Paddy Farmer

(Job Role)

Qualification Pack: Ref. Id. AGR/Q0101

Sector: Agriculture

Textbook for Class IX

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Foreword

The National Curriculum Framework–2005 (NCF–2005) recommends bringing work and education into the domain of the curricular, infusing it in all areas of learning while giving it an identity of its own at relevant stages. It explains that work transforms knowledge into experience and generates important personal and social values, such as self-reliance, creativity and cooperation. Through work, one learns to find one's place in society. It is an educational activity with an inherent potential for inclusion. Therefore, an experience of involvement in productive work in an educational setting will make one appreciate the worth of social life and what is valued and appreciated in the society. Work involves interaction with material or other people (mostly both), thus, creating a deeper comprehension and increased practical knowledge of natural substances and social relationships.

Through work and education, school knowledge can be easily linked to learners' life outside the school. This also makes a departure from the legacy of bookish learning and bridges the gap between the school, home, community and workplace. The NCF–2005 also emphasises on Vocational Education and Training (VET) for all those children who wish to acquire additional skills and/or seek livelihood through vocational education after either discontinuing or completing their school education. VET is expected to provide a 'preferred and dignified' choice rather than a terminal or 'last resort' option.

As a follow-up of this, NCERT has attempted to infuse work across subject areas and also contributed in the development of the National Skill Qualification Framework (NSQF) for the country, which was notified on 27 December 2013. It is a quality assurance framework that organises all qualifications according to the levels of knowledge, skills and attitude. These levels, graded from one to ten, are defined in terms of learning outcomes, which learners must possess regardless of whether they are obtained through formal, non-formal or informal learning. The NSQF sets common principles and guidelines for a nationally recognised qualification system covering schools, vocational education and training institutions, technical education institutions, colleges and universities.

It is under this backdrop that Pandit Sundarlal Sharma Central Institute of Vocational Education (PSSCIVE), Bhopal, a constituent of NCERT, has developed learning outcomes based modular curricula for vocational subjects from Classes IX to XII. This has been developed under the Centrally Sponsored Scheme of Vocationalisation of Secondary and Higher Secondary Education of the Ministry of Human Resource Development.

This textbook has been developed as per the learning outcomes based curriculum, keeping in view the National Occupational Standards (NOS) for the job role and to promote experiential learning related to the vocation. This will enable the students to acquire necessary skills, knowledge and attitude.

I acknowledge the contribution of the development team, reviewers and all institutions and organisations, which have supported in the development of this textbook.

NCERT welcomes suggestions from students, teachers and parents, which will help us to further improve the quality of the material in subsequent editions.

HRUSHIKESH SENAPATY
Director
National Council of Educational
Research and Training

New Delhi
June 2018

About the Textbook

Agriculture is an important part of India's economy. It accounts for about 18 per cent of the country's Gross Domestic Product (GDP) and occupies almost 43 per cent of India's geographical area. The Agriculture Industry employs a large number of people in both the organised and unorganised sectors. The requirement of skilled workforce in this Industry is increasing by the day. Various job roles, such as Paddy Farmer, Solanaceous Crop Cultivator, Tuber Crop Cultivator, Floriculturist–Open Cultivation, Floriculturist–Protected Cultivation, Microirrigation Technician, etc., are in demand by States for producing skilled workers.

A Paddy Farmer specialises in the cultivation of paddy crop as per the practices recommended for a particular agro-climatic zone, type of soil, rainfall pattern and climatic conditions to achieve the desired yield. This textbook for the job role of a Paddy Farmer has been developed to impart knowledge and skills through hands-on-learning experience, which forms a part of experiential learning. It focuses on the learning process of an individual. Therefore, the learning activities are student-centred rather than teacher-centred.

The textbook has been developed with the contribution of subject and industry experts, and academicians. Care has been taken to align the content of the textbook with the National Occupational Standards (NOSs) for the job role so that students acquire necessary knowledge and skills as per the performance criteria mentioned in the respective NOSs of the Qualification Pack (QP). The textbook has also been reviewed by experts to ensure that the content is not only aligned with the NOSs but is also of high quality. The NOSs for the job role of Paddy Farmer covered through this textbook are as follows:

1. AGR/N0101: Seed preparation in paddy
2. AGR/N0102: Land preparation and transplanting in paddy
3. AGR/N0103: Integrated nutrient management in paddy
4. AGR/N0106: Irrigation management in paddy

The textbook has eight Units. Unit 1 gives an introduction to paddy cultivation, its importance, climatic requirements for the cultivation of paddy and paddy growing regions. Unit 2 focuses on land preparation and planting. It includes implements used for land preparation and planting of paddy crop. Unit 3 deals with nursery preparation and transportation of paddy seedlings. Unit 4 throws an insight into the various growth stages of paddy crop. Unit 5 covers the various intercultural operations followed in paddy cultivation. Unit 6 deals with seed preparation, which includes methods of seed production, improved and indigenous rice varieties in India, and traits of rice varieties found here. Unit 7 focuses on water management in paddy. It emphasises on water requirement, methods of irrigation, alternate wetting and drying, and water use efficiency in paddy. Unit 8 deals with integrated nutrient management. It includes soil sampling and analysis, nutrient requirement and its sources, methods and time of fertiliser application, and nutrient deficiency symptoms.

We hope this textbook is useful for teachers and students, who opt for this job role. Suggestions for improving this textbook are welcome.

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The images used in the textbook have been sourced from Creative Commons. Dinesh Kumar of IARI, PUSA, is also thanked for providing the photographs. The photographs have been selected with care and diligence to impart a clearer understanding to learners. Care has been taken not to violate any copyright issue. The images are meant for educational purpose only and are being provided for the use of students and teachers.

Gratitude is also due to the Publication Division, NCERT, for transforming the manuscript into an attractive textbook. Thanks are due to Sweta Jha, *Editor* (contractual), for copyediting the textbook and Chanchal Chauhan, *Proofreader* (contractual), for *proofreading* the manuscript. Pawan Kumar Barriar, *DTP Operator*, Publication Division, and Nitin Kumar Gupta, Naresh Kumar and Rajshree Saini, *DTP Operators* (contractual), are appreciated for layout and design.

Contents

Unit 1

Introduction to Paddy Cultivation

Introduction

Paddy, also known as 'rice paddy', is cultivated in southern and eastern Asia. Paddy fields must always be irrigated and the crop be cultivated in standing water. Paddy plants are cultivated in impermeable subsoil and are bordered by earthen bunds to hold an average of 10–15 cm water in a field for three quarters of the growing season.

The plants produce rice, an edible starchy cereal grain. Roughly, one–half of the world population, including almost the entire East and Southeast Asia, is solely dependent on rice as a staple food. Ninety-five per cent of the world's rice is consumed by humans. The cultivated rice plant, *Oryza sativa,* is an annual grass of the *Gramineae* family.

Paddy cultivation probably started between the fifteenth and twentieth century B.C. in the Himalayan and submontane regions. The domestication of paddy is considered as one of the most important developments in human history. Rice first finds mention in the *Yajur Veda* (1500–800 B.C.), followed by many Sanskrit texts. Rice is consumed by a majority of the Indian population as a staple food. Paddy is a monocot annual plant belonging to *Poaceae (Gramineae)*

Fig. 1.1: Oryza sativa (Asian rice)

Fig. 1.2: Oryza sativa with small flowers

family and the number of its chromosomes is 2n=24. The height of paddy plants, usually, vary from half-a-metre to two metres. Paddy cultivation is labour intensive and the plants need enough water for irrigation.

Sub-species of Paddy

Rice grain can be of different colours and sizes. Rice is a grain belonging to the genus *Oryza*. This genus has two important species — *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice). Species is not the only factor that differentiates between living beings. Variation exists among populations of the same species based on various other factors. Sub-species, race and breed are used to describe the different types of variation. Rice species are further grouped into three sub-species — *Indica, Japonica* and *Javanica.*

Fig. 1.3(a): Indica paddy plant

Indica

Paddy crop cultivated in India belongs to the *Indica* sub-species. It either does not have awns or possesses short and smooth awns. *Indica* is a major eco-geographical sub-species of paddy, primarily grown in tropical and subtropical regions, covering major south and south-east Asian countries. The leaves of the plant are mostly light green in colour, narrow or broad. The plant is medium or tall (except the semi-dwarf gene, which has been introduced into this group of genotypes recently). *Indica* rice varieties have profuse tillering, and slender and flat grains.

Fig. 1.3(b): Japonica paddy plant

Japonica

Named after Japan, this group of paddy plant is characterised by narrow, dark green leaves, medium height tillers, oval and round grains, and short to intermediate plant stature. The panicles may be with or without awns.

Javanica

It denotes the *bulu* and *gundil* varieties of Indonesia mostly suitable for upland paddy cultivation. *Javanica* paddy plants are characterised by broad, stiff and light green leaves, stiff straw and long panicles with awned grains. They, generally, have poor tillering. The spikes of the plant may be with or without awns with long duration maturity.

Fig. 1.3(c): Javanica paddy plant

Rice Varieties

Aerobic rice

Aerobic rice varieties are grown in well-drained, non-puddled and aerated soils, and have an average yield of 4–5 tonne per hectare. Paddy plants, yielding such varieties, are mostly cultivated on levelled and flat lands, where rains, with or without supplementary irrigation, are sufficient to support the crop for a full season.

Hybrid rice

Varieties produced by crossing between two different parents are known as hybrids. Hybrid varieties of rice have been found to be more robust, tillering, nutrient responsive, higher yielding and better than common high yielding varieties (HYVs). Hybrids are less susceptible to diseases, drought and other agronomic vagaries.

Basmati rice

These are characterised by thin and longer grains, and have an aroma with a distinct taste. Such rice varieties are extensively grown and consumed across the world. The rice grains have a light and fluffy texture on cooking. India produces the world's finest *basmati* rice varieties.

Fig. 1.4: A mixture of brown, white and red Indica rice (including wild rice)

Fig.1.5: Golden rice

Golden rice

This is a Genetically Modified (GM) variety of rice that carries a gene for biosynthesis of β-carotene, which is converted to Vitamin A on consumption. However, being a GM crop, there are several impediments for its cultivation in many Asian countries.

Boro rice

It refers to the cultivation of rice between November and May, especially, in the eastern parts of India, i.e., West Bengal, Odisha, Assam, etc. The cultivation of *boro* rice is practised in areas, generally, left fallow during winters due to excessive soil moisture conditions after harvesting of the crop. *Boro* crop planted after the cultivation of *Kharif* crop matures before the onset of next monsoon and fetches higher market price.

Organic rice

Organic rice farming denotes paddy cultivation without the use of fertiliser and chemical pesticides. Such a variety totally depends on Farm Yard Manure (FYM), compost, animal wastes or by-products like cattle and poultry, green manure, mineral nutrients and biological pests, which are important to maintain soil health and check insect–pests, diseases and weeds.

Integrated Rice and Fish Farming

Fish rearing in paddy fields without impacting the rice quality and yield is known as 'integrated rice and fish farming'. It helps in earning extra income, i.e., apart from the main crop (rice) yield. Rice and fish farming is widely practised in Asian countries.

Session 1: Importance of Paddy Cultivation

India is the second largest producer of rice in the world after China and has the largest area under paddy cultivation. Therefore, rice is the principal staple food crop in India. Data on area earmarked for paddy cultivation and production of rice indicate a considerable increase in the area dedicated to its cultivation 1950–51 to 2016–17 (Table 1.1). Within a span of 66 years, rice production in India has increased by about five times, while the productivity (yield/ha) has increased by about four times. The country has HYVs. India has achieved this enhanced production due to the use of advanced and effective agricultural technologies.

Table 1.1: Area, production and yield of rice in India

Year	Area (million hectare)	Production (million tonne)	Yield (kg/hectare)
1950–51	30.8	20.6	668
1960–61	31.1	34.6	1,013
1970–71	37.6	42.2	1,123
1980–81	40.1	53.6	1,336
1990–91	42.7	74.3	1,740
2000–01	44.7	85.0	1,901
2010–11	42.9	96.0	2,239
2016–17	43.4	104.3	2,404

(Source: *Agricultural Statistics at a Glance 2017*, Directorate of Economics & Statistics)

Economic importance of rice in India

Rice is the staple food crop in India. It plays a significant role in the national food and livelihood security system, as well as, helps earn significant foreign exchange as it is exported to other countries. In India, the contribution of rice in the total agricultural export was 20 per cent in 2014–15 and 17.7 per cent in 2015–16 (Directorate of Economics and Statistics, 2016). Rice export (*basmati* and non-*basmati*) reported by the Ministry of Commerce and Industry, Government of India, during 2015–16 is given in Table 1.2.

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Table 1.2: Rice (*basmati* and non-*basmati*) export during 2015–16

Basmati			**Non-*basmati***		
Country	**Quantity (million tonne)**	**Value (US $ million)**	**Country**	**Quantity (million tonne)**	**Value (US $ million)**
Saudi Arabia	0.949	842.22	Senegal	0.888	1603.97
Iran	0.695	571.19	Benin	0.623	1411.12
UAE	0.612	475.18	Nepal	0.504	1182.85
Iraq	0.418	340.97	Coted'l voire	0.449	984.77
Kuwait	0.181	211.68	Guinea	0.396	866.95
UK	0.188	143.14	UAE	0.234	747.78
USA	0.121	131.55	Bangladesh	0.294	617.43
Yemen	0.142	110.49	Somalia	0.269	605.27
Oman	0.105	92.84	South Africa	0.261	570.64
Canada	0.036	38.49	Saudi Arabia	0.152	506.68
Other countries	0.597	519.64	Other countries	2.296	6031.61
Total	4.045	3477.39	Total	6.366	15129.09

(Source: Directorate General of Commercial Intelligence and Statistics 2016, Ministry of Commerce and Industry, Government of India)

Rice straw is used as fodder, fuel, and for making thatched rooftops, mats, hats and straw boards. It is treated with urea to make feeds for ruminants. Rice bran contains 20 per cent oil and other nutritious minerals. Rice bran oil is considered better than other vegetable oils for its low cholesterol level.

Nutritional value of rice

Rice is the predominant dietary source of energy. Starch is the main constituent of rice grain, providing instant energy. Because of higher starch content, it is used for preparing various food items, such as rice flour, rice flakes, canned rice, popped or puffed rice and fermented products. The major nutrients in rice is given in Table 1.3.

Table 1.3: Major nutrients in rice

Nutrients	Rice (white) (per 100 g)	Rice (brown) (per 100 g)
Water (g)	12	10
Energy (kJ)	1528	1549
Protein (g)	7.1	7.9
Fat (g)	0.7	2.9
Carbohydrates (g)	80	77
Calcium (mg)	28	23
Magnesium (mg)	25	143
Phosphorus (mg)	115	333
Potassium (mg)	115	223
Thiamin (B_1) (mg)	0.07	0.4
Riboflavin (B_2) (mg)	0.05	0.09
Niacin (B_3) (mg)	1.6	5.09
Pantothenic acid (B_5) (mg)	1.01	1.49
Vitamin B_6 (mg)	0.16	0.51
Vitamin E (mg)	0.11	0.59

Practical Exercise

Activity

Prepare a bar diagram, depicting the area under rice cultivation and its production in India.

Material required: pen, pencil, eraser, A4–size plain paper, etc.

Procedure

- Collect data on area under rice cultivation in India.
- Arrange the data year-wise for three years.
- Draw a bar diagram, indicating the area under rice cultivation, and its production in the country.

NOTES

NOTES

Check Your Progress

A. Fill in the Blanks

1. Rice is the ____________ food crop of India.
2. The botanical name of Asian rice is _________.
3. _________ rice a genetically modified variety.
4. *Boro* rice cultivation is practised in ______ parts of India.
5. The major nutrient found in rice is __________.

B. Multiple Choice Questions

1. How many chromosomes (2n) are there in rice?
   (a) 20 (b) 22
   (c) 24 (d) 26
2. Which one of the following sub-species of rice is cultivated in India?
   (a) *Japonica* (b) *Indica*
   (c) *Javanica* (d) None of the above
3. A by-product prepared from rice is __________.
   (a) oil (b) wax
   (c) glue (d) soft drink
4. The main constituent of rice is _________, which provides energy.
   (a) starch (b) fat
   (c) protein (d) vitamin

C. Match the Columns

A	B
1. Sub-species	(a) *Oryza glaberrima*
2. *Indica*	(b) From November to May
3. Golden rice	(c) Describes types of variation in rice crop
4. African rice	(d) Genetically modified variety
5. *Boro* rice	(e) Profuse tillering

D. Subjective Questions

1. Describe the economic importance of rice.
2. Write about the following in brief.
   (a) Aerobic rice
   (b) *Basmati* rice
   (c) Golden rice
   (d) *Boro* rice

Session 2: Climatic Requirements and Paddy Growing Regions

Notes

Paddy is a semi-aquatic plant. Tropical climate is most suitable for its cultivation. But paddy crop is also grown extensively in subtropical and temperate climates. In India, paddy cultivation is done almost round the year in different regions, spanning three seasons — *Kharif*, *Rabi* and *Zaid*, depending on the cultivar, climate and availability of water.

Conditions for paddy cultivation

Rainfall

Paddy is, generally, cultivated in areas receiving a rainfall of 750–1250 cm annually.

Temperature

The optimum temperature required for paddy cultivation is 30˚C in the day and 20˚C in the night. But the plant can tolerate higher temperatures up to 40˚C for a short period.

Day length or sunshine

Sunlight significantly influences the growth of paddy crop. Sunshine with low temperatures during the ripening stage improves the grain quality, helps in the development of carbohydrates, and also results in overall better yield.

Soil

Paddy is cultivated in soils with variable characteristics but grows well in soils having a pH of 5.5 to 6.5. Soils with optimum water holding and drainage capacity are suitable for paddy cultivation.

Rice cropping seasons

Paddy cultivation can be carried out throughout the year in the eastern and southern parts of India by taking two–three crops annually. It is mostly cultivated during the *Kharif* season in northern and western India like Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Uttarakhand, Uttar Pradesh, Gujarat, Rajasthan and Maharashtra. Here, only one crop is grown in the *Kharif* season as the temperatures during winters are too low for paddy cultivation. The crop duration, time of sowing and harvesting of the crop is presented in Table 1.4.

Table 1.4: Time of sowing and harvesting paddy crop in India

Local name	Crop season	Sowing	Harvesting
Aus (autumn rice)	Pre–*Kharif*	May–June	September–October
Aman (winter rice)	*Kharif*	June–July	November–December
Boro (summer rice)	*Zaid*	November–December	March–April

Rice growing regions in India

Uttar Pradesh has the largest area under paddy cultivation, followed by West Bengal, Odisha, Chhattisgarh, Andhra Pradesh, Telangana, Bihar and Punjab. These States collectively account for about 92 per cent of the total area under paddy cultivation in the country (Table 1.5). A classification of the regions primarily under paddy cultivation is as follows.

- Arid Western Plains
- Semi-arid Lava Plateau and Central Highlands
- Humid to semi-arid Western Ghats and Karnataka Plateau
- Humid western Himalayan region
- Sub-humid Sutlej–Ganga alluvial plains
- Sub-humid to humid eastern and south-eastern uplands
- Humid Bengal–Assam Basin and humid eastern Himalayan region

Table 1.5: Top 10 rice producing States in India (2014–15)

S. No.	State/UT	Rice (million tonne)	Area (million hectare)	Average yield (kg/ha)
1.	West Bengal	14.7	5.4	2731
2.	Uttar Pradesh	12.2	5.9	2082
3.	Andhra Pradesh and Telangana	11.6	3.8	3036
4.	Punjab	11.1	2.9	3838

5.	Odisha	8.3	4.2	1989
6.	Bihar	6.4	3.3	1951
7.	Chhattisgarh	6	3.8	1581
8.	Tamil Nadu	5.8	1.8	3191
9.	Assam	4.9	2.3	2135
10.	Haryana	4	1.3	3113

(Source: http://www.mospi.gov.in/statistical-year-book-india/2016/177)

Rice ecologies

Ecology refers to the relationship between different organisms and that with their physical surroundings. Paddy is cultivated in different agro ecological zones across India. No other country in the world has such diversity in rice ecosystem as India. There are four distinct ecosystems in India.

Irrigated rice ecosystem

This ecosystem is primarily found in eastern Asia and provides 75 per cent of the global rice production. In India, irrigated paddy is cultivated in bunded fields (an earthen wall around a field) and occupies a total area of about 22 million ha (49.5 per cent). This type of paddy cultivation is mainly practised in Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Jammu and Kashmir, Sikkim, Andhra Pradesh, Tamil Nadu, Karnataka and Gujarat.

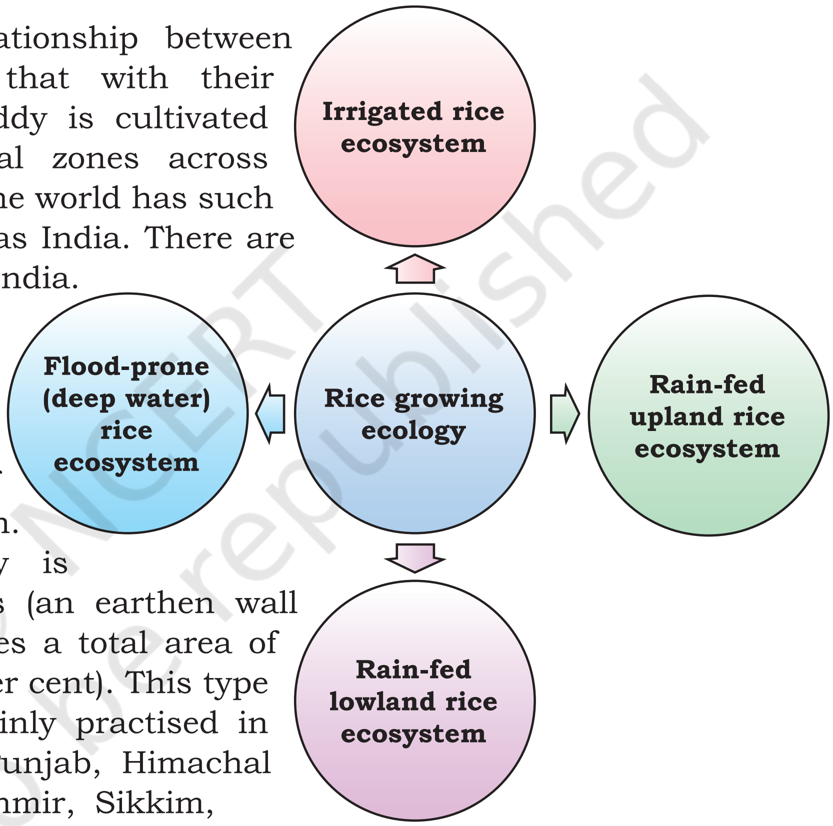

Fig. 1.6: India has four distinct rice ecosystems

Rain-fed upland rice ecosystem

This system is prevalent in Asia, Africa and Latin America. In India, the total area under rain-fed upland paddy cultivation is about six million ha (13.5 per cent). It is grown extensively in eastern and north-eastern States, often seeded in dry seedbed on rolling or sloping land.

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Rain-fed lowland rice ecosystem

About 25 per cent of the global paddy cultivation is under rain-fed lowland ecosystem. India has over 33 per cent area under this ecosystem. The major constraints in this ecosystem include poor soil health, frequent droughts and floods, resulting in poor yield.

Flood-prone (deep water) rice ecosystem

Flood-prone ecosystem is prevalent in South and south-east India, and the central Gangetic plains of Uttar Pradesh and Bihar. Flooding, usually, occurs during June to September, mostly preceded and followed by drought. Paddy varieties to be cultivated in this ecosystem are selected on the basis of their tolerance to water submergence. Their yields are low.

Practical Exercise

Activity 1

Prepare a pie chart, depicting the five largest paddy producing States in India. Indicate these States on the political map of India.

Material required: pen, pencil, A4–size plain paper, compass, India's political map, etc.

Procedure

- Collect State-wise data on paddy production in the current year and arrange it in descending order.
- Select five largest rice producing States in India.
- Indicate these States on the political map of India.
- Calculate the percentage contribution of each State with regard to the total rice production in India.
- Draw a pie chart, indicating the States that are the largest paddy producers.

Activity 2

List the States, where paddy is cultivated under irrigated ecosystem and also indicate them on the political map of India.

Material required: pen, pencil, A4-size plain sheet, India's political map, etc.

Procedure

- Make a list of the States where paddy is cultivated under irrigated ecosystem.
- Indicate these States on the political map of India.

Check Your Progress

A. Fill in the Blanks

1. Rice is a semi-aquatic plant that prefers a __________ climate.
2. There are ____________ distinct rice ecosystems in India.
3. Uttar Pradesh comes under _________________ rice ecosystem.
4. Rice grows well in soils having a pH of _____________.

B. Multiple Choice Questions

1. Paddy is grown in India in the season(s) of ____________.
   (a) *Rabi* only (b) *Kharif* only
   (c) *Zaid* only (d) All of the above
2. The grain quality of rice mainly depends on ___________.
   (a) bright sunshine hours (b) low temperature
   (c) Both (a) and (b) (d) humidity
3. Irrigated rice ecosystem provides _____________ per cent of the global rice production.
   (a) 85 (b) 65 (c) 95 (d) 75
4. Optimum day–night temperature requirement of rice is _____________, respectively.
   (a) 30 and 20°C (b) 35 and 25°C
   (c) 40 and 30°C (d) 25 and 15°C

C. Match the Columns

A		B	
1.	Autumn	(a)	*Boro*
2.	Winter	(b)	*Aus*
3.	Summer	(c)	*Aman*

D. Subjective Questions

1. List the rice growing regions of India.
2. Write a note on rice ecological regions in India.

NOTES

Unit 2

Land Preparation and Planting

17906CH02

Introduction

Land preparation involves tillage of a field in order to provide favourable soil environment for plant growth. Tillage ensures that the field is ready for planting, and will support plant stand and growth. It involves ploughing, harrowing and levelling of the field. Land preparation, therefore, helps in weed control. It also provides congenial conditions for transplanting and a suitable soil surface for direct sowing of the crop to obtain high productivity. In olden days, draft animals were used for harrowing. But today, in this era of mechanisation, tractor operated implements are used for land preparation.

Ploughing

Timely ploughing is an important tillage operation and the crop yield, generally, depends on the quality of the seedbed. It is done soon after a rain (7–8 mm) or after normal irrigation. During *Kharif* season, early ploughing helps in moisture retention and controls weed population.

Advantages of ploughing

- Helps in seed establishment and contact of roots with the soil
- Improves soil fertility as crop residues, stubbles and roots are ploughed into the soil

- Uproots, cuts and destroys the weed population
- Creates conducive soil conditions for soil aeration and better seed germination
- Helps destroy insects and harmful pathogens

Harrowing

This tillage operation is performed after ploughing. Here, the soil is tilled at a shallow depth with the help of harrows. The harrows smoothen and pulverise the soil by breaking large clods into fine tilth and making the soil structure suitable for seed sowing. It is also helpful in carrying out other field operations, for example, cutting weeds in the field, mixing FYM and compost in the soil, etc.

Levelling

Levelling helps modify existing land undulations for carrying out efficient agricultural production and provides adequate slope to a cropped area for surface irrigation along with ensuring unrestricted drainage.

Purpose of levelling

- To ensure efficient application of irrigation water
- To enhance rainwater conservation
- To minimise soil erosion
- To encourage efficient mechanisation
- To check weed population
- To improve nutrient management
- To improve crop stand and establishment

In paddy, minor land levelling is done at the time of puddling by bullock or tractor operated land leveller. These days, laser guided land levellers are also used for carrying out land levelling, especially, when a fresh stretch of land is to be brought into paddy cultivation.

Table 2.1: Implements and machines used in land preparation

S. No.	Implements and machines
1.	**Equipment used for land development**
	Laser land leveller: helps achieve fine levelling in an agricultural field

Notes

2.	**Tillage implements**
	Mouldboard plough: helps in cutting furrow slices into pulverised from of soil
	Reversible two bottom mouldboard plough: a plough that brings up lower soil to the top
	Disc plough: a set of round discs to open up the soil and dry mix the top soil till a depth of 15 cm
	Tyne-type cultivator: a set of narrow tines to disturb the top soil for fine tilth
	Disc harrow: a tractor drawn set of round discs, which cut the soil surface at a shallow depth
	Rotavator: an equipment that can overturn top soil to bottom and vice versa
	Paddy harrow or puddler: a rotary device to churn and mix top soil with water
3.	**Sowing or planting equipment**
	Direct paddy seeder: a drum-type device for direct seeding of a large area in short time
	Tractor mounted direct rice seeder: a normal seed-cum-fertiliser drill for sowing
	Rice transplanter: a device for transplanting rice mechanically
4.	**Intercultural equipment** (implements used for weeding and ensuring soil aeration)
	Conoweeder: a rotary movement harrow that uproots and buries weeds into the soil
5.	**Plant protection equipment**
	Knapsack sprayer: a shoulder and back mounted tank with manual pump spray mechanism
	Power knapsack sprayer: a shoulder mounted tank with a mechanised sprayer
6.	**Harvesting equipment**
	Riding type self-propelled vertical conveyer reaper: a machine that cuts stalks and places them aside
	Self-propelled reaper binder: a machine that makes bundles of paddy crop cut with stalks and keeps them aside
	Combined harvester: a big machine to reap, thresh, winnow and pack paddy seeds

7.	**Threshing equipment**
	Multi-crop thresher: a mechanical device to remove grain from reaped or harvested crop
	Axial-flow paddy thresher: a machine that threshes paddy and also converts stalks into fine chopped straw

Session 1: Implements used for Land Preparation and Planting

Types of plough

Mouldboard plough

Mouldboard plough helps in cutting furrow slices into pulverised form of soil. This farm implement helps to turn and plough various types of plant and vegetation present in the field into the soil. Both single and double bottom mouldboard ploughs are used but double bottom ploughs are more common.

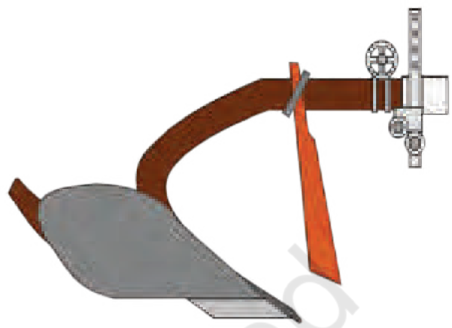

Fig. 2.1: Mouldboard plough

Parts of mouldboard plough

- Beam
- Three-point hitch (hake)
- Height regulator
- Coulter
- Chisel
- Share
- Mouldboard

Fig. 2.2: Disc plough

Disc plough

It is in the shape of a disc (concave shape). It helps reduce friction. This plough cannot be used at higher speed as the cutting process needs to be carried out at low speed. Compared to mouldboard plough, the maintenance cost is lesser. It can be used in sticky soils, dry and hard conditions, and for deep ploughing.

Fig. 2.3: Rotary plough

Rotary plough

It is an implement with steel tynes or blades mounted on a power-driven shaft. It is used to break clods and weeds, and thus, helps in preparing the seedbed. It can cut up to a depth of 9″. However, it is better to make a cut up to a depth of 5″ at the beginning in order to avoid overloading of the machine.

Sub-surface or chisel plough

It helps loosen hard pan of dry soil to allow deep penetration of roots and conservation of moisture. Besides, it aids upward movement of nutrients available in the soil beyond the root zone layer. This implement is mostly used for reclamation of land, which has not been under use for some time or for initiating cultivation on barren soil.

Fig. 2.4: Sub-soiler

Sub-soiler

Sub-soilers are somewhat similar to chisel plough and require heavy power to operate. The shear part of sub-soiler can penetrate deeper than chisel plough. Sub-soiler is an important implement that helps in land reclamation, water conservation and improves drainage.

Fig. 2.5: Disc harrow

Harrow

It is a secondary tillage implement, which breaks large clods into fine tilth. The four types of harrow available on the basis of soil type and requirement of a farmer are disc, chain, chain disc and tyne harrows.

Implements used for seed sowing and transplanting

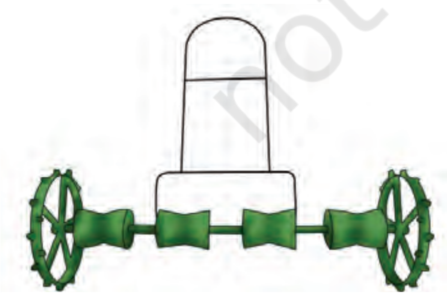

Fig. 2.6: Direct paddy seeder

Direct paddy seeder (drum seeder)

It is a device used for uniform seed distribution and increasing plant population. It is manually operated and consists of a main shaft, seed drum, ground wheel, floats, furrow openers and a handle. It is used for sowing seeds in prepared puddled fields.

Seed-cum-fertiliser drill

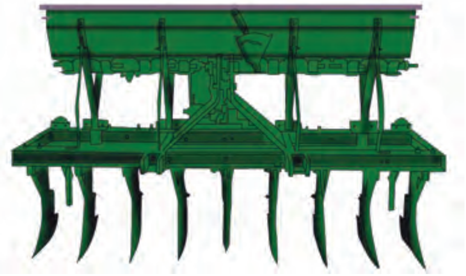

Fig. 2.7: Seed-cum-fertiliser drill

It is a line sowing equipment used for direct sowing of paddy seeds and application of fertilisers simultaneously. It requires 35–45 hp tractors to operate. The seed-cum-fertiliser drill helps in:

- the adjustment of seed rate and fertiliser dose.
- the placement of fertiliser at the appropriate soil depth.
- better germination of crop.
- saving time.

Paddy transplanter

Fig. 2.8: Paddy transplanter

Paddy transplanter involves a tray system for transfer of nursery seedlings. Mat type rice nursery is a pre-requisite for planting with this machine. It is important for ensuring systematic smooth flow of seedlings during transplanting. A paddy transplanter helps save time and money. It is not a labour-intensive implement. All these features make it popular among farmers.

Importance of weeding

Weeds are common in a paddy field. They reduce the yield considerably. Therefore, their eradication is a major challenge that farmers face. Weeds can be removed manually, by the use of chemicals or herbicides, or mechanically. Hand weeding is the most common method used for the removal of weeds. But it is not suited as it is a time-consuming and labour-intensive process. The use of chemicals reduces the weed population considerably. But they are not preferred much by farmers due to their harmful effects on human beings and environment. Mechanical weeding promotes plant growth as it leads to increased soil aeration, root length and better tiller production. It may be done by using manual and power weeders.

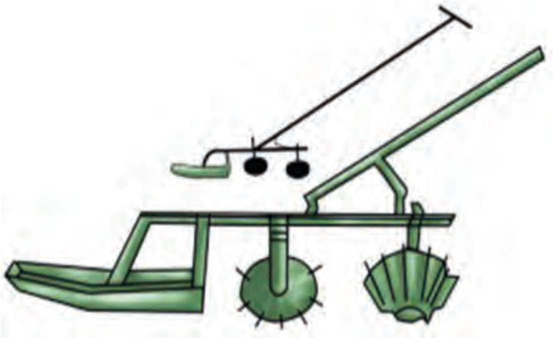

Fig. 2.9: Conoweeder

Fig. 2.10: Weeding by conoweeder

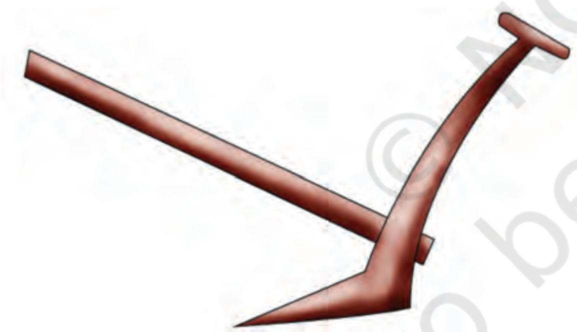

Fig.2.11: Desi (indigenous) plough

Fig. 2.12: Trifal cultivator

Implements used for intercultural operations in paddy cultivation

Conoweeder

The use of a conoweeder facilitates weeding between rows. It is operated manually by a single operator. It uproots and buries weeds in the soil. The weeder does not sink in puddled soil.

Paddy rotary weeder

It is operated manually and helps carry out weeding in paddy row crops. During operation, it can be adjusted up to 20–25 cm, according to row spacing of the plants. One person can easily operate the unit by continuous push and pull action. The use of a rotary weeder helps bury the weeds and improves soil aeration.

Implements used in *biasi* operation

Biasi or 'bueshening' is a method of broadcasting paddy seeds in dry or wet soils after regular field preparation. Paddy plants and weeds grow at same time in the field for up to 30–40 days. *Biasi* operation is done mainly to destroy the weeds, manipulate the root zone of the plants, create semi-puddled conditions, reduce percolation of water and maintain plant population. It is mainly practised in Chhattisgarh and Odisha.

Desi plough

It is single furrow opener animal drawn indigenous plough that is, usually, used in *biasi* operation. *Biasi* operation is a time and labour consuming process.

Trifal

This bullock drawn three-tined cultivator is modified to carry out effective *biasi* operation in order to ensure minimum draft, soil inversion, clogging and low plant mortality. The curved tines and adequate ground clearance minimise clogging. Due to more working width covered by the three tines, the number of passes required for *biasi* ploughing is also minimised.

NOTES

Practical Exercise

Activity 1

Prepare a chart on the different type of ploughs used for paddy cultivation.

Material required: chart paper, photographs of different type of ploughs, glue stick, sketch pens, pen, pencil, etc.

Procedure

- Collect pictures of different type of ploughs used in paddy cultivation. You can also use a computer and access the Internet.
- Paste the pictures on the chart paper and write the names of the ploughs.
- Present it before the class.

Activity 2

Visit a shop selling agricultural implements and identify the different type of implements used in paddy cultivation.

Material required: pen, pencil, notebook, etc.

Procedure

- Visit a shop selling agricultural implements in your area.
- Identify the farm implements used for paddy cultivation being sold there.
- Note down the names of the implements in your notebook.

Check Your Progress

A. Fill in the Blanks

1. Crop residues and vegetation are buried in the soil by ____________ plough .
2. A ____________ plough is used for the reclamation of degraded lands.
3. A _____________ is used to break clods in order to provide fine tilth.
4. A process that modifies undulated land and provides adequate slope is known as _____________.

Notes

B. Multiple Choice Questions

1. Which of the following is not type of plough?
   (a) Mouldboard (b) Chisel
   (c) Rotary (d) Spike
2. ____________ is considered as a secondary tillage implement.
   (a) Chisel (b) Disc harrow
   (c) Disc plough (d) Rotary
3. Which of the following helps improve surface drainage and minimise soil erosion?
   (a) Mouldboard plough (b) Harrow
   (c) Land leveller (d) Disc plough
4. Which of the following helps modify the existing land contours for carrying out efficient agricultural production?
   (a) Plough (b) Harrow
   (c) Chisel (d) Land leveller
5. A conoweeder is used to control ____________ in a paddy field.
   (a) insects (b) diseases
   (c) weeds (d) Water

C. Match the Columns

A		B	
1.	Laser leveller	(a)	Weed removal
2.	Rice transplanter	(b)	Uniform land levelling
3.	Sickle	(c)	Labour saving
4.	Harvester	(d)	Harvesting manually
5.	Weeder	(e)	Harvesting machine

D. Subjective questions

1. Differentiate between the following.
   (a) Ploughing and harrowing
   (b) Mouldboard and disc plough
2. Define tillage. List the different type of ploughs used in paddy cultivation and describe any one plough.
3. Define harrowing. List the type of harrows suitable for paddy cultivation.
4. Define land leveling and explain its significance in paddy cultivation.
5. Differentiate between the following.
   (a) Conoweeder and two-row finger rotary weeder
   (b) Seed-cum-fertiliser drill and rice transplanter

Session 2: Methods of Planting in Paddy Cultivation

Paddy fields are ploughed and harrowed during summer to ensure optimum soil condition and tilth. Addition of Farm Yard Manure (FYM) helps achieve a friable seedbed, which facilitates easy uprooting of seedlings from a nursery for transplanting in a field. Seed sowing in rain-fed rice conditions and transplanting in irrigated systems is done as soon as monsoon arrives. Planting in rows is preferred to ensure crop stand, and carry out easy weeding and intercultural operations. The three common methods practised in paddy cultivation are as follows.

- Direct seeding in dry soil
- Direct seeding in puddled soil
- Transplanting in puddled soil

A method is adopted depending on rice ecology.

- Upland rice: mostly direct seeding in dry soil
- Transplanted rice: generally, done in irrigated and rain-fed rice under low land situation (water stagnated in field)
- Deep water rice: direct seeding and transplanting

Methods of sowing or planting

Broadcasting

It is a primitive method of paddy planting. About 60–80 kg/ha of seeds are scattered randomly across a field to obtain uniform plant stand. Broadcasting can also be done in straight lines at an estimated spacing of 20 cm. Shallow furrows are made in the prepared field, and then, the seeds are broadcast, followed by planking.

Line sowing (drilling)

Seeds are sown either with a seed drill, machine or plough in dry soil, loose enough for holding the seedlings and also moist enough for germination. A levelled field is necessary to ensure seed placement at optimum depth. Besides, adequate water supply is necessary for the growth of the

Fig. 2.13: Line sowing (drilling)

crop. The seeds can be sown and fertilisers be applied at the same time by using ferti-seed drill. In this method, a conoweeder can be used to check weed population in the paddy field.

Advantages

- Seeds are sown at uniform depths.
- Intercultural operations can be carried out in the field conveniently.
- Uniform row-to-row spacing is maintained in line sowing.
- Seed requirement is less in line sowing as compared to broadcasting.
- Sowing is done when the soil has adequate moisture level.
- Line sowing leads to higher yield and improves water use efficiency.

Limitations

- Machine is required for seeds sowing.
- In line sowing, it is important to maintain sufficient moisture in the soil, which may be a challenge.
- It is not possible to maintain exact plant-to-plant (inter row) spacing.
- For sowing, skilled labourers are required.

Dibbling

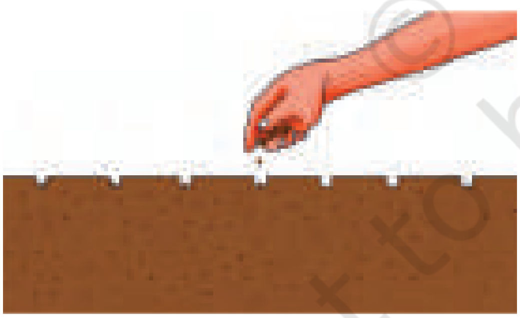

Fig. 2.14: Dibbling

Dibbling or hill planting method is, generally, practised in sloped land, where ploughing and harrowing are difficult. In this method, farmers use a bamboo pole or a long wood attached to a metal scoop. The seeds are dropped into the prepared holes carefully and covered with soil.

Biasi operation

Biasi or 'beushening' is a method of broadcasting paddy seeds in dry or wet soils after regular field preparation. Paddy plants and weeds grow simultaneously in the field for up to 30–40 days. Then, ploughing (single or cross with a *desi* plough) is carried out in the standing crop in 5–10 cm of water. After ploughing, the seedlings are planted erect and gap filling is done (in the field) by transplanting manually. During the process, most weeds are buried in the soil. This process is traditionally known as *chalai*. This practice is followed in some parts of Odisha, West Bengal, Assam and Chhattisgarh.

Direct Seeded Rice (DSR)

This method is, usually, practised in rain-fed and deepwater paddy fileds. DSR requires less labour inputs and the crop tends to mature faster than in transplanting. The primary rationale behind DSR is the economical use of groundwater, which is depleting fast in major rice producing Indo-Gangetic plains. Most DSR is planted like wheat behind the plough or with the help of normal seed-cum-fertiliser drill. In some cases, it is done with a drill that ought to be fit for no-tillage condition. According to land preparation methods, DSR can be sown in the following ways.

- Direct dry seeding
- Direct wet seeding

Fig. 2.15: Direct Seeded Rice

Transplanting

Transplanting of rice is common in Asian countries. In this method, seedlings are grown in a nursery and seedlings that are 20–25 days' old are transplanted in a levelled and puddled field. Puddling helps in controlling the weed population, producing higher yield and saving water. There are two methods of transplanting — manual and mechanical.

Manual transplanting

It is most suited for labour surplus areas and does not require costly machines. Manual transplanting can be done in fields that are undulated and have varying water levels. For such a transplanting,

Fig. 2.16: Manual method of transplanting

the seedlings are raised in dry or wet nursery. To get healthy and vigorous seedlings for transplanting, adequate nursery management practices must be followed. Manual transplanting is either done randomly or in straight rows.

Fig. 2.17: Random transplanting

Random transplanting

In this method, the seedlings are transplanted without a definite distance or space between plants.

Straight row transplanting

In this method, the seedlings are planted in a straight row at an optimum plant-to-plant and row-to-row distance. Wire or ropes are tied with bamboo poles at both the ends and placed along the baseline. Usually, a row-to-row distance of 20–25 cm and plant-to-plant distance of 10–15 cm is considered optimum. Normally, two to three seedlings per hill are transplanted at a depth of 4–5 cm.

Advantages of manual transplanting

- It ensures adequate plant spacing
- Cultural operations are more effectively carried out by implements in this method.
- Other field management activities like fertigation and spraying of chemicals are also easier.

Limitations of manual transplanting

- It is a time-consuming method.
- This method requires a large number of labourers (one hectare of paddy transplanting requires approximately 25–30 people per day). Therefore, the labour costs are high.
- Initially, the plants grow slowly than in direct seeding method, mainly due to transplanting shock.

Mechanical transplanting

Machines are used for transplanting young paddy seedlings in puddled soil. Transplanting by machines is less time-consuming and requires lesser number of labourers than manual transplanting. Normally, 14–15 days' old paddy seedlings are used for transplanting. It must be ensured that the fields are levelled and puddled. Adequate water level must be maintained in the fields at the time of transplanting. The seedlings are, generally, grown in seedling trays or special mat-type nurseries. The machine is set and the seedlings are loaded on the trays for transplanting.

Advantages

- It is a faster and an efficient method of transplanting than manual transplanting as it requires less number of labourers and also ensures timely planting.
- Mechanical transplanting method ensures uniform plant spacing and population density.
- The seedlings recover fast, tiller vigorously and mature uniformly.

Limitations

- The fields must be accessible for smooth entry, exit and movement of machines.
- Mechanical transplanting method is mostly suitable in an irrigated area.
- Effective management practices are required during the preparation of nursery for mechanical transplanting.
- Land preparation and water management are also required if a farmer opts for this transplanting method.
- Skilled labourers are required for operating the machine.

System of Rice Intensification

The System of Rice Intensification (SRI) originated in Madagascar in 1983. The productivity of irrigated paddy is optimised by changing the management of a plant with the intensification of operational activity. In SRI, the nursery is raised and young seedlings

Fig. 2.18: Paddy seedlings planted as per the System of Rice Intensification

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are transplanted in a puddled field. SRI works on the principles of improving the soil conditions, reducing plant population, and application of water for root and plant growth. The basic principles of SRI are as follows.

- Less than 14 days' old seedlings are used for transplanting.
- It ensures early, quick and healthy plant establishment.
- The plant density is reduced as single seedling is planted per hill.
- A spacing of 25×25 cm row-to-row and plant-to-plant in square pattern is maintained.
- Weed management is done by the help of a conoweeder.
- Alternate wetting and drying method of irrigation is practised, which reduce water wastage.
- Organic matter is added to the field improve the soil conditions.

Benefits of SRI

- It enhances productivity by 20–60 per cent.
- The seed rate gets reduced by 75–80 per cent.
- It encourages water saving by 40–50 per cent.

Gap filling in transplanted fields

Some seedlings fail to survive due to transplanting shock or improper transplanting, creating gaps in the field. To obtain optimum crop yield by maintaining adequate plant population, gap filling must be done within 7–10 days of transplanting. To check the emergence of weeds, a pre-emergence herbicide can be used after transplanting. Hand weeding must be carried out at the tillering stage itself (i.e., 20–25 days after transplanting). Maintaining 5-cm water depth continuously from the rooting stage till 15–20 days before harvesting will minimise weed population.

Practical Exercise

Activity

Demonstrate the System of Rice Intensification (SRI).

Material required: measuring tape, rope, seedlings, etc.

Procedure

- Select a suitable land and get it prepared.
- Select healthy seedlings that are less than 14 days' old.
- Measure and mark 25×25 cm row-to-row and plant-to-plant spacing in square pattern.
- Transplant the seedlings as per the layout.
- Irrigate the field intermittently with alternate wetting and drying system.
- Manage weeds with the help of a conoweeder.

Check Your Progress

A. Fill in the Blanks

1. The SRI originated in __________ in 1983.
2. In line sowing, weeds are controlled by the use of a ________________.
3. Manual transplanting is a time-consuming and ___________ activity.
4. Alternate wetting and drying method is used in _______.
5. Under SRI, the seed rate gets reduced by ___________ per cent.
6. In a paddy field, gap filling must be done within ___________ days of transplanting.

B. Multiple Choice Questions

1. In SRI method, the age of seedlings for transplanting is _________ days.
   (a) less than 14 (b) 16–20
   (c) 22–24 (d) 25–28
2. Beushening is a method of _______________.
   (a) field preparation (b) transplanting
   (c) seed broadcasting (d) nursery preparation
3. In SRI, plant-to-plant and row-to-row spacing is __________ cm.
   (a) 15×10 (b) 15×15
   (c) 35×35 (d) 25×25

Notes

NOTES

4. Random method of transplanting comes under ____________ system.
   (a) mechanical   (b) manual
   (c) SRI   (d) *biasi*
5. Normally, less than 14 days' old seedlings are used for transplanting in ___________ system.
   (a) mechanical   (b) manual
   (c) SRI   (d) *biasi*

C. Match the Columns

A		B	
1.	Dibbling	(a)	Old or primitive
2.	Broadcasting	(b)	Weed removal
3.	Square planting	(c)	*Desi plough*
4.	*Biasi*	(d)	SRI
5.	*Chalai*	(e)	Sloped land

D. Subjective Questions

1. Describe transplanted rice and direct seeded rice.
2. Explain in brief the System of Rice Intensification.
3. Describe line sowing, and its advantages and limitations.
4. Explain the various methods of paddy transplanting.

Unit 3

Nursery Preparation and Transportation

Introduction

Transplanting is a process, wherein, young seedlings are transferred from a nursery to be planted in a field. Nursery is a small area, where seeds are sown to raise seedlings. In general, the required nursery area is about 8–10 per cent of the total area to be transplanted. A nursery site needs to be levelled and made free from weeds, insect–pests and diseases. Farm Yard Manure (FYM) and fertilisers containing nitrogen and phosphorus must be added to the nursery soil to increase its fertility. The seed rate for nursery raising depends on the locality, soil type, variety and seed quality. Vigorous seedlings can be raised in the nursery, which can later be transplanted in the field.

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Session 1: Types of Nursery and Seed Sowing

Selection of nursery site

Centrally located flat bed having a slope of less than 3 degrees is ideal for nursery raising. A fertile land having adequate water holding capacity and drainage facility must be selected for the nursery site. Regular supply of irrigation water must be ensured at the site. Avoid a site that is prone to flood, animal attacks, etc., as these may damage the seedlings. Approach roads and irrigation or drainage channels in the nursery site must be carefully planned.

Criteria for nursery site selection

- The soil of the nursery site must be loamy or clayey loam but it must not be too porous. It is important to avoid heavy leaching of nutrients and water.
- There must be fencing around the site to protect crop damage from animals.
- The nursery site must be changed every season to check diseases, insect–pests and weeds.
- The site must have optimum drainage and irrigation facility.
- Adequate and appropriate transportation facility must be available near the nursery site.
- Avoid setting up nurseries under the shade of trees as this can lead to weak seedlings.

Types of nursery

Wet bed nursery

Fig. 3.1: Raising seedlings in a wet bed nursery

The wet bed method of raising paddy seedlings is most popular among farmers. In this method, a fertile and levelled area having adequate drainage facility is selected. Decomposed organic material and inorganic fertilisers need to be added to the nursery soil as they help ensure healthy and vigorous seedling growth. Treated and pre-germinated seeds must be sown in the nursery as they enhance seedling establishment and germination. Such a nursery needs to be raised in about 600–800 m^2 area for transplanting 1 ha land.

Generally, 25–30 kg of seeds are sufficient to transplant 1 hectare land. However, the quantity of seeds depends on the variety to be sown. In this method, the seedlings are pulled out one week prior to transplanting.

Irrigation channels having a width of 30–40 cm must be constructed around the nursery beds as they serve as pathways and barriers against predators. The beds need to be prepared at a width of 1.25 m by choosing a convenient length, normally, up to 5 m. The bed height must be raised up to 5−10 cm and the pre-germinated seeds need to be broadcast in puddled and levelled field. The transplanting of seedlings must be done when they are 20–25 days' old. Younger seedlings are preferred as they are easy and fast to establish.

The seedlings must be pulled with the help of the thumb and index finger, and held close to the roots. It needs to be ensured that the seedlings are handled gently during uprooting and transporting. There must be minimum damage to the roots during uprooting.

Advantages

- Less number of seeds is required per unit area.
- Quick growth can be obtained with strong and sturdy seedlings.

Dry bed nursery

This method is practised in areas, where water is not sufficient to grow seedlings. Dry bed nursery is prepared in dry soil conditions. The seedbed area is 10 per cent of the total area to be transplanted. The seedbed must be ploughed three–four times to achieve the required conditions for sowing. Prepare beds of the same size as in wet nursery. But in dry nursery, the beds must be raised by 15 cm. Channels having a width of 30 cm must be prepared between two beds length wise. The seeds must be sown uniformly in lines at a spacing of 10 cm. The sowing depth needs to be 1–3 cm. Use the same seed and fertiliser rate as in case of wet nursery. After sowing in rows, the sown seeds must be covered with soil. Water is allowed to run through the channels first, and then, the water level is slowly raised to saturate the soil bed. If possible, a thin film of water needs to be maintained

Fig. 3.2: Raising seedlings in a dry bed nursery

(a)

(b)

(c)

Fig. 3.3 (a–c): Raising seedlings in dapog nursery

after five days of sowing. Follow all operations as discussed in case of wet nursery here too.

Advantages

- Heavy rain does not affect the growth of seedlings.
- The seedlings develop better root system.
- They are easy to uproot.
- They are short and sturdy.

Dapog nursery

This method of nursery raising entails growing seedlings on a flat soil surface or raised bed covered with polyethylene sheets or banana leaves. A nursery area of 25–30 sqm is enough for transplanting 1 ha land. If the seed rate of a particular variety is 30 kg/ha, then about 3 kg seeds need to be spread in 1 sqm area. The pre-germinated seeds must be broadcast uniformly over the plastic sheets or banana leaves. The seeds must be packed manually to make a uniform layer. The seeds must not be pressed too hard. Water must be sprinkled gently on the nursery bed three–four times a day to keep it wet for four–five days. The seeds, later, need to be covered with 1–2 cm water till the end.

By this method, the seedlings are raised faster and are ready in 9–14 days of sowing. The seedlings, thus, raised can be rolled like a carpet and carried to the transplanting site. They can be separated by loosening the interlocked roots carefully before transplanting. Three to four seedlings must be transplanted at a hill in the main field. This method saves almost half the time that goes in raising the seedlings. The other advantage is that less area is required to raise the seedlings. The seedlings raised by this method are, generally, delicate, thin and can survive only for about two weeks. When allowed to remain in the bed for a longer period than two weeks, the seedlings may dry up.

SRI nursery

Fig. 3.4: Raising seedlings in an SRI nursery

The ideal site for an SRI nursery is a levelled area having adequate water supply. Drainage channels are necessary for draining out excess water. About 100 m^2 area is sufficient for transplanting 1 ha land. The seed rate for SRI method is low, i.e., 7–8 kg/ha. It is due to the transplanting of only one seedling per hill. Around 6.8 tonne of soil mixture is needed for 100 m^2 nursery. The soil mixture can be prepared with soil (70%) + FYM (20%) + powdered rice hull (10%). Nitrogen, phosphorous and potash fertiliser must be added to this mixture. A wooden frame measuring 0.5 m long, 1 m wide and 4 cm deep must be placed in equal parts on a plastic sheet.

Pre-germinated seeds are required for raising the nursery. The seeds must be soaked in water for 24 hours, and thereafter, incubated for another 24 hours. Next, the pre-germinated seeds need to be spread in the wooden frame uniformly and covered with dry soil having a thickness of 5 mm. Adequate moisture must be maintained by sprinkling water in the wooden frame. The nursery must be protected from heavy rains for the first five days. A spray of 0.5% urea + 0.5% Zinc sulphate solution may be applied after 8–10 days from sowing for ensuring fast growth of the seedlings. The seedlings become ready for transplanting after 12–14 days from sowing. The problem of diseases and insect–pests is minimum in SRI nursery.

Care and maintenance of nursery

Care and maintenance of a nursery are essential for raising healthy seedlings. Factors like moisture, light and temperature need to be conducive for better seedling development. Care and maintenance help in vigorous growth of the seedlings, and may enable them to survive adverse environmental conditions.

Fig. 3.5: Seed germination of rice

Seed germination

It must be ensured that all seeds planted in the nursery are treated with appropriate chemicals to check seed-borne infections. Pre-germination includes two steps — soaking of the seeds and their incubation. The seeds are soaked in a loose cloth or jute bag for 24 hours so that the moisture gets absorbed. Incubation implies withdrawal of excess water from the seeds and keeping them in a ventilated place (close to 30 °C), until they begin to germinate, which, usually, takes 24 to 36 hours.

Irrigation

Make sure that the nursery never dries up or has excess water. Ensure frequent irrigation to keep the nursery soil moist. The following precautions must be taken during irrigation.

- Ensure adequate drainage.
- Maintain 2–3 cm water for up to 10 days during the seedling stage.
- The nursery must be watered in the evening to avoid damage to the seedlings as water becomes hot during the day.
- The seedlings must not be completely submerged in water.

Fertiliser application

Adequate and appropriate fertiliser application practices need to be followed to improve soil fertility conditions. In case of poor seedling growth, apply top dressing of 10 g urea per m^2 after two weeks of sowing.

Disease and insect–pest management

As already mentioned, the seeds must be treated to check the occurrence of diseases and insect–pests. But if diseases or insect–pests attack the seeds despite treatment, then the symptoms must be identified and corrective measures be taken.

Table 3.1: Nursery management schedule

S. No.	Operations	Days
1.	Manage weeds (if needed)	3–5
2.	Manage insect–pests and diseases	10–20
3.	Apply Di Ammonium Phosphate (DAP) fertiliser (if it is not applied as basal dose)	15
4.	Pulling out the seedlings • Short duration • Medium duration • Long duration • SRI method	20–35 20–25 25–30 30–35 Less than 14

Practical Exercise

Activity

Prepare a dry bed nursery for growing paddy seedlings.

Material required: measuring tape, rope, fertilisers, seeds, etc.

Procedure

- Plough or dig the nursery soil of a given area or plot.
- Remove crop stubbles from the soil and level the plot.
- Mix FYM and fertilisers into the soil.
- Prepare a seedbed of 1.25 m width, having a height of about 15 cm.
- Make 30 to 40-cm wide drainage channels around the bed.
- Treat the seeds with fungicides before sowing.
- Broadcast the seeds on the seedbed and cover them with fine soil.
- Irrigate the seedbed after sowing.
- Maintain soil moisture till the seedlings are ready for transplanting.

Check Your Progress

A. Fill in the Blanks

1. For wet bed nursery, the optimum size of the nursery for transplanting 1 ha land is ______ sqm.
2. Dry bed nursery is prepared for _________ soil conditions.
3. A drainage channel is required to remove ______________ water.

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4. Pre-germinated seeds are covered with __________ in SRI system.
5. Pre-germination includes __________ and __________ of seeds.

B. Multiple Choice Questions

1. The most popular type of nursery for paddy cultivation is ____________ nursery.
   (a) *dapog* (b) dry bed
   (c) wet bed (d) None
2. Seedlings in *dapog* nursery are ready for transplanting after ______ days.
   (a) 3–5 (b) 9–14 (c) 20–25 (d) 25–30
3. The problem of diseases and insect–pests is minimum in __________ nursery.
   (a) *dapog* nursery (b) dry bed
   (c) wet bed nursery (d) SRI
4. The size of the nursery area required to transplant 1 ha by SRI method is ______ m^2.
   (a) 10 (b) 50 (c) 100 (d) 1000
5. Seedlings in wet bed nursery are ready for transplanting after ______ days.
   (a) 30–35 (b) 20–25 (c) 15–21 (d) 9–14

C. Match the Columns

A	B
1. Seed treatment	(a) Better root system
2. *Dapog* method	(b) Check occurrence of diseases and insects-pets
3. SRI	(c) Flat soil surface covered with polythene sheet for banana leaves
4. Dry bed	(d) Single seedling per hill

D. Subjective Questions

1. Describe the site selection criteria for a paddy nursery.
2. What is a nursery? Describe different types of rice nursery.
3. Explain how an SRI nursery is prepared.
4. Distinguish between dry and wet bed nurseries. Also, write how are they prepared.

Session 2: Weeds, Insect–pests and Disease Management in a Paddy Nursery

There is severe yield loss if paddy crop is attacked by insect–pests, or acquires some diseases. Better crop management, crop rotation and certain preventive measures can help check the problems. The use of appropriate insecticides can help eradicate such problems after the diagnosis of diseases or insect–pests.

Fig. 3.6(a): Grasses

Type of weeds

The different type of weeds found in a paddy nursery are as follows.

Grasses

Grasses are monocots having narrow, upright and long leaves with parallel venation. Examples of grass weeds are *doob* grass, barnyard grass, *saava,* etc.

Fig. 3.6(b): Sedges

Sedges

These are similar to grasses. They have triangular stems without nodes and internodes. Sedges multiply by rhizomes, for example *motha*, yellow nut sedge, etc.

Broad-leaved weeds

Broad-leaved weeds are, usually, dicot in nature with taproot system. The stem bears branches and leaves possess a net venation. Examples of broad-leaved weeds are *hazardana, kana, bhringraj, brahma manduki*, etc.

Fig. 3.6(c): Broad-leaved weeds

Weed management in nursery

Herbicides are the chemicals used to kill herbs that occur in the form of weeds in a field. Weeds in a nursery can be easily managed by spraying pre-emergence herbicides like *butachlor* at 2.0l/ha or *pendimethalin* at 2.5l/ha. These herbicides need to be applied only after ensuring enough moisture in the field.

Insect–pests and diseases

Insect–pests and diseases adversely affect the crop in a nursery. Sometimes, the entire nursery gets destroyed due to the presence of insect–pests and diseases. Therefore, management of insect–pests and diseases is important.

Insect–pest management

Some of the common insect–pests found in a nursery are army cutworm, thrips, green leafhopper and case worm.

Fig. 3.7: Army cutworm

Army cutworm

The damage caused by the larvae of army cutworm may occur on a large scale during the seedling stage of paddy crop. In severe cases of infestation, the nursery looks like a grazed field. The infestation is severe during July to September. Drain out excess water and spray *chlorpyriphos 20 EC at* 0.05% to check the spread of army cutworm. One can also mix some kerosene in water and use it for flooding the nursery, which suffocates and kills the larvae.

Fig. 3.8(a): Thrips (adult)

Fig. 3.8(b): Thrips

Thrips

The affected leaves show a rolled tip and there are needle-like outgrowths in the leaves at the seedling stage. In severe cases, lower leaves of the plant show chlorosis and scorching. *Phosphamidon 40 SL* or *Monocrotophos 36 SL* are effective in controlling the spread of thrips.

Fig. 3.9: Green leafhopper

Green leafhopper

It causes yellowing of the leaves from the tip to bottom. Rice tungro virus is also transmitted by this insect. Both nymphs and adults cause damage to the leaves by sucking the sap. *Phorate 10G* at 10 kg/ha or *quinalphos 5G* at 30 kg/ha can be used to check the occurrence of green leafhoppers.

Fig. 3.10: Rice case worm

Rice case worm

This insect causes damage at the caterpillar stage. Caterpillars feed on green tissues of leaves, which become whitish and papery in appearance. The spread of rice case worms can be checked by spraying 2 ml *quinalphos 25 EC* or 1.3 ml *monocrotophos 36 SL* in 1 litre of water.

Disease management

The major diseases affecting paddy crop in a nursery are as follows.

Blast

Brown to dark brown boat-shaped spots with ashy centres appear on the leaves. Growing of resistant varieties and application of recommended dose of fertilisers are effective in checking this disease. Spray *carbendazim* at 2g/litre on the seedlings to prevent the occurrence or spread of this disease.

Fig. 3.11: Blast disease in paddy plant

Brown spot

These are dark brown oval spots on the leaves and stems. In severe cases, it causes heavy mortality of the seedlings. For prevention of brown spots, apply dose of recommended fertilisers only.

Fig. 3.12: Brown spot disease in a paddy plant

Practical Exercise

Activity

Identify different insect–pests and diseases in a paddy nursery in your area.

Material required: notebook, pen, pencil, eraser, etc.

Procedure

- Visit a paddy nursery and identify insect–pests and diseases infecting the plants there.
- Write the symptoms that you spot in the plants.
- Collect the specimen of insect–pests and diseases.
- Write the measures that you would take to control the spread of insect–pests and diseases.

Check Your Progress

A. Fill in the Blanks

1. Monocot grasses have parallel leaf __________.
2. Sedges have triangular stems without ______ and ______.
3. Brown spot disease is characterised by oval dark brown spots on ___________ and ______________.
4. Rice tungro virus is transmitted by __________.
5. Army cutworm infestation in rice is severe during ___________ to ___________.

Notes

B. Multiple Choice Questions

1. *Butacholre* is a __________.
   (a) herbicide (b) fungicide
   (c) insecticide (d) nematicide
2. In paddy crop, *butachlor* is used for controlling _________.
   (a) diseases (b) insect–pests
   (c) weeds (d) nematodes
3. The most damaging stage of army cutworms is _________.
   (a) fly (b) caterpillar
   (c) pupa (d) larvae
4. Dark brown and boat-shaped spots on paddy leaves are caused by __________.
   (a) bacterial blight (b) brown spots
   (c) blast (d) sheath blight

C. Match the Columns

	A		B
1.	Broad-leaved weed	(a)	Leaves become whitish and papery in appearance
2.	Rice case worm	(b)	Nursery looks like a grazed field
3.	Army cutworms	(c)	Taproot system
4.	Brown spot	(d)	Nymphs and adults
5.	Green leafhopper	(e)	Mortality of seedlings

D. Subjective Questions

1. Write down the name of common weeds found in a paddy nursery.
2. Describe the insect–pests and diseases that affect paddy plants.

Session 3: Packaging and Transportation

Selection of seedlings for transplanting

Seedling age during transplanting stage largely depends on season, variety and method of paddy cultivation. Usually, three to four-week old seedlings are transplanted during rainy season. Under unfavourable conditions, more than five-week old seedlings are also transplanted. Before transplanting, the roots of the seedlings need to be treated with the suspension of a bio-agent *(Pseudomonas fluorescens)* at 5 g/litre to withstand possible soil-borne fungal infections.

In case of short duration varieties, three to four-week old seedlings can be used. Seedlings aged five to six-week are also used for long duration varieties without much loss to the yield. As a general rule, seedlings at 4–5 leaf stage or 15–20 cm tall are suitable for transplanting.

Uprooting of seedlings

It is a delicate operation in a paddy nursery. An unskilled person may damage the roots while uprooting the seedlings. It may cause poor establishment of the seedlings in the main field and may require gap filling. The seedlings must be pulled out gently only after ensuring enough moisture in the nursery. Take two to three seedlings between the thumb and index finger, positioning the thumb parallel to the seedlings and the index finger almost perpendicular. Apply low pressure downwards prior to pulling out the seedlings while holding them close to the ground or roots. Care must be taken while removing weed seedlings as they might get transplanted in the main field instead of paddy seedlings.

Fig. 3.13: Uprooting of paddy seedlings

Packaging and transportation of seedlings

It must be ensured that there is minimum time lapse between uprooting of the seedlings from a nursery and transplanting them in the main field. For transportation, the seedlings must be picked up a day before or on the same day. The seedlings must be transported in a covered vehicle to avoid direct sunlight. They must be kept in a cool and shady place in the main field. During transportation, the leaves and roots of the seedlings must be kept moistened by sprinkling water at regular intervals.

Packaging protects the seedlings from transportation hazards, and injuries. Pack the seedlings carefully while transporting them to longer distances. The seedlings must be packed in a suitable material (see Table 3.2), ensuring their viability during transportation. Label the packed seedlings with necessary information like name of the seedlings' variety, name of the nursery from where they have been pulled out, age, etc.

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Packaging material

The packaging material must be easily available and affordable. It must be convenient to handle and adaptable for transportation. Besides, it needs to be ensured that the seedlings are protected against drying out and mechanical injury.

Table 3.2: Common packaging material

Hessian cloth	Made from quality jute fibre
Sacking cloth	Made from raw grade jute fibre
Plastic	Low and high density polyethylene
Paddy straw	For wrapping the earthen balls of the seedlings
Dried grass	For wrapping the earthen balls of the seedlings

Practical Exercise

Activity

Demonstrate the packaging of paddy seedlings for transportation.

Material required: paddy seedlings, packaging material like hessian or sacking cloth, paddy straw, dried grass, etc.

Procedure

- Select a nursery site to collect paddy seedlings.
- Irrigate the nursery to maintain adequate moisture.
- Pull out the seedlings gently without damaging the roots.
- Now, wrap the seedlings with a suitable packaging material.
- Sprinkle water on the packaged bundles containing the seedlings.
- Label each package to identify the variety of the seedlings.
- Place the packages in a suitable container to maintain their viability during transportation.
- Perform all activities in a cool and shady environment.

Check Your Progress

A. Fill in the Blanks

1. Generally, three to four-week old seedlings are transplanted during __________ season.
2. Five to six week old seedlings are often used for _________ duration varieties.
3. Packaging of seedlings protects them from various transportation ___________.

4. Under unfavourable conditions, more than __________ week old seedlings are also transplanted.

B. Multiple Choice Questions

1. In general, a seedling suitable for transplanting must be in _________ leaf stage and ______ in height.
   (a) 2–3 and 10–15 cm (b) 4–5 and 15–20 cm
   (c) 6–7 and 25–30 cm (d) 8–9 and 30–35 cm
2. Paddy seedlings must be transported in a covered vehicle to avoid them from coming in contact with __________.
   (a) birds (b) diseases
   (c) insect–pests (d) direct sunlight
3. Paddy seedlings need to be treated with a bio-agent *(Pseudomonas fluorescens)* at the rate of _______ g/litre.
   (a) 7 (b) 5 (c) 4 (d) 3

C. Match the Columns

A		B	
1.	Bio-agent	(a)	Sacking cloth
2.	Packaging material	(b)	Avoids transportation hazards
3.	Packaging	(c)	*Pseudomonas fluorescens*

D. Subjective Questions

1. Describe the process of packaging and transportation of paddy seedlings.
2. Write in brief on the following.
   (a) Age of seedlings for transplanting
   (b) Precautions to be taken while pulling out seedlings
   (c) Packaging material for seedlings

Notes

Unit 4

Growth Stages of Paddy Plant

Introduction

It is necessary to understand the growth and development stages of a paddy plant. As management practices like weeding, irrigation, fertiliser application, etc., are almost linked with the growth and development of the plant, an understanding of the plant's growth pattern is, thus, essential. Paddy plant passes through a number of growth stages, starting from germination to maturity. Before going into details of the growth stages, it is important to understand the morphology (external appearance) of the plant.

Parts of Paddy Plant

There are two major parts of paddy plant.

Fig. 4.1: Root system

Root system

As a rice grain germinates, a sheath or coleorrhiza (embryonic root) can be seen emerging from the soil. This is what happens in upland situation. But in submerged soils, it is the coleoptile (shoot meristem), which emerges ahead of the roots. The radicles (embryonic roots) emerge through the coleorrhiza. Shortly after the radicles appear, secondary roots develop into lateral roots. Later, the embryonic roots disappear and are replaced by adventitious roots, emerging from nodes on the culm.

Shoot system

Plant parts that are visible above the ground, i.e., culm, leaves and inflorescence (panicle), constitute the shoot system.

Culm or stem

The culm or stem of the paddy plant is distinguished by a series of nodes and internodes. The culm is mostly hollow, except at the nodal portion. Leaves are attached to the nodes. The lower portion of the culm produces tillers, which may be primary, secondary or tertiary.

Leaf

The node or nodal region of the culm bears a leaf. The leaves are attached alternately on the culm in opposite direction. One leaf is produced at each node. The topmost leaf below the panicle is known as 'flag leaf'. Each leaf has two parts, i.e., sheath and blade, which are continuous. The leaf sheath is wrapped around the culm above the node. The swelling at the base of the leaf sheath, just above the node, is called 'sheath pulvinus'. It is, sometimes, incorrectly referred to as node.

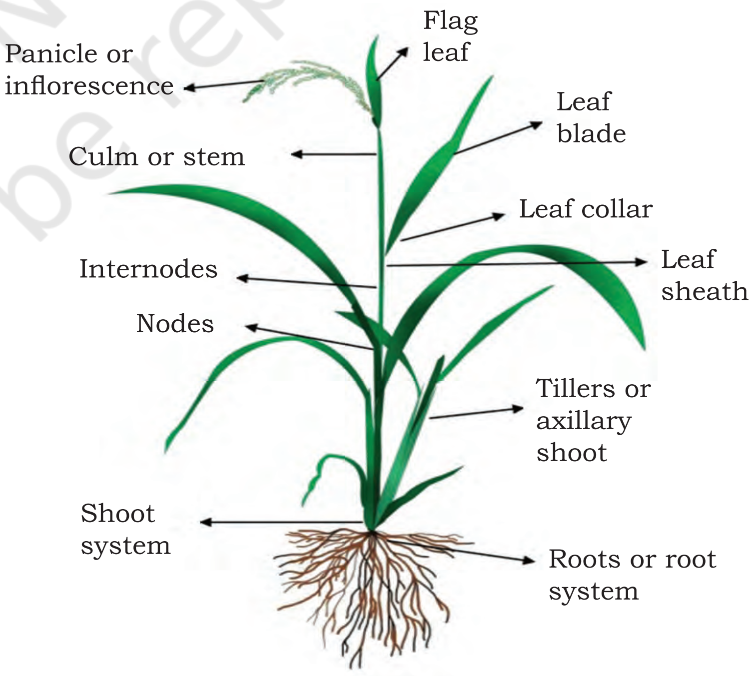

Fig. 4.2: Different parts of a paddy plant

Panicle

Like any other grass family member, paddy inflorescence is called a 'panicle', which consists of a number of 'spikelets' at the apical end of the culm. The panicle base is often called the 'neck'. The primary branch of panicle is divided into secondary and tertiary branches, which bear the spikelets.

Spikelets

These spikelets are borne on the primary and secondary branches. Spikelets are the basic unit of the inflorescence and panicle. Each spikelet consists of pedicel and floret.

Grain

The rice grain is a fertilised and ripened ovule, which has a live embryo capable of germination to produce a new plant.

Growth Phases of Paddy

There are three major growth phases of paddy plant — vegetative, reproductive and ripening.

(a) Seedling stage

(b) Tillering stage

(c) Stem elongation stage

(d) Panicle initiation stage

(e) Booting stage

(f) Heading and flowering stage

(g) Grain filling stage

(h) Grain maturity stage

(i) Seed germination stage

Fig. 4.3 (a-i): Different growth stages of paddy plant

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Vegetative phase

This phase spans from germination to panicle initiation and can be divided into four stages.

Seedling stage

The growth period of paddy plant from the emergence of radicle to the initiation of tillering is referred to as the 'seedling stage'. Normally, this stage takes 15–30 days to complete. Generally, the appearance of the fourth leaf indicates the end of the seedling stage.

Tillering stage

This stage starts with the emergence of the first tiller and ends when the maximum tiller number has reached. The tillering stage continues with the formation of secondary and tertiary tillers. Tillers that bear a seeded panicle with fully ripened grains are called 'effective tillers'.

Stem elongation stage

This stage may start before panicle initiation or may occur during the latter part of tillering. Therefore, there may be an overlap of tillering and stem elongation stages. Generally, the growth duration of a variety is related to stem elongation.

Reproductive phase

The reproductive phase represents the period from panicle initiation to panicle emergence and development. The reproductive phase of all varieties can be divided into three stages.

Panicle initiation and booting stage

This stage starts with the initiation of panicle primordium at the tip of the growing shoot. The panicle primordium is visible to the naked eye about 10 days after initiation. In this stage, three leaves will emerge before the panicle finally emerges from the flag leaf. Panicle initiation occurs first in the main culm or primary tillers, followed by secondary and tertiary tillers. As the panicle continues to develop, the spikelets become distinguishable. The young panicle increases in

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size and its upward extension inside the flag leaf sheath causes the leaf sheath to bulge or swell. This bulging of the flag leaf sheath is called 'booting'

Heading stage

This stage is also called the 'panicle exertion stage'. It is marked by the emergence of panicle tip from the flag leaf sheath. The panicle continues to emerge until it partially or completely protrudes from the sheath of the flag leaf.

Flowering stage

This stage starts when anthers protrude from the spikelets, and later, fertilisation takes place. The flowering process continues until most spikelets in the panicle start blooming. Flowering occurs a day after the heading stage. Generally, the florets open in the morning. It takes about seven days for all spikelets in a panicle to open and get fertilised.

Ripening phase

The ripening phase begins after fertilisation of the female part. It continues through grain filling, milking and drying periods, and lasts 25–35 days. Grain filling occurs as nutrients and water get transported to the grain. It can be broadly divided into three stages.

Milky stage

The endosperm contents offer a milky consistency at this stage. This stage is susceptible to attack by insect–pests.

Dough stage

In the dough stage, milky liquid starts to thicken into a sticky white paste due to the onset of drying process.

Maturity stage

In this stage, the leaves of the plant begin to turn yellow. One way to explain the maturity stage is the endosperm becoming opaque and hard. Also, when about 90 per cent of the total grains reach a stage of containing 25–30 per cent moisture level (ripened), the matured grains, usually, show a change in colour and turn golden brown.

Photo period sensitivity

It is a natural mechanism, depending on a plant's ability to distinguish differences in day and night length. Photo period sensitivity is crucial for the reproductive phase and causes the plants to initiate flowering at a given day length along with the temperature. Photo sensitive varieties cannot be grown across different seasons but insensitive ones can be sown at any time of the year or season.

Practical Exercise

Activity

Visit a paddy field and identify the different growth stages of the plants being grown there.

Material required: notebook, pen, pencil, camera or smartphone etc.

Procedure

- Visit a paddy field in your area.
- Observe the different stages of the plants being grown there.
- Note down your observations in the notebook.
- Click photographs of the paddy plants in different stages.
- Present your observations before the class.

Check Your Progress

A. Fill in the Blanks

1. A natural mechanism based on a plant's ability to precisely distinguish day and night length is called ______________.
2. The inflorescence of paddy plant is known as ________________.
3. A phase from panicle initiation to panicle emergence and development is termed ____________.
4. Paddy plants that cannot be grown across different seasons are called ______________ varieties.

B. Multiple Choice Questions

1. _________ stage is susceptible to attack by insect–pests.
   (a) Heading (b) Ripening
   (c) milky (d) dough

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2. What is the moisture per cent in a grain at maturity stage in paddy plant?
   (a) 5–10 (b) 10–15
   (c) 15–20 (d) 25–30
3. The endosperm becoming opaque and hard is called ________________ stage.
   (a) milky (b) dough
   (c) maturity (d) ripening
4. Panicle exertion stage is also known as ______________ stage.
   (a) heading (b) flowering
   (c) booting (d) ripening

C. Match the Columns

A	B
1. Tillers come out from	(a) External appearance of plant
2. Morphology	(b) Culm
3. Vegetative stage	(c) Leaves begin to turn yellow
4. Photo period	(d) Tillering stage
5. Maturity stage	(e) Day and night length

D. Subjective Questions

1. Describe the shoot and root systems of a paddy plant.
2. Explain the various vegetative stages of a paddy plant.
3. Explain the different stages that constitute the reproductive phase of a paddy plant.
4. Write short notes on the following.
   (a) Milky stage
   (b) Dough stage
   (c) Maturity stage

Unit 5

Intercultural Operations in Paddy

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Introduction

Intercultural operations are performed during seed sowing, crop growth and harvesting for better aeration and weed management. Weeding, fertiliser application, mulching, etc., are the basic activities of intercultural operations. Machinery and implements used for the purpose are called 'intercultural equipment'.

The major objective of intercultural operations is to minimise weed population. Generally, crop–weed competition occurs for moisture, nutrients, light and space. Weed competition causes yield loss in paddy, which may range from 10 to 90 per cent. Direct seeded and transplanted rice are the two major methods of paddy cultivation. Intercultural operations are more crucial for Direct Seeded Rice (DSR) as compared to transplanted rice. In fact, weeds are partially suppressed due to puddling and anaerobic or flooded conditions in case of transplanted rice. Thus, intercultural operations become important for managing weeds, providing aeration and maintaining regular crop geometry in paddy cultivation.

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INTERCULTURAL OPERATIONS DURING SOWING AND PLANTING

Intercultural operations for Direct Seeded Rice (DSR)

Many people, especially, in rural areas of the country, are shifting from agriculture to other sectors. As a result, there is scarcity of labourers and those available are costly for paddy transplanting. Besides, the depleting water level and environmental factors have made farmers adopt dry or DSR method. If machinery is locally available, both big and small farmers can easily adopt DSR method. Diversified weed flora is found in DSR cultivated area due to alternate wetting and drying. It reduces the yield considerably, if not controlled in time.

Stale seedbed technique

Stale seedbed technique is important, where weed seed bank is diversified. In this technique, weeds are facilitated to germinate and encouraged to grow. One to two irrigations are required for the germination of weed seeds before two to four weeks of sowing. After the germinated weeds attain a certain growth, tillage or non-selective herbicide is used to kill the weeds.

Physical practices

Removing weeds by hand (manually) or by machine (mechanically) come under physical practices. Labour scarcity limits hand weeding. Besides, it is costly. However, one or two rounds of hand weeding, along with herbicide application, are required to control weed population. Mechanical weeding is being widely used as it reduces the labour costs and does not cause damage to the crop as no chemical is used. Rotary weeder with motor and other hand weeders are used to remove weeds, particularly, in the DSR system.

Intercultural operations for transplanted rice

Intercultural operations are carried out by different methods. The selection of a method depends on the availability of labour, time, money and implements. It also depends on soil moisture and agro ecosystems.

Manual weeding

In manual weeding, the weeds are uprooted manually or by hand-operated equipment. In this operation, the soil surface is opened and pulverised. Hand weeding must be done at the tillering stage, i.e., 20–25 days after transplanting. Maintaining 5-cm water depth continuously from the rooting stage till 15–20 days before harvesting will keep weed growth in check. It also improves aeration and oxygen supply to the roots. The operation, however, is labour and cost intensive.

Mechanical weeding

Mechanical weeding is carried out in transplanted rice or DSR between rows. A hand-operated rotary weeder is used to carry out the weeding operation when the transplants are 15–20 days' old. This operation is repeated at an interval of 10–15 days till the panicle initiation stage. The equipment helps to cut and burry the weeds. The soil also gets pulverised up to a depth of 10–15 cm, which results in favourable soil conditions for the growth and development of roots, and increased number of tillers.

Intercultural operation in SRI

In SRI method, a conoweeder is used to control weed population. Conoweeder operation is a two-directional intercultural operation. It is easy to operate, where plant-to-plant and row-to-row distance is the same (square planting). A conoweeder must be used 10 days after transplanting. It helps the paddy crop in the following ways.

- Trampling and ploughing of weeds add nutrients to the soil.
- Frequent operation in the soil disturbs and buries the weeds, and facilitates aeration for decomposition, which improves soil health.
- The use of a conoweeder helps prune roots, which lead to increased number of tillers.
- Its use reduces the weeding cost.

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Intercultural operations in *biasi* rice

Biasi (beushening) is used for direct seeded lowland rice in Odisha, Chhattisgarh and Jharkhand and to some extent in West Bengal, Assam and Uttar Pradesh. *Biasi* is used to control weed population and optimise crop stand. This cultivation constitutes 80 per cent of the total rice area of Chhattisgarh. *Biasi* is an intercultural operation, which is done in a direct seeded paddy field by ploughing the area with a local wooden plough and *trifal* cultivator in standing water condition. It means that the crop is ploughed at a depth of 10–15 cm for 30–40 days after sowing, and then, planking or *chalai* is done. In *chalai*, the uprooted seedlings of paddy plants are manually planted in the same place or in gaps to maintain the plant population, and the weeds are buried in the soil by feet. Planking is, then, done to level the furrow, in which the weeds are suppressed into the mud and the paddy plants get established.

Practical Exercise

Activity 1

Demonstrate manual weeding in a paddy field.

Material required: *khurpi*, hand hoe, gumboot, gloves, etc.

Procedure

- Visit a paddy field.
- Identify common weeds present in the field.
- Identify the various tools used to carry out manual weeding.
- Remove the weeds manually.
- Observe the weed population after 15 days.
- Prepare a herbarium file consisting of the weed samples.
- Present your observations before the class.

Activity 2

Demonstrate mechanical weeding.

Material required: rotary weeder, gumboot, gloves, notebook, pen, pencil, etc.

Notes

Procedure

- Visit a nearby paddy field.
- Identify the common weeds found in the field.
- Use a rotary weeder to remove the weeds.
- Observe weed population in the field after 15 days.
- Note down your observations in a notebook and present it before the class.

Check Your Progress

A. Fill in the Blanks

1. ______________ operation in paddy plant is performed from sowing to harvesting.
2. The implements used for carrying out various intercultural operations are known as ____________ equipment.
3. Intercultural operations are more crucial for ____________ rice.
4. In ______________ technique, weed seeds are allowed to germinate, and are then, killed.
5. Intercultural operation improves ______________.
6. Hand weeding in paddy crop must be done after ________ days of transplanting.

B. Multiple Choice Questions

1. __________ herbicides are used in stale seedbed technique.
   (a) Selective (b) Non-selective
   (c) Systemic (d) Non-systemic
2. *In biasi* practice, intercultural operation is done in ___________.
   (a) standing water (b) dry field
   (c) moist field (d) None of the above
3. Diversified weed flora are found in ______________.
   (a) transplanted rice (b) DSR
   (c) SRI (d) nursery
4. Conoweeder operation is a _______-directional intercultural operation
   (a) one (b) two
   (c) three (d) four

NOTES

C. Match the Columns

A	B
1. Square planting	(a) Manual weeding
2. Weeding equipment in SRI	(b) *Trifal* cultivator
3. Cost and labour intensive	(c) SRI
4. *Biasi* (beushening) equipment	(d) Conoweeder

D. Subjective Questions

1. Describe intercultural operations carried out in direct seeded rice.
2. Write about the intercultural operations performed in *biasi* rice.
3. Explain stale seedbed technique.

Unit 6

Seed Production

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Introduction

There is a wide genetic variation in paddy plants across regions, which is because of genetic changes that keep occurring naturally by mutation, re-combination and other genetic or environmental factors. Plant breeders combine genes to develop more adaptable, competitive, healthy and productive varieties. Dwarf high yielding varieties (HYVs) have higher yield potential as compared to traditional tall varieties being cultivated for over centuries across the world.

Session 1: Methods of Seed Production

Seed is a reproduction unit of a flowering plant. But botanically, it is a matured ovule consisting of a living embryo with stored food material enclosed in a protective coat. A seed can produce a new plant. Among the various crop production inputs, seed is one of the most important components.

The purpose of seed production of improved varieties is to grow crops in different seasons and regions in varied growing conditions and production systems across the country. This justifies the wide presence of seed industry.

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Rice is a self-pollinated crop and its seeds can be produced from the previous harvest, except hybrids. For hybrids, the seeds need to be purchased for every new planting. A quality seed must:

- have genetic purity and uniformity.
- conform to the standards of a particular cultivar.
- be disease-free and viable.
- be free from admixtures of other crop seeds, weeds and inert matter.
- have acceptable uniformity with respect to size, shape and colour.

Importance of seed production

Seed is the basic input for crop production. Quality seed alone contributes to about 20–25 per cent of the crop output. However, this output can be further increased by up to 45 per cent with efficient management of other required inputs or resources. A superior quality seed not only increases crop productivity per unit area but also fetches higher price in market and enhances milling recovery, thereby, increasing the income of farmers. Seed purity is an important factor to be considered while producing paddy seed. Paddy is a self-pollinated crop so it is easy to maintain seed purity. The seed production systems for hybrids are not easy as paddy plant contains both male and female organs. Thus, cross pollination in paddy involves separate maintenance of male and female parents. The points that must be taken into account for seed production are as follows.

- Select a land that is free from weeds, soil-borne diseases and infections, etc.
- One must have knowledge about the cropping history of the field at the time of field selection.
- There must be sufficient isolation distance of the seed production field (as recommended) from other rice fields to avoid contaminants of foreign pollen.

Seed production system in India

The seed sector in India is of two types, namely formal and informal.

Formal seed sector

In this sector, seeds are produced scientifically (conventional method) and all certification procedures and standards to produce a particular variety of seed are followed.

Informal seed sector

It is the sector, farmers produce seeds without following the certification procedures and exchange it amongst themselves. It is a traditional method of seed production.

Table 6.1: Difference between scientific and traditional method of seed production

Scientifically produced seeds	Traditionally produced seeds
Planned seed production programme is followed.	No planned seed production programme is followed.
The seed production process follows quality standards, i.e., removal of diseased, off-type and weed plants.	No such process is followed.
Seeds have high germination percentage.	Germination percentage is not assured in such seeds.
Processing, treatment, packaging and labelling procedures are followed.	No such procedure is followed.
Controlled drying of seeds is done.	There is uncontrolled drying of seeds, which affects the seed quality.
Seeds are stored to maintain their vigour and viability.	The seeds are protected from insect–pests and diseases not for vigour and viability.
Seeds cannot be converted into grain unless directed by a seed inspector.	Seeds can be utilised for commercial grain purpose.
Varietal purity can be identified from its breeder seed.	Varietal purity is not known.

A seed production programme largely adheres to a series of successive generations, i.e., breeder, foundation and certified seed (see Table 6.2). There is a need to

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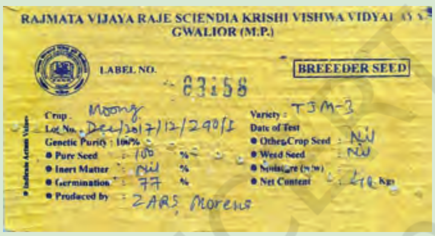
adopt safety measures and quality assurance principles in seed production system at all times so that a farmer gets the best seeds.

Table 6.2: Types of seed

S. No.	Seed type	Tag size and colour	Features
1.	Nucleus seed	Nil	• Not for sale and farmers' use • No physical impurity • Genetically, 100 per cent pure • Produced by authorised breeder or state agriculture universities or institutes • Isolation distance and production process followed strictly
2.	Breeder seed	12×6 cm Golden yellow colour  *Fig. 1: Breeder seed tag*	• Produced from nucleus seed • Produced under strict supervision for maintaining genetic and physical purity as per the set standards
3.	Foundation seed	15×7.5 cm White colour  *Fig. 2: Foundation seed tag*	• Produced from breeder seed • Can be produced by private or government agencies under strict supervision for standards by supervision agencies
4.	Registered seed	15×7.5 cm Purple colour	• Produced from foundation seed • Produced by registered seed growers • Genetic purity is maintained under specific standards

<table>
<tr><td>5.</td><td>Certified seed</td><td>15×7.5 cm
Azure colour


Fig. 3: Certified seed tag</td><td>• Produced from foundation seed
• Produced by registered seed growers under the supervision of seed certifying agencies
• Genetic and physical purity of seed as per the set standards ensured</td></tr>
<tr><td>6.</td><td>Truthful labelled seed</td><td>

15×10 cm
Opal green colour
Fig. 4: Truthful labelled seed tag</td><td>• Labelling is compulsory
• Seed must have gone through germination, viability and physical purity test</td></tr>
</table>

Isolation distance and rouging

Isolation

Optimum isolation is important to ensure genetic purity of parental and hybrid seeds. The isolation distance for cross-pollinated crops is 500 metre. Being a self-pollinated crop, paddy requires an isolation distance of 3–5 metre for a seed production plot. No other crop must be grown in this 'isolation distance area'. To further minimise chances of pollen contamination of the seed production plot from other genotypes, these practices can be followed.

- Physical barriers, such as natural means like mountains, forests and rivers can be used.
- Taller crops like sorghum (*jowar*), maize, pearl millet (*bajra*), sesbania (*daincha*), etc., can be

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grown around short stature crops like paddy, groundnut, chick pea, etc. These barrier crops are planted, covering a band of 3 metre all around the seed production plot.

Roguing

'Roguing' means identifying and removing plants of same species or crop with undesirable characteristics from a field to preserve the quality of the crop being grown there. It is important to maintain the purity of seeds of a genotype (variety or hybrids). It is a continuous process in the seed production plot as off-type plants may appear at any growth stage in the field. Roguing at different growth stages is discussed below.

Roguing at vegetative phase

Plants that appear different from the requisite or established features of the parental variety are removed (rogued out). Leaf shape, size, colour, leaf sheath, nodal or intermodal regions, plant height and other visible features can be used to identify rogues.

Roguing at flowering stage

Early and late flowering types, absence or presence of awns, panicle exertion, anther colour, panicle characteristics, etc., can serve as criteria for roguing out.

Roguing at maturity stage

It involves roguing out plants based on the size, shape and colour of the seeds.

Field inspection

A minimum of two inspections need to be conducted each during the vegetative and reproductive stage.

Tale 6.3: Isolation distance

Fields	Foundation seed plot	Certified seed plot
Fields of other varieties	3 m	3 m
Fields of same variety not conforming to varietal purity requirements for certification	3 m	3 m

Table 6.4: Specific requirements (maximum permitted)

Factors	Foundation seed (%)	Certified seed (%)
Off-types	0.05	0.02
Objectionable weed plants	0.01	0.02

Table 6.5: Seed standards

Factors	Standards for foundation seed	Standards for certified seed
Pure seed (minimum)	98%	98%
Inert matter (maximum)	2%	2%
Huskless seeds (maximum)	2%	2%
Other crop seeds (maximum)	10 seeds/kg	20 seeds/kg
Other distinguishable varieties (maximum)	10 seeds/kg	20 seeds/kg
Total weed seeds (maximum)	10 seeds/kg	20 seeds/kg
Objectionable weed seeds (maximum)	2 seeds/kg	5 seeds/kg
Seeds infected by paddy bunt (maximum)	0.1%	0.5%
Germination (minimum)	80%	80%
Moisture (maximum)	13%	13%
For vapour-proof containers (maximum)	8%	8%

Practical Exercise

Activity

Perform roguing in a paddy field.

Material required: sickles, *khurpi*, gumboot, gloves, herbarium file, pen, pencil, eraser, etc.

Procedure

- Visit a nearby paddy field.
- Identify weeds and off-types of paddy plant being grown there.
- Rogue the off-type plants and weeds.
- Prepare a herbarium file and note down the characteristics of the weeds found there.
- Present it before the class.

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Check Your Progress

A. Fill in the Blanks

1. Seed is a ____________ unit of a flowering plant.
2. Botanically, seed is a matured ____________.
3. The seed sector in India is of two types, namely ____________ and ____________.
4. An isolation distance required for a seed production paddy plot is ____________ metre.
5. A practice of identifying and removing undesirable characteristics in plants from a field is called ________.

B. Multiple Choice Questions

1. Seed production technique involves _______________.
   (a) isolation distance (b) roguing
   (c) seed standards (d) All of the above
2. Standard for certified seeds for minimum germination is __________ per cent.
   (a) 92 (b) 80 (c) 96 (d) 98
3. Field inspection must be done at the _____________ stage.
   (a) vegetative (b) reproductive
   (c) nursery (d) Both (a) and (b)
4. Breeder seed is produced from _______________ seed.
   (a) nucleus (b) foundation
   (c) certified (d) registered

C. Match the Columns

A		B	
1.	Breeder seed	(a)	Opal green colour
2.	Foundation seed	(b)	Azure blue colour
3.	Certified seed	(c)	Golden yellow colour
4.	Truthful labelled seed	(d)	White colour

D. Subjective Questions

1. Describe the types of seed sector in India.
2. Why is isolation distance needed for seed production?
3. Discuss the seed standards for paddy varieties.
4. Write short notes on the following.
   (a) Nucleus seed
   (b) Breeder seed
   (c) Foundation seed
   (d) Certified seed

Session 2: Improved and Indigenous Rice Varieties in India

Notes

Improved crop varieties had played a prominent role in the inception of Green Revolution in India. These are high yielding varieties (HYVs) and are resistant to diseases and insect–pests. It is, therefore, important to emphasise on the production of quality seeds of high yielding varieties or hybrids of field crops. The Government of India has consistently been trying to bring about qualitative improvement in seeds in order to increase the yield. Efforts are also underway to ensure that the seeds and fields are free of diseases and insect–pests, and are drought resistant.

High Yielding Variety

High Yielding Variety (HYV) seeds were the basic component of Green Revolution. HYVs yield higher crop productivity per unit area. These varieties are typically dwarf in stature, non-lodging, highly responsive to fertilisers, irrigation and other farm inputs. Some of them mature early.

Table 6.6: HYVs of rice for upland ecosystem

Name of the variety	Year of release	Duration (days)	Yield potential (t/ha)
Anjali	2003	90	3.5
Sadabahar	2003	105	3.5
Hazari dhan	2003	120	5
Virendra	2006	90	4.5

Upland rice ecosystem

Paddy crop occupies an area of about 6 million ha (3.5 per cent of the total area). The main upland rice growing States are West Bengal, Bihar, Assam, Chhattisgarh, Odisha, north-eastern hill region and eastern Uttar Pradesh. This area mostly practices DSR cultivation. Productivity of this ecosystem is low, unpredictable and unstable due to drought, weeds, less fertile soil, nutritional imbalances, poor cultural practices, poor yielding cultivars, higher incidence of diseases and insect–pests, etc.

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Irrigated rice ecosystem

Under this ecosystem, paddy crop is cultivated in about 22 million hectares (49.5 per cent of the total area under rice cultivation). Irrigated and wetland rice necessitates the construction of bunds, which help in effective and efficient use of water resources, including rains. The major irrigated rice cropping systems in India are rice–rice, rice–rice–rice and rice–wheat. Yields of 4–5 t ha^{-1} are common. HYVs suitable for this system are shown in Table 6.7.

Table 6.7: HYVs of rice for irrigated ecosystem

Name of the variety	Duration (days)	Yield potential (t/ha)
Satabdi	120	8
Naveen	120	5
Geetanjali (aromatic)	135	5
Rajalaxmi (hybrid)	135	7
Ajay (hybrid)	135	7
Abhishek	120	5
Chandrama	125	5
Satya Krishna	135	5.5–6
Chandan	125	5.5–6

Hybrid rice

Hybrid varieties of rice are more robust, tillering, nutrient responsive, higher yielding and better than common HYVs. Hybrids are less susceptible to diseases, drought and other agronomic vagaries. Hybrid rice cultivation has picked up pace since the last decade. It is popular in Uttar Pradesh, Bihar, Jharkhand, Madhya Pradesh and Chhattisgarh. Hybrid rice cultivation is bound to emerge as a private sector seed industry. Hybrids with new features are being introduced in India every year.

Table 6.8: State-wise rice hybrids recommended in India

State	Hybrids
Andhra Pradesh	APHR–1, APHR–2, PHB–71, PA–6201, PA–6444, RH–204, *Suruchi*, DRRH–1, GK–5003, PAC–837, US–312, DRRH–3, NK–5251
Bihar	KRH–2, PA–6201, *Ganga*, JKRH–401
Chhattisgarh	*Indra Sona*, *Suruchi*, HRI–157, DRH–775, PAC–837
Delhi	PRH–10
Gujarat	*Suruchi*, KRI–157, PAC–835, PAC–837, DRRH–3, NK–5251
Goa	KRH–2
Haryana	PRH–10, *Ganga*, HKRH–1, PHB–71, RH–204, *Suruchi*, DRRH–2, *Sahyadri*–4
Karnataka	KRH–1, KRH–2, PHB–71, PA–6201, PA–6444, RH–204, *Suruchi*, GK–5003, PAC–837, HRI–157, US–312, NK–5251
Maharashtra	KRH–2, PA–6444, *Suruchi*, *Sahyadri*–1, *Sahyadri*–2, *Sahyadri*–3, *Sahyadri*–4, NK–5251
Madhya Pradesh	PA–6201, JRH–4, JRH–5, JRH–8, HRI–157, DRRH–3
Odisha	KRH–2, PA–6201, PA–6444, *Ganga*, *Suruchi*, *Rajlaxmi*, *Ajay*, JKRH–401, PAC–835, DRRH–3
Punjab	PRH–10, *Ganga*, PHB–71, PA–6129, *Sahyadri*–1
Puducherry	KRH–2, PA–6129, HRI–157
Rajasthan	KRH–2, RH–204
Tamil Nadu	ADTRH–1, CORH–3, CORH–2, PHB–71, PA–6201, RH–204, DRRH–2, PA–6129, US–312, MGR–1, KRH–2, NK–5251
Tripura	PA–6201, KRH–2, PA–6444
Uttar Pradesh	HRI–157, US–312, DRRH–3, KRH–2, *Pant Sankar Dhan*–1, *Pant Shankar Dhan*–3, PHB–71, PA–6201, PA–6444, *Narendra Sankar Dhan*–2, PRH–10, *Ganga*, *Narendra Usar Sankar Dhan*–3, *Sahyadri*-4
Uttarakhand	DRRH–2, RH–204, *Pant Shankar Dhan*–1, PA–6444, *Pant Sankar Dhan*–3, *Ganga*
West Bengal	KRH–2, CNRH–3, PA–6201, DRRH–2, JKRH–401, *Sahyadri*–4, DRH–775, US–312
Jharkhand	DRH–775
Jammu and Kashmir	PA–837

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Aromatic rice

There exists a number of rice varieties or hybrids that are aromatic. All *basmati* rice varieties are aromatic. But all aromatic rice varieties are not *basmati*. *Basmati* rice is mainly produced in the Indo-Gangetic plains. Best quality *basmati* rice is produced in warm, humid and valley-like conditions. Some of the important aromatic rice varieties are given in Table 6.9.

Table 6.9: Aromatic rice varieties in India

Variety	Duration (days)	Yield (t/ha)	States	Remark
Pusa RH-10 hybrid	125	5–5.5	Punjab, Haryana, Delhi, Western Uttar Pradesh and Uttarakhand	Moderate resistance to blast disease and fine grained
Pusa *Sugandha–2*	125–130	4.0–5.0	Punjab, Haryana, Delhi, Western Uttar Pradesh and Uttarakhand	Moderate resistance to blast and fine grained
Pusa *Sugandha–3*	125–130	4.0–5.0	Punjab, Haryana, Delhi, Western Uttar Pradesh and Uttarakhand	Moderate resistance to blast disease and fine grained
Basmati	130–140	4.5–5.0	Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Delhi, Uttarakhand and Western Uttar Pradesh.	Resistant to blast disease and long slender grains
Pusa *basmati*–1718	136–138	4.5–5 t/ha	Delhi, Punjab and Haryana	Resistant to bacterial leaf blight
Pusa *basmati–1728*	140–145	5–6 t/ha	Punjab, Haryana, Delhi, Uttarakhand and Western Uttar Pradesh	Bacterial wilt resistant
Pusa *basmati–1637*	130	4.2 t/ha	Western Uttar Pradesh, Uttarakhand, Punjab, Haryana and National Capital Region of Delhi	Bacterial wilt resistant
Pusa *basmati–1509*	115	5 t/ha	Punjab, Haryana, Delhi, Western Uttar Pradesh, Uttarakhand and Jammu and Kashmir	Non-lodging and non-shattering
Pusa *basmati–1609*	120	4.6 t/ha	—	—

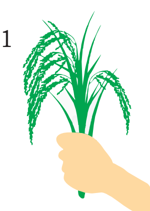
Improved Pusa *basmati–1*	—	—	Punjab, Haryana, Delhi, Western Uttar Pradesh, Uttarakhand and Jammu and Kashmir	Resistance against bacterial leaf blight disease
Pusa *basmati–1121*	145	4.5 t/ha	Punjab, Haryana, Delhi, Western Uttar Pradesh, Uttarakhand and Jammu and Kashmir	—
Pusa *basmati–1401*	140-145	5 t/ha	Punjab, Haryana, Western Uttar Pradesh and Uttarakhand	—
Pusa *basmati–1*	135–140	5–5.5 t/ha	Punjab, Haryana, Delhi, Western Uttar Pradesh, Uttarakhand and Jammu and Kashmir	—
Pusa–1592			Punjab, Haryana, Delhi, Western Uttar Pradesh, Uttarakhand and Jammu and Kashmir	Extra-long slender translucent grain with strong aroma
Pusa rice hybrid–10	110–115	7 t/ha	Delhi, Haryana and Uttarakhand	—

Aerobic rice varieties

Aerobic rice varieties are grown in well-drained, non-puddled and sporadic irrigation areas, and have an average yield of 4–5 tonnes per hectare. These are mostly cultivated on levelled and flat lands, where rains, with or without supplementary irrigation, are sufficient to support the crop for a full season. Aerobic rice is grown on a large scale in our country. Under this system, there is relatively more weed growth as compared to transplanted paddy and may encounter more species of weeds. Therefore, there is a need to control weeds by mechanical, chemical or integrated means. It is recommended to grow aerobic rice in rotation with the usual cropping system and other crops suitable for the given area.

Improved or recommended rice varieties for aerobic conditions in India

It has been found that most HYVs suitable for irrigated or wetland conditions are good for DSR in States



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like Uttar Pradesh, Punjab, Haryana, Chhattisgarh, West Bengal, Bihar, etc. Besides, varieties like CR *Dhan*–200, *Piyari* (Odisha), CR *Dhan*–201 (Chhattisgarh and Bihar), CR *Dhan*–202 (Jharkhand and Odisha) and CR *Dhan*–204 (Jharkhand and Tamil Nadu) are suitable for aerobic rice cultivation. Rice varieties released by the University of Agricultural Sciences (UAS), Bengaluru, for DSR are ARB–6, MAS 946–1, MAS–26.

Practical Exercise

Activity

Identify common high yielding varieties of paddy.

Material required: practical file, pen, pencil, eraser, etc.

Procedure

- Visit the nearby paddy field.
- Talk to the farmer and identify the different varieties of paddy being grown there.
- Note down the names of the varieties that you have identified in the field.
- Write down the characteristics of the varieties that you have identified.
- Write down the growing purpose of each variety.
- Present it before the class.

Check Your Progress

A. Fill in the Blanks

1. High ______________ varieties were the basic component of Green Revolution.
2. *Virendra* variety of rice was developed in the year ____________.
3. *Basmati* rice has a special characteristic of having an ____________.
4. *Basmati* rice is mainly produced in the ____________ plains of India.
5. *Basmati* rice is resistant to ____________ disease.

B. Multiple Choice Questions

1. What is the maturity period of RH–10 hybrid rice variety?
   (a) 110 days (b) 125 days
   (c) 140 days (d) 150 days

2. The total area under irrigated rice in India is about __________ million hectares.
   (a) 12 (b) 22 (c) 42 (d) 32
3. Popular rice varieties played an important role in __________.
   (a) Green Revolution (b) Brown Revolution
   (c) Yellow Revolution (d) White Revolution
4. *Satabdi is* a high yielding paddy variety, which has an yield potential of about _________ tonne/ha.
   (a) 5 (b) 7 (c) 8 (d) 10

C. Match the Columns

A Variety	B Duration (days)
1. *Abhishek*	(a) 105
2. *Basmati*	(b) 90
3. *Anjali*	(c) 120
4. *Sadabahar*	(d) 130–140

D. Subjective Questions

1. Differentiate between the following.
   (a) HYVs and hybrids
   (b) Aromatic and aerobic rice varieties
2. Name two aromatic rice varieties produced in India.
3. Describe the aromatic rice varieties cultivated in different ecosystems of India.

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Session 3: Traits of Rice Varieties

As already mentioned, a number of rice varieties are grown in India. However, the quality of a rice variety is judged by its grain, such as its size, taste, aroma when cooked and colour. Besides, the variety must have optimum yield potential and stability over seasons.

Abiotic stress

Factors, such as extreme low and high temperature, drought, waterlogging or flooding, salinity, etc., adversely affect the growth of plants, yield and seed quality of crops.

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Table 6.10: Rice hybrids tolerant to abiotic stress conditions

S. No.	Abiotic stress	Suitable hybrids
1	Rain-fed or upland	*Pant Sankar Dhan*–1, *Pant Sankar Dhan*–3, DRRH–2, KJTRH–4
2	Summer season	*Rajlaxmi*, CRHR–32, CRHR–4
3	Alkaline soil conditions	PHB–71, *Suruchi* (MPH–5401), JKRH–2000, DRRH–2, DRRH–2, CRHR–5, DRRH–44
4	Salinity (soil or water)	DRRH–28, JRH–8, PHB–71, *Pant Sankar Dhan*–3, KRH–2, HRI–148

Biotic stress

Biotic stress is caused by pathogens, insect–pests, weeds or intra-specific competition for resources, causing yield or quality loss.

Disease and insect–pests resistant varieties

Some institutions have been working on developing rice varieties and hybrids with an aim to introduce disease resistance in the crop. These developed varieties are high yielding, have resistance to diseases and are environment friendly. Improved *Samba Masuri* is resistant to bacterial blight and gives 15–30 per cent higher yield than other varieties that are not resistant to the disease.

Rice varieties to check malnutrition

Rice, though a staple crop in India and the world, is not a rich source of iron, zinc or Vitamin A. Insufficient iron intake may cause anaemia, retard brain development, and increased mortality, especially among women and children. If Vitamin A deficiency persists for a longer period, it may cause blindness. A variety called 'golden rice', which is the first of the Genetically Modified rice varieties, having high beta-carotene content, can help fight malnutrition problem. Other varieties fortified with zinc and iron are likely to be available in market in few years that will also help fight the problem.

Red rice varieties in India

Red rice (*O. longistaminata* and *O. punctata*) is a variety that is red in colour due to the presence of anthocyanin, which is a powerful antioxidant and may help boost the immune system. Coloured rice is, usually, eaten un-hulled or partially hulled, and has a red husk and nutty flavour. Such a variety is rich in manganese, which strengthens plant metabolism. Likewise, magnesium helps in minimising the risk of migraine, blood pressure and heart problems. Red rice is, specifically, typical to the Himalayan and sub-mountainous areas like southern Tibet, Bhutan, etc. Several varieties in Madhya Pradesh, Maharashtra, as well as, southern India are also coloured. The varieties of red rice include the following.

Matta rice

This rice produced in Kerala is also known as 'red parboiled rice', '*Palakkadan Matta* rice', '*Rosematta* rice' and 'Kerala red rice'. It is an indigenous variety grown in Palakkad district of Kerala. It is popularly consumed in Kerala and Sri Lanka, for making idli, *appam* and is also eaten simply steamed.

Bhutanese red rice

It is medium grain rice native to Bhutan in the eastern Himalayas.

Thai red cargo rice

It is a non-glutinous long grain rice variety popular in Thailand and adjoining countries.

Practical Exercise

Activity

Identify biotic stress in a paddy field.

Material required: pen, pencil, notebook, etc.

Procedure

- Visit a nearby paddy field.
- Observe and identify the different types of biotic stress in the field.
- Note down the types of biotic stresses that you observe in the field.
- Present it before the class.

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Check Your Progress

A. Fill in the Blanks

1. Biotic stress factors are caused by pathogens, insect–pests and __________.
2. The improved variety '*Samba Masuri*' carries resistance to _________.
3. The first Genetically Modified rice variety having high content of beta-carotene is ________.
4. *Matta* rice of Kerala is also known as red ______________ rice.

B. Multiple Choice Questions

1. Red coloured variety of rice has ______________ content.
   (a) anthocyanin (b) chlorophyll
   (c) carotene (d) lycopene
2. Thai red cargo rice variety is known for its _________.
   (a) non-glutinous nature (b) long grain
   (c) glutinous nature (d) Both (a) and (b)
3. A variety that can help manage malnutrition problems is ______________.
   (a) red cargo rice (b) golden rice
   (c) glutinous (d)Both (a) and (b)
4. A suitable upland or rain-fed rice variety is ____________.
   (a) *Pant Sankar Dhan*–1 (b) *Pant Sankar Dhan*–3
   (c) DRRH–2 (d) All of the above

C. Match the Columns

A	B
1. Red rice	(a) JRH-8
2. *Matta* rice	(b) Summer season variety
3. Salinity tolerant	(c) Indigenous rice of Kerala
4. *Rajlaxmi*	(d) *O. punctata*

D. Subjective Questions

1. Describe the following.
   (a) Biotic stress
   (b) Abiotic stress
   (c) Varieties of rice for malnutrition problems
   (d) Red rice varieties in India

Unit 7

Water Management

Introduction

Paddy cultivation dominates irrigated agriculture in India and world. Having the required water supply is the most important factor in paddy cultivation. In many tropical region areas, paddy plants suffer either from too much or too less water supply because of irregular rainfall and landscape patterns. Water management includes supplying the required amount of water for optimum crop yield and the best use of limited water supply. Management of water and irrigation system is essential, especially, for farmers who depend on stored water for irrigation. It enables water supply for irrigation during dry season.

> "Around 1300–1500mm is a typical amount of water needed for irrigated rice in Asia. Irrigated rice receives an estimated 34–43 per cent of the total world's irrigation water, or about 24–30 per cent of the entire world's developed freshwater resources."
>
> *Rice Knowledge Bank, International Rice Research Institute*

Session 1: Water Requirement of Paddy

Water is vital for the growth of plants. 'Water requirement' is defined as water required by a crop for optimum growth and development. This requirement may be met by natural precipitation or artificially by irrigation.

Average water requirement

During the entire crop period, the average water requirement of paddy is 1100–1250 mm. It depends on the duration of a variety, characteristics of soil and agro-climatic conditions. However, there is a difference between the field requirement of water and the need

Fig. 7.1: Paddy crop at tillering stage

of the crop to complete its life, depending on the cultivation method adopted. The water requirement of paddy crop under SRI system is 700–800 mm. The average use of water varies from 5 to 8 mm/day.

Critical crop growth stages for irrigation

Critical stage of water requirement refers to a condition, where water stress causes severe reduction in the yield. It is also known as 'moisture sensitive period'. Critical stages of water requirement (when irrigation must be provided) are as follows.

Active tillering

During this phase, there is an increase the number of tillers and height of the plant, which thereby, increases the dry weight.

Panicle initiation

Panicle initiation is the start of the reproductive phase, i.e., the actual panicle or head begins to form just below the flag leaf.

Booting

The entry of paddy plant into the reproductive phase is marked by the bulging of the top leaf stem that conceals the developing panicle. It is called 'booting' or 'flag leaf' stage.

Heading

Heading stage is identified by the emergence of panicle tip from the flag leaf sheath.

Flowering

Flowering begins a day after the completion of the heading stage.

During all these stages, the irrigation schedule must be strictly adhered to unless there is a rain. A reduction in moisture level below the soil saturation level may be avoided. This requirement of paddy plant at the stated growth stages is applicable to all systems of paddy cultivation, i.e., SRI, wet planting and DSR.

Table 7.1: Stage-wise water requirement for paddy

Stage of growth	Water requirement (mm)	Total water requirement (%)
Nursery	44	3.25
Main field preparation	200	16.12
Planting to panicle initiation	458	37
Panicle initiation to flowering	417	33.66
Flowering to maturity	125	10

(Source: Water management, TNAU Agritech Portal)

Practical Exercise

Activity

Visit a nearby paddy field and identify the critical stages for water requirement in the paddy plants being grown there.

Material required: pen, pencil, eraser, notebook, etc.

Procedure

- Visit the nearby paddy field.
- Note down the age of the paddy crops being cultivated there.
- Identify the critical stages of water requirement in the paddy plants.
- Note down your observations and present them before the class.

Check Your Progress

A. Fill in the Blanks

1. The water requirement of paddy crop under SRI system is ____________ mm.
2. _____________ stage of water requirement refers to a condition, where water stress causes severe reduction in the yield.
3. The flag leaf stage is also known as the __________ stage.

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4. The average water requirement of paddy plants for main field preparation is ________ mm.

B. Multiple Choice Questions

1. __________ can be grown under submerged conditions.
   (a) Groundnut (b) Soybean
   (c) Paddy (d) Maize
2. A stage of crop growth that comes before the heading stage is ___________.
   (a) active tillering (b) flowering
   (c) booting (d) panicle initiation
3. The average water requirement of paddy during the entire crop life is _________ mm.
   (a) 800–1000 (b) 1100–1250
   (c) 1500–1650 (d) 1600–1850

C. Match the Columns

A (Stage of growth)	B (Water requirement in mm)
1. Nursery	(a) 200
2. Main field preparation	(b) 44
3. Planting to panicle initiation	(c) 417
4. Panicle initiation to flowering	(d) 125
5. Flowering to maturity	(e) 458

D. Subjective Questions

1. What do you understand by water requirement.
2. Describe the different critical crop growth stages of paddy.

SESSION 2: METHODS OF IRRIGATION

Paddy is the only cereal crop that can stand water submergence. Continuous flooding provides best growth environment for the plant. The soil must be kept saturated throughout the growth period. One of the features favourable to crop production is the elimination of moisture stress. In a transplanted field, about 3-cm water level needs to be maintained, which can steadily be increased to 5–7 cm, according to the growth of the plant until the field is drained 7–10 days before the harvest. In case of wet direct seeded rice, the field must be flooded only once when the plants attain 3–4 leaf stage and light flooding must be ensured in the field. Natural selection pressure (flooding, submergence, drought, biotic stress and nutrient) has led to diversity in paddy agro-ecosystems.

Irrigation methods

Continuous submergence

Continuous submergence of paddy field is practised to increase the availability of nutrients to the plants. It is also helpful in weed management. The submergence of the field with shallow water (up to 5 cm deep) throughout the crop period is favourable for better yield.

Table 7.2: Submergence depth at different stages

Growth stages of paddy crop	Depth of water level (cm)
At the time of transplanting	2
Three days after transplanting	5
Three days after transplanting till maximum tillering stage	2
At maximum tillering stage (only in fertile fields)	Drain the water for three days
From maximum tillering to panicle initiation stage	2
Panicle initiation to 21 days after flowering	5

Source: Water management, TNAU Agritech Portal

Continuous flowing irrigation

- Standing water in lowland rice minimises the irrigation requirement of plants.
- Continuous irrigation increases nitrogen losses from the soil.
- Flowing water from one field to another increases the yield by preventing accumulation of harmful salts in the soil.

Fig. 7.2: Continuous flowing irrigation

Notes

Intermittent submergence

- Intermittent submergence implies submergence during the critical stages of the crop. This practice involves maintenance of soil saturation alternated with drying up to hair cracking stage during the various crop stages.
- Intermittent period between saturation and drying varies from one to nine days, depending on the rainfall pattern and soil texture.
- In order to minimise irrigation requirement in the field, intermittent submergence helps save about 30 per cent water.

Rotational irrigation

- This system of irrigation falls within the realm of Alternate Wetting and Drying (AWD) strategy.
- Irrigation water is applied at regular intervals. However, the irrigation interval is adjusted to ensure that there is no water deficit at any period.
- Shallow submergence is advantageous during the critical period of crop growth.
- The SRI system of cultivation uses this strategy of irrigation.

Precautions for irrigation

- Withhold water for few days till the seedlings are established.
- Field-to-field irrigation could carry pathogens from one field to another.
- Drain the field water two days before the application of fertilisers.
- If irrigation facilities are not available, rainwater harvesting must be carried out by making 25–30 cm bunds around the field.
- To minimise water loss by percolation, it is advisable to maintain the water level at a depth of 5 cm or less.
- At the tillering and flowering stage, the water must be drained out completely for 5–7 days, which helps regulate oxygen supply at plant roots and remove toxic substances (sulphides).

Practical Exercise

Activity

Demonstrate rotational irrigation method in a paddy field.

Material required: spade, *khurpi*, gloves, gumboot, etc.

Procedure

- Apply required amount of irrigation water in the paddy field at regular intervals.
- Measure the water depth in standing water with a scale.
- Observe the weed population and plant growth in the field.
- Note down your observations and present them before the class.

NOTES

Check Your Progress

A. Fill in the Blanks

1. A cereal crop that can withstand water submergence condition is ___________.
2. Wet direct seeded rice field needs to be flooded only once when the plants attain _____________ leaf stage.
3. Continuous submergence of a paddy field increases the availability of ___________.

B. Multiple Choice Questions

1. Intermittent submergence irrigation method saves irrigation up to _________ per cent.
   (a) 20 (b) 30
   (c) 40 (d) 50
2. ____________________ irrigation method is suitable for preventing accumulation of harmful salts in a paddy field.
   (a) Continuous flowing
   (b) Rotational
   (c) Continuous submergence
   (d) Intermittent submergence
3. How many methods are used for rice irrigation?
   (a) Three (b) Four
   (c) Five (d) Six

C. Match the Columns

A		B	
1.	Flood irrigation is applied in	(a)	Tillering and flowering stage
2.	Water level for rice	(b)	Alternate wetting and drying
3.	Intermittent submergence	(c)	up to 5 cm
4.	Water is drained out at	(d)	Paddy crop

D. Subjective Questions

1. Describe the methods of irrigation used in paddy cultivation.
2. What are the precautions that need to be taken during irrigation?

Session 3: Alternate Wetting and Drying, and Water Use Efficiency

Alternate wetting and drying (AWD)

It is a technique that decreases water consumption in a paddy field without reducing the yield. In this method, irrigation is carried out when there is no stagnant water. The gap between flooded and non-flooded soil can vary from two to over eight days. It depends on various factors, such as weather, crop growth stage and soil type.

Fig. 7.3: Panipipe (field water tube)

Implementation of AWD

To implement this technique, a field water tube is used to monitor water depth in the field. The water level will gradually reduce after irrigation. When the water level reaches 15 cm below the soil surface, irrigation needs to be carried out up to a depth of about 5 cm. Re-irrigation must be carried out to maintain the water level before and after one week of flowering. After flowering, during grain filling and ripening stages, irrigation can be allowed to drop again to 15 cm below the soil surface.

The field water tube for monitoring purpose may be made with 30-cm long (plastic or bamboo) pipe having 10–15 cm diameter to provide clear visibility for the water table and for easy removal of the soil trapped inside. It is perforated with many holes all round to enable water flow in and out of the tube. The tube is hammered into the field, leaving 15 cm top portion to protrude above the soil surface. Make sure not to penetrate deeper than the plow pan surface. Before the tube is ready for work, it is cleaned from the inside so that its bottom is visible. Check if it is installed correctly by pouring water into it and examine for leakage through holes on the tube. After the insertion of the monitoring tube, it is irrigation alert when water level in the tube is 15 cm below the soil surface. Check if water level both inside and outside the tube is same when the field is flooded. If it is not same as outside even after few hours, it is likely that the holes of the tube are choked and the tube needs to be reinstalled or relocated (Fig. 7.3).

Advantages of AWD method

The AWD method helps save water by about 35 per cent without reducing the yield. It increases water use efficiency to about 20 per cent more than flood irrigation method. It improves both the quality and yield, besides minimising the irrigation cost. Hence, AWD method increases the profitability of farmers.

Studies have shown that AWD method also reduces methane (CH_4) emission. CH_4 is produced by anaerobic decomposition of organic matter in wet or flooded paddy fields. When water level is allowed to drop below the soil surface, anaerobic condition is waived for some time till re-flooding.

Water use efficiency

It is the outcome of processes operating during the life of a crop to determine the yield (Y) and evapo-transpiration (ET). Water use efficiency (WUE) can be defined as the yield of plant [grain or whole plant biomass in t/ha (Y), per unit of water used by crop (litres of water lost by crop as ET). In other words, WUE=Y/ET.

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Measures to increase water use efficiency

- Puddling and levelling minimise water loss primarily through the soil (percolation losses), thereby, saving water requirement by up to 20 per cent.
- One ploughing with a mouldboard plough, followed by puddling twice gives the best result in terms of crop establishment, water use efficiency and yield.
- Maintain 2–3 cm of water up to seven days of transplanting for better seedling establishment.
- During summer and winter, loamy soil must be irrigated after 1–3 days of disappearance of water in the field.
- Water stress at the time of rooting and tillering stage drastically reduces the yield.
- Due to inadequate drainage conditions, roots of the plants decay and show leaf senescence. There is also a delay in the heading stage resulting in poor quality of grains.

Practical Exercise

Activity

Demonstrate AWD irrigation method in a paddy field.

Material required: field water tube, measuring scale, practical file, pen, pencil, eraser, etc.

Procedure

- Visit a nearby paddy field and select a plot.
- Irrigate it as per the recommendation.
- Insert a field water tube in the irrigated plot.
- Measure the water depth after irrigation and drying.
- Note down your observations in your practical file.
- Present it before the class.

Check Your Progress

A. Fill in the Blanks

1. Alternate wetting and drying technique decreases _______________ consumption in a paddy field.

2. Field water tube is used to measure the ___________ of water.
3. AWD reduces the emission of ___________.
4. WUE stands for _____________.

B. Multiple Choice Questions

1. _____________ greenhouse gas is emitted maximum in a paddy field.
   (a) HFC (b) CFC
   (c) Co (d) CH_4
2. AWD technique can save water up to _______ per cent.
   (a) 35 (b) 40
   (c) 45 (d) 50
3. AWD method helps increase the ______________.
   (a) yield (b) harvesting time
   (c) sowing time (d) number of irrigations

C. Match the Columns

A		B	
1.	Greenhouse gas	(a)	method
2.	Water stress during rooting and tillering stage	(b)	Saves water
3.	Alternate wetting and drying	(c)	Drying
4.	Soil crack	(d)	CH_4
5.	Water use efficiency	(e)	Reduces the yield

D. Subjective Questions

1. What is the importance of alternate wetting and drying method of irrigation?
2. How can water use efficiency be measured?

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Unit 8

Integrated Nutrient Management

Introduction

Integrated Nutrient Management (INM) refers to the combined use of organic, inorganic and bio-fertilisers, and inclusion of blue green algae or *azolla*, etc., to meet the nutritional requirements of a crop. It also includes different sources of nutrient supplementation to create a conducive environment for soil conditioning in order to build soil fertility. The carbon and nitrogen ratio (C:N ratio) of the soil is maintained under INM, which in turn provides highly favourable conditions for crop performance.

Session 1: Soil Sampling and Analysis

Paddy plant takes relatively small amounts of nutrients in the early stages of growth but the quantity intake increases as the plant grows. However, as the plant grows, the daily nutrient intake increases. So, there is a need to provide adequate nutrients to a plant during its developing stages. It is, therefore, necessary to check the nutrient status of soil every year or at an interval of two to three years. This will help in:

- avoiding indiscriminate use of fertilisers (which can be expensive, as well as, wasteful) and ensuring environmental safety.
- maintaining and restoring soil fertility to ensure crop productivity, profitability and sustainability.

To know the status of various nutrients, soil fertility level, pH, etc., by soil testing, it is important to know the fertility status and physical properties of the soil. This will enable maximum production and rational soil management. A soil test programme consists of three basic steps.

- Soil sampling
- Soil sample analysis
- Soil test interpretation

Purposes of soil testing

- It helps evaluate and improve soil productivity.
- It determines the nature of the soil, i.e., alkalinity, salinity or acidic.
- It helps make appropriate use of fertilisers.
- It reveals the condition of soil so that it can be improved with the application of necessary nutrients and implementing other management practices.

Soil sampling

Soil tests and their interpretations are based on the collection of soil samples, and their analysis. Therefore, the samples must be collected in a zigzag pattern from various points, which represent the whole field. To obtain right information about the nutrient status of the soil, it is important to follow the correct procedure of soil sampling.

Fig 8.1: Hand auger to draw soil sample

Before sampling information about the cropping pattern, various management practices being followed in the field, variation along with direction of the slope, soil colour and texture need to be noted. Then, the field from where the samples have to be collected must be divided into sections according to variations in slope and texture, and separate samples need to be collected from each section by using sampling tools like hand auger (Fig. 8.1). Soil samples can also be collected with the help of a spade or *khurpi* by giving a slanting cut to the soil at up to 15 cm depth, creating a 15-cm wide V–notch (triangular/V–shape cut, Fig. 8.2).

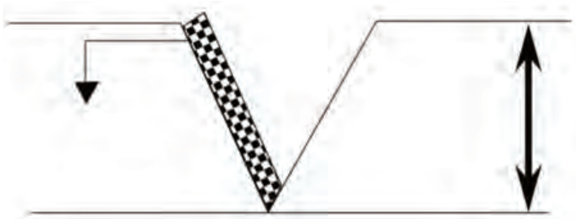

Fig. 8.2: Soil sampling by V-notch method

The samples must be collected from plough depth, i.e., 15 cm for normal agronomic crops and from deeper zones, i.e., 15–30 cm for deep-rooted crops at different spots, and then, all are mixed thoroughly. This composite soil sample is then spread on a clean sheet. It is divided into four equal parts. Two opposite quarters are rejected and the samples from the other two are mixed. To obtain the desired size of the sample (500 g), the procedure is repeated. Before sending the sample to a laboratory, it must be dried and put into plastic bags. The sample bags must be labelled and sent to the nearest soil testing laboratory along with an information sheet, containing the following information.

- Name and address of the farmer
- Identification or number of the field
- Date of sampling
- Local name of the soil, if any
- Colour of the soil (dry or moist)
- Type of land (unirrigated, irrigated or waterlogged)
- Source of irrigation (canal, well or tank)
- Depth of sampling
- Topography (level, sloppy or undulated)
- Crop rotation followed
- Previous crop
- Next crop to be taken
- Details of manures or soil amendments applied earlier to the soil
- Other remarks

The help of a village level or extension worker can be taken to collect the soil samples and in filling the information sheet.

Soil analysis

This is done primarily to check NPK (Nitrogen, Phosphorous and Potassium) content, organic carbon content, electrical conductivity and pH level. It is mainly done in cases, where the crop has shown deficiency symptoms of micronutrients. The collected samples are analysed by using standardised method in the laboratory for the following parameters.

- pH: It indicates whether the soil is acidic, alkaline or neutral in nature.
- Total soluble salts as determined by electrical conductivity (EC) indicates the degree of salinity, alkalinity, etc., of the soil.
- It also helps in ascertaining the soil's lime and gypsum requirement.
- It also helps in finding out the level of organic carbon, which is a measure of nitrogen available in the soil.
- It helps in ascertaining phosphorus and potassium content in the soil.

Soil test interpretations

On the basis of the soil analysis report, one can identify various deficient nutrients with the help of rating charts. The data obtained from soil analysis would be meaningless unless it is correlated with the crop yield, so the report provides this information also. Based on the soil analysis, the data can be interpreted with the help of ratings as given in the following tables.

Table 8.1: Rating of soil on the basis of pH

S. No.	Type of soil	Soil reaction (pH)
1.	Acidic	Less than 6
2.	Normal to saline	6–8.5
3.	Tending to become alkaline	8.6–9
4.	Alkaline	More than 9

Table 8.2: Rating of soil on the basis of Electrical Conductivity (EC)

S. No.	Category	EC (dS/m)
1.	Normal	Less than 1
2.	Critical for germination	1–2
3.	Critical salt levels for growth of sensitive crops	2–4
4.	Injurious to most crops	More than 4

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On the basis of the soil test interpretations, fertiliser recommendations for each crop may be made. The soil fertility status as per its classification into three strata (low, medium or high) is also provided. An example of this 'rating chart' is shown in Table 8.3

Table 8.3: Rating on the basis of nutrient availability

S. No.	Nutrient	Low	Medium	High
1.	Organic carbon	Less than 0.5%	0.5–0.75%	More than 0.75%
2.	Available nitrogen (N)	Less than 280 kg/ha	280–560 kg/ha	More than 560 kg/ha
3.	Available phosphorus (P)	Less than 10 kg/ha	10–25 kg/ha	More than 25 kg/ha
4.	Available potassium (K)	Less than 110 kg/ha	110–280 kg/ha	More than 280 kg/ha

Practical Exercise

Activity

Demonstrate the procedure of soil sampling.

Material required: hand auger, test tube, spade, cultivated field, paper bag, polythene bag and tag

Procedure

- Divide the field into different homogenous units, according to fertility levels.
- Remove weeds, roots, etc., at the sampling spot.
- Take samples from a depth of up to 15 cm with the help of auger, spade or *khurpi*.
- From each sampling unit, collect at least 10 samples.
- Remove all foreign material and mix the samples evenly.
- Divide the collected samples into four equal parts.
- The two opposite quarters are removed and remaining samples from two other parts are mixed. The process is repeated until the desired sample size is obtained.
- Dry the moist sample.
- Collect the prepared sample in a sampling bag.
- Label the bag with following information, i.e., name and address of the farmer, date of collection, previous and present crop record, crop to be grown in the next season, etc.

Check Your Progress

A. Fill in the Blanks

1. For deep-rooted crops, soil samples must be collected from __________ cm deep zone.
2. The desired size of the sample for soil testing is __________.
3. Collect the soil sample in a __________ pattern to represent the whole field.
4. The pH of alkaline soil is __________.

B. Multiple Choice Questions

1. The available nitrogen status in soil is considered low at __________ level.
   (a) less than 240 kg/ha (b) 240–380 kg/h
   (c) 380–480 kg/ha (d) 480–580 kg/ha
2. The available potassium status in soil is considered high at __________ kg/ha.
   (a) Less than 100 kg/ha (b) Less than 110 kg/ha
   (c) 110–280 kg/ha (d) More than 280 kg/ha
3. Soil is injurious to most crops if EC (milli mohs/cm) is __________.
   (a) > 2 (b) > 3 (c) > 4 (d) > 5

C. Match the Columns

A		B	
1.	INM	(a)	Electrical Conductivity
2.	V–notch	(b)	Soil sampling
3.	dS/m	(c)	Use of organic, inorganic and bio-fertilisers
4.	Auger	(d)	Triangular vertical cut

D. Subjective Questions

1. Define soil sampling.
2. Write the procedure of soil conducting sampling.

Session 2: Nutrient Requirement and its Sources

Essential nutrients required by plants

Plants require food for growth and development. A large number of nutrients are absorbed by plants from soil, air and water. Seventeen elements are essential for the

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growth and development of plants. The criteria to judge the essentiality of an element are as follows.

- Deficiency of a particular nutrient makes it difficult for the plant to complete its vegetative or reproductive life cycle.
- Deficiency of a specific nutrient can be corrected by providing that particular element to the plant.
- The nutrients are directly involved in the plant's metabolic activities.

Macro nutrients

Primary nutrients

Out of the 17 essential nutrients, nitrogen (N), phosphorous (P) and potassium (K) are called the primary nutrients because plants need them in large quantities.

Secondary nutrients

Magnesium (Mg), calcium (Ca) and sulphur (S) are the secondary nutrients as they are required in moderate quantities.

Micronutrients

Manganese (Mn), zinc (Zn), boron (B), iron (Fe), copper (Cu), chlorine (Cl), molybdenum (Mo) and nickel (Ni) are micronutrients, and are required in small quantities. Carbon (C), hydrogen (H) and oxygen (O) are obtained from air and water. But all these nutrients, irrespective of the class to which they belong, are essential for plant life. Deficiency or excess of any nutrient limits plant growth.

Sources of nutrients

Plants meet their nutrient requirements from different sources like fertilisers, manures, plant residues and bio-fertilisers. Non-proportional and inappropriate use of fertilisers can damage crops, waste money, possibly lead to dependence of the plants on chemical inputs and deterioration of soil health. Natural biomass can also serve as a source of nutrient for crop plants and can be used after appropriate treatment or conversion, and in some cases even in raw form.

Organic sources

The decomposed remains of plants and animals are used as organic manure for growing plants. Legume plants are used for either green manuring or making enriched composts for recycling of nutrients. Nitrogen fixing bacteria, blue-green algae and solubilising bacteria can serve as organic sources of nutrient supplementation. Organic sources of nutrients are organic manures, green manuring, bio-fertilisers, etc.

Organic manure

Organic manures supply nutrients in a balanced proportion. Usually, large quantities of organic manures are required to meet the crop nutrient requirement. Organic manures include FYM, vermicompost, poultry manure, biogas slurry, etc. These manures are applied to the soil by spreading or broadcasting before sowing or transplanting paddy.

Fig. 8.3: Organic manure

Green manuring

Growing and incorporation of tender biomass of legume crops in soil is known as 'green manuring'. These crop plants fix atmospheric nitrogen, and after decomposition and incorporation, release this nitrogen into the soil, which helps improve its physical and biological properties.

Table 8.4: Green manure crops

Green manure crops	Seed rate (kg/ha)	Green biomass (t/ha)
Sithagathi (*Sesbania speciosa*)	30–40	15–18
Dhaincha (*Sesbania aculeata*)	50	25
Manila agathi (*Sesbania rostrata*)	40	20
Sunnhemp (*Crotalaria juncea*)	25–35	13–15
Wild indigo (*Tephrosiapurpurea*)	15–20	6–7

Fig. 8.4: Green manuring crop Sunnhemp (Crotalaria juncea)

Fig. 8.5: Dhaincha (Sesbania aculeate)

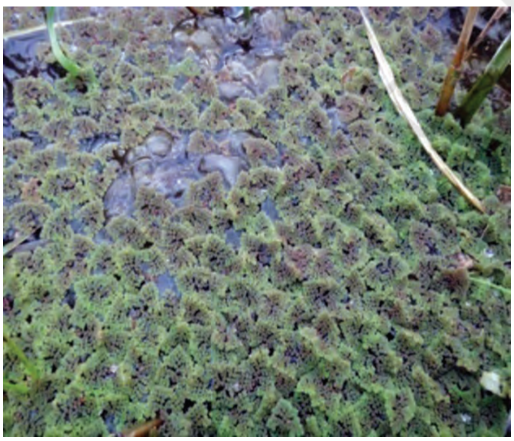

Fig. 8.6: Bio-fertiliser (Azolla)

Green manuring in paddy crop

Sow sunnhemp or *dhaincha* (green manure crop) seeds at the rate of 20kg/ha during summer. The biomass is incorporated into the soil after 40 days of sowing and allowed to decompose *in situ* (on site). This decomposes easily in 10–15 days, after which paddy can be grown in the field. If it is not possible to grow green manuring crop in the field, incorporate the already decomposed green leaves of different plants (neem, pongamia, ipomea, etc.) at 2–3 t/ha, which serves the same purpose as green manure crop. It adds nitrogen and humus to maintain the soil health.

Bio-fertiliser

Bio-fertilisers are eco-friendly and are ready to use live formulations, containing strains of beneficial microorganisms. These microorganisms on application to seed, root or soil help enhance the availability of essential nutrients to the crop and also help build beneficial micro-flora in the soil, thereby, improving the soil health. They are an integral part of INM, which helps in meeting the nutrient requirement of the plant at low cost. Bio-fertilisers that can be used for paddy crop include *azolla*, blue-green algae, *azotobacter, azospirillum, phosphobacteria,* phosphate solubilisers and *mycorrhizae*.

Bio-fertiliser application

Bio-fertilisers are available as carrier-based inoculants. The common filler material used as a carrier include peat or lignite. These bacterial inoculants are, usually, applied for seed treatment. Sometimes, these bio-fertilisers are applied as seedling root dip or directly for field application.

Table 8.5 Quantity of bio-fertilisers required per hectare

Method of application	Number of packets (200g/ha)
Seed treatment	5
Nursery application	10
Seedling dip	5
Main field (soil application)	10

Inorganic sources

Inorganic fertilisers are chemical compounds (either synthesised or natural) that are added to the soil to improve its fertility on an immediate basis. These fertilisers are economical, quick responding and provide the required nutrient element that can increase the crop yield, thereby, resulting in significant profits. As per their chemical composition, these fertilisers may contain one or more nutrient element. A fertiliser, which contains only one of the primary nutrient elements, is called 'single element' or 'sole fertiliser', for example N, P and K.

Some fertilisers contain a combination of primary nutrient elements (N and P, N and K, or P and K) and are known as 'complex' or 'mixed fertilisers'. Those containing N, P and K are called 'complete fertilisers'.

The nutrient content of fertilisers is expressed in per cent. Thus, the total weight of fertilisers does not reflect the quantity of nutrients it contains. For example, a 100-kg bag of Diammonium phosphate (18% N and 46% P) contains 18 kg of N and 46 kg of P, and remaining 36 kg of inert material; 100-kg bag of urea (46% N) contains 46 kg N and 54 kg inert material.

Sources of micronutrient fertilisers

Out of 17 essential nutrients, iron, molybdenum, manganese, zinc, chlorine and sulphates of copper are required for plant growth in small quantities and are known as micronutrients. Micronutrients like sulphates of copper, iron, manganese and zinc are soluble in water, and can be easily applied through foliar application or along with irrigation water.

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Table 8.6: Sources of micronutrient fertilisers

S. No.	Fertiliser source	Nutrient content (%)
1.	Manganese sulphate	Mn– 30.5
2.	Boric acid	B – 17
3.	Ferrous sulphate	Fe – 19
4.	Ammonium molybdate	Mo – 52
5.	Chelated zinc Zn-EDTA (Ethylene diamine tetra acetic acid)	Zn – 12
6.	Chelated Fe-EDTA	Fe – 12
7.	Zinc sulphate monohydrate	Zn – 33
8.	Zinc coated urea	N – 43 + Zn – 2

Practical Exercise

Activity 1

Identify organic and inorganic sources of fertilisers.

Material required: FYM, compost, vermicompost, poultry manure, blue-green algae, *azolla*, PSB, azotobacter, neem cake, chemical fertilisers (NPK), notebook, pen, etc.

Procedure

- Collect the above mentioned organic and inorganic fertilisers sources and label them.
- Write down the characteristics of each fertiliser.

Activity 2

Visit a nearby field and note down the process of green manuring being followed there.

Material required: pen, pencil, notebook, etc.

Procedure

- Visit a nearby field.
- Identify the green manure crop being used there.
- Discuss with the farmer and note down the seed rate, and sowing method of green manure crop.
- Note down the age of the green manure crop.
- Observe and note down the process of green manuring.
- Present your observations before the class.

Check Your Progress

A. Fill in the Blanks

1. Only __________ elements are essential for plant nutrition.
2. Elements that are used in relatively large amounts are called ____________ nutrients.
3. Seed rate of *dhaincha* (*Sesbania aculeata*) for green manuring is ________________.
4. Growing and incorporation of tender biomass of legume species into the soil is known as ______________ manuring.
5. Micronutrients can be applied readily through __________ application.

B. Multiple Choice Questions

1. Ca, Mg and S are called ___________.
   (a) primary nutrients (b) secondary nutrients
   (c) micronutrients (d) None of the above
2. A 100-kg bag of Diammonium phosphate contains ______________.
   (a) 18 kg P (b) 46 kg P
   (c) 80 kg P (d) 120 kg P
3. Bio-fertiliser that can be used for rice crop includes ______________.
   (a) azolla (b) *phosphobacteria*
   (c) *azospirillum* (d) All of the above
4. The botanical name of sunnhemp is ______________.
   (a) *Crotalaria juncea* (b) *Tephrosiapurpurea*
   (c) *Sesbania aculeate* (d) *Sesbania speciosa*
5. Chelated Fe-EDTA contains ____________ per cent of Fe.
   (a) 8 (b)12 (c) 18 (d) 22
6. Zinc coated urea contains ______________ per cent of N.
   (a) 52 (b) 33 (c) 46 (d)43

C. Match the Columns

A	B
1. Sunnhemp seed rate kg/ha	(a) 46% nitrogen
2. *Dhaincha* green biomass	(b) 36 kg
3. 100-kg urea bag contains	(c) 25–35 kg
4. Inert material in 100-kg DAP	(d) 25 t/ha

D. Subjective Questions

1. Write a brief note on essential nutrients required by plants.
2. Describe the methods of bio-fertiliser application.

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3. Differentiate between the following.
   (a) Macronutrient and micronutrient
   (b) Primary and secondary nutrients
4. Define the following.
   (a) Organic manure
   (b) Bio-fertiliser
   (c) Green manuring

SESSION 3: METHODS AND TIME OF FERTILISER APPLICATION

Fertiliser application

The nutrient requirement of every plant is different. It also depends on the type of soil a plant is grown in and the climatic conditions of the area. Besides, the nutrient requirement of a crop differs at different stages of growth. Therefore, there must be timely and adequate application of manures and fertilisers. Response of fertilisers and manures differ as per the types of soil.

Considerations for fertiliser use

- Nutrient content in manures and fertilisers
- Nutrient requirement of a particular crop to be grown
- Timing and methods of manure and fertiliser application
- Residual effects of manures and fertilisers on succeeding crop
- Response of crop after fertiliser application
- Cost of fertilisers

Objectives of fertiliser application

Various methods are used for fertiliser application. The application of fertilisers fulfills the following objectives.

- Makes easy availability of fertilisers to crops
- Minimises fertiliser loss

Application of solid fertilisers

Broadcasting

In this method, manures or fertilisers are spread uniformly by hand all over the field. It can be done before and during transplanting or in standing crop. Broadcasting is two types.

- Basal application at the time of sowing
- Top dressing during crop growth period

Placement

In this method, fertilisers are added to the soil near the seed, seedling or growing plant before or after the sowing of crops. It includes the following.

Plough furrow or single placement

It refers to the application of fertiliser in narrow bands beneath and by the side of crop row or furrow. This is done during the process of ploughing. In this method, fertiliser is applied in moist soil, where it can become easily available to the growing plants during dry seasons.

Deep or sub-surface placement

Placement of fertiliser is, generally, practised for the application of nitrogenous (Ammonium sulphate and urea) and phosphatic fertilisers. Such fertilisers are placed near the root zone as in case of paddy fields.

Localised placement

In this method, fertiliser is applied the soil close to the seed or plant. This method is suitable when relatively small amount of fertilisers are to be applied.

Pellet application

In this method, nitrogenous fertiliser is placed in the form of a pellet at a depth of 2.5–5 cm between rows of plants. These pellets are prepared by mixing one part of fertiliser and 10 part of soil (1:10 ratio). Application of fertilisers by this method improves nitrogen use efficiency in paddy crops.

Application of liquid fertilisers

Foliar application

Dilute solution of fertilisers is sprayed on the foliage of growing plants. Minor nutrients like zinc, boron, iron, copper and manganese are effectively applied by

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this method. However, if required, major nutrients can also be applied as foliar sprays. Leaf scorching occurs due to uncontrolled concentration of solution during foliar spray.

Fertigation

In this method, fertilisers are applied through irrigation water. Nitrogen is the principle nutrient commonly used for this purpose. Also, highly soluble forms of zinc can be readily applied in this way.

Stages of fertiliser application

For obtaining maximum benefits, fertilisers need to be applied to the soil at three stages of the crop cycle.

Basal application

Application of fertilisers before sowing or transplanting is referred to as 'basal application'. Fertilisers may be broadcast or mixed in the soil at the time of puddling to ensure adequate supply of nutrients during the critical seedling establishment phase.

First top dressing

Fertilisers must be top dressed by broadcasting in the field when seedlings enter the active tillering stage, i.e., 20–25 days after transplanting.

Second top dressing

Immediately after panicle initiation (boot leaf stage), second top dressing of fertiliser must be done by broadcasting method. This ensures complete grain filling, increases the size and weight of the grains, and improves the physical quality and protein content of the produce.

Fertiliser dose calculation

For fertiliser dose calculation in a given area, a number of factors need to be considered. These include the following.

- Percentage of nutrient content in fertiliser material
- Desired dose of application
- Area to be covered by a fertiliser

Using the recommended rate of, say 40 kg/ha, calculate the amount of fertiliser required.

$$W = A \times R \times 100 / P$$

Where,

W = weight of fertiliser to be applied (this is what you want to know)

A = area to be fertilised (in hectares)

R = desired rate of application

P = percentage of nutrient element the fertiliser contains

Suppose, the measured field's area is 1.5 ha.

Use the formula

$W = A \times R \times 100/P$

Where,

W = ?

A = 1.5 ha

R = 40 kg/ha for this application (top dressing)

P = 46%

Then,

$$W = 1.5 \times 40 \times 100/46$$
$$= 6000/46$$
$$= 130.0 \text{ kg}$$

It is clear that the said area will need fertiliser application of 130 kg urea.

Each bag of urea weighs 50 kg. Therefore, to convert 130 kg into bags, divide 130 kg by the weight of one bag.

130 kg = 130 kg / 50 kg = 2.6 bags

Practical Exercise

Activity

Calculate the fertiliser quantity needed for paddy crop.

Material required: fertiliser, notebook, pen, pencil, etc.

Procedure

- Measure the plot area under paddy cultivation.
- Check the recommended dose of nitrogen for paddy plant.
- Calculate the quantity of urea to meet the recommended dose of nitrogen.
- Carry out mathematical calculation.

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Suppose, the measured field's area is 1.5 ha. Use the formula

$W = (A \times R)/P$

Where,

$W = ?$

$A = 1.5$ ha

$R = 40$ kg/ha for this application (top dressing)

$P = 46\%$

Then,

$W = 1.5 \text{ ha} \times 40 \text{ kg/ha} / 0.46$

$= 60 \text{ kg}/0.46$

$= 130.0 \text{ kg}$

It is clear that the said area will need fertiliser application of 130 kg urea.

Each bag of urea weighs 50 kg. Therefore, to convert 130 kg into bags, divide 130 kg by the weight of one bag.

130 kg = 130 kg / 50 kg = 2.6 bags

Check Your Progress

A. Fill in the Blanks

1. When fertiliser is applied during the process of ploughing, the method is called ____________.
2. Spreading or broadcasting of fertilisers in standing crop is known as ____________.
3. The depth of nitrogenous fertilisers for pellet application is ____________.
4. The process of spraying fertiliser solutions on the foliage of growing plants is called ____________.
5. Second top dressing of fertiliser must be done at the ____________ stage.

B. Multiple Choice Questions

1. Application of fertilisers into soil close to seed or plant is termed __________.
   (a) pellet application (b) broadcasting
   (c) top dressing (d) localised placement
2. Scorching of paddy leaves is caused by ____________.
   (a) controlled top dressing
   (b) uncontrolled dose of foliar spray
   (c) basal application
   (d) drill placement
3. ____________ of fertilisers is, generally, practised in nitrogenous and phosphatic fertiliser.
   (a) Sub-surface placement
   (b) Plough furrow placement
   (c) Localised placement
   (d) Pellet application

4. Application of fertilisers through irrigation water is known as ______________.
   (a) fertigation
   (b) top dressing
   (c) deep placement
   (d) broadcasting

C. Match the Columns

A		B	
1.	Basal application	(a)	Nitrogenous fertiliser
2.	First top dressing	(b)	Active tillering stage
3.	Pellets	(c)	Band placement
4.	Single placement	(d)	Before sowing

D. Subjective Questions

1. Describe the methods of fertiliser application.
2. Explain the methods of applying fertilisers in solid form.
3. Explain the methods of applying fertilisers in liquid form.
4. Define the following.
   (a) Top dressing
   (b) Fertigation

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SESSION 4: NUTRIENT DEFICIENCY SYMPTOMS IN PADDY

Nitrogen

Nitrogen increases the vigour and growth of paddy plants. It imparts green colour to the plants by synthesising chlorophyll necessary for photosynthesis, promotes leaf, stem and root growth or elongation (height, size, tillers, leaf size, etc.). It is also helpful in promoting the development of panicle.

Deficiency symptoms

Deficiency symptoms start at leaf tips, which become chlorotic and progress along the midrib until the entire leaf is dead. The plants may develop weak stems and exhibit slow growth.

Corrective measures

- Before sowing or transplanting of paddy and during crop growth, apply sufficient nitrogen fertiliser as recommended in the soil test report.
- Carry out foliar application of 1 per cent urea solution when the symptoms are observed every week till the symptoms disappear.

Phosphorus

Phosphorus stimulates root development in young plants, thereby, increasing the number of root hair and their ability to absorb nutrients from the soil. It also helps the seedlings to recover rapidly from transplanting shock. It imparts resistance from drought, facilitates nitrogen absorption, and promotes early flowering and ripening. It also increases protein content of the grains (food value) and invigorates the germinating power of seeds.

Deficiency symptoms

There is purple colour development in lower part of the culms of plants. This deficiency makes the leaves bluish-green and causes stunting of the plants, underdeveloped root system and less number of tillers.

Corrective measures

- If a soil is deficient in phosphorus, then applying phosphorous bacteria as seed coating or using seedling dip method is effective.
- Add phosphatic fertiliser to the soil.
- When soil pH is low, broadcast rock phosphate before flooding in field

Potassium

Potassium strengthens the cell walls, makes the plant, sturdy, helps it to withstand adverse weather conditions and increases the plants' resistance to pathogens. It increases the size, weight and protein content of the grains, thus, improving their appearance.

Deficiency symptoms

The symptoms are scorched appearance along the leaf margins, dark colour of the leaves (spreading from the tips), chlorotic areas on leaf and panicles, weak stems (tendency to lodge), droopiness, reduced photosynthesis and consequent slower growth.

Corrective measures

Potassium deficiency can be corrected by foliar spray of aqueous solution of potassium chloride (KCl) 5 g/lat at an interval 15 days till the symptoms disappear.

Sulphur

Sulphur helps in chlorophyll formation and encourages vegetative growth in plants. It is essential for the formation of proteins, enzymes and certain volatile compounds, including rice bran oil. Moreover, it increases root growth, and stimulates seed formation, quality and size of the grains.

Deficiency symptoms

Deficient plants appear pale green with light green coloured young leaves. Other important symptoms are yellowing of the plants, chlorosis in young leaves, reduced height and reduced tillers with shortened panicles.

Corrective measures

- Apply slow releasing sulphur forms (gypsum, elemental S) into the soil, where leaching is a problem.
- Apply 10 kg wettable S/ha in case of moderate deficiency. For severe deficiency, application of 20–40 kg S/ha is recommended.

Zinc

Zinc helps in the formation of chlorophyll in plants and also influences the formation of important growth hormones. It is associated with water uptake in plants.

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Deficiency symptoms

Typical zinc deficiency symptoms appear in reddish colour on the leaves known as *khaira* disease in paddy plants. It leads to yellowing of the leaves between the veins, and the middle parts of the leaves often collapse to give a scorched appearance. In case of severe deficiency, there is reduction in leaf size. They may even turn white, and subsequently, die. Besides, the plants get stunted and produce few tillers.

Corrective measures

- Zinc sulphate ($ZnSO_4$) must be applied to the nursery seedbed, if deficiency symptoms are observed.
- Pre-soaked seeds or seedlings may be dipped in 2–4% $ZnSO_4$ suspension before sowing and transplanting.
- Zinc sulphate at 5–10 kg /ha must be applied.
- Foliar application of 0.5–1.5 per cent $ZnSO_4$ / ha at tillering (25–30 days after transplanting), 2–3 repeated applications at an interval of 10–14 days is recommended in zinc deficient soils.
- Zn chelates (such as Zn-EDTA) can be used for foliar application.

Practical Exercise

Activity

Identify of nutrients deficiency symptoms in rice plant.

Material required: pen, pencil, notebook, gloves, gumboot, nutrient deficiency symptom colour chart, etc.

Procedure

- Visit a nearby paddy field.
- Identify the deficiency symptoms in the crop.
- Match the symptoms with the colour chart.
- Note down the deficiency symptoms in your notebook.
- Write down the corrective measures to check such deficiencies.
- Present your observations before the class.

Check Your Progress

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A. Fill in the Blanks

1. ___________ enables the seedling to recover rapidly from transplanting shock.
2. _______________ increases a plant's resistance to pathogens.
3. Reduced number of tillers and shortened panicles indicates the deficiency of ___________.
4. *Khaira* disease of paddy is caused by the deficiency of ____________.

B. Multiple Choice Questions

1. ______________ gives green colour, and enhances vigour and growth of paddy plant.
   (a) Nitrogen (b) Phosphorus
   (c) Potash (d) None of the above
2. ____________ helps in chlorophyll formation and encourages vegetative plant growth.
   (a) Potash (b) Sulphur
   (c) Zinc (d) None of the above
3. Scorched appearance along leaf margins indicates the deficiency of ___________.
   (a) Potassium (b) Nitrogen
   (c) Copper (d) Zinc
4. _____________ increases root growth, stimulates seed formation quality and size of grains.
   (a) Copper (b) Zinc
   (c) Sulphur (d) Manganese

C. Match the Columns

A		B	
1.	Zinc	(a)	Root development
2.	Phosphorus	(b)	Weak stems
3.	Potassium deficiency	(c)	Chlorophyll
4.	Sulphur forms	(d)	Water uptake

D. Subjective Questions

1. Discuss the following.
   (a) Nitrogen deficiency symptoms
   (b) Zinc deficiency symptoms
   (c) Corrective measures for deficiency of phosphorus