberated ammonia, the percentage of N is calculated. As per FCO the urea fertilizer should contain 46% N with a tolerance limit of 0.2.

Estimation of ammonical and nitrate nitrogen in ammonium nitrate

When ammonium nitrate sample is distilled with freshly ignited MgO, $Mg(OH)_2$ is formed which in turn liberates NH_3. The liberated ammonia is absorbed in standard acid and estimated by back titrating the excess acid with standard alkali. Afterwards, when Devarda's alloy is added, the hydrogen liberated reduces NO_3 into NH_3 which is then liberated by alkaline steam distillation. The liberated NH_3 is absorbed in a known excess of standard acid and the excess acid is back titrated with standard alkali to estimate NO_3 - N. As per FCO, the ammonium nitrate fertilizer should contain 16.5% each of ammoniacal-N and nitrate-N with a total tolerance limit of 0.2.

Estimation of water soluble phosphorus in single super phosphate (Pemberton Method)

The water soluble P_2O_5 is extracted by filtering with distilled water. The phosphorus is then precipitated as ammonium phosphomolybdate in nitric acid medium, filtered, washed free of acid and dissolved in a known excess of alkali and the excess alkali is back titrated against nitric acid using phenolphthalein as indicator. As per FCO, the SSP should contain 16% of water soluble P_2O_5 with the tolerance limit of 0.1.

Estimatio of Potassium in KCl / K_2SO_4 (Flame photometry)

Weigh 1 g of KCl/ K_2SO_4 accurately and transfer it to a 1000 ml volumetric flask. Dissolve it in distilled water and make up the volume to the mark. Pipette out 10 ml of this solution into a 250 ml volumetric flask and make up the volume to the mark with distilled water. Shake it well to get homogenous solution and measure the concentration of K in the solution using flame photometer. As per FCO, the given KCl should contain 60% K_2O with the tolerance limit of 0.2%%. Based on the percentage, the samples are classified as standard / substandard

Principles and method of estimation of impurities in NPK fertilizers

It is not only important to estimate the macronutrient in different forms present on fertilizer the impurities present in them and estimation also find importance for technical reasons and storage

Sl.No.	**Name of the fertilizer**	**Impurity**	**Permissible limit in % (Max.)**
Straight fertilizer			
1	Ammonium Sulphate	Free Acidity (as H_2So_4)	*0.025
		Arsenic	0.01
2	Urea	Biuret	1.5
3	Ammonium chloride	Chloride as NaCl	2.0
4	CAN	Calcium Nitrate	0.5
5	SSP	Free Phosphoric acid	4.0
6	TSP	Free Phosphoric acid	3.0
7	Potassium chloride	Sodium (as Nacl)	3.5
8	Potassium schoenite	Total Chloride (as Cl) (on dry basis)	2.5
		Sodium (as Nacl)	2.0
9	Potassium Sulphate	Total Chloride	1.5
10	Potassium chloride Granular	Sodium (as Nacl)	3.5
		Magnesium as $MgCl_2$	1.0
NP& NPK complexes:			
11	Nitro phosphate with Potash	Calcium Nitrate	1.0

	15:15:15		
12	Ammonium Poly Phosphate (10:34:0) liquid	Magnesium as MgO	0.5
100% Water soluble complexes:			
13	Potassium Nitrate (13:0:45)	Sodium (as Nacl)	1.0
		Total Chloride (as Cl) (on dry basis)	1.5
		Matter insoluble in water	0.05
14	Mono Potassium Phosphate (0.52.34)	Sodium (as Nacl) (as dry basis)	0.025
15	Calcium Nitrate	Ammoniacal Nitrogen	1.0
16	NPK (13:40:13)	Sodium (as Nacl) (as dry basis)	0.15
17	NPK 18:18:18	i) Sodium (as Nacl)	0.25
		ii)Matter insoluble in water	0.50
18	NPK 13:5:26	i) Sodium (as Nacl) (on dry basis)	0.3
		ii) Matter insoluble in water	0.5
19	NPK 6:12:36	i) Sodium (as Nacl) (on dry basis)	0.5
		ii) Matter insoluble in water	0.5
20	NPK 20:20:20	i) Sodium (as Nacl) (on dry basis)	0.06
		ii) Matter Insoluble in water	0.5
21	Potassium Magnesium Sulphate	i) Total Chloride (as Cl) (on dry basis)	2.5
		ii) Sodium (as Nacl) (on dry basis)	2.0
22	NPK 19:19:19	i) Sodium (as Nacl) (on dry basis)	0.5
		ii) Matter Insoluble in water	0.5
23	Mono Potassium Phosphate	i) Sodium (as Nacl) (on dry basis)	0.5
		ii) Matter insoluble in water	0.5

- 0.04% for material obtained from by product ammonia and by product gypsum.

Method of analysis of impurities in major fertilizer

Sl. No.	Name of the Item	Method of estimation
1	Free Acidity	Acidimetric – Alkalimetric Titration
2	Free Phosphoric Acid	Acidimetric – Alkalimetric Titration
3	Biuret	Spectophotometric Estimation as Copper Complex

4	Calcium Nitrate	Complexometric EDTA method (Volumetric)
5	Magnesium	Complexometric EDTA method (Volumetric)
6	Chloride	Volhards' method of estimation of total chloride (argentometric)
7	Sodium	Atomic Absorption Spectrophotometry
8	Matter insoluble in water	Gravimetric Method
9	Ammmoniacal Nitrogen (in Calcium Nitrate)	Acidimetric – Alkalimetric Method (Volumetric)
10	Arsenic	Identification of coloured spot

Quality of Reagents – AR Grade, Quality of Water – Distilled

Preparation of fertilizer solution for foliar spray

Foliar application of nutrients complements soil application or fertigation in several cases when there is a need for fast remediation, root uptake is disturbed, sub-optimal soil conditions or when soil fertilization is inadequate, This application technique is especially useful for micronutrients but can also be used for major nutrients like N, P, and K basically because the amount applied at any time is small and thus it requires several applications to meet the needs of a crop. The increased efficiency reduces the need for soil-applied fertilizer, reduces leaching and run-off of nutrients, reducing the impact on the environment of fertilizer salts.

Foliar solutions (foliar fertilisers) can be either made using water soluble fertilisers (e.g. urea), inorganic salts (e.g. KCl, K_2SO_4) or by using readymade manufactured concentrated foliar solutions that could be in the form of chelated compounds of metallic ions. Their application rates are often simply stated as a percentage of the nutrient to be applied in solution form e.g. as 1 - 2% Zn foliar fertiliser solution.

Determining the equivalent amount of foliar concentrate to be added to 15 L of wate

$$\frac{1\,L\ foliar\ concentrate}{x} = \frac{200\,L\ water}{15\,L\ water}$$

$$=> x = \frac{1L\ foliar\ concentrate \times 15\ \cancel{L\ water}}{200\ \cancel{L\ water}}$$

$$= 0.075\,L$$

$$= 75\ ml\ foliar\ concentrate$$

(*i*) Determining the area (*ha*) that 15 L of foliar solution will cover

$$\frac{200\,L\ foliar\ solution}{15\,L\ foliar\ solution} = \frac{1\ ha}{x}$$

$$=> x = \frac{1\ ha \times 15\ \cancel{L\ foliar\ solution}}{200\ \cancel{L\ foliar\ solution}}$$

$$= 0.075\ ha$$

$$= 750\ m^2$$

Nutrient spray for rice: Foliar spray of 1% urea + 2% DAP + 1% KCl at PI and 10 days later may be taken up for enhancing the rice yield if sufficient soil moisture is ensured.foliar spray of 1% urea for yield improvement in black gram were prepared by mixing 2 kg of urea in 100 L of water as per treatment.

Nutrient spray for rice fallow pulses: Spray 2% DAP at the time of first appearance of flowers and a second spray at 15 days after first spray for enhanced seed set. DAP solution preparation- 2 kg of DAP is soaked for 24 hours in water in earthen or plastic vessel. It should stirred meanwhile. After 24 hours this DAP mixture is sieved through musline cloth or through nylon net and collect it in plastic or earthen plot. This solution is sprayed by adding 100 litres of water.

Nutrient spray for oil seeds: To overcome manganese deficiency, foliar spray of 0.5% $MnSO_4$ on 30, 40 and 50th day / after sowing. Borax spray @ 0.2 % (2g/l of water) to capitulum at ray floret opening stage to improve seed set and seed filling for sunflower

Foliar spraying to mitigate moisture stress: Foliar spraying of 2% KCl + 100 ppm Boron during dry spell as mid season management practice in black gram

Concept of Soil fertility

Soil fertility refers to the inherent capacity of the soil to supply nutrients in available form and in suitable proportions and at the right time. A fertile soil will contain all the major nutrients for basic plant nutrition **(**e.g., nitrogen, phosphorus, and potassium**)**, as well as other nutrients needed in smaller quantities (e.g., calcium, magnesium, sulphur, iron, zinc, copper, boron and molybdenum).

Sources of nutrients to plants

Soil solution: Plant nutrients (solids and gases) dissolved in the soil solution can move into the plant as the water is taken up by the roots.

Cation exchange sites: Cation Exchange Capacity (CEC)is a measure of the amount of cations that can be held by the soil and released into the soil solution. Soils with a greater cation exchange capacity are able to hold onto more nutrients..

Soil organic matter: Soil organic matter refers to hydrocarbon compounds in various stages of decomposition. It is a store house.of nutrients.

Soil minerals: By weathering, break down, and dissolve, releasing nutrients that plants can take up. Some also can retain nutrients by adsorption on their surfaces, much like CEC.

Plant residues: Include contributions to the soil such as green manure or plowing down of cover crops. As these break down, the nutrients contained are leached into the soil, where they become available to growing plants.

Nutrient transformation and interaction

Mineralization: It is the conversion of a nutrient from the organic (i.e. bound to carbon and hydrogen) form to the inorganic form. The nutrient is released, and is available for uptake by new plants.

Immobilization: It is the reverse process of mineralization, wherein nutrients are converted from the inorganic to organic forms (i.e. taken by soil microbes and incorporated into their cells), making them unavailable to plants.

Nutrient uptake antagonism: Refers to the competition between nutrients for uptake by plants. Phosphorus excess can lead to reduced zinc uptake. Potassium excess has been found to reduce magnesium uptake and vice versa. Calcium excess can cause boron or magnesium deficiencies.

Movement of ions from soils to roots

Mass flow: It is the movement of dissolved nutrients into a plant as the plant absorbs water for transpiration. The process is responsible for most transport of nitrate, sulfate, calcium and magnesium.

Diffusion: It is the movement of nutrients to the root surface in response to a concentration gradient. Thus, a high concentration in the soil solution and a low concentration at the root cause the nutrients to move to the root surface, where they can be taken up. This is important for the transport of phosphorus and potassium.

Root interception: It occurs when growth of a root causes contact with soil colloids which contain nutrients. The root then absorbs the nutrients. It is an important mode of transport for calcium and magnesium,

Diagnostic techniques of soil fertility evaluation

Soil fertility evaluation is key for adequate and balanced fertilization in crop production. Several techniques are commonly employed to assess the fertility status of the soil. The diagnostics techniques are,

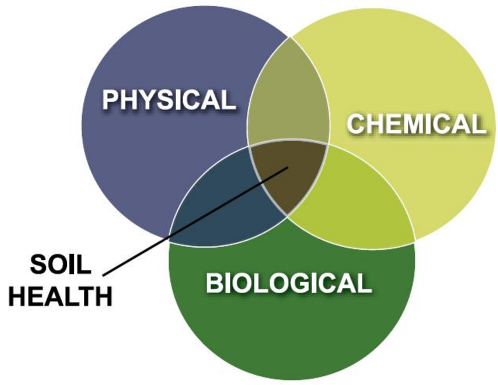
1. Nutrient deficiency symptom of plants
2. Analysis of tissues from plant growing on the soil
3. Biological tests using certain microorganisms as a measure of soil fertility
4. Soil testing

Soil Health- Definition

A modern consensus definition of soil health is “the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals and humans” Healthy soil should have good soil tilth, sufficient depth, good water storage and good drainage, sufficient supply but not excess of nutrients, small population of plant pathogen and insect pests, large population of beneficial organism and low weed pressure, free of chemicals and toxins that may harm the crop.resistant to degradation, resilience when unfavourable condition occur.

Soil Health Assessment

Soil health is a concept that deals with the integration and optimization of the chemical, physical and biological processes of soil that are important for sustained productivity and environmental quality. These measurements include soil texture, available water capacity, field penetrometer resistance, wet aggregate stability, organic matter content, soil proteins, respiration, active carbon and macro and micro nutrient content assessment. Additional indicators are available as adds ons including root pathogen pressure, salinity and sodicity, boron and heavy metals



The Concept of Soil Health

Role of organic manures

Manure is an excellent source of nutrients as well as organic matter. Manures besides supplying plant nutrients, improve the physical, chemical and biological properties of the soil. They also have longer residual effect. They help in improving the soil fertility as well as soil productivity and sustaining soil health.

Physical properties

- Organic manure reduces the bulk density of the soil..
- Improve soil aggregation and increase soil porosity.
- It increases the waterholding capacity of the soil.
- Data used in USLE indicates that increasing the soil organic matter from 1-3 % can reduce erosion to 20 – 33 %.
- Mulching lower soil temperatures in the summer and keep the soil warmer in winter.
- Prevents the surface and subsurface crusting of soil.
- It also regulates the thermal regimes of the soil.

Chemical properties

- Organic matter supplies the nutrients as well as many hormones and antibiotics.
- Humus provides a storehouse for the exchangeable and available cations and prevent leaching.
- It acts as a buffering agent.
- Organic matter makes soil phosphorus more readily available in acid soils.
- Organic acids released help to reduce alkalinity in soils.
- Organic acids and organic anions act as chelating agents and protects the cationic plant nutrients from becoming unavailable

Biological properties

- Organic matter serves as a source of energy for the growth of soil microorganisms.

- Increases the fixation of N by enhancing symbiotic and non-symbiotic N fixing organisms.
- Solubilize the insoluble P by activating the P solubilising microorganisms.
- Fresh organic matter supplies food for earthworms, ant and rodents. These macro organisms improve drainage and aeration.

Identification of different types of fertilizers

Fertilizer is defined as inorganic material, which can supply plant nutrients in available form, having a higher analytical value and definite composition and mostly they are individual products..

Types of fertilizers

***Complete fertilizer*:** They supply all three major nutrients, N, P and K.

***Incomplete fertilizer*:** They supply two nutrients N and K, N and P or P and K etc. Example. Nitrophosphate

***Straight fertilizer*:** A chemical fertilizer that contain only one primary or major nutrient element. Example – Ammonium sulphate, urea

***Complex fertilizer*:** Complex fertilizers are materials which contains more than one primary nutrients such as N, P and K . Example – DAP, MAP

***Mixed fertilizer*:** Mixed fertilizers are physical mixtures of fertilizer materials containing two or three major plant nutrients are made by thoroughly mixing the ingredients either mechanically or manually.

Fertilizers can also be classified based on their physical forms

a) Solid
b) Liquid fertilizers

Solid fertilizers are in several forms *viz*.

1. Powder (Single superphosphate)
2. Crystals (Ammonium sulphate)
3. Prills (Urea, diammonium phosphate, superphosphate),
4. Supergranules (urea supergranules) and
5. Briquettes (urea briquettes).

Liquid fertilizers

1. Liquid form of fertilizers are applied with irrigation water or for direct application.
2. Ease of handling, less labour requirement and possibility of mixing with herbicides

Straight fertilizers

The straight fertilizers can be classified as (i). Nitrogenous (ii) Phosphatic and (iii) Potassic fertilizers. With the emergence of deficiency of nutrients other than N, P and K, other fertilizers are also gaining importance such as carriers of S, Zn, Mn, Fe, B, *etc*.

Classification of Nitrogenous fertilizers

Nitrogenous fertilizers are those fertilizers that are applied for their nitrogen content.
Nitrogenous fertilizers can be classified into four classes namely,

a. Ammonical (NH_4 – N) N fertilizers

e.g. $(NH_4)_2SO_4$ – 20.6 - 21% N; NH_4Cl – 25% N; Anhydrous ammonia – 82% N-

b. Nitrate nitrogen (NO_3 – N) containing N fertilizers

e.g. $NaNO_3$ - 16% N; Ca $(NO_3)_2$ - 15.5% N

c. Both ammonium and nitrate containing N fertilizers

e.g. NH_4NO_3 - 33% N; Calcium ammonium nitrate (CAN) – 20% N

d. Amide fertilizers – It is organic form of N containing fertilizers

e.g. Urea $CO(NH_2)_2$ - 46% N; Calcium Cyanamide ($CaCN_2$) - 21% N

Classification of Phosphatic fertilizers

Depending on the form in which P is present, fertilizers are classified into three groups.

a. Water soluble, mono calcium phosphate ($Ca(H_2PO_4)_2$)

Example, Superphosphates (SSP, DSP and TSP)

a. Single Superphosphate (SSP) – 16 to 18% P_2O_5
b. Double Superphosphate (DSP) – 32% P_2O_5
c. Triple Superphosphate (TSP) – 46 to 48% P_2O_5

b. Citric acid soluble, dicalcium phosphate ($Ca_2H_2(PO4)_2$)or $CaHPO_4$)

Example: basic slag, silicates of lime – 14 to 18% P_2O_5

a. Dicalcium phosphate – 34 to 39% P_2O_5

c. Citric acid insoluble, Tricalcium phosphate ($Ca_3(PO4)_2$)

Example: Rock phosphate – 20 to 40% P_2O_5
Raw bone meal – 20 to 25% P_2O_5
Steamed bone meal – 22% P_2O_5

Potassium fertilizers

Potassium is one of the major nutrients essential for plant growth. It is usually expressed as K_2O. The commonly produced and used K fertilizers are KCl (muriate of potash) and K_2SO_4 (sulphate of potash).

Complex fertilizers

Complex fertilizers have a high nutrient content, owing to which the cost of packing, handling and transport per unit of nutrient is lower than in many straight fertilizers. Complex fertilizers can be broadly classified into ammonium phosphates, nitrophosphates and NPK fertilizers.

Mono Ammonium Phosphate (MAP) is a high-analysis fertilizer containing 52 to 55 % P_2O_5, almost entirely soluble, and 11 to 12 % N.

Diammonium phosphate (DAP) is produced in large quantities. The commecial product contains 18 % N and 46 % P_2O_5, mostly water soluble.

Ammonium phosphate sulphate is about 60% ammonium sulphate and 40% ammonium phosphate, with N content of 16% and P_2O_5 content of about 20%.

Ammonium polyphosphates (APP) may be granular and liquid. Different grades of polyphosphates are marketed like 15-62-0; 12-53-0; 15-60-0, etc. as solid or granular and 10-54-0; 11-37-0 as liquid.

Nitrophosphates contains N and P in different proportions depending upon the process of manufacture.Most important grades of nitrophosphate is 20:20:0 Besides these the other commercially produced complex fertilizer grades are 15:15:15, 20:20:20 etc.

Liquid fertilizers

Liquid fertilizers are becoming more and more common. The liquid fertilizers may be categorized into two groups: clear solutions and suspensions. The major advantage is in handling. The disadvantages are the generally higher price and lower possible analysis compared to dry fertilizers, especially when the material contains potassium.

Micronutrient fertilizers

In India most soils are widely deficient with zinc, boron and molybdenum to the level of about 40–50; 60 and 60–70%, respectively out of other lesser magnitude of deficient micronutrients like Fe, Mn and Cu.

Table. Common micronutrient fertilizers

Micronutrient	Source	Nutrient content (%)	Methods	Doses
Iron	Inorganic:			
	$FeSO_4.7H_2O$	20.5	Soil	10–25 kg ha^{-1} $FeSO_4$
			Foliar	1–3% $FeSO_4$
	FeS_2 (Pyrite)	20-22	Soil	1.5–2.5 t ha^{-1}
	Chelated: Fe-EDDHA	6.0	Soil	0.5–1.0 kg ha^{-1}
Manganese	Inorganic:			
	$MnSO_4,3H_2O$	26-28	Soil	5–15 kg ha^{-1} Mn
	$MnSO_4$	32	Foliar	0.5% $MnSO_4$
Copper	Inorganic:			
	$CuSO_4,5H_2O$	25	Soil	3–6 kg ha^{-1}
	$CuSO_4$, H_2O	35	Foliar	0.2%
Zinc	Inorganic:			
	$ZnSO_4.7H_2O$	12	Soil	5–20 kg ha^{-1}
		25	Foliar	0.2–0.5%
	$ZnSO_4.$ H_2O		Soil	0.5–1 kg ha^{-1}
	Chelated:			
	Zn–EDTA	12	Foliar	0.2–0.5%
Boron	Borax ($Na_2B_4O_7.$ $10H_2O$)	11	Soil	0.5–2.0 kg ha^{-1}
	Solubor ($Na_2B_4O_7.$ $5H_2O$ + $Na_2B_{10}O_{16.}$ $10H_2O$)	20-21	Foliar	0.2–0.5% solution in water
Molybdenum	Sodium molybdate ($Na_2MoO_4.$ $2H_2O$)	39	Soil	0.40–1.0 kg Mo ha^{-1}
			Foliar	0.05–0.10% solution in water

Ammonium molybdate $[(NH_4)_6Mo_7O_{24}.\ 4H_2O]$	54	Seed coating	50–100 g ha^{-1}

Customised fertilizers

Customised fertiliser manufacture basically involves mixing and crushing of urea, DAP, MOP, Zn, S, bentonite sulphur and boron granules for obtaining the desired proportion of N, P, K, S and micronutrients. The farmer need not buy micronutrient separately at extra cost, thus reducing the total cost. Micronutrient with the mixed fertilizer is one of the most convenient methods of fertilizer application and helps in more uniform distribution of nutrient with conventional application equipments.

Value-added/Fortified fertilizers

The deficiency of secondary and micronutrients can thus be overcome by fortification of the presently manufactured N/P/NP/NPK fertilisers to develop value-added/fortified fertilizers.

1. Boronated single superphosphate (16 P 0.15–0.20 B)
2. Zincated urea (43 N 2 Zn)
3. Zincated phosphate (suspension) (12.9 P 19.4 Zn)
4. NPK fertilizer fortified with B (10 N 26 P 26 K 0.3 B)
5. NPK fertilizer fortified with B (12 N 32 P 16 K 0.3 B)
6. DAP fortified with B (18 N 46 P 0.3 B)
7. NPK fertilizer fortified with Zn (10 N 26 P 26 K 0.5 Zn)
8. NPK fertilizer fortified with Zn (12 N 32 P 16 K 0.5 Zn)
9. Calcium nitrate with B (14.6 N 0.25 B)

Soil amendments

Continuous use of a particular type of fertilizer in the same field for a few years may push the soil reaction towards acidity or alkalinity depending upon the nature of fertilizer. Use of neutralizers is, therefore, recommended for field. Except a few, most of the crops respond very well to commonly used fertilizers like urea, single super-phosphate and muriate of potash in neutral soil. Application of lime to the acid soil and gypsum to the alkaline soil should be carried out to bring the soil to neutral range of reaction i.e., 6.5-7.5 pH.

Gypsum Requirement (GR) is the calculated amount of gypsum necessary to add to reclaim the soil. Gypsum requirements depends upon exchangeable sodium content to be replaced, exchange efficiency and the depth of soil to be reclaimed. This determination includes Ca^{2+} required to replace the exchangeable Na^{+} ions plus that required to neutralize the alkalinity.

$$\textbf{Gypsum requirement i.e., me of } Ca^{2+} \textbf{ / 100 g soil} = \frac{\textbf{ESP (Initial) – ESP (Final)}}{100} \times \textbf{CEC}$$

ESP (initial) is obtained from the analysis of soil before reclamation or application of gypsum; ESP (final) is usually kept at 10 and CEC is the cation exchange capacity in C mol (p^+) kg^{-1} of the soil.

Acid soils can be reclaimed to normal soil by introducing suitable base cation and thereby removing excess H^+ and Al^{3+} at exchange complex.

The commonly used materials (supply Ca to remove H^+ + Al^{3+} to reclaim acid soils are

- Quick lime (CaO) which is also known as burnt lime or oxides of lime or simple lime.
- Slaked lime $Ca(OH)_2$ or hydrated lime also known as hydroxide of lime.
- Calcic limestone $CaCO_3$ also known as agricultural lime or carbonate of lime
- Dolomitic limestone $CaMg(CO_3)_2$ Dolomitic form of ground limestone high in Mg

Environmental impact of excessive use of fertilizer application

Nutrients from manure and fertilizers enter lakes and streams through runoff and soil erosion. When nutrients and other pollutants associated with animal manures and commercial fertilizers are not managed properly, they can affect plant and animal life (including humans) negatively. Some of these impacts include algae blooms causing the depletion of oxygen in surface waters, ammonia toxicity, pathogens and nitrates in drinking water and the emission of odours and gases into the air.

Oxygen Depletion

When manure or commercial fertilizers enter surface water, the nutrients they release stimulate microorganism growth reduce the dissolved oxygen content of the water body. The resulting dead fish and other aquatic species degrade the water quality and cause unpleasant odors.

Weed Growth and Algae Blooms

The number of plants and algae in a lake, pond or other water body increase with an increased supply of nutrients, particularly N and P. N and P fertilizer not only stimulate crop growth but have a similar effect on algae and aquatic plants.Eutrophication is the term used to describe the natural or human-accelerated process whereby a water body becomes abundant in aquatic plants and low in oxygen content eventually suffocating fish and other aquatic species.

Ammonia Toxicity

Ammonia-contaminated runoff from fresh manure application sites is toxic to aquatic life. Fish are relatively sensitive to ammonia in water. Concentrations as low as 0.02 parts per million (ppm) may be lethal

Fecal Organisms

The fresh manure from warm-blooded animals has countless microorganisms, including bacteria, viruses, parasites and fungi. Some of the organisms are pathogenic. Manure applications are mismanaged near wells, the risk of bacterial contamination of the groundwater via the well is greatly increased. Therefore, avoid surface application of manure where it can come into direct contact with a well or other drinking water supply.

Nitrates

High levels of nitrates can be toxic to livestock and humans. Nitrates are not adsorbed to soil materials, so they may leach to groundwater. High levels of nitrates in drinking water are known to cause methemoglobinemia (blue-baby syndrome) in human infants and other warm-blooded animals. In humans and livestock, nitrates interfere with oxygen uptake in the circulatory system.

Odours and Gases

Manure odors can degrade the quality of life for anyone subjected to them. In addition, people have a wide range of susceptibility to health effects from odors. Gases are emitted from facilities throughout the year but are released at the highest rates during agitation, pumping and application of liquid manure systems. Volatilization of ammonia to the atmosphere may become a water quality problem near animal production facilities when it is returned to the earth dissolved in rainfall.

Preventing measure to avoid the soil fertilizer erosion

The four factors rate, source, time, and location are known as the 4 Rs of sustainable nutrient management. Following these principles, growers apply fertilizers in a way that maximizes crop nutrition without over-fertilizing:

Right source. Providing fertilizers in crop-available forms that are appropriate for soil conditions, and contain the right balance of nutrients for the particular crop

Right rate. Applying fertilizer in amounts that correspond to crop nutrient demand, taking into account the nutrients already present in soil, and nutrients in other amendments being applied.

Right time. Supplying fertilizer at times when plants need it

Right place Providing fertilizers in a location where plant roots can access the nutrients, and considering spatial variation in soil nutrient availability across fields

All of these factors are also dependent on the local environment and soil conditions. Because of these interactions, what is "right" will vary by farm and by crop type

Applying the appropriate form of nitrogen fertilizer can reduce leaching.. Nitrate fertilizer use should be limited when the leaching potential is moderate to high.

- Nitrification inhibitors can also delay the conversion of ammonium to nitrate
- To minimize losses of phosphorus fertilizer, applications should only be made when needed (determined through soil testings) and at recommended rates.
- Nitrogen fertilizer applications should be timed to coincide as closely as possible to the period of maximum crop uptake.
- Subsurface applied should be used instead of a surface broadcast fertilizer. Te most efficient application method for many crops, especially in erosive soils, is to place dry fertilizer into the ground in bands.
- All surface applied fertilizers should be mechanically incorporated into the soil to reduce losses through surface runoff and volatilization.

- Fertilizer should never be applied to frozen ground, and also should be limited on slopes and areas with high runoff or overland flow.
- Gravity-controlled irrigation or furrow runs should be shortened to prevent over-watering at the top of the furrow before the lower end is adequately watered.
- Conservation tillage reduce phosphorus losses because the residue provides cover and thereby reduces nutrient runoff and erosion by water
- Buffer strips decrease the velocity of runoff and preventing erosion.
- Planting legumes as part of a crop rotation provides nitrogen for subsequent crops.
- Deep-rooted crops can be used to scavenge nitrogen left in the soil by shallow-rooted crops. Cover crops stop erosion and use residual nitrogen in the soil.
- Laser-controlled land levelling equipment improves irrigation efficiency and reduces the potential for nutrient pollution through runoff.
- Follow label directions for storing and mixing fertilizer and for disposing empty containers.
- Storage buildings should have impermeable floors and be securely locked.. Do not store fertilizer in underground containers or pits. To prevent accidental contamination of water supplies, store fertilizer away from the surface water bodies.

Ultimately applying nutrients in a sustainable way helps growers increase the crop production and save money while contributing to the health of both their farms and surrounding environment.

Chapter - 5

Fertilizer Control Order-1985, Its important amendments; Handling, storage and transportation of fertilizer; Function of POS machine- For Fertilizer Retail Dealers:

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Introduction

Fertilizer is the key input for sustainable agriculture in the post green revolution period. The Central Government of India has promulgated the following orders in exercise of the powers conferred under Section 3 of the Essential Commodity Act, 1955, to regulate manufacture, quality, sale, distribution, price, movement etc of fertilizers, to ensure the timely availability of quality fertilizers at reasonable price to the farmers across the country.

I. Fertiliser (Control) Order 1957 / 1985 (F.C.O)

II. Fertiliser (Movement Control) Order, 1960/1973 FMCO)

III. E.C.A. Allocation Orders (Issued Bi-annually)

1. Fertiliser (Control) Order, 1957 / 1985 (F.C.O) now The Fertilizer (Inorganic, Organic or Mixed) (Control) Order, 1985

Initially, the F.C.O. was issued on 23.04.1957 and came into force w.e.f. 15.05.1957. Since, then a lot of changes in fertilizer technology, production and distribution system took place. A number of new products, like micronutrients, fortified fertilizers, etc., also came into the market. This made imperative to make the provisions of the F.C.O. more stringent and upto date so that the fertilizer quality control machinery is more effective. This led to several amendments in the FCO, 1957. Subsequently, an overall review of the FCO, 1957 was conducted by the 'FCO Review Committee set up by the Central Government. Finally, the revised FCO called FCO, 1985 was issued on 25.09.1985 which came into force with immediate effect.

Objective

The main objective of the FCO is to protect the interest of the farmers as well as that of genuine traders/manufacturers from the exploitation by unscrupulous elements. These are achieved by ensuring the availability of fertilizers of right quality and at right time by regulating their quality, price, distribution, sale, etc., the enforcement of the FCO is entrusted to the State Government who has been vested with adequate powers in this regard.

Till July 2021, 11 groups of fertilizers with specifications, including Bio / Organic and Non edible de-oiled cake fertilizers, 100% Water soluble mixtures and offlate Bio-stimulants, Nano Urea have been brought under FCO. Besides, a number of grades of mixture of fertilizers have been notified by the State Governments.

To Handle and store any kind of fertilizer by a Retail Dealer, a set of provisions are laid down from clause 7-9 of FCO. The Sale of fertilizers which are not confirming to the prescribed standards such as non-standard, adulterated, spurious, fake, etc., has been prohibited and all the offences are made cognizable under FCO.

1. Registration for Dealers

1.1 Letter of Authorisation (LOA)

Any person who wants to carry on the business in fertilizers shall obtain necessary permissions under FCO. No body, including a Manufacturer, importer, pool handling agency, a wholesaler, retailer and industrial dealer can carry on the business of selling fertilizer, without obtaining a Letter of Authorization (LOA) under Clause 7-9 of FCO.

The applicant has to apply to the Notified Authority in Form-A1 in duplicate along with source of supply in "O" Form and prescribed fee as fixed by the State Government.

While making application for LOA, dealer is also required to furnish a certificate of source in Form 'O' of FCO for each fertilizer and each manufacturer.

Dealers are required to obtain separate LOA for whole sale and retail sale of fertilizer and separate books of accounts are required to be maintained for whole sale and retail.

1.2 Amendment was brought making the Qualification of any of the following as mandatory for a Retail fertilizer Dealer, to obtain a Letter of Authorization, in October-2015.

It clearly tells that, No authorization letter shall be granted to any applicant under this Order unless the applicant possesses the following qualifications, namely:-

1. Bachelor of science in Agriculture from a recognized University or Institute: or
2. Bachelor of science in Chemistry from a recognized University or Institute: or
3. Diploma in Agriculture Science from a recognized University or Institute: or
4. Certificate Course on agri-inputs for a minimum period of 15 days from National Institute of Agriculture Extension Management (MANAGE), National Institute of Plant Health Management (NIPHM) and other Government approved institutes, 15 days course in INM etc.

However in case of Societies, a person with either of the above qualification needs to be engaged as a person responsible.

1.3 Grant of LOA

The Notified Authority will issue the LOA in Form A2 . The dealer is bound to comply with the provisions of FCO and other terms and conditions mentioned therein, which are as follows:-

i) The letter of authorization shall be displayed in a prominent and conspicuous place in a part of the business premises open to public for inspection by Fertiliser Inspector as well as farmer.

ii) The dealer shall comply with the provisions of the FCO and orders/notifications issued there under .

iii) The dealer should inform the Notified Authority any change in the premises of fertilizer sale depot and godowns.

iv) He should submit the details of opening stock, receipts, sales and closing stock in prescribed proforma to the Notified Authority or any other officer as notified by State Govt, on 5th of every month.

v) He shall file a separate Memorandum of Intimation (MOI) for each place when the business of selling fertilizers is intended to be carried on at more than one place.

vi) He file a separate MoI if business of selling fertilizers is intended to be carried on at more than one place.

vii) He will not sell fertilizer for industrial use.

The validity of the LOA is 5 years from the date of issue.

b. Restriction on Manufacture / Import, sale and distribution of Fertilizer

Clause 19 of FCO strictly prohibits the manufacture, import, sale and distribution of any fertilizer, or their mixture, which is :

- Not of prescribed standard, within the tolerance limit given in Part B, schedule 1 of FCO.

- ✓ Adulterated
- ✓ An intimation
- ✓ Manufactured / imported by a fictitious company
- ✓ Packed in container not properly packed and marked as per Clause 21 of FCO.
- ✓ In fact not a fertilizer
- ✓ Not guaranteed to contain certain minimum percentage of plant nutrients
- ✓

1.4 Display of Stock and position and prices by Retail Dealer:

The daily stock position of different fertilizers along with price should be displayed on the board at a conspicuous place in business premises for the information of farmers.

1.5 Business Premises:

Dealer can stock fertilizer and conduct sale of fertilizer only at the place and address indicated in LOA. If a dealer wants to conduct sale of fertilizer at more than one place, he is required to obtain separate LOA for each selling point.

1.6 Renewal of Letter of Authorization

Every LOA is required to be renewed before its expiry. For this, the dealer is required to apply in duplicate in Form 'A1' together with necessary fee and certificate of source of fertilizer along with their previous LOA to the Notified Authority.

The dealer is required to apply before the expiry of the LOA or within one month of expiring period with late fee prescribed by State Govt.

If the application for renewal of LOA is not made within one month o f expiry of LOA, the LOA would be deemed to have expired on the date on which it expires, and any business on or after that date shall be deemed to have been carried on in contravention of Clause 7.

1.7 Issuance of duplicate copy of LOA or renewal of LOA:

If the LOA or renewal of LOA is lost, the dealer may apply to the Notified Authority for the grant of duplicate certificate the Notified Authority may issue additional copies of LOA on the payment of prescribed fees, if any.

1.8 Amendment in LOA

A dealer may request the Notified Authority for any amendments in his LoA such as inclusion of source of supply from the manufacturer which is Form-O, include godown storage points or deletion of storage points, change in the name of the dealer firm, change of sale premises etc in the existing LOA.

2. Suspension /cancellation of Letter of Authorisation

The Notified Authority may after giving the dealer an opportunity of being heard, cancel or suspend the LOA on any of the following grounds namely:-

(a) The LOA had been obtained by misrepresentation as to a material particular and

(b) That any of the provisions of the order or any condition of the Letter of Authorisation has been contravened.

2.1 Industrial Dealer

The Fertiliser other than Agricultural use is considered as industrial use. A wholesale and retail dealer can sell fertilizer only for agricultural use.

Only Industrial Dealer can sell fertilizer for industrial use. Central Govt will grant specific permission for industrial use of fertilizer.

Application for Certificate of Registration for industrial use is made to Joint Secretary (INM) Deptt. of Agriculture, Co-operation and Farmers Welfare , Ministry of Agriculture & Farmers Welfare, KrishiBhavan, New Delhi who is Controller of Fertiliser.

Industrial dealer cannot carry on the business of selling fertilizer for agricultural use. So either one should get LOA as wholesaler or retailer for agriculture use or only as industrial dealer, but not both of them.

2.2 Notified Authority

The State Government notifies Notified Authority under Clause 26A of FCO. Issuing Letter of Authority for whole sale and retail rests with the Notified Authority.

2.3 Registering Authority

The State Government notifies Registering Authority under Clause 26 of FCO Issuing certificate of manufacture for mixture fertilizer, who are normally State level officers notified under FCO by the respective State Governments.

2.4 Fertilizer Inspectors

The State Government appoints Fertilizer Inspectors under Clause 27 to ensure that the dealers comply to the provisions of FCO. The Dealers shall give any information in his possession with respect to fertilizers being handled, stored by the dealer in his premises.

2.5 Maintenance of Records and Submission of Reports

1.Each dealer is required to maintain stock register as per the format given in Form ‘N’ of FCO.

2.The stock register in form ‘N’ gives daily details of opening balance, receipts during the day, sales during day, source of supply with bill no. and date, First and Last cash /credit memo.

3.The pages of stock register should be numbered and number of pages should be duly certified by inspecting authority.

4.The cash/credit memo should be maintained in Form ‘M’ of FCO which indicates LOA number, address of firm, name/address of purchaser and other details of fertilizer sold like name of fertilizer, brand name, batch number, quantity, rate and total amount.

5.The dealer should also obtain the signature of purchaser on the cash memo.

6.The dealer should submit monthly return to the officer notified by State Govt. showing opening balance, receipts, sales and closing balance for proceeding month.

7.The industrial dealer shall send monthly return to Controller of Fertilizer, in the Ministry of Agriculture & Farmers Welfare, New Delhi.

Handling of Fertilizers

1.Only those material which is notified under FCO shall be handled by the Retail dealers.

2.The stock register shall be promptly updated and shal be tallied with ground balance as well as PoS stocks.

3.Whenever the Fertilizer Inspector visits the dealer premises, all the records ie, stock registers, bill book shall be produced by the dealer and assist the Fertilizer Inspectors

Storage of Fertilizers

1.The godown / storage point should be suitable for storage of fertilizers.

2.The storage point shall be on raised platform preferably.

3.The premises shall be clean without moisture as few products on exposure to humid / temperature may loose their physical structure.

The fertilizer bags shall be neatly stacked enabling the Fertilizer Inspector to draw the samples and also to inspect the premises at ease.

2.6 Sale of non-standard fertilizers

As already mentioned, any fertilizer which is not of the prescribed standards cannot be sold in the market. The fertilizers on exposure to different humidity, temperature and storage conditions, may loose their physical and sometimes even chemical structure. The fertilizers which are containing different nutrients, less than the specified percentage as given in Schedule I of FCO or the standards prescribed by the State Govts for mixtures (after taking into account the tolerance limits given in FCO) are called as non-standard, whose sale is completely forbidden under Clause 19.

However, if a fertilizer product which not being adulterated does not confirm to the FCO standards, a provision has been made in FCO under clause 23 to dispose of the non-standard fertilizers at reduced price.

For this purpose, a dealer is required to apply to the Notified Authority in Form 'H' with full particulars of the non-standard fertilizers like name of fertilizer, source of receipt, reasons for becoming non-standard and the chemical composition analysed by an authorized chemical laboratory and the physical structure along with necessary fee as prescribed by the State Government.

The Notified Authority on receipt of application will arrange for drawal of representative sample of fertilizer by an Authorised Fertiliser Inspector and send it to an authorized laboratory for its analysis. On the receipt of the analysis report from the authorized laboratory, the reduced sale price is to be fixed by the Notified Authority on pro-rata basis of nutrient content.

The permission for sale of non-standard fertilizer is given in Form 'I' by the Notified Authority and the dealer has to apply with the terms and conditions under Form 'I' which are as follows:

i) The dealer will comply with the provisions of Clause 23 (a) of FCO which requires that the word "Non-standard" and also the sign 'X' both in red colour has to be superscribed on each and every bag of non-standard fertilizer.

ii) Non-standard fertilizer cannot be sold to farmers and it can be sold only to fertilizer mixing units, or research farm of Government or University or such bodies.

iii) The price cannot be charged more than the price fixed by the Notified Authority and mentioned in form 'I'.

iv) The Authorisation issued under form 'I' is valid only for the period indicated therein by the Notified Authority.

3 Appeal against Refusal:

1.Any aggrieved person may appeal against the refusal of Notified Authority to grant, amend or suspension/cancellation of LOA within 30 days to the Appellate Authority which are notified by the State Govts under Clause 32A.

2.Like Notified Authority, the appellate authority for LOA and Certificate of Manufacture

may be different. The Appellate Authority will review the case on merit and award the decision. The decision of appellate authority is final as described in Clause 32A of FCO.

3.1 Duties, Responsibilities and Rights of Dealers

A person after getting the Letter of Authorisation in Form A2 becomes bonafide dealer for carrying out business in the sale and storage of fertilisers. On receipt of LOA, he is authorized to store, stock and sale the fertilisers as per the provisions of FCO. In case the quality of the fertilizer becomes non-standard or if there is doubt about the quality of the fertiliser becomes non-standard or if there is doubt about its decrease in the quality, the dealer may inform the Notified Authority in Form 'H' along with details and get the representative sample drawn from the stock and analysed in a Fertiliser Laboratory. The reduced price would be fixed by Notified Authority on the pro rata basis of nutrient content and the authorization may be obtained in Form 'I' under clause 23 for selling non-standard fertiliser. He is bound to comply with the instructions contained in red colour and its reduced price. He is also required to sell this non-standard stock within the period specified in Form 'I' by Notified Authority. However, in case the stock is not liquidated within that period, he has to take fresh approval from the Notified Authority. He should not sell non-standard fertilizer to farmers, but should sell only to mixing unit, research firms of Govt/University or such bodies.

In case the LOA or the renewal is misplaced, the duplicate copy of the same could be

obtained from the Notified Authority after paying necessary fees etc.

In case the dealer has some doubt about the correctness of analysis report of the State Laboratory, he has right to appeal for re-analysis of the reference sample by another authorized laboratory to the Appellate Authority within 30 days.

If the sample fails in re-analysis and there is variation between first and second test result, he can apply for Third Test to the Appellate Authority within 30 days of receipt of re-analysis report.

The test report of Third Test supercedes the two reports.

In case by any reason LOA is suspended or cancelled, he can appeal to Appellate Authority under Clause 32A within 30 days. The decision of the Appelllate Authority is final.

In case the dealer has applied for issuance of LOA and submitted necessary fees, source of fertiliser and is otherwise not disqualified, he is authorized to get the LOA from the Appellate Authority.

The dealer is advised to have a detailed background of the regulatory act/orders concerning the fertiliser trade like Fertiliser Control Order, Essential Commodities Act, Standard of Weights and Measures (Packaged commodity) Rules and Fertiliser Movement Control Order. He should however note the following points:-

i. He should not store, sale, exhibit for sale and offer for sale any fertiliser without having LOA

ii. He should apply for the renewal of LOA along with prescribed fees and certificate of source, within stipulated period.

iii. If failed to make application for renewal of LoA within stipulated time frame, then with fine within 30 days from the date of expiry, renewal application shall be made.

iv. The fertiliser, which does not contain the nutrients of prescribed standard and the bags which do not have proper label and marking and are not machine stitched or if hand stitched do not have lead seals, where manufactuer's name has not been printed, where percentage of the nutrients have not been properly mentioned and which are adulterated or imitated, should not be stored nor offered for sale nor sold.

v. At any point of time, not more than one bag of a type of fertiliser should be kept open for retail sale.

vi. He must issue the cash or credit memo in Form 'M' for every sale and obtain signature of farmers.

vii. In case of PoS sale, a receipt shall be handed over to the purchaser.

viii. He must display prominently the stock position of all the fertilisers along with its price at conspicuous place so that everyone can see it. He should also display LOA in business premises at a conspicuous place.

ix. He should not charge price more than statutorily fixed by the Government and MRP of decontrolled fertiliser indicated on bag

x. In case due to any reasons, the fertiliser stock becomes non-standard or if he feels that the quality of his fetiliser has gone down, he should apply for the disposal of this non-standard fertiliser in form 'H' under clause 23 along with prescribed fees and details. On authorization in Form 'I' he should sell non-standard fertiliser to fertiliser mixing units, research farms and universities or such bodies and not to farmers.

xi. He must give all the information required by an inspector and he must assist in the legitimate duties of the Inspector. He should not refuse the Inspection and drawal of the sample by Inspector.

xii. He must maintain the proper stock register as prescribed by the State Govt and submit necessary details as required by the State Government timely.

xiii. He should not sell fertiliser for industrial use.

xiv. Any change in business premises or godown, should be intimated to Notified Authority.

xv. He should have the detailed background on the use of fertiliser and agronomical practices and should advise the farmers accordingly.

Any non-compliance to the above will attract action under applicable provisions of FCO,EC Act, IPC which includes debarrment / suspension of LoA / cancellation of LoA/seizures / penalty / imprisonment / Crpc proceedings.

Direct Benefit Transfer (DBT) in Fertilizers:

1.The Government has introduced Direct Benefit Transfer (DBT) system in Fertilizers w.e.f. October 2016.

2.Under the fertilizer DBT system, 100% subsidy on various fertilizer grades is released to the fertilizer companies on the basis of actual sales made by the retailers to the beneficiaries.

3. Sale of all subsidized fertilizers to farmers/buyers is made through Point of Sale (PoS) devices installed at each retailer shop and the beneficiaries are identified through Aadhaar Card, KCC, Voter Identity Card etc.

4.Different States/U.T.s have been put on Go-Live mode w.e.f. 01.09.2017 and the Pan-India Roll out has been completed by March, 2018.

5.A Project Monitoring Cell has been set up at Dept. of Fertilizers to oversee implementation of DBT exclusively.

6.24 State Coordinators have been appointed across all States to monitor the on-going DBT activities. Implementation of the DBT in Fertilizer Scheme required deployment of PoS devices at every retailer shop and training of retailers for operating PoS device.

7.Across the country, Lead Fertilizer Supplier (LFS) have conducted 10878 training sessions till date. 2.26 Lakh PoS devices have been deployed across all States.

The Key stake holders are:

1. Owner – DoF

2. Technology Partner - NIC
3. District Administration/State Govt.
4. Fertilizer Companies
5. FAI
6. Fertilizer dealers

Why DBT in Fertilizers:

To monitor the distribution of fertilizer across the value chain from manufacturers to farmers level.

To ensure timely and correct distribution of fertilizers through Aadhar linkage

Role of Retail Dealers:

1.The retailers play key role in the processing of DBT in fertilizers. They are the last point of sale in the process of delivering subsidized fertilizer stocks to the end user I.e. the farmer.

2.To start online sale, after obtaining fertilizer license from the state government, dealers submit ekyc documents to any fertilizer company and the company submits the document on the iFMS portal for a new mFMS ID. After submission, the documents first gets verified by the Lead Fertilizer Supplier and then by the state government. Post final verification, the login Id & the password is sent to the retailer as SMS.

3.Initially, the retailers were given PoS devices of 3 companies- Visiontek & Analogics (Linux based) and Oasys(Android based) which were procured by the fertilizer companies.

Process of Sale of fertilizer at the retail end.

Step 1: The retailer receives the stocks from either manufacturers directly or the wholesalers.

Step 2: As soon as the stocks are sent to the retailer, they are also provided with a DD number in the form of an SMS so that they can acknowledge the stocks and add the stock into their current stock.

Step 3: Whenever a buyer comes for purchase, with the help of a Point Of Sale(PoS) machine, he first captures the Aadhar biometric of the buyer after which the sale happens.

Step 4: Post online sale to the farmer, the stock gets deducted from his existing stock.

Retailer Responsibilities:

1.Retailers are always encouraged to perform online sales only.

2.Also to ease this process, Department of Fertilizers, New Delhi has also extended the sale service to Android devices and Desktop/Laptop systems.

3.In-case the devices are having any Hardware/software issues, solutions are provided as soon as possible.

4.Offline sale will not reflect on the iFMS system and it will lead to blockage of release of subsidy to the fertilizer company who currently bears the upfront of the subsidy amount.

5.In case of connectivity issues, the network services which are available can be switched to by the dealers.

6.The iFMS system currently allows dealers to use a maximum of 10 devices.

7.Beside the dealer as an Admin, he can onboard maximum 2 sub-users which can perform sale and acknowledgement activities too.

8.On their respective PoS devices, dealers must have an active internet connection, hence they can use internet via GPRS/LAN/WiFi modes.

9. In case they are using DBT software on Android/Windows, they need to additionally use a biometric device with RD 2.0 compliance and a wireless printer

10.The following operations can be performed by a retailer on DBT sale software:

1. Aadhar Based Sale
2. Stock acknowledgement
3. Stock reversal
4. Cancellation of sale
5. Updation of Mobile Number
6. Updation of GST number
7. Printing of bills
8. Check current stock on device
9. Onboarding/deboarding of sub-users

11.A dealer has to mandatory complete the acknowledgement of stocks from wholesaler/ manufacturer with a quarter and gets a grace time of 1 month.

12.Any dealer failing to acknowledge stock within the mentioned time, it straight away lead to pending stock on which subsidy cannot be claimed.

13.To improvise the usage and ease of access, DBT cell along with NIC Delhi Regularly provide software updates which the dealer now receives on air.

4. SMS to Buyers: -

The Department of Fertilizers (DoF) has implementation Short Message Services (SMS) to farmers for the sale of fertilizers to farmers in the Direct Benefit Transfer (DBT) project. Buyer will receive a receipt on his mobile through SMS on every purchase of fertilizers.

- The SMS contains the details viz. Invoice no., retailer name quantity purchased, total amount to be paid and the subsidy borne by the Govt. of India. etc.
- SMS module will be used to send periodic SMS to farmer about availability of fertilizer at retail outlet from where he purchased fertilizer last.

Chapter – 6

Biofertilizer for Sustainable Agriculture and their Mass production

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Introduction

During the green revolution in India, chemical pesticides and fertilizers have played a crucial role in boosting agricultural production. Indiscriminate use of chemical fertilizers has contributed to the deterioration of soil health. Biofertilizers are natural nutrient availability systems in which biological processes are involved and can play a significant role in promoting plant health and reduce dependence on chemical fertilizers.

As defined in Fertilizer (Control) Order, Biofertilizers are product containing carrier-based (solid or liquid) living microorganisms which are agriculturally useful in terms of nitrogen fixation, phosphorus solubilization or nutrient mobilization, to increase the productivity of the soil and/or crop. The term biofertilizers include selective micro-organisms like bacteria, fungi, and algae. These microorganisms are capable of fixing atmospheric nitrogen or convert soluble phosphate and potash in the soil into forms available to the plants. Biofertilizer is a cost-effective, eco-friendly & renewable source of plant nutrients and plays a vital role in maintaining long-term soil fertility & sustainability.

Among various biofertilizers, *Rhizobium* was the first microbial inoculant, introduced as a biofertilizer during the early seventies with the introduction of soybean into the country followed by*Azotobacter* and *Azospirillum* in the mid-nineties and Phosphate Solubilising Bacteria (PSB) in the late nineties. Later on, few more inoculants such as *Acetobacter*, Potash mobilizer (*Frateuriaaurantia* and *Bacillus* sp.), and Zincsolubilizeswere also being used as biofertilizers. With the picking up of mycorrhizal biofertilizer production through tissue culture technique, the same was also brought under the FCO with separate specifications. Recently, mixed cultures (consortia) of microorganisms comprising a mixture of *Azotobacter*, *Azospirillum*, PSB, *Pseudomonas fluorescens, Mycorrhiza,* etc. are picking up fast in the market.

Regular use of biofertilizer makes the soil very fertile and increases yield without any adverse effect. In India, Biofertilizers are proven technically successful for almost all crops for major plant nutrients i.e. N-fixers, P -solubilizers & K-mobilizers along with enhanced availability of many micronutrients. Apart from enhanced nutrient availability, these microorganisms have been found effective in controlling many soil born pests. Because of the food safety and increased awareness for organic farming, biofertilizer consumption is expected to increase many folds in coming years.

Commonly used organisms as biofertilizers are categorized as below

Nitrogen-fixing organisms

Rhizobium: Itis a genus of Gram-negative soil bacteria that fix nitrogen. *Rhizobium* forms an endosymbiotic nitrogen-fixing association with the roots of legumes. The bacteria colonize plant cells within root nodules; here the bacteria convert atmospheric nitrogen to ammonia and then provide organic nitrogenous compounds such as glutamine or ureides to the plant. The plant provides the bacteria organic compounds made by photosynthesis.

Azotobacter: *Azotobacter* is a free-living bacterium that can fix atmospheric nitrogen into the soil, being a great source to obtain a natural biofertilizer that can be used in the cultivation of most crops. It is a great source of nitrogen to meet the needs of crops because also has the capabilities to cause rejuvenation of soil microbiology to tap out the biological fixation of nitrogen.

Azospirillum: This is a free-living or non -symbiotic bacteria (does not form nodules but makes association by living in the rhizosphere). *Azospirillum* species establish an association with many plants particularly with C_4 plants such as maize, sorghum, sugarcane, etc. It is the most common organism and can form associative symbiosis on a large variety of plants. Beijerinckin 1925 reported a nitrogen-fixing bacterium under the name of *Spirillum lipoferum*. And Tarrand *et al*., (1978) later on renamed this organism as Azospirillum (Nitrogen fixing Spirillum). *Azospirillum* is recognized as a dominant soil microbe**.**

Blue-Green Algae (BGA): The Blue-green algae are small organisms and can be seen under the microscope as a single cell or large accumulation of cells (colonies) or strings of cells (trichomes). Some accumulations may be so large that they are easily seen with the naked eye. Blue-green algae are also known by different nomenclature such as cyanophytes, cyanobacteria, and most recently cyanoprokaryotes. They have a similar external appearance to that of algae and Azolla growing in a pond their requirements for light, nutrients, and carbon dioxide are also similar. Certain types of blue-green algae have tiny gas vesicles in their cells, which regulate them to float to the water surface or sink to the bottom in response to the changing of light and nutrient availability. In addition to fixing atmospheric nitrogen, BGA also synthesizes and liberates some growth-promoting substances viz., auxin, and amino compounds which stimulate the growth of rice plants. Algae can be multiplied in the paddy field by broadcasting the inoculant at the rate of about 10 kg algal cultures/ha after one week of transplanting.

Azolla: it is a fast growing water fern and can double its weight within a week. Azolla is rich organic manure also. It mineralizes the soil nitrogen rapidly which is made available to the crop in a very short period. Nitrogen release from Azolla is slow but steady, without leaching losses. It also serves as a protein-rich feed to fish and poultry. They use energy derived from photosynthesis to fix nitrogen, hence, called Autotrophs. They are free-living organisms. The Blue-Green Algae (Anabaena azollae) forms a symbiotic relationship with Azolla (aquatic fern) and fixes atmospheric nitrogen. BGA is associated with the Azolla occurring in a ventral pore in the dorsal lobe of each vegetative leaf. The endophyte fixes atmospheric nitrogen and resides inside the tissue of the water fern. BGA and Azolla can also be used in paddy fields, Individually. BGA are capable of performing photosynthetic activity as well as fix the atmospheric nitrogen in flooded rice ecosystem.

Phosphorus Solubilising Microorganisms (PSM) : After nitrogen, the phosphorus is another important primary nutrient for the plants. Only 15 to 20 per cent of applied phosphorus is recovered by the crops and remaining gets fixed in the soil. The fixed form does not contribute to the available phosphorous content in the soil. A group of heterotrophic microorganisms solubilize this fixed phosphorous by producing organic acids and enzymes and make them available to the crops. This group of microorganism is called Phosphorous Solubilizing Microorganisms (PSM). The group includes various species of Bacillus, Aspergillus, Penicillium and Trichoderma. When applied at rock phosphate these organisms solubilize the fixed soil phosphorus and release the citrate and water soluble phosphorus. The microorganisms also help mineralizing organic phosphate compounds present in the organic wastes. While composting, they can be used to hasten composting process when thermophilic phase is over. The use of bacteria in neutral to alkaline and fungus in acid soils improve the efficacy of applied soil phosphorus. Also the fixation of phosphorous is prevented.

Potash Mobilizers: The bacterium (*Frateuria Aurentia*) help to mobilize the insoluble form of potassium for crop growth at a faster rate. It improves resistance of crop plants for pests, and abiotic factors. It is suitable to apply for all crops and compatible with other bio-fertilizers.

Vesicular Arbuscular Mycorrhiza (VAM): The mycorrhiza ('fungus root') is a mutualistic association between fungal mycelia and plant roots. VAM is an endotrophic (live inside) mycorrhizal fungi. It is associated as an obligate symbiotic fungus with majority of crops growing under broad ecological range. More than 85 percent of plant species makes symbiotic association with VAM colonization. VAM help in nutrient transfer mainly of phosphorus, and other micronutrients from soil to the plant roots. They penetrate into root cortex and forms intracellular obligate fungal endo-symbiont. They possess vesicles (sac-like structure) for the storage of nutrients and arbuscular for funneling them into root system. Hyphae of VAM fungi. It also improves water absorption by the roots protects the plant from soil-borne disease incidence.

Production technology of carrier and liquid-based biofertilizers

Biofertilizers usually need a carrier as a medium for convenient application of the microbial inoculants. Generally, carrier-based and liquid-based biofertilizers are being used for the application. In carrier-based biofertilizers, peat, vermiculite, lignite powder, clay, talc, rice bran, soil etc., are used as a carrier. However, carrier-based biofertilizers have disadvantages due to improper sterilization of carrier material and source of contaminations while mixing the bacteria with the carrier, packing, storage condition, poor moisture retention which reduced the shelf-life of the biofertilizers. Moreover, Liquid biofertilizer technology has more advantages over carrier-based biofertilizers in terms of shelf life, sterilization, storage, application, and quality checking.

Production of Liquid Biofertilizers

Liquid bio-fertilizers are special liquid formulations containing not only the desired microorganisms and their nutrients but also special cell protectants or chemicals that promote the formation of resting spores or cysts for longer shelf life and tolerance to adverse conditions.

Isolation of efficient bacterial strains: Specific medium required for culturing the specific bio inoculants for isolation and characterization of efficient biofertilizer strains.

Isolation of *Rhizobium* from root nodules

- ✓ Prepare Congo Red Yeast Extract Mannitol Agar medium (CRYEMA) for isolation of *Rhizobium* (Table 1).
- ✓ Separate pink multilobed nodules of legume plants carefully from the root without any injury and sterilize the nodules with 1% $HgCl_2$ and 70% C_2H_50H.
- ✓ Trample the sterilized nodules with the help of pestle and mortar in sterile water, which is 10^{-1} dilution and make serial dilutions up to 10^{-7}.
- ✓ Spread 0.1 ml of 10^{-5} dilution over CRYEMA petri plates and incubate at 30±2°C for 2-3 days.
- ✓ Pick the small, round, white, translucent colonies with entire margin. Moreover, *Rhizobium* colonies do not take up the colour of congo red dye added in the medium.

Testing nodulation proficiency of *Rhizobium*

- ✓ Fill earthen pots with sterile 1:2 sand soil mix.
- ✓ Inoculate the Rhizobium with surface-sterilized seeds and sow the seeds in pots.
- ✓ Grow the plants under greenhouse conditions and harvest after 10-14 weeks.
- ✓ Record the nodulation data regarding the formation of pink color nodules.

Isolation of *Azotobacter* species

- ✓ Prepare Jensen's N2 free agar medium for isolation of Azotobacter species.
- ✓ Mix 10 g of rhizosphere soil in 100 ml sterile water and 0.1 ml of aliquots from 10-4 and 10-5 serial dilutions spread over the plates and incubate at 30 + 2oC for 3-5 days.
- ✓ Select the colonies showing light brown to black pigment on Jensen's medium.

Isolation of *Azospirillum* species

- ✓ Prepare N2 free bromothymol blue malate medium (NFB) for isolation of Azospirillum species.
- ✓ Wash the Rice/ wheat/ maize roots thoroughly to remove the soli particles
- ✓ Cut the roots into 1 cm and sterilize with 70% alcohol followed by washing for several times with sterile distilled water.
- ✓ Macerated the root samples in sterile mortars and inoculate the 0.1 ml suspension into NFB semi-solid medium screw cap test tubes and incubate at 37°C for 2-3 days.
- ✓ After incubation Azospirillum appeared in the tubes forming characteristic thin dense, white pellicle few mm below the surface of the medium.

- ✓ Streak loopful of the pellicle on the plates of NFB agar medium and incubate at 37°C for one week.
- ✓ Select the light or dark pink, small, dry, slightly convex and rugose colonies.

Isolation of Phosphate Solubilizing Microorganisms (PSM)

- ✓ Prepare Pikovskaya's agar medium for isolation of PSM
- ✓ Mix 10 g of rhizosphere soil in 100 ml sterile water and 0.1 ml of aliquots from 10-4 and 10-5 serial dilutions spread over the plates and incubate at 30 + 2oC for 3-5 days.
- ✓ After incubation, observe the plates for colonies with solubilization zones around them.
- ✓ Isolate and purify the colonies forming more than 6.0 mm zone of solubilization

The solubilizing efficiency of the microorganisms is calculated using following formula

- ✓ Solubilizing efficiency (% S.E) = Z – C /C x 100
- ✓ Z = Solubilization zone (mm)
- ✓ C = Colony diameter (mm)

Preparation of starter culture:

- ✓ Isolated bacterial cultures are subcultures into liquid medium in conical flasks and keep on rotary shaker up to cultures reach the population 1010 – 1011 cells/ ml.
- ✓ After incubation check the quality of starter culture (purity, viable cells, pH etc.,).

Transfer the starter culture into the fermenter (large flasks)

- ✓ Prepare the liquid medium based on the size of the fermenter (large flasks).
- ✓ Sterilize the fermenter (large flasks) and liquid medium to allow it for cool.
- ✓ Inoculate the starter culture (1-2 %) aseptically into the fermenter (large flasks).
- ✓ Incubate the culture in the fermenter (large flasks) until it attains the maximum cell count of about 109 cell/ml.
- ✓ After fermentation (2-5 days depends upon microorganisms) check the quality of the final product (purity, viable cells, pH etc.).
- ✓ Harvest the liquid biofertilizers in sterilized bottles, sore at low temperatures and dispatch to farmers.

Preparation of liquid biofertilizer

Broth for the respective efficient strain of N2 fixing organisms/potash solubilizer/ phosphorus solubilizer is to be prepared. Cell protectant viz. trehalose, PVP is dissolved separately and added into the broth before sterilization. The sterilization of the broth is to be carried out at 15 lb/sq inch for 15 min. A saturated stock solution of glucose and arabinose is to be prepare, sterilized separately, and added into the sterilized broth prepared earlier. This broth is inoculated with pure starter culture at 10 ml/lit under aseptic conditions. Incubate the flasks at 28°C for 2–5 days, depending upon the type of organism till the count per ml reaches 109 cells. Sterilized glycerol is to be added to the inoculated broth. This broth is to be dispensed into the previously sterilized polypropylene bottles and made airtight by a screw cap. The bottles should provide the proper product identification specifying the strains for which it may be used, detailed application instructions for the user, an expiry date, quantity of seed or area to be treated, and the manufacturing company.

Sulfur oxidizer and silicate solubilizer biofertilizer can be prepared by following the same procedure. The broth media prescribed for the respective microbial culture has to be used in each case. Nowadays, commercial liquid biofertilizer unit with automatic bottle filling machines are available.

Carrier-based biofertilizers

Preparation of carrier

Finely powdered peat, lignite, or soil + compost or cellulose powder or soil + wood charcoals may be used as a carrier. The carriers should have the following characteristics.

(1) High organic matter, above 60%

(2) Low soluble salt content (less than 1%)

(3) High moisture-holding capacity (150–200% by weight)

Carrier provides a nutritive medium for the growth of the bacteria and prolongs their survival in culture as well as on inoculated seed. The carriers are powdered to 250–300 mesh (about 75-micron pore size). Peat of 300 meshes is neutralized with 1% calcium carbonate and sterilized at 15 pounds p.s.i. for 4 hrs in an autoclave.

Preparation of inoculants in powder form

In the preparation of inoculants, it is essential that the appropriate moisture content for a specifi c carrier should be determined. The ideal moisture range for the inoculant must be set while considering the bacterial growth and maximum population attainable after mixing, the bacterial survival and anticipated moisture loss from the package over the period of the shelf life. Usually, about one part (by weight) of broth is required for two parts of dry carrier (Fig. 16.3). Final moisture content varies from 30–50%, depending on quality of carriers. After adding the broth culture to carrier powder in 1:2 proportion by weight, it is kept for curing at room temperature (28°C) for 5–10 days in 10 cm deep trays of convenient size. After curing, it is sieved to disperse the concentrated packets of growth and to break lumps. It is then packed in polythene bags of 0.5 mm thickness, leaving 2/3 space open for aeration of the bacteria.

Precautions in handling and use of Biofertilizers

- ✓ Keep away from food and drinks
- ✓ Never apply with fungicides, chemical fertilizers etc. at the same time

- ✓ Never directly expose to sunlight
- ✓ Store at room temperature (25oC-28oC)
- ✓ Use before date of expiry
- ✓ Use crop specific biofertilizers, especially in the case of *Rhizobium*

On-farm production of Biofertilizers

The National Institute of Plant Health Management **(NIPHM)** is actively engaged in Human Resource Development, both in the Public and Private Sector, in Plant Health Management. NIPHM through its core role of Training, Teaching, and Research intends to address the existing and emerging challenges in the field of Plant Health Management to enhance agricultural production by adopting environmentally sustainable practices/technologies. The institute is focusing more on popularizing low-cost farm level mass production of biofertilizers and biopesticides.

Materials required for low-cost production with the approximate cost

The following listed materials required for on-farm production of bacterial bio fertilizers

S.No	Item	Size/unit	The approximate cost (Rs)
1.	Mother clture of biofertilizer	--	--
2.	LPG cylinder 14.5 Kg (extra)	1	2000
3.	Pressure cooker- 20 L	1	6000
4.	Gas stove -2 burner	1	5000
5.	Inoculation chamber	45 x 45 x 40 cm	3000
6.	Sterilisable vials- 5 ml	500	2500
7.	Miscellaneous (bottles, Spirit lamp Jaggery, Cotton, etc.)	-	6500
	Total		**25000**

On-farm production of bacterial biofertilizers

On-farm production of *Rhizobium*

Commonly used bacterial biofertilizers are *, Azotobacter, Azospirilium,* etc. These biofertilizers are manufactured as carrier-based as well as in liquid form. To ensure the use of biofertilizers by farmers and production at farm level, NIPHM has developed on-farm production technique of *Rhizobium* as mentioned below;

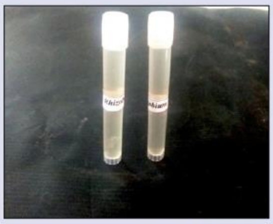
- ✓ Take starter culture of Rhizobium- it can be obtained from any biofertilizer lab.
- ✓ Prepare 'Jaggery solution' by adding 10g of jaggery and 1 g of common salt (NaCl) into 1 L of water.

- ✓ Transfer 1/3 of the Jaggary solution into 1 L glass bottles or flasks and close with a cotton plug for sterilization.
- ✓ Sterilize the bottles containing Jaggary solution in a pressure cooker for 40 min.
- ✓ Cool the bottles at room temperature and inoculate the sterilized Jaggary solution (approx. 300ml) with 3ml of starter culture in bottles using inoculation chamber.
- ✓ Incubate the bottles at room temperature for 2-3 days by shaking the bottles every day for 10 to 12 times to enhance the bacterial growth.
- ✓ Farmers can observe the bacterial growth in bottles. In case of good growth, the jaggary solution will become turbid and light brown.
- ✓ In this way, the solution containing Rhizobium is ready to use for seed treatment of leguminous crops, like cowpea, groundnut, soybean, green gram, red gram, black gram, chickpea, etc.
- ✓ This culture can be stored at room temperature for 3 months.

Seed treatment: Use 200-250 ml of *rhizobium* culture for treatment of seed material required for 1 acre. Mix the culture in seeds to make coat on all the seeds, uniformly.

- ✓ Similarly, on-farm production of other biofertilizers like Azotobacter, Azospirillum, PSB, ZSB can also be done.

On-Farm Production of *Rhizobium*



1. Take starter culture of Rhizobium from any biofertilizer lab

2. Prepare jaggery solution using 10 g jaggery in 1 L water and 1g of common salt

3. Transfer jaggery solution into glass bottles

11. Grow healthy crop with good nodulation

4. Close the bottle mouth with cottonplug

10. Liquid Rhizobium culture can be used for seed treatment (@200ml/ acre seed)

Agriculture Secretary visiting lab

5. Sterilize the jaggery solution in pressure cooker for 40 min and cool at room temperature

9. Rhizobium culture ready to use

8. Shake bottles 3-4 times everyday

7. Incubate bottles at room temperature for 5-7 days

6. Inoculate sterilized jaggery solution with starter culture in bottles using inoculation chamber

Similarly, on-farm production of other biofertilizers like *Azotobactor*, *Azospirillum*, PSB, ZSB can also be done

National Institute of Plant Health Management

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On-farm production of Mycorrhiza

Mycorrhiza or Vesicular Arbuscular Mycorrhiza (VAM) is the roots associated fungal biofertilizer. Mycorrhiza makes a symbiotic association with more than 80% of the plant species. It penetrates into the root cortical cells and increases the rate of absorption of water, phosphorus, and other micronutrients. The techniques of mass production of symbiotic Mycorrhiza are so simple that trained farmers can produce at the farm level. Therefore, it should be popularized for promoting sustainable agriculture. A simple on-farm production methodology for Mycorrhiza developed by NIPHM, Hyderabad being popularized among extension officers and farmers.

Materials Required: Sterilized soil, clay or plastic pots, maize/sorghum/ragi seeds, and Mycorrhiza starter culture

Methodology:

- ✓ Take the required quantity of soil from your own field to fill up the pots. Sterilize soil to minimize the presence of other fungus or pathogens in soil by heating for 2-4 hours using a big metal pan or by drying under the intense heat of the sun for 2-3 days.
- ✓ After cooling, place the sterilized soil is thoroughly cleaned dry pots. For large scale production polythene bags, a trough lined with plastic sheet may be used.
- ✓ Place a pinch of root starter inoculants in the pot and then cover with a thin layer of soil.
- ✓ Sow 3-5 seeds in each pot at such a depth that seedling roots should come in contact with inoculum.
- ✓ Grow the plants for three months under normal conditions.
- ✓ Stop watering the plants after 3 months and cut the upper part of plants or stalks when they are completely dried. Allow the soil in the pot to dry further.
- ✓ Remove the roots along with adhering soil from the pots and dry in shade.
- ✓ Cut the roots finely and save some root inoculants for future use. Mix the fine cut roots with the soil from the pot to produce VAM soil inoculants.
- ✓ Store the root and soil inoculants in sealed plastic bags in a cool dry place.

Precautions for production of Mycorrhiza

- ✓ Compulsory use quality Mycorrhiza mother culture for production (100 Infective propagules per gram)
- ✓ Create physical contact between the mycorrhizal culture and the plant root
- ✓ Care should be taken during plants grow

Application rate: 4-5 kg per acre

Benefited crops: Mycorrhiza or VAM suitable for all cereals, legumes, fruits, and horticultural crops

On farm production of Mycorrhiza

Mass production of *Azolla*

- ✓ Farmer or individual can produce Azolla with low cost investment around Rs.500-Rs. 1000/- .
- ✓ Azolla is a highly productive plant it biomass doubles within 2-5 days under good conditions. Azolla can be produced as monocrop before transplanting rice or as a duel crop along with rice.
- ✓ Pond size depends on quantity of requirement of Azolla.
- ✓ Prepare ploughed and uniform level pond size of 20x2x0.5 m or 10x2x 0.5 m
- ✓ Cover the pond with plastic sheet. Add sieved fertile soil, cow dung, super phosphate and make water level at about 10 -15 cm.
- ✓ Temperature between 25°C -32°C is suitable for Azolla cultivation.
- ✓ Inoculate fresh disease free Azolla into pond within 3-4 weeks Azolla fill the pond and harvest daily by using sieves.

<table>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Polyethene sheet covered in trench</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Addition of soil, cowdung and Azolla culture</td><td>After 7-10 days the Azolla speeded in trench</td></tr>
</table>

Panchagavya preparation and usage

Panchagavya, an organic product is a potential source to play great role for promoting growth and providing immunity in plant system. Bio- chemical properties of panchagavya revealed that it possesses almost all the major nutrients like N, P, K and micro nutrients essential for plant and growth hormones like IAA and GA required for crop growth. Presence of naturally occurring, beneficial, effective microorganisms (EMO‟s) in panchagavya predominantly and lactic acid bacteria, yeast, actinomycetes photosynthetic bacteria and certain fungi besides beneficial and proven fertilizers such as *Acetobacter, Azospirillum* and Phosphobacterium which have the beneficial effect especially in improving soil quality, growth and yield of crops.

Method of preparation

- ✓ Mix thoroughly fresh cow dung (7kg) + Cow ghee (1 kg)
- ✓ Incubate for 2 days
- ✓ Add Cow urine (3 lit) + 10 lit of water
- ✓ Stir properly (morning and evening, daily for 1 week)
- ✓ Add Sugarcane juice (3 lit)
- ✓ Add Cow milk (2 lit)
- ✓ Add Cow curd (2 lit)
- ✓ Add coconut water (3lit)
- ✓ Add yeast 100 gram and 12 ripened bananas

The whole mixture is to be incubated for two weeks and the preparation should be filtered through double layered muslin cloth and stored in bottle under refrigerator and used as and when required.

Method of application

Foliar spray: 3% foliar spray of panchagavya is recommended for all the crops.

- ✓ Soil application: Panchagavya can also be effectively applied in the soil with irrigation water. Panchagaya @50 lit./ha is recommended for soil application with irrigation water.
- ✓ Seed treatment: seeds of different crops can be treated with 3% solution of panchagavya. Seeds should be soaked for half hour and dried under shade and sown.

Time of application

- ✓ For the field crops five panchagavya application are suggested for better results.
- ✓ Before flowering : Two foliar spray at 15 days interval
- ✓ Flowering and grain setting stage : Two foliar spray at 10 days interval
- ✓ Grain /fruit development stage : one foliar spray.

Beneficial effect of panchagavya application

- ✓ Panchagavya is a component of crop production and it plays a crucial role in each and every component of crop management like integrated soil fertility management, integrated pest management, integrated disease management.

Effect on plants

- ✓ Plants sprayed with Panchagavya habitually produce bigger leaves and develop denser canopy.
- ✓ Branching is relatively high.
- ✓ The rooting is prolific and intense.
- ✓ The roots spread and grow into deeper layers were also observed.

Effect on soil fertility

- ✓ Panchagavya improves fertility status in soils by increasing macronutrients, micronutrients and beneficial microorganisms thus increase soil health.
- ✓ It improves water holding capacity of soils because it acts as a organic manure.
- ✓ It encourages growth and reproduction of beneficial soil microorganisms
- ✓ It increases nutrient uptake in plants and enhances plant growth.

Bio fertilizer application technology

Seed Treatment

This is the most common practice of applying biofertilizers.Mix 200 ml of plant health Rhizobium with seeds required for 1 acre and leaves it for 30 min under shade and sow the seeds within 24 hours.

Seedling dip method

Seedlings treatment: Mix 4-5 ml with 1 L of water. Seedlings are dipped in this solution of plant health *Azotobacte/Azospirillum/PSB/ZnSB/KRB* for about 20 minutes before transplanting.

Soil application

Mix 200 ml with 100 kg of FYM or vermicompost. Broadcast and mix in the soil by ploughing the field.

Drip irrigation

Mix 200 ml in 100 L of fertigation tank water and irrigate the field through drip irrigation.

 

Recommended Doses of Biofertilizers:

Sl. No.	Crop name	Recommended Bio-fertilizer	Quantity to be used
1.	Pulses- Chickpea, beans, groundnut, soybean, lentil, Lucerne, berseem, green gram, pigeon pea etc.	*Rhizobium*- Seed treatment	200ml/acre
2.	Cereals -Wheat, oat, barley, etc.	*Azotobacter/ Azospirillum*- Seed treatment	200ml/acre
3.	Rice	*Azospirillum*- Seed treatment	200ml/acre
4.	Oilseeds- Mustard, sesame, linseeds, sunflower, castor	*Azotobacter*- Seed treatment	200ml/acre
5.	Millets- Pearl millets, finger millets, kodo millet	*Azotobacter*- Seed treatment	200ml/acre
6.	Maize and sorghum	*Azospirillum*- Seed treatment	200ml/acre
7.	Forage Grasses- Bermuda grass, napier grass , etc.	*Azotobacter*- Seed treatment	200ml/acre
8.	Plantation Crops, Tobacco, vegetables	*Azotobacter*- Seedling treatment	500ml/acre
9.	Tea, Coffee	*Azotobacter*- Soil treatment	400ml/acre
10.	Rubber, Coconuts	*Azotobacter*-soil/seedling treatment	2-3 ml/plant
11.	Agro-Forestry/ Fruit Plants- All fruit/agro-forestry seedling/saplings	*Azotobacter*- Soil treatment	2-3 ml/ plant at nursery

12.	Leguminous plants/ trees	*Rhizobium*- Soil treatment	1-2 ml/plant
13.	All crops	Phosphate Solubilizing Bacteria	200ml/acre
14.	All crops	*Mycorrhiza*- Soil treatment	3-4 kgs/acre

Dos and don'ts

S.No.	Do's	Don'ts
1.	Keep biofertilizers away from direct heat and sunlight. Store it in cool and dry place.	Don't store biofertilizers bottles/packets under heat and sunlight.
2.	Use only biofertilizers which contain batch number, name of the crop on which it has to be used, date of manufacture and expiry date/period.	Don't sell or use biofertilizers which do not contain batch number, name of the crop on which it has to be used, date of manufacture and expiry period.
3.	Discard the expired biofertilizers as it may not be effective.	Don't prick holes into the bottles or puncture them to pour the content.
4.	Keep bio-fertilizers away from fertilizer or pesticide containers.	Do not mix the biofertilizers with fungicides, insecticides, herbicides and chemical fertilizers.
5.	Mix only compatible bio-inoculants with biofertilizers.	Do not mix biofertilizers with other biofertilizers or pesticides, directly.

Chapter - 7

Concept on Acid soil, Saline Soil, Sodic soil, Soil toxicity, its effect on plant nutrition uptake, Different soil amendments - Lime, Gypsum, the importance and Reclamation of soil

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Introduction

Soil degradation has become a global problem causing decline in crop productivity, and India is confronting the same problem. Various causes have been ascribed for soil degradation which has been categorized as natural soil degradation and human-induced degradation. Natural causes include recurring floods and droughts, earthquakes, landslides, tsunamis, soil acidity due to presence of acidic minerals in the geological beds, naturally induced sodicity due to the presence of high amount of carbonate salts of sodium, salinity caused by the dominance of chlorides and sulphate salts of sodium etc. The human-induced soil degradation on the other hand results from deforestation, using wrong agricultural management practices, improper management of industrial effluents and wastes, over-grazing, surface mining, urban sprawl, and industrial developments. By applying wrong agricultural management practices, the quality of soil deteriorates in which the main culprits are: excessive and injudicious use of inorganic fertilizers, excessive tillage, excessive use of pesticides, over-irrigation of soil, poor crop rotation and residue planning. In India extent of soil degradation is estimated to be 147 million hectares (Mha) of land, including 94 Mha from water erosion, 16 Mha from acidification, 14 Mha from flooding, 9 Mha from wind erosion, 6 Mha from salinity, and 8 Mha from a combination of factors. Therefore, there is an urgent need to restore the crop productivity by managing soil degradation process.

Soil acidity

An acid is a substance which is capable of releasing protons (H^+) in a system. The H^+ ions released is called active acidity which increases with the strength of the acid. The un-dissociated acid is considered to be potential acidity. So the total acidity of an aqueous solution will be the sum of active acidity and potential acidity. The soil acidity may be defined as the proton donating capacity of soil system during its transition from a given state to a reference state. The parameter by which the acidity of the soil could be determined is pH, which is considered very important to know the intensity of the soil acidity and is defined as negative logarithm of hydrogen ion activity and can be written as:

$pH = -\log(a_{H^+})$. Normally the soils which has $pH < 7$ are acid, those with a $pH > 7$ are considered alkaline, and with a pH of 7 are assumed to be neutral. Actually, the pH of the normal soil considered to be between 6.5-7.5. Acidic soil is one which has got enough exchangeable H^+ ions so that to give pH lower than 7.0. The classification of the soil pH ranges is presented in Table 1.

Classification of the soil on the basis of pH range

Classification groups	pH range
Extremely acidic soil	< 4.5
Very strongly acidic soil	4.5-5.0
Strongly acidic soil	5.1-5.5
Moderately acidic soil	5.6-6.0
Slightly acidic to neutral soil	6.1-7.3
Slightly alkaline	7.4-7.8

Adapted from Sparks (2003)

The elements whose abundance in soil causes soil acidity are H, Al, and Fe. The availability of plant nutrients significantly affected with the increase or decrease in the pH of soil solution. The solubility of Al, Fe, and Mn gets increased at low pH and become available to plants and many times it become toxic to plants. But with the increase of pH, the solubility of these elements decreases due to adsorption and precipitation phenomenon. As a result, deficiency symptoms arise in the plants, particularly at higher pH. One of the major problems for plants growing in acid soils is aluminum toxicity. Aluminum in the soil solution causes stunted growth. The degree of toxicity is dependent on the types of plant. Thus, soil pH is a useful indicator of the presence of exchangeable Al and H^+. Exchangeable H^+ is present at pH < 4, while exchangeable Al^{3+} occurs predominantly at pH 4-5.5. An Al polymer however, occurs in the pH range of 5.5-7.0.

Sources of Soil Acidity

i) Dominance of Al and Fe in soil

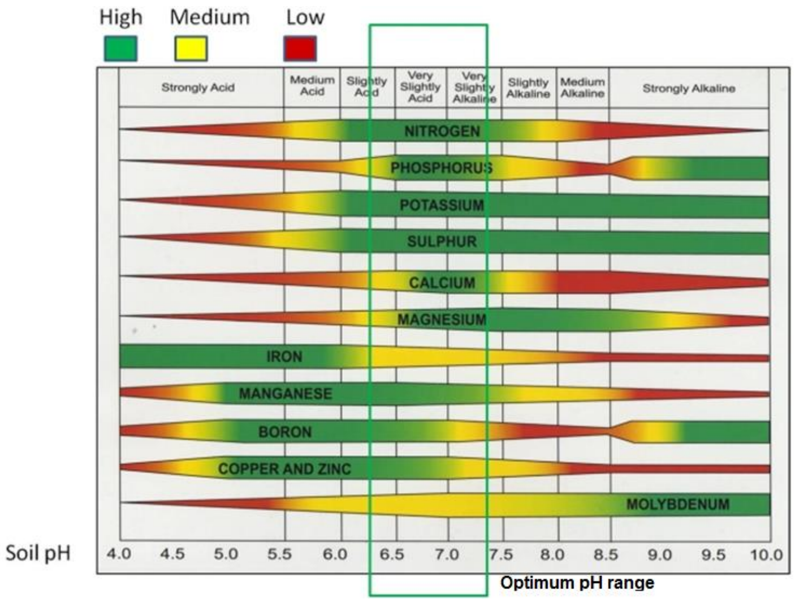
The Al and Fe polymers occur as amorphous crystalline colloids coating the clay and other mineral surfaces. Al ion (Al^{3+}) gets hydrolysed to hydroxyl-aluminium complexs and liberates H^+ ions and lowers pH.

$Al^{3+} + H_2O \leftrightarrow Al(OH)^{2+} + H^+$

$Al(OH)^{2+} + H_2O \leftrightarrow Al(OH)_2^{+} + H^+$

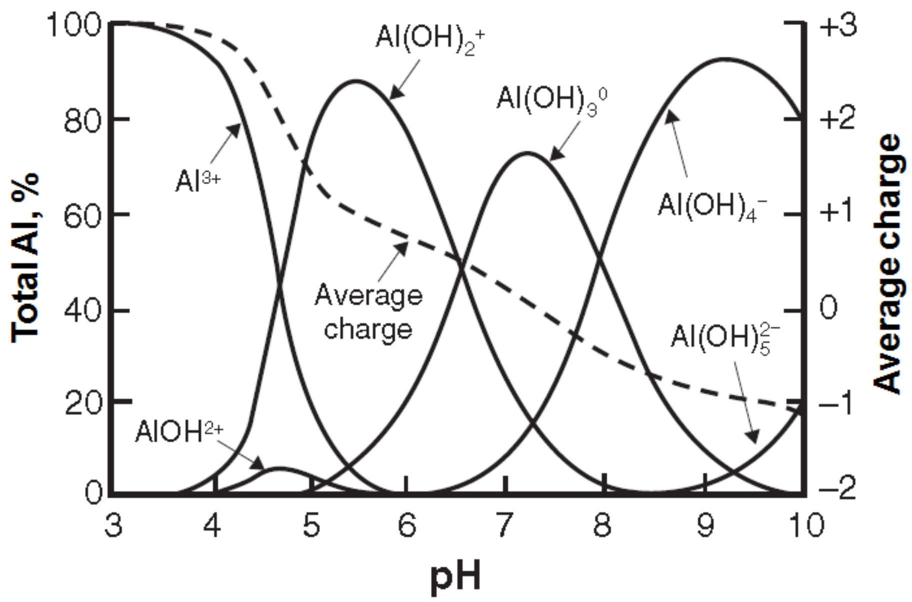
$Al(OH)_2^{+} + H_2O \leftrightarrow Al(OH)_3^{0} + H^+$

$Al(OH)_3^{0} + H_2O \leftrightarrow Al(OH)_4^{-} + H^+$



Availability of plant nutrients with variation in soil pH

The predominance of this ionic complex species is pH specific which is shown in the following picture.



Speciation of ionic species of Al with respect to pH

Similarly, hydrolysis of Fe^{3+} also liberates H^+ ions as shown below:

$Fe^{3+} + H_2O \leftrightarrow Fe(OH)_2^+ + H^+$

Although this reaction is more acidic than Al hydrolysis, the acidity is buffered by Al hydrolysis reactions. Thus, Fe hydrolysis has little effect on soil pH.

Leaching due to heavy rainfall

Generally acidic soils are developed in the regions where the rainfall or precipitation is high enough to leach appreciable amounts of exchangeable bases from the surface soil and relatively insoluble compounds of Al and Fe remains in soil.

Acid forming inorganic fertilizers

Increasing soil acidity is also due to the excessive use of inorganic fertilizers particularly ammonium fertilizers. The NH_4^+ ion replace Ca^{2+} from the exchange sites of the clay and upon nitrification acid is released.

$(NH_4)_2SO_4 \rightarrow 2NH_4^+ + SO_4^{2-}$

$2NH_4^+ + Ca\text{-}Clay \rightarrow CaSO_4\downarrow + NH_4\text{-}Clay$

$NH_4\text{-}Clay + 3O_2 \rightarrow Clay\text{-}H + HNO_3$ (Nitrification step)

Or $NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$)

Decomposition of organic matter (O.M.)

Soil O.M. or humus contains reactive carboxylic acid and phenolic groups that behaves as weak acid releasing H^+. The presence of organic acid in such soil contributes significantly to the soil acidity.

Contribution of Carbon-dioxide (CO_2)

pH is also influenced by partial pressure of CO_2 in the soil atmosphere. The CO_2 concentration in soil air causes the pH to decrease with increase of acidity. The root respiration and decomposition of organic residue increases CO_2 in soil air, which combine with water to produce H^+ ion and lower pH according to the following reaction:

$H_2O + CO_2 \leftrightarrow H_2CO_3$

$H_2CO_3 \leftrightarrow H^+ + HCO_3^-$

Mine spoil and acid sulphate soil

The pH of mine spoils and acid sulphate soils are also very low which is mainly due to oxidation of pyrites and reaction with water, resulting in formation of sulphuric acid. The mine spoil soils are common in open cast coal mining areas. The acid sulphate soils on the other hand are formed when the soil, containing enough sulphide (FeS_2), gets drained and aerated. The sulphide is oxidized to sulphate by combination of chemical and bacterial actions, forming sulphuric acid, which is the major cause of the development of acid sulphate soil. However, the magnitude of acidity depends upon the amount of sulphide present in soil.

$2FeS_2 + 2H_2O + 7O_2 \rightarrow 2FeSO_4 + H_2SO_4$

The high concentrations of sulphuric acid cause the pH as low as 2 in mine spoil soils and < 4 in acid sulphate soils.

Acidic soil occurrence in India

The highly acidic soils in India are restricted to the Himalayan ecosystem, red and lateritic regions of India. The soil with pH value < 4.0 covers 1.9% (6242.6 thousand ha) of the total geographical area (TGA) of India. Moderately acidic pH in the range of 4.5-5.5 covers an area of 24414.6 thousand ha which amounts to 7.4% of TGA. The extent of strongly acidic soil are largest in Arunachal Pradesh followed by Manipur, Sikkim, Tamil Nadu, Kerala, Chhatishgarh, Nagaland, Tripura and Assam.

Management of Acidic soil

The management of the acidic soil depends upon various factors such as the extent of acidity, thickness of sulphide layer, possibility of leaching and draining the land etc. But the most common method is liming of soil.

Liming of soil

Soil acidity is neutralized by application of lime to the soil. The general reaction that explains the reaction of a liming material such as $CaCO_3$ with water to form OH^- ions is:

$CaCO_3 + H_2O \rightarrow Ca^{2+} + HCO_3^- + OH^-$

The OH^- reacts with indigenous H^+ or H^+ formed from the hydrolysis of Al^{3+}. The overall reaction of lime with an acid soil can be expressed as:

$2Al\text{-soil} + 3CaCO_3 + 3H_2O \rightarrow 3Ca\text{-soil} + 2Al(OH)_3 + 3CO_2$.

Kinds of liming materials

Various kinds of liming materials are there for acid soil amelioration.

1. Oxides of lime : burnt lime or quick lime (CaO)
2. Hydroxide of lime: Slaked lime ($Ca(OH)_2$
3. Carbonate of lime: Calcite ($CaCO_3$) and dolomite [$CaMg(CO_3)_2$]
4. Slags: The slags are of three kinds:

- ✓ *Blast furnace slag*: This is a by-product of pig iron manufacturing unit. As a liming material this behaves essentially as calcium silicate ($CaSiO_3$) whose neutralising value is in the range of 75-90%.
- ✓ Basic slag: This is also a by-product of Open-Hearth process in manufacturing steel from pig iron. The impurities are iron, silica and phosphorous whose neutralizing value is in the range 60-70%.
- ✓ Electric furnace slag: It is produced from the electrical furnace during the preparation of elemental phosphorous from phosphate rock reduction and is also used for amelioration of soil acidity.

The efficiency of the liming materials depends upon the neutralizing value (NV) or calcium carbonate equivalent of liming materials, purity of liming materials, and degree of fineness of liming materials. The neutralizing value of some liming materials is presented in the following table.

Neutralizing value (NV) of some liming material

Liming materials	Neutralizing value (%)
Calcium oxide (CaO)	179
Calcium hydroxide [$Ca(OH)_2$]	136
Dolomite [$CaMg(CO_3)_2$]	108.7
Calcite ($CaCO_3$)	100
Basic slag ($CaSiO_3$)	86

Source: (Havlin et al., 2004)

Methods of Lime requirement (LR)

Several methods have been proposed to determine the lime requirement of acidic soil, to raise the pH around 6.5. The soil pH value alone, however, is not a good criterion for lime recommendation, because of variations in the exchange acidity of soil and the nature of crops which may not require as high as this pH to produce maximum yields.

The methods are:

Buffer curve method

The underlying principle is to equilibrate an acid soil with varying concentrations of Ca, and to measure the pH of the equilibrium solution. The amount of lime required can be calculated from the curve obtained by plotting the equilibrium pH against different concentrations of Ca added.

Method proposed by Shoemaker et al (1961)

This method does not apply to the soil whose pH (1:2.5) soil water ratio value exceeds 6.0. In this method, after checking the pH (1:2.5), the soil is shaken with distilled water and buffer solution and pH is measured using pH meter. After that, the lime requirement is calculated on the basis of soil-buffer pH ready reckoner table. To adjust to a rate of agricultural limestone that is less effective than pure $CaCO_3$, multiply the $CaCO_3$ rate by 100/(% effectiveness of agricultural limestone). Commonly the percent of effectiveness of agricultural limestone is 67% which results in a multiplication factor of about 1.5. Also to adjust lime requirement to soil depth other than 15 cm, multiply the agricultural limestone rate by soil depth (cm)/15.

Method based on base saturation of the soil

The method is based on the principle of evaluation of cation exchange capacity (CEC) of the soil, together with its initial base saturation. Taking into account of the desired base saturation of soil, normally 80%, the dose of $CaCO_3$ is calculated.

Saline soil, sodic soil and saline sodic soil

The salt affected soils is characterized as saline soils, sodic soils and saline sodic soils which covers an area of about 932 million hactares across the globe, out of which saline and sodic soils account for 351.5 mha and 581 mha, respectively (Sparks, 2003) and occurs most often in arid and semi-arid climate. In India, about 6.73 mha area is covered by salt affected soil, out of which saline area is 2.96 mha and sodic area account for 3.77 mha (Sharma et al., 2006). Thus, it is obvious that salinity/sodicity induced land degradation could be a wide spread problem that hampers sustainable development of agricultural production.

Saline soil

Saline soils have traditionally been classified as those in which the pH of saturated paste < 8.5, ECe of the saturation extract is > 4 dS m^{-1} and ESP < 15 %. In saline soils, the problem is due to the soluble salts primarily Cl^-, SO_4^{2-} salts of Na. Since, exchangeable Na^+ is not a problem, saline soils are usually flocculated, resulting in good soil permeability. Soil salinity is a major global issue owing to its adverse impact on agricultural productivity and sustainability. It could be both natural or human induced and occur in all types of climatic conditions. Generally speaking, saline soils occur in arid and semi-arid regions where rainfall is insufficient to leach mineral salts out of the root-zone and have high evaporation rate. This results in the increased concentration of salts in soil and surface water. The process by which the saline soil formed is known as salinization. Restricted drainage is another cause, contributing in the formation of saline soils. The high groundwater table and low soil permeability due to unfavourable soil structure also contribute to the salinization of soil

Causes of soil salinization
Natural soil salinization

Weathering of parent material
In the process of weathering of rocks and minerals, the various types of soluble salts are released which are being transported to surface water and groundwater. In the countries lying in the arid and semi-arid regions, the soluble salts get concentrated due to high evapo-transpiration rates and low rainfall. In the area of depressions (low lying) particularly, these salts also gets concentrated, resulting in soil salinization.

Inland coastal salinization
The coastal inland salinization is developed mainly due to sea water ingression, sea breeze laden with salt, cyclones, tidal waves, and floods.

Besides this, river water also contributes in the salinization process by carrying dissolved salts from the upstream and depositing the same to alluvial plains.

Man made soil salinization
Deforestation
The deforestation leads to the decrease in evapo-transpiration rate and increases leaching process. In the area where sub-surface soil layer contains high level of clay or presence of hard pan of calcium carbonates, the downward leaching is inhibited, resulting in lateral movement at shallow depths. The salts of leached water at shallow depths come up to the surface through capillary action, causing soil salinization.

Over irrigation of crops using poor quality waters

Excessive irrigation of crops using poor quality waters may results in the salt build up in soil and leads to salinization. Even, irrigating with good quality water for longer time in absence of proper drainage system may also cause salinization of soil.

Canal water seepage

The canal water seepage is known for the onset of secondary salinization. Due to canal seepage, the water table becomes high and a sort of waterlogging problem arises. The shallow water condition triggers the process of secondary salinization. The Indira Gandhi Nahar Priyojna (IGNP) area in Rajasthan and Sharda sahayak canal command, Uttar Pradesh are the best example of secondary salinization. Besides this, the use of waste water (domestic or industrial), in agriculture and excessive use of inorganic fertilizers may also cause soil salinization.

Reclamation of Saline soil

The poor quality saline soils can be reclaimed best by leaching its salts with good-quality water, having low electrolyte concentrations. The good quality water dissolve the soluble salts present in saline soil and remove it from the root zone. The major constraints in the reclamation of such soil is i) restricted drainage caused by a high water table, ii) low soil hydraulic conductivity due to restrictive soil layers, iii) lack of good-quality water, and iv) the high cost of good quality water.

Sodic soil

As per U.S. Salinity Laboratory Staff (1954), the soil whose pH of saturated paste is greater than 8.5, electrical conductivity of saturated extract, ECe is < 4 dS m^{-1}, and exchangeable sodium percentage, ESP >15 whereas for Indian sodic soils such as those characteristics in the Indo-gangetic plains, according to Gupta & Abrol (1990), the soil ECe is limitless if the weathering of the alkali alumino-silicates produces high concentration of carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) of Na, otherwise ECe < 4 dSm^{-1} at 25^{o}C. Since, laboratory analysis of ESP is time taking method, a simpler method was evolved on the basis of sodium adsorption ratio (SAR) from saturated extract of soil and can be defined as:

SAR = $\frac{Na}{\sqrt{(Ca+Mg)/2}}$ where Na, Ca, and Mg are its concentration (meq L^{-1}) in saturated soil extract.

Soils having SAR values greater than 13 are considered sodic soil. The sodicity induced land degradation is a worldwide problem that affects agriculture and by causing severe losses in soil fertility and productivity. The formation of sodic soil is due to weathering of alkali alumino-silicate with an alkaline hydrolysis, resulting in the increase of pH of soil, with simultaneous precipitation of Ca in the form of $CaCO_3$. The precipitation of $CaCO_3$, in turn make the soil deficient of Ca and preponderance of Na both at the solution and exchange complex. The excess CO_3^{2-} and HCO_3^- of Na and highly hydrated Na ions increase the ζ-potential of the soil exchange complex, which leads to the repulsion of clay particles from each other, causing clay dispersion, clogging of pore space and decreasing hydraulic properties of soil. Soil sodicity has caused severe effects on nutrient imbalance, roots proliferation, microbial activities in soil, and ultimately results in poor crop production. Sodic soils were previously often known by *black alkali soils*, because of the dissolution of organic matter deposited on the surface along with salts.

Saline sodic soils

These soils are formed as a result of combined processes of salinization and alkalization. Saline sodic soils are having pH of saturated soil paste less than 8.5, electrical conductivity is greater than 4 dS m^{-1} and exchangeable sodium percentage greater than 15. In contrast to saline soils, the exchangeable Na gets hydrolyzed when such soils are leached out, resulting in the pH increase and the soil become sodic.

The pathway of the hydrolysis reactions of exchangeable Na are:

i) Hydrolysis reaction of exchangeable Na in absence of free $CaCO_3$

Na [Clay +H_2O = H [Clay + NaOH

NaOH + CO_2 (from soil) = Na_2CO_3 +H_2O

ii) Hydrolysis reaction of exchangeable Na in presence of free CaCO3

Na [Clay +H2O = H [Clay + NaOH

$\frac{H}{H}$[Clay + 2NaOH + $CaCO_3$ = Ca [Clay + Na_2CO_3 +$2H_2O$

Management of sodic soil

The management of sodic soil requires the removal of most of the exchangeable Na from the soils of root zone and replacing these Na with Ca, which can be done by choosing the appropriate chemical amendment amongst the various chemical ameliorants. Amongst the chemical amendments, best amendment is one that can supply Ca directly or indirectly to the soil, which can exchange Na from the soil exchangeable sites. The common amendments are gypsum ($CaSO_4.2H_2O$) and Calcium chloride ($CaCl_2$), capable of supplying soluble Ca directly whereas elemental sulphur, pyrites, and sulphuric acid acts indirectly through its chemical and biological actions by utilizing the inherent calcium carbonate present in sodic soil and releasing Ca ions. The decomposing organic matter such as farm yard manure (FYM), crop residues, and green manure also help in the supply of Ca by releasing organic acids and reacting with $CaCO_3$. The choice of chemicals and its quantity is based on the extent of soil degradation, the availability of the amendment, and the choice of crop to be grown. Above all, the management should be cost effective.

The amendments of sodic soils are:

Gypsum

Gypsum ($CaSO_4.2H_2O$ is commonly found as natural deposits and is available through its mining. It is suggested to ground the gypsum before soil application. When it is applied, the gypsum dissolves (solubility is about 0.25%) and release Ca ions which replace Na from exchange complex as shown below:

$\mathrm{Clay]}^{\mathrm{Na}}_{\mathrm{Na}} + \mathrm{CaSO_4} =$ Clay]Ca + Na_2SO_4 (leachable)

Gypsum also reacts with sodium carbonate present in the soil as;
$Na_2CO_3 + CaSO_4 = CaCO_3 + Na_2SO_4$ (leachable)
Therefore, it is suggested that the soluble salts must be flushed out in order to have greater efficiency of applied gypsum. For sodic soil reclamation, gypsum had been used widely as a chemical amendment.

Calcium chloride ($CaCl_2.2H_2O$): This is highly soluble (solubility 74.5%) and capable of supplying soluble Ca instantly. Its reaction in sodic soil is similar to those of gypsum:

$\mathrm{Clay]}^{\mathrm{Na}}_{\mathrm{Na}} + \mathrm{CaCl_2} =$ Clay]Ca + 2NaCl (leachable)

$Na_2CO_3 + CaCl_2 = CaCO_3 + 2NaCl$ (leachable)

Sulphuric acid (H_2SO_4): It reacts with the inherent calcium carbonate of sodic soil to form calcium sulphate and thus provides soluble calcium indirectly. The reaction can be written as:

$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2$

$\mathrm{Clay]}^{\mathrm{Na}}_{\mathrm{Na}} + \mathrm{CaSO_4} =$ Clay]Ca + Na_2SO_4 (leachable)

$Na_2CO_3 + H_2SO_4 = CO_2 + H_2O + Na_2SO_4$ (leachable)

Because of its corrosive nature, its handling is difficult. So it is not safe to use.

Elemental sulphur (S): Sulphur is a yellow powder which is not soluble in water and does not supply Ca ions directly for exchanging Na from the exchange complex of soil. When applied for sodic soil reclamation, sulphur has to undergo oxidation to form sulphuric acid which in turn reacts with $CaCO_3$ present in the soil to form soluble Ca in the form of calcium sulphate as shown below:

$2 S + 3 O_2 = 2 SO_3$ (microbiological oxidation)

$SO_3 + H_2O = H_2SO_4$

$H_2SO_4 + CaCO_3 = CaSO_4 + H_2O + CO_2$

$\text{Clay}]^{\text{Na}}_{\text{Na}} + \text{CaSO}_4 = \text{Clay]Ca} + Na_2SO_4$ (leachable)

Pyrite (FeS_2): It is another amendment for sodic soil management. In this case both chemical and biological reaction processes are involved. The first step is the oxidation of pyrite to iron (II) sulphate :

$2\ FeS_2 + 2\ H_2O + 7\ O_2 = 2\ FeSO_4 + 2\ H_2SO_4$

This reaction is then followed by the bacterial oxidation of iron II sulphate, a reaction normally carried out by *Thiobacillus ferrooxidans*,

$4\ FeSO_4 + O_2 + 2\ H_2SO_4 = 2\ Fe_2(SO_4)_3 + 2\ H_2O$

Subsequently iron (III) sulphate (ferric) is reduced and pyrite is oxidized by what appears to be a strictly chemical reaction.

$Fe_2(SO_4)_3 + FeS_2 = 3\ FeSO_4 + 2\ S$

Elemental sulphur so produced may then be oxidized by *T. thiooxidans* and the acidity generated favours the continuation of the process

$2\ S + 3\ O_2 + 2\ H_2O = 2\ H_2SO_4$

Summary: $4\ FeS_2 + 2\ H_2O + 15\ O_2 = 2\ Fe_2(SO_4)_3 + 2\ H_2SO_4$

Gypsum Requirement (GR)

It is the amount of gypsum ($CaSO_4.2H_2O$) required to be added to a sodic/alkali soil to reduce the exchangeable sodium content to a desired level under field conditions.

Laboratory method of Gypsum requirement (Schoonover, 1952)

Principle

The gypsum requirement (GR) of the soil is determined by using method proposed by Schoonover (1952). In this method a given weight of the soil is equilibrated with a known amount of Ca solution and the amount of the Ca left in the solution is determined by versenate method. The difference between the amount of Ca added and the Ca left in the solution, gives the amount of Ca exchanged with the Na at the exchange sites.

$[\text{Exchange Complex}]^{Na^+}_{Na^+} + CaSO_4.2H_2O \rightarrow [\text{Exchange Complex}]^{Ca^{2+}}_{Ca^{2+}} + 2Na^+ + SO_4^{2-}$

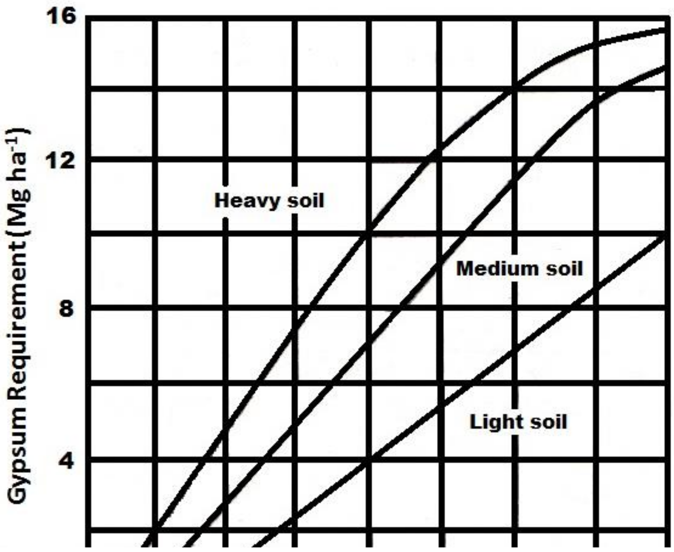
However, the sodic soil of Indo-gangetic plain contains high amounts of sodium carbonate which may reacts with the gypsum solution during determination of GR of the soil by the Schoonover's method.

$Na_2CO_3 + CaSO_4 \rightarrow Na_2SO_4 + CaCO_3$

Consequently, the gypsum requirement may be inflated in those determinations where soluble carbonates have not been leached before treating the sodic soil with a known gypsum solution. The leaching of soluble carbonates before gypsum application may reduce the GR value.

Gypsum Requirement based on soil pH

The GR dose is also evaluated from the pH and texture of the soil for Indo-gangetic sodic soil. Abrol *et al*., (1981) developed a graph to determine the approximate gypsum requirement of soil from pH of the Indo-gangetic sodic soil. This can be very useful for the extension/field workers in field work for advocating the doses of gypsum, as illustrated in the figure given



Relationship between soil pH and gypsum requirement of sodic soil (Source: Abrol *et al*., 1981)

pH (1:2) Soil Water Suspension

Soil toxicity and plant available nutrient uptake

Acid soil

Al toxicity is the most important growth limiting factor in acidic soils (pH < 5.0). Their toxic effect leads to suppression of plant growth and yield. Excess Al interfere with cell division of plant roots; inhibits nodule initiation; fixes P in less available forms in soil; decreases root respiration; interferes with enzymes governing the deposition of sugars in cell wall; increase cell wall rigidityand interferes with uptake and transport of nutrients and water to the plants. At low pH (4.5 or less), H+ toxicity damages root membrane and detrimental to growth.

Benefits of liming

It reduces the solubility of Al. Liming precipitates Al to $Al(OH)_3$ and increase plant's uptake of Ca and Mg, which is being decreased due to the presence of Al^{3+} due to acidity.

Liming also increase plant available P by precipitating Al and Fe.

In acid soil, with the exception of Mo, the availability of micronutrients increases, even results in the toxicity to the plants. With liming, the micronutrients become available for plants uptake, even Mo, becomes available after liming.

The nitrification (conversion from NH_4^+ to NO_3^-) is enhanced by liming to pH 5.5-6.5.

Nitrogen fixation bacterias (both symbiotic and non-symbiotic) is favored by adequate liming.

Saline/ sodic soil

Growth inhibition in salt sensitive crops, even at low salinity is caused by the toxicity effects of Na^+ and Cl^- ions. The high osmotic pressure in the soil solution causes a low soil water potential and when comes in contact with plant cell, the solute moves towards soil solution instead of entering into the plants. The result is cell collapse due to *plasmolysis*. Excess exchangeable Na in sodic soils degrades physical soil properties by breakdown of soil aggregates (dispersion) and lowers the permeability of the soil to air and water, form impermeable surface crusts and hinder the emergence of seedlings.

The availability of some essential plant nutrients is lowered. The concentration of the elements Ca and Mg in the soil solution is reduced as the pH increases due to formation of relatively insoluble $CaCO_3$and $MgCO_3$. Availability of P, Fe, Mn and Zn, are also affected. The sodium, molybdenum and boron are present at the toxic level. Among, micronutrients. Zinc deficiency has been widely reported for crops grown in sodic soils. Boron and molybdenum are not likely to be limiting elements for plant nutrition in sodic soils. In fact, they are often likely to be present in the toxic range.

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Chapter - 8

Importance of Soil / water Testing, Soil / water Sampling techniques, Different simple Soil Testing Kits (Soil Testing Fertilizer Recommendation: Mridaparikshak)

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Introduction

Soil testing is a process by which elements (nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, manganese, copper, iron, zinc, boron, and molybdenum) are chemically removed from the soil and measured for their "plant available" content within the sample. The quantity of available nutrients in the sample determines the amount of fertilizer that is recommended. A soil test also measures soil organic carbon, soil pH, and electrical conductivity (EC). However, soil tests may also include the determination of alkalinity and acidity. The most important step in soil testing is the collection of a representative soil sample.

Importance of soil testing

Soil testing ensures balanced fertilization of crops and thus prevents the unnecessary use of fertilizers which is a costly input. It improves crop yields and ensures sustainable crop yields. Since soil testing leads to balanced fertilization of crops, it prevents the plants, soil and human beings against the pollutions due to excessive nitrates and other elements which could accumulate in soil and water bodies if their application in soil is not regulated or scientifically managed. Imbalanced application of fertilizers also causes problems of environmental pollutions like global warming due to emission of Green House gases such as carbon dioxide and methane. It also causes eutrophication of lakes since excess nutrients reach to water bodies leading to excessive algal growth. Soil testing is especially important for the countries like India because India is a huge importer of fertilizers and every year thousands of crores of rupees are spent on importing the expensive fertilizers. This puts further burden on Govt. since these costly fertilizers need to be subsidized before they are made available to farmers. Hence, judicious fertilizer applications through soil testing is important.

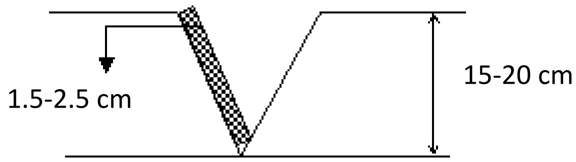
Steps in soil testing

The entire process of soil testing involves following steps: (i) soil sampling (ii) correlation (iii) calibration and (iv) interpretation or recommendation. Soil sampling is the procedure of collecting the representative soil sample. It is a very important step because the entire success of soil testing depends on it. Correlation is finding the relationship between soil analysis method and desired response either in terms of uptake of the nutrient in question or plant yield. This step is generally done by researcher. Calibration is the relationship between soil analysis value, nutrient addition and desired plant response i.e. uptake of nutrient or yield. The calibration tells the amount of fertilizer needed to be applied at a given soil test value for desired yield. These calibrations are done through soil test crop response experiments by the researchers. Soil test interpretation is the final step where the fertilizer recommendations are given to farmers taking into consideration his/her resources, weather and other related factors.

Soil sampling

Soil sampling is one of the most important steps in any soil testing programme. A non representative sample may vitiate the entire results. Only few grams of soil samples are tested for different parameters in the laboratory. This small amount of soil gives indication of that particular nutrient for the whole field which weighs around 2.24×10^6 kg (one hectare furrow slice). Hence, the samples should be accurately taken. Some precautions that need to be followed are:

1. Do not collect the samples at the periphery. There is chance of contamination as fertilizer bags are kept there. Also, animals and other humans pass through the periphery.
2. When collecting the samples first demarcate the area for each subsample based on uniformity in colour, slope, drainage, and contrasting past management practices.
3. Never collect the samples in line. Instead, sampling at several locations in a *zig-zag* pattern ensures homogeneity.
4. Avoid sampling in dead furrows, wet spots, areas near main bund, trees, manure heaps and irrigation channels.
5. For shallow rooted crops, collect samples up to 15-20 cm depth. For deep rooted crops, collect samples up to 30 cm depth. For tree crops, collect profile samples.
6. Clean the spot before taking the soil sample. Remove the surface litter at the sampling spot.
7. It is very important to collect a uniform slice up to sampling depth. It is a common mistake done during sampling when the person digging the hole keeps on collecting the sample while digging. Under such case the sampling becomes skewed with respect to depth. When using *khurpi*, the recommended procedure is to first dig a V shaped cut up to a plough layer (15-20 cm). Remove all the soil. Then take a uniform 1.5-2.5 cm thick slice from the side (See figure below).



Method of taking soil sample

8. At least 10-15 slices should be collected to get a representative sample. The demarcation of area for taking a representative sample is to be done based on visual inspection and past experience regarding the uniformity of soil. The sampling intensity may be increased for larger fields. In case a representative soil sample is to be collected

for larger fields (say 10 hectare) care has to be taken in drawing the sub-samples from a uniform area as discussed in S. No. 2 above.

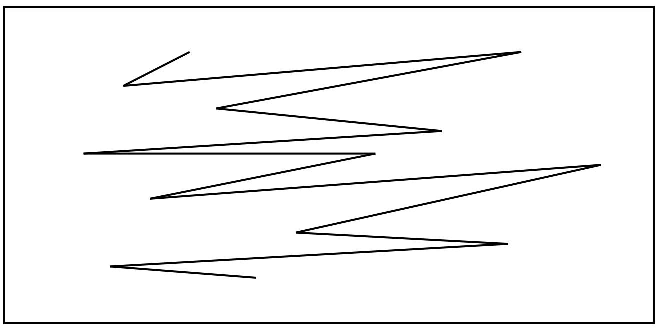
9. Generally higher spatial variability is encountered in irrigated than rain-fed situations. Hence, sampling intensity may be increased in irrigated conditions.
10. Always collect the soil sample in presence of the farm owner who knows the farm better.
11. Collect the sub samples in a plastic tray.

Sampling frequency and timing: Soil testing should be carried out once in every three to five years. Take the soil sample well before sowing/planting, so there is time to treat the soil. Sampling should be done at the same time each year. It is better to take the samples in the same month of the year in which the previous samples were taken. In India samples can be taken during April to June but prior to the application of manures/fertilizers.

Depth: A sampling depth of 15-20 cm is required for most of the field crops. For a pasture crop, a 10 cm depth is normally sufficient. However, for deep rooted crops like sugarcane, cotton, and horticultural crops, sampling from different depths may be needed.
Implement: Khurpi, tube auger or spade may be used for sampling of soft or moist soils. A screw auger can be used on hard or dry soils.

After Collection of Sub Samples

- Mix the samples thoroughly and remove foreign materials like roots, stones, pebbles and gravels.
- Reduce the bulk to about half to one kilogram by quartering or compartmentalization.
- Quartering is done by dividing the thoroughly mixed sample into four equal parts. The two opposite quarters are discarded and the remaining two quarters are remixed and the process repeated until the desired sample size is obtained. Compartmentalization is done by uniformly spreading the soil over a clean hard surface and dividing into smaller compartments by drawing lines along and across the length and breadth. From each compartment a pinch of soil is collected. This process is repeated till the desired quantity of sample is obtained (see figure below).
- Collect the sample in a clean cloth or polythene bag.
- Label the bag with information like name of the farmer, location of the farm, survey number, previous crop grown, present crop, crop to be grown in the next season, date of collection, name of the sampler etc.



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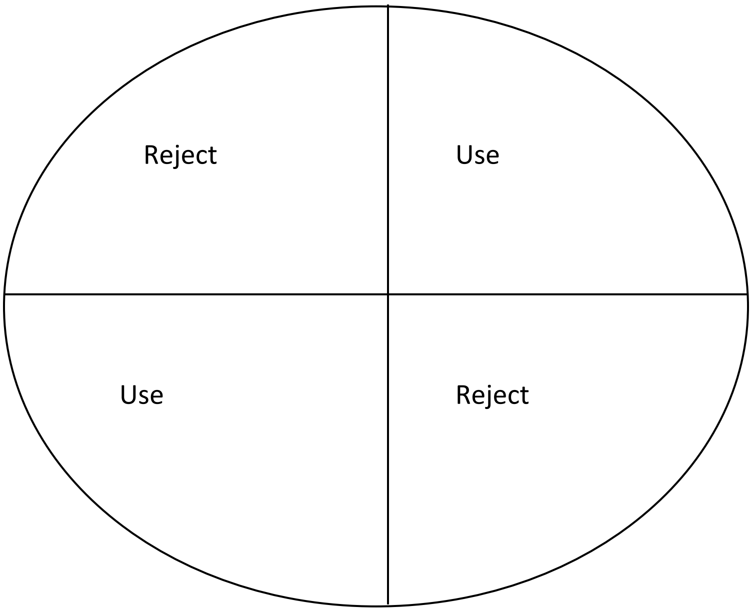
A schematic diagram showing soil sample locations



Quartering technique for reducing the soil volume before analysis

Processing and Storage

- Assign the sample number and enter it in the laboratory soil sample register.
- Dry the sample collected from the field in shade by spreading on a clean sheet of paper after breaking the large lumps, if present. The samples should be dried at 25-35° C.
- The soil aggregates should be broken up by crushing lightly wooden roller, wooden pestle and mortar.
- Sieve the soil material through 2 mm stainless steel or plastic sieve.
- Repeat powdering and sieving until only materials of >2 mm (no soil or clod) are left on the sieve.
- Collect the material passing through the sieve and store in a clean glass or plastic container or polythene bag with proper labeling for laboratory analysis. (If the samples are meant for the analysis of micronutrients, care is needed in handling the sample to avoid contamination of iron, zinc and copper. Brass or iron sieves should be avoided and it is better to use stainless steel or polythene materials for collection, processing and storage of samples.)
- For the determination of organic carbon it is desirable to grind a representative sub sample and sieve it through 0.5 mm sieve.
- Air-drying of soils must be avoided if the samples are to be analyzed for NO_3-N and NH_4-N as well as for bacterial count.

- Field moisture content must be estimated in un-dried sample or to be preserved in a sealed polythene bag immediately after collection.
- Estimate the moisture content of sample before every analysis to express the results on dry weight basis.
- Avoid contact of the sample with chemicals, fertilizers or manures.
- Use stainless steel augers instead of rusted iron khurpi or kassi for sampling for micronutrient analysis.
- Do not use bags or boxes previously used for storing fertilizers, salt or other chemicals. Store soil sample in clean, preferably new, cloth or polythene bags. Use glass, porcelain or polythene jar for long duration storage.

Fertilizer Requirement/Calibration

- *General recommendation*: These recommendations are based on multi-locational trials conducted with graded doses of N, P, K fertilizers to arrive at an optimum dose for the particular crop.
- *Recommendation based on the soil fertility rating*: Most of the recommendations issued from soil testing laboratories in India are based on soil test ratings, the medium soil fertility being equated with general recommended dose. The fertilizer dose is decreased or increased by 25 to 30 percent if the soil is high in fertility or low in fertility as per soil test.
- *Critical limit based recommendation*: Critical limit is the level of soil available nutrient above which that nutrient no longer primary limiting factor.
- *Recommendation based on targeted yield*: The recommendations based on this approach are more quantitative, precise and meaningful because it involve both soil and plant analysis
- *Recommendation based on nutrient index*

$$\text{Nutrient Index} = \frac{(NL \times 1) + (NM \times 2) + (NH \times 3)}{NT}$$

Where NL, NM and NH are number of soil samples falling in low, medium and high categories respectively and NT total number of soil samples.

Index was modified by Ramamoorthy and Bajaj (1969) who gave the limit as

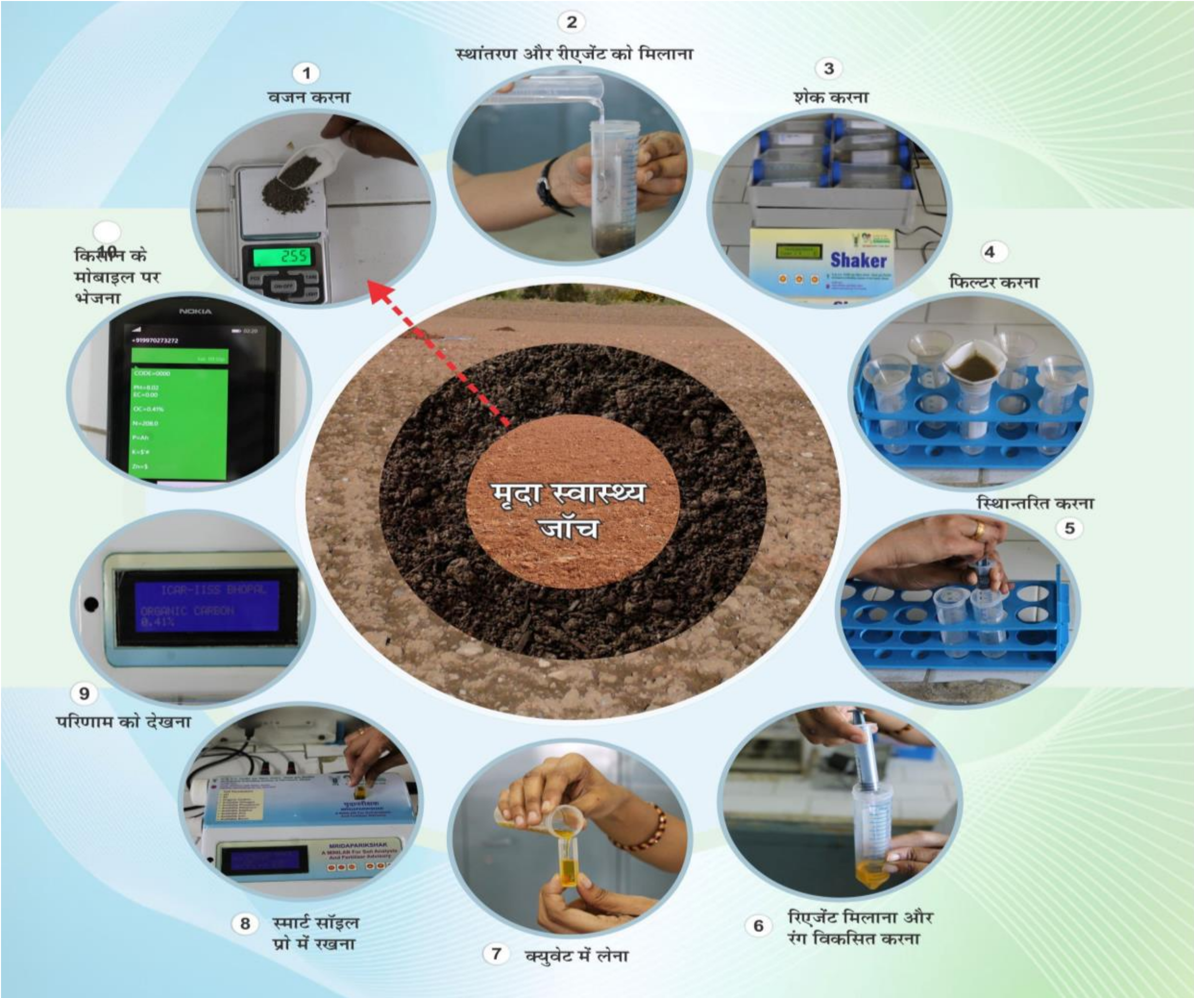
< 1.67 – low 1.67 - 2.33 medium >2.33 - high

Rapid soil testing

Soil testing has failed to gain wide acceptance in India, with only a small increase in sample numbers since inception. Reasons for the low utilisation of soil testing services include: farmers not having the time nor the expertise to collect soil samples; delays in receiving results from laboratories; lack of faith in results produced by laboratories linked to chemical companies; and cost of soil testing. The availability of simple, low cost field-based soil tests could provide a solution to these problems. Several soil test kits are available in India. The most notable are the ones made by ICAR institutions such as Pusa STFR meter from ICAR-IARI, New Delhi and Mridaparikshak from ICAR-IISS, Bhopal. Here, we describe the functioning of Mridaparikshak in detail.

Mridaparikshak, developed by ICAR-IISS Bhopal, is a mini laboratory which obviates the need of expensive and voluminous traditional laboratories. This mini lab can estimate 15 important soil parameters viz., pH, EC, organic carbon, available nitrogen, phosphorus, potassium, sulphur, zinc, boron, iron, copper, manganese, gypsum requirement (GR), lime requirement (LR), and calcareousness. It can also provide soil and crop specific fertilizer recommendations directly to farmers on their mobiles through SMS.

Composition: Mridaparikshak comes with a shaker, a weighing balance, a hot plate, and a smart soil pro, an instrument to determine the soil parameters and displaying of fertilizer nutrient recommendations, and other accessories. The estimation procedure is shown in figure below. Separate probes are provided for measurement of EC, pH, and GR & LR which are based on measurement of soil pH. Mridaparikshak prescribes doses of fertilizer N, P, and K based on the targeted yield equations developed by AICRP on Soil Test Crop Response, and micronutrients rates based on critical level approach.



Functioning of Mridaparikshak

Results: The results as given by *Mridaparikshak* correspond to the results obtained by soil test laboratories. The results are comparable with the results obtained by Walkley and Black procedure for organic C, Subbaiah and Asija method for available N, Olsen and Bray method for available P, neutral 1 N ammonium acetate method of available K, DTPA extraction method for available Fe, Mn, Cu and Zn, and hot water soluble method for available B. The results are stable, and reproducible. It can be operated by young educated farmers/rural youth with short training. This mini lab has a great potential in the assessment of soil fertility parameters and recommendation of balanced fertilizers.

Water testing

Water use can be characterized as a cyclic process aimed at improving the quality of life for humanity. As the world's population grows, so does the importance of effective water management, which in turn places greater emphasis on balancing the need of different users. Water use cycles have many input and withdrawal points, which periodically give rise to a surplus or deficit of water. At present, deficit, which includes both the quality and quantity of water, is more prevalent in most parts of the world. On a global basis, nearly 75% of all water is used for agriculture, especially irrigation, and 57% of the water withdrawn for irrigation is lost through infiltration, evaporation and over irrigation (Biswas, 1985).

Water Sample Collection procedure: Water sample is collected in the bottle after rinsing with the same water 3-4 times. Sample from tube well should be collected directly from the outlet point. When sampling from open wells and piezometers, the sample bottle may be tied to a good quality thread and then lowered into the well till it is filled with water. Care should be taken to collect the sample only after continuous discharge of the source for 10 to 20 minutes. From shallow ponds, lakes, reservoirs, canals, and rivers, water sample should be collected from centre of the width after avoiding the floating debris on the top. About half a liter of the sample is sufficient. After proper marking and labelling, immediately the sample must be sent to the laboratory for analysis in order to avoid any change/ deterioration in its quality due to chemical or microbial activity.

Measurable Irrigation Water Quality Parameters

The parameters generally used to assess water quality are given below:

Physical	**Chemical**	**Biological**
Temperature	BOD, COD, DO	Bacteria
Colour	pH, hardness, total salt, cations/ anions	Algae
Odour	Toxic elements	Virus
Turbidity	Heavy metals	
Foam and froth, suspended solids	Detergents Pesticides	

Important determinations necessary to evaluate quality of a water sample are listed in Table 1. Nitrate content of waters is of interest not only because plants can absorb nitrate to meet their N-needs but also from environmental and health angles because excess of nitrate in drinking waters can be toxic to animals and humans. However, for appraisal of irrigation quality, the water sample is mainly analyzed for total salt (EC), relative proportion of cations, anions and toxic substances, such as excess boron and fluorine. When sewage of any industrial effluent rich in organic matter is to be used for irrigation, determination of bio-chemical oxygen demand (BOD) and chemical oxygen demand (COD) is also desirable.

Practical Suggestions:

- Water sample should not be collected in dirty, used and contaminated bottles. The container should be transparent and preferably new.
- Time interval between collection and analysis of the sample should be short in order to get reliable results.
- If a delay is inevitable, water sample must be protected against bacterial growth either by adding 2-3 drops of pure toluene or by keeping it under refrigeration (4^0C) for the time required.

Table 1: Laboratory determinations of inorganic constituent's needed to evaluate irrigation water quality

Laboratory determination	Reporting symbol	Reporting units*	Equivalent weights (g)
Electrical conductivity	EC_w	dSm^{-1}	-
Calcium	Ca	me/1	20
Magnesium	Mg	me/1	12.2
Sodium	Na	me/1	23
Carbonate	CO_3	me/1	30
Bicarbonate	HCO_3	me/1	61
Chloride	Cl	me/1	35.5
Sulphate	SO_4	me/1	48
Boron	B	me/1	10.8
Nitrate-nitrogen	NO_3-N	me/1	14
Acidity-alkalinity	pH	pH	-
Adjusted sodium adsorption ratio	adj. SAR	-	-
Potassium	K	me/1	39.1
Lithium	Li	me/1	7
Iron	Fe	me/1	55.9
Ammonium-N	NH_4-N	me/1	14
Phosphate- P	PO_4-P	me/1	31

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Chapter - 9

Role of crop rotation, Placement of different fertilizer for better input use efficiency, Rating of soil nutrient status and Recommended dose of fertilizer/manure for different major crops

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Definition of crop rotation

Crop rotation refers to the cultivation of different crops on a particular piece of land over time. The succession of crops to be grown is carefully designed to ensure soil nutrients are sustained, pest populations are controlled, weeds are suppressed and soil health is built. Crop rotation is a system of designing how to cycle a piece of land through various crops, reducing the reliance on chemical fertilisers, pesticides and herbicides. It is how successful farmers nurtured their land over generations, and remains vitally important for farmers today wanting to nourish their local environment whilst growing good, healthy food. The practice of crop rotation dates back to antiquity. Roman agronomists 2000 years ago thus recommended the practice of alternating legumes and cereals in a rotation, including the use of legumes as green manure. This is also a valuable practice in current organic farming systems.

A crop rotation will cycle through cash crops (such as vegetables), cover crops (grasses and cereals) and green manures (often legumes). The exact sequence of crops will vary depending on local circumstances, with the critical design element being an understanding what each crop contributes and takes from the soil.For instance, nitrogen depleting crop should be preceded by a nitrogen fixing crop. The central idea is to have the crops themselves sustain soil health, rather than planting the same crop year in, year out, and then repairing soil health through fertilisers, pesticides and herbicides.

Need of crop rotation

Crop rotation, planting a different crop on a particular piece of land each growing season, is required in organic crop production because it is such a useful tool in preventing soil diseases, insect pests, weed problems, and for building healthy soils. Plants exude a spectrum of photosynthates into the soil that are unique to each plant species, and these root exudates influence the soil microbial biodiversity, which, in turn, supports soil function and plant health. Crop rotations must fit with the farm's production system, equipment, labour, and market demand for the farm's crops.

1.3 General Principles to Guide Crop Rotations

- ✓ Follow a legume crop with a high-nitrogen-demanding crop.
- ✓ Grow less-nitrogen-demanding crops...in the second or third year after a legume sod.

- ✓ Grow annual crops for only one year in a particular location
- ✓ Don't follow one crop with another closely related species.
- ✓ Use crop sequences that promote healthier crops.
- ✓ Use crop sequences that aid in controlling weeds.
- ✓ Use longer periods of perennial crops on sloping land.
- ✓ Try to grow a deep-rooted crop...as part of the rotation.
- ✓ Grow some crops that will leave a significant amount of residue.
- ✓ When growing a wide mix of crops...try grouping into blocks according to plant
- ✓ Family, timing of crops, (all early season crops together, for example), type of crop (root vs. fruit vs. leaf), nutrient needs, or crops with similar cultural practices.

Advantages of crop rotation

A well-designed crop rotation makes land both more productive and more environmentally sustainable. It improves the financial viability of a farm by increasing productivity whilst reducing chemical input costs. Key advantages of crop rotation are:

- ✓ Improved soil fertility and structure
- ✓ Disease control
- ✓ Pest control
- ✓ Weed control
- ✓ Increased Soil Organic Matter • Erosion control
- ✓ Improved biodiversity
- ✓ Increased yield
- ✓ Reduced commercial risk

Improves soil fertility and structure

Crop rotation improves the physical and chemical conditions of soil and thus improves the overall fertility. Nitrogen-fixing legumes such as soybeans and alfalfa in crop rotations fix atmospheric N2 into the soil through root nodules. This nitrogen is then available for subsequent crops. Deep rooted cover crops can draw up nutrients such as potassium and phosphorus from deep in the soil profile, making these nutrients available for subsequent shallow rooted cash crops. Growing a hay crop in a rotation can result in improved tilth and bulk density.

Disease control

Crop rotation helps to control common root and stem diseases that affect row crops. Crop rotation is highly effective against diseases whose pathogens have a small host range and require soil or crop residue to overwinter. For such diseases, rotating a non-host crop immediately after a host crop prevents the pathogen from reproducing. The pathogen inoculum, ordinarily preserved in crop debris, does not have the necessary conditions for its survival and the disease spread is controlled. For example, soybean cyst nematode populations can be cut in half by rotating soybean with wheat and corn. In the absence of crop rotation, growing the same crop on a particular land year after year gives pathogens continued optimal conditions, and their population will increase rapidly.

Pest control

Crop rotation can be used as a tool to manage those insects which are non-mobile, whose larvae or eggs overwinter in soil and which have a narrow range of crops to feed on. For instance, corn rootworms can be managed effectively with crop rotation. These insects lay eggs in the corn fields they live on, and emerge to damage subsequent crops. Rotating a non-host crop immediately after a corn crop means that emerging larvae starve due to scarcity of food. Note that this practice is ineffective in some areas where rootworm populations have developed mechanisms to survive crop rotation.

Weed control

Including cover crops into crop rotation systems provides greater competitions to the weeds for their basic needs such as nutrients, space and light. Cover crops ultimately crowd out the weeds, slowing down weed growth and proliferation for a reduced weed population in subsequent crops.

Increased soil organic matter

Crop rotation will add more crop residues, green manures and other plant debris to the soil. Crop rotation also requires less intensive tillage, which means that soil organic matter does not degrade as quickly. Increased soil organic matter improves soil infiltration and water holding capacity, which enables water to be absorbed into the soil. Furthermore, increased soil organic matter improves overall soil structure and the chemical and biological properties of the soil.

Erosion control

Crop rotation helps control the erosion of soil from water and wind by improving the soil structure and reducing the amount of soil that is exposed to water and wind. Crop rotation also supports reduced or no- till farming, which ensures even better protection against erosion. Cover crops are effective in reducing raindrop impact, reducing sediment detachment and transport, slowing surface runoff, and so reducing soil loss.

Improved biodiversity

Crop rotation helps improve soil biodiversity by changing crop residue and rooting patterns. Different crops benefit different species, and so a range of crops will lead to a more diverse and healthy soil microbial community. Similarly, the microbial community is supported by rotating crops with a high C: N (such as corn) with low C: N crops (such as soybeans).

Improved yield

Crop rotation can help increase yield. Corn and soybean that is rotated with another crop yields 10% more than when the same crop is grown continuously. The increased yield is the result of all of the individual soil and plant health benefits from crop rotation.

Reduced commercial risk

Different crops have resistance capacities against different adverse climatic conditions. For instance, some crops have good tolerance against flooding conditions while some others have improved drought resistance. Growing different crops in rotation minimizes the impact of crop failure due to adverse weather.

Reasons for beneficial effect of rotation

1. Impact of nutrients fixed/released by first crop on subsequent crop.
2. Impact of underground residues left by first crop on subsequent crop.
3. Impact of organic practices of first crop on subsequent crop due to slow nature of availability of nutrients.

Important aspects for success of crop rotation

Selecting the right crops for your system

A successful crop rotation requires the selection of the right crops for your farm. Different crops have different light, water, nutrient, air and temperature requirements, and so a crop rotation must be designed to ensure that each crop will get all the basic needs sufficiently.

The following factors should be considered when designed a crop rotation for your farm.

The types of crops

A crop rotation should be designed using crop types which complement each other. For example, cereals are complemented by legumes. The benefits from crop rotation will not be as strong if different crops of the same type are grown in succession (for example, growing two different cereals in rotation).

The type of crop roots

Some crops have strong roots capable of penetrating deep into the soils. These crops are great to grow on compacted soils as their roots improve the soil structures, porosity and other physical properties. They also draw up nutrients from deep in the soil profile, making them available for subsequent shallow rooted crops.

The need to improve the soil fertility

Legumes fix nitrogen in the soil, making it available for subsequent crops. Nitrogen fixing crops are ideal to precede nitrogen demanding crops, or to rebuild nitrogen levels after nitrogen demanding crops.

The need to protect your land against erosion

Cover crops will protect the land from erosion between crops, and will improve soil structure and suppress weeds. The soil and climatic factors of your land, such as the soil physical, chemical and biological characteristics, overall soil fertility, rainfall, temperature and presence of pests. A good crop rotation will work with the natural conditions of the land.

How to introduce a successful crop rotation

Though different farms have their own climatic and management constraints to deal with, some general rules for rotation are below

- ✓ In all things, strike a balance between cash and non-cash crops. This creates a profitable and sustainable crop rotation system.
- ✓ Deep-rooted plants should be grown alternately with shallow-rooted crops. This type of rotation combination improves soil structure and drainage capacity. For example, the alternate combination of corn with cabbage is a good rotation combination for the physical properties of the soil. Nitrogen-demanding crops should be grown immediately after nitrogen-fixing plants. For example, soybeans should be followed by maize. Plants with high biomass of roots can be grown alternately with plants with low biomass of roots. Legumes such as red clover and orchard grass having high root biomass can be grown alternately with low root biomass crops such as soybeans and maize.
- ✓ Very fast-growing crops like buck-wheat, sun hemp and radishes should be grown alternately with slow- growing crops like winter wheat and red clover. Slow-growing crops are more vulnerable to weeds. Therefore, in a rotation system they should be grown immediately after weed-suppressing crops such* as winter rye.
- ✓ Crop rotation can alternate between Autumn and Spring crop plantings; this strategy is very effective in reducing weather risk, spreading work pressure and suppressing weeds. Try to cover the soil with crops as much as possible. Alternate leafy crops with straw crops to aid in weed suppression.

Placement of Fertilizers

Definition Placement of fertilizer refers to the placement of fertilizers in soil at a specific Place with or without reference to the position of the seed. Placement of fertilizers is normally recommended in small quantity of fertilizers application. Due to poor root development and low soil fertility and Phosphatic and Potassic fertilizer requirements, this method is preferred.

Common methods of placement

Plough sole placement

In this method, fertilizer is placed at the bottom of the plough furrow in a continuous band during the process of ploughing. Every band is covered as the next furrow is turned. This method is suitable for areas where soil becomes quite dry up to few centimetres below the soil surface and soils having a heavy clay pan just below the plough sole layer.

Deep placement

It is the placement of ammoniacal nitrogenous fertilizers in the reduction zone of soil particularly in paddy fields, where ammoniacal nitrogen remains available to the crop. This method ensures better distribution of fertilizer in the root zone soil and prevents loss of nutrients by runoff.

Localized placement

It refers to the application of fertilizers into the soil close to the seed or plant in order to supply the nutrients in adequate amounts to the roots of growing plants. The common methods to place fertilizers close to the seed or plant are as follows:

Drilling

In this method, the fertilizer is applied at the time of sowing by means of a seed- cum-fertilizer drill. This places fertilizer and the seed in the same row but at different depths. Although this method has been found suitable for the application of Phosphatic and Potassic fertilizers in cereal crops, but sometimes germination of seeds and young plants may get damaged due to higher concentration of soluble salts.

Side dressing

It refers to the spreading of fertilizer in between the rows and around the plants. The common methods of side dressing are: Placement of nitrogenous fertilizers by hand in between the rows of crops like maize, sugarcane, cotton etc., to apply additional doses of nitrogen to the growing crops and Placement of fertilizers around the trees like mango, apple, grapes, papaya etc.

Band placement

If refers to the placement of fertilizer in bands. There are two types of band placement of fertilizer and these are stated below:

Hill placement

It is practiced for the application of fertilizers in orchards. In this method, fertilizers are placed close to the plant in bands on one or both sides of the plant. The length and depth of the band varies with the nature of the crop.

b) Row placement

When the crops like sugarcane, potato, maize, cereals etc., are sown close together in rows, the fertilizer is applied in continuous bands on one or both sides of the row, which is known as row placement.

Rating OF Soil Nutrient Status

Fertility status of the soil for essential plant nutrients limiting the growth,can be known well in advance through soil analysis. As such ,deficiencyes can be corrected before sowing/planting through application of manures/fertilizers. Soil testing and plant analysis are useful for framing fertilizer recommendations to different crops. Rating of soil nutrient stats gives an idea in advance about the availability of nutrients to crops.The soil test methods that proved efficient in measuring the available nutrients, adopted by most of the soil testing laboratories in the country (ICAR 2009), their rating are given in Table.

Table. Rating charts for soil test values of essential nutrients

Parameters	Categorization of the soil tests				
	Very low	Low	Medium	High	Very high
Organic carbon (%)	< 0.25	0.25 – 0.49	0.50 – 0.75	0.76 – 1.00	> 1.00
Avail. N (kg/ha)	< 136	136 – 271	272 – 544	545 – 816	> 816
Avail. P_2O_5 (kg/ha)	< 11	11 – 22.5	22.5 – 56	56.1 – 84	> 84
Avail. K_2O (kg/ha)	< 68	68 – 135	136 – 337.5	338 – 506	> 506
Avail. S (mg/kg)	< 5	5 – 10	10 – 15	15.1 – 22.5	> 22.5
Parameters		Deficient		Sufficient	
Exch. Ca [cmol(p^+)kg^{-1}]		< 1.5		> 1.5	
Exch. Mg [cmol(p^+)kg^{-1}]		< 1.5		> 1.0	
DTPA-Fe (mg/kg)		0.0 – 4.5		> 4.5	
DTPA-Mn (mg/kg)		0.0 – 2.0		> 2.0	
DTPA-Cu (mg/kg)		0.0 – 2.0		> 2.0	
DTPA-Zn (mg/kg)		0.0 – 0.6		> 0.6	
HWS-B (mg/kg)		0.0 – 0.5		> 0.5	

Recommended Dose OF Major Field Crops of Assam

The standard package of Practices are published by jointly by the Assam Agricultural University and Department of Agriculture and Horticulture,Govt. of Assam. As such all production technologies of all major crops for kharif and rabi seasons as well as of horticultural crops are given in details. Besides a package of Practices of organic crop production for some selected crops of Assam is also published during the year 2019. All thaese POPs are revised in recently held POP workshop on 9th August ,2021. In the following table the recommended dose of fertilizer for major crops of Assam is furnished in brief.

Ahu Rice

Manures and fertilizers

Compost or FYM @ 10 t/ha or 15 q/bigha should be applied.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
A. Semi-dwarf varieties :				
N	40	Urea	88	12
P_2O_5	20	SSP	125	17

K_2O	20	MOP	32	4
B. Tall varieties :				
N	20	Urea	44	6
P_2O_5	10	SSP	62	9
K_2O	10	MOP	17	3

Nutrient recommendation for semi-dwarf varieties is 30:30:20 kg/ha N, P_2O_5, K_2O in North Bank Plain Zone. Granulated mixed fertilizer at appropriate doses can also be applied. Diammonium phosphate (DAP) in combination with rock phosphate or alone at the recommended level of nutrients (40:20:20) can be applied as substitute for SSP and MRP or their combinations as an economic source of phosphate. For Hill Zone reduction of 50% chemical fertilizer by incorporating 10 t of FYM/ha is recommended.

Time of Application of Fertilizers

- ✓ Apply full dose of phosphatic fertilizer at the time of final ploughing.
- ✓ Apply half of nitrogenous and half of potassic fertilizer 15-25 days after germination or after first weeding.
- ✓ The second top dressing with the remaining N and K_2O is to be done 40-50 days after germination or after second weeding.

Transplanted Ahu

Manures and Fertilizers

Well rotten FYM or compost has to be applied @ 10t/ha inaddition to the fertilizers at rates given below in areas with moderate fertility level.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/bigha	kg/ha
Semi dwarf varieties:				
N	40	Urea	88	12
P_2O_5	20	SSP	125	17
K_2O	20	MOP	32	4

Above rates of nutrients will be valid for most of the rice growing areas of Assam. In case of poor soil, the rates of nutrients may be raised to the extent of 60:30:30 kg/ha N, P_2O_5 and K_2O respectively. Granulated mixed fertilizers at appropriate doses can also be applied. Di-ammonium phosphate (DAP) in combination with rock phosphate or alone at the recommended level of nutrients (40:20:20) can be applied as substitute for SSP and MRP or their combinations as an economic source of phosphate.

Time of application of fertilizers:

- ✓ Only 1/3rd of the total urea, full doses of super phosphate and potash at the time of final puddling should be applied.
- ✓ The second 1/3rd and third 1/3rd doses of urea should be applied at tillering and panicle initiation stages respectively. Top dressing of urea should be preceded by weeding.
- ✓ Super phosphate can also be incorporated into the soil at active tillering stage (25-35 days after transplanting) along with the second dose of nitrogenous fertilizers.

Transplanted Sali Rice

Manures and Fertilizers:

Well rotten FYM or compost @ 10t/ha has to be applied during field preparation. In addition, the following nutrients are to be applied at rates given below in areas with moderatefertility level.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
A. Semidwarf varieties				
N	60	Urea	132	18
P_2O_5	20	SSP	125	17
K_2O	40	MOP	66	9
B. Tall varieties:				
N	20	Urea	44	6
P_2O_5	10	SSP	62	8
K_2O	10	MOP	16	2

In case of poor soil, the rates of fertilizers may be required to increase to the extent of60:30:30 kg/ha N, P_2O_5 and K_2O respectively. Diammonium phosphate (DAP) in combination with rock phosphate or alone at therecommended nutrient level (40:20:20) can be applied. In monocrop *sali* areas of Barak Valley Zone, sowing of *dhaincha* is recommended asgreen manuring crop before *sali* rice.

The optimum doses for NPK for HYV of *sali* rice is 60:20:40 and 60:20:20 for lowand medium fertility classes of soil respectively in Hills zone.

Time of Application of Fertilizers

a) For short duration varieties (100-120 days).

i) Half of urea and whole of super phosphate and muriate of potash should be applied at the time of final puddling. In standing water, urea along with super phosphate and muriate of potash can be applied in pallet form.

ii) Second dose (half) of urea should be applied at the time of panicle initiation stage.

b) For medium and long duration varieties (120-150 days).

i) Half of urea and entire quantity of super phosphate and muriate of potash should beapplied at the time of final puddling.

ii) Of the remaining part of urea, half at tillering stage i.e. 20-30 days after transplanting andother half at panicle initiation stage should be applied.

iii) For long duration varieties under rainfed low land situation with water depth between 30-50 cm, basal incorporation of prilled urea at 30 kg N/ha is recommended.

iv) Split application of potassic fertilizer half as basal and half at maximum tillering stage isrecommended for North Bank Plain Zone.

N.B.

i) Urea should be applied by mixing with moist soil in 1:10 proportion i.e. I part of ureawith 10 parts of moist soil and incubate for 48 hours.

ii) In case single super phosphate is not available diammonium phosphate (DAP) may beused with appropriate adjustment with urea.

iii) In the case of non-availability of single super phosphate in time, application can bedelayed up to 30 days of transplanting.

iv) Standing water, as far as practicable, should be drained out before application of fertilizer.

v) In case bacterial leaf blight symptoms appear, stop top dressing of urea.

Mixed Fertilizers

Granular mixed fertilizer of 15:15:15 grade can also be used to meet the NPK requirement of rice crop. 133 kg/ha (19 kg/bigha) of 15:15:15: grade mixed fertilizers will be equivalent to 20:20:20 kg/NPK/ha (3:3:3 kg/bigha) which is to be supplemented by top dressing of 45 kg/ha urea to give 40:20:20 kg/ha (6:3:3 kg/bigha) of NPK. Half the dose will give 20:10:10 kg/ha (3:1.5:1.5 kg/bigha) of NPK.

Recommendation for use of Rock Phosphate (If super phosphate is not used)

1. For raising two successive rice crops i.e. *ahu* followed by *sali* 60 kg P_2O_5/ha (300 kg/ha MRP) as rock phosphate) should be applied at least 20 days ahead of *ahu* transplanting
2. For monocrop rice apply 30 kg P_2O_5/ha (150 kg as rock phosphate) at least 20 days ahead of ahu transplanting.
3. Application of FYM as per recommendation helps in rapid release of phosphorus from this source.

Bao Rice

Application of neem coated urea @ 30 kg N/ha in two equal splits as basal and atmaximum tillering stage is recommended.

Preparation of *neem* coated urea

Neem coated urea can be prepared by mixing 50 kg urea with 500 ml *neem* oil over a polythene sheet till uniform yellow colour is obtained. As an alternative to neem coated urea, application of 4% urea solution as foliar sprayat maximum tillering stage (150 DAS) @ 30 kg N/ha is recommended..

Fertility Management

Land situation	Nutrient requirement			Fertilizer requirement		
	(kg/ha)			(kg/bigha)		
	N	P_2O_5	K_2O	Urea	SSP	MOP
Low lying area	0	0	0	0	0	0
Periphery of low-lying area	40	20	20	12	18	4
Irrigated area	60	30	30	18	27	6

N.B. For Barak Valley Zone and Central Brahmaputra Valley Zone, in the periphery of low lying area NPK dose of 20:10:10 kg/ha (5 kg urea, 9 kg SSP and 2 kg MOP/bigha is recommended)

Boro Rice

Fertility Management:

Land situation	Nutrient requirement			Fertilizer requirement		
	(kg/ha)			(kg/bigha)		
	N	P_2O_5	K_2O	Urea	SSP	MOP
Low lying area	0	0	0	0	0	0
Periphery of low-lying area	40	20	20	12	18	4
Irrigated area	60	30	30	18	27	6

N.B. For Barak Valley Zone and Central Brahmaputra Valley Zone, in the periphery of low lying area NPK dose of 20:10:10 kg/ha (5 kg urea, 9 kg SSP and 2 kg MOP/bigha is recommended).

Time of application:

In marshy areas whole of super phosphate and muriate of potash is to be applied and entire quantity of urea is to be top dressed after 21-25 days of transplanting. For irrigatedarea, 1/3rd urea as basal and 1/3rd at the time of tillering and the remaining part at panicle initiation stage are to be applied. Super phosphate can also be incorporated into the soil at active tillering stage 25-35 days after transplanting along with second dose of N.

Maize

Manures and Fertilizers:

A combination of organic and inorganic fertilizer gives better results than inorganic fertilizer alone.

Compost or FYM @ 5t/ha should be applied

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
N	60	Urea	134	18

P_2O_5	40	SSP	250	33
K_2O	40	MOP	67	9

For Hills Zone, a dose of 90:40:40 kg/NPK per hectare is recommended under rainfed condition.

Method of Fertilizer Application

FYM or compost should be applied during land preparation. The entire quantity of SSPand MOP and half of the total urea is to be applied in furrows (8-10 cm deep) and covered with4-5 cm of soil. Sowing of seed should be done at least 2 days after fertilizer application. The remaining half of urea should be top dressed in two equal doses followed by earthing up; in each case. The first ¼ at 35 days after germination or when the plants are at kneehigh stage and the second ¼ at the tassel initiation stage of the crop i.e. 45-60 days after germination or at the time of elongation of the flag leaf whichever is earlier. The fertilizer should be applied on both sides of row and weeds should also be removed from the field duringthis operation. However, before application of the fertilizer a light hoeing is to be given between the lines 2-3 days ahead.

Black Gram and Green gram

Manures and Fertilizers

Compost or FYM @ 1t/ha or 1.3q/bigha should be applied.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
Without Rhizobium culture*				
N	15	Urea	32	4
P_2O_5	35	SSP	220	30
K_2O	15	MOP	25	3.5
With Rhizobium culture				
N	10	Urea	22	3
P_2O_5	35	SSP	220	30
K_2O	15	MOP	25	3.5

*For Upper Brahmaputra Valley, Barak Valley and North Bank Plains Zones, NPK fertilizer dose of 15:35:10 kg/ha respectively have been recommended. . For Central Brahmaputra Valley Zone, 15kg/ha of K_2O is also recommended. The quantity of N is to be reduced proportionately to the quantity of N added in the form of FYM (each tonne of FYM contributes about 5 kg N). Diammonium phosphate (DAP) 75 kg/ha or 10 kg/bigha should be applied in lieu of urea and SSP in non inoculated crops.

Seed inoculation with Rhizobium and PSB culture

Seed inoculation

For seed inoculation with rhizobium culture, either Majuli 10 or any other suitable strains may be used. Seeds should be inoculated with 150 g/3-4 kg seeds. Detail instructions are available in each packet of culture. Also inoculate seeds with PSB @ 50 g/kg seeds alongwith Rhizobium.

Sugarcane

Manures and Fertilizers

Compost or FYM has to be applied @ 10 t/ha in trenches/furrows before planting cane. Besides, the following fertilizers are to be applied.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
N	135	Urea	300	40
P_2O_5	70	SSP	440	60
		Or MRP	350	50
K_2O	60	MOP	100	15
Alternatively the followingfertilizers may be used :				
N	135	Urea	235	34
P_2O_5	70	DAP	150	20
K_2O	60	MOP	100	15

Granulated mixed fertilizer may also be used instead of the above fertilizers. The per hectare requirement of mixed fertilizer of 15:15:15 grade is 450 kg (64 kg/bigha) which shouldbe applied in trenches/furrows at planting followed by top dressing of urea @ 150 kg/ha (21 kg/bigha).

Time and Method of Application of Fertilizers

Entire quantity of phosphatic and half of potassic fertilizers are to be applied in furrows/trenches and mixed well with the soil before planting the setts. Nitrogenous fertilizers are to be applied in two splits, 1/3rd at planting and 2/3rd at first earthing up. The remaining halfof the potassic fertilizer may be top dressed along with urea. Application of nitrogenous fertilizer should be completed within 90-100 days of planting.

Jute

Manures and Fertilizers

Wherever possible cowdung or compost should be applied @ 5t/ha during land preparation; and the amount of nutrients thus supplied will be reduced by corresponding reduction from the recommended dose of fertilizer. One tonne of cowdung or compost suppliesapproximately 5 kg N, 2-5 kg P_2O_5 and 5.0 kg K_2O.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
A. For Capsularis:				
N	40	Urea	88	12
P_2O_5	25	SSP	156	20
K_2O	30	MOP	50	7
B. For Olitorius:				
N	30	Urea	66	9
P_2O_5	25	SSP/MRP	156/125	20/15
K_2O	25	MOP	42	6

Note: In case of phosphatic fertilizers "Mussorie phos" can be substituted for SSP in olitorius jute at least 3 weeks ahead of final land preparation.

Mode of Application

Apply 50% and 50% P_2O_5 and 100% K_2O as basal dressing at the time of final land preparation and the remaining fertilizers at 4-6 weeks after sowing (CBZ, BVZ & NBPZ). Top dressing of fertilizer mixture grade 8:10:12 at 15 DAS and MOP with subsequent foliar spray of urea is recommended.

Foliar Spray of Urea

Where top dressing is not possible, foliar spray of urea is advocated. Urea (11.5 kg N/ha) is sprayed between 40-60 days after sowing. The first dose of urea should preferably be given 40-50 days after sowing with low volume power sprayer (Micronette) and the second spray is to be given after 10-15 days. With Aspee Bolo sprayer, three sprayings are required, the first spray being followed by two more sprays at an interval of 10 days. With hand operated(high volume) sprayer, it will be necessary to spray 2 times; the first one (40-45 DAS) being followed by another spray at 55-60 days after sowing.

Forage crops : Hybrid Napier

Manures and Fertilizers

Apply compost or FYM @ 8-10 t/ha or 1-1.5 t/bigha.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
N	120	Urea	265	35
P_2O_5	50	SSP	310	45
K_2O	30	MOP	48	7

Nitrogenous fertilizer should always be applied in 4 splits. Entire quantities of phosphatic and potassic fertilizers along with the first split of nitrogen are to be applied as basal dressing and the other 3 splits at the time of intercultural operation and after alternate cutting. Fertilizer savings to the tune of 50% could be possible by application of vermicompostand FYM @ 2.5t/ha each along with 50% recommended dose of fertilizer.

Forage crop

Oat

Fertility Management:

Per hectare				Per bigha			
FYM	**N**	**P_2O_5**	**K_2O**	**FYM**	**N**	**P_2O_5**	**K_2O**
4t	40kg	20kg	20kg	6q	9kg	3kg	3kg

Application of 54 kg urea, 125 kg SSP and 33 kg MOP per hectare as basal dose and34 kg urea after first cutting (60-70 days after sowing) as top dressing is essential. 50% recommended dose of fertilizer+ vermicompost @ 2.5t/ha + FYM @ 2.5t/ha should be applied if oat is grown in fodder based cropping sequence.

Field Pea

Fertility Management

Compost or FYM @ 4-5 t/ha or 6 q/bigha should be applied.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
A. Without Rhizobium culture				
N	20	Urea	45	6
P_2O_5	46	SSP	287	38
K_2O	0	MOP	-	-
B. With Rhizobium culture				
N	10	Urea	22	3
P_2O_5	46	SSP	287	38
K_2O	0	MOP	-	-

Rapeseed

Fertilizer Management:

Application of FYM or compost @ 2-3 t/ha is beneficial for the crop.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
(a) Plains:				
Rainfed condition				
N	40	Urea	87	12
P_2O_5	35	SSP	220	30
K_2O	15	MOP	25	25
Irrigated condition				
N	60	Urea	130	18
P_2O_5	40	SSP	250	33
K_2O	40	MOP	66	9
(b) Hills				
Rainfed condition				
N	65	Urea	140	20
P_2O_5	35	SSP	220	30
K_2O	0	MOP	0	0
Central Brahmaputra Valley Zone				
Rainfed condition				
N	60	Urea	130	18
P_2O_5	30	SSP	190	27
K_2O	30	MOP	50	6

Apply 75% N and P when seeds are inoculated with Azotobacter @ 40 g/kg seed and PSB @ 40 g/kg seed.

If SSP is not used as source of P, sulphur @ 20 kg/ha in the form of gypsum (133 kg/ha) should be used. NPK may be supplied in the form of mixed fertilizers. Nutrient requirements are to be adjusted according to contents in fertilizers. Rapeseed-mustard have been found to respond well to the application of borax in some agro-climatic zones of Assam. For higher yield of rapeseed and Mustard in the North Bank Plains Zone, a fertilizer dose of 60:40:40 kg NPK/ha is recommended. However, the earlier doses of 40:35:15 and 40:20:20kg NPK/ha have also been recommended for those farmers who cannot afford a higher dose. Borax @ 10 kg/ha for North Bank Plains Zone, 5-10 kg/ha for Upper Brahmaputra Valley Zone and 7.5kg/ha for Central Brahmaputra Valley Zone are recommended dose of fertilizers.

Potato

Fertility Management

Ten tonnes or 5 truck loads or 20 cart loads of well decomposed FYM should beapplied per hectare in the furrows before planting.

Nutrient	Requirement (kg/ha)	Form	Fertilizer requirement	
			kg/ha	kg/bigha
Rainfed				
N	60	Urea	133	19
P_2O_5	50	SSP	312	45
K_2O	50	MOP	83	12
Irrigated				
N	60	Urea	133	19
P_2O_5	100	SSP	624	90
K_2O	100	MOP	168	24

Entire quantity of fertilizers should be applied in furrows as basal application and becovered with a thin Jayer of soils so that tubers do not come into direct contact with the fertilizers. The crop booster 'Green Harvest' is recommended @ 25 g/10lit of water at 30 daysafter planting.

Chapter – 10

Production Procedure of Different Organic Manures(FYM, Compost, Vermicomposting, Green Manure, PROM) and Crop Residue Management

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Introduction:

For growth and development, plaant absorbs a large number of elements from the soil and other sources. At present twenty elements are considered essential for plant growth. The essential elements include carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, chlorine, iron, manganese, boron, zinc, copper, molybdenum nickel, cobalt, sodium and silicon. Bulky organic manures they contain small percentage of nutrients and applied in large quantities. Farmyard manure, compost, vermicompost, crop residues and green manures are most important bulky organic manures. They have several advantages as (i) supply all essential plant nutrients (ii) improve physical conditions of soil (soil structure) water holding capacity, aeration, buffers soil surface temperature), (iii) increases availability of nutrients, (iv) stimulates soil flora and fauna, and (v) control parasitic nematodes and fungi to some extent by altering balance of microorganisms in the soil. Different methods of production of manures, compost and green manure and crop residue management have been described in the article

Farmyard Manure (FYM): Farmyard manure is the traditional organic manure. The term 'FYM' refers to decomposed mixture of dung and urine of farm animals along with litter and left-over material from roughages or fodder fed to the cattle. FYM contains 0.5 % N, 0.25 % P_2O_5 and 0.5 % K_2O, on an average basis.

Improved method for preparation of FYM

Trench method of preparing FYM advocated by C.N. Acharya is found one of the best method for preparing FYM. In this method, the manure preparation should be carried in trenches of suitable size, say 6 to 7.5m length, 1.5 to 2.0m width and 1.0 m depth. All available dry litter and refuse from the farm and the houses should be heaped up near the cattle shed and portions of litter mixed with earth if available should be spread in the shed in the evening at 2 to 3 kg per animal for the absorption of urine. The litter should be localized in the areas where urine generally drops and soaks into the ground. Every morning the urine soaked litter and dung should be well mixed and then taken into the manure trench. A section of 90 cm length of the trench from one end should be taken up for filling with daily collection of refuse from cattle shed. When the trench is filled to the height of 45 to 60 cm above ground level, the top is made dome shaped and plastered with cow dung mixed with soil. The manure becomes ready by about three months. By this time the next 90 cm length of the trench being filled up. When the trench is completely filled up say in about three months, a second trench is taken for filling in the similar manner. By the time the second trench is filled up, the manure of first trench would be ready for use in 4-5 month after plastering. Generally two such trenches would be sufficient to carry out the process round the year for a farmer having 3-4 heads of cattle. The chemical preservatives like gypsum, rock phosphate are added to reduce losses and enrich FYM. Bacteria and actinomycetes play active role in decomposition. Generally 60-70 per cent moisture in initial stage and 30-40 per cent moisture in decomposed manure (ready to use) as well as 50-60°C temperature under the heap are favourable for the activities of these micro-organisms. It is possible to prepare by this process 5 to 6 t of FYM per year per heads of cattle.

Ways to minimize losses of nutrients from FYM

- Adopt trench method of FYM preparation for handling of dung, urine and farm waste.
- Adoption of BYRE system in collection of FYM.
- Spread the FYM in the field before ploughing, instead of piling of FYM in small heaps in the field.
- Use of chemical preservatives like gypsum and rock phosphate at recommended doses i.e. 450 to 900 g per day per animal in the cattle shed where animal passes urine.

Composting

Composting is a technique for turning on-farm organic waste materials into a farm resource. However, farmers are unable to make the best use of the composting opportunities available to them. This is because they face various constraints, among them a lack of awareness on efficient and labour-saving technology for compost making. There are a range of methods available for composting under for different situations. The important methods of composting are mentioned here to provide the updated information on compost production.

Composting process and types of composting

Composting is the natural process of 'rotting' or decomposition of organic matter by microorganisms under controlled conditions. Raw organic materials such as crop residues, animal wastes, food garbage, some municipal wastes and suitable industrial wastes, enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting. Compost is a rich source of organic matter. Soil organic matter plays an important role in sustaining soil fertility, and hence in sustainable agricultural production. In addition to being a source of plant nutrient, it improves the physico-chemical and biological properties of the soil.

Types of composting

Composting may be divided into two categories by the nature of the decomposition process. In anaerobic composting, decomposition occurs where oxygen (O) is absent or in limited supply. Under this method, anaerobic micro-organisms dominate and develop intermediate compounds including methane, organic acids, hydrogen sulphide and other substances. In the absence of O, these compounds accumulate and are not metabolized further. Many of these compounds have strong odours and some present phytotoxicity. As anaerobic composting is a low-temperature process, it leaves weed seeds and pathogens intact. Moreover, the process usually takes longer than aerobic composting. These drawbacks often offset the merits of this process, viz. little work involved and fewer nutrients lost during the process. Aerobic composting takes place in the presence of ample O_2. In this process, aerobic microorganisms break down organic matter and produce carbon dioxide (CO_2), ammonia, water, heat and humus, the relatively stable organic end product. Although aerobic composting may produce intermediate compounds such as organic acids, aerobic micro-organisms decompose them further. The resultant compost, with its relatively unstable form of organic matter, has little risk of phytotoxicity. The heat generated accelerates the breakdown of proteins, fats and complex carbohydrates such as cellulose and hemi-cellulose. Hence, the processing time is shorter. Moreover, this process destroys many micro-organisms that are human or plant pathogens, as well as weed seeds, provided it undergoes sufficiently high temperature. Although more nutrients are lost from the materials by aerobic composting, it is considered more efficient and useful than anaerobic composting for agricultural production. Most of this publication focuses on aerobic composting.

Composting objectives may also be achieved through the enzymatic degradation of organic materials as they pass through the digestive system of earthworms. This process is termed vermicomposting.

The aerobic composting process

The aerobic composting process starts with the formation of the pile. In many cases, the temperature rises rapidly to 70–80 °C within the first couple of days. First, mesophilic organisms (optimum growth temperature range = 20–45 °C) multiply rapidly on the readily available sugars and amino acids. They generate heat by their own metabolism and raise the temperature to a point where their own activities become suppressed. Then a few thermophilic fungi and several thermophilic bacteria (optimum growth temperature range = 50–70 °C or more) continue the process, raising the temperature of the material to 65 °C or higher. This peak heating phase is important for the quality of the compost as the heat kills pathogens and weed seeds. The active composting stage is followed by a curing stage, and the pile temperature decreases gradually. The start of this phase is identified when turning no longer reheats the pile. At this stage, another group of thermophilic fungi starts to grow. These fungi bring about a major phase of decomposition of plant cell-wall materials such as cellulose and hemi-cellulose. Curing of the compost provides a safety net against the risks of using immature compost such as nitrogen (N) hunger, O deficiency , and toxic effects of organic acids on plants. Eventually, the temperature declines to ambient temperature. By the time composting is completed, the pile becomes more uniform and less active biologically although mesophilic organisms recolonize the compost. The material becomes dark brown to black in colour. The particles reduce in size and become consistent and soil-like in texture. In the process, the amount of humus increases, the ratio of carbon to nitrogen (C:N) decreases, pH neutralizes, and the exchange capacity of the material increases.

Techniques for effective aerobic composting

Simple replication of composting practices does not always give the right answer to potential composters. This is because composting takes place at various locations and under diverse climates, using different materials with dissimilar physical, chemical and biological properties. An understanding of the principles and technical options and their appropriate application may be helpful in providing the optimal environment to the compost pile which are as follow.

Improved aeration

In order to obtain the end product of uniform quality, the whole of the pile should receive a sufficient amount of O_2 so that aerobic micro-organisms flourish uniformly. The methodologies deliberated in this publication made use of the techniques as presented below.

Pile size and porosity of the material

The size of the pile is of great significance and finds mention in the sections on passive composting of manure piles and turned wind-rows. Where the pile or wind-row is too large, anaerobic zones occur near its centre, which slows the process in these zones. On the other hand, piles or wind-rows that are too small lose heat quickly and may not achieve a temperature high enough to evaporate moisture and kill pathogens and weed seeds. The optimal size of the piles and wind-rows should also consider such parameters as the physical property (porosity) of the materials and the way of forming the pile. While more porous materials allow bigger piles, heavy weights should not be put on top and materials should be kept as loose as possible. Climate is also a factor. With a view to minimizing heat loss, larger piles are suitable for cold weather. However, in a warmer climate, the same piles may overheat and in some extreme cases (75 °C and above) catch fire.

Ventilation

Provision of ventilation complements efforts to optimize pile size. Ventilation methods are varied. The simplest method is to punch holes in the pile at several points. The high temperature compost method of Chinese rural composting involves inserting a number of bamboo poles deep into the pile and withdrawing them a day later, leaving the pile with ventilation holes. Aeration is improved by supplying more air to the base of the pile where O deficiency occurs most often. In addition to the above-mentioned vertical poles, Ecuador on-farm composting uses a lattice of old branches at the base to allow more pile surface to come into contact with the air, and the composting period is reduced to two to three months in warm seasons. This technique is also practiced in the rapid composting method developed by the Institute of Biological Sciences (IBS) in the Philippines, where the platform should be 30 cm above the ground. The passively aerated wind-rows method (uses a more sophisticated technique. It entails embedding perforated pipes throughout the pile. As the pipe ends are open, air flow is induced and O is supplied to the pile continuously. The aerated static pile method takes this aeration system a step further; a blower generates air flow to create negative pressure (suction) in the pile and fresh air is supplied from outside. Turning once the pile is formed and decomposition starts, the only technique for improving aeration is turning. Frequency of turning is crucial for composting time. While the Indian Bangalore method requires six to eight months to mature, the Indian Coimbatore method (turning once) reduces the time to four months, and the Chinese rural composting pit method (turning three times) reduces the time to three months. An extreme example is the Berkley rapid composting method, which employs daily turning to complete the process in two weeks. In some cases, turning not only distributes air throughout the pile, it also prevents overheating as it kills all the microbes in the pile and terminates decomposition. However, turning too frequently might result in a lower temperature.

Methods of composting

There are several methods for preparation of compost, however, only some important ones are discussed here as under –

(i) Activated compost method: In this process the basic raw material i.e. straw and other farm wastes are treated with mixture of cattle dung and urine as decoction so that every portion of mass comes in contact with the inoculants (dung + urine) and fermentation takes place evenly. On piling up in a heap of about 1–1.5 m height and turning over from time to time, keeping moist with dung and urine decoction, very high temperature attained. When the temperatures begin to drop at the end of one week the volume of the material gets reduced. Further quantity of the basic material is added onto the heap. About 25 per cent of the new materials should be added at one time and thoroughly mixed with starters (dung +urine decoction) at intervals as before. If methodology is properly carried out, the compost will be ready in 5-6 wk.

(ii) Indore method: The waste materials such as plant residues, animal wastes, vegetable wastes and weeds can be composted with the Indore Method. First the waste materials are chopped into small pieces of 5-10 cm size and are dried to 40-50 per cent moisture before stacking. Then they are spread in layers of 10-15 cm thickness either in pits or in heaps on 1 m width, 4-6 m length and 1 m depth. The heap is properly moistened with dung, using earth or night soil. Sufficient quantity of water is sprinkled over the heap to wet the composting materials to the level of 50 per cent moisture. Periodical turnings, usually three times at 15, 30 and 60 d after filling, are given to aerate and the material is covered with a thin layer of soil of about 2-3 cm thickness. Under the aerobic process of decomposition, losses of organic matter and nitrogen are heavy (40-50 per cent at initial stage). This process, however, involves considerable labour in the preparation of the heap and periodical turnings and so becomes expensive and impracticable when large quantities of materials are to be processed. The site selected must be at a high level to prevent rain water stagnation. It should be nearer to cattle shed and waste source for easy transporting.

(iii) Bangalore method (aerobic and anaerobic process): This process of composting was developed by Dr. C. N. Acharya in 1949. The basic raw material is spread in a pit of 6 m length, 1.2 m width and 0.9 m depth to a depth of 15cm layer, moistened with 80–100 litre of water if the material is dry. Over this FYM or preferably a mixture of dung, urine and litter from the cattle shed is placed as a layer of 5 cm thickness. It is again covered on the top with a layer of earth to a thickness of 15 cm. It is beneficial to mix the earth with bone meal or oil cakes, wood ash, etc., to improve manurial value of the compost. The piling of layers is continued till the heap raises above the ground level to a height of 60 cm. Then the heap is kept open for one week to facilitate aerobic decomposition. Later the heap is plastered with a layer of moist clay for anaerobic fermentation to occur. The crakes that occur in the clay layer, have to be sealed off periodically. The compost will be ready in 4-5 mo period starting from the day of preparation. This process is called as aerobic and anaerobic decomposition of compost. In this process the basic raw material is not so well decomposed as in the other methods. But organic matter and nitrogen contents are well conserved. The number of turnings is reduced. The out turn of the compost is relatively greater and cheapest process.

(iv) Coimbatore method: It is anaerobic degradation followed by aerobic process. First, pits of 4 m length, 2 m width and 1 m depth is formed in which crop residues or farm wastes are filled to a thickness of about 15 cm. Over this layer, cow dung slurry to enhance the rate of bio-degradation is applied to a thickness of 5 cm. Above this layer, 1 kg of bone meal or rock phosphate is applied to minimize the nitrogen loss and to add phosphorus. Thus, application of crop residues/ farm wastes, cowdung slurry, bone meal and rock phosphate in alternate layers is repeated till the height reaches 0.5 m above the ground level. Then the above ground portion is covered with red earth or mud to prevent the rain water entry and it becomes anaerobic process. After 30-35 d, the material is turned and it becomes an aerobic process. The compost will be ready within five months.

(v) NADEP Compost: NADEP (also popularly known as Nadepkaka) method of making miracle compost was first invented by a farmer named Narayan Deorao Pandharipande (also popularly known as Nadep kaka) living in Maharashtra (India). Build a rectangular tank of 3 m length, 2 m width and 1 m depth made of brick walls and floor with mud plaster. Leave holes in the tank walls for aeration (about 4 holes along each side wall and two holes in each enclosure wall). Plaster the inner walls and the bottom of the tank with mud and cow dung mixture. For filling of compost pit put first layer of 15 cm of plant waste material followed by second layer of cow dung slurry (4 kg dung mixed with about 100 litres of water) and drench thoroughly. Then add 2 cm of sieved fine soil (60 kg) as third layer. Keep adding layers in this way until the materials are heaped 15 cm above the lip of the tank. Add another 7 cm layer of fine soil on the top heap and seal the tank with cow dung plaster. Build a temporary shed of thatch and bamboo to shield compost tank from direct sunlight and rain. After 3-4 mon., digestion is complete and compost is ready having dark colour and pleasant smell. Sieve through a thick mesh and use the compost. In order to improve the quality of compost, at 75-80 days make some holes by bamboo. Add 500 g PSB, 500 g Azotobacter and 500 g Rhizobium to 23 litres of water and pour through the holes and the holes are closed. This will increase the quality of compost. The disadvantage or limitation of this method is using large proportion of soil which is not desirable or acceptable in all situations.

Correcting the problems

A. If the materials are cool and dry

- Lift up the top layers and put them to the side of the pit or heap.
- Sprinkle water or cattle urine or cattle urine diluted with water on the material in the bottom.
- Then put back the material in layers of about 25 cm each sprinkling water or a mixture of water and urine over each.
- Replace the testing stick and cover the heap or top of the pit with soil, leaves, plastic etc., as described earlier.

B. If the materials are too wet

- Collect some more dry plant materials and/or some old dry compost. Break up and mix the materials. If old dry compost is not available, use only the dry plant materials. Lift off the top of the heap or take out the top half of the materials from the pit and put them to one side.
- Mix the new dry materials with the wet compost materials in the bottom.
- Put back the materials from the side of the heap or pit. If these materials are wet and decaying, put in alternate layers of new dry plant materials with the wet materials.
- If the top materials are moist and brown showing compost making has started, put them back as they are.
- Put back the vertical testing stick.
- Do not seal the top but make a new test after a week. If the stick is warm or hot and the smell is good, good compost making has started and the heap or top of the pit can be sealed and covered. Testing for heat and moisture should be done every week to 10 days until mature compost is made.

Qualities and use of good compost

Although the quality of compost is best evaluated through the growth and productivity of the plants grown on soil treated with it, it is possible to evaluate compost quality through seeing, touching and smelling:

- Good quality compost is rich in plant nutrients and has a crumb-like structure, like broken up bread.
- It is black or dark brown and easily holds moisture, i.e. water stays in it, and it does not dry out fast.

- It has a good smell, like clean newly-ploughed soil, with a smell somewhat like that of lime or lemon.

Vermicomposting: The term vermicomposting means the use of earthworms for composting organic residues. Earthworms can consume practically all kinds of organic matter and they can eat their own body weight per day, e.g. 1 kg of worms can consume 1 kg of residues every day. The excreta (castings) of the worms are rich in nitrate, available forms of P, K, Ca and Mg. The passage of soil through earthworms promotes the growth of bacteria and actinomycetes. Actinomycetes thrive in the presence of worms and their content in worm casts is more than six times that in the original soil.

Nutrient composition of vermicompost

S. No.	**Nutrient**	**Content**
1	Organic carbon	1 9.15 to 17.98 %
2	Total nitrogen	1.5 to 2.10 %
3	Total phosphorus	1.0 to 1.50 %
4	Total potassium	0.60 %
5	Ca and Mg	22 to 70 m. equi. / 100 g
6	Available S	128 to 548 ppm
7	Copper	100 ppm
8	Iron	1800 ppm
9	Zinc	50 ppm

Types of worms

A moist compost heap of 2.4 m by 1.2 m and 0.6 m high can support a population of more than 50 000 worms. The introduction of worms into a compost heap has been found to mix the materials, aerate the heap and hasten decomposition. Turning the heaps is not necessary where earthworms are present to do the mixing and aeration. The ideal environment for the worms is a shallow pit and the right sort of worm is necessary. Lumbricus rubellus (red worm) and Eisenia foetida are thermo-tolerant and so particularly useful. Field worms (Allolobophora caliginosa) and night crawlers (Lumbricus terrestris) attack organic matter from below but the latter do not thrive during active composting, being killed more easily than the others at high temperature.

European night crawlers (Dendrabaenaveneta or Eiseniahortensis) are produced commercially and have been used successfully in most climates. These night crawlers grow to about 10–20 cm. The African night crawler (Eudrilus eugeniae), is a large, tropical worm species. It tolerates higher temperatures than Eisenia foetida does, provided there is ample humidity. However, it has a narrow temperature tolerance range, and it cannot survive at temperatures below 7 °C. Vermicomposting is in use in many countries. Experiences from selected countries are described as case studies.

Important factors for good vermicomposting

- Sieving and shredding – decomposition can be accelerated by shredding raw materials into small pieces.
- Blending – carbonaceous substances such as sawdust, paper and straw can be mixed with N-rich materials such as sewage sludge, biogas slurry and fish scraps to obtain a near optimum C:N ratio. A varied mixture of substances produces good quality compost, rich in macronutrients and micronutrients.
- Half digestion – the raw materials should be kept in piles and the temperature allowed to reach 50–55 °C. The piles should remain at this temperature for seven to ten days.
- Maintaining moisture, temperature and pH – the optimum moisture level for maintaining aerobic conditions is 40–45 percent. Proper moisture and aeration can be maintained by mixing fibrous with N-rich materials. The temperature of the piles should be 28–30 °C. Higher or lower temperatures reduce the activity of microflora and earthworms. The height of the bed can help control the rise in temperature. The pH of the raw material should not exceed 6.5–7.The steps in this process are:
- Cattle dung is collected from cow shelters.
- The dung is kept for about 7–10 days to let it cool.
- Beds/rows of dung and crop residues/leaves, etc. are made about 1 m wide, 75 cm high and with a distance of 75 cm between two rows.
- In the beds/rows, crop waste such as leaves, straw etc. is layered alternatively with the dung to thus make a height of about 75 cm. The beds are kept as such for 4–5 days to cool. • Water is sprinkled to let the compostable matter cool down.
- Earthworms are put on the top of the manure row/bed. About 1 kg worms in a metre-long manure row are inoculated.
- It is left undisturbed for 2–3 days after covering with banana leaves. Covering with jute bags or sacks is not recommended as it heats the manure bed.
- The bed is opened after 2–3 days. The upper portion of about 10 cm of manure is loosened with the help of a suitable hand tool.

- The bed is covered again. The worms feed on an upper bed of about 10 cm. This portion becomes vermicasted in about 7–10 days.
- This portion (vermicasted manure) is removed and collected near the bed. Another upper portion of 10 cm is loosened and covered again with the leaves.
- Moisture is maintained in the bed by regular sprinkling of water.
- The loosened portion of the manure is vermicasted in another 7–10 days and is removed again.
- Thus, in about 40 days, about 60 cm of the bed is converted into vermicompost and is collected on 3–4 occasions.
- The remaining bed of about 10 cm in height contains earthworm mixed manure.
- Fresh manure mixture/organic residues, etc. are again put on the residual bed containing earthworms of about 10 cm and the composting process is restarted.
- The manure collected from the bed is freed of worms through sieving. Uncomposted or foreign matter is also removed in this way.
- The screened manure is bagged and used or sold as required.

Specifications of vermicompost

S. No.	Specifications	
i	Moisture, per cent by weight, maximum	25
ii	Colour	Dark brown to black
iii	Odour	Absence of foul odour
iv	Particle size	Minimum 90% material should pass through 4 mm IS sieve
v	Bulk density (g/cm^3)	0.7-0.9
vi	Total organic carbon per cent by weight, minimum	18
vii	Total nitrogen (as N) per cent by weight, minimum	1
viii	Total phosphates (as P_2O_5) per cent by weight, minimum	0.8
ix	Total potassium (as K_2O) per cent by weight, minimum	0.8
x	Heavy metal content (as mg/kg), maximum	

	Cadmium (as Cd)	5
	Chromium (as Cr)	50
	Nickel (as Ni)	50
	Lead (as Pb)	100

Harvesting of vermicompost

Stop watering before one week of harvest. Sometimes the worms spread across the pit come in close and penetrate each other in the form of ball in 2 or 3 locations. Heap the compost by removing the balls and place them in a bucket. However, under most instances, top layer has to be disturbed manually. Earthworms move downward and compost is separated. After collection of compost from top layers, feed material is again replenished and composting process is rescheduled. The material is sieved in 2 mm sieve, the material passed through the sieve is called as vermicompost which is stored in a polythene bag. Recomposting is done in the same pit or bed. Similar, to the above described pit/heap method, vermicompost can be prepared in wooden box or brick column in similar way. In-situ vermicomposting can be done by direct field application of vermicompost at 5 t/ha followed by application of cowdung (2.5 cm thick layer) and then a layer of available farm waste about 15 cm thick. Watering should be done at an interval of 15 d.

Precautions

(i) Do not cover vermicompost beds/heaps with plastic sheets.

(ii) Do not overload the vermicompost heap to avoid high temperature that adversely affect their population.

(iii) Dry conditions kill the worms and water logging drive them away. Watering should be done daily in summer and every third day in rainy and winter seasons.

(iv) Addition of higher quantities of acid rich substances should be avoided.

(v) Make a drainage channel around the heap to avoid stagnation of water particularly in high rainfall areas in rainy season.

(vi) Organic materials used for composting should be free from non-degradable materials.

Green manuring: Green manuring can be defined as a practice of ploughing or turning into the soil undecomposed green plant tissues for improving physical condition of soil as well as soil fertility.

Advantages of Green Manuring

- It adds organic matter in the soil, stimulates the activity of soil micro-organisms.

- It improves structure of soil.
- It decreases runoff, soil erosion and facilitates penetration of rainwater.
- It holds plant nutrients, prevent leaching of nutrients.
- Leguminous green manure crops adds nitrogen to the soil (fixes 60 – 100 kg N/ ha).
- It increases availability of plant nutrients like P, Ca, K, Mg& Fe.

Disadvantages of Green Manuring

- Under rainfed conditions, if adequate rains are not received after burying the green manure crop, it may affect proper decomposition and ultimately germination of subsequent crop and termite attack.
- Loss of one crop, green manuring may not be always economical.
- The cost of growing green manure crops may be more than the cost of commercial fertilizers.
- An increase of diseases, insects and nematode is possible.

Desirable characteristics in an Ideal Green Manure Crop

(i) Short duration, fast growing, high nutrient accumulation ability.

(ii) Legume with good nodular growth habit.

(iii) Less water requirement.

(iv) Can grow well on poor exhausted soils.

(v) Deep rooted, can open sub-soil and take nutrients from lower regions.

(vi) Leafy habitat capable of producing heavy tender growth early in its life cycle.

(vii) Large quantities of non-fibrous tissues for rapid decomposability containing fair percentage of moisture and nutrients.

Types of Green Manuring

Green manuring is done by two types, one is green manuring in-situ and another is green leaf manuring. The details are given as under–

(i) **Green Manuring In-situ** (Important crops & plants)

- Sesbania aculeata (dhaincha)
- Sesbania speciosa (Sithagathi)

- Sesbania rostrata (Sesbania)
- Crotalaria juncea (sunnhemp)
- Tephrosia purpurea (wild indigo)
- Indigo feratinctoria (indigo)
- Phaseolus trilobus (pillipesara)

(ii) **Green Leaf Manuring** (Important crops & plants)

- Glyricidia maculata (glyricidia)
- Pongamia glabra (karanj)
- Azadirachta indica (neem)
- Ipomoea carnea (Besharam)
- Cassia auriculata (Avaramsenna)
- Thespesia populnea (Portia tree)

Stage of incorporation

In in-situ green manuring the best stage of incorporation is flowering stage of the crop. In green leaf manuring incorporate the leaf before mature or attain woody nature. Plants at very young stage may not be incorporated as they will decompose very easily, leaving little residue in the soil.

Time of incorporation

It is applied as basal dressing before main crop is raised in the field. Usually about 6 – 8 wk time is found to be sufficient for decomposition. In fruit crops, plantation crops, sugarcane, etc. green manure crop is grown along the planting of main crop and incorporated after 40-50 d of growth at the time of earthing or intercultural operation. The plants /green leaf are trampled by working the implement and later on levelling the land. In some cases when it is grown along the crop it is incorporated with inter cultivation like in sugarcane.

Crop Residue Management:

After crop harvesting, the left-over plant material including leaves, stalks and roots is known as crop residue. It is estimated that India generates approximately 500 mt of crop residue annually as per Govt. of India, 2016 statistics. Cereals, fibers, oilseeds, pulses and sugarcane contributed the majority of crop residue with production estimates of 352, 66, 29, 13 and 12, mt, respectively. Among cereal, crops, rice, wheat, maize, and millets together contributed (70%) of crop residue followed by fiber crops (13%).

Crop residues as compost

For preparing compost, crop residues are used as animal bedding and then heaped in dung pits. In the animal shed each kilogram of straw absorbs about 2-3 kg of urine, which enriches it with N. The residues of rice crop from one-hectare land, on composting give about 3 tons of manure as rich in nutrients as farmyard manure (FYM). The rice straw compost can be fortified with P using indigenous source of low-grade rock phosphate to make it value added compost with 1.5 % N, 2.3 % P_2O_5 and 2.5 % K_2O.

Mushroom cultivation

Use of residues in mushroom production represents a valuable conversion of inedible crop residues into valuable food, which despite their high moisture content has two to three times as much protein as common vegetables and an amino acid composition similar to that of milk or meat. Wheat and rice straws are excellent substrates for the cultivation of Agaricus bisporus (white button mushroom) and Volvariella volvacea (straw mushroom), two of the four most commonly grown fungi.

Crop residues as bio-fuel

Biofuel is an important strategy to reduce dependence on fossil fuel. Conversion of ligno-cellulosic biomass into alcohol is of immense importance, as ethanol can either be blended with gasoline as a fuel extender and octane enhancing agent or used as a neat fuel in internal combustion engines. Theoretical estimates of ethanol production from different feedstock (corn grain, rice straw, wheat straw, bagasse and saw dust) vary from 382 to 471 l t-1 of dry matter

Crop residues as biochar

Biochar is a fine-grained charcoal having high carbon material produced through slow pyrolysis (heating in the absence of oxygen) of biomass. It can potentially play a major role in the long-term storage of carbon in soil. Biochar converted from plant biomass contains a unique recalcitrant form of carbon that is resistant to microbial degradation, therefore can be used as a carbon sequester, when applied to soil.

Crop residues as livestock feed

Cultivation of forage crops in tropical developing countries has been limited due to inadequate technical support, such as non-availability of quality forage seeds/planting materials. Small farmers in rural areas depend on crop residues to feed livestock.

Crop residue as surface mulch

- Residue retention on the surface of soil seems to be a better option for conservation of soil and avoiding water losses by evaporation.
- It also reduces the weed seed germination and helps in building of soil microbial populations results in increasing soil organic carbon- a direct indicator of soil health.

- Zero -till wheat has been adopted in the rice wheat system in the northwest IGP with positive impacts on wheat yield, profitability and resource use efficiency. New advance generation seed drill is evolved for this purpose.
- The Happy seeder works well for direct drilling in standing as well as loose residues provided the residues are spread uniformly.

Ways to leave more crop residue

- Use high residue producing crops; Plant crops such as corn in your rotation.
- Spread residue evenly; Spreaders on harvesting equipment will help.
- Skip fall tillage, especially after soybeans. Fall-tilled soybean ground is very vulnerable to erosion in late winter and early spring.
- Make fewer tillage passes.
- Use cover crops; Rye and wheat are good options when you grow low-residue crops such as soybeans.
- Set chisels and disks to work shallower. Residue will be buried to about one-half the tillage depth.
- Don't use a moldboard plow.
- Drive slower on tillage operations. Tilling at higher speeds throws more soil and covers more residue.
- Use straight points and sweeps on chisel plows. Twisted points may bury about 20 percent more residue.
- No-till drill soybeans. No-till drilling keeps more crop residue on the soil surface and produces a canopy faster than row planting.
- Go no-till on sloping land or ridge-till on flatter land. Both disturb only the crop residue in the rows.
- Don't till when soil is wet. Tilling wet soil will cover more residue than tilling when the soil is dry.

How to measure crop residue on fields

- Use a 50-ft rope equally divided into 100 parts. A 50-ft. tape measure using each 6-inch and 12-inch mark also works well.

- Stretch the line diagonally across the rows. Count the number of marks, tabs or knots that have residue under them. It is important to use the same point under each mark for accuracy If a piece of residue is smaller than one-eighth of an inch, don't count it.
- Walk the entire length of the rope or tape. The number of marks with residue under them equals the percentage of cover. If your rope or tape has only 50 marks, then multiply your count by two.

Repeat the above steps three times in different areas of the field. Add the scores together and divide by three to find the average percentage of cover for the field.

PROM (Phosphate Rich Organic Manure):

PROM is produced by composting high grade phosphate rock in fine size with natural organic matter collected from a variety of sources such as FYM, straw of paddy, wheat, pulses, oil seeds, sugar cane vegetable waste, cakes or waste from fruits and sugar industries and distillery etc. Most of field crops have responded to PROM application most favourably and yields are at par with or higher compared to recommended P application through fertilizer (DAP and SSP). PROM application has found to have higher residual effect on the next crop grown in succession whereas, fertilizer had no or little residual effect. PROM also help in maintaining nutrient balance in the soil due to organic matter which help in obtaining sustainable field crop production. Soil fertility is also restored and maintained.

Process and duration of composting of PROM

The process of composting may be either aerobic or anaerobic or a combination of both. Addition of cellulose and lignin degrading, microorganisms improved the effectiveness of decomposition, while phosphate solubilizing and plant growth promoting microorganism further improved the concentration of available phosphorus and quality of PROM. Methan producing organisms during anaerobiccomposting may also be added to enhance methanogenesis. Addition of nitrogen fixing microorganisms to the end product is recommended. The duration of composting range from 110 to 120 days.

Composition of PROM

- Phosphate (P_2O_5) : 15-18 %
- Organic Carbon : 11-16 %
- C: N ratio : 20:1
- Sulfur : 4-5 %
- Moisture : 15 %
- Micronutrient : Minute amount

Ingredients Requires for PROM

- Rock Phosphate (34/74)
- Organic matter, farm waste, garden/fresh waste
- PSB Culture
- Azotobacter Culture
- Water

Method to prepare PROM

A. PROM from cow and buffalo dung

- The fresh cow and buffalo dung contain nearly 87 per cent moisture therefore, 100 kg high grad rock phosphate (34/74) with 1600 kg cow and buffalo dung on the 1:2 basis i.e. one part rock phosphate and two part dry matter.
- About 236 kg well rotten FYM (on dry weight basis) is taken and its clumps are broken.
- This material is well saturated with water and covered with jute/plastic. Water is regularly sprinkled over this material so as to moisten the material. After 50-60 days thoroughly mix the material again and then cover with jute/plastic and moistened well.
- After 110 days of the first mixing add 1 kg PSB culture in well composted phosphate enriched FYM. Again the material is covered with gunny/plastic and keep as such for another 10 days.

- PROM is now ready for use in the field.

B. From PROM crop/farm waste Straw of wheat, mustard, soybean, rice, pulses etc. can be used and allowed to decompose for 120 days.

C. To produce PROM from crop/farm waste, first the crop/farm waste be crushed to smaller size (less than 5 cm). Mix the crop waste with high grade rock phosphate in the ratio of 2:1 on dry weight basis. Thoroughly kneaded with 10% cow dung slurry. Covered the moistened material with plastic/gunny to keep the total material moistened. Periodically add sufficient water on the composting material to keep bacterial activity sufficient for composting. After 60 days the composting material may be remixed thoroughly and moistened by adding sufficient water. On completion of compositing at 110 days add PSB 1 kg/100 kg high grade rock phosphate, allow it for 10 days. After 20 days PROM produce is ready for use in the field/garden crops.

D. To enrich the PROM add Azotobacter 1 kg/100 kg high grade rock phosphate used to produce PROM. The low grade phosphate ores analyzing + 18% P2O5 in 150 micron size is not useful for PROM production due to following drawbacks:

(i) In the low grade PR, the presence of carbonate gangue minerals [calcite/dolomite in case of Mussourie Rock Phosphate (MRP) and dolomite in case of Rajasthan Rock Phosphate (Raj. Phos)] neutralizes the acidity generated by FYM/organic manure.

(ii) The phosphocompost prepared with low-grade PR required to be added to the fields in larger quantities, attracts high costs

Raw material specifications for production of PROM:

a. Rock phosphate mineral: The rock phosphate mineral should contain a minimum of 32 % total P_2O_5 analyzed on dry basis. The maximum moisture content should not exceed 12 per cent. The particle size on dry sieve analysis should be 80 % passing through 200 mesh (i.e. 74 microns) (Table 3).

b. Chemical composition of high grade, Udaipur rock phosphate

(i) P_2O_5: 34.00 % (ii) MgO : 1.92 % (iii) R_2O_3 : 1.55 % (iv) LOI : 4.02 % (v) F : 3.10 % (vi) CaO : 46.00 % Mineralogically the material is pre-dominantly fluorapatite followed by some carbonate fluorapatite and chlorapatite. Minor minerals oligoclasesillinite quartz etc. The material is 90-99 % less than 74 microns and 85-95 per cent less than 44 microns in size (Table 3).

Table 3: Specifications for production of PROM

Parameters	**Organic Compost (FCO 2009)**	**Phosphate Rich Organic Manure (FCO 2013)**
Arsenic (mg/Kg)	10.00	10.00
Cadmium (mg/Kg)	5.00	5.00
Chromium (mg/Kg)	50.00	50.00
Copper (mg/Kg)	300.00	300.00
Lead (mg/Kg)	100.00	100.00
Mercury (mg/Kg)	0.15	0.15
Nickel (mg/Kg)	50.00	50.00
Zinc (mg/Kg)	1000.00	1000.00
C/N ratio	<20	Less than 20:1

pH	6.5-7.5	(1:5 solution) maximum 6.7
Moisture, percent by weight, maximum	15.0-25.0	25.0
Bulk density (g/cm^3)	<1.0	Less than 1.6
Total Organic Carbon, per cent by weight, minimum	12.0	7.9
Total Nitrogen (as N), per cent by weight, minimum	0.8	0.4
Total Phosphate (as P^2O^5) percent by weight, minimum	0.4	10.4
Total Potassium (as K^2O), percent by weight, minimum	0.4	10.4
Colour	Dark brown to black	-
Odour	Absence of foul Odour	-
Particle size	Minimum 90% material should pass through 4.0 mm IS sieve	Minimum 90% material should pass through 4.0 mm IS sieve
Conductivity (as dsm-1), not more than	4.0	8.2

Organic matter: The composition of organic matter may vary with the type of substrate used, particularly carbon and nitrogen contents, but at the end of the process the composition is established to maintain the uniformity of the product. The organic matter should not contain any heavy metal contamination and should have a C:N ratio of 30-35 to bring in better enhancement and product stability.

Application Mode

It is recommended to use two (2) to three (3) bags of PROM as an equivalent of one (1) bag of DAP. Though different crop have different nutrient requirement, the application can be minimum two (2) bags to maximum three (3) bags depending upon crop grown and type of soil. The balanced use of chemical fertilizers and organic compost also complements the Government move towards a Nutrient Based Subsidy (NBS) regime started in April 2010. The NBS provides for a 'fixed subsidy for every kg of primary nutrient' (N,P,K,S) in any fertilizer product for the whole year, while giving the industry the freedom to fix retail prices.

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Chapter 11

Communication skills and Innovative extension tools including ICTs to reach out to farmers

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Prelude

Gandhian dictum of decentralization has not been made applicable in the agricultural sector. The blood vein of the nations' entire system has been centralized and corporatized throwing the poorer farmers out of the system. The trend shows that agriculture is no more a village economy these days. Both the government and the farmers got baffled with re-introduction of newer techniques like organic farming, natural farming, and natural manures. Most of them are newer names given to our ancestral, traditional techniques.

Agriculture was once popularly hailed as "God's profession". Today's farming is not that divine. It exerts pressure, greediness, economic rivalry, and even slavery. Governments are not doing enough to tackle the issues created artificially and those arise from nature. Monetary compensations to meet the failures have made the farmers lazier than ever. More number of farmers is running out of this profession due to expansion of cities, industrial development, and depletion of resources leading to the suppression of their right of being "the sons of soil".

India is home to 103 million farm families who manage 165 million agricultural land holdings spread over more than 600,000 villages in 598 rural districts of the country. In the era of knowledge and information, the agricultural extension agent-farmer ratio is as low as 1:2000. This leads to information gap. Farmers are ill equipped to deal with changing market trends and opportunities and hence do not find agriculture as efficient or remunerative. Further, the farmers do not have full access to the latest information and advice. Deciding on incomprehensive information obtained from input dealer may often lead to imperfect decisions, which ultimately result in poor crop yield, and even crop failure and eventually farmer suicides (Anup Kumar Das and Ranjit Borah, 2017).

The current extension service delivered through trained officers at the local level also needs improvement in terms of speed and location specific agro advisory service. Furthermore, most of the agricultural advice is generic to block-levels and rarely deals with plot level advice concerning the requirements of individual farmers. With precision agriculture being the future, there is a strong need to align the needs of farmers, their existing experience and knowledge base with modern agricultural trends and practices. The development and dissemination of ICT in rural sectors in recent years, provides viable alternatives to overcome the physical barriers of face-to-face inter personal communication. Use of ICT in extension, enables the extension workers to be more effective in meeting the information needs of the farmers and to speed up the extension process.

Challenges

Agriculture is faced with greater challenges than ever before in the history. Climate change, exhaustion of soil, non-availability of farm work force, newer race of pests and diseases also compound the crisis. At the same time, the productivity needs to be enhanced, quality to be promoted to the international status, youth to be attracted towards agriculture in as much as the farming has become unviable economically.

Despite wide range of reform initiatives in agricultural extension in India in the past decades, the quality of information provided to marginal and small farmers is uneven. There is an observation that the present extension delivery system functions only as subsidy delivery mechanism rather than technology delivery mechanism; because of this work culture in the extension system, the ***extension education per se*** is not happening across the country. The days of mass extension is coming to a close while demand for the commodity based group extension is highly on the increase. Paid extension and or private extension through Public-Private-Partnership mode are also paying dividends in many states and this phenomenon requires our attention.

Present scenario indicates that youth and farm women are not interested to take up farming as viable business proportionate for their livelihood. How to motivate the youths and stakeholders to take up farming as profitable one? ICT is one such tool has little faith, which can facilitate speedy transfer of farm technological information especially on Market Information, Pest and Disease Control, Value Addition and Weather Information.

Importance of Information and Communication Technologies (ICT)

ICTs are emerging as an important tool for the development of societies and have driving forces in the economies worldwide. ICTs are no more confined to assist high-end research and development; the new technologies have made significant improvements in the life-styles and the efficiency-levels all sectors of economy. The positive impact of ICTs is most visible in service-sector, where the efficiency levels have gone very high. New businesses like "Business Process Out-sourcing (BPOs)", Banking and Insurance, Railways, Transport, the entertainment industry and other industries and organizations, are all taking maximum advantage of the ICT revolution.

India has a long history of using radio and television for reaching rural communities with new information on agriculture and rural development. Besides radio, television and print media, new avenues in the form of ICT enabled portals, call centres, community radio, information kiosks, digital photography, digital videos, social medias etc. are being used for disseminating information on agriculture. Improved availability and access to new ICT technologies - especially personal computers, the Internet and mobile telephones - in the last two decades has provided a much wider choice in collection, storage, processing, transmission and presentation of information in multiple formats. ICTs are also providing greater access to information and communication among the hitherto un-reached geographies and populations.

A number of important initiatives have been taken to provide ICT hardware and connectivity to all organizations involved in Agricultural Education, Research, Development and Extension, Simultaneously, content development and content aggregation initiatives have also been taken by Ministry of Agriculture, in collaboration with State Departments of Agriculture and National Informatics Centre (NIC) to provide agricultural information relating to crop production, protection, schemes and marketing information of various commodities to the farming community.

According to Claire J. Glendenning, Suresh Babu and Kwadwo Asenso-Okyere (2010), despite the variety of agricultural extension approaches that operate in parallel and sometimes duplicate one another, the majority of farmers in India do not have access to any source of information. This severely limits their ability to increase their productivity and income and thereby reduce poverty. Another problem is that the extension agent found difficult to reach the targeted audience. (Shely Mary Koshy and N. Kishore Kumar, 2016).

In this context, Information and Communication Technology (ICT) has the potential to revolutionize Indian farming sector in terms of significantly improving farm productivity, production and profitability at the level of lakhs of small, marginal, tenant and women farmers (Amrit Patel, 2016.). Farmer can access and use information related agriculture and allied sectors. Among all ICT tools, telephone services have been made available in small towns, markets and villages. Mobile and Telephone which is a powerful electronic machine that was a farmer's dream earlier has become a reality as the farmers can immediately make use of it to address their field problems and other farm related problems (Manhas *et al*, 2005)

With rapid spread of internet facility in rural areas ICT now has the potential to significantly contribute towards solving one of the most important major national concern namely Doubling Farmers' Income (DFI) by 2022 through dis-intermediation in both procurement of inputs and services, minimizing the costs through e-procurement and maximizing their share in consumer price through e-marketing by bringing producers and sellers together and most importantly by providing individualized Extension Advisory Services to majority of Farmers.

Information Needs of Farming Community

India's Agriculture has now entered a post-Green revolution stage. Demands for agriculture technology are changing and diversifying. Demands for information are changing. In 1960s and 70s the farmers were asking for crop-technology and packages of practices, whereas now the focus has shifted to market prices, credit-access, value-addition opportunities, supply chain and value chain linkages. The main objective of farmer's concern has shifted from high production to high returns, and hence the issues like quality, timeliness and post-harvest technology are getting prominence in the farmers' queries. Farmers' information needs have expanded considerably during last two decades. One department or Agricultural scientists alone cannot address these information needs.

There has to be an on-line network of multi-stakeholders in the Agriculture-value-chain to address farmers' current and emerging information needs.

The Akshaya Project of Government of Kerala has identified the following as the critical information needs for the farming community:

- Access to warehouse, markets with prevailing price information;
- Access to (government information on) schemes, subsidies, modern agricultural methods, best practices, soil testing, seeds, plantlets, fertilizers, pest control;
- Facilities for grading agricultural produce and ensuring correct price for their produce;
- Logistics support, cost sharing possibilities;
- Access to micro credit; and
- Agri Insurance support / faster claim processing

There are many other information needs of the farmers. Information need, by its very nature is a dynamic concept, and hence the ICT enabled systems are more suitable to address the information needs of the clientele groups.

Existing Information Access Mechanism

The prevailing information access mechanism of farmers is mostly influenced by the respective State Government / Agriculture University's information delivery mechanisms. In early fifties, the Gramsevak / Village Level Worker (VLW) served as a key-man in Community Development Programme. They had multiple functions to perform and Agriculture was just one of the subjects. The National Extension Scheme launched in 1953, was the first scheme to have specific focus on Agricultural extension. In early sixties and seventies by the department of Agriculture at district level was the sole information provider on the crop varieties, package of practices and also on pest and disease control measures to be taken. Their efforts were complemented by the farmers and Agriculture input dealers, by canvassing these messages to the fellow farmers.

The launching of Training and Visit system (T&V), under National Agricultural Extension Projects I, II and III, during 1970s and 80s gave a great fillip to information delivery mechanism of State Agriculture departments, as it introduced a system of regular and crop/ season specific interaction among Agricultural research scientists, State Agriculture departments and farmers. The fortnightly workshops were a novel concept to have a regular interaction among the scientists and the extension functionaries. The establishment of KVKs (in almost all rural districts), and support of mass-media particularly the All India Radio and Doordarshan have played a very important role in the diffusion of new Agricultural technologies. The print media, the vernacular press also supplemented the extension efforts at local levels. The private T.V. channels are a new entry, and have got tremendous positive feedback from farmers. The other traditional extension mechanisms included demonstrations, farmers meetings and krishi-melas at district, state and national level.

The emergence of ATMA (Agricultural Technology Management Agency in late 1990s and their expansion of Extension Reforms programmes in 2003 and 2005) at district level provides integrated extension information delivery through Farm Information and Advisory Centers (FIACs) at block level and Farmers' Groups at village level. Currently ATMAs are operating 713 Districts in the Country. Krishi Vigyan Kendras (KVKs), one in each rural district, are another source of Agricultural Information / advice.

The State Agriculture Universities (SAUs) have also established their own extension network in some states (e.g. in A.P. each district has a District Agricultural Advisory and Technology Transfer Centre (DAATTC) with three SAU scientists serving the farmers' needs). The electronic media (Television-both public and private broadcasters and All India Radio) and Print Media (Agricultural Journals, Magazines, Newspaper supplements and dedicated Agricultural newspapers – like Agro One from Pune) are complementing the extension efforts of Department of Agriculture in a big way. According to NSSO (2005) Survey T.V. and Radio have reached out to over 13% and 9% Farmers in the rural India, out of a total outreach of less than 41% achieved by all extension channels. Over 15000 Agri-Graduates have established Agri-Clinic and Agri-Business Centres in the rural areas after getting 2 month long intensive training supported by Government of India.

Tele-advisory services have been initiated by Government of India as Kisan Call Center (KCC), wherein any farmer in the country can make a call on toll free line 1551 (thru Land line) and 18001801551 from any mobile network to access state specific question-answer service on Agriculture and related areas. Almost all the State Agricultural Universities (SAUs)/ Indian Council of Agricultural Research (ICAR) Institutes run their own Farmer friendly call centers for specific mandate areas/ crops.

A number of private multinational companies involved in Procurement/ Manufacturing / Marketing of Agricultural Inputs/ produce have also initiated extension efforts (using state-of-the-art ICTs) to provide latest production technologies to the farmers. Still a lot needs to be done to provide integrated, single-window complete and authentic information on Agricultural issues to the farmers.

Use of ICTs in Agricultural Extension: Options and Opportunities

Information and Communication Technologies (ICTs) have opened whole new set of options for the Agricultural Extension scientists, Extension officers in the research and extension system to improve the speed, accuracy of the communications at relatively lower costs. The ICT tools like Internet, e-mail, on-line Expert Systems, Call Centres, Short Message Service (SMS) and information portals on Agricultural marketing information, packages of practices and subject specific discussion groups on Internet have enhanced access of Extension personnel to the latest information within and outside the country. Communication is the central mechanism of Extension process. ICTs provide new dimensions to communication as a process. These include:

- Access to Information resources of the whole world, beyond state and national boundaries (improved reach).
- Most of the time access is free (less cost).
- Instant access to the important resources –people and literature. Extension journals, newsletters (less time).
- Facilitates two-way communication –e-mails, Chat Groups, discussion forums.
- Information is available any time.
- Little or virtually no chance for Information-distortion, as the communication is between the user and communicator directly.
- Easy documentation as all the communication is in digital form, including e-mails, audio and video exchange.
- ICTs provide a unique opportunity to the Agriculture sector to bridge the gap between the Lab (national and international), Market and Farmers.

Information and Communication Technology Initiatives (ICT) at TNAU

Tamil Nadu Agricultural University (India) has explored the power and potential of Information and Communication Technology (ICT) intervention in Transfer of Farm Technology which may accelerate the speed of flow of technology, weather data and price information to extension system and finally reach to the needy farmers. Effort on promotion of ICT will help the 'young minds' to be in the farming. The paper highlights about the following experimentation executed by e-Extension Centre, Directorate of Extension Education for up-scaling and usage.

1. TNAU AGRI TECH PORTAL http://agritech.tnau.ac.in/
2. TNAU Multi Video Conference facility http://vcon.tnau.ac.in (Meeting ID protected)
3. Dynamic Market Price Information for Perishable Commodities http://agritech.tnau.ac.in/dmi/2015/index.html
4. TNAU- Agricultural Market Information System http://agritech.tnau.ac.in/amis/index.html
5. TNAU-IIT, Chennai Mobile Agro Advisory Services http://e-vivasaya.rtbi.in/aas/index.php (Password protected)
6. TNAU Video Modules http://www.agritech.tnau.ac.in/technologivideostnau.html
7. TNAU Plant Protection Information http://agritech.tnau.ac.in/crop_protection/crop_prot.html
8. TNAU e-Course information http://agridr.in/tnauEAgri/
9. TNAU Weather Information Network http://tawn.tnau.ac.in/
10. TNAU-ICAR Mobilizing Mass Media for Sharing Agro Information http://agritech.tnau.ac.in/govt_schemes_services/mmedia/index.html
11. TNAU-online e-Radio http://agritech.tnau.ac.in/comm_e_radio.html

A successive extension approach will depend on how it enhances the information flow along the members of agriculture value chain, and whether this is done sustainably and effectively. Sustainability and effectiveness of extension are determined by the four factors, the type of information provided, how and to whom the information is provided, the strength of feedback in each link, and the capacity of the approach to provide relevant information.

Tamil Nadu Agricultural University (TNAU) is the pioneer institute, takes initiative services of the e-Extension approach as a whole to meet farmers' needs in Tamil Nadu. TNAU e-Extension approach consists of diverse technology and knowledge systems called Agritech Portal, Expert System, Daily Market Information, Agricultural Market Information System, Domestic and Export Intelligence Cell. The extension officials from Research Stations, Krishi Vigyan Kendra (Agricultural Science Centre), Agriculture Technology Information Centre and Staff of the Department of Agriculture receive their information from various sources of TNAU e-Extension technology and knowledge systems through the different mediums like internet, tablet computers, mobile phone SMS, video conference. Apart from this, the extension officials are often provided with training about TNAU e-extension approaches. In this approach, the farmer is at the end of the information chain get the wholesome agricultural information not only production, it include processing, marketing, storage, handling and allied agriculture sector information.

Agritech Portal– Transforming the Lives of Farming Community

Agritech Portal is a new initiative by e-Extension Centre of Directorate of Extension Education, Tamil Nadu Agricultural University to eliminate the communication gap between the university scientists, agriculture officials and farmers. This dynamic portal holds around six lakh pages in Tamil and English with multiple media content. The Portal (http://agritech.tnau.ac.in) has been dedicated to service on 27th Sep, 2009 for the benefit of field extension officials and other stakeholders. Agritech portal transfer the agriculture related information and new technologies to the farmers and extension officials

As on 2018-19, the daily visitors are 24,750-32,500 (approximately), average time on site 22-24 minutes, Repeated page hits / day 68%, New visitors / day 9,650-11,850 (approximately) and updation is on daily basis. Currently, ninety per cent of the extension officials of Tamil Nadu refer the Agritech portal to give advice to farmers (Sankari, 2009). Accordingly, the Government of Tamil Nadu has taken-up the portal initiative as flagship programme under National e-Governance and Tamil Nadu State e-Governance to share all developmental programmes for the well-being. TNAU agritech portal has also been awarded the 'Best e-governance agri portal' by Government of India during 2010-11 and 2014-15.

Expert System in Agriculture and Animal Husbandry

An Expert System (ES), also called a Knowledge Based System (KBS), is a computer program designed to simulate the problem-solving behavior of an expert in a narrow domain or discipline. The expert system could be developed for decision-making and location specific technology dissemination process. An expert system is software that attempts to reproduce the performance of one or more human experts, most commonly in a specific problem domain, and is a traditional application and/or subfield of artificial intelligence. Expert system helps in selection of crop or variety, diagnosis or identification of pests, diseases and disorders and taking valuable decisions on its management.

As network project of Indian Council of Agricultural Research, the expert system was developed for agriculture (Paddy, Sugarcane, Banana, Ragi and Coconut) and animal husbandry for the three state in their respective languages *i.e*., Tamil Nadu (Tamil), Karnataka (Kannada) and Kerala (Malayalam) to provide timely expert advice with ICT initiatives to farmers. The Expert System developed to cater to the needs of Farmers, Extension workers, Scientists, Students based on this, the three components viz., Decision Support System, Crop Doctor / Health Adviser and Information System were developed.

a. Information System

Information system is web based static information wherein all the technological information and complementary information about the crop have been loaded in this component. The validated contents and images have been organized based on the package of practices. Special feature of the information system is user-friendly navigation with image-based presentation. The static information system is highly useful for the extension officials, scientists, and policy makers and administers as ready reference material and bibliography of concerned crop. This content can be updated dynamically then and there based on the advancement of the technologies.

b. Decision Support System (DSS)

Decision support systems are a class of computer-based information systems including knowledge-based systems that support decision-making activities. DSS is a computerized system for making decisions. A decision is a choice between alternatives based on estimates of the values of those alternatives. Supporting a decision means helping farmers working alone or in a group gathers intelligence, generate alternatives and make choices. Accordingly, the DSS has been contemplated and designed to get best possible options and decision by farmer themselves for the day today agriculture operation. Drop down formula or multiple combo boxes have been created using simple dot net programme. Each box in the DSS is correlated with each one for retrieving the best possible decision support for crop cultivation.

The Decision Support System is consisting of details about Season, Variety, Soil, Water, Land preparation, Nursery Management, Cultivation, Irrigation, Nutrient Management, Farm Implements, Post Harvest Technology, Marketing, Institutions and Schemes.

c. Crop Doctor:

Crop doctor is a vital component in the expert system, which act as artificial intelligence. It is picture and image based 'if and then rule' based programme which has written using dot net programme. It deals with diagnosing the pest, disease and nutritional disorders affecting the selected crops. The first obvious sign is given as thumbnail images in the Key Visual Symptoms (Primary Symptom) with multiple stages (Secondary Symptoms). Primary and secondary symptoms have been documented in stage-by-stage and loaded in the expert system shell by using if and then rule based programme. The concerned experts have validated all the symptoms, which loaded in the expert system shell.

Dynamic Market Information (DMI)

Credible and timely information plays a crucial role in agricultural marketing, particularly for perishables. Due to lack of proper market information channel and interference of middle man, the farmers have been exploited often and forced to sell their produce at lower price in their nearby market. The harvested produce can be sold at premium price information of the nearest alternative markets is disseminated to farmers on demand and daily basis. They can make better decision to harvest the produce at right time and send their consignment to particular market where the market price is higher for his/ her produce. The power of information and mobile technology is making things possible to get the required information at required time. Dynamic Market Information (DMI) Service is one such initiative to provide accurate market related information to farmers and related stakeholders on daily basis. Directorate of Extension Education, Tamil Nadu Agricultural University and Back office at TNAU to interface with e- Resource Division of Agro Marketing Intelligence and Business Promotion Centre, Trichy are controlling DMI service.

In Dynamic Market Information (DMI) Service, every day 13-market analysts collects wholesale and retail price data from 13 markets (Bangalore, Chennai, Cochin, Coimbatore, Hosur, Kumbakonam, Madurai, Mettupalayam, Ottachatram, Panruti, Thalaivasal, Thirunelvali and Trichy) of 160 perishable commodities and send it to e-Extension Centre. Before 12 Noon, the price details will be uploaded in (http://agritech.tnau.ac.in/dmi/2015/) both in Tamil and English.

Domestic and Export Market Intelligence Cell (DEMIC)

Domestic and Export Market Intelligence Cell was established in CARDS, TNAU to disseminate real time price information and domestic and export market intelligence on agricultural commodities for better scientific decision-making by farming community, traders, firms and researchers. This project was funded by Department of Agricultural Marketing and Agribusiness, Government of Tamil Nadu. Price forecasts were made for major crops well in advance of sowing seasons which include the anticipated prices during harvest of these crops, quality standards to get higher prices, markets offering highest prices, market offering highest prices etc. Tamil Nadu is forecasting prices for 14 agricultural commodities viz., Maize, Bajra, Groundnut, Gingelly, Sunflower, Coconut, Small Onion, Potato, Coriander, Turmeric, Chillies, Bengal gram, Black gram and Cotton (Murugananthi, 2013). The price forecasts are made twice before sowing and harvest and disseminated through various media like text SMS, voice SMS, Radio including FM radios, TV, Newspapers in English and Tamil (Regional Language), Farm magazines, Regulated Markets, KVKs and through Department of Agriculture and Agricultural Marketing and Agribusiness, Government of Tamil Nadu. Again during harvest of these crops recommendations are made whether to store the produce or not and the duration of storage for getting maximum prices. (http://www.tnau.ac.in/cards/demic.html)

TNAU Videoconferencing

Videoconferencing is the conduct of a videoconference (also known as a video conference or video teleconference) by a set of telecommunication technologies, which allow two or more locations to communicate by simultaneous two-way video and audio transmissions. Videoconferencing differs from videophone calls in that it's designed to serve a conference or multiple locations rather than individuals. Over the years the cost of telecommunications has reduced considerably making it possible to use the technology for the benefit of the community.

e-Extension Centre under Directorate of Extension Education in Tamil Nadu Agricultural University has two kind of video conferencing facility to invite, share, interact and educate on the farm information among scientist, extension officials and farmers. Internet Protocol based video conference system is used to link with external institutes and organizations. Server linked Multiple Video Conferencing system is established with the support of National Agricultural Development Programme (NADP- 2007-08) budget to link among TNAU centres. The main hub (TNAU, Coimbatore) is being connected with the 60 Centres of TNAU (14 KirishiVigyanKendras + 36 Regional Research Station /Agricultural Research Station /Horticultural Research Stations + 10 Agricultural Colleges) for information sharing and exchange. The basic purpose of conferencing system is to have face-to-face interaction and communication among the users. The video conferencing link of TNAU is http://vcon.tnau.ac.in/scopia/entry/index.jsp.

Video Clipping (3GP) for Cloud Computing

In the era of globalization, information technology has brought out sea change in the lives of rural masses. Earlier mass media like print, radio and Television ruled the roost by striving to the core to impart technical knowledge to lakhs of populace. Still three is a void in the technological reach as it seemed to be costly affair. To impregnate the concept of **seeing is believing** and to enrich the skills in the advanced farm technology, Video plays a crucial role in the dissemination of innovation.

As the video clipping would more revealing and picturesque, technology may easily be learnt without losing its sheen, thereby providing comprehensive knowledge amongst the rural people. To augment the productivity video clipping support with technical backup, when floated in mobile, computers, pad or else any other information tools would create a lasting impact. Handy tools like mobile are at the disposal to get acquaintance with technology round the clock.

Vital information could be delivered through video clipping by using cloud computing method there by encouraging adoption rate at the higher order and to bring a trickledown effect. Tamil Nadu Agricultural University has done a stupendous task in delivering and dissemination of agricultural technology run over in decades. The Educational Media Centre strives to document the technologies and sell it to farmers on cost basis in the form of video lessons for 2 decades. With the support of NADP project, there are 1000 short video clippings documented across Tamil Nadu and linked with TNAU AGRI TECH PORTAL for wider reach and usage.

Mobile Application

Mobile devises are called as last mile connectivity tool without any interface; it directly delivers messages to the indented audience. There are large number of initiatives are taking place by public, civil society and private organizations with various operations like electric motor controlled panel system, climate parameters with sensor based applications, GIS and GPS mapping and navigations, nutrient analysis formats and image processing.

TNAU has come out with variety of mobile applications under crop doctor programme. Still, it needs technical and technological outreach on location and farmer specific advisories with processing, value addition, logistics and consumer reach is need.

Importance of Artificial Intelligence (AI)

Agriculture is seeing rapid adoption of Artificial Intelligence (AI) and Machine Learning (ML) both in terms of agricultural products and in-field farming techniques. Cognitive computing in particular is all set to become the most disruptive technology in agriculture services as it can understand, learn, and respond to different situations (based on learning) to increase efficiency. In order to further strengthen the Tamil Nadu State Extension Service, an innovative approach of Artificial Intelligence (AI) with machine learning process to be explored to provide instantaneous information to the Extension Functionaries and Farmers on Farm to Fork of supply chain.

Initiatives for Dissemination of Market Information

In India a number of projects have been initiated to bring market information to the farmers. A few of the initiatives giving market information is given below (Anandaraja *et. al.,* 2009).

Marketing Research and Information Network (AGMARKNET)

It is a central sector scheme which was launched by the Department of Agriculture and Cooperation in March 2000. The scheme aims at progressively linking important agricultural produce markets spread all over India and the State Agriculture Marketing Boards/ Directorates and the Directorate of Marketing and Inspection (DMI) for effective exchange of market information. The market information network, AGMARKNET, is being implemented jointly by DMI and National Informatics Centre (NIC), using NICNET facilities available throughout the country. The objective of the scheme is to facilitate collection and dissemination of information for better price realization. The portal covers market, price, infrastructure and promotion related information for efficient marketing. The markets are reporting daily prices and arrivals data using a comprehensive national-level database at Agmarknet Portal (www.agmarknet.nic.in). An arrangement has been worked out with Indian Farmers Fertilizer Cooperative Limited (IFFCO) for regular transmission of prices and arrivals data from Agmarknet to the touch screen multimedia kiosks being installed by them at the rural cooperative societies.

State Marketing Boards

In India, Agriculture is being considered as State Subject. In this context, each state government took an initiative to establish a new development department (line department) called Directorate of Agricultural Marketing and Agri-Business. All most all the state governments in India has launched a webpage for the directorate and is providing details on schemes, welfare activities, policy notes and in fact Marketing Information too. Such initiatives have been made by Maharashtra State Marketing Board (http://www.msamb.com/), Andhra Pradesh Agricultural Marketing Board (www.ap.nic.in), Delhi Agricultural Marketing Board (http://www.delagrimarket. org/), Karnataka State Agricultural Marketing Board (http://www.ksamb.gov.in/), http://maratavahini.kar.nic.in/), Gujarat State Agricultural Marketing Board (http://agri.gujarat.gov.in/boards_corporations/gs-agri-mark-board/index.htm), Rajasthan Agricultural Marketing Board (http://www.rajamb.com/) and Tamil Nadu State Agricultural Marketing Board (http://www.tnsamb.com/othractivities.html). These websites provide daily information on Non-Perishable commodities such as Cereals, Pulses, Oil Seeds and Cash crops like Cotton and Sugarcane. Further, they have networked with Regulated Markets to inform the market arrivals, minimum, maximum and model prices.

Market Information related ICT Initiatives

There are various ICT based initiatives taken up by government and private bodies to provide effective market related information to the farming community. Some of the significant initiatives are described below.

eNam Overview (http://enam.gov.in/enam/)

National Agriculture Market (eNAM) is a pan-India electronic trading portal which networks the existing APMC mandis to create a unified national market for agricultural commodities. eNAM is not a parallel marketing structure but rather a device to create a national network of physical mandis which can be accessed online. It seeks to leverage the physical infrastructure of the mandis through an online trading portal, enabling buyers situated even outside the Mandi/ State to participate in trading at the local level. The eNAM electronic trading platform has been created with an investment by the Government of India (through the Ministry of Agriculture & Farmers' Welfare).It offers a "plug-in" to any market yard existing in a State (whether regulated or private). The special software developed for eNAM is available to each mandi which agrees to join the national network free of cost with necessary customization to conform to the regulations of each State Mandi Act.

States interested to integrate their mandis with eNAM are required to carry out following three reforms in their APMC Act.

a) Single trading license (Unified) to be valid across the state
b) Single point levy of market fee across the state; and
c) Provision for e-auction/ e-trading as a mode of price discovery

Mandis do not lose any business. eNAM basically increases the choice of the farmer when he brings his produce to the mandi for sale. Local traders can bid for the produce, as also traders on the electronic platform sitting in other State/ Mandi. The farmer may choose to accept either the local offer or the online offer. In either case the transaction will be on the books of the local mandi and they will continue to earn the market fee. In fact, the volume of business will significantly increase as there will be greater competition for specific produce, resulting in higher market fees for the mandi.

Ministry of Agriculture & Farmers' Welfare, Govt. of India has appointed Small Farmers' Agribusiness Consortium (SFAC) as the Lead Implementing Agency of eNAM. SFAC will operate and maintain the eNAM platform with the help of a Strategic Partner, presently NFCL.

Vision: To promote uniformity in agriculture marketing by streamlining of procedures across the integrated markets, removing information asymmetry between buyers and sellers and promoting real time price discovery based on actual demand and supply.

Mission: Integration of APMCs across the country through a common online market platform to facilitate pan-India trade in agriculture commodities, providing better price discovery through transparent auction process based on quality of produce along with timely online payment.

e-Arik: ("Arik" means "Agriculture" in the *Adi* tribal dialect of Arunachal Pradesh State), a research project to experiment the application of ICTs in agricultural extension services provision and also to measure its impact on the tribal farmers has been implemented in "Yagrung" village of East Siang District of Arunachal Pradesh State. The project provides local market information for vegetables, fruits, meat and fish on daily basis. (www.earik.in)

TN-AGMARKNET: Tamil Nadu Agricultural University and the Department of Agricultural Marketing and Agri-business, Govt of Tamil Nadu initiated the Domestic and Export Market Intelligence Cell (DEMIC) which provides market data as well as price behaviour at regular intervals in Tamil Nadu. Further, the Market Intelligence Cell displays data on arrival and transaction of important agricultural commodities in the Regulated Markets of Tamil Nadu which is available in AGMARKNET. Using this data, the Market Intelligence Cell forecasts the prices of these commodities in the forthcoming months and the same is transmitted to the Regulated Markets and the farmers through web, All India Radio, television and newspapers. (www.tnagmark.tn.nic.in)

Conclusion

Agricultural production system has been evolving into a complex business system requiring the accumulation and integration of knowledge and information from many diverse sources. In order to remain competitive, the modern farmer often relies on agricultural specialists and advisors to get information for decision-making. Unfortunately assistance of the agricultural information is not always available when the farmer needs it. In order to alleviate this problem, TNAU were experimented ICT tools like Agritech Portal, Expert Systems, as a powerful tool with extensive agriculture information. Addition with DMI and DEMIC provide necessary and comprehensive market advisories consisting of the price, product, place and time intelligence to farmers taking proper sowing and selling / storing decisions so as to maximize their net profits. Major social network tools like m-Kisan, Blogger, Face book, Twitter and YouTube are also explored and linked with the TNAU Portal for reaching the unreached.

Artificial Intelligence (AI) is leapfrog in other developmental sectors like health, advisory system, warning advisory compared to farming and its enterprises. As farmers are slowly moving towards Personal Digital Assistance (PDA) based mobile applications. Hence, it is appropriate and efforts and initiatives needs to focused on realistic Artificial Intelligence (AI) based application on real time is the order of day. It may overcome the general recommendations and advisories which provided by the extension wing into farm specific and crop specific advisories.

Farmers need to be re-oriented on production strategy on basis of consumer willingness and requirement on all aspects like preferred variety, season, certification, availability etc. Research system has to be focused on value addition and supply concept on evolving new formulation and technology development. The outreach system has to be dynamically fine tuned on market linkage, aggregation, providing value added information on commodity wise and helping the socially and economically weaker farmers into the mainstream lifeline.

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