Enhancing Agricultural Productivity and Rural Livelihoods through Scaling-up of Science-led Development in Odisha: Bhoochetana

Capacity Building program for district level officials of the Department of Agriculture, Govt. of Odisha

ICRISAT DEVELOPMENT CENTER

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

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INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

Contents

Introduction

This Manual is being developed to build the capacities of the DOA officials who are one of the key stakeholders of the Odisha Bhoochetana Project. Collaborative organizations such as Department of Agriculture, State Agricultural Universities (SAUs), Krishi Vigyan Kendras (KVKs), and Civil Society organizations will be the other stakeholders in the area of Capacity Building which is an integral component of the Odisha project. The Bhoochetana project requires close to two thousand and five hundred officials of the Department of Agriculture to be trained in soil health, agronomy, IPM and IDM for scaling up bhoochetana objectives in all districts of Odisha. To achieve this ICRISAT trained Master Trainers from the DOA in two programs organized at ICRISAT in the month of July. These Master Trainers in turn will now train all officials in the districts including the Agricultural overseers and VLWS who are key people on the ground for effective transfer of technology. ICRISAT Development Center will prepare training materials and will be present when the actual training programs are held in the districts and will be there always to handhold and assist the Master Trainers. We sincerely hope this will be a new paradigm in improving production by the farmers by a massive capacity building up to the lowest level of official hierarchy.

The Manual is in a modular form so that any tailor-made program can be organized depending on the need of stakeholders. The contents have been developed by ICRISAT scientists who have also developed tools for presentations for a program. Following are the major themes of the proposed program.

- Soil fertility and nutrient management
- Fertilizer calculation and soil health cards
- Climate change impacts, adaptation and mitigation strategies, Cropping system management
- Crop care, gap filling, weed management
- Harvesting, threshing, Yield estimation by Crop Cutting procedures
- Integrated pest and disease management (IPDM), pest surveillance, chemical control and safety aspects of pesticide application at farm level

Sessions

Session 1: Soil sampling methodology

At the end of this session you will be able to:

- Define correct Soil Sampling procedure as a first step towards INM
- Practice various sampling methods, tools to be used

Soil Sampling

Soil sampling is an integral component of fertility evaluation and nutrient recommendation for efficient use of nutrients in crop production. Each sample collected must be a true representative of the area being sampled. Utility of the results obtained from the laboratory analysis depends on the sampling precision. Hence, collection of large number of samples is advisable so that sample of desired size can be obtained by sub-sampling. As per Government of India guidelines of standard sampling methodology, soil sampling should be done at the rate of one sample for ten-hectare area. For soil survey work, samples are collected from a soil profile representative to the soil of the surrounding area. There are 3 types of soil sampling viz., simple random, systematic and stratified random sampling. Following several seasons' work experience in earlier projects, the methodology based on the principle of stratified random sampling was found most appropriate for collecting soil samples at village and block level of entire Odisha state.

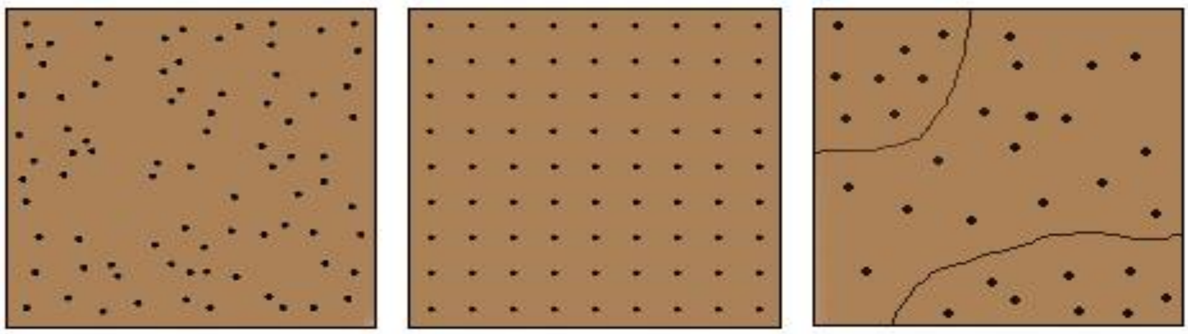

Figure 1.1: Types of Soil sampling.

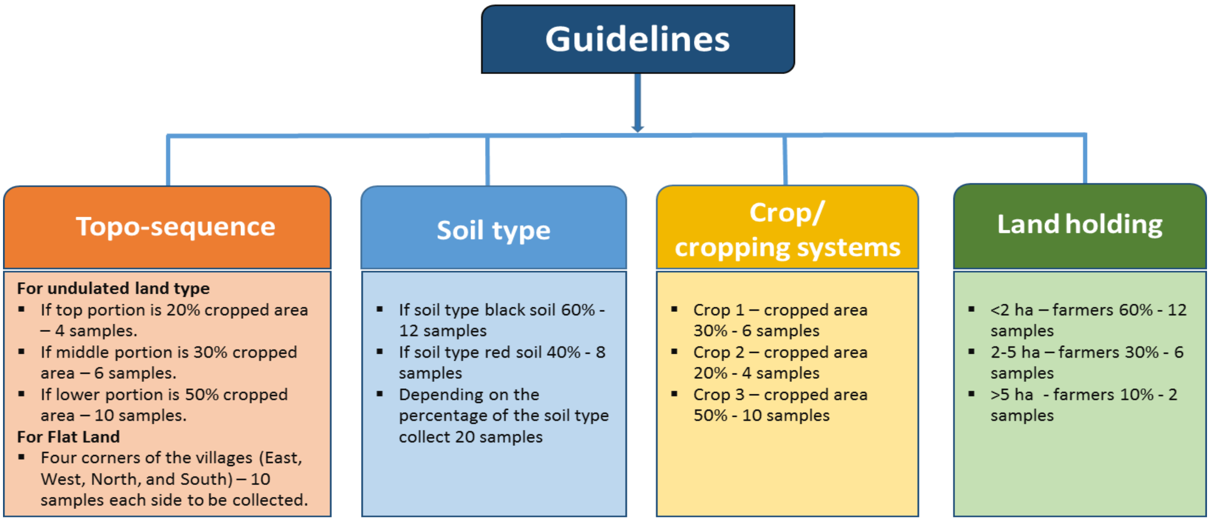

Figure 1.2: Guidelines for stratified random sampling

Soil sampling in annual agricultural crops

- Follow stratified soil sampling method to ensure collection of a representative sample
- Divide target village into three topo-sequences.
- At each topo-sequence location, take samples proportionately from different farm-holding sizes.
- Within farm size class in a topo-sequence, take samples representing soil colour, texture, cropping system and agronomic management
- Remove the surface litter at the sampling spot.
- Drive the auger to a plough depth of 15 cm and draw the soil sample.
- Collect at least 10 to 15 samples from each sampling unit and mix together to make a composite sample and place in a bucket or tray.
- If auger is not available, make a 'V' shaped cut to a depth of 15 cm in the sampling spot using spade.
- Remove thick slices of soil from top to bottom of exposed face of the 'V' shaped cut and place in a clean container.
- Mix the samples thoroughly and remove foreign materials like roots, stones, pebbles and gravels.
- Reduce the bulk to about half to one kilogram by quartering or compartmentalization.
- Quartering is done by dividing the thoroughly mixed sample into four equal parts. The two opposite quarters are discarded and the remaining two quarters are remixed and the process repeated until the desired sample size is obtained.
- Compartmentalization is done by uniformly spreading the soil over a clean hard surface and dividing into smaller compartments by drawing lines along and across the length and breadth. From each compartment a pinch of soil is collected. This process is repeated till the desired quantity of sample is obtained.
- In Grid sampling system, follow above stratification principles – only one sample per 10 ha.
- Follow precautions not to collect samples from recently fertilized plots, bunds, channels, marshy spots, near trees, cow dung heap or other non-representative areas.

Materials required

1. Spade or auger (screw or tube or post whole type)
2. Khurpi
3. Core sampler
4. Sampling bags
5. Plastic tray or bucket

Soil sampling in horticultural plantations

- For soil sampling in horticultural plantations, follow following protocols;
- Divide the orchard into blocks of trees of the same species, age and other characteristics like topography, soil color, soil texture and management practices.
- Within a block, select representative 5 trees.
- From each indicator tree in a block, pull 3 to 4 cores.
- Mix the resulting 15-20 cores in the block and take ~1 kg (following partitioning method) composite sample.
- Sampling depth varies from crop to crop as in Table 1.1.

Table 1.1. Recommended soil sampling depth and distance from tree trunk.

Sl	Crop	Recommended sampling depth (cm)	Recommended distance from tree trunk for sampling (cm)
1	Mango	0-40	75-100
2	Citrus	0-25	100-125
3	Gauva	0-30	75-100
4	Ziziphus	0-40	75-100
5	Papaya	0-45	75-100
6	Banana	0-25	0-25
7	Pomegranate	0-45	25-50
8	Cashew	0-30	
9	Coconut	0-30	
10	Cocoa	0-30	
11	Chillies	0-15	

Note: In general, the sampling spot is the center point between trunk and spread of canopy.

Soil sampling precautions to be followed (Non-negotiable)

- Collect the soil sample during fallow period.
- In the standing crop, collect samples between rows.
- Sampling at several locations in a zig-zag pattern ensures homogeneity.
- Fields, which are similar in appearance, production and past-management practices, can be grouped into a single sampling unit.

- Collect separate samples from fields that differ in colour, slope, drainage, past management practices like liming, gypsum application, fertilization, cropping system etc.
- Avoid sampling in dead furrows, wet spots, areas near main bund, trees, manure heaps and irrigation channels.
- For shallow rooted crops, collect samples up to 15 cm depth. For deep rooted crops, collect samples up to 30 cm depth. For tree crops, collect profile samples.
- Always collect the soil sample in presence of the farm owner who knows the farm better

Figure 1.2 (a) Locating GPS coordinates

Figure 1.2 (b) Collecting the soil sample at 0-15 cm depth

Figure 1.2 (c) Mixing of soil samples collected from different spots

Figure 1.2 (d) Packing of collected soil sample

Session 2: Soil fertility status

At the end of this session you will be able to:

- Define soil fertility status of plot
- Underline soil analysis and nutrient status of Odisha soils

Background

Odisha Bhoochetana project aims at improving and sustaining crop productivity and rural livelihoods through science based natural resource management (soil management in particular) in the state of Odisha. This will provide a sound base for precise fertilizer management not only for NPK but also deficient secondary and micro nutrients. Declining soil health is often cited as one of the reasons for stagnating or declining yields. The limiting nutrients do not allow the full expression of other nutrients, lower the fertilizer response and crop productivity. The constraints of emerging S, Zn, Mn and B deficiencies in specific cropping systems/ regions also need to be alleviated to enhance soil-crop productivity.

Preliminary soil analysis results for pilot sites have shown multi-nutrient deficiencies of secondary and micro nutrients like sulphur (S), boron (B) and zinc (Zn) along with nitrogen (N), phosphorus (P) and potassium (K). The imbalanced and sole use of high analysis NPK fertilizers coupled with declining use of organic manures in the past decades have resulted in soil fertility degradation through developing negative balances of secondary and micronutrients and low carbon (C) levels. The deficiencies will further aggravate when we attempt increasing the crop productivity without resorting to proper soil fertility management practices.

District	OC	Av P	Av K	Av Ca	Av Mg	Av S	Av Zn	Av B	Av Fe	Av Cu	Av Mn	No of samples
Koraput	24.51	12.53	10.80	15.13	46.26	87.08	49.09	82.90	0.32	0.95	0.00	1269
Malkangiri	42.24	43.42	29.27	10.22	39.88	58.94	51.87	92.34	0.98	2.55	1.77	509
Angul	33.63	21.86	7.75	6.08	23.73	36.18	61.67	79.90	2.94	2.84	8.33	1020
Deogarh	28.46	34.62	12.56	5.13	21.28	42.31	55.13	75.64	1.79	1.03	0.51	390
Jagatsinghpur	44.23	7.98	21.83	1.63	3.17	57.79	55.48	63.17	0.48	0.10	2.02	1040
Kendrapara	27.39	16.96	12.70	0.52	1.48	36.43	19.30	35.91	0.00	0.00	0.00	1150
Khurda	61.69	30.46	32.77	12.62	27.38	64.85	25.62	82.69	0.00	0.23	2.46	1300
Kandhamal	41.59	32.23	8.07	8.28	53.60	71.10	40.57	86.91	1.76	5.63	0.41	1474
Nayagarh	54.13	7.60	18.65	3.75	12.50	47.69	41.92	80.87	0.87	0.19	1.44	1040
Kalahandi	51.25	45.71	8.30	2.77	17.59	53.75	63.04	86.79	3.21	1.34	4.91	1120
Rayagada	52.77	12.97	2.87	7.13	34.06	44.26	27.62	79.50	3.66	2.67	1.19	1010
Cuttack	36.98	13.13	27.80	1.54	7.53	41.04	17.91	82.69	0.88	0.11	0.71	1820
Dhenkanal	32.23	34.47	14.85	3.79	17.38	41.75	18.93	74.37	0.78	0.10	1.75	1030
Puri	43.52	6.97	30.00	9.86	14.44	49.72	29.65	63.24	0.07	3.66	7.04	1420
Nabrangpur	38.42	34.38	14.34	11.87	36.69	70.40	59.44	95.05	0.25	1.40	4.86	1213
Bhadrak	40.44	10.99	18.13	1.54	3.52	48.90	38.24	57.36	0.55	0.22	0.99	910
Jajpur	49.31	14.92	32.54	5.54	17.77	46.85	25.23	77.00	2.38	0.77	2.77	1300
Jharsuguda	40.44	26.00	18.00	19.56	42.44	38.89	26.00	90.44	0.67	0.67	0.67	450
Sambalpur	39.49	25.30	13.68	12.56	34.62	44.44	40.77	92.39	2.48	1.45	2.91	1170
Boudh	50.81	11.62	24.32	5.14	20.81	51.89	66.22	93.78	7.57	1.62	5.95	370
Sonepur	35.64	30.77	18.33	5.51	25.26	24.62	64.10	90.13	1.79	2.05	3.72	780
Bargarh	36.06	14.26	20.84	7.48	37.61	28.84	53.29	90.13	1.29	2.71	2.52	1550
Balangir	46.25	38.93	12.03	4.10	21.32	43.85	75.94	92.35	6.07	5.41	7.11	1829
Nuapada	22.37	38.05	0.61	0.61	3.65	26.94	72.15	80.06	1.52	1.07	7.76	657
Balasore	52.06	25.48	43.35	11.42	31.29	37.29	41.55	68.71	4.58	3.10	5.81	1550
Mayurbhanj	45.13	52.58	38.77	25.96	50.11	66.45	39.25	91.65	0.72	1.09	1.54	3317
Gajapti	62.78	20.56	4.63	40.37	76.48	82.04	42.22	92.59	3.52	0.74	2.04	540
Ganjam	45.09	26.73	10.89	4.95	20.96	39.89	32.03	64.02	1.14	0.07	3.42	2810
Keonjhar	47.86	50.19	31.10	18.05	42.79	71.82	56.95	90.13	1.10	3.70	2.21	1540
Sundergargh	47.93	50.14	13.00	14.65	37.28	45.63	40.23	95.54	1.22	5.31	1.13	2130

Outcomes of Odisha Bhoochetana soil analysis:

- More than 82 per cent analyzed soils are acidic in nature with low soluble salts
- Organic carbon is deficient (41%) in most of the analyzed soil samples
- Exchangeable bases followed the deficiency order: Ca > K > Mg
- Sulphur deficiency (48%) was also prominent in analyzed soils
- Boron (80%) was the most limiting amongst all micro-nutrient followed by zinc (43%)
- Micronutrient deficiency followed the order: Zn > Fe >Mn> Cu

Session 3: Soil test based balanced nutrient management

At the end of this session you will be able to:

- Schedule soil test based balanced nutrient management
- Apply foliar application of fertilizers
- Perform fertilizer calculations

Soil testing is essential and is the first step in obtaining high yields and maximum returns from the money invested in fertilizers. Soil testing as a tool for judicious fertilizer use is a well-recognized practice all over the world which takes care of too little, too much or disproportionate applications of nutrients. The soil testing and fertility management programs have been given adequate importance for sustaining crop production and balanced fertilization in Indian agriculture. Fertilizers have been and will continue to be the key input for achieving the estimated food grain production goals of the country. But, the escalating cost coupled with increasing demand for chemical fertilizers and depleting soil health necessitates the safe and efficient method of nutrient application. The soil test based fertilizer recommendation is therefore the actual connecting link between research and its practical application to the farmers' fields. A farmer who follows only the soil test based fertilizer recommendations is assured of a good crop. A fertilizers recommendation from a soil testing laboratory is based on carefully conducted soil analyses and the results of research on the crop, and it therefore is more scientific information available for fertilizing that crop in the field. Nutrient management plays a major role in increasing the crop yield. Plant nutrition along with other management practices viz. improved cultivar, pest and disease management, soil and moisture conservation, water management, weed control, interculture, cropping systems also has decisive effect on crop yields. Despite concerted efforts by the state the requisite knowledge on improved package of practices among the farmers is lagging. Several efforts are undertaken by the government agencies, NGOs and researchers to spread the importance of soil testing and balanced soil test based fertilizers application which ultimately has implication on crop yield.

Soil test-based basal application of micro/secondary nutrient fertilizers

- Addition of recommended deficient secondary and micro nutrients like S, B and Zn as basal application within 30 days of sowing.
- To add yearly doses of recommended S, B and Zn. Yearly full doses per ha are 15 kg S, 0.25 kg B and 5 kg Zn.

Foliar application of fertilizers

If basal applications of S, B and Zn are missed within 30 days, the alternate option could be to resort to foliar application of nutrients to cover-up losses in yields and incomes. Plants can absorb nutrients from dilute solutions applied on to the leaves; and so Zn, B and S deficiencies can be readily corrected through foliar application as described below:

- Foliar application of *Agribor* (0.1%) + Zinc sulphate(0.5%) + Unslaked lime (0.25%), 2-3 times at 7-10 days interval between 30–60 days after sowing/transplanting. For making above fertilizer solution, dissolve 100 g *Agribor* + 500 g zinc sulphate + 250 g lime in 100 l of water (For ½ acre).

- Urea meant for top dressing may further be split and applied along with micronutrient sprays, @ 1-2% (i.e. 1-2 kg urea/100 l of solution) for getting higher efficiency.
- Addition of unslaked lime is needed to neutralize acidity caused by zinc sulphate ionization. The solution required for one ha is 500 l.
- Optimum time of day for foliar application is early morning (7 to 10 am), because of less evaporation and longer period absorption of nutrients through opened stomata. Major drawbacks in foliar application are that it needs more labor and plants lose critical period of 1 month or more without proper nutrition which adversely affects crop growth. Moreover, it has little or no effect in improving soil fertility. However, it is an efficient corrective measure for any deficiency in the standing crop and has the following advantages:
- Smaller quantities of the nutrients are required than when applying to the soil.
- The danger of fixation and/or leaching is reduced.
- Nutrients applied to the foliage are absorbed more rapidly than when applied to the soil.
- It provides a convenient method of application for fertilizers required in small amounts.

General Recommendations:

- Biomass generation from soil fertility point of view, and short duration pulse promotion in summer/*rabi* fallows – greengram, blackgram, horsegram.
- The quantities should be based on crop and soil test results as recommended by the respective SAU or NARS institute
- The sources of nutrients should be in compliance with soil, crop, variety and availability in the local market
- The sources should be environmental friendly and culturally compatible
- Apply 25 per cent higher N, P and K over and above RDF if the nutrient status is low and 25 percent lesser if soil status is high
- Boron should be applied to soil @ 1kg per ha every year
- Sulphur should be applied to soil @ 30 kg per ha (200 kg gypsum) for cereals and 45 kg per ha for oilseeds in deficient soils
- Zinc should be applied to soils @ 5 kg Zn/ha/year (25 kg $ZnSO_4$) in case of paddy, 2.50 kg /ha/year for pulses and other cereals and 2 kg Zn/ha/year for oilseeds in deficient soils
- Preference should be given to use biofertilizers like Azospirillum, Azotobacter, PSB, Rhizobium
- Promoting the seed priming with 1 % zinc sulphate heptahydrate and 1 % KH_2PO_4 in acidic soils
- Promoting application of well decomposed poultry manure @ 2.5 t/ha in furrows as a substitute of lime in management of acid soil.

Fertilizers and Fertilizer Application

Types of Fertilizers and Manures

Among the plant nutrients required in large amounts for successful crop production are nitrogen (N), phosphorus (P), and potassium (K). These elements may need to be supplied regularly to maintain high crop productivity. Commercially available fertilizers are divided into single element fertilizers (urea or potassium chloride) and complex fertilizers with two or more nutrients (mono-ammonium phosphate or di-ammonium phosphate).

Analysis or Grade of Fertilizers

The amount of a nutrient element in a fertilizer is expressed as a percentage. Ammonium sulphate usually has 20% N. This means that every 100 kg of ammonium sulphate contains 20 kg of nitrogen. The three major nutrients are thus expressed as a percentage of each element in the order N–P–K. A complex fertilizer labeled 14–14–14 contains 14% N, 14% P and 14% K. The remaining 58% is carrier materials that usually have no effect on crop production.

Group exercise: Fertilizer Calculation

Calculate the rate of nutrients to be applied per unit area. Identify the fertilizers that will supply the nutrients, either singly or in combinations. Then calculate the amount of fertilizer that will supply the required amount of nutrients ha^{-1}, m^{-2}, $plot^{-1}$, or for a row. Application rates for major nutrients are reported as kg ha^{-1}.

Procedure for Calculation

Calculate the quantity of a straight fertilizer to supply 120 kg of N ha^{-1} for total area 0.5 ha. The fertilizer to be used is ammonium sulphate.
Step 1. Ammonium sulphate contains 20% N or 20 kg N in each 100 kg.

Therefore, 120 kg N will be available from:

$$\frac{100 \text{ kg ammonium sulphate} \times 120 \text{ kg N}}{20 \text{ kg N}} = 600 \text{ kg of ammonium sulphate.}$$

To supply 120 kg N requires 600 kg of ammonium sulphate for 1 hectare area

Step 2. The required ammonium sulphate for 0.5 ha to provide 120 kg N ha^{-1} will be:

$$\frac{600 \text{ kg ha}^{-1}}{2} = 300 \text{ kg of } (NH_4)_2SO_4$$

The amount of ammonium sulphate for a plot of 0.50 ha will be 300 kg

Similarly, the other two plant nutrients can be obtained by using straight fertilizers such as single superphosphate (7% P) or triple superphosphate (20% P), and muriate of potash (50% K).

Calculation for Using Double Carriers

When two nutrients are to be applied simultaneously, we can use double carriers. For instance, if N and P are to be applied, we can use diammonium phosphate (DAP), that contains 18 kg N and 46 kg P per 100 kg and urea that contains 46% N.

In a plot the area is 0.5 ha. The desired application is 100-17-0 ha^{-1} by using DAP and urea.

1. First, calculate the quantity of DAP to provide 17 kg of P. DAP contains 46% P and 18% N. Therefore, 17 kg P would be supplied in:

$$\frac{17 \text{ kg P X } 100 \text{ kg DAP}}{46 \text{ kg P}} = \mathbf{36.95\ kg\ DAP\ \sim 37\ kg\ DAP}$$

2. Now, find the N available in 36.95 kg of DAP, if 100 kg of DAP has 18% N

$$\frac{18 \text{ kg N X } 36.95 \text{ kg DAP}}{100 \text{ kg DAP}} = \mathbf{6.65\ kg\ of\ N\ \sim 6.7\ kg\ N}$$

3. DAP supplied **6.7 kg N**, therefore to reach the remaining target dose of nitrogen i.e 100 kg N, we need to subtract quantity of N supplied through DAP from recommended dose

$$100 – 6.7 = 93 \text{ kg N}$$

Urea contains 46% N. Therefore, kg N will be available from

$$\frac{100 \text{ kg urea X } 93 \text{ kg N}}{46 \text{ kg N}} = 202 \text{ kg of urea to supply } 46 \text{ kg N}$$

Therefore, 37 kg of DAP and 203 kg of urea will be required to provide 100 -17- 0 for 1 hectare

The required DAP is 18.5 kg and required urea is 101 kg for 0.5 ha

Session 4: Soil health card

At the end of this session you will be able to:

- Know about the nutrient and health status of soils
- Understand the contents of soil health cards (SHC)

Soil health cards prepared from soils collected from Odisha are GPS-based for approximately 40,000 samples. It will include farmer details including survey number, district, mandal, village, mobile number, soil type, soil depth and month and year of sampling. It has the initial soil test values for 13 parameters, based on which soil test based nutrient recommendations are given for 24 crops. General recommendations are also provided taking into consideration the status of Odisha soils.

Salient features of Soil health cards under Odisha Bhoochetana:

- Soil test values for 13 parameters
- Deficient parameters are indicated based on critical limits
- Soil test based fertilizer calculation for 24 crops are provided
- Two generic fertilizer combination doses (kg per acre) for 24 crops are provided
- General recommendations for correcting deficiency and sustainable soil health

Figure 4.1: Soil health cards.

Session 5: Cropping system management

Learning objectives:

- *Define climate change and climate smart agriculture*
- Practice Cropping systems management and length of growing period
- Selection of cropping systems
- Choosing appropriate sowing window and seed rate

Agroclimatic Zones of Odisha

Odisha State has to broad regions; the plateau region and the coastal region. Based on rainfall, soil and crops, there are ten agroclimatic zones in Odisha (Table 5.1).

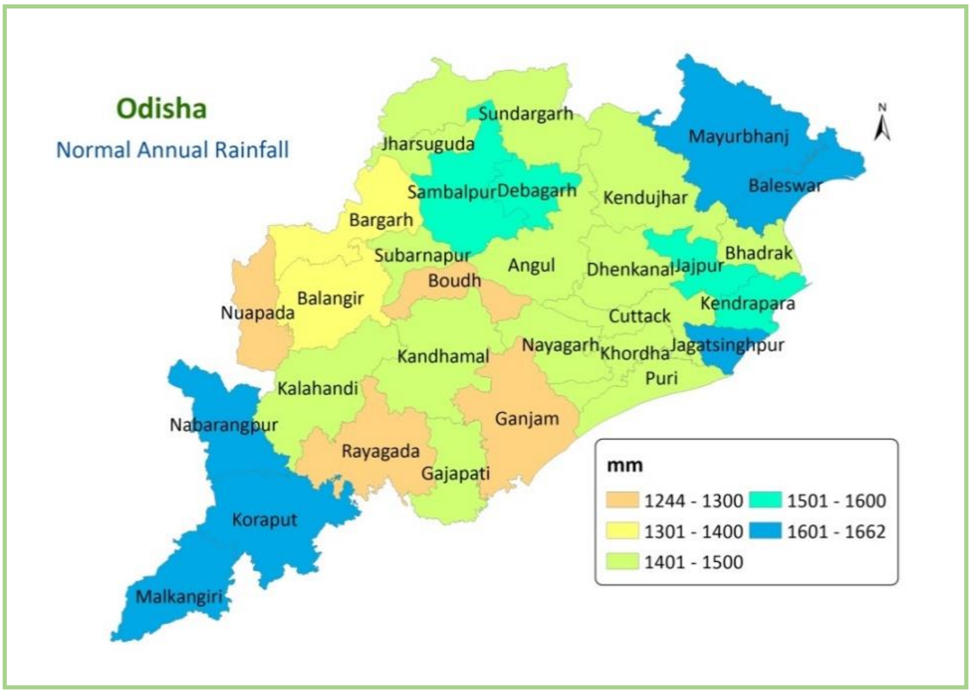

Figure 5.1: Annual rainfall.

Table 5.1. Agroclimatic zones of Odisha.							
Sl	Agroclimatic Zone	Agricultural Districts	Climate	Normal			Broad Soil groups
				Mean annual rainfall (mm)	Mean maximum summer temp(°C)	Mean minimum winter temp (°C)	
1	North Western Plateau	Sundargarh, parts of Debagarh, Sambalpur &Jharsuguda	Hot & moist sub-	1600	38	15	Red, Brown forest, Red & Yellow, Mixed Red & Black
2	North Central Plateau	Mayurbhanj, major parts of Kendujhar, (except	Hot & moist sub-	1534	36.6	11.1	Lateritic, Red & Yellow, Mixed Red & Black
3	North Eastern Coastal Plain	Baleswar, Bhadrak, parts of Jajpur&hatdihi block of Kendujhar	Moist sub-humid	1568	36	14.8	Red, Lateritic, Deltaic alluvial, Coastal alluvial & Saline
4	East & South Eastern Coastal	Kendrapara, Khordha, Jagatsinghpur, part of Cuttack , Puri, Nayagarh& part of	Hot & Humid	1577	39	11.5	Saline, Lateritic, Alluvial, Red & Mixed red & Black
5	North Eastern Ghat	Kandhamal, Rayagada, Gajapati, part of Ganjam&	Hot & moist, sub-	1597	37	10.4	Brown forest, Lateritic Alluvial, Red, Mixed Red &
6	Eastern Ghat High Land	Major parts of Koraput, Nabarangpur	Warm & humid	1522	34.1	7.5	Red, Mixed Red & Black, Mixed Red & Yellow
7	South Eastern	Malkangiri & part of Kendujhar	Warm & humid	1710	34.1	13.2	Red, Lateritic, Black
8	Western Undulating Zone	Kalahandi & Nuapada	Hot & moist sub-	1352	37.8	11.9	Red, Mixed Red & Black and Black
9	Western Central Table Land	Bargarh, Balangir, Boudh, Subarnapur, parts of Sambalpur &	Hot & moist sub-	1614	40	12.4	Red & Yellow, Red & Black, Black, Brown forest,
10	Mid Central Table Land	Angul, Dhenkanal, parts of Cuttack & Jajpur	Hot & moist sub-	1421	38.7	14	Alluvial, Red, Lateritic, Mixed Red & Black

Though Odisha receives good rainfall, there is great spatial variation in annual rainfall (Figure 5.1). Districts like Baudh, Ganjam, Nuapada and Rayagada receive rainfall between 1200-1300 mm, while Koraput, Malkangiri, Nabarangapur, Jagatsinghapur, Baleshwar and Mayurbhanj districts receive above 1600 mm of annual rainfall. Across the various districts, about 80 to 90 per cent of the annual rainfall is received in the Kharif (Jun-Oct) season.

Length of growing period

Length of the rainfed crop-growing period (LGP) is defined as the length of the rainy season, plus the period for which the soil moisture storage at the end of rainy season and the post-rainy season and winter rainfall can meet the crop water need. Because the amount and distribution of rainfall varies considerably from year to year so does the rainfed crop-growing period. Growing period length also depends on the type of soil under a given quantity of rainfall. In areas receiving rainfall for two months, the growing season may be 80 days in a coarse textured soils or 100 days in soils of clayey or clay texture. Similarly in areas with five rainy months, the LGP ranges from 180 to 210 days depending upon soil texture and moisture holding capacity. Therefore, LGP depends on the rainfall distribution, soil depth, water holding capacity and moisture release characteristics of the soil. This assumes great importance from a watershed perspective where soil depth changes with slope and alters the LGP across the watershed, being highest in the low-lying areas and lowest in the upper reaches of the watershed. The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) estimated LGP using the FAO method, where the growing period starts when P > 0.5 PET and ends with utilization of an assumed quantum of stored soil moisture (100 mm) after P falls below PET. The study indicated that LGP vary from 90 days in NW India to 300 days in NE region. In semi-arid region, LGP varies between 120-150 days, in dry sub-humid climates it varies from 150-180 days.

Table 5.2 Variability in rainfed crop-growing period in selected districts of Odisha.

District	Rainfed crop-growing period		
	Beginning	Ending	Duration (days)
Malkangiri	10 Jun	25 Nov	160-170
Mayurbhanj	10 Jun	15 Nov	150-160
Nuapada	20 Jun	31 Oct	130-140
Puri	15 Jun	28 Nov	160-170

Climate variability and change impacts on agriculture

The rate of increase of atmospheric carbon dioxide (CO_2) over the past 70 years is nearly 100 times larger than that at the end of the last ice age. As far as direct and proxy observations can tell, such abrupt changes in the atmospheric levels of CO_2 have never before been seen. Carbon dioxide remains in the atmosphere for centuries and in the ocean, where it acidifies the water, for even longer. In July 2017 the CO_2 content has gone up to 407.25 ppm. Atmospheric CO_2 growth rate has increased from about 0.73 ppm per year to 2.11 ppm per year from 1959 to 2014. Under the threat of increased greenhouse gases and resultant higher temperatures and uncertainty in rainfall regimes, there is a critical need to understand the climate variability and assess climate change and its impacts on crops for developing and communicating suitable adaptation and mitigation strategies to all stakeholders particularly farmers and agricultural extension personnel and planners to enhance resilience and also to reduce greenhouse gas emissions.

Table 5.3. Rainfall changes in selected districts of Odisha.				
District	Change in Rainfall (mm) Between (1991-2017) and (1961-1990)			
	Summer	Kharif	Rabi	Annual
Cuttack	34	179	-15	198
Kandhamal	25	159	-17	165
Angul	2	138	-15	125
Sundargarh	0	80	-6	74
Ganjam	25	52	-29	48
Khurda	13	41	-14	40
Koraput	-25	53	-10	18
Bhadrak	5	16	-29	-8
Kendujhar	6	-6	-10	-10
Sambalpur	-11	-12	2	-21
Balangir	-11	-4	-14	-29
Nuapada	-27	1	-20	-46

To understand the rainfall variability, fifty seven years' (1961-2017) monthly rainfall data of twelve districts were collected and seasonal totals computed for all the years. The thirty-year period from 1961 to 1990 was considered as normal and seasonal rainfall for this normal period was compared with the average rainfall of 27-years (1991-2017) for the selected districts (Table 1.3). It is seen that Cuttack district witnessed greatest increase of 198 mm in annual rainfall; while Nuapada district experienced a decreased rainfall of about 46 mm. Results indicate that rainfall in increasing in certain districts and is decreasing in some other districts. These trends indicate the need for assessing the crops and cropping patterns with reference to changing moisture regimes.

Climate Smart Agriculture

Climate-smart agriculture (CSA) is a way to achieve short-and-long-term agricultural development priorities in the face of climate change and serves as a bridge to other development priorities. The three conditions viz., food security, adaptation and mitigation are referred to as the "triple win" of climate-smart agriculture. Climate-smart agriculture includes practices and technologies that sustainably increase productivity, support farmers' adaptation to climate change, and reduce levels of greenhouse gases.

Climate change adaptation

Climate change adaptation refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

Adaptation strategies need to be identified properly for increasing resilience of agricultural production to climate change. Several improved agricultural practices are evolved over time in various regions of the country. Management practices that are being followed under conditions of weather aberrations could also become potential adaptation strategies for climate change.

Resilience to climate change requires identifying climate smart crops and management practices and degree of awareness of community. Intercropping with grain legumes is one of the key strategies to improve productivity and sustainability of rainfed agriculture. Productive intercropping options identified to intensify and diversify rainfed cropping systems are

- Groundnut with maize
- Pigeonpea with maize
- Pigeonpea with soybean

Some of the other initiatives are ridge planting systems; seed treatment; Integrated Pest Management (IPM); adoption of improved crop varieties and production technologies; promoting community-based seed production groups and market linkages. Farmers need to be encouraged to practice seed treatment with *Trichoderma* sp and fungicides for managing seedling diseases and IPM options for controlling pod borer in chickpea and pigeonpea. Improved water use efficiency through IWM is the key in rainfed agriculture. Alternative sources of irrigation water are the carefully planned reuse of municipal wastewater and drainage water.

Climate change mitigation

Strategies for mitigating methane emission from rice cultivation could be alteration in water management, particularly promoting mid-season aeration by short-term drainage; improving organic matter management by promoting aerobic degradation through composting or incorporating it into soil during off-season drained period; use of rice cultivars with few unproductive tillers, high root oxidative activity and high harvest index; and application of fermented manures like biogas slurry in place of unfermented farmyard manure.

Methane emission from ruminants can be reduced by altering the feed composition, either to reduce the percentage which is converted into methane or to improve the milk and meat yield. The most efficient management practice to reduce nitrous oxide emission is site-specific, efficient nutrient management. The emission could also be reduced by nitrification inhibitors such as nitrapyrin and dicyandiamide (DCD).

Direct Seeded Rice (DSR) is an alternative method that can reduce the labour and irrigation water requirements. In the face of increasing population and growing demand for food, the upgrading of rainfed areas through DSR can help in soil and water conservation and deal with risks arising from climate change. Conservation agriculture technology helps to cope up with climate change impacts.

Legume-based systems are more sustainable than cereal only systems on *Vertisols.* Several soil and crop management practices affect carbon (C) sequestration in the soil. Among them, conservation tillage, regular application of organic matter at high rates, integrated nutrient management, restoration of eroded soils, and soil and water conservation practices have a relatively high potential for sequestering C and enhancing and restoring soil fertility in the longer-term.

Leaf Color Chart (LCC) is an easy-to-use and inexpensive tool for determining nitrogen status in plants. Use of the LCC promotes timely and needed application of N fertilizer in rice and wheat to save costly fertilizer and minimize the fertilizer related pollution of surface water and groundwater. It is a promising eco-friendly and inexpensive tool in the hands of farmers.

Renewable energy and farming are a winning combination. Wind, solar, and biomass energy can be harvested forever. Among various renewable sources of energy, biomass, which is produced right in the villages, offers ample scope for its efficient use to carry out domestic, production agriculture, livestock rising and agro-processing activities through thermal and bio-conversion routes. Usage of solar energy is slowly increasing in rural India for solar cookers for cooking, solar drier for drying agriculture produce, solar water heaters and solar photovoltaic systems for pumping devices which are used for irrigation and drinking water. Farmers can lease land to wind developers, use the wind to generate power for their farms, or become wind power producers themselves.

Implementing Integrated Watershed Management Programme in a holistic way can mitigate the adverse effects of climate variability and change, and enhance the capacity of small-farm holders to manage extremes of drought and floods in a sustainable way. Agroclimatic analysis at watershed level coupled with crop-simulation models, and better seasonal and medium duration weather forecasts, help build resilience to climate variability / change.Farmers having access to climate and weather information are more likely to take better crop management actions. Scaling-up of issue of weather-based agroadvisories for better crop management using new ICT tools to reach the farming community will enhance resilience to climate variability and change.

Cropping systems management and length of growing period

Smallholder rainfed farmers find crop management for sustained or improved productivity as challenge in resource-poor situation like in Odisha having a risk of rainfall variability. Farmers are exposed to major constraints for crop productivity such as low soil fertility, water stressed environment as well as flooded condition, risks due to uncertain seasonal weather conditions besides low farm incomes. Although there is no blanket recommendation of improved management practices common for all crops, some affordable cropping system management technologies and appropriate methods of implementation of these technologies that help sustain and improve the productivity of rainfed crops are discussed in this section.

Choice of the crops grown under rainfed conditions should be made based on length of the humid period during the crop-growing season. In arid regions, where rainfall is about 300 mm, the length of humid period is about 1 to 4 weeks. Short duration drought resistant pulses like mungbean, mothbean, cowpea and cereals of 10 to 12 weeks duration like pearl millet and minor millets are suitable. In semi-arid regions, where the length of the humid period is around 6 weeks, rainy season crops like maize, groundnut, sorghum, cotton and vegetables are grown in soils that have a capacity to hold less than 150 mm of water. Additional post-rainy season crops can be grown on conserved soil moisture, in soils that can hold more than 200 mm. In soils with 150-200 mm capacity, intercropping is possible.

In sub-humid areas like Odisha, where humid period is more than 12 weeks duration and the rainfall is twice that of PET, rice-based cropping system is suitable, as other crops cannot tolerate water stagnation. Choice of post-rainy season crops is related to the moisture regime that plays a major role. In medium-deep Alfisols which provides greater potential for sole paddy cropping during rainy season with the cultivars of 120 to 130 days duration. Similarly, in upland areas of Odisha, intercropping with short to medium-duration crops viz, pigeonpea is best suited to make better use of soil water availability.

Selection of cropping systems

Depending on the normal rainfall and type of soil, crops and the cropping systems are generally evolved over years by farming communities in an agro-ecoregion. Other considerations that determine the choice of cropping systems include food and fodder requirements, commodity markets, crop rotational requirements, pests and diseases endemics affecting productivity. Depending on the possible length of growing season as estimated from seasonal rainfall, potential evapotranspiration and soil characteristics, a double cropping system either a sequential systems or an intercrop systems could be adopted to enhance crop intensity and annual productivity (table 5.4). While selecting sequential systems, duration of each crop and suitability of sowing windows in each cropping season are more critical. Sequential system requires short duration crops/cultivars to fit into possible crop growing season and to improve productivity.

Table 5.4 Potential cropping systems in relation to rainfall and soil type.

Rainfall (mm)	Soil type	Length of growing season (weeks)	Suggested cropping systems
350-600	Red soils and shallow Black soils	20	Single rainy season cropping
350-600	Deep Aridisols and sandy soils	20	Single cropping either in *Khari* for *Rabi*
350-600	Deep Black soils	20	Single post rainy season cropping
600-750	Red soils, Black soils, Entisols	20-30	Intercropping
750-900	Entisols, deep Black soils, deep Red soils and Inceptisols	30	Double cropping with monitoring
> 900	Entisols, deep Black soils, deep Red soils and Inceptisols	>30	Double cropping assured
>1000	Entisols, deep Black soils, deep Red soils and Inceptisols	>30	Paddy based cropping system

In Odisha, receiving >1000 mm rainfall and 30 weeks of effective growing season only paddy based cropping system is possible in Red soils, shallow Black soils, deep Aridisols and Entisols. In deep Black soils, a sequence post rainy season crops viz., chickpea/ blackgram/ maize/ greengram is possible. Intercropping is possible in regions having 20-30 weeks of effective growing season and having medium to black soils. With the availability of improved rainfed technologies like rain water management, choice of crops and agronomic practices, a greater proportion of rainfed lands can be brought under intensive cropping system.

Intercropping

Planning of cropping system should be done yearly on entire catchment basis. The type of planning should lead to a proper balance between food, fiber and fodder crops. When the rainfall is between 600-800 mm with a distinct period of moisture surplus, intercropping system should be adopted in uplands for improved crop production. Even in higher rainfall upland areas, intercropping facilitates growing either cereal-legume or legume-legume system of different maturity patterns (Table 5.5). Intercropping minimize risk of crop failure in rainfed systems.

Table 5.5 Efficient intercropping systems for rainfed lands.

Intercropping system	Row ratio	Plant population	
		First crop	Second crop
Maize/ Pigeonpea	2:01	180,000	60,000
Maize/ Blackgram	1:02	70,000	60,000
Castor/ Pigeonpea	1:02	250,000	60,000
Pigeonpea/Black gram or Green gram	1:02	60,000	120,000
Groundnut/ Castor	5:01	250,000	60,000

With intercropping systems, both crops should differ in crop duration, rooting depths, and be different in plant growth habit and configuration. Two crops in the systems should not have common pests and diseases to perpetuate. It is well known that multiple hosts for a particular pest can aggravate the perpetuation of the insect or disease to epidemic proportions. Hence crop rotation and crop diversification are better options to sustain or improve the crop productivity and income to the farmers.

Mixed cropping (mixing seeds of two or more crops and broad casting the mixture) should be avoided as it hinders post-sowing operations. Choice of varieties with in the crops is very important to harness total intercropping advantage. Cereal-legume intercropping systems should be advocated to minimize fertilizer use, reduce pest and disease incidence, take full advantage of growing season, produce balance foods, provide protein rich legume fodder for cattle. Some examples of appropriate intercropping systems are listed in Table 5.5.

Figure 5.2: A maize-pigeonpea intercropping.

Sequential Cropping

The objective should be to maximize economic returns from the system. Therefore, emphasis should be placed on growing season, integrated soil, water and nutrient management, integrated pest and disease management with special emphasis on oilseeds and pulse crops. In addition, timely land preparation and sowing, suitable method of sowing, contingency planning for aberrant weather, balanced fertilization, runoff water collection and lifesaving irrigations, and need based pest and disease management are pre-requisites for successful and productive cropping systems.

Choosing appropriate sowing window and seed rate

Farmers choose a sowing window, mainly depending on the rainfall, *in-situ* soil moisture and normal timing in the season. Their considerations include sufficient or excess soil moisture to effect seed germination, expected dry spells in the season, planning for second season crop and crop productivity. Informed decision-making to increase cropping intensity in a favorable season using skill of probabilistic rainfall forecast and crop modeling to help farmers improve crop productivity by increased use of nutrient inputs efficiently.

In rainfed systems, managing required population is critical issue. It is evident that sufficient seed rate in case of groundnut, soybean and chickpea can significantly enhance crop yields, however due to higher seed costs as well as prospects of low rainfall or soil moisture, farmers tend to adopt low seed rate resulting in sparse population and low productivity especially with rainfed crops. Maintaining optimum seed rate and plant population significantly improves crop productivity.

Table 5.6 Information on crop critical stages, water requirement and sensitivity to weather anomalies.

Crop	Critical growth stages	Water requirement (mm)	Duration (days)	Crop sensitivity
Rice	Tillering, primordial initiation, boot leaf, flowering, grain filling	800+400	110-150	Cool temp - head sterility
Sugarcane	Tillering, flowering, cane maturity	1500-2500	270-365	Frost-ripening
Wheat	Emergence, crown root initiation, tillering, flowering, milky or dough stage, grain hardening	450-650	100-130	Frost –germinate Requires cold for flowering
Chillies	Seedling establishment, vegetative branching, flowering, pod development and ripening	600-1000		Water stress-flower drop
Maize	Emergence, primordial initiation, tasseling and silking, grain filling	500-800	100-140	Frost-germination
Soybean		450-700	100-130	Frost-germinate
Groundnut	Emergence, flowering, pegging, pod development	500-700	90-140	Frost-germinate
Sunflower	Emergence, heading, flowering, seed filling	600-1000	90-130	Frost
Safflower	Emergence, rosette branching, capsule formation, flowering, seed development	600-1200	120-160	Frost tolerant
Chickpea	Emergence, flowering, pod development	300-500	85-130	Frost-flowering

Source: FAO Irrigation and drainage paper 33, 56

Intercropping with grain legumes is one of the key strategies to improve productivity and sustainability of rainfed agriculture. Productive intercropping options identified to intensify and diversify rainfed cropping systems are:

- Groundnut with maize
- Pigeonpea with maize
- Pigeonpea with soybean

Some of the other initiatives are ridge planting systems; seed treatment; integrated pest management (IPM); adoption of improved crop varieties and production technologies; promoting community-based seed production groups and market linkages. Farmers need to be encouraged to practice seed treatment with Trichoderma spp. and fungicides for managing seedling diseases and IPM options for controlling pod borer in chickpea and pigeonpea. Improved water use efficiency through IWM is the key in rainfed agriculture. Alternative sources of irrigation water are the carefully planned reuse of municipal wastewater and drainage water.

Table 5.7 Efficient sequential cropping systems for rainfed lands

Cropping system Kharif-Rabi	Kharif crop	Rabi crop
	Row spacing (cm)	Row spacing (cm)
Rice-chickpea	22.5	22.5-30
Rice-black gram /green gram	22.5	22.5-30
Maize-black gram	60	30
Maize-green gram	60	30
Pigeonpea + green gram	75	30
Pigeonpea + black gram	75	30

ICRISAT assessed several sequential and intercrop systems on different soil types and recorded a yield advantage ranging between 20-35% with maize/ pigeonpea, green gram/ black gram/ pigeonpea intercrop systems, and yield advantages ranging from 20-50% with maize-chickpea, paddy-chickpea, paddy-black gram/ green gram sequential systems compared to sole crop traditional systems in different years. On Alfisols, groundnut/millet and groundnut/pigeonpea intercrop systems were evaluated for enhancement of productivity, and recorded yield advantages ranging between 10-25% in long-term experiments.

Seed treatment

Seed treatment with fungicide and insecticide is desirable to avoid damage to germinating tender seedlings from seed borne or soil borne fungi and insects. If seed treatment is done with systemic fungicides or systemic insecticides, seedlings will be protected from diseases or insects for a month. Seed treatment should be done with Imidacloprid at the rate of 2 mg kg^{-1} to control sucking insects like jassids and aphids, and Chloripyriphos at the rate of 4 ml kg^{-1} of seed to control soil borne insects. Mancozeb at the rate of 3 gm kg^{-1} or Carbendazim at the rate of 1 gm kg^{-1} of seed will be sufficient to control fungal diseases. Combination of fungicides also recommended in seed treatment module, where seed treatment with Thiram and Carbendazim (1:1) at the rate of 2.5 g kg^{-1} were found to be the effective component in groundnut IDM. Seed of legume crops should be treated with crop specific efficient biological nitrogen fixing bacterial (*Rhizobium*) strains. In order to enhance fixation, appropriate tillage methods should be adopted for surface soil to provide good aeration. Leveled fields with gentle slope no water stagnation even after high rainfall events is desirable to facilitate good aeration and higher N fixation in the root zone. Seed priming is another technique used to improve seed distribution at sowing and, good germination and also exerts drought tolerance in crops.

Table 5.8 Information on crop critical stages, water requirement and sensitivity to weather anomalies.

Crop	Critical growth stages	Water requirement (mm)	Duration (days)	Crop sensitivity
Rice	Tillering, primordial initiation, boot leaf, flowering, grain filling	800+400	110-150	Cool temp - head sterility
Banana		1200-2200	300-365	Frost-injury
Sugarcane	Tillering, flowering, cane maturity	1500-2500	270-365	Frost-ripening
Wheat	Emergence, crown root initiation, tillering, flowering, milky or dough stage, grain hardening	450-650	100-130	Frost –germinate Requires cold for flowering
Cotton	Emergence, vegetative and reproductive branching, budding, flowering, boll development	700-1300	150-180	Water stress-Bud, boll drop
Chillies	Seedling establishment, vegetative branching, flowering, pod development and ripening	600-1000		Water stress-flower drop
Maize	Emergence, primordial initiation, tasseling and silking, grain filling	500-800	100-140	Frost-germination
Sorghum	Emergence, primordial initiation, boot leaf, flowering, grain filling	450-650	100-140	Frost-germinate, head sterility
Soybean	Emergence, flowering & pod development	450-700	100-130	Frost-germinate
Groundnut	Emergence, flowering, pegging, pod development	500-700	90-140	Frost-germinate
Sunflower	Emergence, heading, flowering, seed Filling	600-1000	90-130	Frost
Safflower	Emergence, rosette branching, capsule formation, flowering, seed development	600-1200	120-160	Frost tolerant
Chickpea	Emergence, flowering, pod development	300-500	85-130	Frost-flowering

Source: FAO Irrigation and drainage paper 33, 56

In rainfed systems, managing required population is critical issue. It is evident that sufficient seed rate in case of groundnut, soybean and chickpea can significantly enhance crop yields, however due to higher seed costs as well as prospects of low rainfall or soil moisture, farmers tend to adopt low seed rate resulting in sparse population and low productivity especially with rainfed crops. Maintaining optimum seed rate and plant population significantly improves crop productivity.

Weeding and intercultural operation

Weeding and intercultural operation are most important in dry land farming, as higher density weed population compete and efficiently steal the valuable scarce soil nutrients and moisture affecting cultivated crops. It is estimated that weeds on an average cause 20% crop production loss in India. Interculture for inter-row weeding and soil mulching to prevent moisture loss from lower layers, which is very important for rainfed crops frequently affected by long dry spells. Initially slow growing and low population crops like cotton, maize, and some vegetable crops are more prone to weed infestation. Special classes of weeds those are parasitic weeds like *Striga* on sorghum, and *Orabanche* on tobacco require cultural practices and resistant crop varieties to control these weeds. Besides intercultural operations, control measures include crop rotation of crop holidays are some cultural measures. Although chemical control measures are expensive, they are effective and some chemicals are selective in timing and crop specific also. Pre-emergence herbicides and post-emergence crop specific herbicides are also available.

Crop diversification

The main objective is to enhance the farm income by targeting crop diversification and intensification through suitable cropping system management. The diversification will be targeted by two ways. First by crop diversification and second by agricultural diversification.

a. Crop diversification

In India, crop diversification is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops. It is intended to give a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and also to help in reducing risk in agriculture. The introduction of new compatible crop as well as improved varieties of crop is a technology planned to promote as a part of this program. The aim is to enhance plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses.

b. Agricultural diversification

Agricultural diversification is a process of a gradual movement out of subsistence food crops (particularly staple foods) toward diversified market oriented crops that have a larger potential for return to land. This process is triggered by the availability of improved rural infrastructure, rapid technological advancements in agricultural production, and changing food demand patterns. Hence, this process of diversification towards high-value crops is likely to accelerate agricultural growth and usher in a new era of rural entrepreneurship and generate employment opportunities.

Crop intensification

Enhancing the cropping intensity through managing the existing cropping system either through vertical or horizontal expansion will be focused in both the regions. The major constraints include – lack of short duration cultivars, soil fertility decline and poor agronomic practices. In Odisha, introducing pulses in rice fallows on 50 ha area per district using improved technologies (viz, suitable varieties, zero till machineries etc.) is one of the best approaches to enhance on-farm production and income. Similarly, vertical integration through intercropping system with pulses and nutri-cereals should be targeted to realise enhanced per unit area productivity. In simple term, we should look forward to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities.

Diversification/intensification will be taken place either through area augmentation or by crop substitution. If carried out appropriately, it can be used as a tool to augment farm income, generate employment, alleviate poverty and conserve precious soil and water resources. Major driving forces for crop diversification/intensification targeted are increasing income on small farm holdings, mitigating effects of increasing climate variability, balancing food demand, improving fodder for livestock animals, conservation of natural resources, minimizing environmental pollution, reducing dependence on off-farm inputs, depending on crop rotation, decreasing insect pests, diseases and weed problems, increasing community food security.

Direct seeded rice (DSR)

In the conventional puddled transplanting system (PTR), large quantity of irrigation water is used for puddling which breaks capillary pores, destroys soil aggregates and results in formation of hard pan, creating problems for the establishment and growth of succeeding crops. Since the water resources (both surface and underground) are shrinking day by day and the profit margins are decreasing in PTR mainly because of high labour cost and water requirement, so switching over from PTR to DSR cultivation took place. PTR has higher labour demand as compared to DSR as labour is required for uprooting seedlings from the nursery, field puddling and transplanting of the seedlings. Moreover, in case of high wages and low water availability, direct seeding of rice is advantageous.

Major reasons to adopt DSR

Water -guzzling puddled transplanted rice
Conventional rice establishment system requires substantial amount of water. It has been reported that water up to 5000 litres is used to produce 1 kg of rough rice. Rice is a major freshwater user and consumes about 50% of total irrigation water used in Asia and accounts for about 24-30% of the withdrawal of world total freshwater and 34-43% of the world's irrigation water.

Increasing demand and competition of water from non-agricultural sector
The share of water for agriculture is declining very fast because of the increasing population, lowering of the water table, declining water quality, inefficient irrigation systems, and competition with non-agricultural sectors. At present, irrigated agriculture accounts for 70 and 90% of total freshwater withdrawal globally and in Asia, respectively. In the major rice-growing Asian countries, per capita water availability reduced by 34-76% between 1950 and 2005, and is likely to decline by 18-88% by 2050. In Asia, the share of water in agriculture declined from 98% in 1900 to 80% in 2000, and is likely to further decline to 72 % by 2020.

Water wise-direct seeding practice
The establishment technologies, which inherently require less water, and are more efficient in water use are demanded by the grim water scenario in agriculture together with the highly inefficient traditional transplanting system. DSR being a water wise technology, provides the solution. Both methods of DSR (Dry and Wet) are more water efficient, and have an advantage over PTR. However, with increasing shortage of water, Dry-DSR with minimum or zero tillage (ZT) further enhances the benefits of this technology by saving labour.

The rising cost and scarcity of labour at peak periods

DSR saves labour as it avoids nursey raising, uprooting seedlings, transplanting as well as puddling. Further the demand for labour is spread out over a longer period in DSR as compared to PTR, where more labour is required at the time of transplanting thus resulting in its shortage. Rapid economic growth in Asia has increased the demand for labour in non-agricultural sectors resulting in less labour availability for agriculture.

Other Reasons

Adverse effects of Puddling

Puddling breaks capillary pores, destroys soil aggregates, disperses fine clay particles and form a hard pan at shallow depth. It is beneficial for rice as it control weeds, improves availability water and nutrient, facilitates transplanting and results in quick establishment of seedling. Although puddling is known to be beneficial for growing rice, it can adversely affect the growth and yield of subsequent upland crops because of its adverse effects on soil physical properties, which includes poor soil structure, sub-optimal permeability in the lower layers and soil compaction. The harmful effects of puddling on ensuing crops increased interest in shifting from CT-PTR to Dry-DSR on ploughed soil (No puddling) or in ZT conditions, where an upland crop is grown after rice. This is especially relevant to the rice-wheat system in which land goes through wetting and drying phenomenon. It, therefore, becomes imperative to identify alternative establishment method to puddling especially in those regions where water is becoming scarce, and an upland crop is grown after rice.

Rising interest in conservation agriculture

Conservation agriculture (CA) involves zero tillage (ZT) or reduced tillage (RT) followed by row seeding using a drill. Conservation tillage, when utilizes crop residue as mulch with improved crop and resource management methods, is termed CA or integrated crop and resource management (ICRM). Declining/stagnating crop and factor productivity and a deteriorating resource base in cereal systems like rice-wheat have led to the promotion of conservation tillage-based agriculture.

Best fit in cropping system

Besides the savings in labor and water, economic benefits brought out by DSR through the integration of an additional crop (crop intensification) are another reason for the rapid adoption of DSR. Earlier maturity of DSR as compared to PTR fits this crop well in different cropping systems.

Methods of direct seeding

Directed seeded rice can be established by two principal methods:, dry-DSR and wet- DSR. These methods differ from others either in land preparation (tillage) or crop establishment method or in both. Dry and wet-seeding, in which seeds are sown directly in the main field instead of transplanting rice seedlings, are commonly referred to as direct seeding. Direct seeding is the oldest method of rice establishment and was shifted with time by transplanting.

a. Dry DSR

In Dry-DSR, rice is established using several different methods, including (i) broadcasting of dry seeds on unpuddled soil after either ZT or CT (ii) dibbled method in a well-prepared field and (iii) drilling of seeds in rows after CT, minimum tillage (MT) using a power tiller-operated seeder, ZT or raised beds. In case of both CT and ZT, a seed-cum-fertilizer drill is used, which, after land preparation or in ZT conditions, places the fertilizer and drills the seeds.

b. Wet DSR

Wet-DSR involves sowing of pre-germinated seeds (radicle 1- 3 mm) on or into puddled soil. When pre-germinated seeds are sown on the surface of puddled soil, the seed environment is mostly aerobic and this is known as aerobic Wet-DSR. When pre-germinated seeds are sown/drilled into puddled soil, the seed environment is mostly anaerobic and this is called as anaerobic Wet-DSR. Wet-DSR under aerobic and anaerobic, seeds can either be broadcasted or sown in-line using a drum seeder[81] or an anaerobic seeder with a furrow opener and closer.

Gap filling after germination

It is important to achieve optimum plant population which is often neglected. Any gap more than 30 cm should be filled up. For this some amount of seed should be kept in reserve. Gap filling should be done as soon as possible preferably within a week so that there is not much difference in growth of plants.

Some of the implements which may be used in the project (low cost mechanization):

Nipping Machine

Nipping machine is a very simple machine which is the modified version of low volume sprayer which has been attached with the surgical blade for cutting the young twigs (Figure 5.3a). In order to induce more number of secondary and tertiary branches, removing the top shoot or apical bud (nipping) is advised in pigeon pea. It breaks apical dominance and induces secondary branch growth in turn resulting in increased flower bearing and pod setting.

Manual seedling planter

The manual seedling planter or easy plater is hollow rod shaped tool which has a sharp edge at the bottom with a lid that can be opened by the spring operated lever at the other end of the hollow rod (figure 5.3b). To plant the seedling, first the seedling should be dropped into the hollow rod and insert the rod into soil, press the lever and remove the tool back from the soil without releasing the lever. In this process seedlings will be planted in the soil and large areas will be covered in less time with less number of labor.

Manual Seed dibbler

A dibbler is a simple tool used by gardeners to poke and create holes in the ground. It is useful for creating holes and furrows for planting seeds into the soil (Figure 5.3c) . A dibbler is used by pushing the tapered end into the soil to the depth required and twisting it to loosen the soil. Seed dibbler is very effective tool for dibbling the bold crop seeds which also helps in reducing seed rate, drudgery of women during sowing, and ensure uniform germination. ICRISAT has demonstrated its usage in 100 acre the farmers field for sowing Pigeonpea, Chickpea, Cotton, Groundnut, Soybean etc. and farmers have found it useful and effective even for gap filling and bund sowing of these crops.

Zero till multi crop planter

Due to fragmented and small land holdings and variable farmer typology, it is neither affordable not advisable to purchase many machines for the planting of different crops by the same farmer. The multi-crop planter can plant different crops with variable seed size, seed rate, depth, spacing etc., providing simple solution to this. In addition to adjustments for row spacing, depth, gears for power transition to seed and fertilizer metering systems, the multi-crop planters have precise seed metering system using inclined rotary plates with variable grove number and size for different seed size and spacing for various crops. This provides flexibility for use of these planters for direct drilling of different crops with precise rate and spacing using the same planter which does not exist in flutted roller metering drills. Hence, the same multi-crop planter can be used for planting different crops by simply changing the inclined plates. The planter can also be used to make the beds and simultaneously sowing the crop just by mounting the shovels and shapers which can be easily accomplished due to the given provision in the machine. The planter has the provision of drilling both seed and fertilizer in one go. Also, as seed priming is very important for good germination and optimum plant population, the multi-crop planters provides opportunity to use primed seeds which is not possible in flutted roller metering drills (Figure 5.3d).

Figure 5.3(a): Nipping machine.

Figure 5.3(b): Manual seedling planter

Figure 5.3(c): Manual seed dibbler

Figure 5.3(d): Zero till multi crop planter

Aerobic composting

- Aerobic composting refers to the process of composting using decomposing microbial culture and ensuring enhanced aeration.
- Aerobic composting can effectively be practiced on ground surface; however, for effective handling, cemented platform (2 m wide and 3 m or as required long) may be constructed.

Composting materials –

Organic waste=100 kg

Dung = 20 kg

Rock phosphate = 4 kg

Urea = 0.5 kg (priming of raw biomass @ 0.5% should be done before one week to lower C:N ratio)

Microbial culture = 1.0-2.0 kg ton^{-1}

Procedure

- Spread raw biomass on cemented platform.
- Sprinkle rock phosphate @ 4 kg per 100 kg straw biomass on the waste material and then sprinkle cow dung slurry. Fill in layers, Fill the heap up to 0.75 m height.
- Do turnings of biomass (upside down and vice-versa) at 10 days' interval up to 50 days.

Precautions

- Take care to maintain proper moisture content by watering at alternate days.
- Instead of sole use of huge amounts of fertilizer nutrients, the integration of cost effective biofertilizers can contribute in enhancing the use efficiency of fertilizer management to bring in better economics or benefit/cost ratio. Biological fertilizers include mainly – vesicular arbuscular mycorrhizae (VAM), phosphate solubilizing micro-organisms (PSM) and nitrogen fixing bacteria.

Aerobic composting and different factors affecting composting process

Aerobic composting is a decomposition process carried out by microorganisms in presence of oxygen whereas anaerobic composting is carried out by anaerobic microorganisms and vermi composting is carried out by Earthworms. Aerobic composting is called as hot process and anaerobic, vermi composting are cool processes. In the first couple of days of aerobic composting, the temperature of the heap raise to 65^{o}C – 70^{o}C which is called as thermophilic phase. The decomposition starts with mesophilic phase (25^{o}C - 45^{o}C for 2 to 5 days) and then proceeds to thermophilic phase (>45^{o}C for 10-15 days) followed by drop down of temperature to mesophilic conditions which prevails till the end of the process.

- The microbial action in the first mesophilic phase raises the temperature of the heap by their metabolic activity, and then the thermophilic bacteria breakdown polymeric substances. Finally further breakdown and maturation of compost happen in the second mesophilic phase.

$$\text{Organic matter} + O_2 = \text{Compost} + CO_2 + H_2O + NO_3^- + SO_4^{2-} + \text{Heat}$$

Different factors affecting aerobic composting

Particle size

The size reduction of biomass increases the exposed surface area for microbial action. The ideal particle size for aerobic composting is 5 cm. The size reduction can be achieved either by tractor mounted shredding machine or electric shredding machine. Tractor mounted shredding machine has the advantage of mobility of machine to the biomass location otherwise have to transport the biomass to the electric shredding machine.

Figure 5.4: Tractor run shredding **machine**

Shredder machines

Table 5.9 Different models of tractor mounted shredder machines.			
Model	Power (HP)	Machine (RPM)	Approx. output capacity (Kg/Hr)
CS33	5 to 10	2800	500
CS50	10 to 15	1600	1000
CS80	30 to 40	1100	3000
C80	25 to 30	1100	2000 – 3000
CS80 heavy duty	50	1100	3000

Nutrients

The microorganisms require Carbon (C), Nitrogen (N), Phosphorus (P), and Potassium (K) as primary nutrients for their metabolic activities and growth. The ideal C:N ratio of biomass material for composting is 30:1 and the range between 25 to 40 is satisfactory. The wide ranges of C:N ratio lead to longer composting time and less C:N ratio leads to loss of excess nitrogen into atmosphere by denitrification (Denitrifying bacteria). The C:N ratio can be maintained by blending the green and brown biomass or by adding nitrogen source like Urea or DAP to the biomass that is deprived of nitrogen. The C:N ratios of different agricultural waste are listed in the below table (table no 3.3). The C:P ratio of the biomass should be between 75:1 and 150:1 (Misra *et al.,* 2003).The biomass with high lignin content takes longer time for decomposition. High content of the lignin leads to slow decomposition due to the recalcitrant nature of lignin. Lignin also reduces the bioavailability of other cell wall constituents. Addition of lignin decomposing fungi may increase the rate of decomposition.

Table 5.10: List of C:N ratios of different biomass.		
Material	N%	C:N
Wheat straw	0.3 – 0.5	80-130
Rice straw	0.3 – 0.5	80-130
Cotton stalks	0.6	70
Maize stalks and leaves	0.8	50-60
Sugar cane trash	0.3 – 0.4	110-120
Green weeds	2.45	13
Fallen leaves	0.5 - 10	40 – 80
Grass clippings	2.15	20
Cow dung	2.0	19
Biogas slurry	2.0	20.4

Aeration (Turning over)

Aeration of the heaps is very important as the composting process is led by aerobic microorganisms. Frequent turnover of the heaps i.e., for every 7 to 10 days supplies enough aeration required by the microorganism. Turning over can be done either manually or by compost heap aerator machine (windrow turnover machine). The machine turnover achieves aeration, proper heap shape and supplies moisture also by the water tank attached to the machine.

Figure 5.5: Compost heap turning over machine.

Moisture

The ideal moisture content of 50% should be maintained for better and fast decomposition. Irrigation of heaps on every alternative day is required to maintain the moisture content. Over irrigation of heaps leads to development of anaerobic condition and slows down the process. To monitor the moisture content take a handful of composting biomass and squeeze it. No water should drip out, but still the biomass should be wet. If water drips out of the squeezed biomass it indicates excess moisture content and one should stop irrigating heaps until moisture content becomes normal.

Figure 5.6: Irrigation of aerobic composting heaps.

Temperature

Aerobic composting has mesophilic (25^oC to 45^oC) and thermophilic phases of temperature (45^oC to 70^oC). Although the composting process starts with mesophilic phase with in few days it enters the thermophilic phase as the temperature raise due to the microbial activity in mesophilic phase. The increased temperature of the windrows (heaps) indicates the robust microbial degradation of the polymers like starch, cellulose, hemicellulose etc. present in the biomass. The change in temperature of the heap is an indicator for the progression of composting process and one can monitor the process using thermometer. The temperature of the heaps can be regulated by aeration and turnings.

Table 5.11. Ideal characteristics of good quality compost.

Sl	Characteristic	Range
1	C/N ratio	<20
2	pH	6.5 – 7.5
3	Color	Dark brown to black
4	Odor	No foul odor
5	Total organic carbon % by weight	12
6	Total Nitrogen (as N) % by weight	8
7	Total Phosphate (as P_2O_5) % by weight	0.4
8	Total Potash (as K_2O) % by weight	0.4
9	Particle size	Minimum 90% of the material should pass through 4.0 mm sieve

Vesicular Arbuscular Mycorrhizae (VAM)

- VAM infects roots, increases effective root surface and soil volume explored for nutrient uptake through extensive mycelia along with solubilizing effect by chemicals released.
- VAM culture may be applied either as mixed with organic composts and spread at sowing/transplanting; coated onto the seed; seedlings dipped into the VAM spore solution; or sprayed onto soil around the plant and watered into the root zone.
- Depending upon the number of spores in VAM culture, the quantity of the culture should be adjusted in a way to apply 10 to 20 spores per individual germinating plant.

Vermicomposting

Vermicomposting is a simple process of composting with the help of earthworms to produce a better enriched end product. In vermicomposting process, earthworms consume biomass and break it into small pieces which expose raw waste biomass to intensive microbial decomposition. Moreover, after passing through the earthworm gut, resulting earthworm castings (worm manure) are also rich in microbial activity to hasten the composting process.

Basic Requirements

- **Earthworms:** *Eisenia fetida* and *Eudrilus eugenae* species of earthworms are consistently used in vermicomposting for their high multiplication rate and efficacy to convert organic matter into vermicompost.
- **Organic Raw Biomass:** Various sources of wastes like crop residue, cattle waste, dairy sludge, brewery yeast, vine fruit industry sludge, textile mill sludge, sugarcane industry wastes like press mud, bagasse and trash, kitchen and agro wastes, paper waste and sludge are converted into valuable organic manures using earthworms. In general cow dung is the most preferred food for earthworms and so it is best to mix it with other raw biomass.
- **Environmental & Other**: Earthworms dislike sunlight; therefore cool and shade is the first and foremost requirement for vermicomposting. It have a moist environment for earthworms to live. The ideal moisture-content range for materials in conventional composting systems is 45-60%. Worms are oxygen breathers and cannot survive anaerobic conditions.

Composting material

- Various ingredients required and ideal ratios in general are as under,
    - Dry organic wastes (DOW) 100 kg
    - Dung slurry (DS) 30 kg
    - Rock phosphate (RP) 4 kg
    - Earthworms (EW) 1000–1500
    - Water (W) 10 L every three days

Procedure

- Fill the biomass in layers of 15-30 cm at weekly interval. In case of crop residues being the dominant biomass, sprinkle dung slurry after crop residue layer.
- Release about 1-2 kg earthworms after filling 1st biomass layer.
- Rock phosphate can be added in between the layers to increase P content of the compost.
- The height of the heap must to taken to max 0.7-0.8 m.
- Once vermicompost is mature, stop watering a week before harvesting.
- Harvest entire heap except bottom 15-30 cm biomass and keep the harvest near the heap.
- Immediately start filling the harvested heap.
- After 15-20 days, the harvested vermicompost can be taken for field application.

Precautions

- Different feeds can contain a wide variety of potentially toxic components. Prominent among them are de-worming medicine in manures, particularly horse manure.
- Some naturally occurring tannin in trees like as cedar and fir can harm worms and even drive them from the beds.
- Materials of animal origin such as eggshells, meat, bone, chicken droppings, etc are not preferred for preparing Vermicompost.
- The material should be free from plastics and glass pieces as they damage the worms' gut.
- After completion of the process, the Vermicompost should be removed from the bed at regular intervals and replaced by fresh waste materials, because earthworm casts are toxic to their population.
- The earthworms should be protected against birds, termites, ants and rats.

Phosphate solubilizing micro-organisms (PSM)

- PSMs can solubilize the complex insoluble form of phosphorus into simple soluble forms that can be taken up by plants.
- For PSM application, mix the culture uniformly with the seeds by using minimum amount of water, dry the inoculated seeds under shade and sow immediately.
- If the seed is to be treated with pesticides; first follow the pesticide treatments and finally treat seeds with PSM.
- For transplanted crops, mix the inoculants with desired stickers in bucket of water, stir the mixture vigorously and then dip the roots of seedlings in this mixture before transplanting.
- Use 5 to 10 g culture (~10^9 spores/cells per g) per kg of seed, 1 to 2 kg for soil application per acre of land, 1 kg for root application (root dipping) of one acre of crop.

Nitrogen fixing Bacteria

- *Azotobacter*/*Azospirillum*group of bacteria in association with non-leguminous while *Rhizobium* in leguminous crops fixes the atmospheric nitrogen and makes it available to plants.
- For inoculating N-fixing bacteria, mix the culture uniformly with the seeds by using minimum amount of water, dry the inoculated seeds under shade and sow immediately.
- For transplanted crops, mix the inoculants in bucket of water, stir the mixture vigorously and then dip the roots of seedlings in this mixture before transplanting.

Use 15 to 20 g culture (~10^9 spores per g) per kg of seed, 1 to 2 kg for soil application per acre of land, 1 kg for root application (root dipping) of one acre of crop.

Harvesting of crops, threshing and drying, crop cutting for yield estimate

Learning objectives

- Harvesting, threshing,
- Crop sample crop cutting procedure for estimating yield

Figure 5.7: Combine Harvester.

Time of harvesting

Timely harvesting is important to reduce damage due to molds, birds, insects, and losses due to shattering and rains. Crops should be harvested when they are physiologically mature. At this stage, the moisture content of the grain is about 25-30%. The following chart indicates physiological maturity in some of the crops, an example of when the grain can be harvested without reduction in yield.

Table 5.12 Symptoms of physiological maturity.

Crop	Symptoms
Sorghum	The grain forms a black layer at the hilum.
Millet	Similar to sorghum.
Groundnut	Kernels develop a distinct seed-coat color and the inside of the shell develops dark marks.
Pigeonpea	Pods dry, seed develops a typical color of the variety and becomes hard.

For example, at physiological maturity, sorghum or pearl millet seeds develop a black spot at the bottom.

An abscission layer is formed between the seed and the spikelet. Thus the nutrient flow from the plant to the seed is cut off and there is no more accumulation of nutrients in the seed therefore, no further growth takes place.

After physiological maturity, the seed starts drying due to solar radiation.

Seed can also be dried artificially in a dryer after harvesting at physiological maturity.

Advantages of Harvesting at Physiological Maturity

- Damage due to birds and molds can be avoided
- Seed germination on the ear head can be avoided

- Loss of seeds due to shattering can be avoided since there is 25 to 30 % moisture in the seed at physiological maturity.
- The desirable moisture percentage for safe storage of sorghum and pearl millet seed is 10%, which can be obtained by sun or artificial drying. Field can be prepared for the next crop while there is some soil moisture.

Methods of Harvesting

Plots can be harvested by hand or by harvesters. Crops should be harvested according to maturity groups and at physiological maturity.

Cloth bags used to collect harvested material should be tagged, indicating field details survey numbers and a duplicate tag should be put in the bag.

Figure 5.8: Blade harvester- groundnuts.

Procedure for Crop cutting for yield estimation

Crop cutting experiment (CCE): A method of yield estimation

The yield of given crop is estimated through conducting Crop Cutting Experiments (CCEs) as designed by General Crop Estimation Surveys (GCESs). In this method a portion of field is selected by following random sampling method. The experiment consists of marking the plot, harvesting, threshing and cleaning the produce; and recording the weight of the produce. Proper monitoring is very important for undertaking CCEs by the concerned field staff. Number of fields and crops for undertaking CCE to be selected strategically in targeted village. Following are the steps to undertaken CCE:

Materials required for undertaking CCE:

- A Measuring tape of 30-meter length
- Four straight, long bamboo pegs or wooden pegs each of 1-meter length, those are spiked at one side and has broader shoulder at another side
- A coil of nylon thread of 30-meter length required to mark the area
- A digital weighing balance
- Gunny bags for sample collection
- Tags for writing the field and sample information

- Data sheet, Pencil, Marker etc.

Steps to follow

Selection and marking of field:

- Select the CCE plot which should represent entire field and crop situation. Uniformly mature field should be selected
- For long standing crops such as pigeonpea, sorghum, pearl millet, the marking should be made by long sticks with the prior information to farmer not to disturb the marked plot
- Marking of the plot within a field to be done one weeks before or on the date of harvesting.
- Marking of the experimental plot (5m x 5 m) to be done preferably on South-West corner;
- Conduct one CCE for smaller fields (e.g., less than one ha); and two or more CCEs for larger fields
- Avoid the border area during the marking for CCE
- If the sub-plot is irregular in shape, try to locate the highest possible rectangle sub-plot
- Ensure that CCE to be done both for treated and control plots (beside the treated field) to understand the treatment effect
- If control field is not available at nearby side; it should be located nearest location of with similar soil and slope.

Harvesting of the marked plot

- The date of harvesting is to be fixed by the Field Assistant in consultation with the particular farmer; Field assistant to be in regular contact with farmer so that s/he should not cut the marked plot without informing FA
- While harvesting, care has to be taken that there is no loss of grain and biomass;
- It should not have mixed with bulk harvesting; preferably it is suggested to harvest CCE plot before the bulk harvest to avoid the error
- Proper care also to be made during the sample processing such as i) carrying the produce to the threshing ground; ii) threshing; iii) winnowing; iv) cleaning and weighing.

Figure 5.9: (Left) Picture showing marked CCE plot; and (Right) collected sample from marked area.

Figure 5.10: (Left) Weighing fresh weight (S1) from marked area; (Right) Taking sub-sample and weighing sub-sample (S2).

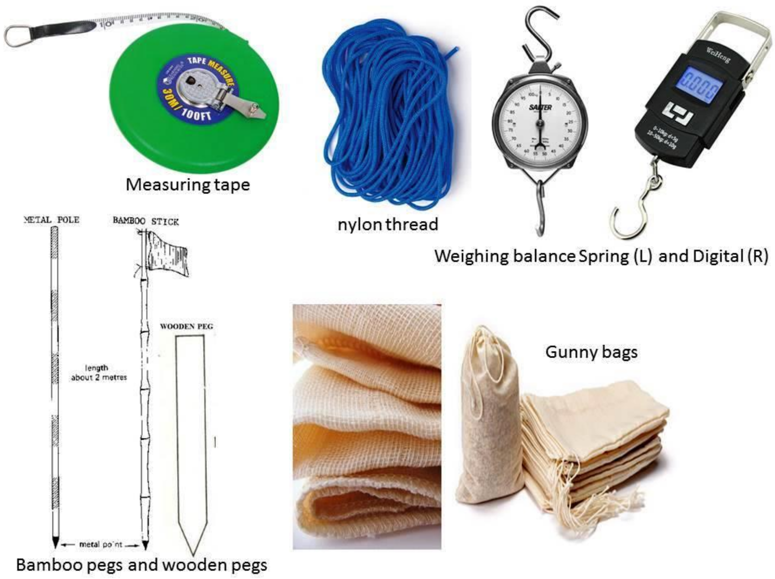

Figure 5.11: Materials for CC.

Sub-sample collection from harvested sample

- Take the fresh weight of produce from the selected CCE area immediately after the harvesting (S1)
- Take the sub-sample weight (nearly 1-2 kg) from the collected harvest (S2) and keep into the marked gunny bag
- Along with the this, also record required details such as i) sample no.; ii) village name; iii) farmer name; iv) date of harvesting; v) crop and variety; vi) treatment
- The collected sample in bag need to be kept in aerated condition (such as roof top, threshing flour, etc.) for sun drying.

Figure 5.12: Sub-sample processing and measurements.

Processing of sample

- After sun drying, segregate seed and biomass and weight them separately (Seed weight=S3; Husk weight= S4; Straw weight =S5). Take the separate weight of grain and husk.
- A piece of cloth or tarpaulin to be used for threshing to avoid contamination and damage
- Ensure that, this operation is completed ASAP otherwise it may be damaged by various means such as due to over drying, bird and rodents attack, etc.

$$Grain\ yield\ \left(\frac{Kg}{ha}\right) = \frac{Sub\ sample\ dry\ wt\ (S4)}{\text{Area marked (25 m2)}}\, x\, \frac{Total\ Fresh\ wt\ (S1)}{\text{Sub sample fresh wt (S2)}}\, x\ 10000\ m2$$

Example: A farmers' participatory field demonstration on chickpea crop was conducted. Nearby farmer is considered as control plot for comparing treatment effect. Crop cutting experiments were conducted in both of the fields. Below is the example shown for crop yield estimation and understanding impact of technology demonstration.

Table 5.13 Procedure for crop yield estimation.		
Data collected	Treated field	Control field
Technology demonstration	Improved cultivar+ Balanced nutrient application	Local cultivar+ normal practice
Marked area (Length x width)	5 m x 5 m (25 m^2)	5 m x 5 m (25 m^2)
Total fresh weight (S1)	4.800 Kg	4.00 Kg
Sub-sample fresh weight (S2)	1.650 Kg	1.60 Kg
Sub-sample dry weight (S3=S4+S5)	1.155 Kg	1.12 Kg
Sub-sample: seed weight (S4)	0.740 Kg	0.67 Kg
Sub-Sample: Straw weight (S5)	0.415 Kg	0.45 Kg
Yield estimation		
Grain yield	861 (Kg/ha)	670 (Kg/ha)
Straw yield	483 (Kg/ha)	450 (Kg/ha)

Session 6: Plant protection – Integrated Pest Management (IPM)

At the end of the session you will be able to:

- Identify important pests of major crops in Odisha
- Describe the tools for IPM

What are pests?

Pest can be defined as any living organism which hurts human interests. Living things (insects, mites, fungi, bacteria, viruses, weeds) that destroy human food in the field / storage or those that are detrimental to man's domestic animals or unwanted plants in the field that compete for space and nutrients with the main crop are all examples of the different forms of pests. Simply put a pest is "any organism at the wrong place at the wrong time".

Different tools of Integrated Pest Management (IPM)

IPM Definition

What is cultural control?

Cultural control involves modification in farming practices to suppress pest population.

Examples:

Maintaining optimum moisture content: If possible water should be given by drip irrigation, so that the root zone always has water in the proper proportion (As a general rule of thumb, soil profile should contain 50% soil particles, 25% air and 25% water). Mulching is another way of preventing the loss of water.

Proper nutrient management: Fertilizer schedule should be decided after thorough checking of soil and water analysis. The pH of the soil should be in proper range (6.0 to 6.5) which facilitates the uptake of all the nutrients. As the pH goes to the extreme ends of acidity or alkalinity, the uptake of some nutrients is hampered causing deficiencies while the uptake of some nutrients is in excess causing toxicities. In either case, the growth or development of such plants is adversely affected. Often times farmers put more nitrogenous fertilizers than required which is absorbed by the plants. Such plants act as a magnet for pests and disease-causing organisms.

Crop rotation: Taking the same crop in the same field year after year is not advisable because the pests can find a reliable food source at predictable intervals. Instead crops should be alternated with other crops so that pests which attack one crop cannot attack the other crop. Planting a leguminous crop after cereals can help in fixing nitrogen in the soil and this increased nitrogen becomes available to the successful crop as well.

Intercropping: Planting the field with monocrop favors rapid spread of pests and diseases since the pest or pathogen has no barrier to its spread. But planting intercrops can help in slowing down the spread of pest or disease thereby giving farmer more time to initiate the control measure and increases the probability of successful reduction in the pest/disease incidence. If a cereal legume intercrop is taken, then the legumes fix nitrogen that becomes available to the cereal crop as well.

Adjusting sowing dates: June 30 is the cut-off date for *Kharif* planting of *jowar* because late-sown *jowar* is severely damaged by *jowar* shootfly.

What is Mechanical/Physical control?
Mechanical control involves the usage of physical means such as fences, barriers, traps, etc to manage field pests.

Examples:
Handpicking: Most simple way is handpicking of pest life stages such as egg masses, larvae, pupae, adults, diseased material. Pests collected in this way should be destroyed by burning away from the field.

Pest traps: Installing adequate amount of sex pheromone traps to attract the male adults of a specific pest, can help in confusing the natural mating system of the male adults and thus bringing down the amount of fertilized eggs laid by the female insects. Putting light traps at night that attract many pest insects that are nocturnal. One advantage of light trap is both males and females are attracted towards them unlike in pheromone traps where mostly males get trapped.

Bagging of young fruits like pomegranates to keep them safe from boring insects.

Heat: The increased temperature can be used to kill any live stages of pests within an agricultural commodity. E.g. using hot water treatment for internal pests of mangoes

What is biological control?
Biocontrol involves usage of the pests' natural enemies to minimize the pests and their damage

Examples
Use of natural enemies of crop pests, predators, parasites and pathogens that control the pests as part of the natural cycle.

Predators are generally bigger in size than their prey (pests) and consume more than one individual during their lifetime. The action is quick.

Parasitoids are insect parasites of arthropods that kill relatively slowly from within.

Pathogens are disease causing agents that cause fatal disease in the target pests.
The practice of ecological engineering alters the agroecosystem in such a way that the impact of biocontrol agent is more pronounced. This can be done by planting certain plants across the periphery of the field. These plants provide a source of nectar and pollen for the natural enemies to feed in the absence of their natural prey. These crops include sunflower, cowpea, okra, onion, maize and marigold.

What is chemical control?
Chemical control involves the use of pesticides to manage pests. Use of pesticides should be the last resort when the (Economic Threshold Level) ETL is crossed.

Examples

Pesticides may be classified according to:

a) Target pest species:

- Insects : Insecticides
- Fungi: Fungicides
- Bacteria: Bactericides
- Mites: Miticide/Acaricide
- Mollusks: Molluscicide
- Rodents: Rodenticides
- Nematodes: Nematicides

b) Basis of their routes of entry into the body system of the target pest:

- **Stomach poisons:** These enter the body of the pest through the mouth during feeding into the digestive tract from where these are absorbed into the systems. Stomach poisons are more effective against chewing insects and useful in controlling insects with siphoning or sponging types of mouth parts (housefly for an example). Examples: sulfur, lead arsenate, etc.
- **Contact poisons:** These poisons enter the body directly through the cuticle by contact with the treated surface of the foliage, stem, etc. These poisons act on the nervous system of the pest. These may also be applied directly on to the body of the pest as a spray or dust. Examples: benzene hexachloride, dichloro diphenyl trichloro ethane, endrin, quinalphos, carbamates, etc. Some of the known pesticides derived from plants also have contact action Examples: pyrethrum, rotenone, sabadilla, nicotine, etc.
- **Systemic poisons:** These poisons are applied on the plants' surface such as the foliage, green parts of the stem, and near the roots from where these are translocated into the plant tissues. Most of the systemic poisons act as stomach poisons, or both as stomach and contact poisons. The parts of the plant where these poisons have been translocated become lethal to the pests feeding on these parts of the plants. Systemic poisons are more effective against sucking pests. They have a selective action with little effect on the predators and parasites directly, unless acting through the food chain. Translocation of these poisons takes place mostly through xylem vessels. Examples: demeton-omethyl, phosphamidon, monocrotophos. Phorate, Carbofuran, dimethoate, mevinphos, aldicarb, etc.
- **Fumigants:** These are volatile poisons and enter the body of the pests through the respiratory system. These are widely used in controlling stored grain pests. All types of pests can be killed by fumigants irrespective of the types of mouthparts provided a gas-tight atmosphere is ensured (i.e., fumigants are nonselective). Even for soil pests such as nematodes, fumigation is effective. Examples: dichlorvos, hydrogen cyanide, methyl bromide, paradichlorobenzene, ethylene dichloride, carbon tetrachloride, naphthalene, nemagon, aluminum phosphide, etc.

List of pests and diseases is provided as separate handout

Surveillance and ETL

Pest Surveillance

One of the basic requirements in managing pests on a research farm is constant vigil and surveillance, monitoring of biotic and abiotic components of the crop ecosystem to assess or predict pest outbreaks. Implicit in this concept is the principle of economic threshold (ET) level, the point at which pest control is initiated.

The use of precise monitoring techniques coupled with accurate economic threshold (ET) levels allows the most effective and efficient use of pesticides. The approach is essential to minimize costs, to maintain stability of the agroecosystem, and to reduce the amount of pesticides released into the environment. However, pest surveillance should not be concerned with pest incidence only. It should be used as a tool to determine the factors which actually cause pest occurrence.

Uses of pest surveillance

Surveillance is important for predicting pest outbreaks.

The degree of success of the plant protection measures will largely depend upon an effective pest surveillance and monitoring programs.

By sampling immature stages of insect/pests, it is possible to forecast the numbers of pests expected in the later stages and spray dates are determined so that the first larvae are destroyed.

Surveillance methods

Systematic sampling

Taking samples in the alternate rows and beds, depending upon the size of the plot and the number of rows, it can easily be decided about the rows and beds in which the sampling can be done.

Diagonal fashion

The person should start taking samples from one corner and walk diagonally taking samples from alternate beds. Once the samples are taken in one diagonal line, samples should be taken from the nearest other corner. The percentage of pest incidence and the number of pests per plant are to be calculated.

Economic Threshold and Economic Injury Level

At the economic threshold level, the treatment needs to be initiated so that the damage does not reach the economic injury level (EIL). Below the level of economic threshold, the cost of control exceeds the amount of damage done and therefore control is not advised.

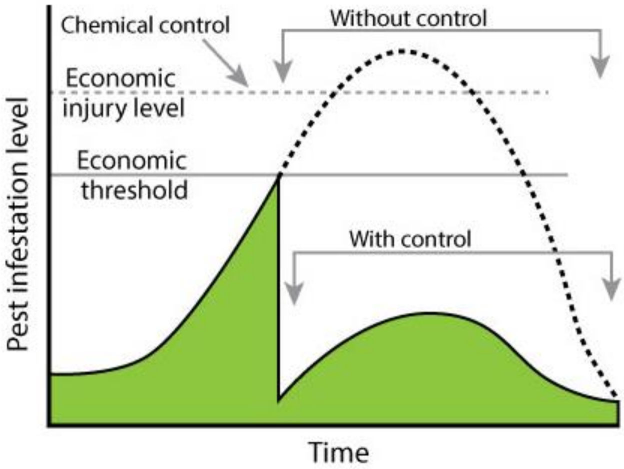

Figure 6.1: showing the ET and EIL.

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The use of precise monitoring techniques coupled with accurate economic threshold levels (ETL) allows the most effective and efficient use of pesticides. The approach is essential to minimize costs, to maintain stability of the agro ecosystem, and to reduce the amount of pesticides released into the environment. However, pest surveillance should not be concerned with pest incidence only. It should be used as a tool to determine the factors which actually cause pest occurrence.

Uses of pest surveillance

1. Surveillance is important for predicting pest outbreaks.

2. The degree of success of the plant protection measures will largely depend upon an effective pest surveillance and monitoring programs.

3. By sampling immature stages of insect/pests, it is possible to forecast the numbers of pests expected in the later stages and spray dates are determined so that the first larvae are destroyed.

Figure 6.2: Surveillance crew in a groundnut field.

Figure 6.3: A pheromone trap in groundnut.

Figure 6.4: Observation for thrips in groundnut.

Basic Scouting Information		
Client: Al Lium Farms	Location: Al's Back 40	Crop: Onions
Date: July 1, 2014	Scout: Courtney Counter	Crop stage: 5 leaf

Crop and Pest Information			
Pest, disease, disorder	How field was scouted	Summary #	Threshold (if applicable)
Onion thrips	Measurements: # thrips and leaves Sample unit: plants #Sample units: 50 #Samples/location: 5 #Locations: 10	0.5 thrips/leaf	1 thrips/leaf
	Measurement: Sample unit: plants #Sample units: #Samples/location: #Locations:		
	Measurement: Sample unit: plants #Sample units: #Samples/location: #Locations:		
	Measurement: Sample unit: plants #Sample units: #Samples/location: #Locations:		

Figure 6.5: Surveillance data sheet.

Timing of spray application

Pesticides are frequently applied as a prophylactic or on a fixed calendar schedule irrespective of the occurrence or level of the pest population. However, fewer applications are needed if they are timed more accurately and this will reduce selection pressure for resistance. A routine pest assessment is required, preferably aided by a pest forecast of the probable level of infestation, to avoid fixed schedules.

Economic injury level: It is the lowest population density that will cause economic damage.

Economic threshold: The population density at which control measures should be applied to prevent the increasing pest population from reaching the economic injury level.

Apart from counting the number of insects in a crop, various trapping techniques can be used to sample populations, e.g., pheromone traps, light traps, and attractant (such as fishmeal) traps.

Time of sampling and the stage of the life cycle sampled are most important. Detection of eggs is most important to avoid delay in taking the appropriate control measure.

Some larvae are very difficult to find until they reach the third or fourth instar while others feed inside plant parts. A pesticide application should be done early, at the start of an infestation of first instar larvae, otherwise less control is achieved.

Know the signs of a potential problem.

The most obvious sign of a problem is physical damage to the crop. Stands that show patches of thinning, stunting, or dying off may be the first indication of an infestation, as they are usually visible from a distance. If the problem is due to insect damage, examine individual plants to determine chew in or sucking damage to leaves, stems, flowers and buds, and possibly, the insects themselves.

Being able to recognize the symptoms of damage within the crop and on individual plants can help to indicate the presence of an insect pest and its identification.

Symptoms of insect damage will vary, depending on the type of mouthparts of the insect pest. Damage caused by insects with chewing mouthparts is often easy to identify, even when the insects are not readily visible. These insects may remove material from leaves, stems, or other plant parts giving it ragged or chewed look. Injured roots will often show sign of bored holes or lesions, while above ground the plant may appear wilted or stunted. Examples of insects with chewing mouthparts are grasshoppers, larval and adult beetles, larvae of moths and butterflies (caterpillars) and larvae of flies (maggots).

It is more difficult to discern damage caused by insects with sucking mouthparts as the symptoms are often not readily visible. Insects with sucking mouthparts pierce the plant and feed on sap and juices Damage may appear as tiny dots where the mouthparts have pierced the plant tissues. Eventual symptoms may include dead plant tissue in leaf tips, heads, etc. Since these insects inject a chemical to prevent the sap from coagulating while feeding, plant juices will continue to flow after the insect have moved on. Therefore, evidence of sucking insects may be seen as glistening sap extruded on pods and stems.

More advanced symptoms of severe injury include shriveled stems and seeds and a reduction in number of seeds set. Extreme cases in canary seed have been observed where aphid feeding has resulted in empty, whitened tips of heads. Examples of insects with sucking mouthparts are leafhoppers, plant bugs (e.g. Lygus) and aphids.

There are many other signs of insect infestations: lodged plants; silken webs; discoloration of plan tissue; cocoons or pupae found on leaves; insect frass (faeces) on and around plants; and of course direct observation of insect adults and/or larvae. These signs should arouse suspicion of a potential problem and help determine what insect(s) could be causing the damage.

Scouting

Insects are rarely uniformly distributed throughout a field. They are simply too dependent on local environmental conditions and, often, terrain is variable even within a single field. Hills and depression within a field dictate the local pattern of soil moisture, and insects sensitive to soil moisture condition will distribute themselves accordingly.

Cutworms, for example, can be found first on the tops of hills, because of the warmer, drier soil, and may not be noticed in low-lying areas until the insects become larger and more numerous. Conversely wireworms will be less abundant on hilltops, preferring the more moist soils found in low-lying areas.

Many insects tend to be edge feeders because of migration from ditches and adjacent fields with damage more prevalent around the margins. Therefore, field scouting can be most effective while surveying along the field borders. Concentrating control in affected areas can reduce input costs while keeping insect populations below the economic threshold. Scouting for signs of infestation where they are most likely to occur will lead to early detection.

The life stage of an insect is an important factor to determine the best timing for control measures. For example, egg and pupal stages are usually difficult to control. These are non-feeding life stages and are not considered a threat to the crop. Because they are immobile in these stages they are often in locations that are more difficult to access by predators and control measures (e.g. Bertha Army worm pupae or Wheat Midge cocoons in the soil).

Even larvae, which are more susceptible to insecticides, can be difficult, or not economically feasible to manage when they are below the soil surface. In a few cases, insects (e.g. blister beetles) may exhibit both destructive and beneficial behavior depending on life stage. As adults, blister beetles can cause serious damage to portions of canola fields. However, the larval blister beetle is predatory on grasshopper eggs.

Once the presence of a pest has been confirmed, its identification must be verified. Correct identification may require consulting a reference guide or an entomologist. To facilitate this process collect samples of the damage and a few specimens of the pest, including as many life stages a possible. The insect and associated damage should be compared with good reference material.

Sampling

Once the pest has been identified, the level of infestation in the crop must be established. There are several important points to consider while sampling.

It is important to utilize a sampling technique that is appropriate for the type of insect being monitored. The monitoring method is largely related to specific insect behavior. Highly mobile insect like flea beetles and grasshoppers provide two different examples of monitoring techniques.

Rather than attempt to count flea beetles, a per cent plant damage threshold is used. For grasshoppers the economic threshold is measured in insects per m^2. However, sampling such mobile insects by counting the number within a measured area is difficult.

Session 7: Plant protection – Integrated Disease Management (IDM)

At the end of the session you will be able to:

- Identify important diseases of major crops in Odisha
- Describe the tools for IDM

What are plant diseases?

In general, a plant becomes diseased when it is continuously disturbed by some causal agent that results in an abnormal physiological process that disrupts the plant's normal structure, growth, function, or other activities. This interference with one or more of a plant's essential physiological or biochemical systems elicits characteristic pathological conditions or symptoms.

Plant diseases can be broadly classified according to the nature of their primary causal agent, either infectious or noninfectious. Infectious plant diseases are caused by a pathogenic organism such as a fungus, bacterium, mycoplasma, virus, viroid, nematode, or parasitic flowering plant. An infectious agent is capable of reproducing within or on its host and spreading from one susceptible host to another. Noninfectious plant diseases are caused by unfavorable growing conditions, including extremes of temperature, disadvantageous relationships between moisture and oxygen, toxic substances in the soil or atmosphere, and an excess or deficiency of an essential mineral. Because noninfectious causal agents are not organisms capable of reproducing within a host, they are not transmissible.

In nature, plants may be affected by more than one disease-causing agent at a time. A plant that must contend with a nutrient deficiency or an imbalance between soil moisture and oxygen is often more susceptible to infection by a pathogen; a plant infected by one pathogen is often prone to invasion by secondary pathogens. The combination of all disease-causing agents that affect a plant make up the disease complex. Knowledge of normal growth habits, varietal characteristics, and normal variability of plants within a species—as these relate to the conditions under which the plants are growing—is required for a disease to be recognized.

The study of plant diseases is called plant pathology. Pathology is derived from the two Greek words *pathos* (suffering, disease) and *logos* (discourse, study). Plant pathology thus means a study of plant diseases. Some of plant disease symptoms are necrosis, leaf spots, wilting, leaf curl, rosetting, and rots.

How does a disease develop?

In order for a disease to develop, there must be a suitable host plant, an infectious pathogen (microorganism that causes the disease), and a suitable environment.

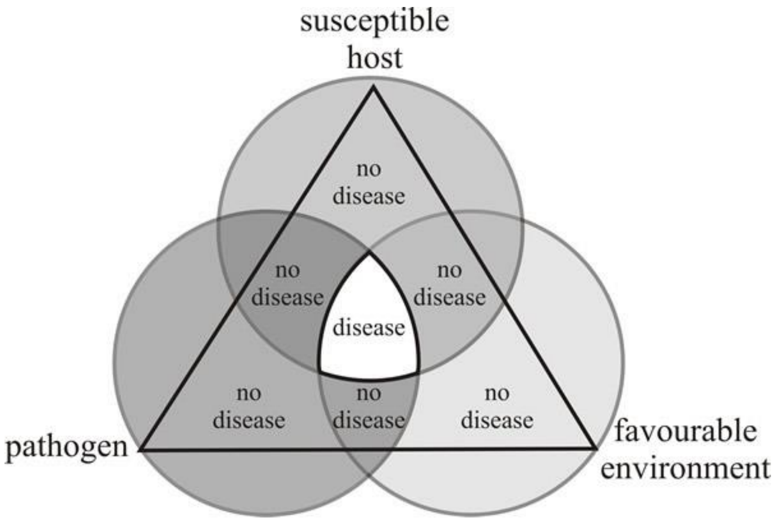

Figure 7.1: Disease triangle.

Integrated Disease Management (IDM)

The damage due to disease-causing agents such as fungi, bacteria, viruses, nematodes etc. can be minimized if the following management practices are adopted.

Cultural methods

Exclusion: Avoid bringing into contact disease-causing inoculum with a healthy host plant. Try to keep the disease-causing propagules as far away from healthy crops as possible. Use healthy (seed or vegetative) planting material from a recognized source that is free from disease. This will help in the prevention of disease getting established should a favorable environment occurs.

Eradication: In order to contain the disease, all plants showing the symptoms of disease along with their adjacent plants that look fine should be destroyed immediately before the diseases sweeps across the entire field causing widespread damage. It would result in the loss of few plants but would save the other healthy plants from getting infested. This again points to the fact that surveillance of the field is of utmost importance.

Control vectors: Many viral diseases are spread from plant to plant by arthropod vectors. Once the plant gets infected there is no cure. Uprooting and burning is the only option. Hence to control such diseases control of the vectors is absolutely essential.

Resistant varieties: Use resistant/tolerant varieties to a particular disease that is prevalent in a given area.

Avoidance: It is better to avoid certain factors that predispose plants to diseases such as ill-drained soils, shade, inadequate irrigation, improper fertilization. Do not injure the plants because injury can be a source of entry for disease-causing pathogens.

Field sanitation: Any plant material containing disease inoculum must be destroyed completely. Weeds that act as wild reservoirs of disease-causing pathogens need to be eliminated.

Biological control

Use of live bio-agents to control various fungi. E.g. use of Trichoderma which is a fungal bio-agent that controls many soil borne pathogens.

Chemical control

Use of fungicides, bactericides, nematicides as per the requirement. All the necessary safety precautions need to be followed in the same way as dealing with insecticides. For more information about the different fungicides look in the appendix.

Symptoms of Diseases

Most names for plant diseases are descriptive of the physical appearance of the affected plant. Some of the common disease symptoms are as follows:

Table 7.1 Common disease symptoms of the affected plant.

Fungal Diseases	Bacterial diseases	Viral diseases
Anthracnose	Leaf spot with yellow halo	Mosaic leaf pattern
Damping off of seedlings	Fruit spot	Crinkled leaves
Leaf spot	Canker	Curled leaves
Chlorosis	Crowngall	Yellow leaves
Powdery mildew		Plant stunting
Downy mildew		

Session 8: Plant protection – Pesticide formulations and their safe handling

At the end of the session you will be able to:

- Learn pesticide formulation and calibration
- Safe handling of chemicals

Pesticide formulations, calculations and calibrations

Pesticides, with a few exceptions, are sold and used as formulated products formulating a pesticide improves its performance and increases its environmental safety. Pesticides are first manufactured as technical grade (active ingredient or a.i.). In this form, they are unsuitable for direct use because of the following reasons:

They have unsuitable physical characteristics. They are generally waxy or lumpy solids or viscous liquids. In this form, they are difficult to apply.

They have high purity levels and hence the required dose is difficult to disperse. The quantity involved is very small to be evenly and effectively dispersed over a specified area.

The toxicity of the a.i. is much higher compared to the formulations Thus, application of a.i is not only hazardous but also needs specialized training and knowledge in handling.

The a.i. does not have the ideal physiochemical characteristics which the formulations have.

Formulations contain the a.i. in a definite concentration together with other materials such as inert carriers, emulsifiers, wetting agents, solvents, thickeners, encapsulants, etc.

According to the intended mode of application, the common formulations can be grouped as follows:

- Emulsifiable concentrates (EC)
- Wettable powders (WP or WDP)
- Ultra-low volume concentrates (ULV)
- For dry application directly from the container
- Dusts (D)
- Granules (G)
- Encapsulated granules
- For application as a gas or vapor
- Fumigants
- Smoke generators or tablets that vaporize iii) Aerosols and pressurized sprays
- Other formulations
- Seed protectants (dry or liquid)
- Baits for rodents, slugs, flies, cockroaches, etc.

Type of Formulations

Emulsifiable concentrates (EC): These are concentrated solutions of the technical grade material containing an emulsifier to help the concentrate mix readily with water for spraying. The emulsifier is a detergent that causes the suspension of microscopically small oil droplets in water, to form an emulsion. When an emulsifiable concentrate is added to water and agitated (i.e., stirred vigorously), the emulsifier causes the oil to disperse uniformly throughout the carrier (i.e., water) producing an opaque liquid. Liquid formulations are easy to transport and store, and require little agitation in the tank. However, care must be exercised in handling the toxic concentrates.

Wettable powders (WP): When an inert dust is impregnated with the pesticides, and a wetting agent is incorporated, the resultant powder, if mixed with water with continuous agitation, forms a fine suspension. To formulate a wettable powder, the technical grade of the toxicant is added to an inert diluent and a wetting agent (comparable to a dry soap or detergent) is added in the required ratio, and the whole combination is thoroughly mixed. Wettable powders usually contain 50% of the inert talc or clay but may even be mixed in a proportion of 75% a.i. and 25% other inert substances. Constant stirring of the mixture is generally required after addition of water, as otherwise the suspension may settle to the bottom of the liquid. Wettable powders are easy to carry, store, measure, and mix. However, care must be taken to protect against inhalation during handling.

Dusts: These are the simplest of formulations and the easiest to apply. In a formulated dust, the following two types of mixtures are usually found:

Undiluted toxic agent, e.g., sulfur dust used for control of mites and powdery mildew.

Toxic a.i. plus an inert diluent. This is the most common dust formulation sold as 2%, 5%, or 10% a.i dust.

Dusts are the least effective and, although prices are lower, have the least economic return. Dusts give poor deposit on the target plants. It has been calculated that not more than 10-15% of the applied material is retained on the surface.

This is a formulation in which the chemical is in the form of small granules of inert material, either as a coating on the surface of the inert granules, or as an impregnated toxicant in the granules. The a.i. of the granules varies from 3% to 10% in India, but may be up to 25% in some countries. The size of the granules varies from 20 to 80 mesh (i.e., the number of grits (granules) per inch of the sieve through which they have to pass). Granular pesticides can be applied on to the soil, or may be placed in the whorl of leaves depending on the nature of pest control required.

Granular insecticides: These may be more economic since precise applications are possible with them. When applied in the soil, they are generally less harmful to beneficial insects such as bees. For systemic insecticides, granule application is excellent since they are placed in the root zone.

Ultra-low volume sprays (ULV): Ultra low volume applications are so formulated that in many instances, they do not need any further dilution or only a small quantity of diluent carrier is needed. The total volume required with the ULV formulations is from 2 to 4 L ha^{-1}. These formulations require specialized application techniques. ULV sprayers, helicopters or fixed-wing aircraft fitted with spray booms are used. With ULV applications, drift may be a problem.

Botanical insecticides: The following botanical extracts can be prepared at the farm level.

1. 5% neem seed kernel extract (NSKE) which can be prepared by soaking 50 gm of powdered neem seeds (cover should be preferably removed to reduce the interference of mucilaginous material in the NSKE extraction) in 1 litre of water overnight. The next day strain this liquid through a cloth and spray on the crops. The quantity can be adjusted according to the requirement on the farm. Caution needs to be exercised that the seed used is not more than 6 months old.
2. Chilli garlic ginger extract which can be prepared by mixing pastes of 18gm garlic, 9gm chilli and 9gm ginger in one litre of water. This extract is recommended to be used immediately for maximum effectivity.

Resistance in insects: Using the same insecticide over and over or different insecticides with the same mode of action can lead to the development of resistant individuals in the insect population which are unable to be controlled by the same insecticides. Five modes of action of chemical pesticides depending on what physiological system they target (IRAC, 2016). For details refer to the IRAC mode of classification provided in the appendix. The chemical name are provided first with trade names in parentheses.

Plant Protection Equipment

Selecting the right equipment for pesticide application is important for successful pest control. The correct usage of equipment and its proper maintenance are important factors which affect the ability to place pesticides on target more economically and effectively. The choice of equipment depends on its specific use and the need of a particular pest control measure.

Different Types of Plant Protection Equipment Generally Used

- Hand sprayers and atomizers
- Hand compressed sprayers
- Knapsack sprayers
- Tractor-mounted sprayer
- Motorized knapsack mist blowers
- Ultra-low volume or controlled-droplet applicators (ULV/CDA)
- Fogging machines/fog-air sprayers
- Hand-carried dusters
- Hand-carried granule applicators
- Power dusters
- Aerial application (Aircraft sprayers)
- Injectors and fumigation equipment.

Selection and Use of Spraying Equipment

Spraying equipment should be selected on the basis of:

- Frequency of pesticide application,
- Availability of diluent (water, oil, kerosene, etc.),
- Availability of labor (human or animal power),

- Area requiring treatment,
- Characteristics of area (machine equipment for large areas, hand operated equipment for smaller areas),
- Durability of equipment,
- Cost of equipment,
- Availability of after sales service,
- Operating cost, and
- Speed required to treat an area (this will depend on type of crop, stage of crop growth, and volume of spray solution to be applied).

Table 8.1. Volume of water or any diluent carrier at flowering.

Volume	Field crops (L ha- 1)	Trees and bushes (L ha- 1)
High volume (HV)	>600	>1000
Medium volume (MV)	200 - 600	500 - 1000
Low volume (LV)	50 - 200	200 - 500
Very low volume (VLV)	5 - 50	50 - 200
Ultra-low volume (ULV)	<5 <50	

The efficacy of a pesticide in any application technique is mainly influenced by the following three factors

Mean level of deposit (dosage): This refers to the total amount of toxicant (active ingredient) used in treating a unit of the target area;

Distribution of deposit: The surface of the leaf may be completely covered by a chemical (active ingredient) deposit in the case of runoff (high volume) spray, but the deposit may be unevenly distributed; and

Wetting agents tend to decrease droplet size and increase spreads, and low volatility carriers help prevent the evaporation of small droplets (low and ultra-low volumes) and ensure better distribution.

Commonly Used Spraying Equipment (show them in field practicals)

- Hand-operated hydraulic sprayers (knapsack sprayers)
- Power-operated hydraulic sprayers (tractor-mounted sprayers)
- Air carrier sprayers (mist blowers)
- Electrodyne sprayers (electrostatic sprayers)
- Birky sprayers (Birky knapsack sprayers)
- Controlled-droplet application sprayers

Calibration of spraying equipment (group exercise and demo)

To achieve good results from spraying, the sprayer must be clean and in working condition. It must be calibrated before every major spraying operation so that the exact quantity of spray is delivered on the target, which may be plants in the case of insecticide application or soil in the case of herbicides.

The volume of application depends on the:

- Droplet size the sprayer can deliver (depending on the size of the orifice of the nozzle tip),
- Surface area to be sprayed/applied,
- Weather conditions,
- Pesticide formulations (EC, WP)
- Availability of diluent,
- Spraying pressure (maintain uniform pressure throughout the operation),
- Uniform spray swath, and
- Speed of an operator/tractor: maintaining a tractor's or operator's (in the case of manual operation) constant forward speed is essential.

Calibration of knapsack sprayers

- Rinse and clean the sprayer.
- Determine nozzle discharge (by selecting a nozzle) in L min^{-1} at known pressure (V).
- Calculate the walking speed of the operator (starting point, end point) in M min^{-1} (L).
- Determine the width of the spray swath in meters (W).
- Calculate the area sprayed in one minute (W x L) M^2 min^{-1}

Area sprayed min^{-1} = Swath width of spray x Forward speed min^{-1}.

The application rate for any given area:

Volume of spray in L $unit^{-1}$ area = Nozzle discharge (L min^{-1}) x Area

Area sprayed min^{-1}

OR

L ha^{-1} = V x 10000 / L W

g. Calculate the number of spray loads ha^{-1}

Loads ha^{-1} = Rate of application ha^{-1}

Tank capacity of sprayer

Example: How many ls of the commercial formulation Rogor® 30 EC (dimethoate) is required to treat an area of 0.5 ha, if the recommended dose is 0.1%?

a. Compute the total volume of spray (in L) needed to treat the area

Volume of spray after sprayer calibration: 320 L ha^{-1}

EC form: Rogor® 30 EC

Recommended dose: 0. 1 %

Area to be treated: 0.5 ha

320 L x 0.5 ha = 160 L

Formula: $\dfrac{\text{Amount of spray required x \% of spray concentrate}}{\text{\% of ai (EC)}}$

$$\dfrac{160 \text{ L x } 0.1 = 0.533 \text{ or } 533 \text{ mL.}}{45}$$

Therefore, 533 mL of Rogor® 30 EC must be mixed in 160 L of water to spray 0.5 ha.

Off-season maintenance and storage. All plant protection equipment must be stored in a cool and dry place and in the shade.

Equipment should be washed thoroughly with plain water before storage.

Grease and lubricants should be applied to joints and surfaces wherever required to protect from rust.

Storage of Equipment

After each day's field work and at the end of the season, the sprayer's pump, control units, booms, hoses, and engine should be checked thoroughly before storing in a dry place. All spraying equipment should be kept locked and away from children, food, and farm animals, and measures taken to prevent rats from nibbling at hoses and other parts. Many small hydraulic sprayers are preferably stored upside down with the lid removed to allow complete drainage of formulation. If engines are to be stored for a prolonged period, the spark plug should be removed and a little oil, preferably formulated with anti-rust additives, poured into the crank case. The engine should be turned over a couple of times to enable the oil to spread evenly. At the end of each day, it is advisable to add some oil to any type of sprayer pump. This is not necessary if the sprayer is to be used again the following day.

Safety Precautions

The importance of taking safety precautions while handling and applying pesticides is often underestimated. An effort must be made to give a comprehensive account of the various aspects of the safe use of pesticides, especially for staff operating spraying equipment and handling chemicals.

Pesticide Selection

The most important step in pesticide safety is its proper selection. First of all, the pest problem must be correctly identified. Control measures need not be taken if the pest is not of economic importance. Once economic damage due to a pest has been established, the appropriate pesticide and method of treatment can be chosen. Buying an excess of pesticide should be avoided.

Handling and Mixing

The following safety guidelines should be followed while handling pesticides:

- Read the label on the pesticide container and leaflet carefully and follow the instructions therein. Make the calculations required for dilution.
- Obtain the application equipment required, including personal protective devices.
- Never work alone when handling highly toxic pesticides.
- Never leave pesticides unattended; children or animals may be affected.
- Mix chemicals in the open or in a well-ventilated area.
- Measure and mix quantities accurately.
- Never eat, drink, smoke, rub eyes or face while working with pesticides.
- Do not use the mouth to siphon a pesticide from the container.
- Disposal of Empty Containers and Unwanted Pesticides
- Empty the spray tank completely during spraying.
- Never empty the spray tank into irrigation canals, waterways, ponds or a well.
- Decontaminate and destroy devices such as empty containers, buckets, and measuring cups after use.
- Decontaminate all protective clothing and footwear.
- After handling pesticides, take a bath with plenty of water, detergent or soap.

All pesticides and pesticide containers must be disposed of carefully, failing which animal poisoning or environmental contamination can occur. Pesticide wastes should be buried. The site must be chosen carefully to prevent contamination of surface water runoff or groundwater. Pesticide wastes should be buried under at least 1/2 a m of soil mixed with lime to enhance degradation. Initially the pit should be lined with 5-10 cm of clay and coated with 2-3 cm of lime. Wastes should be added to the pit in layers not more than 10-15 cm deep and inter mixed with lime and bio degradable household waste,

Recognizing Pesticide Poisoning

The fundamental principle of safety in the use of pesticides is to prevent poisoning by exercising care. It is easier to prevent poisoning than to treat it. Different pesticides act differently on the human body, and the mechanism and mode of action varies for different insecticides. Some general symptoms however apply. They are listed below.

Symptoms of Organophosphorus poisoning

Headache, giddiness, nervousness, blurred vision, weakness, nausea, cramps, diarrhea and discomfort in chest are some symptoms of poisoning. Other symptoms are sweating, excess salivation, rapid heartbeat, and vomiting. Advanced stages of poisoning usually result in convulsions, loss of bowel control, loss of reflexes, and unconsciousness.

Symptoms of Carbamate poisoning

The symptoms of Carbamate poisoning are essentially the same as those caused by Organophosphorus pesticides.

Symptoms and signs of Organochlorine pesticide poisoning

Nervousness, nausea, diarrhea, and convulsions may result from an exposure to a large dose. Liver and kidney damage have been observed in laboratory animals when administered repeated large doses.

First aid

Immediate medical attention can prevent pesticide exposure from turning into pesticide poisoning. All pesticides have recommended antidotes. Antidotes are drugs and chemicals which counteract the effect of pesticides. Though they do not prevent poisoning, once symptoms of poisoning develop, they counteract that action. Therefore, antidotes are not prophylactic and shouldn't be used routinely prior to handling pesticides. In the event of pesticide exposure:

- Remove patient from the source of contamination,
- Remove contaminated clothing and give patient a bath,
- Keep the patient calm, comfortable, and warm,
- Give the patient immediate medical attention,
- Identify the pesticide as accurately as possible, and if breathing has stopped, initiate artificial resuscitation.

Antidotes

Antidotes should be administered only under the supervision of a registered medical practitioner.

Following are the antidotes generally used:

- Atropine: This antidote for Organophosphates or Carbamate poisoning is administered orally and in severe cases injected. In case of Organochlorine poisoning, this drug can become a lethal poison.
- Vitamin-K (Phytonadione): This is the preferred antidote for anticoagulant poisoning such as that caused by warfarin (Corax®).
- Calcium gluconate: This is administered intravenously and is effective against some Organochlorine insecticides.
- Amyl nitrate: Inhalation
- Diumthiosulphate may be given intravenously.

Personal Protective Equipment

Personal protective equipment (Fig. 5.13) prevents pesticides from coming in contact with the body or clothing. These also protect the eyes and prevent the inhalation of toxic chemicals. Personal safety gear includes clothing that covers the arms, legs, nose, and head. Gloves and boots are used to protect the hand and feet, and hats, helmets, goggles, and face masks to protect the hair, eyes, and nose. Respirators are used to avoid breathing dust, mist or vapor.

Overall: Overalls made of cotton are the best but should not be worn without additional protective clothing. When there is a chance of contacting wet spray, large sleeves with cuff-buttons, and pants with buttons at the bottom offer good protection.

Aprons: Waterproof rubber or plastic aprons are effective. They should be long enough to protect the general clothing.

***Figure 8.1: Personal Protective Equipment (PPE)*.**

Head protection

Dust and mist settle easily on hair. Hats that are water resistant, wide brimmed with sweatbands are effective in protecting it. Many helmets provide attachments for face shields and goggles.

Goggles: These are used to protect the eyes from splashes, spills, mist, and droplets. Goggles with plain lenses and full side shields are preferable. The lenses may become coated with pesticide droplets during spraying; hence cleaning tissues or an extra pair of goggles are a must.

Face shield: A face shield is a transparent acetate or acrylic sheet which covers the face and prevents it from splashes or dust. Face shields allow better air circulation and provide a greater range of vision than goggles.

Hand and feet protection

Gloves: Dermal exposure occurs the most in the hand region. The use of gloves reduces this risk. Gloves should be up to 2 to 3" long below the elbow i.e., they should extend to the mid forearm. Waterproof gloves, such as those made of rubber, latex or PVC are preferable. After use, they should be discarded away from ponds, wells, and animals or even incinerated.

Footwear: Shoes made of rubber or synthetic materials like PVC and nitrite can be used to prevent dermal exposure of feet. Protective footwear should be calf-high and worn with the legs of the protective pants on the outside to prevent spray from getting in. Leather or fabric shoes should never be worn as they absorb pesticides. Shoes should be checked for any leakage or damage before use.

Respiratory equipment

A respirator is a device that offers protection to the lungs and respiratory tract. Different kinds of respiratory equipment are used based on the type and toxicity of pesticides. They include nose filters/disposable masks, cartridge respirators, canister-type respirators/gas masks, positive pressure breathing apparatus, self-contained breathing apparatus, and powered air cartridge respirator.

Safety in Application of Pesticides

Misuse of pesticides can be extremely dangerous. Apart from polluting the environment, they may prove fatal to human beings, animals, birds, and fish. Phytotoxicity often results when used in excess in plants. Judicious use, and careful and safe handling may prevent hazards. Safe handling of pesticides involves their proper selection and careful handling during mixing and application.

Safety during Application

- This reduces risk and prevents pollution. It also ensures safety to animals, which may be nearby. The following precautions may be taken while applying pesticides.
- Wear clothing and use equipment that are protective.
- Spraying should be done in the windward direction, taking care to see that there are no animals, people, or animal feed nearby.
- Apply the correct dosage. Do not use higher dosages than recommended.
- Do not blow, suck or apply the mouth to any sprayer nozzle or other spraying equipment.
- Check the sprayer and spraying equipment for leaks before use. Use properly maintained and functioning equipment.

If any irregular symptoms are noticed during application, medical attention should be sought immediately.

Ill Effects of pesticides

Effects can be classified as follows:

- Acute effects (direct, short-term)
- Chronic effects (indirect, long-term)

5 million agriculture workers suffer poisoning every year, and about 20.000 are killed by pesticides (accidental). Very often caused by Organophosphates (*Parathion*). Poisoning can occur by farm application and by eating contaminated food.

Chronic effects (indirect, long-term):

Even very low levels of pesticide can cause health problems, as they can accumulate within the organism. Pesticides exposure have been linked to:

Neurological problems (OP)

Cancer

Reproductive problems (endocrine disruptors, OP)

Neurological problems:

Many organo-phosphates (OP) interfere with the neurological system. OP have been linked with depression, cognitive problems especially in children, poor learning capacity.

Cancer

Many pesticides are clearly recognized as carcinogenic, substances that can greatly increase the chances of suffering cancer (Vinson et al 2011). The risk of lymphoma and leukaemia increased significantly in exposed children when their mother was exposed during pregnancy. The risk of brain cancer was correlated with paternal exposure either before or after birth. The incidence of brain cancer was influenced by the father's exposure to pesticides.

Reproductive problems

Certain pesticides mimic hormones, these are endocrine disruptors. Data suggests that endocrine disrupting chemicals could be implicated in the rise of human reproductive abnormalities. *Reduced male fertility, testicular cancer, low sperm numbers and quality have all been linked to long-term exposure of some pesticides.*

The indirect toxicity related to two principles:

Organism’s tissues (especially in fatty tissues for fat soluble organochlorines such as DDT) and Bio magnification – an increase in concentration up the food chain.

Movement of Pesticides in the environment:

Pesticide residues can move very far distances in air, in water (rivers, lakes, sea), in groundwater (aquifers, wells), in trophic web (zooplankton, etc.)

Pesticide atmospheric transport:

Same as natural reserves can be polluted, so organic products grown without chemicals.

Use of live bio-agents to control various fungi. E.g. use of Trichoderma which is a fungal bio-agent that controls many soil borne pathogens.

Chemical control

Use of fungicides, bactericides, nematicides as per the requirement. All the necessary safety precautions need to be followed in the same way as dealing with insecticides. For more information about the different fungicides look in the appendix.

Handouts

Weed management

Conoweeder

Weeds are one of the major biological constraints that compete with crops for natural resources as well as added inputs, reduce produce quality and impose various hazards, to both health and environment. Weeds cause up to one–third of the total losses in crops yield, besides acting as alternate hosts of disease, pest and nematodes. Proper weed management is of utmost importance as weeds account for the maximum losses among various pests. Thus, it is required to redesign the strategies from time to time for the successful management of ever increasing problem of weeds.

Proposed strategy

- Understanding major weed problems associated with crops and cropping systems of the pilot area, losses caused by weeds and management practices used by farmers
- Creating awareness of losses caused by weeds and the critical period of crop weed competition to manage weeds.
- Emphasizing the need for cultural management practices which are cost effective, easy to practice, acceptable and accessible to small & large farmers and ecologically sound.
- Integrating preventive, cultural, manual, mechanical and chemical control methods based on farmer's needs, crops grown and location specificity.
- As per the timeline of the activities of crops production, diversification and intensification for sustainable crop production.

Weed management practices to be used

Weeds are to be managed during the critical period of crop weed competition (Table: 1) to minimize the losses caused by weeds using the following methods individually or in an integrated manner as per the location, crop, and farmers need. Coordinated weed management programs should emphasize integrated weed management (IWM) approaches (i.e., cultural, manual, mechanical, biological and chemical methods).

Cultural practices

Timing: Weeds need to be controlled from crop planting/seeding until the crop canopy closes during the cropping season. Weeds should be prevented to set seed in fallow period.

Land preparation and levelling: Use land preparation to control growing weeds and to allow weed seeds to germinate. Kill newly emerging weeds by repeat tillage/herbicide use at adequate (~10day) intervals (stale seedbed technique).

Reduce weed entry into fields: Prevent the introduction of weeds into fields by:

a) use clean good quality seed; b) keep seedling nurseries free of weeds to make sure weeds are not planted with the rice seedlings; c) keep irrigation channels and field bunds free of weeds to prevent weed seeds or vegetative parts entering the fields; d) use clean equipment to prevent field/crop contamination; and e) rotate crops to break weed cycles.

Fallow management: Kill weeds in fallow fields (e.g., use tillage) to prevent flowering, seed-set and the build-up of weed seeds in the soil, as "one year of seeds, seven years of weeds".

Crop-weed competition: Select a weed-competitive variety with early seedling vigor, and high tillering to suppress weeds. Transplanted crops tend to have fewer weeds and less yield loss than direct seeded crops. Transplant healthy, vigorous seedlings that can better compete with weeds in early stages. Maintain an adequate plant population that closes its canopy by maximum tillering to shade out weeds. Apply Nitrogen (N) fertilizer just after weeding to minimize rice-weed competition for N.

Water management: In rice, water gives the best control for weeds (if water is available). Many weeds cannot germinate or grow under flooded conditions (e.g. most grasses and some sedges). Maintain a 2-5 cm water level in the field to minimize weed emergence and lower weed pressure. Good land leveling is critical to avoid high spots where weeds can become established.

Cropping systems: Use of suitable cover crops, intercrops, green manure crops and appropriate crop rotations.

Conservation agriculture: using crop rotations, residues and minimum tillage for better weed management based on location specificity.

Manual weed control: is ecologically sound, provides clean and thorough weeding; good for resource-poor farmers, where labor is available at low wages**.** Weeds are removed and collected from crop fields by hand. The collected weeds are piled on bunds or in case of certain weeds, taken home to feed animals. Manual weeding is a part of IWM. Manual weed control to be undertaken during the critical period or from planting until the crop canopy closes. Start hand weeding within two weeks of planting (or when weeds are large enough to weed). Repeat the weeding once or twice more at 30-32 and 40-42 days after transplanting (DAT) or 40-42 and 50-52 days after sowing (DAS). Do not allow weeds to flower and set seeds in a crop field.

Hand weeding is labor-intensive, costly and time-consuming; involves high drudgery and stress on labor (bending all the time to remove weeds); difficult if the soil surface is not moist and loose; costly if wages are high; difficulty in identifying and removing certain grassy weeds at early stages (e.g. weedy rice, *Echinochloa* spp.). Weeds may survive if pulled and dropped on to wet soil or into standing water)

Mechanical weed control, using human/animal drawn implements or power weeders, is a part of IWM.

- Improved weeding tools use results in labour saving (about 2040 man days per hectare), better and timely weed control.
- Seeding/planting in straight rows is a prerequisite for mechanical weeding.
- It needs less labor and costs less than hand weeding.
- It involves less drudgery and stress than in hand weeding.
- Weeds are controlled using a rotating hoe (push or rotary or conical or power weeder) to cultivate, uproot and bury emerging young weeds between rows of crop plants.
- Weeds need to be controlled from planting until the crop canopy closes.
- In rice, with 2-3 cm of water in the field, start using a rotating hoe when emerged weeds are young (3- to 4-leaf stage). Repeat the hoeing one to two more times at 20-22 and 30-32 DAT or 30-32 and 40-42 DAS. Use good land levelling and standing water to reduce weeds.
- Remove the weeds near the plants (intra row weeds) by hand.

Generally hoeing follows the row direction up the field and back. If the field is uniformly transplanted/seeded on a regular square pattern, it may be possible to hoe in perpendicular directions, only suitable for row-planted crops.

- Timely inter-cultivation may not be practical and difficult in hardened soil or where water is limited.
- Difficult to remove weeds within crop rows.
- Only effective with young weeds (2- to 4-leaf stage).
- Needs more labor (6-8 person-days per ha per weeding) than chemical weed control.
- May damage crop roots.
- The operation needs to be repeated.
- Still some drudgery and stress on labor (if rotating hoe is motorized, it will help).

Herbicides use as a component of IWM.

Herbicides are an important component of IWM because of their effectiveness in weed management at a lower cost due to acute labor shortage and increased cost of labor for manual weeding. But, herbicide application is knowledge intensive and requires technical guidance for their proper use to avoid possible adverse effects due to their misuse. More herbicide amount of herbicide application may injure crop while too little herbicide may not be effective. Hence:

- Apply recommended herbicide to recommended crop only at recommended dose and recommended time of application only.
- Handle the herbicide safely by reading the label before herbicide use and following directions and precautions given on the label.
- Note down the active ingredient (a.i.) in the commercial herbicide formulation (C) and recommended rate of application in kilograms of a.i. per hectare (RR), area to be treated in hectares (A). Compute the quantity of herbicide formulation per hectare (Q) by using the formula: $Q = RR \times A \times 100/C$
- Prior to herbicide spray, determine the application rate of a sprayer, given the nozzle delivery, walking speed and swath and number of spray loads to treat a given area and the correct amount of herbicide for each load.

- Keeping the nozzle the same distance from the ground and walking speed constant will ensure uniform application of herbicide.
- Spray herbicides correctly using protective clothing and minimizing spraying hazards.
- Store unused herbicide in original container in a locked storage area and make sure to keep it away from children.
- Dispose the used herbicides containers properly.

Critical period of crop-weed competition in some of the major crops		
Critical period of crop-weed competition	Critical period	Yield reduction (%)
Crops		
Rice (Dry-direct-seeded)	15-45	40-60
Rice (Wet-direct-seeded)	15-45	30-35
Rice (transplanted)	30-45	15-20
Cotton	15-60	40-50
Wheat	30-45	25-40
Pulses		
Pigeonpea	15-60	24-40
Greengram	15-30	30-50
Black gram	15-30	30-50
Chickpea	30-60	15-35
Lentil	30-60	20-30
Pea	30-45	20-30
Oil Seeds		
Castor	30-60	30-35
Groundnut	40-60	40-50
Linseed	20-45	30-40
Mustard	15-40	15-30
Safflower	15-45	35-60
Sesame	15-45	15-40
Soybean	20-45	40-60
Sunflower	15-30	30-50

Source: DWR, Jabalpur.

Mechanical tools for weed management.		
Implement	Approximate cost (Rs.)	Use
Manual dry land weeder (CRIDA, TNAU & other agriculture universities developed weeders)	600-1000	For inter row weeding (removal of shallow rooted young weed seedlings) in upland crops at an optimal soil moisture of 8 to 10%
Power rotary weeder	40,000 to 1,00, 000 (depending on the capacity)	For inter row weeding in several crops during initial crop growth period (prior to crop canopy cover)
Tractor drawn weeding cum earthling up equipment	15000	For inter row weeding and inter culture operation in several crops (cotton, maize, sorghum, soybean, sugarcane etc.)
Conoweeder	1500	For inter row weeding in row seeded/transplanted irrigated rice
Two row finger type paddy rotary weeder	900	For inter row weeding in row seeded/transplanted irrigated rice
Battery operated portable wetland weeder	8000	For inter row weeding in row seeded/transplanted irrigated rice

Major herbicides for weed control in dry- seeded rice.		
Herbicide	Dose (g a.i./h a)	Application time (DAS)*
Glyphosate	1,000	Before crop planting
Paraquat	500	Before crop planting
Pendimethalin	1,000	1–3
Oxadiargyl	90	1–3
Pyrazosulfuron ethyl	20	1–3
Bispyribac-sodium	25	15–25
Azimsulfuron	17.5–35	15–20
2,4-D sodium salt	1,200	15–25

*DAS=Days after seeding

Major herbicides for weed control in transplanted rice.		
Herbicide	g a.i./ha	Application time *
2,4-D	750-1000	20-25 DAT
Bensulfuron (0.6%) + Pretilachlor- (6%) (Londex power 6.6%)	660	0-3DAT
Chlorimuron + Metsulfuron- methyl	4	15-20 DAT
Anilophos	400	3-5 DAT
Ethoxysulfurn	15	10-15 DAT
Cyhalofop- butyl	60-75	10-15 DAT
Fenoxaprop- ethyl	60-80	25-30 DAT
Pendimethalin	1000-1500	6-7 DAT
Pyrazosulfuron	25	8-10 DAS
Pretilachlor	750	3-7 DAT
Thiobencarb	1000-1500	6 7 DAT

*DAT – Days after transplanting

Herbicides for weed control in maize		
Name	Dose (g a.i. /ha)	Time of application
Atrazine	750-1000	PRE (0-3 DAS)
Pendimethalin	1000 -1500	PRE (0-3 DAS)
Metribuzin	200-300	both PRE (1-3 DAS) and POE (upto 15 DAS)
2,4-D	500	POE (20-25 DAS)
Tembotrione	100-120	POE (15-35 DAS).

PRE= Pre-emergence application; POE=Post emergence application DAS-Days after sowing

Herbicides for weed control in soybean.		
Name	Dose (g a.i. /ha)	Time of application*
Pendimethalin	750-1000	0-3 DAS
Imazethapyr	100	20-25 DAS
Quizalofop-ethyl	50	20-25 DAS
Chlorimuron-ethyl	6	15-20 DAS
Fenoxaprop	80	20-25 DAS
Fenoxaprop + Chlorimuron-ethyl	80+6	20-25 DAS
Imezethapyr+imazamox	35+35	20-25 DAS

Herbicides for weed control in green gram, black gram and pigeonpea.		
Name	Dose (g a.i. /ha)	Time of application *
Alachlor	2000-2500	0-3 DAS
Fluchloralin	750-1000	Preplanting incorporation
Oxadiazon	250	0-3 DAS
Oxyfluorfen	100-125	0-3 DAS
Pendimethalin	750-1000	0-3 DAS
Quizalofop-ethyl	40-50	15-20 DAS

*Days after sowing

Improved varieties recommended for districts					
Sl.	District	Crop	Variety	Class of seed	Available at
1	Angul	Rice	Swarna Sub-1	FS	KVK, Dhenkanal
	Angul	Rice	MTU 1001	FS	KVK, Angul
	Angul	Arhar	PRG 176	CS	KVK, Deogarh
2	Balasore	Rice	CR Dhan409 (Pradhandhan)		
	Balasore	Rice	Maudamani		
3	Bhadrak	Rice	CR Dhan409 (Pradhandhan)		
	Bhadrak	Rice	CR Dhan506		
4	Baragarh	Rice	Swarna Sub-1	FS	KVK, Baragarh
	Baragarh	Rice	MTU 1001	FS	SRF, Gambharipalli
	Baragarh	Arhar	PRG 176	FS	KVK, Baragarh
5	Bolangir	Rice	Shahabhagidhan	FS	KVK, Bolangir
	Bolangir	Rice	Swarna Sub-1	FS	KVK, Bolangir
6	Boudh	Rice	MTU 1001	FS	RRTTS & KVK, Sambalpur

	Boudh	Rice	Sahabhagidhan	FS	RRTTS, sambalpur
	Boudh	Arhar	PRG 176	FS	KVK, Boudh
7	Cuttack	Rice	Maudamani		
	Cuttack	Rice	Pradhandhan		
8	Deogarh	Rice	MTU 1001	FS	RRTTS & KVK, Sambalpur
	Deogarh	Rice	Sahabhagidhan	FS	RRTTS, sambalpur
	Deogarh	Arhar	PRG 176	CS	KVK, Deogarh
9	Dhenkanal	Rice	Maudamani		
	Dhenkanal	Rice	Pradhandhan		
	Dhenkanal	Groundnut	Devi	BS	AICRP on Groundnut
10	Ganjam	Rice	Maudamani		
	Ganjam	Rice	Pradhandhan		
	Ganjam	Arhar	PRG 176	FS	KVK,Ganjam-1
11	Gajapati	Rice	Maudamani		
	Gajapati	Rice	Pradhandhan		
	Gajapati	Ragi	Bhairabi	FS	KVK,Ganjam-1
12	Jagatsinghpur	Rice	Maudamani		
	Jagatsinghpur	Rice	Pradhandhan		
13	Jajpur	Rice	CR Dhan409 (Pradhandhan)		
	Jajpur	Rice	Maudamani		
14	Jharsuguda	Rice	Swarna Sub-1	FS	KVK, Baragarh
	Jharsuguda	Rice	MTU 1001	FS	SRF, Gambharipalli
	Jharsuguda	Maize	OMH- 14 -7	Hybrid	Dept. of PBG, CA, Bhubaneswar
15	Kandhamal	Rice	MTU 1001	FS	RRTTS & KVK, Kalahandi
	Kandhamal	Rice	Swarna Sub-1	FS	KVK,Ganjam- l &Ganjam II
	Kandhamal	Arhar	PRG 176	FS	KVK, Boudh
16	Kalahandi	Rice	MTU 1001	FS	RRTTS & KVK, Kalahandi
	Kalahandi	Rice	MTU 1010	FS	RRTTS & KVK, Kalahandi
	Kalahandi	Arhar	PRG 176	FS	KVK, Boudh
17	Kendrapara	Rice	Maudamani		
	Kendrapara	Rice	Pradhandhan		
18	Keonjhar	Rice	Maudamani		
	Keonjhar	Rice	Pradhandhan		
	Keonjhar	Niger	Utkal Niger 150	TL	KVK, Keonjhar
19	Khordha	Rice	Maudamani		
	Khordha	Rice	Pradhandhan		
	Khordha	Arhar	PRG 176	FS	KVK,Ganjam-1
20	Koraput	Rice	Mandakini	FS	RRTTSS, Jaypore
	Koraput	Arhar	Manak	CS	KVK, Koraput
21	Malkangiri	Rice	MTU 1001	FS	KVK, Malkangiri,
	Malkangiri	Ground nut	Devi	CS	KVK,Kandhamal
	Malkangiri	Niger*	Utkal Niger 150	TL	KVK, Malkangiri
22	Mayurbhanj	Rice	Maudamani		
	Mayurbhanj	Rice	CR Dhan101 (Ankit)		
	Mayurbhanj	Arhar	PRG 176	CS	KVK, Deogarh
	Mayurbhanj	Ground nut	Devi	CS	KVK,Kandhamal

23	Nabarangpur	Rice	Khandagiri	FS	KVK, Nabarangpur
	Nabarangpur	Arhar	PRG 176	FS	KVK, Nabarangpur
24	Nayagarh	Rice	Maudamani		
	Nayagarh	Rice	CR Dhan101 (Ankit)		
25	Nuapada	Rice	Sahabhagidhan	FS	KVK, Nuapada
	Nuapada	Groundnut	Devi	CS	KVK,Kandhamal
26	Puri	Rice	CR Dhan409 (Pradhandhan)		
	Puri	Rice	CR Dhan506		
27	Rayagada	Rice	Ranidhan	FS	KVK, Rayagada
	Rayagada	Arhar	Asha	CS	KVK, Rayagada
	Rayagada	Niger	Utkal Niger 150	CS	KVK, Koraput
28	Sambalpur	Rice	MTU 1001	FS	RRTTS & KVK, Sambalpur
	Sambalpur	Rice	Sahabhagidhan	FS	RRTTS, sambalpur
29	Sonepur	Rice	Sahabhagidhan	FS	KVK, Sonepur
	Sonepur	Rice	Ranidhan	FS	KVK, Sor.epur
30	Sundergarh	Rice	Pratikshya	FS	KVK, Sundergarh I
	Sundergarh	Arhar	PRG 176	CS	KVK, Deogarh

Bio-culture for rapid composting

Bio-culture is a combination of various microorganisms specific and essential for enhancing the composting process.

Instructions for Bio-culture usage:

- Dosage: 1kg per 1000 kg of shredded biomass.
- For 1000 kg of heap of shredded biomass, prepare slurry of Bio-culture i.e., 1 kg in 50 liters of water.
- Sprinkle slurry of Bio-culture in every layer while making the heap of shredded biomass.

General instructions for composting:

- Place a wide plastic sheet on the ground before piling up the biomass.
- For 1000 kg of heap of shredded biomass, 200 kg of cow dung should be added in each layer (one layer of biomass and one layer of cow dung slurry).
- Heap can be of 4-5 feet width and 3-4 feet in height.
- Heap should be turned on a weekly basis until compost is ready.
- Spray water while turning the heap to maintain the moisture level around 40-50%.
- Compost will be ready in 40-45 days. Sieve the compost to get the fine powder.
- Store in a cool and dry place, away from sunlight.

Pests and diseases of crops

Insect pests of paddy					
Paddy (Oryza sativa L.)					
Pest	Scientific Name	Symptoms	ETL	Control Measures	Pest picture
Paddy stem borer	*Scirpophaga incertulas*	In vegetative stage larva enters the stem and feeds on the growing shoot and causes drying of the central shoot known as "dead heart". In grown up plant whole ear heads become dried and yield chaffy grains called as "white ear".	25% damage Or 2 egg mass/m^2	Clipping of leaf tips of the seedlings at the time of transplanting. Apply Cartap 4 G @ 25 kg/ha or Fipronil 0.3 G @ 25 kg/ha or Chlorpyriphos 10 G @ 10 kg/ha. Install pheromone traps @ 8 traps/ha for pest monitoring or 20 traps/ha for direct control through mass trapping. Replace lures at 25 to 30 days interval during the crop period.	
Gall midge	*Orseolia oryzae*	Maggot feeds at the base of the growing shoot Causing formation of a tube like gall that is similar to "onion leaf" or "Silver-shoot". Infested tillers produce no panicles.	10% silver shoots	Optimum recommendation of potash fertilizer. Setup light trap and monitor the adult flies. Spray any one of the following insecticides Phosalone 35 EC 1500 ml/ha or Carbosulfan 25% EC 800-1000 ml/ha or Chlorpyriphos 20% EC 1250 ml/ha or Fipronil 5% SC 1000-1500 g/ha or Fipronil 0.3% GR 16670-25000 g/ha or Thiamethoxam 25% WG 100 g/ha	
Green leaf hopper	*Nephotettix virescens*	Yellowing of leaves from tip to downwards. Plant stunted with reduced vigor Withering or complete drying of plant by sucking the plant sap.	10% damage	Spray Carbaryl 50 WP @ 900 g ha or Acephate 50 WP @ 700 g/ha or Ethofenprox 10 EC @ 500 ml/ha or Imidacloprid 200 SL @ 125 ml/ha or Thiamethoxam 25 WG @ 100 g/ha or Clothianidin 50	

		Pale green adults feeding on upper parts of the crop.		WDG 30 g/ha.	
Brown plant hopper	*Nilaparvata lugens*	Yellowing, browning and drying of plant. Circular patches of drying and lodging of matured plant. Affected plant dries up and gives a scorched appearance called "hopper burn". It is vector of grassy stunt, ragged stunt and wilted stunt diseases.	1/tiller	Spray Imidacloprid 200 SL @ 125 ml/ha or Thiamethoxam 25WG @ 100 g/ha or Ethofenprox 10 EC @ 500 ml/ha or Acephate 50 WP @ 950 g/ha or Carbaryl 50 WP @ 900 g/ha or Neem oil 3% 15 lit/ha	
Leaf folder	*Cnaphalocrocis medinalis*	Leaves fold longitudinally and larvae remains inside. Larva scrapes the green tissues of the leaves, becomes white and dry. During severe infestation the whole field exhibits scorched appearance.	10% damage	Avoid excessive nitrogenous fertilizers. Spray NSKE 5 % or chlorpyriphos 20 EC 1250 ml/ ha or Phosalone 35 EC 1500 ml/ha or Acephate 75 % SP 666-1000 ml/ha or Azadirachtin 0.03% 1000 ml/ha or Carbosulfan 6% G 16.7 kg/ha or Chlorantraniliprole 18.5% SC 150 g/ha or Chlorantraniliprole 0.4% G 10 kg/ha or Fipronil 80%WG 50-62.5 g/ha or Flubendiamide 39.35% M/M SC 50 g/ha or Flubendiamide 20% WG 125-250 g/ha or Thiamethoxam 25% WG 100 kg/ha	

Hispa	*Dicladispa armigera*	Scraping of the upper surface of the leaf blade leaving only the lower epidermis as white streaks parallel to the midrib. Tunneling of larvae through leaf tissue causes irregular translucent white patches that are parallel to the leaf veins. Damaged leaves wither off. Rice field appears burnt when severely infested.	1-2 adults/hill	Leaf tip containing blotch mines should be destroyed. Cut shoot tips to prevent egg laying by the pest. Clipping and burying shoots in the mud can reduce grub populations by 75 - 92%. Spraying chlorpyriphos 20 EC 1250 ml/ ha.	
Gundhi bug	*Leptocorisa acuta*	Grains become chaffy. Black spots on the grains at the site of feeding puncture. Buggy odour in rice field during milky stage	5 bugs/100 earheads	Spray Carbaryl 50 WP @ 1,500 g/ha during afternoon hours. Dust Malathion or Carbaryl @ 30 kg of the formulation/ha	
Panicle mite	*Oligonychus oryzae*	infested plants look pale and loss of chlorophyll on the leaves will be seen by a dirty brown colour.		Spray Sulphur wettable powder @ 3 g/litre, Dicofol @ 5.0 /ml/litre or Profenophos 50 EC @ 2.0 ml/litre water.	
Pigeonpea Cajanus cajan (L.) Millsp.					
Pod borer	*Helicoverpa armigera* (Hüb.)	Feed on flowers and pods. Defoliation in early stages. Pods with round holes	1 larva/plant Or 2 eggs /plant	Pheromone traps Helilure @ 2/ac. Spray Neem oil 0.3% @ 1ml/L. Emamectin benzoate 5SG 0.2g/L. Indoxacarb 15.8 SC 0.2 ml/L. Chlorantraniliprole 18.5 SC 0.2 ml/L. Spinosad 45SC 0.2 ml/L	

Spotted pod borer	*Maruca testulalis*	Bore holes on the buds, flower or pods. Infested pods and flowers are webbed together.	5 larvae/10 plants	Spray Neem oil 0.3% @ 1ml/L. Emamectin benzoate 5SG 0.2g/L. Indoxacarb 15.8 SC 0.2 ml/L. Chlorantraniliprole 18.5 SC 0.2 ml/L. Spinosad 45SC 0.2 ml/L	
Red gram pod fly	*Melanagromyza obtusa*	Dark brown encrustationon the pod wall. Dry pods showing pin head size hole, Seeds shriveled, striped and partially eaten	5 larvae/10 plants	Azadirachtin 0.03 % @ 1ml/L. Dimethoate 30EC @ 1.5ml/L. Emamectin benzoate 5SG 0.2ml/L. Indoxacarb 15.8 SC 0.3 ml/L. Chlorantraniliprole 18.5 SC 0.2 ml/L. Spinosad 45SC 0.2 ml/L. Neem oil twice followed by triazophos 40EC @ 1ml/L	
Pod bugs	*Riptortus pedestris*	Pods with black spots. Shedding of green pods. Poorly filled pods with shriveled grains inside		Azadirachtin 0.03 % @ 1ml/L. Dimethoate 30EC @ 1.5ml/L. Chloropyriphos 20 EC @1.5ml/L	
Bean Aphids	*Aphis craccivora*	Leaves, inflorescence stalk and young pods covered with dark colored aphids. Honey dew secretion with black ant movements	20/2.5 cm shoot length	Dimethoate 30 EC 1.5 ml/L. Imidacloprid 17.8SL @ 0.5ml/L	

Leaf hopper	*Empoasca kerri*	Leave mottled and yellowish in colour. Green colour insects found under surface of leaves		Dimethoate 30 EC 1.5 ml/L. Imidacloprid 17.8SL @ 0.5ml/L	
Eriyophid mite	*Aceria cajani*	Vector of red gram sterility mosaic virus. Infected plants will not flower, stunted growth. Leaves turn yellow with specks.		Dicofol 2ml/lit or wettable sulphur 2g/lit of water.	
Blister beetle	Mylabris phalerata	The adult feeds voraciously on buds and flowers.		Manual collection or collection with insect net and killing of adults in kerosenized water appears to be the only possible solution	
Groundnut (*Arachis hypogaea* L.)					
Red Hairy caterpillars	Amsacta albistriga, A. moorei	Caterpillars cause defoliation of the crop- all the leaves eaten away leaving the main stem alone		Set up 3 to 4 light traps and bonfires immediately after receipt of rains, after sowing in the rainfed season to attract and kill the moths. Phosalone 35 EC 1.5 ml/L or Dichlorvos 76 EC 2 ml/L.	

Groundnut leaf miner	Aproaerema modicella	Young larvae mine into the leaflets, feed on the mesophyll and form small brown blotches on the leaf. Later stages larvae web the leaflets together and feed on them, remaining within the folds. Severely attacked field looks "burnt" from a distance	1 larvae/ meter row	Dimethiate 30 EC 1.5 ml/L or Chlorantraniliprole 18.5 SC 0.2 ml/L. Spinosad 45SC 0.2 ml/L.	
Tobacco caterpillar	Spodoptera litura	Freshly hatched larvae feed gregariously, scraping the chlorophyll, soon disperse. Sometimes the feeding is so heavy that only petioles and branches are left behind	8 egg masses/100 m row	Apply poison bait in the evening. Intercrop lab-lab with groundnut 1:4 ratio. Quinalphos 25 EC 1.5 ml/L.	
Aphids	*Aphis craccivora*	Stunting and distortion of the foliage and stems. They excrete honeydew on which sooty molds flow forming a black coating. Act as vector for peanut stripe virus and groundnut rosette virus complex		Imidacloprid 17.8 SL 0.5 ml/L or Quinalphos 25 EC 1.5 ml/L	
Thrips	*Scirtothrips dorsalis Frankliniella schultzei*	Tender leaves showing yellowish green patches on the upper surface and brown necrotic areas and silvery sheen on the lower surface. Severe infestations cause stunted plants		Imidacloprid 17.8 SL 0.5 ml/L or Quinalphos 25 EC 1.5 ml/L.	

Groundnut white grub	*Holotrichia consanguinea Holotrichia serrata*	The grubs feed roots and damage pods. Grubs feed on fine rootlets, resulting in pale wilted plants, dying in patches.		Carbofuran 3G 1 kg/ac Chlorpyrifos 20EC 5 ml/L Phorate 10G 10 kg/ac	
Termite	*Odontotermes spp*	Wilting of plants in patches. Termites penetrate and hollow out the tap root and stem thus kill the plant. Bore holes into pods and damage the seed.			
Jassids	*Empoasca kerri*	Whitening of veins and chlorotic patches especially at the tips of leaflets, in a typical 'V' shape. Heavily attacked crop looks yellow and gives a scorched appearance known as 'hopper burn'.		Imidacloprid 17.8 SL 0.5 ml/L or Quinalphos 25 EC 1.5 ml/L.	
Maize (*Zea mays* L.)					
Stem fly	*Atherigona orientalis*	The maggot feeds on the young growing shoots results in "dead hearts".	10% damage	Seed treatment with imidacloprid 70 WS 10 g/kg of seeds. Dimethoate 30 EC 1.5 ml/L.	

Stem borer	*Chilo partellus*	Central shoot withers and leading to “dead heart”. Bore holes visible on the stem near the nodes.	10 % damage	Emamectin benzoate 5SG 0.2g/L. Chlorantraniliprole 18.5 SC 0.2 ml/L. Spinosad 45SC 0.2 ml/L	
Earworm	*Helicoverpa armigera*	Larva feeds on silk and developing grains.		Set up of light traps. Set up sex pheromone traps at 2/ac. Emamectin benzoate 5SG 0.2g/L. Chlorantraniliprole 18.5 SC 0.2 ml/L. Spinosad 45SC 0.2 ml/L	
Aphids	*Rhopalosiphum maidis*	Colonies of aphids feed on the plant sap. Yellowing of leaves.		Imidacloprid 17.8 SL 0.5 ml/L or Quinalphos 25 EC 1.5 ml/L.	
Shoot bug	*Peregrinus maidis*	Plants become stunted and yellow. The leaves wither from top downwards. The midribs of the leaves turn red due to egg-laying and may dry up subsequently.		Imidacloprid 17.8 SL 0.5 ml/L or Quinalphos 25 EC 1.5 ml/L.	

Fall army worm	*Spodoptera furgiperda*	Larvae feed on whorl		Spinetoram 12 SC @ 0.2ml/L or Chlorantraniliprole 18.5 SC 0.2 ml/L.	
Chickpea (*Cicer arietinum L.*)					
Pod borer	*Helicoverpa armigera*	Skeletinization of leaves. Feeds flower and green pods. Make circular holes and feed the grains.	1larvae/meter row	Set up of light traps. Set up sex pheromone traps at 2/ac. Emamectin benzoate 5SG 0.2g/L. Chlorantraniliprole 18.5 SC 0.2 ml/L. Spinosad 45SC 0.2 ml/L	
Cut worm	*Agrotis ipsilon*	Caterpillars cut the tender plants at the base.		Profenophos 50EC @ 1.5ml/L or Chlorantraniliprole 18.5 SC 0.2 ml/L. Spinosad 45SC 0.2 ml/L	

Important diseases of paddy-Blast

- Causal agent
  - Fungus
- Predisposing factors
  - High relative humidity
  - Frequent and prolonged periods of rain showers
  - Cool daytime temperatures
  - In upland paddy, large day night temperature differences
- Identification
  - White to grey-green lesions or spots
  - Older lesions on the leaves are elliptical or spindle-shaped
  - Some resemble diamond shape, wide in the center and pointed toward either ends
- Minimizing disease incidence
  - Seed treatment with fungicides
  - Add reasonable level of N
  - Careful control of weeds
  - Proper plant density
  - Drain rice fields early to control epidemics

Important diseases of paddy-Sheath Blight

- Causal agent
  - Fungus
- Predisposing factors
  - High temperature (28-32 C)
  - High levels of Nitrogen fertilizers
  - Relative humidity of crop canopy 85-100%
- Identification
  - Greenish grey lesions develop on the sheath
  - Undergo expansion and spread to other leaves and tillers
  - Older lesions have grey white centres and brown margin
- Minimizing disease incidence
  - Add reasonable level of N
  - Proper plant density
  - Careful control of weeds
  - Drain rice fields early to control epidemics
  - Treat seeds with fungicides

Important diseases of paddy-Bacterial blight

- Causal agent
  - Bacterium
- Predisposing factors
  - High temperature (25-34 C)
  - High levels of Nitrogen fertilizers
  - Relative humidity above 70%
  - Heavy rains or splashing irrigation water
  - Use of trimming tools while transplanting
- Identification
  - In seedlings, yellowing and drying of leaves and wilting of plants
  - In older plants, water-soaked lesions develop
  - Legions have a wavy margin and progress towards the leaf base
  - Bacterial ooze can be seen in early morning which later dries up
- Minimizing disease incidence

  - Add balanced amount of N
  - Ensure good drainage of fields and nursery
  - Proper sanitation
  - Careful control of weeds
  - Avoid rice ratooning and growth of volunteer seedlings
  - Spray neem oil 3% or NSKE 5%
  - Spray Streptomycin sulphate + Tetracycline combination 300 g + Copper oxychloride 1.25kg/ha.
  - If necessary repeat 15 days later.

Important diseases of pigeonpea-powdery mildew

- Causal agent
  - Fungus
- Predisposing factors
  - Cool humid weather
  - Warm humid weather
- Identification
  - Infected plants can have white powdery fungal growth on all aerial parts
  - Powdery patches are seen on lower surface
  - Corresponding upper surface shows yellow chlorotic patches
  - Premature defoliation of affected leaves
  - Young plants become stunted
- Minimizing disease incidence
  - Remove volunteer plants
  - Avoid ratooning

– Proper sanitation
– Spraying with NSKE @ 5% at 10 days interval from the first date of appearance
– Spray Carbendazim @ 1g/lit
– Spray wettable Sulphur @ 2.5g/lit

Important diseases of pigeonpea- Powdery mildew

- Causal agent
  – Fungus
- Predisposing factors
  – Hot dry weather
  – Rain after prolonged dry spell
  – Crop more susceptible in reproductive stage than in vegetative stage
- Identification
  – Infected plants dry up prematurely and suddenly
  – Plant when uprooted reveals rotten roots
  – Early symptoms on stem and branches are spindle shaped lesions
- Minimizing disease incidence
  – Seed treatment with T viride @ 4g or P fluorescens @ 10g/kg
  – Carbendazim @ 2g/kg seed
  – Spot drenching with Carbendazim @ 1g/lit

Important diseases of pigeonpea/chickpea –Dry root rot

- Causal agent
  – Fungus
- Predisposing factors
  – Hot dry weather
  – Rain after prolonged dry spell
  – Crop more susceptible in reproductive stage than in vegetative stage
- Identification
  – Infected plants dry up prematurely and suddenly
  – Plant when uprooted reveals rotten roots
  – Early symptoms on stem and branches are spindle shaped lesions
- Minimizing disease incidence
  – Seed treatment with T viride @ 4g or P fluorescens @ 10g/kg
  – Carbendazim @ 2g/kg seed
  – Spot drenching with Carbendazim @ 1g/lit

Important diseases of maize-Downy mildew

- Causal agent
  - Fungus
- Predisposing factors
  - Warm and humid weather
- Identification
  - Chlorotic striping of leaves and leaf sheaths
  - Dwarfing of plants
  - Downy growth on underside
  - Sometimes tassel malformation
- Minimizing disease incidence
  - Rogueing of affected plants
  - Soil application of *P. fluorescens* (or) *T. viride* @ 2.5 kg / ha
  - Spray Mancozeb 2g/lit at 20 days after sowing

Important diseases of Maize-Rust

- Causal agent
  - Fungus
- Predisposing factors
  - Warm and humid weather
- Identification
  - Small powdery pustules appear on the leaf surface
  - Early stage pustules brown, later turn black
  - Alternate host *Oxalis* species has orange colored pustules
  - Sometimes tassel malformation
- Minimizing disease incidence
  - Rogueing of affected plants
  - Destroying alternate hosts
  - Soil application of *P. fluorescens* (or) *T. viride* @ 2.5 kg / ha
  - Spray Mancozeb 2g/lit at 20 days after sowing

Pictures in this handout have been taken from several websites including, IRRI, TNAU, ICRISAT and various other sources.

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