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

# Manual on the Training Workshop for Master Trainers of the Department of Agriculture, Government of Odisha

*15 - 17 July 2019*

ICRISAT DEVELOPMENT CENTER
ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

# Contents

## Introduction

This Manual is being developed to train the DOA staff e who are one of the key stakeholders of the Odisha Bhoochetna Project. Collaborative organizations such as Department of Agriculture, State Agricultural Universities (SAUs), Krishi Vigyan Kendras (KVKs), Civil Society organizations will be the other stakeholders in the area of Capacity Building which is an integral component of the Odisha project. 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 has also developed tools for presentations for a program. It has a section on “Adult Learning Principles” (Andragogy) for equipping trainers for an appropriate training methodology- often ignored or little understood. Following are the major themes of the proposed program.

- Climate and weather, climate change impacts, adaptation and mitigation strategies
- Soil fertility and soil health , Integrated nutrient management
- Fertilizer calculation, fertilizer application, fertigation
- Cropping system diversification
- Crop care, gap filling, weed management
- Harvesting, threshing, Yield estimation by Crop Cutting procedures
- Integrated pest and disease management (IPDM), pest surveillance, concept of ETL
- Field practical on Soil, sampling, farm machinery, RWH structures, dual purpose rain gauge, calibration of sprayers
- Methodologies of training, participatory training, developing training tools, protocols for conducting and designing training programs- group exercise, case studies, Andragogy

# Sessions

## Session 1: Climate of Odisha, Climate smart agriculture

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

- Define Weather and climate
- Study climate change and variability of weather parameters
- Learn water balance and Length of Growing period
- Characterize different types of droughts
- Apply climate change adaptation and mitigation

**Global Warming**

Greenhouse gases trap heat in the atmosphere and without the greenhouse gases, earth surface temperatures would have been much lower than what we observe now. Carbon dioxide, Methane and Nitrous Oxide are the major greenhouse gases. Growing concentration of greenhouse gases in the atmosphere is raising our temperatures around the world, which is known as "Global Warming". Carbon dioxide enters the atmosphere mostly through burning fossil fuels. Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills. Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste. Global atmospheric concentration of $CO_2$ has increased from preindustrial level of 280 parts per million (ppm) to 408 ppm in Feb 2018. Global projections indicate higher temperature of 1.5 to 4.5°C by the year 2050, as a result of enhanced greenhouse gases. Significant increasing trends in mean maximum temperature over many states in India were reported.

**Weather and climate**

Weather, the day-to-day state of the atmosphere, consists of short-term variation of energy and mass exchanges within the atmosphere and between the earth and the atmosphere. It results from processes that attempt to equalize differences in the distribution of net radiant energy from the sun. Acting over an extended period of time, these exchange processes accumulate to become *Climate*. To define in simple terms, *climate* is the synthesis of weather at a given location over a period of about 30 years. *Climate*, therefore, refers to the characteristic condition of the atmosphere deduced from repeated observations over a long period. More than a statistical average, climate is an aggregate of environmental conditions involving heat, moisture and motion. Any study of climate must consider extremes in addition to means, trends, fluctuation, probabilities and their variations in time and space.

**Climate change and variability**

Evidences over the past few decades show that significant changes in climate are taking place all over the world as a result of enhanced human activities through deforestation, emission of various greenhouse gases and indiscriminate use of fossil fuels. Climate change has aroused serious consciousness because it can result in severe impacts on most vulnerable sections of society, sectors and regions. Changes in climatic parameters affect agriculture and water demand of an area. Changed rainfall patterns lead to frequent extreme conditions like floods, droughts and cyclones. Changes in temperatures impact crop yields, enhance crop water requirements and change the length of the growing period; all these necessitates changes in crops, varieties and management practices at specific regions for sustainable agricultural production.

Various studies show that climate change in India is real and it is one of the major challenges faced by Indian Agriculture. India Meteorological Department (IMD, 2017) reported that the annual mean temperature for the country in the year 2016 was +0.87 °C above the 1971-2000 average, thus making the year 2016 as the warmest year on record since 1901. At the country scale, no long-term trend in the onset date of southwest monsoon over Kerala and total monsoon rainfall over whole country was observed.

A study carried out by ICRISAT under the National Initiative on Climate Resilient Agriculture (NICRA) project based on the gridded rainfall and temperature data of India Meteorological Department quantified the changes in areas under different climates in India. The study indicated a net reduction in the dry sub-humid area (10.7 m ha) in the country, of which about 5.1 Million ha (47%) shifted towards the drier side and about 5.6 Million ha (53%) became wetter, comparing the periods 1971-1990 and 1991-2004 (Kesava Rao et al., 2013). Results for Madhya Pradesh have shown the largest increase in semi-arid area (about 3.82 Million ha) followed by Bihar (2.66 Million ha) and Uttar Pradesh (1.57 Million ha). Relatively little changes occurred in AP; semi-arid areas decreased by 0.24 Million ha, which were shifted to both towards drier side (0.13 Million ha under arid type) and wetter side (0.11 Million ha under dry sub-humid type). Results indicated that dryness and wetness are increasing in different parts of the country in the place of moderate climates existing earlier in these regions.

Based on data for sixty years (1951-2010), Rathore *et. al*. (2013) reported significant increasing trends in mean maximum temperature over all states in India except those in the Indo-Gangetic plains wherein spatially coherent decreasing trends were observed in the annual mean maximum temperature with significant decrease over Haryana (-0.02 °C/year) and Punjab (-0.01 °C/year). Maximum increase in annual mean maximum temperature was observed in Himachal Pradesh with a rate of change of about +0.06 °C/year. Rate of increase in annual mean minimum temperature was highest in Sikkim (0.07 °C/year) while the rate of decrease was highest in Uttara hand (-0.03 °C/year).

**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 1.1).

**Table1.1. Agroclimatic zones of Odisha.**

| Sl. No. | 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-humid | 1600 | 38.0 | 15.0 | Red, Brown forest, Red & Yellow, Mixed Red & Black |
| 2 | North Central Plateau | Mayurbhanj, major parts of Kendujhar, (except Anandapur&Ghasipura block) | Hot & moist sub-humid | 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 | 36.0 | 14.8 | Red, Lateritic, Deltaic alluvial, Coastal alluvial & Saline |
| 4 | East & South Eastern Coastal Plain | Kendrapara, Khordha, Jagatsinghpur, part of Cuttack , Puri, Nayagarh& part of Ganjam | Hot & Humid | 1577 | 39.0 | 11.5 | Saline, Lateritic, Alluvial, Red & Mixed red & Black |
| 5 | North Eastern Ghat | Kandhamal, Rayagada, Gajapati, part of Ganjam& small patches of Koraput | Hot & moist, sub-humid | 1597 | 37.0 | 10.4 | Brown forest, Lateritic Alluvial, Red, Mixed Red & Black |
| Sl. No. | Agroclimatic Zone | Agricultural Districts | Climate | Normal | | | Broad Soil groups |
| | | | | Mean annual rainfall (mm) | Mean maximum summer temp (°C) | Mean minimum winter temp (°C) | |
| 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 Ghat | Malkangiri& part of Kendujhar | Warm & humid | 1710 | 34.1 | 13.2 | Red, Lateritic, Black |
| 8 | Western Undulating Zone | Kalahandi &Nuapada | Hot & moist sub-humid | 1352 | 37.8 | 11.9 | Red, Mixed Red & Black and Black |
| 9 | Western Central Table Land | Bargarh, Balangir, Boudh, Subarnapur, parts of Sambalpur &Jharsuguda | Hot & moist sub-humid | 1614 | 40.0 | 12.4 | Red & Yellow, Red & Black, Black, Brown forest, Lateritic |
| 10 | Mid Central Table Land | Angul, Dhenkanal, parts of Cuttack &Jajpur | Hot & moist sub-humid | 1421 | 38.7 | 14.0 | Alluvial, Red, Lateritic, Mixed Red & Black |

**Long-term rainfall trend in Odisha**

Long term (1871-2016) rainfall data (source: IITM, Pune) of Odisha subdivision was analyzed for the southwest monsoon season (Jun-Sep) for identifying long term trends and short term variability in the time series. It is seen that there is large year-to-year variability in the monsoon rainfall (Figure 1.1). Analysis shows cyclic pattern with short period increasing and decreasing trends and there appears a slightly increasing trend after 1990 onwards.

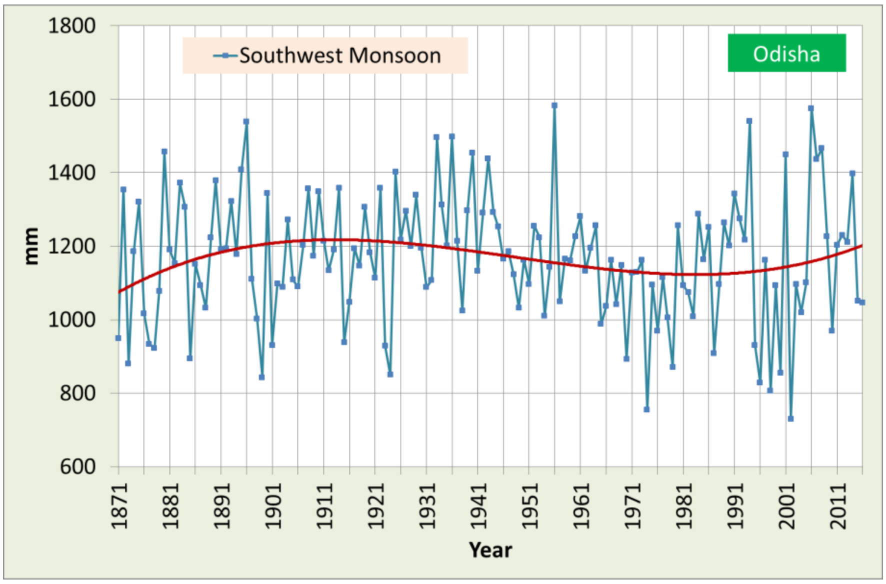


***Figure1.1: Monsoon rainfall variability in Odisha.***

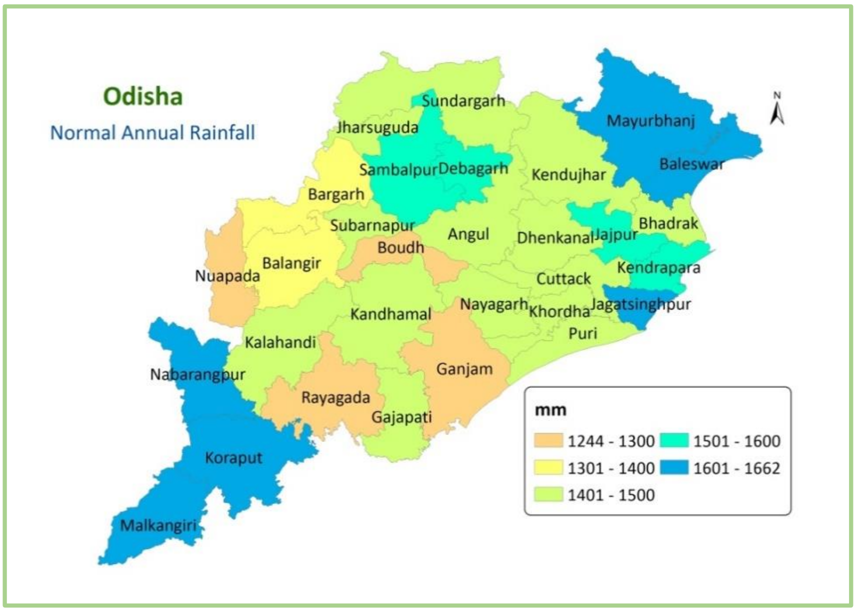


***Figure 1.2: Annual rainfall in districts of Odisha.***

Though Odisha receives good rainfall, there is great spatial variation in annual rainfall (Figure 2.2). 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.

## Rainfall probability

Rainfall characterization of watersheds helps in understanding the sowing period characters and to identify the optimum sowing windows. Selection of crops and cultivars is thus influenced by beginning of sowing rains as well as rainfall distribution in the season.

Characterization of a watershed based on average rainfall can yield good results, provided the rainfall distribution is normal. However, weekly rainfall totals include a number of zeros. Hence several researchers suggested “fitting of incomplete gamma distribution” to this kind of skewed data. Weekly rainfall that can be expected at different probability levels based on incomplete gamma distribution model can be computed using suitable software. As an example weekly rainfall expected at different probability levels were computed for Nuapada and Cuttack districts (Figure 2.3) based on long-period rainfall data (1987-2016).

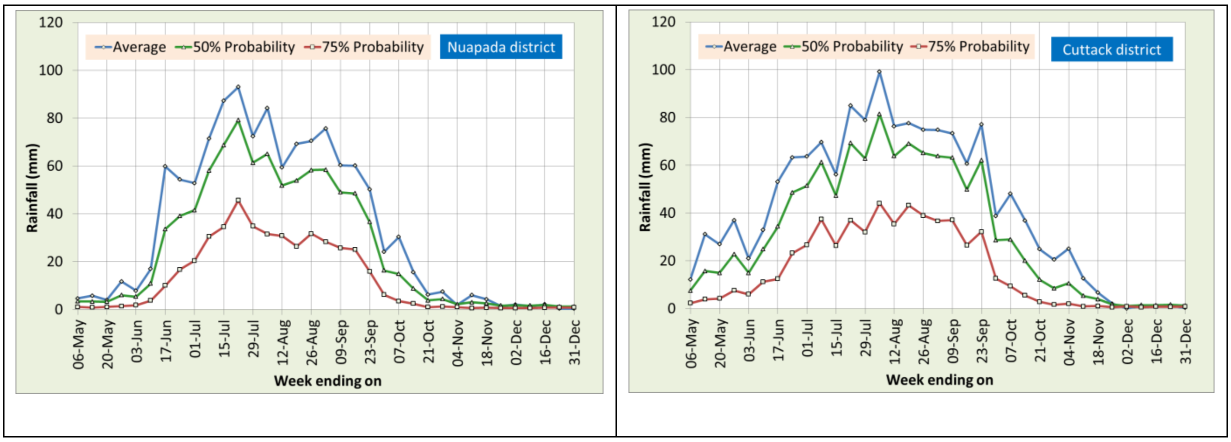


***Figure 1.3: Probability rainfall distribution in Nuapada and Cuttack districts.***

In Nuapada district, peak rainfall occurs in the middle of July while it occurs in the first week of August in Cuttack. In three out of four years (75 per cent probability), above 20 mm rainfall is received during July to middle of September in Nuapada. In Cuttack district, above 20 mm rainfall is received from last week of June to third week of September, indicating comparatively better moisture regime at Cuttack compared to Nuapada.

## Dry and wet spells

Agricultural operations are determined by the receipt of certain amount of rainfall at each stage. Specific amounts of rainfall are required for activities like land preparation, sowing, transplanting, fertilizer application etc. Thus, estimation of probabilities with respect to a given amount of rainfall is useful for rainfed agricultural planning. *Initial Probability* is the probability of receiving a certain amount of rainfall in a given week and is denoted by P(W). The interesting point to be noted is that the probability of getting a next week as a wet week, given the condition that the current week is a wet week – can be estimated. These are called Conditional Probabilities and denoted by P(W/W).

**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 1.2. 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 |

Based on long period (1987-2016) gridded rainfall data (India Meteorological Department) of representative pixels of the four districts, beginning and end of the rainfed crop-growing season / periods were delineated and the LGP was estimated (Table 1.2).

Results indicate that there is variability in the beginning, ending and thus the length of the rainfed crop-growing period across the selected districts in Odisha. Short period of about 130 to 140 days is seen in Nuapada while in Malkangiri and Puri districts, the rainfed crop-growing period could be 160 to 170 days.

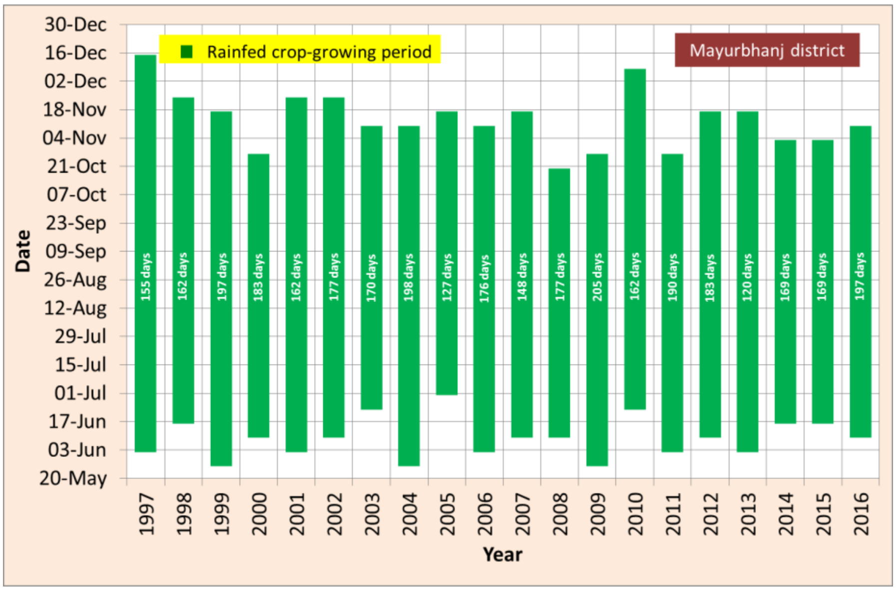


***Figure 1.4: Variability in the rainfed crop-growing period in Mayurbhanj district***

Due to changes in the onset of southwest monsoon rains and rainfall distribution, growing period characters change across years at a location. Considering rainfall data of 20 years (1997-2016), beginning and ending of crop-growing period was estimated for Mayurbhanj district (Figure 1.4).

Results show that though the normal beginning of the season is 10 June and ends by about 15 November. Variability in both beginning and ending is seen. Rainfed crop-growing period began as early as last week of May in the year 2004 while it was delayed up to the first of July in the year 2005. In the year 2008, the growing period ended as early as 20 October while in the years 1997, the growing period was extended up to middle of December. Shortest period of about 135 days was observed in the year 2008, while the year 1997 witnessed the longest rainfed crop-growing period of about 200 days. There is more variability in the ending of the season compared to the beginning of the period.

Crop-growing period of a watershed can also be estimated based on the rainfall, PET data and Available Water holding Capacity (AWC) of the soil. In Odisha, at present, rainfall data is available at block level (total 314 blocks) and weather parameters required for estimating PET are available at district level. Data on AWC is available for only dominant soil types occurring in the State. Using the above data on Available Water holding Capacity (AWC) of soils, weekly rainfall and potential evapotranspiration, soil water balance indices and length of rainfed crop-growing period can be estimated.

At the farm / watershed level, there will not be much change in the PET and rainfall amount. But the available water holding capacity of soils occurring in a watershed will vary significantly from soil to soil. Since the soils occurring in a watershed vary in depth, texture, coarse fragments and type of clay, organic matter content etc., the WHC of the soils also varies accordingly, which may range from very low to very high in one watershed area itself. This affects the crop growth significantly, particularly during the grain formation and later maturity stages, and hence at the watershed level, the LGP is decided significantly by the AWC of the soils occurring in a watershed area. This variation in LGP due to the difference in the AWC of the soils occurring in a watershed area is very important for crop planning at watershed level.

Soil moisture availability period determines effective cropping season. In very dry areas, effective cropping season is normally 11 - 17 weeks, which restricts the choice of crops and limits the farmer to a single crop in the rainy season. In semi-arid and sub-humid regions, the effective cropping season is comparatively longer (22 - 32 weeks). Rainfall pattern and soil depth together determines the choice of crops and cropping systems. On shallow to medium Alfisols and related soils, only single season cropping, mostly during the rainy season is possible. Amount of pre-monsoon rains received in May determines whether or not double cropping is possible on Alfisols.

**Drought characterization**

Drought is a climatic anomaly, characterized by deficient supply of moisture resulting either from sub-normal rainfall, erratic rainfall distribution, higher water need or a combination of all the three factors. More than 60 definitions have been reported on the assessment of drought. National Commission on Agriculture in 1976 has categorized drought into three types, viz., meteorological drought, hydrological drought and agricultural drought based on the concept of its utilization which re defined as below:

**Meteorological drought:** It is a situation when there is significant (> 25%) reduction in rainfall compared to normal over an area.

**Hydrological drought:** Meteorological drought, if prolonged, results in hydrological drought with marked depletion of surface water and consequent drying up of reservoirs, lakes, streams and rivers.

**Agricultural drought:** It occurs when soil moisture and rainfall are inadequate to support a healthy crop growth during growing season; cause extreme crop stress and crops may wilt permanently.

For agricultural planning purposes, knowledge on agricultural droughts is of paramount importance. Crop production under rainfed conditions is influenced by various intensities of drought experienced at different crop growth stages; therefore, knowledge on the frequency of agricultural droughts of varying intensities is essential for developing suitable technologies for increased and sustainable production. Impact of drought depends on the phenological stage of crop as the water requirements of a crop vary with phenological phases. Droughts have a multiplier effect on crop production during the subsequent years also due to:

- Non-availability of quality seeds for sowing of crops
- Inadequate draught power for carrying out agricultural operations as a result of either distress sale of cattle or loss of life
- Reduced use of precious inputs like fertilizers as the investment capacity of the farmers' decline
- Non-availability of raw material in agro-based industries, and

- Deforestation to meet the energy needs in domestic sector as agricultural wastes may not be available in required quantity

Drought is a creeping phenomenon and its effect can be felt after it has happened. Earlier approach for drought management was to wait until an event occurs and try to mitigate its consequences by whatever means available. Water needs in agricultural sector are going to be very high, as several thousand tons of water is required to produce each metric ton of food grains. Therefore, long-term strategies for mitigation of droughts have to be based upon conservation, development and management of water resources. In this context, the farmer-participatory consortium model for integrated watershed management developed by ICRISAT was very successful and is being scaled-up in many states in India and more countries in Southeast Asia and Sub Saharan Africa.

**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 1.3. 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.

Studies indicate that in the past fifty years, temperatures are continuously increasing in several parts of India, particularly in Rabi season. Analysis of temperature data for 66 years (1951-2016) for Odisha indicated (Figure 1.5) that the Rabi maximum temperature increased by about 1.2 °C from 28.8 to 29.6 °C. Increase in Rabi temperature affects the productivity of crops like wheat, chickpea and mustard.

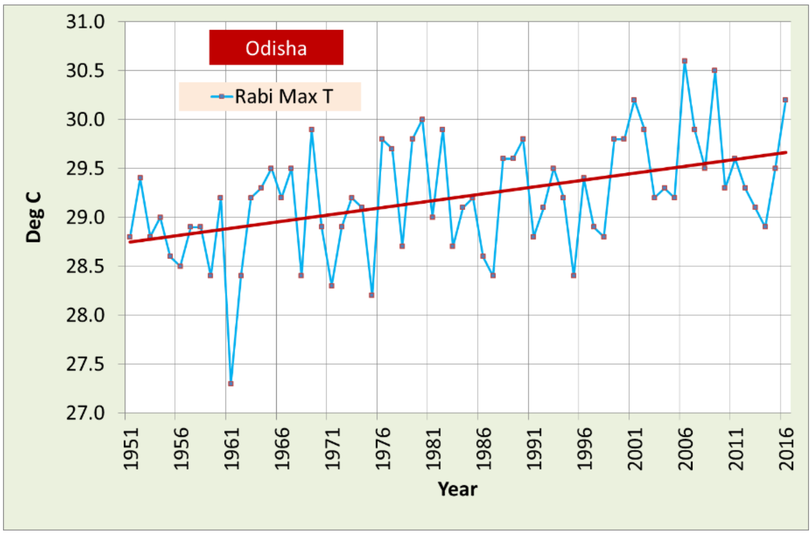


***Figure 1.5: Rabi maximum temperature change in Odisha.***

**Climate projections**

Projections of future climate are based on the output of atmosphere / ocean general circulation models and are used to simulate conditions in the future based on projected levels of greenhouse gases. There are several models available with different spatial resolutions. Majority of projections of future climate come from Global Circulation Models, which vary in the way they model the climate system, and so produce different projections about what will occur in the future. Representative Concentration Pathways (RCPs) are the four greenhouse gas concentration trajectories adopted by the IPCC which are used for climate modeling and research.

Projections based on CESM!_CAM5 climate model under RCP 8.5 for 2030s for Odisha indicate that both maximum and minimum temperature are projected to increase by 0.9 to 3.0 °C compared to the present conditions (Table 1.4). Though the projected annual rainfall is positive (85 mm), June and July together are projected to receive lower rainfall of about 39 mm compared to the present conditions.

| Table 1.4. Temperature and rainfall projections for Odisha. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Element | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
| Max T °C | 0.9 | 1.0 | 1.2 | 1.2 | 0.9 | 1.6 | 1.4 | 1.3 | 0.9 | 1.2 | 1.4 | 1.0 | 0.9 |
| Min T °C | 2.3 | 2.3 | 2.1 | 2.1 | 1.4 | 1.6 | 1.5 | 1.3 | 1.3 | 2.2 | 2.9 | 3.0 | 2.3 |
| Rainfall | 6 | 5 | 1 | 6 | 18 | -34 | -5 | 3 | 50 | 15 | 17 | 3 | 6 |

In general, minimum temperature is projected to increase more compared to maximum temperature. Changes in temperatures impacts crop yields, enhance crop water requirements and change the length of the growing period; all these necessitates changes in crops, varieties and management practices at specific regions for sustainable agricultural production. Studies indicate that though the rainfall increases, the number of rainy days are likely to decrease, causing flooding a more frequent event during the sensitive crop-growing period. Duration between two rain events in the crop-growing period is likely to be longer. These lead to a peculiar situation of extreme events like droughts and floods occurring one after another in the crop-growing period. Identifying and developing crop cultivars with enhanced water use efficiency, tolerance to both drought and floods is the need.

**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 bioconversion 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.

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## Session 2: All about soil

*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
- Recall how to understand a Soil Card for efficient nutrient management

### Soil Sampling

Soil testing is an essential component of soil resource management. 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. In general, sampling is done at the rate of one sample for every two hectare area. However, at-least one sample should be collected for a maximum area of ten hectares. For soil survey work, samples are collected from a soil profile representative to the soil of the surrounding area.

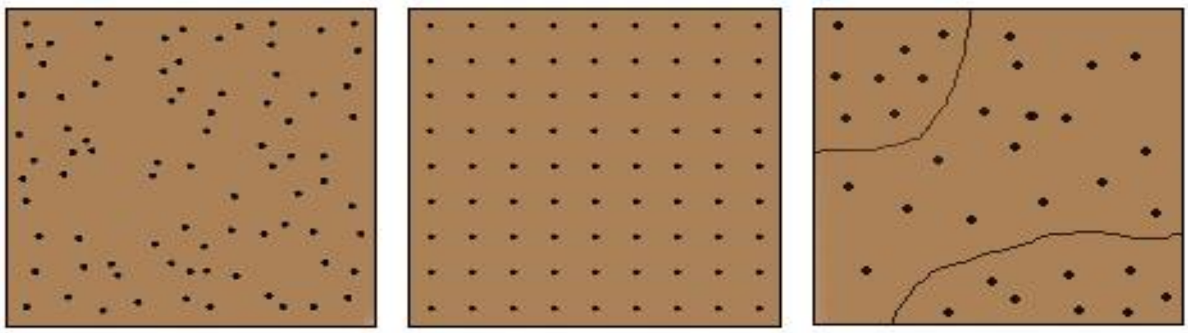

***Figure 2.1: Types of Soil sampling.***

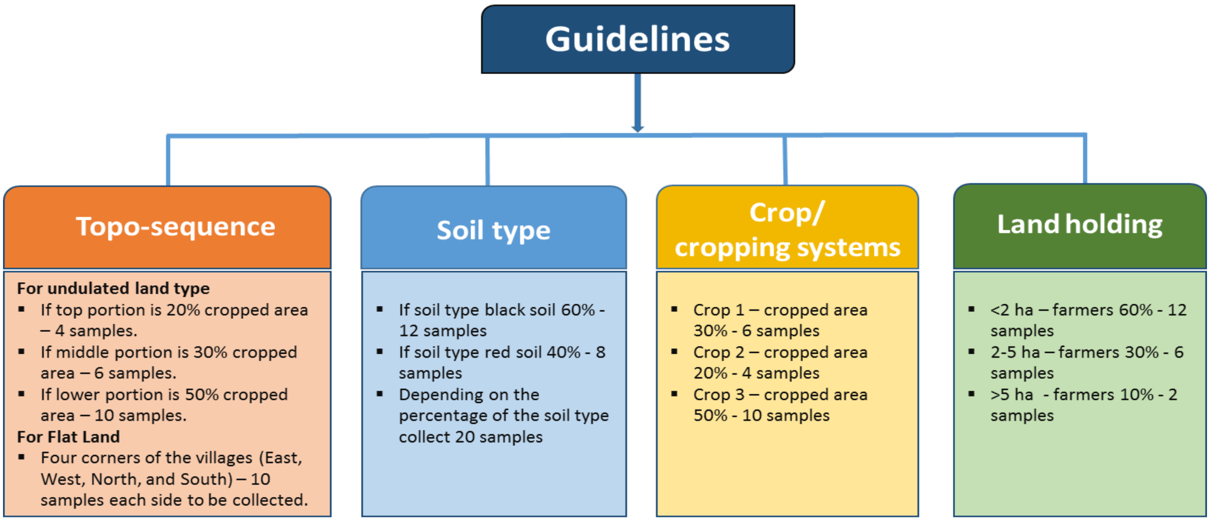


***Figure 2.2: Guidelines for stratified random sampling***

***Figure 2.3: Equipment for soil sampling- Screw augur, Plastic tray, Polythene bag, label and marker***

**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 hole 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 2.1.

| Table 2.1. 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.

### Horticultural Plantations - Leaf Sampling

With tree crops it is important to use plant analysis to check nutrient mobilization related deficiencies due to reasons like extensive root systems and nutrient storage by woody plants and slow internal nutrient transport. There has to be a specific plant part at a specific stage of the growth because the concentration of different nutrients varies significantly over the life cycle of a plant. Generally, the recently matured fully expanded leaf just before the onset of the reproductive stage is collected. The proper plant tissue to be sampled is indicated in Table 2.2.

| Table 2.2 Plant tissue sampling guidelines for horticultural crops. | | | |
|---|---|---|---|
| Sl | Crop | Tissue | Growth stage |
| 1 | Mango | Leaves + Petiole | 4-7 month old leaves |
| 2 | Citrus | 3-5 month old leaves from new flush. 1st leaf of the shoot | June |
| 3 | Guava | 3rd pair of recently mature leaves | August/December (Bloom stage) |
| 4 | *Ziziphus*/Ber | 6th leaf from apex from secondary shoot | 2 months after pruning |
| 5 | Papaya | 6th petiole from apex | 6 month after planting |
| 6 | Banana | Petiole of 3rd open leaf from apex | 4 month after planting |
| 7 | Pomegranate | 8th leaf from apex | April/August months |
| 8 | Cashew | 4th leaf from tip of matured branches | At beginning of flowering |
| 9 | Coconut | Pinnal leaf from each side of 4th leaf | |
| 10 | Cocoa | 3rd or 4th leaf from apex of shoot | |
| 11 | Chillies | Most recent fully developed leaves | |

**Precautions in soil sampling and transportation**

- Do not take sample by the side of the road or places where manure heaps are stacked
- Do not put samples in empty fertilizer/chemical bags
- Take separate samples for problematic areas
- Dry the sample collected from the field in shade by spreading on a clean sheet of paper after breaking the large lumps, if present.
- Spread the soil on a paper or polythene sheet on a hard surface and powder the sample by breaking the clods to its ultimate soil particle using a wooden mallet.
- Sieve the soil material through 2 mm sieve.
- Repeat powdering and sieving until only materials of >2 mm (no soil or clod) are left on the sieve.
- Collect the material passing through the sieve and store in a clean glass or plastic container or polythene bag with proper labeling for laboratory analysis.
- For the determination of organic matter it is desirable to grind a representative sub sample and sieve it through 0.2 mm sieve.
- Air-drying of soils must be avoided if the samples are to be analyzed for $NO_3$-N and $NH_4$-N as well as for bacterial count.
- Field moisture content must be estimated in un-dried sample or to be preserved in a sealed polythene bag immediately after collection.
- Record all information for the sample and ensure that number on sampling bag and in data sheet are same.
- Put a tag (with bag number written using lead pencil) inside the sample bag for additional security.
- Tightly put a rubber around the top of bag to avoid loss of sample during transportation.
- Pack samples very carefully.
- Arrange to transport collected samples on a fortnightly basis

**Points to be considered**

- 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 2.4 (a) Locating GPS coordinates***

***Figure 2.4 (b) Collecting the soil sample at 0-15 cm depth***

***Figure 2.5 (c) Mixing of soil samples collected from different spots***

***Figure 2.6 (d) Packing of collected soil sampl.***

### Soil health cards

Soil health cards prepared from soils collected from Odisha will be GPS based soils collected information. It will include farmer details including survey number, district, mandal, village, mobile number, soil type, soil depth and month and year of sampling. It will have the initial soil test values for 12 parameters, based on which farmer based nutrient recommendations will be given for 20 crops. General fertilizer based recommendations will be drawn up for Odisha soils as per the OUAT guidelines.

## ମାଟି ସ୍ୱାସ୍ଥ୍ୟ ପତ୍ରିକା

(ମାଟି ପରୀକ୍ଷା ଅନୁଯାୟୀ ସାର ଅନୁମୋଦନ)

ଚାଷୀ କ୍ରମାଙ୍କ : OD 28244 | ପତ୍ରିକା ସଂଖ୍ୟା : 28244

### ସାଧାରଣ ବିବରଣୀ

| | | |
|---|---|---|
| ୧. ଚାଷୀର ନାମ | : | Sebati Kanhar |
| ୨. ଜିଲ୍ଲା | : | Nayagarh |
| ୩. ବ୍ଲକ | : | Dasapalla |
| ୪. ଗ୍ରାମ | : | Kujamendhi |
| ୫. ଆଧାର ସଂଖ୍ୟା | : | 920559946089 |
| ୬. ଖାତା ସଂଖ୍ୟା/ପ୍ଲଟ ସଂଖ୍ୟା | : | 60/310 |
| ୭. ଅକ୍ଷାଂଶ | : | 20.3473 |
| ୮. ଦ୍ରାଘିମା | : | 84.5158 |
| ୯. ମାଟିର ପ୍ରକାର | : | Sandy |
| ୧୦. ନମୁନା ମାଟିର ଗଭୀରତା | : | 0-15 cm |
| ୧୧. ନମୁନା ସଂଗ୍ରହର ମାସ ଓ ବର୍ଷ | : | May-June 2018 |

### ମାଟିରେ ଥିବା ରାସାୟନିକ ପଦାର୍ଥରପରିମାଣ

| ମାଟିର ଗୁଣାବଳୀ | ଆବଶ୍ୟକ ସୀମା | ପରୀକ୍ଷଣ ମୂଲ୍ୟ | ମାଟି ଉର୍ବରତା ପରିମାପକ |
|---|---|---|---|
| ୧. କ୍ଷାରାମ୍ଳ ମୂଲ୍ୟ | 6.5-7.5 | 6.41 | Ac |
| ୨. ବିଦ୍ୟୁତ୍‌ବାହିତ (ଡ଼େସିସାଇମେନ୍/ମି) | <1.0 | 0.06 | N |
| ମୂଖ୍ୟ ଖାଦ୍ୟସାର ଲବ୍ଧାଙ୍କ | | | |
| ୩. ଜୈବ ଅଙ୍ଗାର (%) | 0.5-0.75 | 0.51 | M |
| ୪. ଲବ୍ଧ ଫସଫରସ୍ (କେଜି/ହେ) | 14-40 | 22.43 | M |
| ୫. ଲବ୍ଧ ପଟାସ (କେଜି/ହେ) | 118-280 | 635 | H |
| ଉପମୂଖ୍ୟ ଖାଦ୍ୟସାର ଲବ୍ଧାଙ୍କ | | | |
| ୬. ଲବ୍ଧ କାଲସିୟମ (ମିଗ୍ରା/କେଜି) | 300 | 2491 | S |
| ୭. ଲବ୍ଧ ମାଗ୍ନେସିୟମ (ମିଗ୍ରା/କେଜି) | 120 | 464 | S |
| ୮. ଲବ୍ଧ ଗନ୍ଧକ (ମିଗ୍ରା/କେଜି) | 10 | 7.60 | D |
| ଅଣୁ ଖାଦ୍ୟସାର ଲବ୍ଧାଙ୍କ | | | |
| ୯. ଲବ୍ଧ ଦସ୍ତା (ମିଗ୍ରା/କେଜି) | 0.60 | 0.26 | D |
| ୧୦. ଲବ୍ଧ ବୋରନ (ମିଗ୍ରା/କେଜି) | 0.50 | 0.37 | D |
| ୧୧. ଲବ୍ଧ ଲୌହ (ମିଗ୍ରା/କେଜି) | 6.00 | 65.60 | S |
| ୧୨. ଲବ୍ଧ ତମ୍ବା (ମିଗ୍ରା/କେଜି) | 0.40 | 2.80 | S |
| ୧୩. ଲବ୍ଧ ମାଙ୍ଗାନିଜ୍ (ମିଗ୍ରା/କେଜି) | 4.00 | 32.26 | S |

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L-Low-ସ୍ୱଳ୍ପ
M-Medium-ମଧ୍ୟମ
H-High-ଉଚ୍ଚ
Electrical Conductivity
N-Normal-ସାଧାରଣ
Cri-Critical-ସଙ୍କଟସୀମା
Inj-Injurious-କ୍ଷତିକାରକ

Ac-Acidic-ଅମ୍ଳ
Neu-Neutral-ନିଷାରାମ୍ଳ
Alk-Alkaline-କ୍ଷାର
D-Deficient-ଅଭାବ
S-Sufficient-ପର୍ଯ୍ୟାପ୍ତ

*Figure 2.7: Sample soil health card.*

## Session 3: Soil fertility status and soil test based balanced nutrient management

*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
- Schedule soil test based balance nutrient management
- Apply foliar application of fertilizers
- Demonstrate Aerobic composting for OM
- Practice Fertilizers and fertilizer application

**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.

**Table 3.1. Odisha Bhoochetana project, District and Block wise Initial soils nutrient % deficient data**

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Angul | 32.98 | 30.87 | 6.73 | 46.83 | 2.79 | 35.48 | 60.29 | 78.37 | 0.77 | 1.35 | 2.69 | 1040 |
| Deogarh | 28.46 | 47.95 | 11.28 | 58.72 | 1.54 | 42.31 | 54.62 | 75.64 | 1.03 | 0.26 | 0.26 | 390 |
| Kendrapara | 26.92 | 25.30 | 10.77 | 32.65 | 0.00 | 35.81 | 18.80 | 35.21 | 0.00 | 0.00 | 0.00 | 1170 |
| Jagatsinghpur | 44.23 | 16.06 | 18.65 | 49.62 | 0.00 | 57.79 | 55.29 | 63.17 | 0.10 | 0.00 | 0.77 | 1040 |
| Khurda | 61.69 | 40.08 | 30.46 | 72.85 | 4.46 | 64.85 | 25.46 | 82.69 | 0.00 | 0.23 | 0.15 | 1300 |
| Nayagarh | 54.13 | 18.56 | 15.77 | 39.13 | 1.35 | 47.69 | 42.02 | 80.87 | 0.10 | 0.00 | 0.29 | 1040 |
| Kandhamal | 41.59 | 40.37 | 6.58 | 78.70 | 0.81 | 71.10 | 40.64 | 86.91 | 0.75 | 2.04 | 0.14 | 1474 |
| Kalahandi | 50.35 | 53.42 | 7.11 | 36.40 | 0.09 | 52.81 | 61.93 | 85.26 | 0.44 | 0.00 | 0.53 | 1140 |
| Nabrangpur | 38.29 | 45.19 | 12.33 | 70.91 | 2.38 | 70.17 | 59.24 | 94.74 | 0.08 | 0.08 | 1.15 | 1217 |
| Rayagada | 52.77 | 17.52 | 1.98 | 62.28 | 1.19 | 44.26 | 27.62 | 79.50 | 1.19 | 0.40 | 0.10 | 1010 |
| Cuttack | 36.98 | 22.42 | 25.71 | 49.40 | 0.38 | 41.04 | 17.91 | 82.69 | 0.33 | 0.05 | 0.22 | 1820 |
| Dhenkanal | 31.92 | 40.48 | 12.88 | 48.85 | 0.77 | 41.35 | 18.65 | 73.65 | 0.29 | 0.00 | 0.77 | 1040 |
| Puri | 43.52 | 14.65 | 27.61 | 51.62 | 3.17 | 49.72 | 29.65 | 63.24 | 0.07 | 1.13 | 1.90 | 1420 |
| Bhadrak | 40.44 | 20.33 | 15.60 | 21.10 | 0.66 | 48.90 | 38.24 | 57.36 | 1.76 | 1.32 | 1.32 | 910 |
| Jajpur | 49.31 | 23.69 | 29.38 | 54.54 | 2.46 | 46.85 | 25.23 | 77.00 | 0.69 | 0.00 | 0.62 | 1300 |
| Sambalpur | 39.49 | 35.04 | 12.39 | 69.06 | 4.53 | 44.44 | 40.68 | 92.39 | 0.94 | 0.09 | 0.43 | 1170 |
| Boudh | 48.21 | 28.21 | 20.77 | 41.54 | 1.79 | 49.23 | 62.82 | 88.97 | 2.56 | 0.00 | 0.00 | 390 |
| Sonepur | 35.64 | 40.13 | 14.62 | 51.54 | 1.54 | 24.62 | 63.97 | 90.13 | 0.26 | 0.13 | 0.51 | 780 |
| Bargarh | 35.76 | 23.03 | 18.75 | 56.81 | 2.56 | 28.60 | 52.85 | 89.38 | 0.45 | 0.19 | 0.32 | 1563 |
| Balangir | 46.12 | 50.85 | 10.23 | 37.55 | 0.88 | 43.87 | 75.92 | 92.30 | 1.70 | 0.77 | 0.88 | 1819 |
| Nuapada | 22.37 | 49.01 | 0.15 | 16.29 | 0.00 | 26.94 | 72.15 | 80.06 | 0.30 | 0.00 | 0.76 | 657 |
| Ganjam | 44.30 | 38.11 | 9.72 | 39.27 | 2.10 | 39.20 | 31.50 | 62.90 | 0.35 | 0.03 | 0.28 | 2860 |
| Gajapti | 60.54 | 28.57 | 3.75 | 81.79 | 8.39 | 79.11 | 40.71 | 89.29 | 1.43 | 0.00 | 0.18 | 560 |
| Keonjhar | 45.92 | 54.97 | 27.87 | 67.57 | 6.51 | 69.29 | 53.79 | 86.98 | 0.06 | 0.24 | 0.18 | 1690 |
| Sundergargh | 47.33 | 59.10 | 10.41 | 73.98 | 1.81 | 45.25 | 39.41 | 94.62 | 0.14 | 2.53 | 0.05 | 2210 |
| Jharsuguda | 45.67 | 39.33 | 21.00 | 77.67 | 3.00 | 50.67 | 32.67 | 93.67 | 0.00 | 0.33 | 0.00 | 300 |
| Balasore | 52.00 | 33.42 | 41.68 | 64.45 | 5.16 | 37.35 | 41.48 | 68.06 | 1.10 | 0.26 | 1.29 | 1550 |
| Mayurbhanj | 44.98 | 63.16 | 36.27 | 76.68 | 8.41 | 66.26 | 39.12 | 91.35 | 0.27 | 0.00 | 0.30 | 3328 |
| Koraput | 24.51 | 23.80 | 9.46 | 85.82 | 3.94 | 87.08 | 49.01 | 82.90 | 0.00 | 0.08 | 0.00 | 1269 |
| Malkangiri | 41.43 | 51.06 | 26.59 | 65.90 | 4.43 | 57.80 | 50.87 | 90.37 | 0.00 | 0.96 | 0.39 | 519 |

**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

**Soil test based balanced nutrient management**

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 programmes have been given adequate importance for sustaining crop production and balanced fertilization in Indian agriculture. Fertilizer has 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 play 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.

**Fertigation**

- Identify area with drip systems in agricultural and horticultural crops
- Promote crop-specific fertigation schedules for regulated supply of micronutrients.
- Emphasize to promote regular fertilizers like N, K, Zn, B in fertigation
- Filter the regular fertilizer nutrient-solution before putting in the system

**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°C – 70°C which is called as thermophilic phase. The decomposition starts with mesophilic phase (25°C - 45°C for 2 to 5 days) and then proceeds to thermophilic phase (>45°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.

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

**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 3.1: Tractor run shredding* machine**

### Shredder machines

**Table 3.2. 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 |

**Table 3.3. Trouble shooting different problems in shredding.**

| Problem | Possible cause | Remedy |
|---|---|---|
| Rotor stalls or stops | Obstructed discharge | Use branch or similar object to clear discharge |
| | Plugged rotor | Clear rotor, feed material more evenly |
| | Feed material that id too large | Reduce size of material |
| Chipper does not chip | Dull chipper blades | Rotate or sharpen blades |
| | Drive belts loose or worn | Inspect drive belts, adjust or replace if needed |
| | Attempting to feed branches that are too large | Limit branch size |
| | Broken or missing chipper blades | Replace blades |
| Hard to feed chipper, requires excessive power to chip | Dull chipper blades | Reverse or sharpen blades |
| | Obstructed discharge | Use branch or similar object to clear discharge |
| | Improper blasé clearance | Adjust clearance between chipper anvil and chipper blades |
| Shredder requires excessive power or stalls | Obstructed discharge | Use branch or similar object to clear discharge |
| | Plugged rotor | Clear rotor, feed material into shredder more evenly |
| | Wet or green material will not discharge | Alternatively feed dry material or install large discharge screen |
| Belt squeals when engaging clutch | Engaging clutch too fast | Engage clutch more slowly |
| | Plugged rotor | Clear rotor, feed material more evenly |
| | Belt tension too loose | Replace belt |
| Material around chipper wraps around too fast | Stringy, green material bypasses chipper blades | Rotate branch or material when feeding to cut completely |
| | Dull chipper blades | Sharpen blades |
| | Improper blade clearance | Adjust clearance between anvil and chipper blades |

### 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 3.3: 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 3.2: 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 slow down the process. To monitor the moisture content take a hand full 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 3.3: Irrigation of aerobic composting heaps.***

### Temperature

Aerobic composting has mesophilic (25$^{o}$C to 45$^{o}$C) and thermophilic phases of temperature (45$^{o}$C to 70$^{o}$C). 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 3. 4. Ideal characteristics of good material for 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:** *Eiseniafetida* and *Eudriluseugenae* 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 1$^{st}$ 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.

## 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.

### Storing Fertilizers

Since the quality of fertilizer is affected by the way it is stored, care must be taken to select a storage area that is dry and well ventilated. Place wooden pallets on the floor and stack fertilizer bags on them. Do not place more than eight bags in a stack, otherwise the pressure on the bag at the bottom will lead to the fertilizer caking. Stack only unbroken bags and arrange the stacks closely to minimize air space between them.

### Precautions

- Do not store fertilizer with insecticides or herbicides
- Do not store with fuels, oil, flammable liquids, acids, sulphur, or explosives
- Do not smoke in the storage area
- Store the fertilizer in moisture-proof containers or bags.

### Fertilizer Calibration

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 a plot with 10 rows. Each row is 10 m-long and 0.5 m-wide. Therefore, the total area is 50 $^{m2}$. The fertilizer to be used is ammonium sulphate.

Ammonium sulphate contains 20% N or 20 kg N in each 100 kg.

Therefore, 120 kg N will be available from:

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

To supply 120 kg N $ha^{-1}$ requires 600 kg of ammonium sulphate.

The required ammonium sulphate for each m² to provide 120 kg N $ha^{-1}$ will be:

$$\frac{600 \text{ kg ha}^{-1} \text{ ammonium sulphate X } 1000 \text{ g kg}^{-1}}{10{,}000 \text{ m}^2 \text{ ha}^{-1}} = 60 \text{ g m}^{-2} \text{ of } (NH_4)_2SO_4$$

The plot area in this example is 10 m X 5 m or 50 $m^2$.

The amount of ammonium sulphate for a plot of 50 $m^2$ will be:

$$60 \text{ g m}^{-2} \text{ X } 50 \text{ m}^2 = 3000 \text{ g or } 3 \text{ kg plot}^{-1}.$$

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 20 kg P per 100 kg and urea that contains 46% N.

In a plot the area is 50 $m^2$. 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 20% P and 18% N. Therefore, 17 kg P would be supplied in:

$$\frac{17 \text{ kg P in } 100 \text{ kg DAP}}{20 \text{ kg P}} = 85 \text{ kg DAP}$$

2.Now, find the N available in 85 kg of DAP if 100 kg of DAP has 18% N

$$\frac{18 \text{ kg N X } 85 \text{ kg DAP}}{100 \text{ kg DAP}} = 15.3 \text{ kg of N}$$

Urea contains 46% N. Therefore, 84.7 kg N will be available from

<u>100 kg urea X 84.76 kg N</u> or 184 kg of urea to supply 46 kg N

Therefore, 85 kg of DAP and 184 kg of urea will be required to provide 100 -17- 0.

The required DAP is 8.5 g $m^{-2}$ and required urea is 18.4 g $m^{-2}$.

**Fertilizer Application - Manual**

***Figure 3.4: Fertilizer application-basal dose.***

**Hand Application**

Most soils will need some fertilizers applied for good crop establishment, good vegetative growth, and increased grain production. The elements that are frequently needed for good crop growth are nitrogen and phosphorus. The fertilizers supplying these nutrients may be applied as a basal application before or at sowing. Sometimes, a portion of the required amount is applied as a top dressing. Fertilizer needs to be applied carefully so that the material does not damage germinating seeds. At the same time, the required amount of various nutrients must be available near the seedlings for them to produce the desired yield.

**Application at Sowing**

- Open the furrows with tractor-mounted or hand-drawn furrow openers a little deeper than the sowing depth. Fertilizers should be placed slightly below the seeds and to the side to avoid fertilizer burn from direct contact with the emerging primary root.
- Distribute the calculated amount of fertilizer uniformly in a band, one replication at a time.
- Cover the fertilizer lightly with soil to prevent direct contact with the seed.
- Complete each fertilizer application, replication by replication. Do not hand apply fertilizer across replications.
- Sow the seed, close the furrows, and immediately compact the soil around the seed.
- Animal-drawn fertilizer drills or tractor-drawn applicators could be used for placing fertilizers before sowing.

**Top Dressing**

Most crops need a top dressing of fertilizer, especially nitrogenous fertilizer, to meet the demand of the crop at the critical stages of plant growth. Top dressing is usually done for sorghum and millet just prior to the boot stage.

***Figure 3.5: Application of top dressing by tractor.***

**Procedure**

- Open a furrow about 5–6 cm deep and about 5–6 cm away from the crop row, one replication at a time, with a sickle, hoe or tine. Do not damage the roots while doing so. Hand applications can be done by making holes beside and between the plants to reduce root damage. Drill 5-6 cm holes uniformly 5–6 cm away from each plant or in clusters of two to three plants. Care should be taken to distribute the fertilizer uniformly among the holes.
- Distribute the fertilizer uniformly to all the plants.
- Cover the fertilizer immediately after application.

In intercropping trials where more than two rows of crops have been sown closely, fertilizer may be top dressed by opening furrows near the cereal row in a cereal/legume combination. Fertilizer may be side dressed to the cereal crop in the same way as for a sole crop.

**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 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, Azatobacter, PSB, Rhizobium
- Promoting the seed priming with 1 % zinc sulphateheptahydrate 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

## Session 4: Cropping system management for sustainable crop productivity and income in Odisha

*At the end of the session you will be able to …*

- Define Tillage and Seedbed preparation
- Illustrate Selection of suitable varieties
- Underline Cropping systems management and length of growing period based on agroclimatic data
- Identify Cultural practices mainly weed control

**Introduction**

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.

**Objectives of Tillage**

**The objectives of tillage are to:**

- Loosen, granulate, and condition soils to promote plant growth
- Kill weeds and manages crop residues
- Incorporate fertilizer
- Conserve moisture and prevent soil erosion.

Primary tillage can have a profound influence on soil structure or the arrangement of primary soil particles, in turn influencing the movement and availability of water and air, and resulting root growth.

***Figure 4.1: A Soil profile.***

As the soil profile develops, soil structures are formed by a natural aggregation of soil particles. A good soil structure is stable, allows root penetration, retains adequate water for plant growth but drains excess water. The major soil structures are crumb, granular, blocky, prismatic, columnar, and massive. Granular and crumb structures are generally characteristic of surface soils that contain larger amounts of organic matter. A modification in soil structure through constructive tillage procedures may be required for improved plant growth.

**Types of soil structure**

Crumb or granular structures are best maintained when soil moisture ensures good structure formation, when organic matter can be incorporated, and surface drainage is ensured by minimum tillage.

Massive, prismatic and blocky are poor soils structures that usually have lower organic matter, a high amount of clay, drain poorly, and may contain less calcium. Improper cultivation practices produce poor soil structures and tilth.

***Figure 4.2: Clod formation in Vertisols.***

***Figure 4.3: Clod formation in Alfisols.***

The short-term favorable effects of tillage are the breaking up of clods for a more favorable seedbed where good soil-seed contact is provided with adequate moisture for vigorous plant growth. Over longer periods, when the soil is wet or very dry, tilling reduces surface soil granulation. Light and medium textured soils form good tilth more easily. Major difficulties arise with clayey soils. So cultivation should aim at obtaining aggregates in the range of 2 to 20 mm without compacting the lower soil layers.

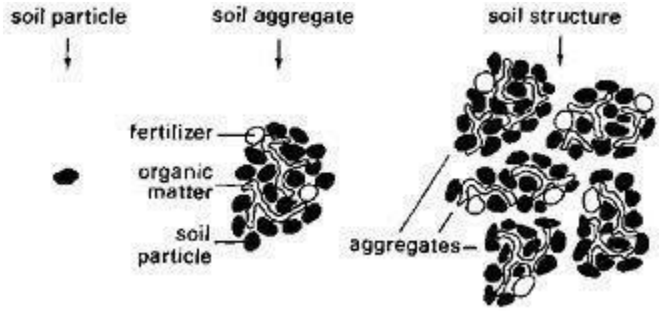



***Figure 4.4: Formation of soil structure.***

Eliminating weeds so that they don't compete with crops and managing crop residues to maintain organic matter content can together improve soil structure and its tilth (well decomposed humus is porous and bonds well with clay particles to help form stable crumb and granular structures). Excessive cultivation increases the oxidation of organic matter and evaporation of moisture leading to tilth deterioration.

**Tillage and Tilth**

A good tilth allows seed to come in close contact with the soil. This happens when the soil has a granular structure and is compacted below and above the seed to facilitate the capillary movement of water from soil to seed.

Where row cropping is followed, the seedbed should develop within the row in which the seed will be planted. If possible, the space between rows should be cultivated sparingly to minimize disturbance in soil structure. Soil disturbance prevents germination and reduces loss of nutrients and moisture between the rows. Thus seedbed preparation should be restricted to the seed row and not the whole field. Plowing and all subsequent tillage operations can impair tilth if the soil is wet or very dry.

Pulverization of the surface soil can destroy the natural soil aggregates. That is why minimum tillage practices avoid the destruction of soil structures where only the top 5-10 cm may be cultivated for moisture infiltration and conservation, planting, and weed control.

**When to Till the Soil**

How does one know when to cultivate the soil? Wet soil is compacted by tillage whereas dry soil breaks into clods which may be difficult to reduce to enable close soil-seed contact for rapid seed germination. Sandy soils have wider range of moisture content suitable for cultivation than clayey soils.

Loamy and clayey soils tend to make clods that need breaking up by weathering or machines, which is a costly affair. Moreover, clayey soils feel sticky when wet. When soil moisture is less than the plastic limit, the soil will be friable, which is the time for tillage. When a soil is easily crushed between the thumb and forefinger, it is said to be friable. Tillage operations are most ideal when the soil can be formed into a concrete shape and it crumbles when dropped.

The range of moisture needed for medium textured soils such as loams or silt loams is quite wide, and is about 60% of their field capacity. Sandy soils do not become plastic; they tend to stay loose throughout a normal soil moisture range. Soil moisture content can be considered optimum for cultivation when it increases granulation and structure formation is greatest. Cultivation above the soil's moisture limit creates a platy or laminar structure.
Using a plow may be essential for good tilth on fine textured soils. On more sandy soils, a disk, chisels or a cultivator can produce an ideal seedbed.

**Types of Tillage**

Tillage systems can be classified according to the number of operations involved and the equipment used into conventional tillage, minimum tillage, and no till or zero tillage.

**Conventional Tillage**

- Conventional tillage includes primary tillage and a few secondary tillage steps. The number of operations vary from crop to crop and with soil type. Conventional tillage involves:
- Pre-plowing operations (e.g. shredding or disking crop residue)
- Plowing to pulverize soil
- Disk harrowing or field cultivating
- Harrowing with tooth-type harrows
- Using one or multi-row cultivators (depending on crop, area, and weed problems)
- Ridging or bedding to shape the soil.

**Minimum Tillage**

Minimum tillage, also known as optimum, reduced or economy tillage, is motivated by the principles that reduced energy and labor inputs can bring higher returns; crop production does not depend on preparing a "clean field" (i.e., no previous crop residue); and that soil should be disturbed as little as possible.

**Minimum tillage practices include:**

- Maintaining crop residue on the surface to conserve moisture and build soil organic matter
- Reducing the number of passes over a field
- Eliminating pre-plowing
- Passing once (instead of several times) with secondary tillage equipment such as disks or spring tooth harrows
- Tilling strips for planting and leaving inter-row space under residue
- Use of herbicides to eradicate weeds

**No till or Zero Tillage**

Zero tillage is described as being the opposite of conventional tillage and the most radical of minimum tillage systems. No till or zero tillage supports the principle of minimum tillage by reducing tillage to only one operation: that of opening the soil for the seed at planting. This system has been widely adopted for corn, soybeans, and cowpeas. For instance, corn can be planted in stubble from the previous crop or in a mulch of other cover crops which have been killed by an herbicide. The practice is spreading to other crops, including small grains.

Zero tillage is also called as no till. Zero tillage is an extreme form of minimum tillage. Primary tillage is completely avoided and secondary tillage is restricted to seedbed preparation in the row zone only.

Till planting is one method of practicing zero tillage. The machinery accomplishes four task in one operation: clean a narrow strip over the crop row, open the soil for seed insertion, place the seed and cover the seed properly. A wide sweep and trash bars clear a strip over the previous crop row and planter-shoe opens a narrow strip into which seeds are planted and covered.

In zero tillage, herbicide functions are extended. Before sowing, the vegetation present has to be destroyed for which broad spectrum, nonselective herbicides with relatively short residual effect (Paraquat, Glyphosate etc.,) are used.

**Tillage Implements**
**Animal-drawn Equipment**

Primary and secondary tillage operations are important to produce a good seedbed. Animal-drawn equipment used by farmers may not achieve this objective as they may not produce the required tilth and uniform depth for good seed germination. Moreover, the soil structure may not be ideal.

**Seedbed Preparation, Texture of Soil, Physical Properties**

A seedbed provides the optimum environment for seed germination, root growth, and eventually good crop growth. An ideal seedbed should also provide for weed control, fertilizer application, irrigation, and drainage of excess water. A seedbed can be sown on a flat surface, ridges and furrows or broad-beds and furrows (BBF) of different width.

Seedbeds can be prepared by hand, animal-drawn equipment, or with tractors. Using animal-drawn equipment may require more passes over the field to produce a good seedbed. After harvest, the land can be opened with a moldboard plow which will invert the soil, incorporate organic residues, and help control weeds. The big clods can be broken in subsequent operations with harrows, when the moisture content of the soil is optimal. On a heavy soil, like black clays, broad-beds can be prepared by a bed former with furrows for irrigation and surface drainage. A ridger can deepen the furrows when required. Fertilizer and seed can be placed in the dry seedbed for early seedling emergence.

Tractor operations are useful in cultivating large areas as well as in soils where much power is required to pull implements. Tractor-drawn implements can go deeper into the soil to increase water infiltration and break hard layers. Plowing followed by harrow prepares flat seed bed.

A seedbed can be shaped into ridges and furrows by ridgers. When the surface soil is very loose, packing the top layer may stabilize it against wind and water erosion. However, all machine operations are dependent on trained operators to achieve high quality of field work.

*Figure 4.5: The multipurpose Tropicultor being used for sowing.*

An improved animal-drawn tool carrier called the Tropicultor developed at ICRISAT and now commercially available in the local market, is an excellent bullock-drawn multipurpose machine that can be used for tillage operations and can produce a good seedbed. It can also be used for sowing, fertilizer application, interculture, etc. The basic machine has a toolbar with different attachments just like a tractor. It can cover an area of 150 cm in one pass. It is a versatile equipment regularly used at ICRISAT in its plots under the watershed program. It has reached farmers' fields in India and Africa.

**Conservation of soil and water**

The main aim of these practices is to reduce or prevent either water erosion or wind erosion, while achieving the desired moisture for sustainable production. The suitability of any *in-situ* soil and water management practices depend greatly upon soil, topography, climate, cropping system and farmers' resources. Based on past experiences several field based soil and water conservation measures have been found promising for the various rainfall zones in India (Table 4.1).

*Figure 4.6: Formation of broadbed and furrow.*

**Broadbed and furrow (BBF) land management system**

**Why Broadbed and furrow landform**

Cultivation practices are affected by the sticky nature, poor infiltration, impeded internal drainage of the soils when wet, especially on heavy soils. These soils will have

- Excessive hardness and difficult workability when dry
- Risk of losing post-rainy season crops
- Risk associated with moisture stress or water logging during rainy season
- Lack of adequate resource

On black soils the problem of water logging and water scarcity occurring during the same cropping season are quite common. There is a need for an *in-situ* soil and water conservation and proper drainage technology on deep black soils that can protect the soil from erosion throughout the season and provide control at the place where the rain falls. A raised land configuration "Broadbed and furrow" (BBF) system has been found to satisfactorily attain these goals (Fig. 4.8).

BBF formation with tropicultor. Groundnut crop on BBF.

***Figure 4.7: Broadbed and furrow system at ICRISAT center Patancheru, Andhra Pradesh.***

**Recommended agro-ecology**: Soil: medium to deep black soils (*Vertisols*)

Rainfall: 700 – 1300 mm

Slope: maximum up to 5%

**BBF formation**

The BBF system consists of a relatively raised flat bed or ridge approximately 95-105 cm wide and shallow furrow about 45 cm wide and 15 cm deep (Fig.4.8).

The BBF system is laid out on a grade of 0.4-0.8 % for optimum performance. It is important to attain a uniform shape without sudden and sharp edges because of the need in many crops and cropping systems to plant rows also on the shoulder of the broadbed. This BBF system is most effectively implemented in several operations or passes. After the direction of cultivation has been set out, furrows are formed by an implement to which two ridgers are attached and tied with a with a chain or a multipurpose tool carrier called "Tropicultor"

The furrowers must be in the lower field drain at starting and end up 2 meters after the distant peg. This is essential in all types of seedbed preparation; otherwise seedbeds will fall short of their full length and will need remaking.

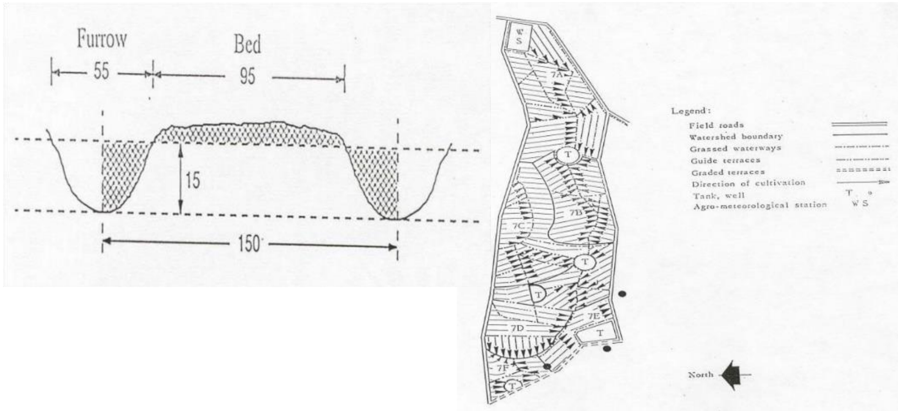



***Figure 4.8: Broad bed and furrow system dimension topographic map.***

**Benefits**

The raised bed portion acts as an *in-situ* ‘bund’ to conserve more moisture and ensure soil.
It is important to have the ridgers operate at shallow depth to attain straight lines; sharp curves must be avoided. A bed former is used to further shape up the broadbeds. If opportunity arise (after showers) before the beginning of the rainy season, another cultivation is done to control weeds and improve the shape of the BBF. Thus, at the beginning of the growing season this seedbed is receptive to rainfall and, importantly, moisture from early rains is stored in the surface layers without disappearing in deep cracks in black soils. The BBF formed during the first year can be maintained for the long term (25-30 years). This will save considerable cost as well as improve the soil health.

The shallow furrows provide good surface drainage to promote aeration in the seedbed and root zone; prevents water logging of crops on the bed.

- The BBF design is quite flexible for accommodating crops and cropping systems with widely differing row spacing requirements.
- Precision operations such as seed and fertilizer placement and mechanical weeding are facilitated by the defined traffic zone (furrows), which saves energy, time, cost of operation and inputs.
- Can be maintained on the long term (25-30 years)
- Reduces runoff and soil loss and improves soil properties over the years.
- Facilitates double cropping and increases crop yields.
- Can be adopted for groundnut crop in red soils with a reduced gradient along the bed (0.2– 0.4%).

The toolbar with an ‘A’ frame has furrowers, both of equal size and leveled on a flat ground. Each furrower is placed 75 cm from the center of the toolbar and fitted firmly. The wheel track of tractor should be 150 cm wide. Mark the first pass with two pegs equally spaced from the side of the field.

***Figure 4.9: Uniform plant stand on broadbeds.***

Sowing in dry soil should be done at a uniform depth as determined by seed size, the soil's moisture-holding capacity, and anticipated frequency of initial rains. The soil should be uniformly compacted around the seed to ensure uniform and rapid seedling emergence. Once sowing is completed in a dry seedbed, the seeds will not start germinating until moisture reaches the depth of sowing. When dry sown, seeds are placed deeper so that a light shower will not wet the seeds and start their germination. Species with large seeds (maize, pigeonpea, and sorghum) can be sown deeper. When the seeds are sown too deep, the seedlings produce a longer epicotyl than when sown at a shallow depth. Such seedlings take longer to emerge and become weak by the time of emergence.

The depth of dry sown seed should be such that germination will start only after the rainfall has provided adequate soil moisture for seedling growth until the next predicted shower (10–15 days). Therefore, one must be ready for resowing if the second rain is greatly delayed. Any gap filling must be completed within 3–5 days after general emergence or the entire experiment may require resowing.

Sowing in *Alfisols* is done under moist conditions as there is usually not much problem entering the field within a day after the rains. However, sowing must be finished quickly before the moisture in the top layer is lost. The moisture-holding capacity of *Alfisols* is much lower than that of *Vertisols*. Timely operations are important, particularly furrow opening and closing during planting to conserve limited soil moisture and ensure rapid and even growth of seedlings.

**Filling Gaps after Germination**

Seedling emergence may not be uniform due to poor seed quality, inadequate soil moisture, soil-borne diseases, insect damage, faulty compaction during sowing, or non-uniform sowing depth. If a plant stand is not uniform, gap filling or re sowing may be necessary. Gaps must be filled to ensure that intra-row as well as inter-row competition is uniform.

**Tackling drought**

**Mulch**

Mulching is a practice to cover the soil surface either by crop residues or synthetic material to prevent evaporation from the soil surface thereby conserving moisture as much as possible.

Straw mulch will reduce run-off compare to bare plots after harvesting of crops. Various types of mulch can be used in the standing crop which reduces surface evaporation well as run off resulting in soil erosion. Keeping the soil covered should be an important intervention in the cropping system in the dry areas. In the Semi Aridareas 50% of the rainfall is lost from the field is from the field as nonproductive soil evaporation. Option to reduce soil evaporation includes dry planting, conservation agriculture and mulching

**Important agronomic practice to prevent soil erosion, reduce evaporation and conserve moisture**

- Organic mulch @ 4 t/ha reduces run-off 37-15% and 18-5.4 ton soil loss
- Example – 2 t/ha mulch material
- Crop mulch in hilly areas – ginger, colocasia, turmeric, lantana camera
- Grass mulch in rabi
- Recycling sunhemp in situ one month after sowing increased yield of wheat as next crop
- Weed cover, pruning of agro-forestry plants , thinned crop after planting over-population
- Leucaena – 2t/ha incorporate after 30 days of maize
- Timely sowing,
- Quick crop canopy development and manipulation to cover the bare soil as quickly as possible
- Not leaving a bare soil when monsoon comes
- Dry seeding techniques before rains ( ICRISAT experience in black soil)


***Figure 4.10: (a) Straw mulch*** ***(b) Plastic mulch***

***Figure 4.11: Mulch between crop rows.***

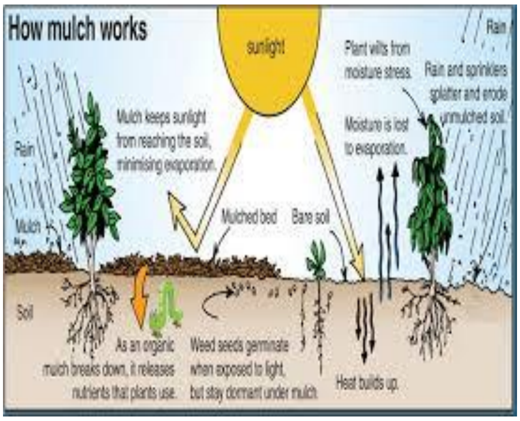



***Figure 4.12: How it works.***

**Breaking capillary**

Breaking the capillary to reduce soil evaporation is a simple operation in a standing crop before the crop canopy covers the soil. When the soil is compact after a rain, specially in lighter soils, the soil micro capillaries join ad bring the moisture from deeper layers and evaporate from the surface. A simple operation of running a harrow (spike tooth type or bullock drawn harrow on the surface will break the capillary action from the root zone, thereby stopping evaporation from the surface (add a bullock drawn harrow)

***Figure 4.13: Bullock drawn implement by farmer.***

***Figure 4.14: A farm pond.***

**Improved crop agronomy**

Delayed planting after the sire specific optimum planting date often results in low grain yield. High seeding rate, consequent high population can offset the delayed planting s to some extent.

In dryland agriculture adjusting the plan population and row spacing are often needed for efficient use of light and water to achieve high harvest index of crops. But these practices are crop, site and season specific depending on the water availability in a season and there is no one formula for success. A high density population uses soil moisture early in the season resulting in low grain yield. On the other hand a low density population will not fully extract soil moisture thus giving low yield. Harvest index and amount of water extracted can be affected by planting geometry, but the variation can be very wide before grain yield can be severely affected. Therefore the best strategy is to select a moderate plan population and row width for higher yield and higher water use efficiency (WUE). The combinations will be determined by the crop variety, season and the site where the crop is grown.

**Some of the Implements which may be used in the project.**

*Figure 4.15: Chipper cum shredding.*

*Figure 4.16: Manual seedling planter.*


*Figure 4.17: Manual seed dibbler*


*Figure 4.18: Zero till multi crop bed planter.*

**Cropping systems management and length of growing period based on agroclimatic data**

Before a cropping system is decided for an area it is important to select a crop variety based on the following considerations.

- His crop variety should fit the LGP of the zone based on agroclimatic data.
- If it is a rainfed crop the moisture availability must conform the requirement of the crop
- If available a climate smart variety should be chosen to avoid climate change and adapt to any change.
- The variety should be disease or pest resistant endemic to an area.
- The variety should be high yielding
- It should have wide consumer acceptance and market demand

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 mung bean, moth bean, 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 4.1). 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 4.1. 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 *Kharif*or *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 4.2). Intercropping minimize risk of crop failure in rainfed systems.

**Table 4.2. Efficient intercropping systems for rainfed lands.**

| Intercropping system | Row ratio | Plant population | |
|---|---|---|---|
| | | First crop | Second crop |
| maize/pigeonpea | 2:1 | 180,000 | 60,000 |
| Maize/blackgram | 1:2 | 70,000 | 60,000 |
| Castor/pigeonpea | 1:2 | 250,000 | 60,000 |
| Pigeonpea/black gram or green gram | 1:2 | 60,000 | 120,000 |
| Groundnut/castor | 5:1 | 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 4.2.

***Figure 4.19: 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 (Table 3). 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, insitu 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 4.3: 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 |

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.

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 4.4: Efficient sequential cropping systems for rainfed lands. | | |
|---|---|---|
| Cropping system | *Kharif* crop | Rabi crop |
| *Kharif-Rabi* | Row spacing (cm) | Row spacing (cm) |
| Rice-Chickpea | 22.5 | 22.5-30 |
| Rice-Blakgram /G.gram | 22.5 | 22.5-30 |
| Maize-chickpea | 60 | 30 |
| Maize-blackgram | 60 | 30 |
| Maize-greengram | 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% withmaize/pigeonpea, greengram/blackgram/pigeonpea intercrop systems, and yield advantages ranging from 20-50% with maize-chickpea, paddy-chickpea, paddy-blackgram/greengram 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.

**Addition of organic manures and amendments**

To sustain or improve productivity, soil organic carbon, a quality indicator needs to be improved with addition of organic manures. Soil organic matter (OM) is the base for biological activity, improves nutrient and water availability, and enhances soil aeration. Soil organic matter maintenance or enhancement in tropical soils is possible through long-term addition of crop residues, farmyard manures/livestock litter and vermicompost from farm wastes. These materials add not only OM to enrich degraded soils but plant nutrients at useful levels to enhance crop productivity. Besides recycling crop/livestock waste, green manuring with Gliricidialoppings is another successful practice demonstrated on ICRISAT's operational watersheds for enriching soil OM to sustain crop productivity. Spreading tank silt on lighter soils to improve the soil structure, there by moisture retention and also adding sand to clayey Alfisols to reduce surface crusting and improve soil aeration are some crop productivity enhancement options. In semi-arid environments, saline or alkaline and in high rainfall areas, acid soils are known to be problematic for management. Reclamation with amendments like lime addition in the range of 2.5-to 7.5 t $ha^{-1}$ for acid soils, and gypsum for saline and alkaline soils based on the rainfall situation is suggested.

**Crop water requirement and Water management**

Dry land crops vary widely in their water requirement for crop growth and maturity. Besides soil type, rainfall and temperature in the region, which determines length of crop growing period, crop water requirement is critical to plan crops and cropping systems appropriate for a region. Knowledge on critical growth stages of crops, those can be affected by water deficit resulting in varying degree of crop yields, is very important to effectively use available water in rainfed situations. Table 5 provides information on crop critical stages; water requirement and sensitivity to weather abnormalities are given.

**Weeding and Interculture**

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 nutria-cereals will be targeted on 50 ha area per district. In simple term, we will be looking 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.

**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.

**Weed management**

***Figure 4.20: 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).

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

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

***Figure 4.21: 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 4.5. 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 4.22: A Blade harvester- groundnuts.***

**Seed Drying**

Seeds must be dried to moisture content that would not deteriorate seed quality and germination in the storage. For medium term storage seeds of cereals should be dried to a moisture content below 12% and vegetable and oil seeds below 9%. The common practice of drying on concrete roads by farmers should be avoided. Grains can be dried on tarpaulin or polythene sheets covering the ground preferably of black color. Grains should not be over dried so that grains do not break during threshing. Vegetable seeds should be dried in shade and never under very hot sun.

**Factors Affecting Drying**

Drying is affected by air circulation, temperature, and relative humidity. Too little air can lead to growth of molds on the upper layers of the seed while too much of it can lead to case hardening and slipping of the skin. High temperature can lead to loss of seed viability. The right temperature for seed to dry is between 32° and 43° C.

Natural Air Drying

In this process air is forced through the seeds provided the ambient relative humidity of air is less than 50%.

When hot air is used to dry seeds it is important that seeds are cooled to ambient temperature before storing them.

**Drying in Storage**

Seeds are dried in storage when they are already dried to about 12% moisture. It is a slow process, and requires periodic ventilation to maintain low humidity.

**Threshing**

Threshing can be done manually or by using a plot thresher. Manual operation requires a large number of semi-skilled labor as each harvested plot has to be threshed separately to record the final yield of a crop.  This requires covered areas so that rain does not affect the crop. Mechanical threshers are efficient and time-saving.

**Threshing by Machines- an example**

***Figure 4.23: A Thresher.***

The heart of any thresher is the threshing section. The process separates the seed from its loose covering or shell and plant material.

All threshers have threshing drum consisting of a cylinder and concave, a blower to separate seeds from the chaff, and sieves to separate stalks. The threshers can be powered by electric motors or fuel engines.  Some of the care that needs to be taken while using threshers:

- Machinery should be operated by trained personnel
- Operators should wear half-sleeved shirts. In case full-sleeved shirts are worn, fold the sleeves. Avoid loose garments; for even a small piece of thread can drag your hand into the machine in a matter of seconds.
- Dusty operations require nose masks
- Ensure that the belt guards are in place. Be more vigilant about fast moving parts like belts, pulleys and cylinders.
- Exercise great care while feeding the crop
- Attempt repairs only after stopping the machine. Even if the engine stops, it takes time before moving parts like the cylinder come to a dead stop.
- The operator must wash himself thoroughly after operations.
- Others working near the thresher should be made aware of safety hazards.

**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 concern 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 4.24: Picture showing marked CCE plot; and (Bottom) collected sample from marked area.***

***Figure 4.25: (Left) Weighing fresh weight (S1) from marked area; (Right) Taking sub-sample and weighing sub-sample (S2).***

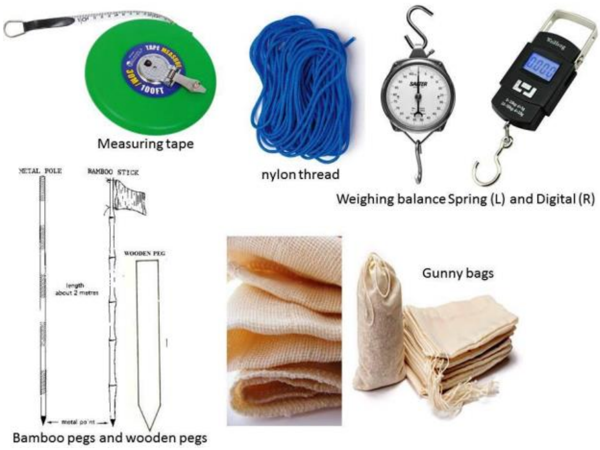



***Figure 4.26: Materials for CC.***

**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 4.27: 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 farmer’s 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 4.6: Yield estimation for farmer's participatory field demonstration on chickpea | | |
|---|---|---|
| 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 5: Plant protection – Integrated Pest and Disease Management (IPM and IDM)

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

- Define pests
- Study the types of insect pests
- Describe the tools for IPM
- Learn pesticide formulation and calibration
- Know the different spraying equipment

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".

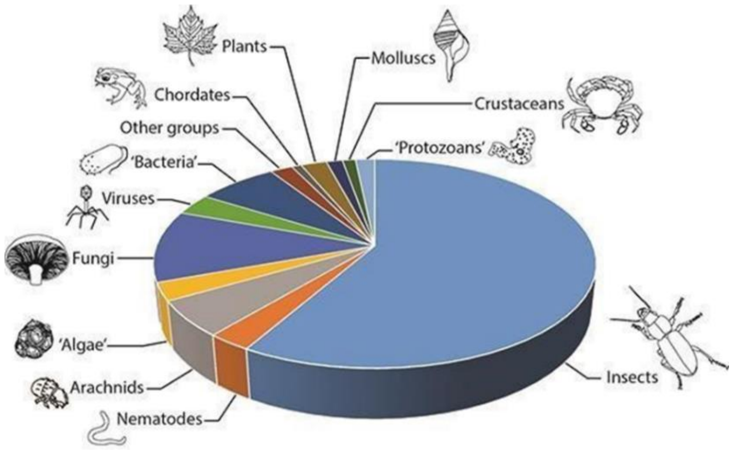



***Figure 5.1: Comparison of the numbers of different categories of living organisms.***

### Class Insecta or Hexapoda

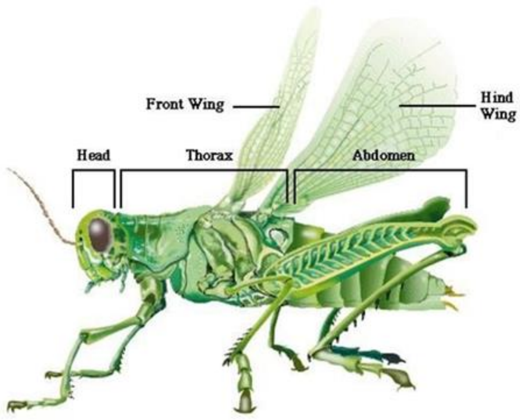



***Figure 5.2: Body regions of a typical insect.***

Head: Main function is sensory and ingestion. Bears a pair of antennae and simple/compound eyes.

Thorax: Main function is locomotion and digestion. Bears 3 pairs of legs and one or two pairs of wings. Some insects can be wingless in the adult stage. Most immature insects are wingless. The digestive system is present in the thoracic region.

Abdomen: Main function is reproduction and excretion. Bears the genitalia in adult insects. Part of digestive system is present in the abdomen which also helps in excretion of waste materials out of the body.

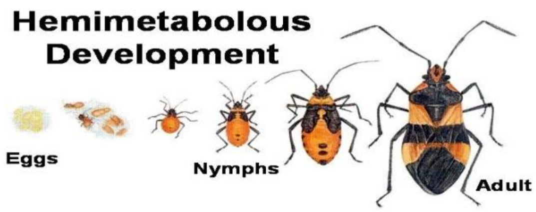



*Figure 5.3: Incomplete metamorphosis.*


*Figure 5.4: Complete metamorphosis.*

**Types of insect mouth parts: Broadly insect mouth parts are of two types**

a) Chewing or Cutter-like. E.g. caterpillars/grubs

*Figure 5.5: Chewing type of mouth parts of a caterpillar.*

b) Sucking or Straw-like. E.g. aphid, whiteflies, mealy bugs, mites etc.

***Figure 5.6: Sucking type of mouth parts of a plant bug.***

**Different tools of Integrated Pest and Disease Management (IPDM)**

**Cultural control:** Below are few of the methods of cultural control

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.

**Physical control:** Is used to control pests by some kind of mechanical means.

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

**Biological control:** Use of natural enemies of crop pests, predators, parasites and pathogens (Appendix) 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.

**Chemical control:** Use of pesticides should be the last resort when the (Economic Thresh hold level ) ETL is crossed.
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

**Site of action**

Insecticides/ acaricides can be classified on the basis of their routes of entry into the body system of the target pest. They can be grouped as follows.

**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.

**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:

For spraying after mixing with water/oil

- 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).

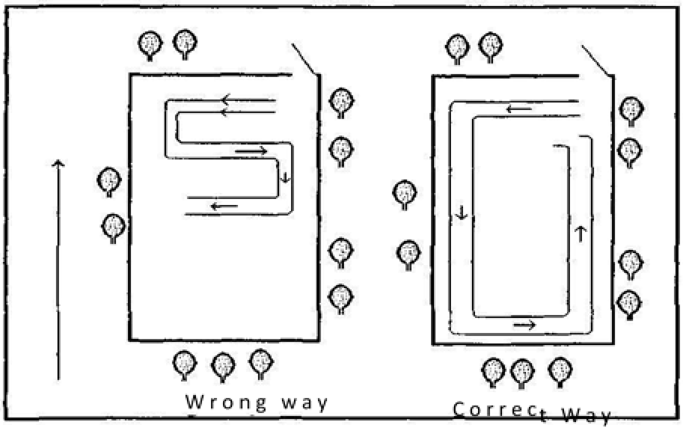



***Figure 5.7: The correct and wrong ways of spraying.***

| **Table 5.1. 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
- Dusters

**1. Hand-operated Hydraulic Sprayers**

These sprayers are the most widely used. They are small and compact e.g., knapsack and hand compressed sprayers.

**2. Knapsack sprayers (lever operated)**

The lever-operated (piston/diaphragm type) knapsack sprayer is one of the most commonly used sprayers. In this equipment, liquid is drawn through a valve into a pump chamber with the first stroke. When the lever returns to its original position, the liquid in the pump chamber is forced past another valve into a pressure chamber. The valve between the pump and the tank is closed during this operation to prevent the return of the liquid into the tank. A good seal between the pump and cylinder is obtained by a 'cup washer' or 'O' ring. As liquid is forced into the chamber, air is trapped in a part of the pressure chamber and compressed. This forces the liquid from the pressure chamber through a hose into the nozzle. Compression sprayers, hand sprayers, and shoulder-slug compression sprayers fall under this category.

**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:

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

OR

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

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

$$\text{Loads ha}^{-1} = \frac{\text{Rate of application ha}^{-1}}{\text{Tank capacity of sprayer}}$$

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

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

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

**Controlled-droplet Application (CDA) Sprayers**

These sprayers (Fig. 5.8) apply the correct size and uniform droplets on a given target area so that optimum use is made of the spray volume and dosage. It is a logical extension of the ultra-low volume (ULV) concept.

The most promising method of controlling droplet size within fairly narrow limits is by using centrifugal energy nozzles (spinning discs or cups) which adjust droplet size by varying their rotational speed. A suitable formulation and flow rate are selected so that at a given rotational speed, droplet formation is from ligaments with a minimum number of satellite droplets.

The volume of spray depends not only on the droplet size selected but also on droplet density. Uniform droplet density can be obtained by using as little as 500 mL $ha^{-1}$ of the formulation with a droplet size of 46 m or 1-8 L $ha^{-1}$ at 70 µm or 200 L $ha^{-1}$ at 340 µm droplets.

***Figure 5.8: Controlled-droplet application sprayer.***

**Spraying procedure**

To avoid contact with the spray, the drift operator must walk progressively up-wind across the field through non-treated crops. The sprayer is held either with the handle across the front of the operator's body or over his shoulder, with the disc above the crop pointing downwind. The Spinning disc is normally held 1 m above the crop. It may be necessary to hold it lower while spraying the first swath along the leeward side of a field in order to reduce the chemical's drift outside the treated area.

**Dusters**

Appliances that are used for distributing dust formulations are called dusters. Dusters may be manually or power operated. Machines used for applying dusts mainly consist of a hopper (dust chamber) with an agitator, an adjustable orifice or other metering mechanism, and delivery tubes. Some dusters are power operated, e.g., motorized mist blower-cum-dusters, tractor-mounted dusters, and rotary dusters.

The following types of power dusters are generally in use:

**Tree duster**

This duster has an upright metallic discharge tube varying in length from 1 to 4 feet, which helps carry the dust upwards to the trees. The height up to which the dust can be carried depends on the length of the tube and the engine's horsepower. Generally, a long hose (10 feet) is used to dust tall trees.

**Row crop duster**

This duster has 4-8 outlets in the fan chamber. Each outlet is connected by flexible pipes meant to spread the dust, and arranged on an iron rod in the rear of the tractor for delivering the dust right on the crop. Crops grown in a row are most suitable for treating with these dusters. Row crop dusters can be fitted on to any vehicle or animal-drawn trolley and can dust vast areas.

**All-purpose dusters**

These range from the small knapsack and wheel barrow or skid type dusters to the large tractor or vehicle-mounted power dusters. They usually have a single delivery outlet connected to a 4-6-ft multidirectional flexible delivery pipe. They are used for all kinds of crops except tall trees, and can dust 20-30 acre day$^{-1}$ depending on crop height and formulation dosage.

**Self-propelled dusters**

Power dusters of this type are mounted on a frame carried by 3 or 4 wheels driven by an engine.

**Different Types of Nozzles and their Main Uses**

Nozzles are an important part of spraying equipment. They vary in their delivery system.

**Hydraulic Energy Nozzles**

In this type of nozzle, liquid under pressure is forced through a small opening. The velocity of the liquid breaks it into droplets. Properties of the liquid, such as surface tension, specific gravity, and volatility influence the delivery of the spray mix.

The various types of hydraulic energy nozzles are:

Cone jet nozzles: Hollow cone jet and solid cone jet which are used for foliage sprays (Fig. 5.9).

Flat fan: This is used for spraying on flat surfaces and in aerial spraying.

Impact nozzle or flood jet: This is a low pressure nozzle with coarse spray, mainly used for herbicide application (Fig. 5.10a).

Other types: The adjustable nozzle (Fig. 5.10b) and the swirl nozzles (Fig. 5.11) for spraying in two different directions.

The main components of a hydraulic spray nozzle are:

Side view

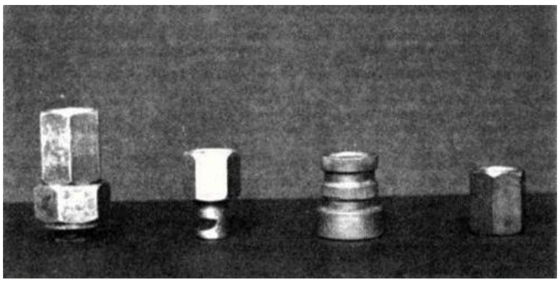


***Figure 5.9: Types from left - Flat fan, Flood jet, Hallow cone, Hallo cone.***

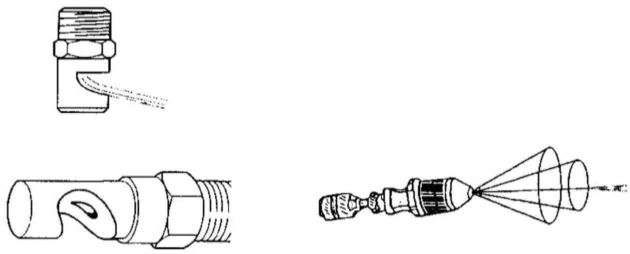


***Figure 5.10: (a) An impact nozzle, (b) An adjustable nozzle for distant target.***

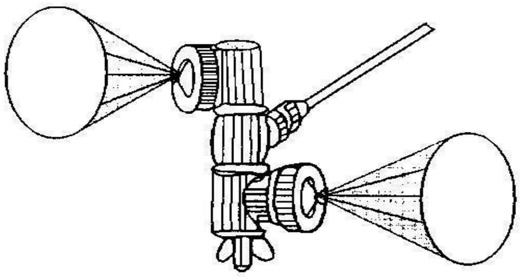


***Figure 5.11: A swirl nozzle used for spraying in two different directions.***

**Effect of Droplet Size and Spray Coverage**

**Distribution of spray**

Droplet size, density, and penetration can be visible on water-sensitive papers tagged on to a plant at different heights. Droplets deposited on the plant surface spread and increase up to 3 times in size. The smaller the droplet, the greater the spread factor.

**Nozzle Erosion and Spray Pattern**

The accuracy of the deposition of spray droplets depends on the nozzle. The orifice of the nozzle tip gets enlarged over a period of time by the combined effects of the chemical action and the abrasive effect of the particles. These may be in the 'filler' portion of wettable powder formulations, where foreign particles are frequently suspended in the spray. This is referred to as nozzle-tip erosion and results in an increase in liquid flow rate, droplet size, and an alteration in spray pattern. An increased flow rate can lead to an overdose of pesticides. The discharge from a nozzle or group of nozzles can be measured with a patternator (Fig. 5.12), which monitors the liquid discharged through a flow meter. Water is sprayed into one, two or three nozzles on to a channeled table and collected in a sloping section which drains into calibrated collecting tubes at the end of the channels. The nozzle is usually mounted 45 cm above the tray and connected to a similar spray line. The patternator can be placed under a tractor boom to find out the variation in spray distribution along its length. The coefficient of variation of a boom pattern can be obtained when limits for individual nozzle patterns have been defined using a fluorescent tracer technique to determine liquid distribution.

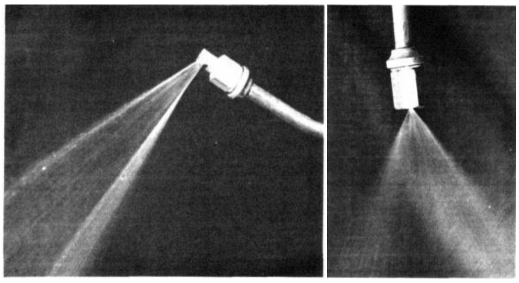


***Figure 5.12: Nozzles and their spray pattern.***

| **Table 5.2. Advantages and disadvantages of CDA over conventional spray applications.** | |
|---|---|
| Advantages | Disadvantages |
| Produces smaller and uniform size droplets | The smaller droplets tend to evaporate easily and drift from the target area |
| The smaller the droplet, the greater the | Application has to be under ideal weather |
| Spread factor and the better the coverage | Conditions |
| No diluent is required | Selective in use of formulations |
| Easy to carry, use, and maintain | Hazardous to operator and surroundings because of the use of high concentration of chemicals |
| Covers large areas in less time and with less inputs | Losses due to wind |
| Wider swaths and no runoff | Strict adherence to weather conditions |

**Calibration of Equipment**

The spray volume can be calculated theoretically by the following formula:

Application rate in L $ha^{-1}$ = 600 L x L $min^{-1}$ (nozzle discharge) Swath width (m) x Speed m min- 1

**Maintenance and Safe Handling of Equipment**

Regular preventive maintenance of equipment is required so that the components which are subject to wear and tear are replaced before they wear out. Proper maintenance of equipment is, therefore, essential.

**Problems Associated with Spraying Equipment**

**Nozzle blockages**

If a nozzle blockage occurs while spraying, the nozzle tip and filter should be replaced with clean points. The blocked nozzle should be cleaned and spares should be taken to the field. When spares are not available, water or a solvent should be taken to the site of operation to clean the blockage. The occurrence of blockages can be reduced by filtering the spray liquid while filling the chamber.

**Inefficient pumps**

Pumps are fitted with 'O' ring seals or leather or synthetic cup washers. As the seals can get damaged due to suspended spray particles, they should be checked regularly. Apart from cleaning and replacing damaged parts, it may be necessary to change the formulations used or to improve the filtration of water before use.

**Leakage**

'O' ring washers and other types of seals are liable to wear and tear or damage when hose connections, trigger valves, and other components are unscrewed. Compression spray equipment and certain motorized knapsack mist blowers function properly provided they are airtight.

**Maintenance and safe handling**

- Daily maintenance
- Clean after use.
- Check pump, nozzles, etc., before operation with water.
- Inspect mobile parts.

**Periodic preventive maintenance of the following is important:**

- Pumps
- Pipes and connections
- Pressure gauges and pressure regulators
- Agitator
- Nozzles and booms
- Tank components
- Engine

**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 additionalprotective 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 5.13: 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 faceand 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 thisrisk. 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 usedto 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.

**Pest surveillance, Economic Threshold Level and Integrated Disease Management (IDM)**

- Identify and manage major pests of crops
- Apply Economic Threshold Level in the field
- Perform pest surveillance
- Perceive the ill effect of pesticides
- Identify diseases and symptoms of field crops

**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.

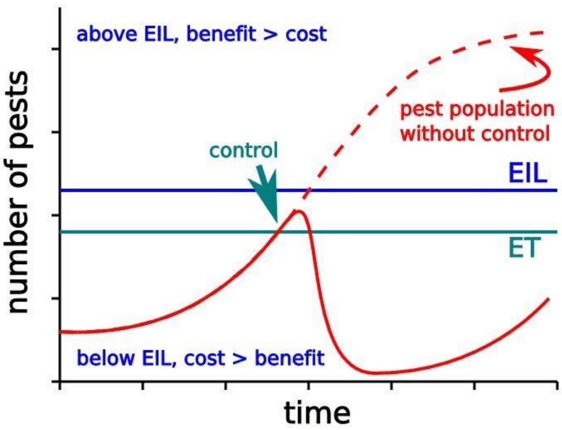



***Figure 5.14: showing the ET and EIL.***

One of the basic requirements in managing pests 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 level, the point at which pest control is initiated.

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 5.15: Surveillance crew in a groundnut field.***

***Figure 5.16: A pheromone trap in groundnut.***

***Figure 5.17: 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<br>Sample unit: plants<br>#Sample units: 50<br>#Samples/location: 5<br>#Locations: 10 | 0.5 thrips/leaf | 1 thrips/leaf |
| | Measurement:<br>Sample unit: plants<br>#Sample units:<br>#Samples/location:<br>#Locations: | | |
| | Measurement:<br>Sample unit: plants<br>#Sample units:<br>#Samples/location:<br>#Locations: | | |
| | Measurement:<br>Sample unit: plants<br>#Sample units:<br>#Samples/location:<br>#Locations: | | |

***Figure 5.18: 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.

**Crop Monitoring Techniques**

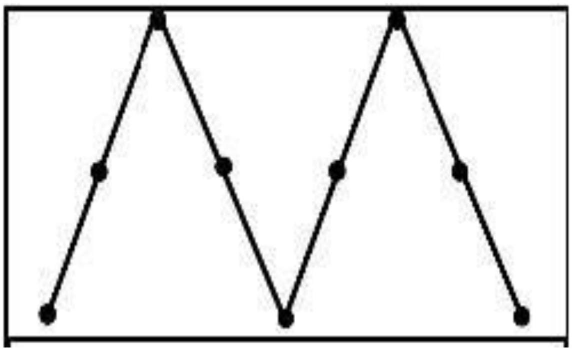


***Figure 5.19: Pattern 1 – Used for insects that often are uniformly distributed: including aphids, bertha armyworm, diamondback moth and lygus bugs.***

Every field should be monitored on a regular basis to detect specific insect pests and to determine densities within the crop (e.g. Pattern 1). With an adequate monitoring program to establish presence of pest species and to monitor changes in population densities, producers are more likely to be aware of potential problems.

The first step is to determine the potential insect pests. Producers unfamiliar with the possible insect pests of a crop should acquire a production guide for the crop. The second step is to identify the insects their life stages and to detect their presence by the effect they have on the crop.

**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 no 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.

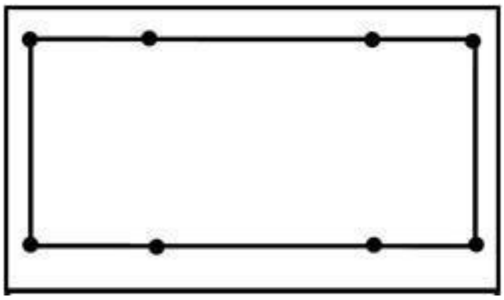


***Figure 5.20: Pattern 2 – Used when pests are at the edges of fields. Including flea beetles, Colorado potato beetle and grasshoppers.***

**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 using Pattern 2. 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 agronomist. 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. I uncertainties remain, contact the Agriculture Knowledge Centre at 1-866-457-2377, or contact the Crop Protection Laboratory (address below). These resources will help to ensure a proper identification.

**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.

**An example for estimating grasshopper densities**

Before counting grasshoppers in a field or roadside, measure a distance of 50 m on a reasonable level surface. Usually, this will be adjacent to the actual area to be sampled, such as a road. Flag both ends using markers or specific fence posts on the field margin. These points should be easily visible for the observer because they will be used as starting and end points.

To begin the count, start in the area to be sampled, aligned with one of the markers. Walking parallel to the measured distance, move through the crop toward the other marker making some disturbance with your feet to encourage any grasshoppers to jump. Any grasshoppers that jump through a one meter field of view in front of the observer are counted. A meter stick can be carried as a visual guide to give perspective for a one meter width. After doing this a few times, one can often visualize the required width and a meter stick may not be required.

At the end of the 50 m, the total number of grasshoppers counted is divided by 50 to give an average per $m^2$. A hand-held counter can be useful to count the number of insects while the observer measures off the required distance. This tool may not be practical under high insect populations.

It is important to sample randomly and gather numerous samples. The samples must represent, a much as possible, the entire field being monitored. Random sampling reduces the risk of biased estimates that could result from uneven distribution of insect populations. Collecting numerous samples will also increase the accuracy of an overall field estimate.

Areas of a field may have insect numbers that are in excess of economic thresholds. However, other areas may be very low in pest densities. In these situations, a decision could be made to either not spray, due to the overall average density being below economic threshold, or to concentrate control measures on the more highly infested areas. Either choice would actually benefit the produce financially while reducing environmental impacts.

Keep in mind the edge-effect. In situations where insects migrate into a field from an adjacent field or ditch, the population density is likely to be highest at field margins. Some pest species prefer the edges of a field because of light, temperature or moisture factors.

Edge effects can also be important for other reasons. Although they may distort true population estimates, they may indicate a potential problem before it becomes serious. Be sure to sample throughout the field, not only the field margin, to avoid overestimating population densities.

Sampling methods can vary according to the particular pest.

1) % damage to leaves, plants, foliage, or

2) % of Plants showing damage; or

3) % adults or larvae/stem / plant.

Walk through the crop to obtain or observe the required sample units (i.e. leaves, stems, whole plant or insect counts) every few steps. To get an accurate population estimate, sample randomly a reasonably spaced interval.

As previously discussed, the best estimate of a population or damage will be achieved with adequate representative samples taken over a well-distributed pattern. A zigzag route through the field sampling approximately every 10 meters is a commonly used pattern.

If the chart says:

1) % adult insects or larvae / $m^2$

Use a meter-stick or pre-measured piece of string to mark off a square meter of the crop. Examine this area, counting the numbers of pests seen. Do this at several randomly chosen and widely-spaced sites Average your results.


***Figure 5.21: Scouting for insects using a sweep net.***

**Appendix**

Plant Protection and Surveillance Unit: Data Sheet

**ICRISAT - Farm and Engineering Services Program an Example**

Field No: Scientist concerned:

Area: Name of observer:

Date:

**Pigeonpea Flowering Stage**

No. of insects plants- 1

| Sl. No | No. of plants | *Helicoverpa* | | Leaf weber | Exelastis | | Lampides | | Blister | Others |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Egg | Larvae | | Egg | Larvae | Egg | Larvae | | |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |

**Groundnut**

No. of plants with insects/no. of plants (meter row)$^{-1}$

| Sl. No | Thrips/terminal fold *Frankliniella, Scirto thrips* | *Helicoverpa*larvae | | | Spodoptera | Aphids | Leaf miner | Others |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | | | | |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |

**Ill Effects of pesticides**

**Effects can be classified as follows**:

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

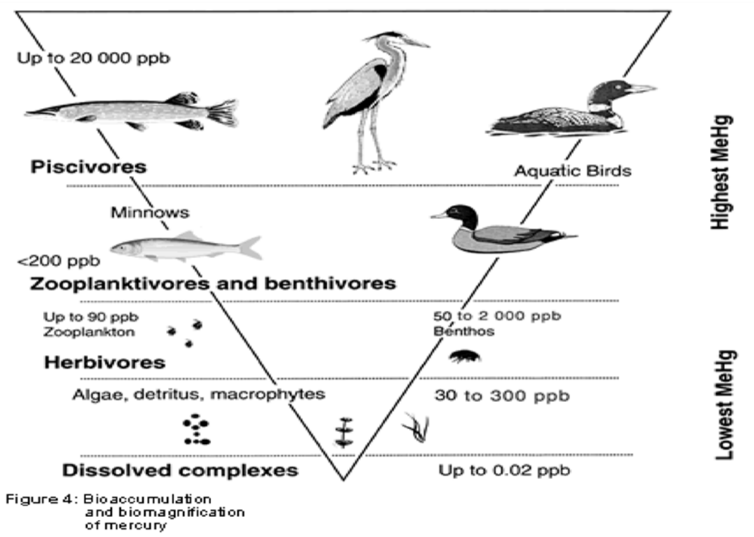



*Figure 5.22: Bioaccumulation: the tendency for a compound to accumulate in an organism.*

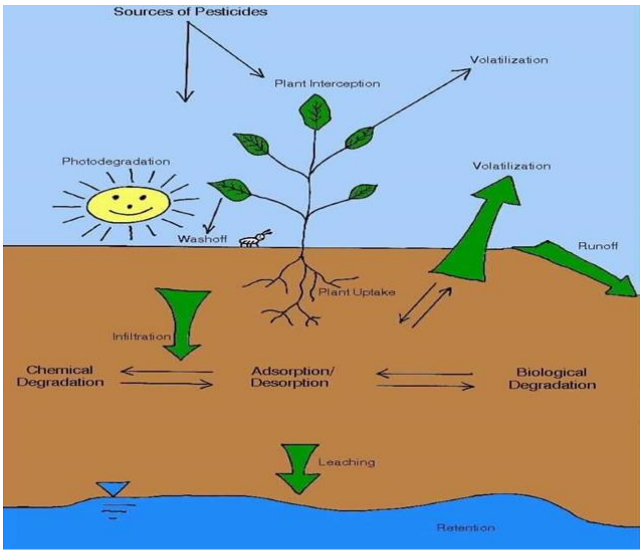



*Figure 5.23: Environmental impact of pesticide residues.*

**Environmental Impacts**

**Loss of biodiversity**

- Global amphibian decline
- Declined in bee populations

**Danger to fish species**

- Endangered Pacific salmon

**Groundwater pollution**

- Contamination of drinking water
- Entry of residues in food chain

**Loss of biological control of pests**

Pesticides might harm pest's natural enemies. Chinese scientists have recently shown that the majority of 14 commonly used insecticides had a drastic lethal effect on a beneficial wasp that helps pest control in rice (Wang et al., 2008). Even after 7 days after insecticide application, residues were killing this beneficial wasp. E.Resistance to pesticides:

In the beginning, most pests were sensitive to DDT but a few were resistant. The resistant forms survived and reproduced. In the end, most pests were resistant to DDT

**Diseases of field crops**

***Figure 5.24: Field crops affected by diseases.***

**Definitions of plant disease**

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.

**Disease triangle**

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.

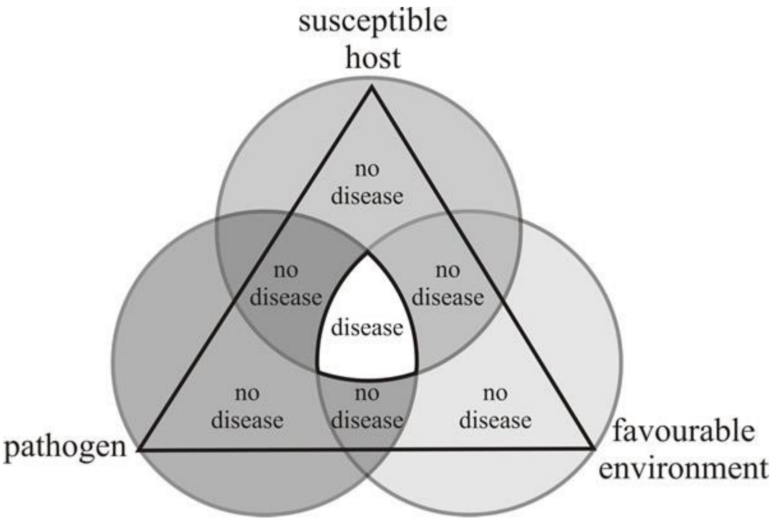



***Figure 5.25: Disease triangle.***

**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.

**Fungal diseases**

Most plant diseases – around 85 percent – are caused by fungal or fungal-like organisms. Following are few symptoms of a fungal disease:

- Anthracnose
- Damping off of seedlings
- Leaf spot
- Chlorosis
- Powdery mildew
- Downy mildew

**Bacterial diseases**

Following are the major symptoms of bacterial diseases**:**

- Leaf spot with yellow halo

- Fruit spot
- Canker
- Crowngall

**Viral diseases**

Following are the symptoms of viral diseases:

- Mosaic leaf pattern
- Crinkled leaves
- Curled leaves
- Yellow leaves
- Plant stunting

## Session 6: Principles and Methods of Training

*At the end of this session participants will be able to:*

- Define the importance of communication
- List the participants acquisition of knowledge
- Employ the factor of motivation
- Recognize the System approach to training
- List the areas of training
- The trainers roles and responsibilities

**Introduction**

A measure of the success of training is the relationship that develops between trainer and trainees. In a sound, productive training situation there is mutual respect and trust between them, with the trainer taking care to ensure that even the weakest trainee performs to the highest possible level, and the trainees feeling a desire within themselves to achieve. In this situation the trainer is the motivator and the trainees are the motivated.

It is intended that the modules that follow will be of assistance to those wishing to train and those already training.

The objective is to address the basic elements necessary for the effective preparation, implementation and evaluation of training, with the aim of that training being "to get the message across".

To achieve that objective, the modules that follow are intended to provide guidance to trainers in the skills of conveying their message successfully and transferring related information. Training is essentially the instructing of others in information new to them and its application. It may, and often does, involve the teaching of new skills, methods and procedures.

Very few people are born trainers, and most of those who wish to be trainers require training. Even those few who are born trainers benefit from training, and their effectiveness is enhanced as a result.

The most important element in a training situation is the trainer. The trainer who is enthusiastic, energetic and genuinely interested in both the subject and getting his or her message across will evoke the greatest response from the trainees. The trainer who lacks interest in training, who has little or no enthusiasm for the subject of the training and who merely goes through the motions of training is a failure. Such a trainer wastes not only his or her own time but also that of the trainees. The inept trainer is quickly identified by the trainees, who react with inattention, lassitude, undisciplined behaviour and absence from training sessions.

Successful training - that which produces the desired result - lies almost entirely in the hands of the trainer. In the trainer's hands lies the heavy responsibility for ensuring that the trainees achieve the maximum possible from the training.

**Why training is important?**

Being educated and skilled is a privilege in our country as many do not get the chance. Utilizing the knowledge and skill optimally to achieve professional assignments efficiently is the main reason we need training. Sometimes, updating our skill and knowledge with latest developments in the field of expertise is required to harness their potential. Regular training has no substitute to acquire new skill sets and to gain expertise in them. For example, driving a car, swimming or yoga sessions are examples of skill-training whereas on farm or in-industry apprenticeships are skill and knowledge training. The three basic importance of training are:

- Knowledge transfer
- Skill development
- Capacity building

**Principles of effective communication - "Getting the message across"**

**Objective**

To familiarize the participants with the elementary principles of successful oral communication of information and to heighten awareness of the factors that interfere with communication and reduce its effectiveness

**Suggested method of instruction:**

- Lecture/discussion with maximum trainee participation through questioning and relating of personal experience

**Aids**

- Handouts
- Power point presentations
- Videos using projectors, peico projectors, using tablets in rural areas

**Time frame**

- One hour lecture/discussion

**Content**

- Effective communication
- Interference
- Ways of avoiding interference

**Presentation suggestions**

The foregoing module is easily adapted to discussion. The trainer should attempt to elicit from the trainees their experiences with transmission, interference and ways of avoiding interference, which are well within the purview of trainee experience.

Trainees should be asked to tell the course participants about good communicators and poor communicators they have known, describing why they are memorable. The reasons they give should be related to the types of interference and ways in which interference was or could have been avoided.

Such a discussion invariably brings out other indirectly related aspects of spoken communication which provide points of reference when subjects in later modules are being dealt with.

**Learning outcome**

Participants should be aware of effective communication principles.

**Effective communication**

Communication specialists compare the way people communicate to the way a radio transmission takes place. That is to say:

Transmitter (Speaker/writer) >> Message >>> Receiver (Listener/reader)

Three types of transmission are identified:

- Spoken
- Written
- Gesture/sometimes referred to as "body language"

Transmission is in code:

- Spoken language
- Written language
- Gestures

In spoken language the unit of code is the word, heavily supported by gestures. Some communication specialists believe that at least 40 % of the full meaning of messages transmitted by speech is conveyed by body language (gestures). In written language the units of code are words and symbols (e.g. figures, punctuation). In the remainder of this module and the modules that follow reference to communication is to spoken communication only and assumes the transmitter can be seen by the receiver.

| |
|---|
| **Successful communication depends on the message being received by the receiver intact and interpreted by the receiver to have the same meaning as when transmitted** |

**Interference**

Frequently the message suffers from interference. That is, something interferes with the message between its transmission and reception and distorts it. The following are some types of interference.

**Weak transmission**

- Speaking too softly
- Speaking in a flat voice (monotone) without inflection
- Not speaking in a direct line with the receiver
- Insufficient volume of transmission to prevail over competing transmissions and
- localized noise (static)

**Garbled transmission**

The transmitter (speaker) often scrambles the contents of the message so that the facts it contains are not in logical order and often appear unrelated.

**Wrong language**

The transmitter may use words, terms and expressions unknown to the receiver.

**Pitching message at the wrong level**

The speaker may transmit information in a context beyond the experience of the receiver (this may involve the use of wrong language). This is sometimes called "transmitting or talking over the receiver's head". Examples are teaching watershed management or IWMP to people who have no experience in watershed management principles thereby transmitting detailed and profound scientific messages to a receiver without a scientific background.

**Receiver not receiving**

- Receiver turned off (gone to sleep!)
- Tuned into another transmitter
- Transmission too weak
- Strength of receiver diminished (lack of interest - boredom)
- Receiver distracted by a competing focus of interest (an attractive person walks by)
- Receiver fatigued

**Competing transmissions**

The receiver may be unable to select between transmissions (too many people talking at once).

**Overloading the message**

The receiver does not possess the capacity to retain all of the information contained in the message. This frequently leads to receiver confusion/fatigue and anxiety.

**Ways of avoiding interference**

- Speak up and out
- Speak slowly and deliberately
- Use language that the receiver understands
- Do not talk over the receiver's head
- Ensure you have the attention of the receiver
- Only transmit your message in suitable surroundings where there is no, or little, competition
- Make the message succinct (as few words as possible) and transmit it in the simplest terms
- Plan the message in logical order

| |
|---|
| **As a trainer it is essential that you get your message across-otherwise your effort to train will be wasted** |

**Summary**

To be a successful communicator

- Use your voice effectively
- Know your subject
- Know what you want to say
- Prepare your message carefully
- Arrange your points logically
- Display interest and enthusiasm
- Sound convincing and sincere

**Effective oral communication**

**Objective**

To assist the trainee-trainers to identify and become acquainted with the essential elements of getting the message across and becoming an effective oral communicator

**Content**

- The importance of being an effective oral communicator
- Essential elements in transmitting a message
- Communication hazards

**Exercise**

Each trainee is required to give a three- to four-minute impromptu talk. The following are examples of possible subjects:

- My reasons for attending the course
- The aspect of my work I enjoy the most
- Why I think Watershed technology is important

In giving this talk the trainee will be expected to take into account the essential elements in transmitting a message.

A handout sheet may be helpful to assist the trainees with their short presentations. The following is an example:

- Describe your work.
- Why is it important to you?
- Which aspect of your work do you enjoy the most?
- Which aspect do you dislike the most?
- What do you think you are best at?
- What aspect of your work would you like to know more about?
- If you had a choice, which aspect of "Quality control" would you like to specialize in and why?

**Learning objectives:**

- Improved and updated know-how
- Methods of knowledge dissemination to various stake holders
- Updating of knowledge and skill sets
- Recognition from the department
- Improved communication skills

**Learning outcomes:**

- Knowing the Odisha Bhoochetana project objectives, strategy and activities better
- Enhancing productivity and input use efficiency among the local farming communities
- Improved staff competence for the department

**The importance of being an oral communicator**

As a trainer much of your effectiveness is measured by your ability to speak with clarity and conviction in getting your messages across.

Men and women in training positions are expected to be highly competent at presenting ideas, giving directions and explaining procedures. In fact, this quality of being an effective communicator is generally considered to be an essential element of the effective trainer's skills.

The information you communicate as a trainer is often critical to the people you train and to the workings of the organization as a whole. The way you explain procedures or give directions can make the difference between an employee being productive or frustrated. Sometimes clear information from you can make the difference between people doing a job safely or unsafely, working efficiently or inefficiently or doing things correctly or incorrectly.

How you present even an obviously brilliant idea can make the difference between whether or not anyone listens to you. The way in which you interpret and transmit information about agency policies, goals, values and procedures has significant influence on the way your staff or subordinates develop their perceptions and their commitments to the organization.

Communicating clearly - "getting your message across" - is not an inherited ability; people are not born with it. It is a learned skill developed through planning and practice.

**Essential elements in transmitting a message**

**Strengthen your main point with supporting points**

Your explanations, instructions or ideas are more compelling when supported by clear facts and observations. Your objective is to gain respect and belief from your listeners and for them to gain insight into the details of the message you are communicating. The following guidelines will make the transmission of your message effective.

- Use simple language. Avoid technical jargon unless you are sure that everyone understands it.
- Keep your explanation short so you do not risk boring people. Do not swamp them with unnecessary detail (which is called "overloading").
- Choose reasoning that is natural and familiar to your listeners and your topic.
- Make your explanations as colorful as possible, using examples to illustrate your point.
- List all your supporting points first; then return to each point and fill in the details.
- Use visual aids, where possible, to illustrate your points.

www.youtube.com/watch?v=4EiM_-oSWzI-

**Why train? The trainer's role and responsibility**

**Objective**

To introduce the participants to the basic principles of training in the simplest possible way and to establish fully the responsibility of the trainer

**Content**

- The process of learning
- Factors that hinder learning
- Obtaining and holding the learners' attention
- Facilitating understanding
- Steps in skill training

**Approach**

Discussion should play a major part in the presentation. Because of their life-experiences the trainees will be familiar with learning, even though they may never have analyzed the process. Therefore the major task of the trainer is to plan a sequence of questions that will lead the trainees to an identification of the elements and steps in the learning process and the factors that hamper learning. Trainees should be encouraged to recall the good trainers and teachers they have known and to identify the skills that made their training and teaching memorable.

The material in the lecture and power point presentation is in point form and requires explanation by the trainer.

**Learning outcome**

The participants should be aware of and understand the trainer's role and responsibilities.

| |
|---|
| **Why train?**<br>To improve the trainee's knowledge and skill<br><br>*What is the responsibility of the trainer?*<br>To get the message across - that is, to ensure that the trainees have received and understood the message<br><br>Training is not easy<br>Training is hard work<br>Some trainers merely go through the motions of training<br>Some trainers are unsuccessful |

**The process of learning**

The successful trainer possesses insight into the process of learning. The learning process conforms to the following pattern: external sensations stimulate the sense organs - ears, eyes, body (touch), nose and tongue - and the nervous system conveys impressions to the relevant sections of the brain. The brain then transmits impulses to the muscles and organs of movement and speech, and the end result is a reaction.

**Observing the learners**

The only way the trainer can know if people have learned the material is by observing their behavior:

- Their actions
- Their written impressions
- Their speech

**Factors that hinder learning**

- The learning plateau: at intervals the rate of learning flattens out as the brain rests
- Saturation: if the message is overloaded the receiver rejects the excess and learning stops
- Fatigue: a tired receiver is not as receptive as an alert one
- Inability to concentrate: the longer the message, the more concentration decreases from beginning to end

**Obtaining and holding the learners attention**

Before people can learn any material they must focus their voluntary attention on it. The desire to learn comes from within; it is spontaneous.

The good trainer tries to gain and maintain voluntary attention in every session he or she presents.

- Relate what you aim to teach to those subjects in which you know the trainees are interested.
- Introduce the session in such a way that the trainees will not only see and become interested in this relationship, but will want to learn more about it.
- Begin with a good story to which the trainees can relate. An effective trainer makes it his or her business to know the background of the trainees.
- Having done these things, maintain the trainees' attention by doing all that is possible to facilitate their understanding and absorption of the material.
- Ensure that the trainee's learning is an active process in which the trainer and trainees are equal partners in terms of participation.

**Facilitating understanding**

To facilitate understanding, the trainer proceeds from:

- Known to unknown
- Simple to complex
- Whole to part and back to whole
- Concrete to abstract
- Particular to general
- Observations to reasoning
- Point to point in logical order

To facilitate absorption, remember that trainees learn only by impressions received through their senses.

**Steps in skill training**

Having learned a skill, trainees must reinforce its acquisition by using it. Learning by doing is the basic principle underlying the acquisition of any skill.

- When teaching skills, the trainer most often achieves the best results by keeping the talk short and by working through a set sequence of discrete steps, as follows:
- Show the trainees the actual skill they are to acquire.
- Demonstrate and explain, step by step, the operations involved (this requires an analysis of the total procedure by the trainer).
- Have trainees imitate the necessary actions.
- Have trainees practice performing the operations.
- Devote at least 50 % of the session to trainee practice time.

**Summary**

The first rules of training are:

- Make the best use of the most effective channels to the brain - the senses: sight, hearing, touch, taste and smell.
- Use a combination of the senses. For knowledge, use the trainees' eyes and ears. For manual skills, use the trainees' hands, eyes and ears.
- Make presentations as vivid as possible.

These are the basic principles of instruction - the means by which the instructor reaches and makes an impression on the brains of the trainees.

**Learning Systems and Methods of Training**

**Introduction:**

Learning systems and methods of training are important factors in designing a training program

**At the end of this session participants will be able to:**

- Distinguish between Pedagogy and Andragogy
- Appraise the principles of Adult learning
- Design a program using Andragogy followed by a group exercise

**Principles**

**Adults must want to learn** .They learn effectively only when they are free to direct their own learning and have a strong inner motivation to develop a new skill or acquire a particular type of knowledge.

**Adults will learn only what they feel they need to learn.** Adults are practical in their approach to learning; they want to know, "How is this going to help me right now? - Is it relevant (Content, Connection and Application)."

**Adults learn by doing.** Children also learn by doing, but active participation is more important among adults.

**Adult learning focuses on problems and the problems must be realistic.** Children learn skills sequentially. Adults start with a problem and then work to find a solution.

**Experience affects adult learning** .Adults have more experience than children. This can be an asset and a liability.

**Adults learn best in an informal situation** .Children have to follow a curriculum. Often, adults learn by taking responsibility by the value and need of content they require to understand

and the particular goals it will achieve, being in an inviting environment and having roles as an active participant in the learning process makes it efficient.

**Adults want guidance** .Adults want information that will help them improve their situation or that of their children. They do not want to be told what to do. They want to choose options based on their individual needs.

Adult learning styles

A learning style refers to how a person learns, categorizes, and processes new content. Each person may have multiple preferred learning styles. The three primary learning styles are: visual, auditory, and kinesthetic.

Visual learners tend to learn by looking, seeing, viewing, and watching. Visual learners need to see an instructor's facial expressions and body language to fully understand the content of a lesson. They tend to sit at the front of the classroom to avoid visual distractions. They tend to think in pictures and learn best from visual displays. During a lecture or discussion, they tend to take detailed notes to absorb information.

Auditory learners tend to learn by listening, hearing, and speaking. Auditory learners learn best through lectures, discussions, and brainstorming. They interpret the underlying meaning of speech by listening to voice tone, pitch, and speed and other speech nuances. Written information has little meaning to them until they hear it. They benefit best by reading text out loud and using a tape recorder.

Kinesthetic learners tend to learn by experiencing, moving, and doing. Kinesthetic learners learn best through hands – on approach and actively exploring the physical world around them. They have difficulty sitting still for long periods of time, and easily become distracted by their need for activity and exploration.

History of Andragogy

Originally the term Andragogy wasused by Alexander Kapp (a German educator) in 1833, Andragogy was developed into a theory of adult education by EugenRosenstock-Huessy and was popularized in the US by American educator Malcolm Knowles. Knowles asserted that Andragogy (Greek: "man-leading") should be distinguished from the more commonly used *P*edagogyGreek: "child-leading".

In 1967, Knowles made use of the term "androgogy" to explain his theory of adult education. Then, after consulting Merriam-Webster, he corrected the spelling of the term to "andragogy" and continued to make use of the term to explain his collection of ideas about adult learning.Knowles' theory can be stated with six assumptions related to motivation of adult learning:

Need to know:

1. Adults need to know the reason for learning something.

2. Foundation: Experience (including error) provides the basis for learning activities.

3. Self-concept: Adults need to be responsible for their decisions on education; involvement in the planning and evaluation of their instruction.

4. Readiness: Adults are most interested in learning subjects having immediate relevance to their work and/or personal lives.

5. Orientation: Adult learning is problem-centered rather than content-oriented.

6. Motivation: Adults respond better to internal versus external motivators.

On this formal level 'above practice' and specific approaches, the term andragogy could be used relating to all types of theories, for **reflection, analysis, training**, in person-oriented programs as well as human resource development.

Recent research has expanded andragogy into the online world, finding that using collaborative tools like a wiki can encourage learners to become more self-directed, thereby enriching the classroom environment. It gives scope to self-directed learners. Andragogy helps in designing and delivering the solution focused instructions to self-directed. The methods used by Andragogy can be used in different educational environments (e.g. adolescent education).

**Differences from pedagogy**

Here are some of the main differences between pedagogy and andragogy:

| | **PEDAGOGY** | **ANDRAGOGY** |
|---|---|---|
| **LEARNER**: | • The learner is dependent on the instructor, the teacher schedules all the activities; determining how, when and where they should take place<br>• Teacher is the one who is responsible for what is taught and how it is taught<br>• Teacher evaluates the learning | • Learner is self-directed and moves towards independence<br>• Learner is responsible for the learning<br>• Self-evaluation is seen |
| **LEARNER'S EXPERIENCE** | • There is little experience which could be gained from this kind of learning<br>• Method is didactic | • There is large quantity of experience gained<br>• Method used is problem solving, discussion, service-learning[17] |
| **READINESS TO LEARN** | • Standardized curriculum set which will be based on societal needs | • Curriculum is more application based and it revolves around life |
| **ORIENTATION TO LEARNING** | • Here, it is a process of acquiring subject matter | • Here learning is for performing tasks and solving problems |
| **MOTIVATION** | • Motivation is by external pressure, and there is lot of competition for grades | • It is driven by internal motivation. Includes self-actualization, self-confidence etc. |

**What are the Principles of Training**

**Introduction**:

It is important to set the objectives at the very beginning of Designing a Training program

**At the end of this session participants will be able to:**

- Setting the objectives of a training program
- Using cognitive verbs

**Learning objectives:**

- Improved and updated know-how
- Methods of knowledge dissemination to various stake holders
- Updating of knowledge and skill sets
- Recognition from the department
- Improved communication skills

**Learning outcomes:**

- Knowing the Odisha Bhoochetana project objectives, strategy and activities better
- Enhancing productivity and input use efficiency among the local farming communities
- Improved staff competence for the department

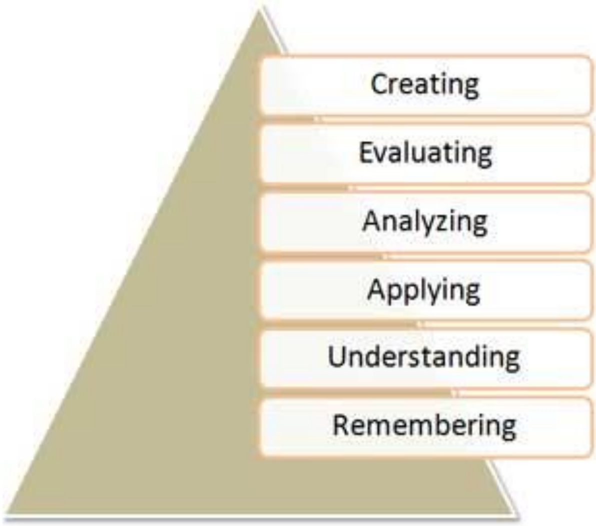



***Figure 6.1: Bloom's Taxonomy of Learning Domains.***

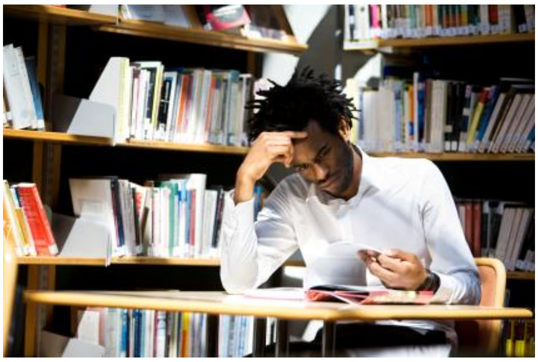
Bloom's Taxonomy was created in 1956 under the leadership of educational psychologist Dr Benjamin Bloom in order to promote higher forms of thinking in education, such as analyzing and evaluating concepts, processes, procedures, and principles, rather than just remembering facts (rote learning). It is most often used when designing educational, training, and learning processes.

**The Three Domains of Learning**

The committee identified three *domains* of educational activities or learning (Bloom, *et al.* 1956):

- **Cognitive**: mental skills (*knowledge*)
- **Affective**: growth in feelings or emotional areas (*attitude or self*)
- **Psychomotor**: manual or physical skills (*skills*)

**Cognitive Domain**



The cognitive domain involves knowledge and the development of intellectual skills (Bloom, 1956). This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. There are six major categories of cognitive processes, starting from the simplest to the most complex

- Knowledge
- Comprehension
- Application
- Analysis
- Synthesis
- Evaluation

**Remembering**

- Exhibit memory of learned materials by recalling facts, terms, basic concepts, and answers.
- Knowledge of specifics – terminology, specific facts
- Knowledge of ways and means of dealing with specifics – conventions, trends and sequences, classifications and categories, criteria, methodology
- Knowledge of the universals and abstractions in a field – principles and generalizations, theories and structures
- Questions like: What are the health benefits of eating apples?

**Understanding**

Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating the main ideas

**Translation**

- Interpretation

- Extrapolation Questions like: Compare the health benefits of eating apples vs. oranges.

**Applying**

Using acquired knowledge. Solve problems in new situations by applying acquired knowledge, facts, techniques and rules.

Questions like: Would apples prevent scurvy, a disease caused by a deficiency in vitamin C?

Learners should be able to use information to solve problems, identify connections and relationships and how they apply. It is important for students to be able to use prior knowledge in new situations. For example, a student should be able to apply a method used in their own lives.

**Analyzing**

Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations

- Analysis of elements
- Analysis of relationships
- Analysis of organizational principles

Questions like: List four ways of to conserve moisture and explain which ones have the highest benefits. Provide references to support your statements.

Analysis is being able to break down information into component parts, and determine how the parts relate to one another. An example of analysis is having students summarize something and then analyzing why certain things happened.

**Synthesizing**

Builds a structure or pattern from diverse elements; it also refers the act of putting parts together to form a whole (Omari, 2006). Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions

- Production of a unique communication
- Production of a plan, or proposed set of operations
- Derivation of a set of abstract relations

Questions like: Convert a wrong way to conserve rain water to replace a correct way replacing the choice of options. Explain the benefits of using the right way chosen vs. the original ones.

**Evaluating**

Present and defend opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria

- Judgments in terms of internal evidence
- Judgments in terms of external criteria

Questions like: Which kinds of potatoes are best for frying and why?

**The highest level is evaluating which requires critical thinking.**

| **Examples, key words (verbs), and technologies for learning (activities)**<br><br>**Categories** | |
|---|---|
| **Remembering**: Recall or retrieve previous learned information. | **Examples**: Recite a policy. Quote prices from memory to a customer. Recite the safety rules.<br>**Key Words**: defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognizes, reproduces, selects, states<br>**Technologies**: book marking, flash cards, rote learning based on repetition, reading |
| **Understanding**: Comprehending the meaning, translation, interpolation, and interpretation of instructions and problems. State a problem in one's own words. | **Examples**: Rewrite the principles of test writing. Explain in one's own words the steps for performing a complex task. Translate an equation into a computer spreadsheet.<br>**Key Words**: comprehends, converts, defends, distinguishes, estimates, explains, extends, generalizes, gives an example, infers, interprets, paraphrases, predicts, rewrites, summarizes, translates<br>**Technologies**: create an analogy, participating in cooperative, taking notes, storytelling, Internet search |
| **Applying**: Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the classroom into novel situations in the work place. | **Examples**: Use a manual to calculate an employee's vacation time. Apply laws of statistics to evaluate the reliability of a written test.<br>**Key Words**: applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, shows, solves, uses<br>**Technologies**: collaborative learning, create a process, blog, practice |
| **Analyzing**: Separates material or concepts into component parts so that its organizational structure may be understood. Distinguishes between facts and inferences. | **Examples**: Troubleshoot a piece of equipment by using logical deduction. Recognize logical fallacies in reasoning. Gathers information from a department and selects the required tasks for training.<br>**Key Words**: analyzes, breaks down, compares, contrasts, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, separates<br>**Technologies**: Fishbowls, debating, questioning what happened, run a test |
| **Evaluating**: Make judgments about the value of ideas or materials. | **Examples**: Select the most effective solution. Hire the most qualified candidate. Explain and justify a new budget.<br>**Key Words**: appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes, discriminates, evaluates, explains, interprets, justifies, relates, summarizes, supports<br>**Technologies**: survey, blogging |
| **Creating**: Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure. | **Examples**: Write a company operations or process manual. Design a machine to perform a specific task. Integrates training from several sources to solve a problem. Revises and process to improve the outcome.<br>**Key Words**: categorizes, combines, compiles, composes, creates, devises, designs, explains, generates, modifies, organizes, plans, rearranges, reconstructs, relates, reorganizes, revises, rewrites, summarizes, tells, writes<br>**Technologies**: Create a new model, write an essay, network with others |

## Session 7: The components of a Training program

*At the end of the session you will be to*

- Characterize your audience
- Decide on a curriculum
- Need for training
- Writing content
- Decide on the tools to be used
- Judging the performance of the participants
- Decide on a system of course feedback
- Delivering a training program
- Quality of a Good Trainer

**Audience characterization- know your audience**

Before you start planning for a training program you must know who are your trainees or participants. Try to find out the background, their livelihood (specially for farmers) what they do, their problems, their experience and their expectations, educational background. Most of our programs we never do this and we only try to find out all these on the day the program starts. Obviously this needs an advance planning much ahead of the actual event so that the Training can be designed accordingly, subject matter can be decided and delivery mechanisms can be planned.

**< Q – Ask the participants their experience. What are their problems when you do not know who the participants are and what their background is >**

This can be done in two ways.

1. Meeting the participants with a set of questions
2. Or meeting in a group to gather information

**Decide on a curriculum**

The most important exercise is what should be the area of training, what topics, what participants will learn (learning outcome) how much can be taught. The biggest question is where to start.

**< Ask participants where they would start >.**

Most of our program even at National level has a top down approach. We take it for granted what we are going to teach is what they require. Often there is a mismatch resulting in a very poor executed program. Building capacity is not an easy job. If it has no impact, whatsoever, the whole exercise becomes futile. The question then arise how do we find out what they need or the “Training Need “. Again this needs advance planning, a structured exercise with stakeholders through well designed survey instrument (TNS) and analyze the information. More on it later.

Once we know our audience thoroughly and we have analyzed the NEED the next step is to decide on the Curriculum. This should be planned well and clearly, state the topics /area to be covered, list major objectives and learning outcomes. It should also a have session plan with timeline, tools required (more later), select competent resource persons and many more. In fact this is the blue print or Master Plan of a training program. A well-developed curriculum will help to decide further impacts and should be the broad overall plan to guide the program further on. An example is appended.

**<How many of you have done this exercise, show an example of the present program >**

**Training need survey (TNS)**

We have already talked about this. This should be planned much ahead of actual training program

1. Map the stakeholders first before you take this exercise. Who are your target group, their experience, age group, their livelihood etc.

   **<showSujala mapping exercise in the PPT >**

2. Design a survey instrument which should capture essential information
3. Fill it up by actually meeting the stakeholders, specially if the target group is farmers in their own environment.
4. Analyze the data
5. Design the program starting with the curriculum
6. Often this is called The Training Need Survey and the analysis as the Training Need Assessment

**< Show the instrument for Sujala project, append in the Manual>**

**Designing a Training program**

Once the curriculum is ready decide on a session plan with realistic timeline for each session. The plan should have brief outline of each session. Once this is finalized the timeline (time allotted to each session) should be adhered to strictly. The common danger is when a resource person does not adhere to the time allotted to him, as a result the whole program is disturbed. Training Coordinator's role is important in smoothly running the program.

**Documentation**

A trainig program must document all the activities as well as documenting the training materials for record as well as for posterity. The "Manual" is the most important document with the following information

- Background of the program, why it is planned. What is the necessity, what it will do for whom it is planned.
- What are the Objectives of the program**.< how to write an objective- Blooms taxonomy>**
- Detailed session plan as discussed earlier
- Appropriate content which is the supporting information on the new knowledge

- Description of each session with learning outcomes, references if any, list of tools that will be used
- In the age of Digital Agriculture the Manual can be in digital format provided participants have access to computers or Tabs.. Otherwise a print version will be an ideal format.

**Writing the "Content "**

What is the content in a manual. This is the most important part of a manual as this should be the "New "knowledge which is being transferred to the stakeholders for building their capacity. Therefore lots of attention must be given to writing the Content. It is an Art in itself.

The trainer needs to look at the curriculum which is the blue print of any training program as emphasized earlier. Look at the learning outcome of the session and write the content describing, principles, concepts and the new knowledge supporting the learning outcomes. The content may include statements, scientific information supported by data, graphs, charts, pictures to drive home the important assumptions.

**<an example – a session plan and the contents from the main manual >**

For any capacity building program the content is the new scientific knowledge based on solid proven research data and not just stories. Therefore this needs competent resource persons with sound knowledge of the scientific knowledge that is being transferred.

**What are the tools**

Once you have written the content for all the sessions you need to decide how you are going to present this to the audience. In other words what are the tools that can be used for presenting a session. Normally in a Lecture Mode of presentation the most commonly used tool is the Power Point Presentation in a digital format. Therefore it has graphical presentation with pictures, written statement, and can include graphs and charts. Some of the other tools are

- PPTs, computer graphics, videos, movies
- Posters, paper cutouts, any other form visuals( remember visuals are the most effective tools for retaining information )
- Samples, exhibits
- Games, role plays
- Visually important tools in participatory process ( VIPP )
- Skits, dramas
- Exposure visits

Do remember that your tools must support the learning outcomes and they are designed to help a trainer to present his session. These have to align with the content. Therefore tools have to be innovative and not just copy of the content. In case of a program involving stakeholders at farm level one has to plan for tools in a village surrounding, especially when the participants are all women, may be form a self-help group. Framer generated video production is an innovative tool for dissemination of knowledge by the NGO Digital Green with great success. Therefore the tool will have to be prepared for the participants depending on their background etc.

**Performance of the participants**

How do we judge whether the participants have acquired and retained the new knowledge or understood the presentations. Most of our training program we never try to evaluate the performance, hence training becomes a ritual and number game to attain the target rather than real transfer of knowledge.

The easiest way to evaluate is to use a set of questions at the beginning and one at the end and analyze the results to see the progression. Most of the times it is positive with usual variation but at times there can be negative progression as we have seen a couple of times. This happens when some participants do not participate wholeheartedly.

**<example from the last course with NGO partners >**

**Course feedback**

It is equally important to know a honest feedback from the participants about the program through an appropriate questionnaire This should be a honest feedback and not just good words.

**< Discuss the feedback for this program >**

The feedback should be analyzed, shared with the participants or their organization so that any shortcomings can be addressed in any future program. What people liked and not liked, which topics were discussed well, which resource person was good or mediocre and needs improvement are important criteria for any course feedback. This will help to design and conduct a program better in future.

**Back on the job application**

What is this? This is a short session on how this program can be utilized by a participant when he goes back to his normal duties. This is an area seldom given thought and discussed with the participants <**More when the PPT is presented, >**. This should include a structured action plan and how the training can be used in his normal DUTIES, WHAT CAN BE DONE AND WHAT CANNOT BE DONE.

**Delivery of program or conducting a program**

Delivery of program is like a stage performance or a drama by a group of Artists. After a long planning and rehearsals the drama is performed on a stage in front of an eager audience. After all the planning exercise is over, manuals are prepared, tools are designed, questionnaires are ready comes the physical delivery of the program. Some of the essential components are

- Venue of the program with facilities available such as class room, fields for any experiential session
- Seating arrangement- should be a “U” shaped for better interaction with the participants. Never arrange a Theater style seating arrangements for obvious reasons.
- Projection facilities, computers, audio equipment if the hall is large
- Place for any poster presentations
- Refreshment arrangements
- Participants stay arrangements if the program is Off Campus
- Standby power connections

- Reprographic facilities
- Area for any Hands on Training
- White board , flip charts and markers

It is important for resource persons to be familiar with the venue and facilities available and rehears his presentation specially to keep to the time allotted to him. (How to be a good trainer – later)

The program will require Coordinators to coordinate the activities for a smooth running of a program. A small secretariat will be a good idea for support services during the full duration of the program. Plan for any experiential learning and exposure visit also.

**How to maintain quality of a program**

This is an area quite neglected. Poor quality of training material including tools, bad program delivery, and poor quality of trainers with poor communication abilities will contribute towards a very poor program indeed and the resources will be wasted. Therefore each component of a program design and delivery has to be of high standards which is easier said than done. The quality can be easily judged once the course feedback is analyzed from the participants.

**Who is a good "Trainer "**

**Qualities of A Great Trainer**

Most of us conduct Training Programs for the Developmental projects on a regular basis for our stakeholders at various level- from District level departmental staff to the grassroots level – farmers, user associations ,community organizations and so on. The enormity of the challenge of a good training program hinges on the quality of the training material, how well the program is designed and delivery mechanism so that the expected outcomes are achieved. Central to all these is the "Trainer "who actually delivers the program. One cannot be a superlative trainer overnight. It needs effort; understand the nuances of training and commitment. How you can be a Good Trainer". After all the success or failure of a program depends on how well the program was delivered.

**Current scenario**

Most of the programs that we deliver are treated like a seminar. The trainer takes a superior posture like a school teacher and treats the participants like a bunch of school children. But in all development projects the participants of training programs are adults- whether they are farmers or departmental staff. They come with some expectation, their varied experience, and their problems. Their age, qualification, experience varies widely because of their livelihood patterns, their economic status etc. Before conducting a program for a group of adult one must ask the following question. Therefore they must be treated as adults and use the Adult learning techniques which is called Andragogy.

- Who are the participants – their age, experience, livelihood
- Their educational profile
- What are the expected problems they may have
- What could be their expectation
- Is the program tailor-made to address their problem and meet their expectation
- Is the design of the program will meet the expected outcome and will have an impact

As a trainer one must know the answers as far as possible beforehand so that one can design the program suitably

**What are some of the top qualities every trainer should have?**

**A great trainer has all of the following things:**

1 ***A command of the material.*** A good trainer knows the material, lives it, breathes it, and can infuse their own experience into it. They may not know every facet, **but they know where to get answers if they don't.**
2. ***Preparation and practice.*** A good trainer makes delivering a class look easy and seamless. You don't want the learners to see "behind the curtain." Many instructor will look at his notes frequently or look at the slide and talk. He will be lagging on timing, and ran out of song before the routine was over.
3. ***Rhythm and energy***. There are ebbs and flows in energy in a class. A great trainer is attuned to his or her own energy level and that of the class. A good trainer knows when the more dry or factual content is coming up and adjusts delivery accordingly. A good trainer takes note of when learners are tuning out, antsy, restless or distracted
4. ***Readiness to allow and encourage participants*** *to learn from themselves and the class in order to create as many organic learning moments as possible*. In many professional learning classes, there is a wealth of knowledge in the classroom and cross-pollination can be an effective way to illustrate the material and provide new perspectives.
6. ***An excellent organization supporting them.*** There were people who will do their jobs well despite obstacles, but it won't be unusual to find yourself in a pilot with a trainer who read the slides and notes word for word.

**How do you make your lessons interesting?**
Try to "tell a story" through the materials, make the course relevant, interesting and fun. Additionally, to ensure that the delivery serves the materials well, create what you have found to be the most extensive facilitator guide.

**Characteristics of a trainer**

It is common experience that trainers, when they get together, often wonder what the characteristics of a trainer are. This is often a poser by those who aspire to be a trainer. Often, persons having the necessary attributes are not sure about the qualities that make a good trainer. It is in this context that it is necessary to identify some of the significant qualities that go to enhance the performance of a trainer. Some of these qualities are: -

**Empathy:** This is the ability to put oneself in the shoes of another. It is the faculty for recognizing the fears and uncertainties in the minds of trainees when learning additional techniques or skills. Empathy enables a trainer to point out personal difficulties encountered by him in similar learning situations, so as to put the learners at ease.

**Honesty:** This is the courage to recognize personal strengths and weaknesses and to be frank about these aspects to the personnel being trained, for their own benefit.

**Patience:** This is shown in the willingness to compliment slow progress and refrain from the anger when mistakes are made. It includes the techniques of repeating instructions, breaking down a task into small units and allowing time for learners to try out.

**Pace:** This is closely integrated with empathy and patience. This is an external speed governor, which acts more to slow down than to speed up. It is far better to move slowly and attain complete mastery, than to push for rapid and sloppy completion.

**Democracy:** This refers to the kind of atmosphere created when learning takes place. The trainer should be supportive and non-threatening in presentation. The tone of voice and facial expression should lead the learners to feel comfortable in raising questions, offering suggestions, reinterpreting instructions and generally to feel relaxed while they learn.

**Purpose:** This emphasizes the element of tenacity in achieving the training goals. A good trainer conscientiously moves a group of learners along to a pre-set destination. There may be stops and shifts, but the eye is always fixed on certain performance standards and levels.

**EXCELLENT COMMUNICATION SKILLS**

It may sound obvious, but trainers should have great communication skills. The best trainers can break down complex ideas and explain them clearly to trainees. They also need to be able to listen actively, but also be sensitive enough to pick up on non-verbal communication.

The training environment must also maintain open lines of communication, so trainees are comfortable enough to ask questions. Any extra training material must also be easy to follow and actually helpful to the trainee.

Nobody looks forward to 'yet another training session'. To get around this, trainers should use different methods to get trainees excited about taking the course. Whether it's changing the delivery format or the type of course material handed out, you should always aim to make your courses lively.

To keep training courses upbeat, great trainers always encourage participation. Asking questions during training will keep trainees engaged, and it also helps trainers assess how much of the material the participants are assimilating. Adults learn best when they can practice what they learn. To be considered effective, training sessions must include practice segments.

**POSSESSES INDUSTRY KNOWLEDGE**

Good trainers understand the concepts and nuances that prevail in the industry. They know what makes the workforce and customers tick, and they also have an eye on its trends. This knowledge is crucial as delegates can quickly spot a trainer who's only reading from a prepared slide.

Having adequate knowledge also helps with designing an effective training programme. It can help trainers choose which training medium to use, the type of activities to include, etc. An added bonus is that a well-read trainer can always find an angle to make even the most boring topic lively.

**PASSIONATE ABOUT LEARNING**

Trainers who are passionate about learning understand that it is an ever-evolving process. Recognizing the value of learning in their own lives, they spend time developing themselves as well. The passion they devote to honing their skills is reflected in the quality of the training they offer.

Their continuous learning exposes them to different methods of engaging trainees and learning styles, too. By keeping abreast of the latest insights in training, good trainers will remain in demand.

**HIGH LEVEL OF PROFESSIONALISM**

The best trainers understand that people learn at different speeds and in different ways. Regardless of how fast trainees pick up on the concepts taught, the trainer must always remain patient. They also create time to interact with each delegate to make sure they understand the material before moving on.

Excellent trainers are also open-minded and willing to listen to different points of view. They don't assume they know everything and will never talk down to their trainees.

Unfortunately, not every trainer is effective, and that is because not every trainer possesses these characteristics. It is not enough to simply talk to the trainees - a trainer must also be insightful, charismatic, passionate, and above all, have exceptional communication skills.

Without these characteristics, trainees won't be engaged and the training session will not be worthwhile. But a trainer who does have these characteristics will have the ability to convey clear messages, help people develop and potentially change someone's entire mind-set for the better.

**Characteristics of a Good Trainer VS Bad trainer**

| **A good trainer** | **A bad trainer** |
|---|---|
| • He will be energetic, enthusiastic and will try the Program make it interesting<br>• He will be confident, show empathy with the participants<br>• He will present innovative training material, will not read from the slide, pace his presentation and keep within time<br>• Will allow questions and discuss will try understand their problem and give answers | • He will be boring<br>Dull and will show no interest in the program<br>• He will be floundering, as he may not be thoroughly conversant with the subject<br>• Will be a monologue, no modulation of voice, no humor and avoid questions |

**Hints on preparing your material- most of us prepare slide for our presentation. Here are some Dos and Don'ts which will make your presentation lively, attract attention of the viewers.**

- Restrict the number of slides to minimum- remember the slides will have points for elaboration and discussion. Therefore you can't put too much material in your slides which will be boring and the audience will go to sleep.

- As a rule of thumb for a 40 minutes presentation you should not have more than 20 slides.
- Ideally each slide should not have more that 7-8 bullet points with fonts big enough so that the last bench can read it.
- Use minimal color combinations- ideally use contrast colors for background and your bullet points. The best are Black against white, Yellow against blue or vice- versa.
- Do not use pastel colors – they may be difficult to read
- Use graphics wherever possible to make the slides interesting
- If you are presenting a Table your columns should not be more than five and rows not more than five.
- **Do not read from the slides**- your material in the slide is to highlight important points
- Do not put chart /graph and table for the same data unless you want to show a trend
- Modulate your voice so that the verbal part of the presentation is interesting- idea is to keep the attention of the listeners to you.
- Keep eye contact with your audience- do not look at the ceiling and talk.
- Your slides should exactly follow your content that you have included in the Manual
- Divide your presentation in to subsections and allot time for each while planning for your presentation.
- Ask questions to keep audience glued to your talk.
- **If you do not have an answer to a question immediately never try to bluff, admit that you do not have an answer but will get back with the answer- this is very important to establish your credibility with your audience.**
- If you are in outdoor and your audience are the farmers of the project, prepare charts, graphs, videos, models and other VIPP material as you may have people who may not be literate.

## Session 8: Group Exercise- Designing a Training Program for DOA staff in Odisha

**This exercise is to design a Training program for DOA staff in your district in Odisha.**

**The group should be divided into district wise representation (2-3 persons)**

**Task:**

- Write a Curriculum for a two day program at  for your district
- Give a structure of a Manual
  - Session plan for two days
  - What will be the learning outcomes
  - What will be the content
  - What will be the tools
  - Plan any experiential learning session
  - Design a feedback questionnaire

**Notes:**

**ICRISAT-India (Headquarters)**
Patancheru, Telangana, India
icrisat@cgiar.org

**ICRISAT-India Liaison Office**
New Delhi, India

**ICRISAT-Mali (Regional hub WCA)**
Bamako, Mali
icrisat-w-mali@cgiar.org

**ICRISAT-Niger**
Niamey, Niger
icrisatsc@cgiar.org

**ICRISAT-Nigeria**
Kano, Nigeria
icrisat-kano@cgiar.org

**ICRISAT-Kenya (Regional hub ESA)**
Nairobi, Kenya
icrisat-nairobi@cgiar.org

**ICRISAT-Ethiopia**
Addis Ababa, Ethiopia
icrisat-addis@cgiar.org

**ICRISAT-Malawi**
Lilongwe, Malawi
icrisat-malawi@cgiar.org

**ICRISAT-Mozambique**
Maputo, Mozambique
icrisatmoz@panintra.com

**ICRISAT-Zimbabwe**
Bulawayo, Zimbabwe
icrisatzw@cgiar.org

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