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# Contents

# Chapter - 1
# Crop Residue Management Machinery

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# Chapter - 1

## Crop Residue Management Machinery

**Anurag Patel, Bhupendra Singh Parmar and Satish Kumar Singh**

**Abstract**

The major research and development efforts in the green revolution era were focused on enhancing the productivity of selected food grains and a few other crops. Under the changing scenario, the present agriculture system needs to shift from a production-oriented to a profit-oriented, sustainable resource conservation farming system. Crop residue are the major concern in rice-wheat cropping system along with cereals, cotton, chilli, pulses, and oilseed produces million tonnes of straw and burned in the field by the farmers. Conservation agriculture offers good promise to manage the residue in a productive and profitable manner in which residues can be used to improve soil health, increase crop productivity, reduce pollution, and improve agricultural sustainability.Conservation agricultural technologies help mitigate climate change by reducing the use of energy, emissions of greenhouse gases into the atmosphere and adding organic carbon to the soil.Various crop residue management machineries under conservation agriculture are discussed in this chapter, which help in conserving the environment and human health issues.

**Keyword:** Conservation agriculture, crop residue, straw management, farm machinery

### 1. Introduction

Conservation agriculture (CA) represents a fundamental change in the soil and cropping system management, which in turn leads to consequential changes in the required field operations and related mechanisation solutions. Management of crop residues in conservation agriculture is vital for the long-term sustainability of Indian agriculture. Burning of residues must be stopped and should be used positively for CA to improve soil health and reduce environmental pollution. Even in regions where crop residues are used for animal feed and other useful purposes, some amount of residue must be recycled into soil. Several technologies are available, but they require improvement for adoption by resource-poor, low-skilled farmers. For example, the Happy Seeder seems to be one of the potential technologies for managing residues.

Crop residues, regarded as non-economical parts of the farm's produce, are generated in large volumes. The Ministry of New and Renewable Energy (2009) estimated that about 500-550 Mt of crop residues (MNRE, 2017), of which nearly 91-93 Mt is lost due to residue burning. These residues are used as animal feed, compost, thatching for rural homes, and fuel for domestic and industrial use. The burning of one tonne of rice straw alone accounts for the loss of 5.5 kg of nitrogen, 2.3 kg of phosphorus, 25 kg of potassium and 1.2 kg of sulphur, besides the organic carbon. The problem is severe in irrigated agriculture, particularly in the mechanized rice-wheat system. The main reasons for crop residue burning in fields are a lack of labor, the high cost of removing the residues, and the use of combines in the rice-wheat cropping system. Primary crop types whose residues are typically burned include rice, wheat, cotton, maize, millet, sugarcane, jute, rapeseed-mustard and groundnut. Farmers in northwest India dispose of a large part of the rice straw in the field (in-situ) by burning it.

To manage the residues in a productive and profitable manner, CA offers good promise. With the adoption of conservation agriculture-based technologies, these residues can be used to improve soil health, increase crop productivity, reduce pollution, and improve agricultural sustainability and resilience conserving technologies (RCTs) involving no or minimum tillage, direct seeding, bed planting, and crop diversification with innovations in residue management are the possible alternatives to conventional energy and input-intensive agriculture.

In India, 110 million tonnes (Mt) of wheat, 122 Mt of rice, 71 Mt of maize, 26 Mt of millets, 141 Mt of sugarcane, 8 Mt of fibre crops (jute, mesta, cotton), 28 Mt of pulses, and 30 Mt of oil seeds were produced in the year 2017 (Devi *et al.* 2017). It is natural that a large volume of crop residues are produced both on and off farm and the country produces an estimated 500-550 Mt of crop residues per year.

Traditionally, crop residues have numerous competing uses, such as animal feed, fodder, fuel, roof thatching, packaging, and composting. Cereal residues are mainly used as cattle feed. In states like West Bengal, rice straw and husk are used as domestic fuel or in boilers for parboiling rice. The uses for various residues are different in different states. Farmers use residue either themselves or sell it to other landless households or intermediaries, who in turn sell the residues to industries. The remaining residues are left unused or burned in the field. In states like Punjab and Haryana, where rice residues are not used as cattle feed, large amounts of rice straw are burned in fields. Sugarcane tops in most areas are either used for feeding dairy animals or burned in fields for ratoon crops. Residues of groundnut are burned as fuel in brick kilns and lime kilns**.** Cotton, chilli, pulses, and oilseed residues are mainly used as fuel for household needs. Coconut shells, stalks of rapeseed and mustard, pigeon pea, jute, mesta, and sunflower are used as domestic fuel.

It is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin is applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological process.

Conservation agricultural technologies help mitigate climate change by reducing the use of energy, emissions of greenhouse gases into the atmosphere and adding organic carbon to the soil. New technologies, on one hand, are encouraging farmers to take up new ways of managing their resources more productively, and crop residues in-situ are maintained, on the other hand, throwing new challenges to the scientific community to solve emerging problems.

There are different conservation machineries used, such as straw collectors, pick-up-and-press stackers, balers, tractor-operated straw balers, and choppers. The residue management on the physical properties of soil structure due to a reduction in soil disturbance by crop residues, as the amount of residue on the soil surface increases, it modifies soil structure, microspores and aggregate stability, soil temperature, and soil moisture, resulting in increased soil probity and hydraulic conductivity. The effect of residue management on soil chemical properties It increases organic carbon and soil pH significantly.

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residue management on soil chemical properties It increases organic carbon and soil pH significantly.

Developments of appropriate farm machinery to facilitate residue application and successful planting of a crop in the rotation under a layer of residues on the soil surface. A combine harvester collects and removes residues from the field. Large volume and transport are a major bottleneck in using the residues where they are required. Machinery for volume reduction would facilitate the process of residue use for CA. In the context of conservation agriculture and to prevent the burning of biomass, the chapter aims:

- Calculate the amount of crop residues generated in the country each year, as well as the extent of on-farm burning.
- Assess the energy and environmental impacts of on-farm burning of crop residues.
- Determine competing uses for crop residues and their potential for adoption.
- Assess the potential of using crop residues for conservation agriculture and its constraints. Burning of rice residues, a prevalent practice in northwest India is involved therein.
- Develop a model plan for managing crop residues at the local and regional scales.
- Research and policy issues for safe and sustainable management of crop residues for productive, profitable and sustainable agriculture.

## 2. Crop residues in India

In India, 100.0 million tonnes (Mt) of wheat, 113.0 Mt of rice, 28.0 Mt of maize, 25.0 Mt of pulses, 355.0 Mt of sugarcane, 35.5 Mt of cotton crops, and 36.0 Mt of oilseeds were produced in the year 2018-19. It is only natural that a large amount of crop residue is produced, both on and off the farm. It is estimated that approximately 620 Mt of crop residues are produced per year in the country (Table 1).

**Table 1:** Crop-wise residue generation in 10 states of India

| S. No. | States | Crop residue generated (Mt/yr) | | | |
|---|---|---|---|---|---|
| | | **Cereal crops** | **Fiber crops** | **Oilseed crops** | **Sugarcane** |
| 1. | Andhra Pradesh | 33.07 | 16.07 | 2.50 | 5.80 |
| 2. | Arunachal Pradesh | 0.56 | 0.00 | 0.06 | 0.01 |
| 3. | Assam | 8.15 | 2.01 | 0.29 | 0.41 |

| | | | | | |
|---|---|---|---|---|---|
| 4. | Bihar | 19.87 | 3.27 | 0.20 | 1.87 |
| 5. | Chhattisgarh | 8.87 | 0.01 | 0.11 | 0.01 |
| 6. | Goa | 0.24 | 0.00 | 0.01 | 0.01 |
| 7. | Gujarat | 8.18 | 28.62 | 5.06 | 5.85 |
| 8. | Haryana | 24.73 | 7.58 | 2.15 | 1.93 |
| 9. | Himachal Pradesh | 1.95 | 0.00 | 0.01 | 0.02 |
| 10. | Jammu and Kashmir | 2.76 | 0.00 | 0.11 | 0.00 |
| | India | 361.85 | 122.37 | 28.72 | 107.50 |

## 3. Crop residue management machinery

The straw yield is usually calculated from grain production data based on the grain: straw ratio, which is averaged at 1:1.5 for wheat and 1:1.3 for rice. For the current level of rice and wheat grain production of about 165 million tonnes, nearly 225 million tonnes of straw are produced every year, which shows a huge amount of straw available for disposal. It is to be emphasized that all of the straw cannot be recycled as it would pose problems in incorporating the huge quantity into every season on one hand, while on the other hand, it would make the straw unavailable to other sectors of the economy. Straw can be used in a variety of ways, including cattle feed, paper, pulp, and board manufacturing industries, chemicals, power generation, mushroom cultivation, and other horticultural uses. This indicates that comprehensive planning is needed so that each sector can get its share of straw on a long-term basis. In India, field baling has been suggested as an option for collecting straw after combining in order to decrease the adverse effects of open field burning on the environment and soil health. The importance of maintaining trash cover has long been recognized. However, this often interferes with the placement of seed in firm and moist soil. Therefore, farmers frequently burn the fields, which is not an eco-friendly practice. After partial burning for removal of loose straw, seed could be placed in the soil in an anchored stubble condition. Uniform spreading of straw during harvesting itself by mounting a device at the rear of the combine and then using drills under loose straw conditions or chopping loose as well as anchored stubbles with a rotary shredder followed by residue drills are some of the viable options. The machinery required for conditions ranging from straw management to conservation agriculture is discussed further below.


**Fig 1:** Crop residue management

## 3.1 Combine harvester with SMS

The most practical way to manage crop residue is with the combine harvester. The crop residue should be spread uniformly over the entire width of the header cut area. You need to use combine harvester spreading attachments to achieve uniform residue distribution. These systems use varying amounts of horsepower to operate, so they affect costs as well as performance and capacity. A number of adjustments can be made to most new chopper/spreaders so the spread will match the header width under the crop conditions at the time. Using a wide cutter header or a double swath makes uniform spreading more difficult, and after-market or modified straw and chaff spreading attachments may be required. Earlier, the combines were used in Punjab, Haryana, and Western U.P., but at present, they are being used extensively in the whole of U.P., Uttaranchal, Bihar, Rajasthan, M.P., and southern states for the harvesting of rice and wheat. The major reasons for the popularity of combine harvesters in different states have been consistent labour shortages, high wage rates during harvesting season, and uncertainty of weather. The combines have become a source of income for many of the agro-industries and private entrepreneurs who use them on a hire-purchase basis at a rate varying from Rs. 1200–1500/ha for wheat to Rs. 1500-2000/ha for rice in different regions. The combining intensity, defined as the ratio of the total area of combine harvestable crops to the area actually harvested by combines expressed on a percentage basis, is very high in the states like Punjab, at 72.35 percent for wheat and 81.80 percent for paddy.

## 3.2 Straw combine

It is a tractor-drawn, PTO-operated straw reaper with a trailer. The crop stubble cut height is 70-80 mm. The crop residue after cutting reaches the thresher where it is threshed. A trailer is filled with straw every half an hour. The straw-loaded trolley is unloaded with the help of a tractor hydraulic in the field, or straw can be unloaded onto another trolley and transported to the farm shed. 70-80% of the crop residues are cut and threshed by this machine. The capacity of the machine is 730 kg/h with a tractor having 35 hp or above. M/s Ratan Industries, Moga, Punjab, is commercially manufacturing the machine.

## 3.3 Reaper and Binder

Harvesting of crops is one of the most labor-intensive operations in agriculture. However, the most common method of crop harvesting in India is the manual method, which is time- and labor-intensive and requires 18 to 25 man–days per ha. It is estimated that harvesting and threshing consume about one third of the total labor requirements of a complete crop production system. In multiple-cropping systems with short-duration high-yielding varieties, less time is available between harvesting of one crop and sowing of the subsequent. Rapid urbanization and the migration of agricultural labor resulted in late harvesting, causing heavy grain losses. Harvesting wheat crops in eastern Uttar Pradesh is mostly done by hand with a sickle, which is time-consuming and labor-intensive due to a labor shortage. The feedback of machine operation was collected by some farmers at the time of harvesting and the performance of the reaper binder at the farm was satisfactory.

## 3.4 Baler

A baler is a machine used to compress hay or straw into bales for easy transport and storage. A bale is the simplest minimum package for marketing. Balers are divided into stationary balers and field balers. They are further classified into rectangular balers and round balers according to the bale shape they produce. According to the density of the bale, they could be high (200-350 kg/$m^3$), medium (100-200 kg/$m^3$) or low density (100 kg/$m^3$) balers. The balers, however, recover only about 25-30% of the potential straw yield after combining, depending upon the height of the plant cut by combines. The baling cost is Rs. 800 per ha. The total cost of operation, including baling, collection, transportation up to a 5 km distance, and stacking, is Rs. 1300/ha or Rs. 650 per tonne of straw.

### 3.5 Shrub master

It is a tractor PTO-operated piece of equipment. It consists of cutting blades (swinging flails) joined to the bar, a gear box for transmission of power at the right angle, universal joints with telescopic shaft to connect the tractor PTO and gearbox, adjustable side skids for controlling cutting height of shrubs or grass, a safety guard and hitching frame. The bar with cutting blades at the ends is mounted on the gearbox shaft. Thus, the vertical shaft of the gearbox provides rotary motion to the bar. Due to centrifugal force, the cutting blades mounted on the bar swing open to the cutting position in the horizontal plane. The cutting takes place purely through impact, and the flails need not be sharp-edged. The blades are made of medium-carbon steel or alloy steel and are hardened. It is used for the clearance of shrubs and monsoon growth in forests, fields, fairways, verges, helipads and general clearance of grass in fields with tractors having 25 hp or above.

### 3.6 Mowers and Shredders

Mowers and shredders are available in two basic types: rotary or flail. Power requirements for both are relatively high, but they produce a more uniform residue cover. A balance is needed between standing stubble and chopped residue on the surface. Too much chopping to create short or no stubble leaves a mat of residue which may not flow around the ground opener. Besides mowers, shredders are another type of machine used for mulch management. They consist of knives rotating vertically at high speed around a horizontal axle. Usually, they reduce the biomass to small pieces. The advantages include a fairly even spread of the mulch, the control of pests and diseases, and the fact that the shredded pieces do not interfere with the planting operation. However, the biggest disadvantage of shredders is that the chopped residues decompose much more quickly, which means they would not last as long on the soil surface as non-chewed residues. Another serious disadvantage is the high energy consumption. For this reason, shredders should only be considered in special cases for residue and cover crop management. Rotary slashers suffer from the same disadvantage.

### 3.7 Rotavator

The Rotavator is suitable for preparing seedbeds in a single pass both in dry and wetland conditions. It is also suitable for incorporating straw and green manure into the field. It consists of a steel frame, a rotary shaft on which blades are mounted, a power transmission system, and a gearbox. The blades are of the L-type and are made from medium-carbon steel or alloy steel, hardened and tempered to a suitable hardness. The PTO of the tractor drives the rotovator. The rotary motion of the PTO is transmitted to the shaft carrying the blades through the gearbox and transmission system. A good seedbed and pulverization of the soil are achieved in a single pass of the rotavator. Different sizes of rotavators are commercially available. The size varies from 1.2 to 2.2 m. The field capacity of equipment is 0.36-0.44 ha/h. The residue left with different land preparation activities is shown in Table 6.3. The residue left after the operation of plough and chisel is a minimum of 10% and a maximum of 50-70 with one cultivator operation.

### 3.8 Harrows

Harrowing may be needed to achieve uniform residue distribution, especially for heavy crop residues. Harrows can spread straw but not chaff. It is better to harrow in the fall before the straw has settled. Increasing harrowing speed increases the spreading action but also increases the risk of knocking down standing stubble. Tine harrows will often satisfactorily spread straw. They depend on dry straw conditions to do a uniform job. Adjustments to give a smooth flow of straw are not easy with older models. Heavy harrows are better at spreading straw after harvest or breaking up surface straw in the spring. Many models can be adjusted from the tractor to match field conditions at that moment. Some have down pressure features to increase the action and control the bounce of the harrow frame. Heavy harrows can also satisfy the incorporation requirements of some herbicides. Oscillating harrows, although no longer common, often provide the best action for spreading evenly settled straw, but warm, dry conditions are important for efficient equipment operation. The aggressive action of these harrows makes shallow incorporation of granular herbicides possible. Rotary harrows are ideal for the shallow incorporation of herbicides into the soil. These harrows rarely plug up, and they leave the residue on the soil surface. However, they do not spread straw. Take care not to harrow too much because the loose straw left on the surface may be blown away by strong winds.


### 3.9 Chisel

It is a tool for minimum or reduced tillage. It has a rigid, curved or straight shank with relatively narrow shovel points. The standards are arranged on heavy frames in two or three staggered rows to permit trash to pass between them without choking. The depth of ploughing may be as shallow as desired or as deep as 450 mm or more. As the soil is broken by stirring, it is not inverted and pulverized to the extent that MB or disc ploughs crush the soil. Hence, the chisel plough is used for stubble mulch or sub-surface tillage practice. It can be used to loosen hard, dry soil before the regular plough is used. It is also used for breaking up hard layers of soil just below the regular ploughing depth. Working equipment requires adequate soil moisture to function properly; otherwise, clogging with residue, poor weed control and lifting of stones/clods on the top surface occur.


### 3.10 M.B. Plough

The tractor-operated mould board plough with two bottoms was considered. Three main forces are applied, like draught force, side draft, and vertical force, which are considered in the plough bottom. Because the mould board plough is a primary tillage implement, the plough bottom experiences high magnitude reaction forces from the soil during tillage, and these reaction forces directly affect the plough bottom's construction elements. If the construction elements cannot compensate for reaction forces, they become useless due to plastic deformation or fracture. Therefore, the structure must have been designed as stable and durable enough to avoid undesirable failure cases. Proper selection and use of agricultural machines are important factors to achieve this end. Selection of appropriate tractor power and implements is more complex and tedious due to the computational work involved in solving the equations for draught and working width and depth of ploughing of mould board plough bottom.

### 3.11 Sub-soiler

Sub-soiler ploughs are heavier than chisel ploughs since they are used to penetrate soil depths of 500 to 900 mm. Tractors of 60–85 hp are required to pull a single standard sub-soiler through hard soil at a depth of 900 mm. One standard is generally used for the deeper depths, but two or more can be used for sallower operations. Sub-soilers are commercially available in both trailing and mounted units. For conservation agriculture, sub-soilers should work under crop residues (have cutting disks), not lift clods to the soil surface, requiring subsequent tillage (shanks bent to the side) and be only considered an exceptional repair tool. It can be used in dry soil only and water infiltration will not improve much when used improperly.


### 3.12 Happy turbo seeder

Happy Seeder is one of the unique techniques that are used for sowing wheat without any burning of rice residue. This technology is eco-friendly for the environment for the health of the soil as well as saving water. Sowing wheat on time requires the burning of rice residue, which decreases the soil fertility and is harmful to human beings, animals and the environment. The burning of rice residue produces gases that create very harmful situations for our environment. Therefore, the Dasmesh Turbo Happy Seeder is the most successful implement for sowing wheat in rice residue without burning rice residue instead of without any burning.

- Possibility of sowing wheat crop immediately after rice harvesting, i.e. a choice for long-duration wheat and rice varieties.

- It is possible to sow wheat in residual moisture, thereby saving one irrigation.
- Timely sowing of wheat even after long-term basmati rice varieties.
- Crop residue as much helps with moisture and temperature conservation.
- Improved soil health.
- Environmentally friendly technology to check air pollution.

### 3.13 Zero till drill

Our highly efficient Zero till Seed and Fertilizer Drill is extensively used for sowing a wide variety of crops like maize, wheat, peas, mustard, etc. The Zero till Seed and Cumulative Fertilizer Drill provided by DASMESH is in huge demand in the market for durability, high speed, and performance. Our low-maintenance seed drilling machine is easy to operate and handle. We are counted among the prominent agriculture zero-till seed and fertilizer drill manufacturers based in India.

- Specially designed and made of high-quality material.
- Works smoothly & efficiently.
- Frame made of heavy-duty material.
- Export quality heavy duty structure.
- Nuts & bolts made of high tensile steel.
- Every part made with computerized CNC machine.

### 3.14 Slit till drill

Under clean and standing stubble field conditions, the machine was able to undertake sowing operations without any prior field preparation. The machine required 30-40 percent less draught to operate than a no-till drill with inverted "T" style furrow openers, according to reports. Due to the shorter growing season, timeliness of sowing, freeing up crop residue for use as mulch, and the need to avoid late season dryness, Shumba *et al*. (1989 and 1992) determined that reduced or zero tillage appeared to be more promising in Zimbabwe. Moldboard plough tillage was replaced by shallow tine tillage, which used only 14% of the draught force of the former and resulted in less soil disturbance. The zero-till-slit seed drill was compared against combined tillage and seeding equipment, zero-till seed drill, roto-till seed drill, strip-till seed drill, and enhanced conventional seed drill in the field. The field experiment was carried out using a split-split-split plot design and a statistically designed slit drill. The rotary slit cutters devised and used in the produced zero-till-slit seed drill performed admirably in the field, opening narrow slits on untilled plots with 50% standing stubble and loose straw and allowing seeds to be put precisely in the straw fields. In comparison to the combined tillage and seeding equipment used in the study, the zero-till-slit seed drill had higher field capacity, higher field efficiency, lower fuel consumption, lower percentage of wheel slide, and lower cone index. In comparison to the combined tillage and seeding equipment examined in the study, the use of a zero-till-slit seed drill resulted in higher plant emergence and a higher plant population at higher rice yields.

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# Chapter - 2
# Resource Recycling in Integrated Farming System


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# Chapter - 2

## Resource Recycling in Integrated Farming System

**E. Anusha, P. Neeshma, M. Chandana and P. Yavanika**

### Abstract

Integrated farming systems approach is not only a reliable way of obtaining fairly high productivity with substantial fertilizer economy but also a concept of ecological soundness leading to sustainable agriculture and also deriving maximum compatibility and replenishment of organic matter by way of proper recycling of organic residues/wastes obtained through integration of enterprises like fishery, poultry, goat, milch animal, mushroom and sericulture activities. The recycling process could reduce the cost of production per unit of grain, meat, milk, egg, edible mushroom, biogas etc., thereby widen the gap between the production cost and net return.

**Keywords:** Productivity, resources, recycling, sustainable agriculture

### Introduction

Agriculture has always been considered as the back-bone of our country. In India 70% of rural population is engaged in agriculture and 80% of population live, directly or indirectly on income delivered from agriculture. There are 115 million operational holdings in the country and about 80% are marginal and small farmers. To fulfill the basic needs of house hold including food (cereal, pulses, oilseeds, milk, fruit, honey, meat, etc.), feed, fodder, fiber, etc. warrant an attention about integrated farming system. Integrated farming system approach is not only a reliable way of obtaining fairly high productivity with substantial fertilizer economy but also a concept of ecological soundness leading to sustainable agriculture and also deriving maximum compatibility and replenishment of organic matter by way of proper recycling of organic residues/wastes obtained through integration of enterprises like fishery, poultry, goat, milch animal, mushroom and sericulture activities. The recycling process could reduce the cost of production per unit of grain, meat, milk, egg, edible mushroom, biogas etc. thereby widen the gap between the production cost and net return. An effort has been made for a holistic integration of different farming enterprises such as linking poultry, pigeon and goat rearing with cropping with the objectives of increasing income and effective recycling of farm wastes and by-products to sustain the soil productivity and fertility. The present investigation on resource recycling from different IFS models was envisaged to identify a suitable combination of components for maximum returns and employment generation.

**Integrated farming system**

At present, the farmers concentrate mainly on crop production which is subjected to a high degree of uncertainty in income and employment to the farmers. In this contest, it is imperative to evolve suitable strategy for augmenting the income of a farm. Integration of various agricultural enterprises *viz*., cropping, animal husbandry, fishery, forestry etc. have great potentialities in the agricultural economy. These enterprises not only supplement the income of the farmers but also help in increasing the family labour employment.

1) The integrated farming system approach introduces a change in the farming techniques for maximum production in the cropping pattern and takes care of optimal utilization of resources.
2) The farm wastes are better recycled for productive purposes in the integrated system.
3) A judicious mix of agricultural enterprises like dairy, poultry, piggery, fishery, sericulture etc. suited to the given agro-climatic conditions and socio-economic status of the farmers would bring prosperity in the farming.

**Primary goals of IFS**

- Maximization of yield of all component enterprises to provide steady and stable income.
- Rejuvenation of systems productivity and achieve agro-ecological equilibrium.
- Avoid build-up of insect pests, diseases and weed population through natural cropping system and keep them at low level of intensity.
- Reducing use of chemicals.

**Objectives of integrated forming**

- Should be area specific; formulate models involving main and allied enterprises for different farming situations.

- It should ensure optimal utilization and conservation of available resources with efficient recycling within each system included.
- It should raise the net return of the farm household by complementing main activity with allied enterprises.
- It should address the nutritional insecurity of resource poor farmer’s vulnerability and poverty of landless laborers.

**Integrated farming system models**

- Agricultural + livestock.
- Agricultural + livestock + poultry.
- Horticulture + fish culture + poultry.
- Pig cum fish culture.
- Agricultural + silvipasture.
- Sericulture + fish culture.
- Fish culture + sericulture.
- Agricultural (rice) + fish + mushroom cultivation.
- Agricultural + duckery + poultry.

**Recycling**

- Process to change waste into new products.
- Prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage.
- Reduce air pollution from incineration and water pollution from land filling.
- Lower greenhouse gas emissions.
- Key component of modern waste reduction and is the third component of the "Reduce, Reuse, Recycle".

**Why we go for recycling through waste??**

- According to a conservative estimate, around 600 to 700 Mt of agricultural wastes available in India every year, but most of it is not used properly. We must convert this waste into wealth by mobilizing all biomass in bio energy and supply nutrients to the soil.

**Recyclable resources**

- Recycling of organic wastes such as crop residues, dung and urine from domesticated animals and wastage from slaughter house, human excreta and sewage, bio mass of weeds, organic wastes from fruit and vegetables production and household wastes, sugarcane trash, oilcakes, press mud and fly ash from thermal power plants is the fundamental in the sustainability of farming system.

- Material not suitable for direct application can be applied after composting or vermin composting.
- The ultimate goal of sustainable agriculture is to develop farming systems that are productive and profitable, conserve the natural resources base, protect the environment and enhance health and safety and to do so over the long term.

**Effective recycling of resources**

- The effective recycling of farm resources is possible by adoption of farming system research.
- Crop by-product is utilized as fodder for animals and animal by-product i.e. milk and dung may be utilized for increasing income and soil fertility, respectively**.**

**Agricultural waste**

Agricultural waste is composed of organic wastes (animal excreta in the form of slurries and farmyard manures, spent mushroom compost, soiled water and silage effluent).

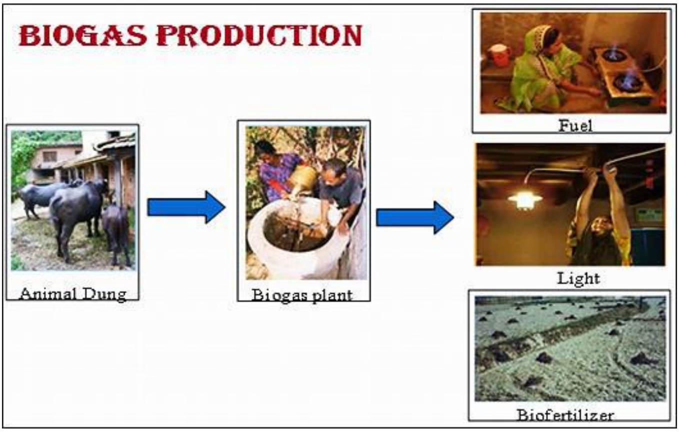
**Include**

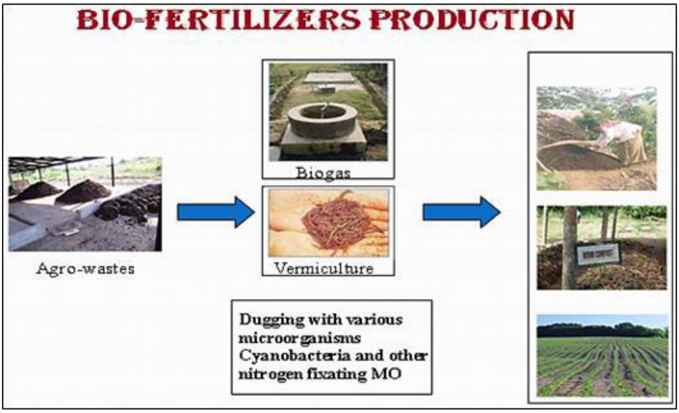
- **Field Wastes:** Weeds and straws.
- **Animal Wastes:** Animal dung and dead bodies.
- **Agro-Industrial Wastes:** Sugar cane: Molasses.

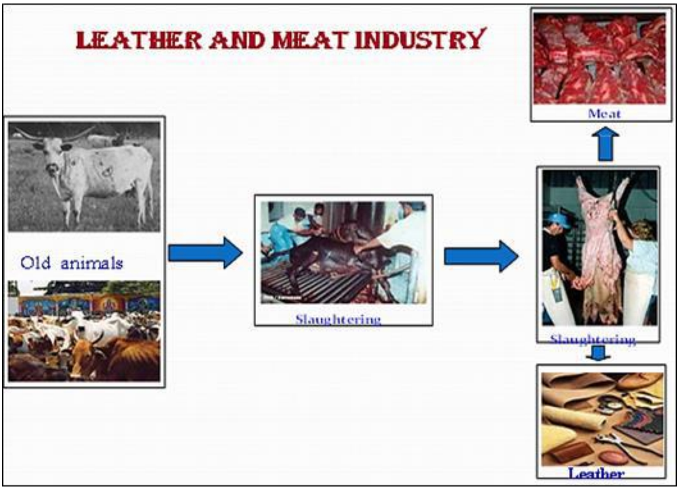
**Management of recycling agro-wastes**

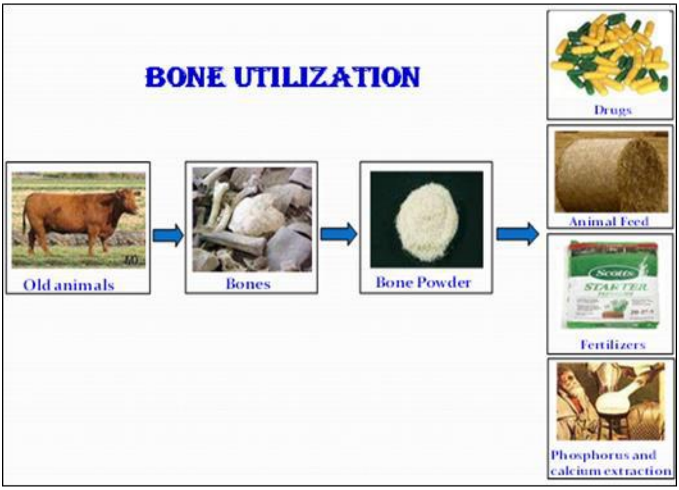
- If wastes are not properly handled they can pollute surface and groundwater and contribute to air pollution.
- The proper management of waste from agricultural operations can contribute in a significant way to farm operations.
- Waste management helps to maintain a healthy environment for farm animals and can reduce the need for commercial fertilizers while providing other nutrients needed for crop production.
- The waste which is reduce, recycle and make it usable for different purpose is a waste management.

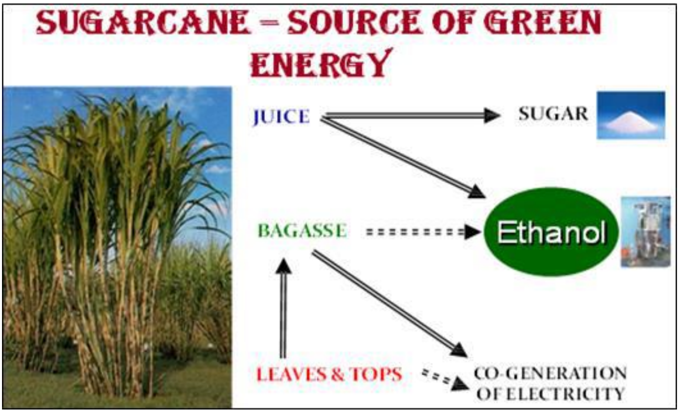

Biogas
Pulpand Paper
Bio-fertilizer
Phosphorus andcalcium
Agro-Wastes
Leather Industries
Fuel
Meat
Alcohol production

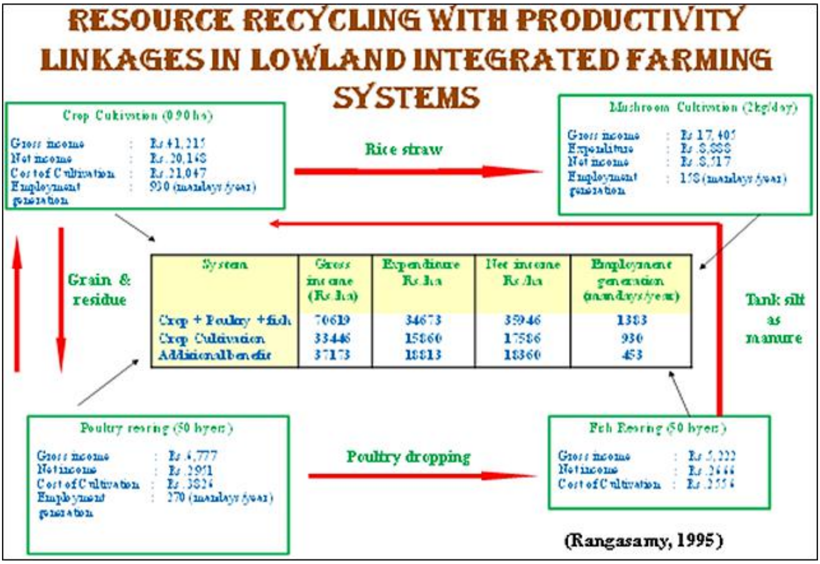

BIOGAS PRODUCTION
Animal Dung
Biogas plant
Fuel
Light
Biofertilizer

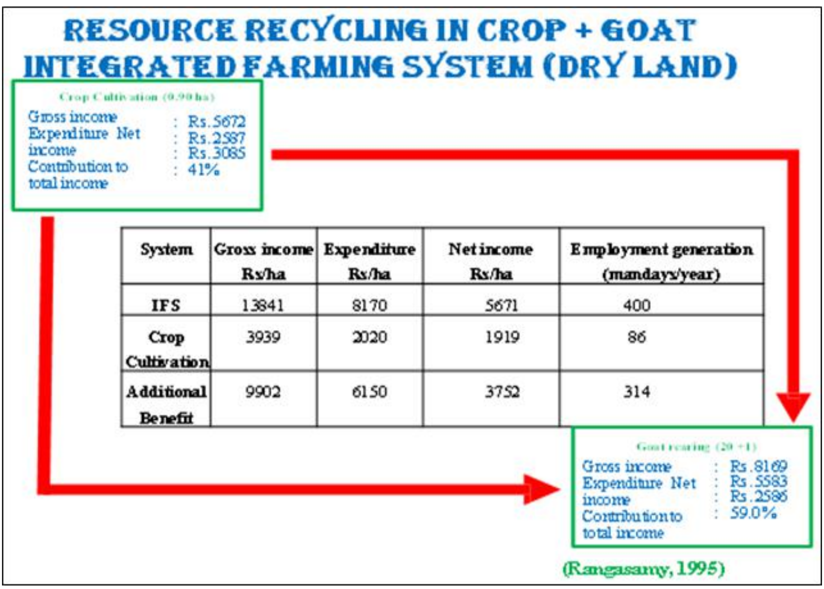

BIO-FERTILIZERS PRODUCTION
Agro-wastes
Biogas
Vermiculture
Dugging with various microorganisms Cyanobacteria and other nitrogen fixating MO


LEATHER AND MEAT INDUSTRY
Old animals
Slaughtering
Slaughtering
Meat
Leather


BONE UTILIZATION
Old animals
Bones
Bone Powder
Drugs
Animal Feed
Fertilizers
Phosphorus and calcium extraction


SUGARCANE – SOURCE OF GREEN ENERGY
JUICE
SUGAR
BAGASSE
Ethanol
LEAVES & TOPS
CO-GENERATION OF ELECTRICITY




### Recycling of animal wastes

- Animal wastes refer mainly to dung and urine along with bedding and mixed soil.
- These wastes available in dairies, slaughter houses and rural area.
- Unfortunately, nearly 50% of the cattle dung production in India today is utilized as fuel and is thus lost to agriculture.

- Amount and quality of excreta of animal depends upon age and weight of the animal.
- Total quantity of fodder and concentrates fed daily to the animals.

**Annual production of animal wastes and their composition**

- Animal wastes produce in India around 2046.8 Mt which can potential supply 17.77 Mt plant nutrients.
- Poultry manures are produced 8.0 Mt which is sufficient to fertilize about 3.56 Mha of land annually.

Integration of poultry + fish + mushroom + cropping applied with recycled poultry manure sustained the productivity of soil through addition of bio-resource residue with better NPK nutrient supply potential.

**Table 3:** Nutrient value of recycled poultry manure

| Particulars | Content (%) | | | Nutrient added (kg) | | |
|---|---|---|---|---|---|---|
| | N | P | K | N | P | K |
| Raw poultry manure. | 4.81 | 3.06 | 1.44 | 33.7 | 21.4 | 10.1 |
| Settled silt of the pond in which poultry dropping is used as source of fish feed. | 3.52 | 1.38 | 1.06 | 158.4 | 62.1 | 47.7 |

Rangasamy (1996).

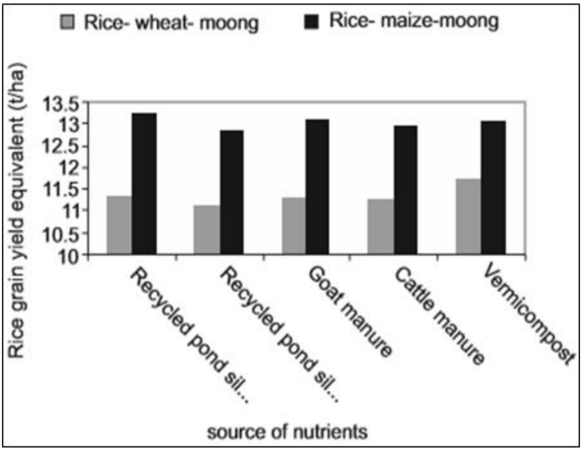



**Fig 1:** Productivity (RGEY) of different cropping sequences (mean yield of 2007-10)

Among different cropping sequences, under IFS compared, rice– maize mungbean recorded higher average mean yields of 13.25, 12.86, 13.11, 12.94 and 13.07 tonnes when applied with recycled fish pond silt + poultry manure, duck manure, goat manure, cattle manure and vermicompost, respectively than rice–wheat–mungbean cropping sequence However, rice–

maize–mungbean sequence registered higher average productivity of 13.25 tonnes with recycled pond silt + poultry manure (50 + 50%), followed by vermicompost in combination with 50% inorganic fertilizers. An average of 35.2 tonnes of grasses and legume mixture (maize–napier– berseem) was also obtained from 0.1 ha/year and was utilized as feed for animals.

**Sanjeev Kumar *et al.* (2012)**

**Table 4:** Productivity (RGEY) kg/ha and economics of different farming systems (mean value of three years)

| Farming system | RGEY (tonnes/ha) | Production cost (t/ha) | Gross return (Z/ha) | Net return (Vita) | Net return/day (t) | Sustainability index (%) |
|---|---|---|---|---|---|---|
| Cropping alone | 9.23 | 48 000 | 110 76m0 | 62 760 | 172 | 19.3 |
| Crop + fish + poultry | 18.61 | 83 945 | 223 405 | 139 460 | 382 | 67.4 |
| Crop + fish + duck | 15.36 | 70 219 | 184 520 | 114 301 | 313 | 51.5 |
| Crop + fish + goat | 19.63 | 83 925 | 235 404 | 151 479 | 415 | 75.1 |
| Crop + fish + duck + goat | 21.20 | 94 915 | 254 400 | 159 485 | 437 | 80.0 |
| Crop + fish + cattle | 21.18 | 125 625 | 254 240 | 128 615 | 352 | 60.6 |
| Crop + fish + mushroom | 16.56 | 70 799 | 198 671 | 127 872 | 350 | 60.2 |
| Mean | 17.40 | 82 490 | 208 791 | 126 301 | 346 | 59.2 |
| SD a- | 4.22 | 24 138 | 50 632 | 31 902 | 87 | |
| CV (%) | 24.2 | 29.2 | 24.2 | 25.3 | 25.1 | |

Results on different combinations for three years revealed that integration of crop + fish + duck + goat resulted in highest system productivity in terms of rice-grain equivalent yield. Crop + fish + duck + goat and crop + fish + cattle model recorded 130% more productivity over cropping alone. Similarly crop + fish + goat model gave 113% higher productivity than growing crops alone. Besides inorganic fertilizer application of recycled pond silt, poultry manure, duck manure, goat manure and cowdung as FYM, composted residues (cereal residues) and vermicompost under different IFS module provide congenial situation to increase the yield.

Sanjeev Kumar *et al.* (2012)

**Table 5:** Total organic residues/ manures (kg $ha^{-1}$) through various farming systems

| Treatments | Residue addition (kg/ha) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Crops | Goat | Poultry birds | Cow | Rabbit | Fish pond silt | Total |
| $F_1$ | 2475 | - | - | - | - | - | 2475 |
| $F_2$ | 3850 | - | - | - | - | - | 3850 |
| $F_3$ | 5060 | 2470 | - | - | - | - | 7530 |
| $F_4$ | 5720 | 2480 | 270 | - | - | - | 8470 |
| $F_5$ | 5896 | 2510 | - | 11208 | - | - | 19614 |
| $F_6$ | 3925 | 2660 | - | - | 890 | - | 7475 |
| $F_7$ | 4567 | 2680 | 299 | 12088 | - | 980 | 20623 |

Vinod Kumar *et al*. (2017)

The total organic residue added by the crops + goat + poultry birds + HF cow + fishery farming system (F7) was higher in the second year (20,623 kg ha-1) than the first year (19,122 kg $ha^{-1}$) and it was followed by crops + goat + dairy farming system (F5) with a residue addition of 18,368 and 19,614 kg $ha^{-1}$ for the first and second year, respectively.

**Table 6:** Productivity (RGEY) of different cropping systems

| Cropping sequence | Recycled poultry manure | Recycled Pigeon manure | Recycled Goat manure | Vermicompost |
|---|---|---|---|---|
| Sugarcane (planted)-sugarcane (ratoon)-Banana 0.25 ha | 40120 | 37788 | 38304 | 37376 |
| Banana-Turmeric-Rice-Banana-0.25 ha | 39993 | 39187 | 39669 | 39652 |
| Maize-Rice-Sesame-Sunhemp 0.25 ha | 17109 | 16268 | 16331 | 16633 |

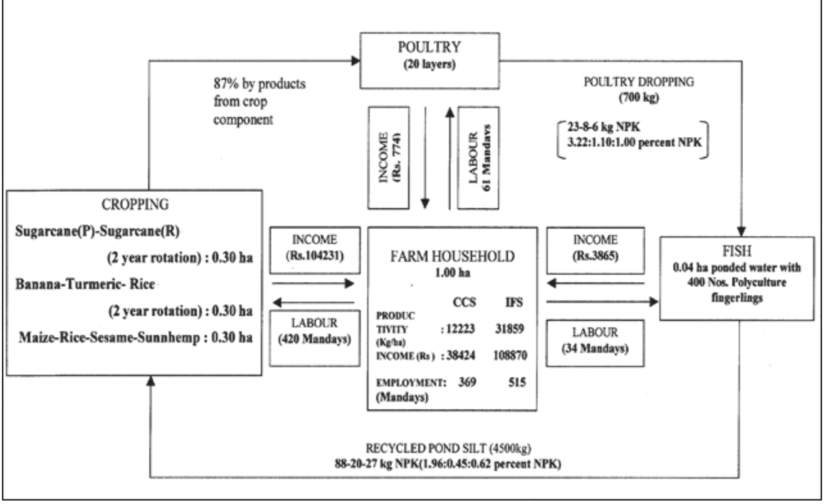
Jayanthi *et al.* (2003)

**Table 7:** Productivity (rice grain equivalent yield) of components

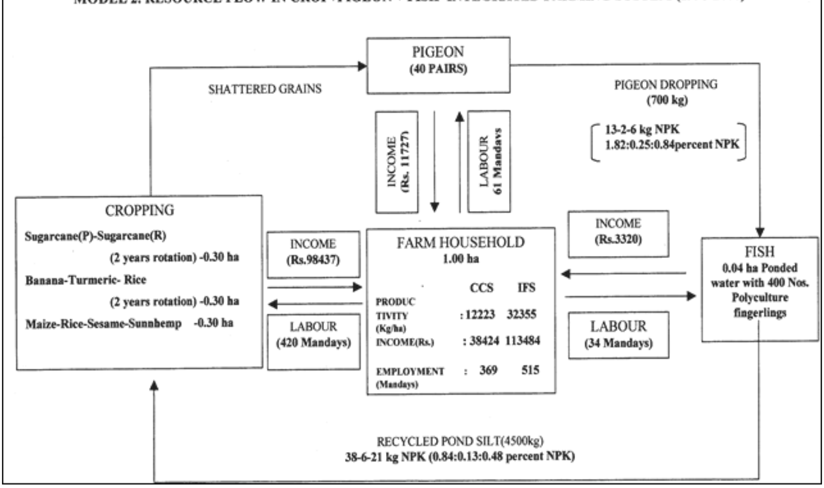
| Farming systems | Crop | Component Productivity (kg) | | | | Total system productivity (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|
| | | Poultry | Pigeon | Fish | Goat | |
| Cropping alone | 12223 | - | - | - | - | 12223 |
| Crop + Fish + Poultry | 29166 | 630 | - | 2063 | - | 31859 |
| Crop + Fish + Pigeon | 27973 | - | 2592 | 1790 | - | 32355 |
| Crop + Fish + Goat | 28809 | - | - | 1983 | 8818 | 39610 |

Jayanthi *et al.* (2003)

MODEL 1. RESOURCE FLOW IN CROP+POULTRY+FISH INTEGRATED FARMING SYSTEM (1998-2000)




MODEL 2. RESOURCE FLOW IN CROP+PIGEON + FISH INTEGRATED FARMING SYSTEM (1998-2000)



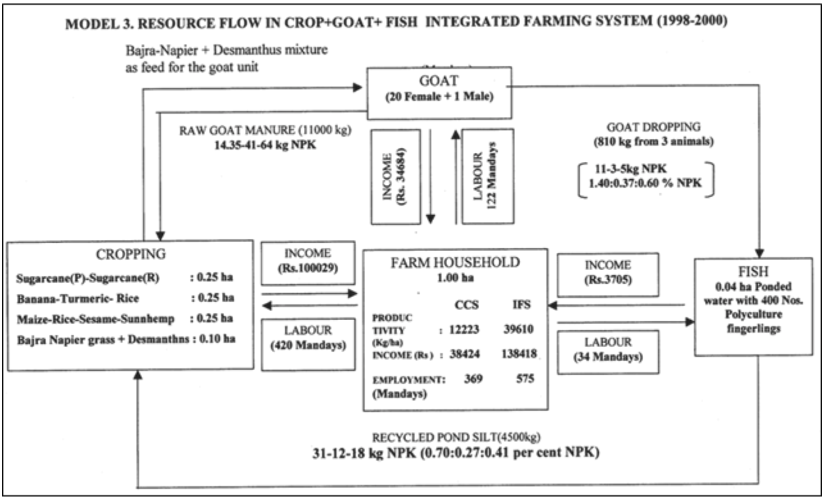



**Table 8:** Average productivity (t) and economics (USD) of individual components under developed integrated farming systems

| Components | RGEY (t) | Production cost | Gross return | Net return | B/C ratio |
|---|---|---|---|---|---|
| Crop alone | 8.02 | 1057 | 2121 | 1064 | 2.0 |
| Crop + poultry manure | 9.84 | 1143 | 2586 | 1443 | 2.3 |
| Crop + duck manure | 9.60 | 1148 | 2524 | 1376 | 2.2 |
| Crop + goat manure | 9.78 | 1139 | 2571 | 1432 | 2.3 |
| Crop + FYM | 9.68 | 1136 | 2544 | 1408 | 2.2 |
| Crop + vermicompost | 9.94 | 1145 | 2612 | 1467 | 2.3 |
| Poultry (100 no./batch) | 4.50 | 538 | 118 | 643 | 2.2 |
| Duck (30 + 5) | 1.56 | 241 | 409 | 168 | 1.7 |
| Goat (20 + 1) | 5.56 | 536 | 1462 | 926 | 2.7 |
| Cattle (3 + 3) | 7.99 | 1453 | 2100 | 647 | 1.4 |
| Mushroom (100 bags) | 1.06 (155kg) | 125 | 279 | 154 | 2.2 |
| Fish fed with poultry droppings (0.06 ha) | 0.99 (170kg) | 106 | 263 | 157 | 2.5 |
| Fish fed with duck droppings (0.06 ha) | 0.82 (140kg) | 106 | 216 | 110 | 2.0 |
| S.E.M. ±<br>CD | –<br>– | 5.58<br>16.35 | 12.62<br>33.79 | 7.7<br>22.58 | 0.013<br>0.039 |

Kumar *et al.* (2012)

**Table 9:** Year wise organic matter production and potential nutrient recycling from lowland IFS model

| Year | Residues from cropping system (kg) | Cow Dung (kg) | Cow Urine (lit.) | Others (kg) | Recycled N (kg) | Recycled P (kg) | Recycled K (kg) |
|---|---|---|---|---|---|---|---|
| 2011-12 | 10379 | 4852 | 2715 | 284 | 96.2 | 18.6 | 63.0 |
| 2012-13 | 10878 | 3948 | 3458 | 275 | 101.2 | 18.1 | 63.7 |
| 2013-14 | 11328 | 4359 | 3646 | 256 | 106.9 | 19.1 | 66.6 |
| 2014-15 | 8497 | 5318 | 3710 | 212 | 100.3 | 16.8 | 54.2 |
| Average | 10271 | 4619.3 | 3382.3 | 256.8 | 101.2 | 18.2 | 61.9 |

Manjunath *et al.* (2017)

**Table 10:** Production and recycling of organic manures in integrated farming system model

| Organic manures | Area ($m^2$) | Production (q) | Gross return (Rs.) | Cost of production (Rs.) | Net return (Rs.) | Family labour (Man days) | B:C |
|---|---|---|---|---|---|---|---|
| FYM | 40 | 46.4 | 3250 | 600 | 2650 | 6 | 5.42 |
| Goat Manure | 8 | 7.6 | 1000 | 120 | 880 | 1 | 8.33 |
| Poultry manure | 2 | 1.65 | 300 | 120 | 180 | 1 | 2.50 |
| Vermi compost | 12 | 32 | 25600 | 5180 | 20420 | 39 | 4.94 |
| Total | 62 | 87.65 | 30150 | 6020 | 24130 | 47 | 5.01 |

Anil Kumar *et al.* (2019)

**Table 11:** Farm production, utilization and recycling of produces in integrated farming system model

| Enterprises | Area (ha) | Economic yield (q) | Family consumption/use in farm (q) | Sold produce (q) | Straw yield (q) | Broken rice & husk/other | Use (q) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Feed | Composting |
| Field crops | 0.606 | 30.80 | 10.85 | 20.55 | 26.67 | 3.26 | 18.56 | 11.3 |
| Vegetables | 0.027 | 116.52 | 4.04 | 112.48 | 14.75 | 0 | 0 | 14.7 |
| Animal husbandry | 0.028 | 2.85 | 0.44 | 2.41 | 0 | 0 | 0 | 54.0 |
| Poultry | 0.002 | 0.53 | 0.20 | 0.33 | 0 | 0 | 0 | 1.68 |
| Fisheries | 0.13 | 0.70 | 0.22 | 0.48 | 0 | 0 | 0 | 0 |
| Lac cultivation | 0.20 | 1.40 | 0 | 1.40 | 7.80 | 0 | 0 | 7.80 |
| Organic manures | 0.006 | 87.65 | 87.65 | 0 | - | 0 | - | - |
| Azolla | 0.001 | 1.44 | 1.44 | 0 | - | 0 | - | - |
| Minor forest produce | on bunds | 2.80 | 0.60 | 2.20 | 0 | 0.60 | 0.60 | 0 |
| Total | 1.0 | 244.69 | 104.8 | 139.85 | 49.22 | 3.86 | 19.16 | 89.6 |

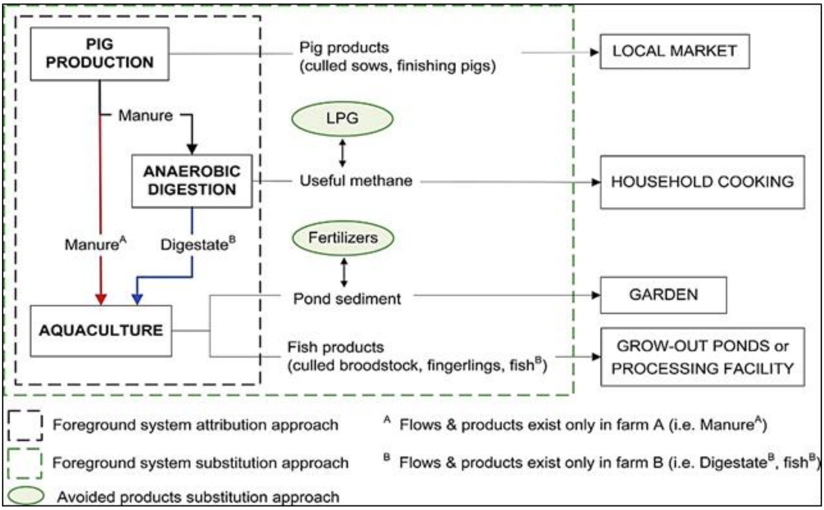
Anil Kumar *et al.* (2019)

**Table 12:** Benefit cost analysis of runoff recycling systems under different conditions

| Serial number | Item | For sites having seepage loss <6 mm/day | For sites having seepage loss >6 but less than 10 mm/day | For sites having seepage loss >10 mm/day, i.e. lined tanks |
|---|---|---|---|---|
| 1 | Total annual cost of pond for unit command area of 1 ha | Rs. 4200/- | Rs. 6000/- | Rs. 8000/- |
| 2 | Net return from crop alone | Rs. 9278/- | Rs. 9278/- | Rs. 9278/- |
| 3 | Net return from crop + horti | Rs. 11178/- | Rs. 11178/- | Rs. 11178/- |
| 4 | Net return from crop + horti + fish | Rs. 13778/- | Rs. 14778/-[a] | Rs. 16778/-[b] |
| 5 | B–C ratio from crop alone | 2.20 | 1.55 | 1.16 |
| 6 | B–C ratio from crop + horti | 2.66 | 1.86 | 1.40 |
| 7 | B–C ratio from crop + horti + fish | 3.28 | 2.46 | 2.09 |
| 8 | Expected B–C ratio from crop + horti + fish + duckery | >3.50 | 3.00 (approximately) | 2.50 (approximately) |
| 9 | Ground water recharge from catchment area, tank and command area for unit system having 1 ha command area (estimated from simulation) | 3000 $m^3$ | 4000 $m^3$ | 2500 $m^3$ |

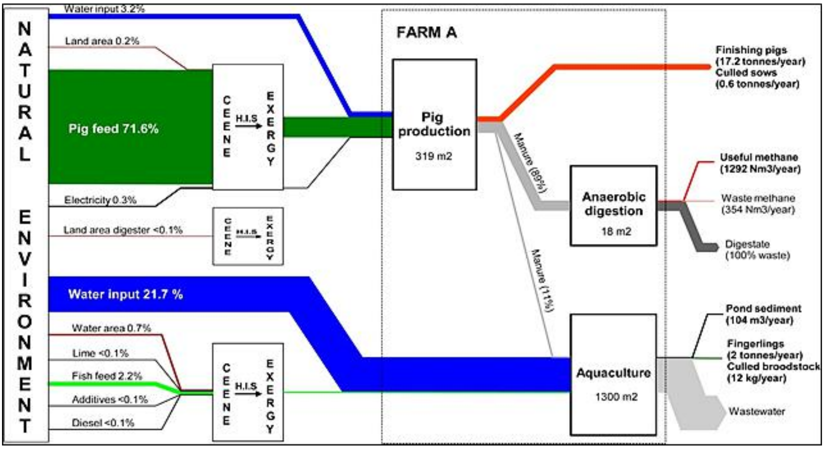
1 US $ = Rs. 47.40/-.
[a] Fish production will be more as the water area will be larger.
[b] Fish productivity will be higher as the water will be less turbid.

Srivastava *et al.* (2004)




Trang *et al.* (2015)

**Fig 2:** Overviews of the VACB foreground system for two applied approaches, i.e. partitioning and substitution. LPG: liquefied petroleum gas




Trang *et al.* (2015)

**Fig 3:** Sankey diagram of the weighted average life cycle from cradle to farm A gate (thickness of a flow is proportional to its exergy content; percentage (%) is out of the overall annual resource use of the farm: 7553 GJ year-1). 'Manure' flow includes fresh manure (53% of exergy content of flow), urine (6%) and wastewater from cleaning the pigsty. H.I.S: Human Industrial System.

## Conclusion

- Efficient utilization of scarce and costly resources is the need of the hour to make crop production a viable proposition in the present-day competitive scenario.
- Following the concept of Integrated farming systems through supplementation of allied agro-enterprises by recycling the waste of one enterprise in another is a right step in this direction.
- It provides alternate and sustainable avocation to marginal and sub-marginal farmers. Fruit, mushroom, apiary, animal production and poultry have been more viable with them.
- The crop residues and biomass available in plenty in the crop production system need to be properly managed to harness full benefits.
- Improving the integrated approach not only enhances farm income but also overcomes environmental pollution.
- A better planning and utilization of the available resources will user in bright prospects for the farm economy as a whole.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# Chapter - 3
# Oyster Mushroom Cultivation

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# Chapter - 3

## Oyster Mushroom Cultivation

**Shambhu Katel, Honey Raj Mandal and Rohit Sharma**

**Abstract**

Oyster Mushrooms are saprophytic fungi that are macro edible. It may be cultivated on a variety of substrates with acceptable food quality and quantity. Cap, stem and spore print are the basic morphological components. Preparation of substrate, development of spawn, incubation and eventually fruiting and harvesting are the steps in its production. The main goal is to become acquainted with the oyster mushroom growth technique as well as to gain knowledge of the causal agents of various diseases and pests, as well as the relevant control measures.

**Keywords:** Ascomyceteous, macro-fungi, spawn, straw

**Introduction**

Mushrooms are macro-fungi with a distinct fruiting body that can be epigeous, or hypogeous and is large enough to be seen with the naked eye. However, this is not a perfect definition. Mushroom is a saprophytic plant with a fleshy and spore-bearing nutritive organ that belongs to a group of organisms that differ in many ways from flowering plants and animals and feeds primarily on dead and decaying organic matter. Mushrooms are edible fungi that belong to the genus Pleurotus and the Basidiomycetes class. It is a saprophyte because it lacks the ability to synthesize its own food due to a lack of chlorophyll. As a result, it is reliant on dead and decay, which also lacks roots. Instead, during the vegetative stage of growth, mushroom mycelia secrete enzymes that break down substrate compounds like cellulose and lignin. It has the potential to solve many of the world's growing problems, such as food scarcity, unemployment, pollution and so on.

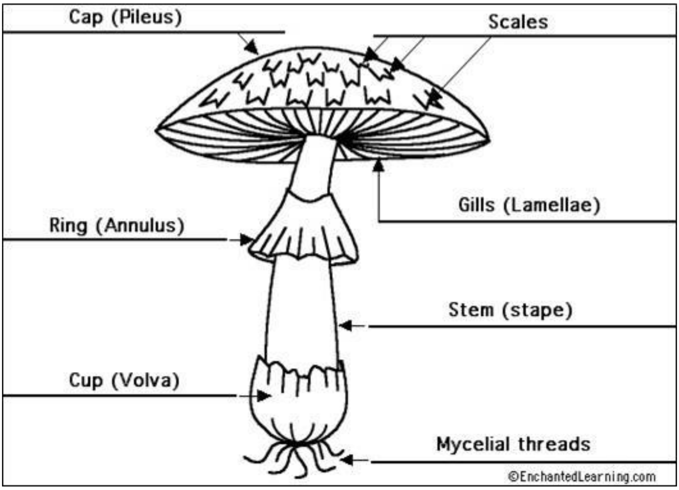


**Fig 1:** Mushroom

Mushrooms come in both edible/medicinal and poisonous varieties. However, the term "mushroom" was used for the edible macro fungi and "toadstools" for the poisonous gill macro fungi. However, the toadstool has no meaning, and to avoid confusion, the terms edible, medicinal, and poisonous mushrooms are used instead. Similarly, cultivated edible mushrooms are achlorophyllous, macroscopic, basidiomycetous or ascomycetes variants of certain fungi that bear spores embedded in fleshy fruiting bodies and are marketable as food. Edible mushrooms, once referred to as "food of the gods" and still considered a delicacy, can be consumed on a regular basis as part of the human diet. Mushroom cultivation has huge production in China, India, and other developing countries because of the cheap and readily available raw materials required, as well as faster means of communication and marketing and higher purchasing power. There are approximately 38,000 species of mushrooms known in the world, of which approximately 2000 are edible and over 1,000 are poisonous. As a result, mushrooms can be classified into different groups. Some of them are listed below:

**A. Structural classification**

1) **Edible mushroom category:** This category includes fleshy and edible mushrooms. Example, *Agaricus bisporus*.
2) **Medicinal mushroom category:** This category includes mushrooms that are thought to have medicinal properties. Example, *Ganoderma lucidum*.

3) **Poisonous mushrooms:** Those that have been proven to be poisonous. Example, *Amanita phalloides*.

4) **Other mushrooms:** A miscellaneous category that includes a large number of mushrooms whose properties are still unknown.

**B. Ecological classification**

i) **Saprophytes:** They obtain nutrients from dead organic materials through decomposition. Example white button, crimini, shiitake and oyster mushrooms.

ii) **Parasites:** They depend upon living plants and animals for food and cause harm to the host. Example Polypores /Bracket fungi or shelf fungi.

iii) **Mycorrhiza:** There exists a mutual relationship between the host plants and animals. There by forming a special partnership where each partner enjoys some vital benefits from the other. Example Perigold black truffle, Tuber melanosporum and matsutake mushroom (*Tricholoma matsutake*).

**Advantages of mushroom cultivation**

1) **Reduce environmental pollution:** Farmers burn a lot of waste, like cereal straws, which pollutes the air. These raw materials, on the other hand, can be used to cultivate mushrooms.

2) **Medicinal properties:** They can be used in the treatment of diabetes. It is ideal for people who have heart disease or hypertension. Because of the folic acid found in oyster mushrooms, it can also treat anemia.

3) **Nutritional value:** Good source of crude protein, fat, phosphorus, iron high moisture content varies between 70-95% depending on harvest time and environmental conditions, whereas dried mushrooms have a moisture content of 10-13%.

Cultivated mushrooms are a good source of several vitamins. Depending on the species, such as:

- Riboflavin (vitamin B2) ranging from 1.8–5.1 mg/100 g DW.
- Niacin (vitamin B3), ranging from 31–65 mg/100 g DW.
- Folates (vitamin B9), ranging from 0.30–0.64 mg/100 g DW.

They are also good sources of:

- Phosphorus (493-1390 mg/100 g DW).
- Magnesium (20-200 mg/100 g DW).

- Zinc (4.70-9.20 mg/100 g DW).
- Copper (0.52-3.50 mg/100 g DW).

Mushrooms, however, have low:

- Sodium (130-420 mg/100 g DW).
- Calcium (1-25.0 mg/100 g DW).
- Iron (2.80-12.30 mg/100 g DW).
- Manganese (0.51-2.1 mg/100.

**4)** **Possibility of employment:** Mushroom cultivation needs a lot of labor. As a result, it will serve as a means of creating employment, particularly for rural women and youths seeking to improve their social standing.

**5)** Mushroom cultivation is a profitable business. The harvested fruiting bodies can be sold in a local market to supplement family income or exported to provide an important source of foreign exchange, which will undoubtedly improve people's economic standards.

**6)** It is a low-risk agricultural venture that can provide immediate benefits to the community. *Volvariella volvacea* (straw mushroom) and *Pleurotus sajor caju* (oyster mushroom) are two fast-growing mushrooms.

**7)** Other uses

1) *Fomes fomentarius* and *Ganoderma applanatum* are used in embroidery, hats and photo frames, among other things.
2) *Polyporus applanatus* is a curio-making species.
3) *Deodolea quercina* is used to make combs for human and horse grooming.
4) Powder inhaler made from *Polyporus nigricans*.
9) *Polyporus bisporus* is a plant that is used to dye clothes.
10) Plants such as *P. fomentarius* and *P. ignitarious* have been used to decorate flower pots.
11) Ink was made by *Coprinus comatus* (poisonous if taken with alcohol).
12) Surgical gowns are made from *Lycoperdon giganteum*.

## Oyster mushroom

The Oyster mushroom is an edible mushroom with excellent flavor and taste. They are rich in biologically active compounds, serve as important functional foods and are used in cosmetics. China, India, Japan, South Korea, Taiwan, Thailand and Vietnam are Asia's top consumers and producers of oyster mushrooms. In terms of global mushroom production, the oyster mushroom ranks third behind the white button and shiitake. The edible, basidiomycetic and saprophytic oyster mushroom family includes the king oyster mushroom (*Pleurotus eryngii*).

Oyster mushroom cultivation is preferred by mushroom growers due to its ease of cultivation and increased profitability, as it converts a higher percentage of substrate to fruiting bodies than other mushrooms.

### Morphological characters

### Cap

They grow in a shelf-like formation with overlapping clusters with a fan shape of about 2-10 inches. They are Smooth, with scales. The gills are white and are attached to and running down the cap and stem.

### Stem

The stem is absent but is sometimes it may be stubby and off center if the mushroom is growing on the side of a log. If it's growing on the top you will see a more well-developed stem. Ring and sack are absent around the stem and base respectively.

- **Spore print:** It is White to lilac-gray in colour. It's best to make the spore print on a dark background.

### Production of oyster mushroom

Mycelium grows best at temperatures between 10 and 35 $^oC$. Mycelium grows best at temperatures between 23 and 28 $^o$Celsius. The ideal temperature for fruiting bodies to develop is 18-24 $^oC$. The pH of the substrate used to make the bed should be between 6.8 and 8.0. In the substrate, the C:N ratio is between 30-60:1. The development of the fruiting bodies necessitates a lot of air circulation and a lot of resonable light. During the summer months, the cultivation practices can be carried out by providing the extra humidity required for the plant's growth and development. It was also adaptable to a wide range of agro-climatic conditions on various agricultural wastes. Mushroom cultivation is influenced by a variety of factors, including temperature, humidity and the sterility of the substrates, all of which act independently or in combination. Mushroom cultivation is known for being environmentally friendly, as it has no negative impact on the environment when compared to other crops.

Different steps for production of oyster mushroom are discussed below

i) **Mushroom species selection:** whether the species has organoleptic qualities that are acceptable to the indigenous population or the international market. if suitable cultivation substrates are abundant and if environmental requirements for growth and fruiting can be met without the use of prohibitively expensive mechanical control systems.

ii) **Examples of spawn substrates:** A mushroom substrate is a type of lignocellulose material that aids in mushroom growth, development and fruiting. The quality, quantity and nutritional value of mushrooms produced are all dependent on the mushroom growing substrate. Fungal contamination of substrates, on the other hand, is well-known as a major issue in mushroom cultivation. In terms of mycelium run, average yield and quality, different strains of king oyster mushroom respond differently to different substrates, supplements, supplement amount and environmental factors. Oyster mushrooms can be grown on a variety of plant waste substrates. Sawdust, paddy straw, sugarcane, corn stalk, corn corbs, waste cotton, banana leaves and pseudo-stem, water hyacinth, duck weed, rice straw are some examples. Sawdust and rice straw are the most commonly used substrates for mushroom cultivation.

1) Wheat grain +1.5% gypsum.
2) Cotton seed hull 88%, wheat bran 10%, sugar 1% and gypsum 1%.
3) Saw dust 78%, wheat bran 20%, sugar 1%, gypsum 1%.
4) Saw dust 58%, spent coffee grounds/spent tea leaves 20%, cereal straw 20%, sugar 1% and gypsum 1%.

iii) **Good quality fruiting culture:** A fruiting culture is one that has the genetic capacity to form fruiting bodies under appropriate growth conditions. The stock culture chosen should be acceptable in terms of yield, flavor, texture, fruiting time and so on.

**Sources of culture**

a) **Tissue culture:** Select a large, healthy mushroom in the later button or egg stage. It should be cleaned with a solution of 75% alcohol. The mushroom should be split in half longitudinally by hand and some inside tissue should be taken from the upper part of the stipe. With a sterile needle, it should be placed centrally on the medium's surface. As soon as the tissue is transferred, the test tube should be closed and dated before being returned to the incubator, which should be set between 25 and 34 degrees Celsius depending on the mushroom used. Within two or three days, a small piece of tissue will produce some white, delicate mycelia. They grow upward, encircling the test tube's inner wall. After about ten days, the mycelium will have grown rapidly and will cover the entire surface of the agar medium. Then it is ready to be transferred to the spawn substrate to produce spawn.

b) **Spore culture:** Individual spores can be transferred to a test tube or Petri dish which allows them to develop and germinate into the mycelium. Some single spore isolates from homothallic mushrooms, such as *Volvariella volvacea* or *Agaricus bisporus,* can be used to make spawn as a fruiting culture. A test tube culture can be obtained from a research laboratory as an alternative to culturing in the laboratory as described. The benefit of this is that cultures kept in reputable culture collections have already been tested for their production characteristics and are guaranteed to be pure.

**Culture media**

Mushrooms grow on a variety of culture media and agar formulas, both natural and synthetic, depending on the organism and purpose of cultivation.

A. **PDA (Potato dextrose agar):** It is the most basic and widely used medium for growing mycelia of most cultivated mushrooms. It is available commercially as a ready-to-use powder that can be used to make the medium in the laboratory with a concentration of 20gm/l of distilled water. Alternatively, it can be made in a laboratory using the following ingredients.

The producer for making PDA are listed below:

1) Peeled potatoes are discarded after being weighed and cut into cubes. They are cooked in a casserole with at least one liter of water until soft.
2) The potatoes are removed and one liter of water is added to the broth. The broth is returned to the casserole, along with the dextrose and agar.
3) The solution is heated and occasionally stirred until the agar is melted. The hot solution is then poured into clear flat bottles, filling them to a depth of about 2.5 cm from the bottom.

4) When using test tubes for stock cultures, at least 10 ml of liquid agar solution is added. Cotton wool is used to plug the bottles or test tubes.

**B. Ready-made MEA (Malt extract agar):** MEA is easily available in the market. The recommended amount of powder (20 gm) is mixed with 1 liter of water, then melted and sterilized. one percent peptone or 0.5% yeast may be added, for faster mycelial growth for both PDA and MEA.

**iv) Development of spawn**

1) **Mushroom spawn preparation:** The word spawn comes from the French word espandre, which means "to spread or expand" and is derived from the Latin word expandere, which means "to spread". Webster's dictionary defines mycelium as "the mycelium of fungi, especially of mushroom grown to be eaten, used for propagation." Spawn is a substrate into which a mushroom mycelium has been impregnated and developed and which will be used as a seed in mushroom propagation.

2) **Spawn substrates:** To make mushroom spawn, a variety of materials, mostly agricultural waste, can be used. Chopped rice straw, saw dust, water hyacinth leaves, used leaves and cotton waste are some of these. Most laboratories use cereal grains/wheat, rye, or sorghum as mother spawn and agricultural wastes as planting spawn substrates.

The method for preparation of substrate includes

Organic materials, such as farm waste, are commonly used as substrate for mycelium growth, which results in the production of mushrooms. Saw dust, rice bran, rice straw, wheat bran and wheat straw are among the substrates used. Substrate preparation is widely recognized as the most critical stage in the manufacturing process for ensuring a lower incidence of disease and a higher yield. Pasteurization of substrates such as grasses is done before hand to eliminate potential competitors. Pasteurization can be done by applying hot water treatment (70 $^{o}$C) to the substrate for a few hours.

3) **Preparation of mother spawn:** For 2 hours, wheat grains are soaked in water. Dead seeds should be removed. The grains are then washed again and boiled in water for at least 10-15 minutes. After that, the grain is allowed to cool. The grains are treated with precipitated chalk (1.5 percent on a wet basis). The grains are then loosely packed in bottles that are only two-thirds full. Cotton wool

is used to plug these. The grain is sterilized in a pressure cooker for about 1 hour at 121 $^{o}$Celsius.

4) **Preparation of planting straw (Rice straw):** Rice straw is cut into 2 to 3 cm pieces and soaked in water for 4 to 12 hours.

**Fig 2:** Cutting of rice straw

The excess water is drained and the straw pieces are mixed with a solution of 1% sucrose, 1.5 % chalk and 2% wheat/rice ban in water. The final moisture content should be around 60%. The mixture is then placed in glass bottles or plastic bags and sterilized for at least one hour at 12 $^{o}$C before being inoculated with mother spawn.

## V. Mushroom spawn handling

1) **Maintenance of spawn quality:** Most mushrooms can be refrigerated, however, they should be warmed to room temperature before being used as an inoculum or planting spawn. The planting spawn's vigorous growth is a requirement for good growth and yield, as it will outcompete many competing organisms and produce more mushrooms. Old spawn should not be used because its vigor may have started to decline.

2) **Spawn quantities:** The amount of spawn used has no direct effect on yield. Using more spawn, on the other hand, may reduce the effects of competitive organisms in the planting substrates. The more spawn used, the more quickly it will colonize the substrate. It is recommended that 2-4 percent of the spawn be inoculated into the spawning substrate.

## VI. Care of spawn running

The substrate is placed in beds and steam pasteurized to kill off any potentially competitive microorganisms. After the compost has cooled, the spawn can either be broadcast across the bed surface and firmly pressed against the substrate to ensure good contact, or it can be inserted 2 to 2.5 cm deep into the substrate. The phase during which mycelium grows from the spawn and permeates into the substrate is known as spawn running. Mushroom production requires healthy mycelial growth.

### VII. Incubation, fruiting and management of fruiting

During the incubation period, the temperature is kept between 20 and $25^0$ C to achieve the best results and the bags are kept in the incubation room without being disturbed for 15 to 25 days, depending on the size and condition of the bags. The relative humidity should be kept between 70 and 85% during fruiting by spraying or sprinkling water on the gunny bags. At the time of fruiting, at least 8-12 hours of sunlight are required.

**Fig 3:** Watering in gunny bags

### VIII. Observation

Mushroom, then should be observed thoroughly, following changes can be seen.

**3rd day:** No changes may be seen except some dew collected at the top of bag.

**6th day:** Minute threads of mycelium spread around the spawned grain can be seen.

**10th day:** White mycelial thread can cover larger area.

**15th day:** Mycelium may extent to larger areas but nearly same as in 10th day.

**25th day:** Now the fungus cover most of the part and at that day the plastic covered can be removed and placed in another room for further production.

## IX. Harvesting and Yield

Harvesting is done when the cap has the diameter of 8-10 cm.

**Fig 4:** Fully grown mushroom

Picking is done by twisting gently so that it is pulled out without leaving any stalk and also the nearby fruiting bodies are not disturbed. When the base of the stipe is deeply immersed within the straw, cutting the base of stipe with Sharpe knife can be done. It is possible to get 500-800 g to a kilogram fresh mushrooms per kilogram of the dry substrate (rice straw). The bags are kept in the growing chamber after the first harvest to allow other mycelium to grow and produce more fruiting bodies, which can then be harvested again. For marketing, the harvested mushrooms are placed in perforated polythene bags.

## X. Post-harvest handling

Mushrooms are perishable, and they frequently change after harvest, rendering them unfit for human consumption. Wilting, ripening, browning, liquefaction, loss of moisture, loss of texture, aroma, and flavor are among the most visible changes.

### Diseases of mushroom

### Fungal diseases

1) Green mold Disease

Causal Organism: *Trichoderma* spp.

*Penicillium cyclopium*

*Aspergillus* spp.

Cultivated oyster mushrooms are infested by green mold diseases in many countries. The pathogen responsible for the Green Mold diseases is *Trichoderma aggressivum*. Also new species including *T. harzianum* and *T. asperellum*. The main symptoms of Green mold diseases is the appearance of greenish mycelium in the compost, bagging layer or fruiting bodies of *P. ostreatus*. In addition, they release extracellular enzymes, secondary toxic compounds as well as volatile organic compounds. Therefore, it decreases production and wipes out the entire crop.

**Management**

Good sanitation practices (concentration of Formalin could be correctly used maximum. 2%); ensure compost is properly pasteurized prior to use and sterilize any supplements.

**2) Dry bubble diseases**

**Causal organism:** *Verticillium fungicola*

During warmer weather, the disease is commonly encountered around the farms. The pathogen responsible for dry bubble diseases is *Mycogone perniciosa*. Symptoms include development of fungal host and irregularly shaped, light brown necrotic lesion on the caps part of the mushroom.

**3) Wet bubble diseases**

**Causal organism:** *Mycogone perniciosa*.

There is a development of large undifferentiated and irregular masses of tissue and other symptoms include swollen stripes, wart-like growth, cap spotting etc. In heavily infected areas, white mycelium can grow out onto the surrounding area and turns brown as the spores mature.

**Management**

- Sanitation of mushroom house, disposal of spent compost and removal of infected fruiting bodies. Use of properly sterilized casing soil and compost for mushroom cultivation.
- Fungicides such as Dithane M-45 (0.3%), Benlate, Carbendazim or Thiabendazole (0.05%) has also been reported to control this fungi.

**4) Cobb web Diseases**

**Causal organism:** *Hypomyces rosellus* (*Cladobotryum dendroides*).

It causes the yield loss up to 40%. One of the main symptoms include fungal growth of mycelia over the surface of mushroom. The colonies rapidly extended on the surface within 2-3 days. Thus, the colony's surface turned pale brown and yellow.

**Management**

- Cobweb mold is favored by high humidity. Control strategies include lowering humidity and/or increasing air circulation.
- Infected mushroom beds and fruiting bodies be removed from mushroom house.
- Treat small spots of cobweb immediately with salt or formaldehyde.

5) **Brown Blotch bacterial diseases:** The bacteria responsible for this disease is *Pseudomonas alcaligenes*. It causes heavy economic losses when the cultivation on scale was large. The most typical symptoms are superficial brown lesions on the pileus. The pathogen responsible for producing tolassin compound.

**Viral diseases in mushroom**

**a) La France/Die back/Mummy Disease**

Mycelium degeneration, fruiting suppression and mushroom death in rapidly. The mushroom mycelium eventually vanishes. Infected mushrooms are off-white in color and shaped like drumsticks. Other symptoms include dwarfing, premature opening of veil, development of an elongated spindly stem with a small cap, formation of a thickened stem with a thin flat cap and malformed or absent gills.

**Management**

Cleaning, disinfecting and steaming wood are all recommended. Pasteurization (60-62 °C for 6 or more hours) of compost, spawn, equipment and empty rooms, as well as cleaning HEPA filters and general sanitation, are all used as controls.

a) X-diseases.

b) Brown disease and watery stripe.

c) Dieback disease.

Mushrooms get infected by different viral diseases. Mushrooms get shriveled, leathery and brown color. In addition, stripes become watery and grey under humid conditions. Sometimes, delay in the appearance of pinhead formation.

**Insect-pests of mushroom**

1) **Scarids:** *Lycoriella ingenua* (Mushroom sciarid fly) is one of the most common flies affecting its cultivation. They are small fungal gnats with size varying from 1.5-5mm. Yield loss is directly due to its larvae and indirectly from damage of the compost, which inhibits the growth of mycelia. They also act as a vector for the various disease agents, nematodes, mites and other contaminants. Control may be primarily by the application of conventional synthetic pesticides such as chlorpyrifos, diazinon, malathion etc.
2) **Phorids:** They are small hump backed black flies of size 1.9-3mm. The spheroids Megaselia halterata is a common pest of mushroom. The larvae of these flies feed on mushroom mycelia and even burrow into mushrooms once they are formed. Adults act as a vector of other pests and diseases.
3) **Cecids:** They are rarely visible and are dark brown in color. Cecids are smaller than ascarids. Larvae begin to feed on the mushroom and make a downward groove in the stripe. Additionally, they feed on the outside of the stipe and gills. At a later stage, there is bacterial growth and causes discoloration.
4) **Mites:** Oyster and other cultivated mushroom are infested by many groups of mites. The raw materials used for the preparation of mushroom beds may be the source of infection of mites in mushroom house. Phorid flies is also one the agents for the transport of mites. Mites causes allergic reaction to humans.
5) **Spiders:** They cause loss by eating mycelium and fruiting bodies of the oyster mushroom. Furthermore, spiders do damage by spreading the fungal spores. Prevention can be done by chalk powder spread on the surface of the floor and walls. If there is presence of cob web then it needs to be destroyed.

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# Chapter - 4
# Role of Nutraceuticals in Human Health


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# Chapter - 4

## Role of Nutraceuticals in Human Health

**Rashmi Misra and Dr. Anupam Dakua**


### Abstract

Nutraceuticals are defined as the products which may be the food itself or may be a part of the food or may be any dietary supplement which is having potential health benefits beyond its Nutrition including prevention and treatment of different diseases. The significance and urgency of nutraceuticals is expanding day by day globally in terms of scientific aspects, legal aspects, and marketing strategies for health promotion, morbidly and mortality rate reduction and health care costs. The use of Nutraceuticals is approximately 50%–70% in developed countries. Nutraceuticals however can create certain risk if they will be used without the guidance of a Physician or any medical/paramedical professionals. Proper monitoring and supervision very much required before opting for any health-related product as the products can interact with other medicines and diet which we are taking and can create adverse effects especially in case of most vulnerable populations (Young Children, Pregnant and Lactating Women, Old Age people and chronically sick people). Nutraceutical products like soya products, peanut containing products, Mushroom, Fish oil etc. may cause allergies and other critical signs and symptoms. It varies from Individual to Individual depending upon the individual body system.

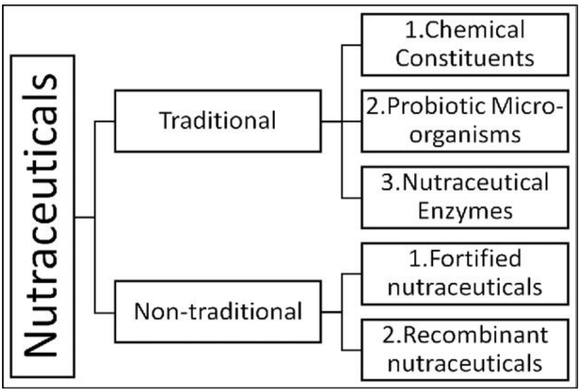

**Keywords:** Nutraceuticals, probiotic, prebiotic, phytochemicals, dietary supplements

### Introduction

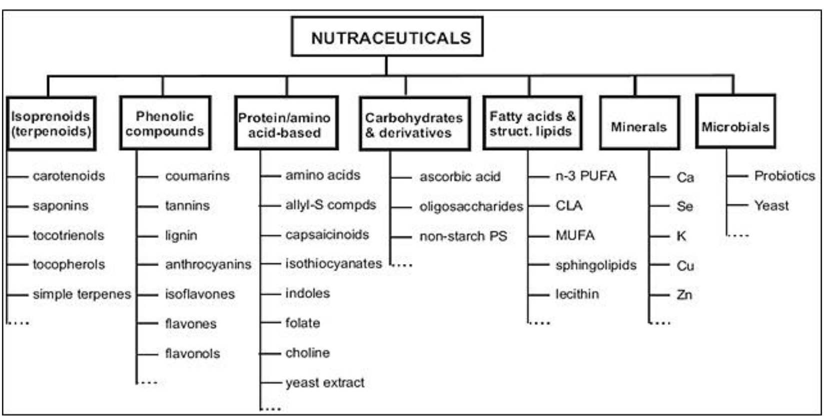
Nutraceuticals is not a single term rather it is a hybrid term or Umbrella term derived from Nutrition and Pharmaceutical which comprises a wide range of different nutritional and health care products which are having potential health benefits beyond its Nutrition includes phytochemicals, dietary supplements, functional foods, medical foods etc. On the basis of its chemical constituents, they are classified as polyphenols (flavonoids, anthocyanins, isoflavones, flavanones, coumarins, tannins, lignins), isoprenoid derivatives (saponins, carotenoids, terpenoids, tocotrienols, tocopherols, terpenes), Carbohydrate derivatives (ascorbic acid, oligosaccharides, Non-starch polysaccharides), fatty acid and structural lipids, amino acid derivatives, Micronutrients (vitamins, minerals) and Probiotics and Prebiotics).

### Classification of nutraceuticals

On the basis of natural and artificial ingredients or methods incorporated to make different Nutraceutical products, it has been classified into two types;




### Other classifications of nutraceuticals




### Nutraceutical products

Nutraceutical products would be very healthy when we will consume it with proper guidance and supervision by a professional or else it will be showing adverse effects on human body. Now a days a wide variety of Nutraceutical Products are available in Market. We can purchase it from any retailer shop or else we can also purchase them by cybershopping.

### Functional foods

Functional foods are defined as the food ingredients which claims to provide extra health benefits beyond their nutritional value. They can include whole foods, grains, green Leavy vegetables, fruits, spices and condiments, fortified(Something new will be added to the food to make it more healthy, more bioavailable and more nutritious) and enriched foods(The quantity of some existing nutrients in the foods will be increases to make it more healthy, more bioavailable and more nutritious) , probiotics( Healthy Live microbes adequately administered in food to make it more healthy which will create a positive healthy impact in host.  and prebiotics (Compounds in food that will induce the growth of Healthy Microflora in Human Gut or Human Gastro Intestinal Tract) etc.

### Dietary supplements

Dietary supplements are manufactured products that are prepared from some natural foods or by adding any synthetic ingredients to improve the quality of food to make it more nutritious and enrich. It includes functional foods also which will provide extra health benefits beyond its nutritional value. Different Pharmaceutical companies are producing varieties of dietary supplements. They can be consumed in addition with diet. Consumption and recommendation of different dietary supplements would be varied according to the age, gender, food preference, food intolerances, physiological and pathological conditions of an Individual.

## Role of nutraceuticals in human health

Nutraceuticals have numerous health benefits. It can be used to treat variety of diseases like Obesity, Diabetes, Cardiovascular diseases (Atherosclerosis, Arteriosclerosis, Hypertension etc.), Hormonal disorders (Thyroid, PCOS), Deficiency diseases like Anaemia, nerve weakness, paraesthesia, Osteoporosis, Baldness etc. It can also be used to cure skin diseases, bowl movement related issues, delaying ageing etc.

## Case studies related to role of nutraceuticals in different diseases in human being

There are some studies which were undertaken by different researchers to find out the impact or role of Nutraceuticals on different Diseases in case of Human Being are given below:

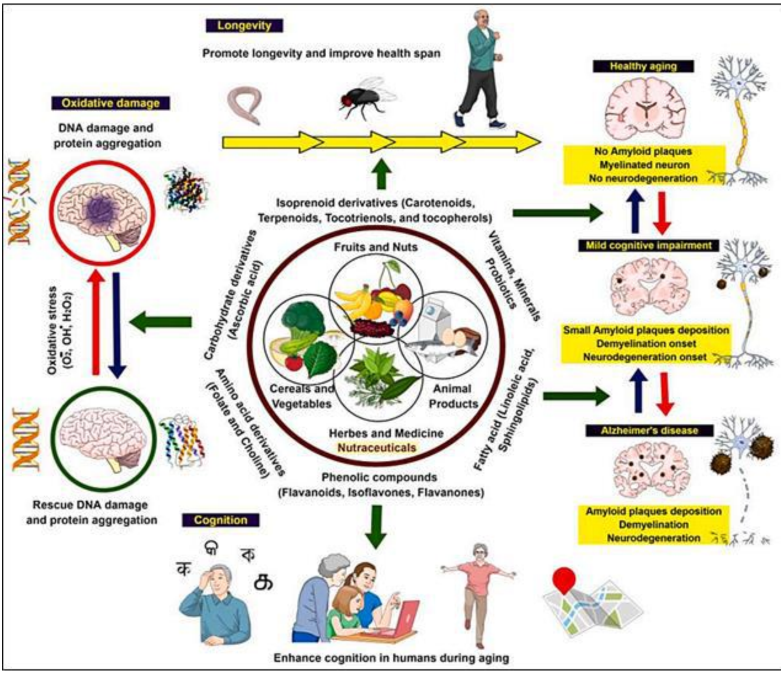
### Study-1

### Role of Nutraceuticals in cognition during aging and related disorders

Singh. P *et al*., 2021.

### Objectives

Nutraceutical plays vital role in improving cognition and also helping in preventing quick ageing process. The objective of the study was to highlight the important role of Nutraceuticals in preventing and reducing cognitive ageing and its progression towards dementia.




### Findings

Considering the advantages as well as drawbacks of presently used nutraceuticals, plant derived phytochemicals (Plant derived metabolites) offering cognitive as well as numerous physiological benefits. Combined approach is always better than a single approach that means we should take balanced diet which includes foods from ICMR recommended 5 Food groups, apart from that we can take Nutraceuticals or different dietary supplements as a complement to the regular diet as per requirement for a healthy body. Nutraceuticals are rich in Antioxidants which helps in removing excess number of free radicals from the body which leads to Oxidative stress and cell deterioration which is the main cause of ageing. So, Nutraceuticals or different Phytochemicals are playing a vital role in providing immunity to defend oxidative stress and to delay early ageing.

### Study-2

### Role of nutraceuticals in the prevention and treatment of hypertension and cardiovascular diseases

Alves, Q.L *et al.*, 2019.

**Objectives:** In this review, the researcher has given emphasis to assess the benefits of using Nutraceuticals in prevention and treatment of Hypertension and Cardiovascular Diseases.

**Findings:** Vitamins, Flavonoids, Garlic, Onions, Lycopene (Pigment found in Tomatoes) etc have been seen to provide numerous health benefits and plays vital role in preventing and controlling High Blood Pressure.

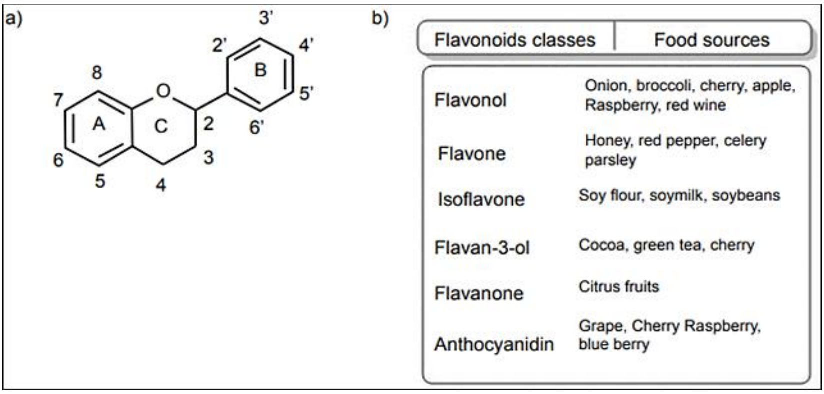



**Fig 1:** a) Basic structure of the flavonoids; b) Flavonoids classes and food sources of flavonoids

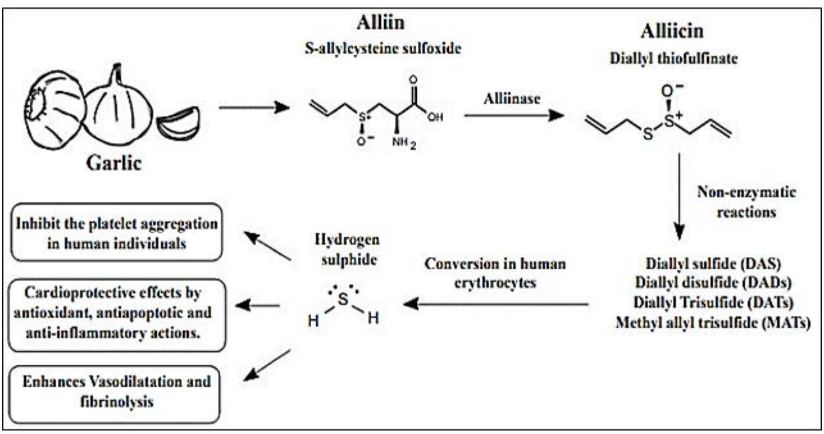



**Fig 2:** Garlic and its cardiovascular effects via hydrogen sulfide signaling

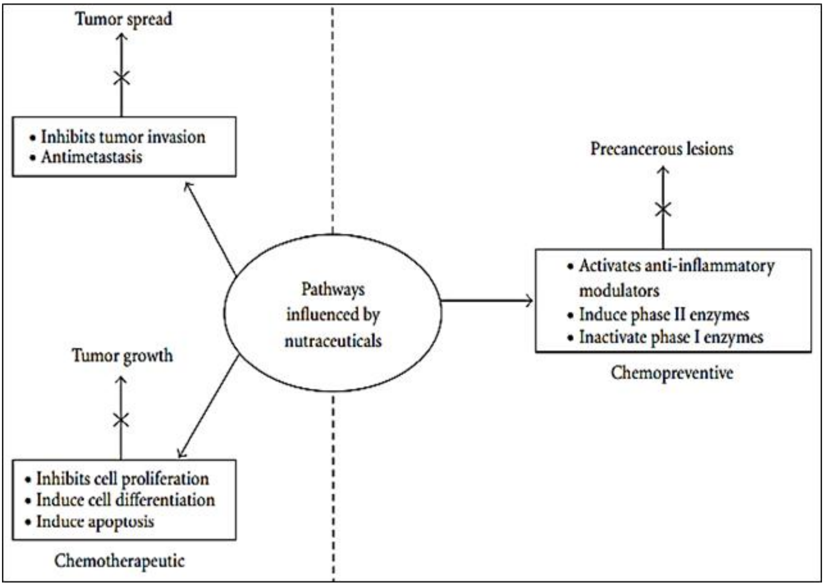
## Study-3

## The role of nutraceuticals in chemoprevention and chemotherapy and their clinical outcomes

Saldanha S.N *et al.*, 2012.

**Objectives:** In this review article, it has been highlighted the effect of combinational bioactive dietary compounds or Nutraceuticals in chemoprevention and chemo therapy in case of cancer patients.

**Findings:** SFN (Sulforaphane) is a strong inducer of UDP27 glucuronyl transferase (UGT1A1). UGT1A1 is an important enzyme which plays vital role in the detoxification process of carcinogens formed in the body. Lower doses of SFN demonstrate antagonistic effects on cell proliferation and higher doses of both compounds (SFN and 3,3-Diindolylmethane) had synergistic effects. Synergism of compounds is preferred if the outcome is tumour regression. Combine therapy is always better and more effective than a single therapy.




**Classification of nutrients as phytochemicals and their major food source availability**

| Phytochemical class | Bioactive compound | Source | *Molecular formula | Reference |
|---|---|---|---|---|
| Alkaloid | Caffeine | Cacao, tea, coffee | $C_8H_{10}N_4O_2$ | [20] |
| | Theophylline | Cacao, tea, coffee | $C_7H_8N_4O_2$ | |
| Monoterpenes | Limonene | Citrus oils from orange, lemon, mandarin, lime, and grapefruit | $C_{10}H_{16}$ | [21] |
| Organosulfides | Allicin | Garlic | $C_6H_{10}OS_2$ | [22–25] |
| | Indole-3-carbinol | Cabbage | $C_9H_{11}NO_2$ | [26] |
| | Isothiocyanates | Broccoli | CNS | [27] |
| | Sulforaphane | Broccoli | $C_6H_{11}NOS_2$ | [28] |
| Carotenoids | Beta-Carotene, lycopene | Tomatoes | $C_{40}H_{56}$ | [29] |
| Flavonoids | Epigallocatechin-3-gallate | Green tea | $C_{29}H_{22}O_{15}$ | [30] |
| | Quercetin | Black tea | $C_{15}H_{10}O_7$ | [31] |
| | Curcumin | Turmeric | $C_{21}H_{20}O_6$ | [32] |
| Phenolic Acids | Capsaicin | Chilli peppers | $C_{18}H_{27}NO_3$ | [33] |
| | Ellagic acid | Black berries, raspberry | $C_{14}H_6O_8$ | [34, 35] |
| | Gallic acid | Pomegranate, nuts | $C_7H_6O_5$ | [36, 37] |
| Stilbenes | Pterostilbene | Blueberries and grapes | $C_{16}H_{16}O_3$ | [38] |
| | Resveratrol | Almonds, blueberries, grapes | $C_{14}H_{12}O_3$ | [39] |
| Isoflavones | Daidzein | Soy | $C_{15}H_{10}O_4$ | [9, 40] |
| | Genistein | Soy | $C_{15}H_{10}O_5$ | |

**Assessment of the chemotherapeutic and chemo preventive effects of nutraceuticals in combination studies**

| Combination of nutraceutical | Dose used | Pathways affected or mechanistic action | Organ of study | Phase of study |
|---|---|---|---|---|
| Curcumin + paclitaxel | 50 μM/L + 10–50 μM/L based on the gene assessed | Inactivation of NF-κB and other metastatic genes. | Breast | *In vitro* |
| Curcumin + paclitaxel | 2% w/w 10 mg/kg | Inhibition of metastasis | | *In vivo* |
| Curcumin + xanthorrhizol | Synergistic effect in the range from 5 to 20 μg/mL | Induction of apoptosis | Breast | *In vitro* |
| Curcumin + docosahexenic acid | Ratio of DHA to CCM MCF-7 55 : 30 μM MCF10A 95 : 45 μM MDA-MB 35 : 35 μM SK-BR-3 60 : 40 μM MDA-MB 50 : 25 μM | Inhibition of proliferation, more synergistic in one of the 5 cell lines tested. Enhanced uptake of curcumin by the cells. Upregulated genes involved in cell cycle arrest, apoptosis, inhibition of metastasis, and cell adhesion. Downregulated genes involved in metstasis and invasion. | Breast | *In vitro* |
| Curcumin + genistein | 10 μM + 25 μM 10 μM +25 μM 11 μM + 25 μM | Change in cell morphology and growth inhibition | Breast | *In vitro* |
| Curcumin + sulphinosine | 15 μM + 10 μM | Alter multidrug resistance genes. Alters the cell cycle with cells inhibited primarily in the S G2/M phase of the cycle | Lung | *In vitro* |
| | | Inhibition of cell proliferation and induction of apoptosis. | | |

| Combination of nutraceutical | Dose used | Pathways affected or mechanistic action | Organ of study | Phase of study |
|---|---|---|---|---|
| Resveratrol + n-Butyrate | 50 $\mu$M + 2 mM/L | Inhibited cell proliferation and induced differentiation. Attentuated p27 (Kip1) levels but enhanced p21 (Waf1/Cip1) expression. | Colon | *In vitro* |
| Resveratrol + 5-Fluorouracil | 200 $\mu$M + $IC_{50}$ 800 $\mu$M | Inhibited cell proliferation and induced apoptosis by increase in capase 6 activity | Colon | *In vitro* |
| Resveratrol + genistein | 250 mg/kg each in the AIN-76 diet | Suppressed prostate cancer development and mediated apoptosis by affecting the expression of steroid-receptor coactivor-3 and insulin-like growth factor-1 | Prostate | *In vivo* |
| Genistein + sulforaphane | 5 $\mu$M/L + 15 $\mu$M/L | Affected DNA methyltransferase activity and reversed the gene expression of promoter hypermethylated genes of retinoic acid receptor h (RARb), RARB, p16INK4a p16 and | Esophagous | *In vitro* |

**Study-4**

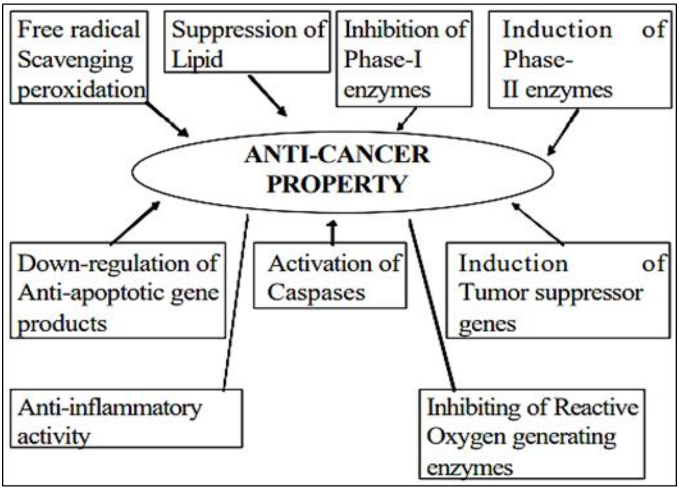
**Spices for Taste and Flavour: Nutraceuticals for Human Health**

Srinivasan. K, 2017.

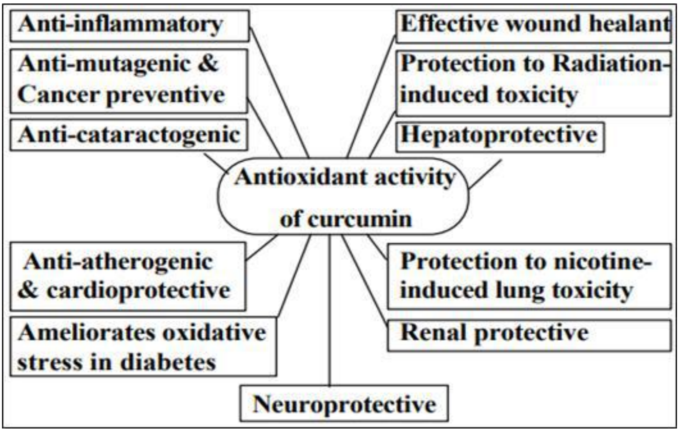
**Objective:** This article is based on the importance of different spices (Nutraceutical compounds) for Human Health.

**Findings:** It is found that different spices and condiments like turmeric, cumin seeds, fenugreek seeds, asafoetida, onion, garlic etc having numerous health benefits.

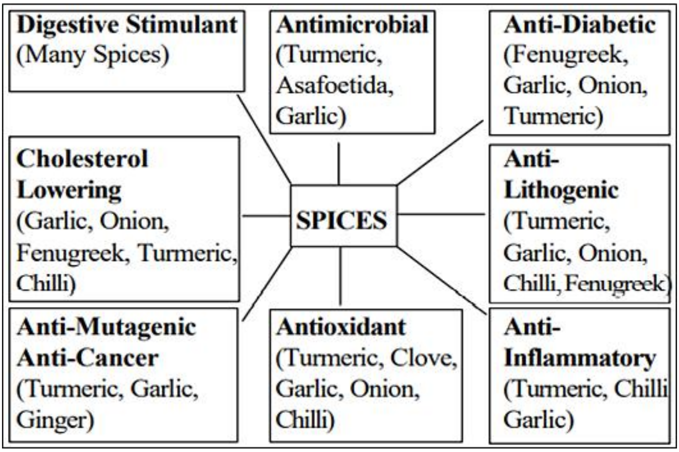
**Mechanism of anti-initiation, anti-promotion, antiprogression and anti-metastasis potential of spices**




**Health implications of antioxidant property**



**Summary of multiple health effects of spices**




**Study-5**

**Role of nutraceuticals in various diseases: a comprehensive review**

Chintale A *et al*., 2013.

**Objective:** To analyse the potential health benefits of Nutraceutical Foods or compounds in case of Human being.

**Findings:** It was found that various vitamins, spices, condiments, herbs and phytochemicals are having numerous health benefits in case of Humans.

**Nutrients and their health benefits**

| Nutrients | Health benefit |
|---|---|
| Vitamin A | Antioxidant, essential, for growth and development and in the treatment of certain skin disorders. |
| Vitamin E | Antioxidant, helps form blood cells, muscles, lung and nerve tissue, boosts the immune system. |
| Vitamin K | Essential for blood clotting |
| Vitamin C | Antioxidant, for healthy bones, gums, teeth and skin, in wound healing, prevent common cold and attenuate its symptoms. |
| Vitamin B1 | Helps to convert food in to energy, essential in neurologic functions. |
| Vitamin B2 | Helps in energy production and other chemical processes in the body, helps maintain healthy eyes, skin and nerve function. |
| Vitamin B3 | Helps to convert food in to energy and maintain proper brain function. |
| Folic acid | Produce the genetic materials of cells, in pregnancy for preventing birth defects, RBCs formation, protects against heartdisease. |

## Herbals and their therapeutic significance

| Herbals (Botanicalsource) | Therapeutic activity |
|---|---|
| Aloe Vera gel (Aloe Vera L. N.L.Burm.) | Dilates capillaries, anti-inflammatory, emollient, wound healing properties. |
| Ephedra (Ephedra sinica Stapf.) | Bronchodilator, vasoconstrictor, reduces bronchial Edema. |
| Garlic (Allium sativum L.) | Antibacterial, antifungal, antithrombotic, hypotensive anti-inflammatory |
| Licorice (Glycyrrhiza glabra L.) | Expectorant, secretolytic, treatment of peptic ulcer. |
| Ginger (Zingiber officinale Rosc.) | Carminative, antiemetic, cholagogue, positive inotropic. |

## Phytochemicals and their effects

| Phyochemicals | Source and content | Action |
|---|---|---|
| Carotenoids | Genistein, quercetin, rutinObtain from tomatoLycopene and β-carotene. | Inhibit carcinogenesis in tumour cells. Induce apoptosis in prostate cancer cells and malignant lymphoblast cells by DNA fragmentation, poly ADP-ribose polymerase (PARP) cleavage, and caspase-3activation. |
| Stilbenes | Obtain from grapes, peanuts, and pines Resveratrol (3,5,4-trihydroxy-trans-stilbene) | Induces apoptosis and inhibits the growth of various human tumour cells, including oral squamous carcinoma, promyelocytic leukaemia, human breast cancer cells, and prostate cancer cells, oesophagealcarcinoma cells by induction of p53 at the mRNA and protein levels. |

## Conclusion

Nutraceuticals are the compounds which may be the food itself or may be a part of the food or it may include other synthetic dietary healthy supplements. This chapter highlights the concept, classification, sources and health benefits of Nutraceuticals in Human being. Either one food or any supplement would be giving maximum satisfactory result when it will be utilised or consumed judiciously with monitoring and proper supervision as per the need of an Individual. It will vary according to age, gender, socio-economic condition, food preference, likings and dislikings, physiological and pathological conditions. To avail maximum benefit from a Nutraceutical product, before using that we should consult one dietitian or any physician so that they can guide us about the best product for us as per our bodily requirement.

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# Chapter - 5
# Effect of Biopriming with Plant Growth Promoting Rhizobacteria (PGPR)


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# Chapter - 5

## Effect of Biopriming with Plant Growth Promoting Rhizobacteria (PGPR)

**SP Monalisa and Subhalaxmi Roy**

### Abstract

Biopriming is a quality enhancement technique in which treats the seeds with beneficial micro-organisms under controlled hydration which enhances the preparatory processes prior to germination without the emergence of the radicle. PGPR application is very essential for sustainable agriculture. Biopriming agents (Biocontrol agents) directly release growth promoting hormones viz. indole acetic acid, gibberellin and cytokinin or stimulate their production in the plant. They also improve the availability of minerals like nitrogen, phosphorus, potassium and iron. The PGPR biopriming enhances production of soluble protein, soluble sugar, phenolic acid, salicylic acid and plant growth hormones. The biopriming technology also induce early DNA and protein synthesis and enhances the expression of RUBISCO and chl a/b, ß-tubulin and GST genes which have better carboxylation capacity and efficient photosynthesis where by stimulate early germination process and vigorous plant growth. Lastly this study confirms the beneficial effects of biopriming on seed germination plant stand establishment, growth and development.

**Keywords:** Biopriming, PGPR, RUBISCO and seed germination

### Introduction

Seed is the basic unit of agriculture and seed quality plays an important role in the production of agronomic and horticultural crops. Characteristics such as trueness to variety, germination percentage, purity, vigour and appearance are important to farmers planting crop and to homeowners establishing lawn and gardens. Seed enhancement is a range of treatments of seeds that improves their performance after harvesting and conditioned but before they are sown. They include priming, steeping, hardening, pre-germination, pelleting, and encrusting and film coating. They are used to improve seed sowing, germination and seedling growth by altering seed vigour and or the physiological state of the seed. The alteration may improve vigour or the physiological state of the seed by enhancing uniformity of germination.

Secretion of nutrients by plant roots enhances the abundance of micro-organisms in the rhizosphere. Plant and rhizosphere micro-organism have a close association, some are beneficial and others are detrimental. Beneficial micro-organisms have the ability to live within or in the vicinity of plant roots and promote plant growth and developments are known as plant growth promoting rhizobacteria (PGPR) (Kloepper, 1980 and Kavino, 2008). PGPR affect plant growth in two different ways, indirectly or directly. The direct and indirect effects of PGPR on plant growth and development are noticeable (Glick, 1995 and Patten, 2002). The direct promotion of plant growth by PGPR entails either providing the plant with a compound that is synthesized by the bacterium, for example phytohormones or facilitating the uptake of certain nutrients from the environment (Glick, 1995). The indirect promotion of plant growth occurs when PGPR prevent the deleterious effects of one or more phytopathogenic organisms. This can be happen by producing antagonistic substances or by inducing resistant to pathogens (Glick, 1995). The PGPR plays an important role in improving and maintaining soil structure and bioremediation of contaminated soil. The PGPR based on the application in agriculture are classified into various groups (Table-1).

PGPR and their interactions with plants are exploited commercially (Podile and Kishore, 2006) and hold great promise for sustainable agriculture. Applications of these associations have been investigated in maize, wheat, oat, barley, peas, canola, soybean, potatoes, tomatoes, lentils and cucumber (Gray and Smith, 2005). For a sustainable agriculture, symbiotic PGPR (Rhizobium and Frankia) and non-symbiotic (*Azotobactor*, *Azospirillum* and *Bacillus*) are commercially applied to enhance yield and reduce the use of harmful agrochemicals. Survival of PGPR on seed and in soil mainly depends on the method of application and competency of the introduced bacteria with other bacteria present in the rhizosphere.

Augmentation of PGPR into plants can be achieved by different methodologies including direct soil application, root dipping method, seed coat, seed pelleting and seed priming. Direct application of inoculums into the soil is advisable when the plant tissue contains some antagonist microbes or pesticidal compounds. It is a simple and easy method but the requirement of large inoculums make it very costly further, it needs special care during transportation and after field application (Bashan, 1998). The root dipping method is mainly focused for biocontrol but it requires preparation of plant nurseries which is not cost effective for some plants (Srinivasan, 2009, Munif, 2013, Bashan, 1990).

**Table 1:** Major groups of PGPR based on the application in agriculture

| PGPR | Group | Application | References |
|---|---|---|---|
| *Azotobacter chroococcum* | Biofertilizer | Increasing the availability of nutrients to plant | Kumar *et al*., 2001 |
| *Bacillus* sp. | Biofertilizer | Increasing the availability of nutrients to plant | Canbolat *et al*., 2006 |
| *Stenotrophomonas maltophilia* | Biofertilizer | Increasing the availability of nutrients to plant | Mehnaz *et al*., 2010 |
| *Rhizobium leguminosarum* | Phytostimulator | Plant growth promotion generally through phytohormones | Noel *et al*., 1996 |
| *Azotobacter chroococcum* | Phytostimulator | Plant growth promotion generally through phytohormones | Verma *et al*., 2001 |
| *Xanthomonas* sp. | Phytostimulator | Plant growth promotion generally through phytohormones | Sheng and Xia 2006 |
| *Bacillus* sp. | Phytostimulator | Plant growth promotion generally through phytohormones | Wani and Khan 2010 |
| *Pseudomonas putida* | Rhizoremediation | Degrading organic pollutants | Tripathi *et al*., 2005 |
| *Psychrobactor* sp. | Rhizoremediation | Degrading organic pollutants | Ma *et al*., 2011 |
| *Bradyrhizobium* sp. | Rhizoremediation | Degrading organic pollutants | Dary *et al*., 2010 |
| *Pseudomonas chlororaphis* | Biopesticide | Controlling diseases mainly by producing antibiotics and antifungal metabolites | Lie *et al*., 2007 |
| *Bacillus substilis* | Biopesticide | Controlling diseases mainly by producing antibiotics and antifungal metabolites | Cazorla *et al*.,2007 |
| *Pseudomonas fluorescence* | Biopesticide | Controlling diseases mainly by producing antibiotics and antifungal metabolites | Braud *et al*., 2009 |
| *Streptomyces* sp. | Biopesticide | Controlling diseases mainly by producing antibiotics and antifungal | Bhattacharyya and Jha 2012 |

| | | | |
|---|---|---|---|
| | | metabolites | |
| *Micromonospora* sp. | Biopesticide | Controlling diseases mainly by producing antibiotics and antifungal metabolites | Franco-Correa *et al.*, 2010 |

Seed priming is a seed quality enhancement technique in which seeds are soaked with water or in a solution of a specific priming agent with restricted water availability under control conditions followed by drying of seeds into its original weight that initiates preparatory germination related processes and maintaining the seeds into $G_2$ phase by extending lag phase of germination. Seed priming enables seed to germinate and emerge even under adverse agro-climatic conditions such as cold and wet or extreme heat. Uniform emergence helps optimize harvesting efficiency which can increase yield potential and quality. All the plants emerge at same time, mature at the same time, if we are following this seed priming methods. Priming also helps improve vigour for fast and healthy plant development. Seed priming methods are of different types, hydropriming, halopriming, osmopriming, solid-matrix priming and biopriming. Hydropriming means seeds are soaked with normal water (Mabhaudhi *et al*., 2011). Halopriming means seeds are soaked with a solution containing NaCl, $KNO_3$, $CaCl_2$ and $CaSo_4$ etc (Golezani, 2010 and Soughir, 2012). The Osmopriming means seeds are soaked with osmoticants like sugar, mannitol, PEG etc (Arin, 2003, Golezani, 2008 and Navin, 2014). Biopriming means priming with the use of biocontrol organisms (Nithya, 2015 and Sureshrao, 2016). This described review mainly concerned on physiological, biochemical and molecular changes in seedling of PGPR bioprimed seeds and how these changes/influences the germination, seedling vigour index, growth, development of plants.

**Biopriming method**

Biopriming is a new technique of seed treatment that integrates biological (inoculation of seed with beneficial organism to protect seed) and physiological aspects of disease control. It is recently used as an alternative method for controlling many seed and soil borne pathogens. It is an ecological approach using selected fungal antagonist against soil and seed borne pathogens. Biological seed treatments provide an alternative to chemical control with additional benefits of induced disease resistance, eco-friendly nature and sustainable disease management. *T. viride*, *T. harzianum*, *P. fluorescence* are different biocontrol agents frequently used for biopriming treatments. Several researchers have investigated the use of beneficial micro-organisms in the priming medium to control disease proliferation during priming itself (Waren and Bennet, 2001). Biopriming is associated with an increase in hydrolytic enzyme activities, reactive oxygen species (ROS) detoxifying enzyme activities and alternation in internal plant hormone levels, and also a differential expression of genes in plants that contributes the enhanced plat growth and resistance against biotic and abiotic stress. Innovative research studies at biochemical, proteomics and transcriptome levels are necessary to understand the role of biopriming with PGPRs in phyto-stimulation and nutrient enhancement.

**The direct effect of biopriming**

PGPR in primed seeds are colonizing the root surface of plant and competing with other organisms which are present in the rhizosphere. Bioprimed seeds help for secretion of compounds and mineral solubilisation. PGPR in the primed seeds convert atmospheric Nitrogen into plant absorbable form by the process of BNF (Biological nitrogen fixation) due to the presence of nitrogenase enzyme coded by nif gene (Thakuria *et al*., 2004 and Kim *et al*., 1994). The nitrogen fixing PGPR may be symbiotic like rhizobia and diazotrophs or non-symbiotic like *Azospirillum*, *Azotobactor* and *Cyanobacteria* (Glick *et al*., 1999 and Ahemad *et al*., 2012).

Phosphorus is an important part of nucleic acid, phophoproteins, phospholipids, phosphate molecules and enzymes in plants and its major role to influence the growth of the Lateral root system/morphology, root development, root branching and root to shoot ratio (Lopez-Bucio *et al*., 2002 and Jin J *et al*., 2005). PGPR used in biopriming have also the ability to solubilize potassium from potassium bearing minerals by excretion of organic acids (citric, tartaric and oxalic acids) directly dissolving the rock phosphate (Sheng *et al*., 2006).

Potassium is another important macronutrient which improves the nitrogen use efficiency, enzyme activation, stomatal activity, water, nutrient, sugar transport helps in photosynthesis in pants (Prajapati and Modi 2012, Van Brunt and Sultenfuss 1998, Thomas and Thomas 2009).

Bioprimed seeds produced siderophore which suppressed the plant diseases and improved plant growth (Keshwani *et al*., 2014 and Jain *et al*., 2012). Some of the PGPR like *P. putida*, *B. species* and *Enterobacter* sp. Under stress condition produced 1-Aminocyclopropane-1-carboxylate (ACC) deaminase and reduced ethylene content in plants which helps the growth and development of plants (Patten and Glick, 1996). PGPR helps to produced auxin which is an enhancer of plant cell division and differentiation, xylem and root development, Lateral and Adventitious root formation (Patten and Glick, 1996). *Salvia officinalis* bioprimed seeds with PGPR produced moderate auxin, high germinability and reduced higher root growth (Mansour *et al*., 2014).

Bioprimed seeds with IAA released rhizobacteria loosened plant cell wall and increased root exudation form plant, availed additional nutrient to plants and supported growth of the plant in the rhizosphere. The gibberellin and cytokinin produced by *Azotobacter chrococccum* and *Rhizobium leguminosarum* have a positive effect on plant growth and development.

**Biopriming with PGPR effect on the physiological parameters**

Physiological parameters include the root length, root depth, root thickness, root shoot ratio involved for the growth and development of plants. Biopriming seeds with PGPR reported the enhancement of roots and producing a vigorous root system. Root to leaves ratio increased in Rice reported by Marcela *et al*., 2014. Bioprimed crops increased the root shoot ratio, root system, leaf number, leaf area and chlorophyll content (Priya *et al*., 2016 and Rawat *et al*., 2012). Bioprimed soybean seeds increased root and shoot length (Anith *et al*., 2015). Bioprimed rice seed with PGPR increased lignin content in plants (Marcela *et al*., 2014). Bioprimed seeds increased the plant nutrient uptake, nutrient use efficiency in plants, good plant stand in normal condition as well as stressed condition (Tanwar *et al*., 2013, Moeinzadeh *et al*., 2010, Muruli *et al*., 2013).

Biopriming with PGPR minimizing the time required for lignification of micropropagated plants and accelerates production process (Kavino *et al*., 2010, and Ramamoorthy *et al*., 2002).

**Biopriming with PGPR effects on biochemical parameters**

Bioprimed seeds have an advantage over non-bioprimed seeds at the early process of germination ($G_1$ and $G_2$ phase of germination) because those primed seeds have large carbohydrate reserves, which strength the plants to withstand in low oxygen stream under flooded condition (Ella *et al*., 2011). Bioprimed seeds enhanced the production of proteins, hormones, phenol and flavonoid compounds which helps in better plant growth and development. (Cyr *et al*., 1990 and Volence *et al*., 1996). Compared to non-primed seeds, soluble protein percentage, and seedlings were higher in bioprimed seeds. (Dhanya *et al*., 2014). Bioprimed seeds with PGPR produced high total protein, free amino acid content during the different growth stages (Aishwath *et al*., 2012 and Warwate *et al*., 2017 and Ahmed *et al*., 2014). Total soluble sugar and reduced sugar content in plants increased after biopriming (Hafsa *et al*., 2014). Bioprimed seeds responsible for increasing the efficient mitochondrial development by increasing the ATP producing system (Chen, 2007). Bioprimed with PGPR enhanced the synthesis of specific phenolic acid in plants at different growth system (Singh *et al*., 2003) and also the total phenol content in rice (Marcela *et al*., 2014). Biopriming increased the Indole acetic acid content in plant so that it enhanced the number of roots, root hairs, plant cell division, cell differentiation, xylem and root development, lateral and adventitious root systems, pigment formation and synthesis of metabolites (Spaepen *et al*., 2011). Biopriming also stimulate the production of defense-related enzymes (Peroxidase, superoxide dismutase, catalase, lyases etc.) which gives fitness benefit to plants against abiotic and biotic stresses.

**Biopriming with PGPR effects on gene expression**

Biopriming leads to transcriptome level changes that make plant quick responsive. Microtubules consist of α tubulins and ß tubulins. α tubulinsand ß tubulins are the structural elements in cell growth and development, morphogenesis and main role in regulation and signal transduction. As compared to untreated seeds, the accumulation of ß tubulin preceded DNA synthesis earlier, approximately 12 hr in primed seeds. It was earlier reported that, the ß tubulin was higher after priming in Pepper and were found to be correlated with improved seed germination (Lanteri *et al*., 1993). The transcriptome level studies provide a platform for comparative analysis of the plant roots response towards PGPR used in biopriming and a pathogen. Repairing of the damaged part of the seeds and reduction in metabolic exudates were facilitated with priming by early transcription and protein synthesis. Pseudomonas fluorescence priming in rice seeds showed over expression of RUBISCO, led to increase in photosynthesis activity (Kandasamy *et al*., 2009) and also biopriming enhanced the RUBISCO and chl a and chl b binding genes, which helps to increase the carboxylation activity and photosynthesis activity (Hussain *et al*., 2016 and Mommer *et al*., 2005). Biopriming also regulated the respiration, energy metabolism and early reserve mobilization events in crops (Chen, 2007 and Paparella *et al*., 2015). Upregulation of expansion gene which is responsible for cell wall loosening was found important for coleoptile formation and elongation (Choi *et al*., 2003 and Magneschi *et al*., 2009). Hussaion *et al*., 2016 reported the expansa in genes expression enhanced in bioprimed rice plant under submerged condition. In rice, the expression of NADH-GOGAT and GAPDH enhanced which involved in energy production and biomass accumulation (Tamura *et al*., 2011 and Hussain *et al*., 2016).

In *Pseudomonas fluorescens* primed rice plant, the over expression of GST, which was essential in induced systemic resistance (ISR) and protecting cells from oxidative damage reported by Kandasamy *et al*., 2009. Bioprimed also induced overexpression of genes involved in the regulation of secondary metabolism, development, and transport protein and metal handling.

## Conclusion

Biopriming is a seed quality enhancement technology which has a direct and indirect effect on plant growth and development PGPR with biopriming have the ability to produce plant growth hormones (IAA, gibberellin and Cytokinin) and also have nitrogen fixation ability, which help in plant growth and development. Biopriming (biocontrol agents) producing some antibiotics, antifungal metabolites and by degrading organic pollutants. Biopriming has reported a positive impact on seed quality parameters like seedling vigour, germination percentage, and speed of germination, growth, development, yield, production and productivity of crops. Biopriming with PGPR enhances the plant root system which is a major parameters for better production. Biopriming also enhances the total protein content, reduced sugar content and ATP production in plants. Biopriming also helps in producing efficient mitochondrial development by augmenting energy metabolism. In bioprimed seeds, the induction of DNA synthesis, transcription and protein synthesis was found earlier as compared to non-primed seeds. Further biopriming found to enhance the expression of RUBISCO, chl-a, chl-b, protein coding genes, expansin genes, GST gene and ß tubulin. So, biopriming improves all parameters like physiological, biochemical and molecular which is very much essential for modern agriculture.

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# Chapter - 6
# Fate of Genetically Modified Crops in India and the World

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# Chapter - 6

## Fate of Genetically Modified Crops in India and the World

**Ikkurti Gopinath, B.K. Namriboi and Kamre Kranthi Kumar**

**Abstract**

The acceptance of genetically modified (GM) organisms specifically crop plants has initiated intense public debates in many parts of the world and in India also this has engaged the attention of government and farming societies. Crops/varieties developed from or using GM organisms and thus engineered are often referred to as GM crops or transgenic plants. The initial objective for developing GM crops was to induce crop protection and herbicide tolerance. There are several regulations governing GM crops that differ from country to country countries to assess and manage the risks and benefits of GM crops. Over the past decade biotechnology has been very successful in helping farmers producing higher yield. The acceptance of the GM crops among farmers is still a challenge regarding few notable failures in India. Therefore, it is important to regulate GM crops in every aspect.

**Keywords:** Biotechnology, crops, farmers, India, regulate, transgenic.

**Introduction**

Biotechnology is one of the most reviewed and extensively researched agricultural developments in human history. One such achievement using biotechnology, however, has given multiple promises, concerns and question, namely Genetically Modified Organisms (GMOs). The acceptance of GMOs caused intense public debates in many parts of the world and in India also this has engaged the attention of government and farming societies. GMOs are the ones whose genetic material (usually DNA) is altered by the application of recombinant DNA technology resulting in an organism that is genetically engineered or modified carrying a transgene. Numerous genetically modified (GM) crops or transgenic crops carrying required novel quality traits have been developed and released for economic purpose as biotechnology advanced rapidly. These include pest resistant cotton, maize, canola and herbicide glyphosate resistant soybean, cotton and viral disease resistant potatoes, papaya and squash. In addition to these, several transgenic crops are under the process of development and screening by concerned regulatory bodies some of which possess traits for bio fortification, phytoremediation and molecular farming. Commercial cultivation of GM crops started in the early 1990s. The initial objective for developing GM crops was to induce crop protection and herbicide tolerance. China was the first country that commercialized transgenic plants by introducing a virus resistant tobacco in 1992. In 1994 Calgene was approved to commercialise FlavrSavr tomato, the first genetically modified food. The main GM crops under commercial cultivation are soybean, maize, canola and cotton. The area under GM crops has increased from 1.7 million hectares in 1996 to 190.4 million hectares in 2019 (http://www.statista.com). India contributes 11.4 million hectares of the area and stands 5$^{th}$ on global scale for area under GM crops in 2017. The top rankers in the list are USA (71.5 million hectares), Brazil (52.8 million hectares) followed by Argentina, Canada and India. The preference of GM crops varies from country to country with insect resistant cotton in African countries and India to herbicide resistant soybean in USA. ISAAA and PG Economics Ltd. reported biotech crops provided 186.1 billion dollars in economic gains to some 17 million farmers, many of whom are female, smallholder farmers solely responsible for the livelihood of their families and communities. The increase cultivation of GM crops has raised many issues relating to food and environmental safety with socio-economic issues that include possible toxicity, allergenic reactions, non-target organisms, evolution of pest resistance and private sector monopoly. There are several regulations governing GM crops that differ from country to country countries to assess and manage the risks and benefits of GM crops. Regulation varies with the intended use of the crop with most marked differences occurring between the USA and Europe while in India the same is regulated by GEAC, NBRA and Ministry of Environment, Forest and Climate Change (MoEFCC). With the ever-increasing population we cannot feed the world of tomorrow with yesterday’s technology.

## What are genetically modified crops

GM stands for 'genetic modification' or 'genetically modified'. By genetic modification plants, animals and micro-organisms having specific qualities are produced. According to WHO the GMOs are those organisms (i.e. plants, animals or microorganisms) whose genetic material is altered by introduction or modification of the genetic element which otherwise is not possible by Mendelian breeding and natural. The technology is often called “modern biotechnology” or “gene technology”, sometimes also “recombinant DNA technology” or “genetic engineering”. It allows selected individual genes of interest to be transferred from one organism into another, also between nonrelated species (cis/transgenic). Foods produced from or using GM organisms are often referred to as GM foods.

**How is GM crops processed?**

The whole process of creating a genetically modified crop, from locating the required transgene in a foreign organism to its final expression in the recipient organism is a stressful yet robust process which outpaces the natural sexual reproduction mechanism and usually increases the organism’s DNA content from outside cell. The possible process of recombinant DNA technology used for developing transgenic crops involves gene transfer from alien sources into economic crop plants to yield the desired quality and fulfil the objective. Of the various available methods, one mediated through *Agrobacterium tumefaciens* is most common (Walden *et al*., 1990).

In an affected plant, Agrobacterium induces production of certain protein molecules, opines, which are fed on by the bacteria, whose genetic information (*vir* region) is provided by a bacterial plasmid itself which channels into the genome of host. The plasmid is called tumour inducing (*Ti*) plasmid. By means of restriction enzyme the *Ti* plasmid is disarmed by digesting out the *vir* region of the *Ti* plasmid responsible for opine synthesis and the alien DNA gene is deposited in the *Ti*-DNA. The transformed cells are tested for the presence of the transgene by the use of selectable or scorable markers which are carried forward for regeneration followed by hardening. Many genes relevant to agricultural uses were transferred into the crop plants.

The process also follows a direct gene transfer. The target DNA is directly injected into the host-plant cells using chemical method (PEG-poly ethylene glycol), electroporation, particle gun bombardment (use of tungsten or gold coated DNA *i.e.,* micro projectiles) or microinjection of DNA directly inside the plant cells.

The basic steps involved in the development of a transgenic plant are summarised as under.

- Cutting DNA strands at specific points by using specific restriction endonucleases. A few restriction endonucleases are Bam HI, Eco RI, Eco R II, Hind II, Hind III, Taq I, etc.
- Insertion of DNA fragments into suitable vector and to produce recombinant DNA using endonucleases.

- Introduction of recombinant DNA into suitable organism/cell called a host. Generally, *E. coli* is the host.
- Transformation of host cell and selection of host cells transformed by recombinant DNA.
- Identification of clones having genes of interest and isolation of gene.
- Introduction of foreign gene into a plant and regeneration of transformed plant having new, novel gene which the target plant never had.

Therefore, it is inappropriate to call the genetically-engineered crops as genetically modified crops. However, the term genetically modified crops is used for genetically engineered crops since the term 'genetic engineering' applied to food crops invites a fear and negative impact in the minds of the public.

**GM crops in India and the world**

GM crop technology has revolutionized agriculture in the US, Canada, China and Argentina. It exhibits the potential for wider impact that could solve many of the current problems in agriculture worldwide. The GM crops that are to become available in the future could boost crop yields while enhancing the nutritional value of staple foods and eliminating the need for inputs that could be harmful to the environment. Whereas, the GM crops must be carefully analysed and studied for the environmental, health and economic risks prior to full scale adoption, there have been negligible instances of adverse health or environment impacts caused by the types of GM crops that are already available and thus far proven to be beneficial to farmers. The future success of GM crops in India and globally depends on various factors like the social economy of the country, the systems of agricultural practices and the governing regulatory systems which also have a great deciding factor.

**Status of GM Crops in India**

In India, the area under Bt cotton increased by 600,000 hectares, from 10.8 million hectares in 2016 to 11.8 million hectares in 2019, which is equivalent to 93% of the total cotton area of 12.24 million hectares grown in the country (http://www.pib.gov.in). In 2017, the Genetic Engineering Appraisal Committee (GEAC) of the Ministry of Environment, Forests & Climate Change (MoEF & CC) approved and recommended the economic release of mustard hybrid Dhara Mustard Hybrid-11 (DMH-11), a transgenic mustard. Parental lines of the hybrid were containing events Varuna bn 3.6 and EH-2 modbs 2.99 that were developed using barnase, barstar and bar genes developed by the Centre for Genetic Manipulation of Crop Plants (CGMCP) of the University of Delhi on May 11, 2017 (GEAC, 2017). Similarly, the GEAC of MOEF&CC kept in abeyance applications related to import of crude and processed soybean oil derived from different herbicide tolerant soybean events; soybean for food and feed purposes and import of distillers dried grains with soluble (DDGS) derived from biotech maize in 2017 (ISAAA,2017). India has enhanced farm income from Insect Resistant cotton by US$21.1 billion in the 13-year period from 2002 to 2016 and US$1.5 billion in 2016 alone. This comes as a result of average of 29% yield gain since 1996. These immense benefits have been enjoyed by more than 7.5 million farmers and their families and have contributed greatly to the improvement of economic status in the community (Brookes and Barfoot, 2018). India has approved 11 events for commercial production with includes 6 events of GM cotton and 5 events of GM soybean (http://www.isaaa.org/gmapprovaldatabase)

**Status of GM crops in the world**

From ahead of the first commercialization of first GM crop there has been a greater degree of public awareness of GM crops and the status of GM crops has dramatically changed. Farmers have enjoyed additional crops production benefits such as 92.2% and 98.5% additional maize and cotton production, respectively. For example, additional production to GM soybean added 202.3 million tonnes to soybean production in Argentina and Paraguay from 1996 to 2018.

**1. Global area under GM crops**

Almost 190.4 million hectares of world crop acreage planted with GM crops which is equivalent to almost 20% of the total land area of China (956 million hectares) or the USA (937 million hectares) and more than 7 times the land area of the United Kingdom (24.4 million hectares). The Americas constitute the largest growing region, but GM cotton area is substantial in Asia. The accumulated biotech crop area (planted since 1996) surged to a record 2.3 billion hectares/5.8 billion acres. Utilization of GM crops have changed farming land footprint as well allowing more yield from lesser land.

**2. Transgenic countries**

Of the total number of 29 countries planting biotech crops in 2019, 24 were developing countries and 4 were industrialized countries. The top ten countries, each of which grew over 1 million hectares in 2019, was led by the USA which grew 71.5 million hectares (40% of global total, higher by 2% in 2016), Brazil with 52.8 million hectares (26%), Argentina with 24 million hectares (12%), Canada with 13.1 million hectares (7%) and India with 11.9 million hectares (6%). The other notable countries are Paraguay, Pakistan, China, South Africa and Bolivia (ISAAA, 2017). The commercialization of a new transgenic crop is scrutinised by the regulatory bodies of the country and taken further as per the norms and needs. For example, Herbicide resistant cotton is approved in countries like Argentina, Australia, Brazil, Colombia, Costa Rica, Mexico, Paraguay, South Africa and US whereas the Insecticide resistant cotton is also accepted over these countries in Burkina Faso, China, India, Myanmar, Pakistan and Sudan with India being the largest producer of Bt cotton. Maize is approved as herbicide resistant transgenic crop in many countries rather than as an insecticide resistant transgenic crop. USA has approved 213 events in GM crops for commercial utilization where the maximum is contributed by maize and soybean.

## 3. Dominant transgenic traits

- Herbicide resistance (HT) : 63%
- Insect resistance due to *Bt*(IR) : 18%
- HT + IR stacked : 19%
- Abiotic stress tolerance
- Altered growth/yield component traits
- Disease resistance
- Modified product quality

## 4. Transgenic crops

In 2019, the most GM crops planted were soybean, maize, cotton and canola (Fig. 1). Many crops, among them foods, have been subjected to genetic modification. Alfalfa, Melon, Rose, Argentine, Canola, Papaya, Soybean, Carnation, Petunia, Squash, Chicory, Plum, Sugar Beet, Cotton, Polish canola, Sweet pepper, Creeping Bentgrass, Poplar, Tobacco, Flax, Linseed, Potato, Tomato, Maize, Rice and Wheat.

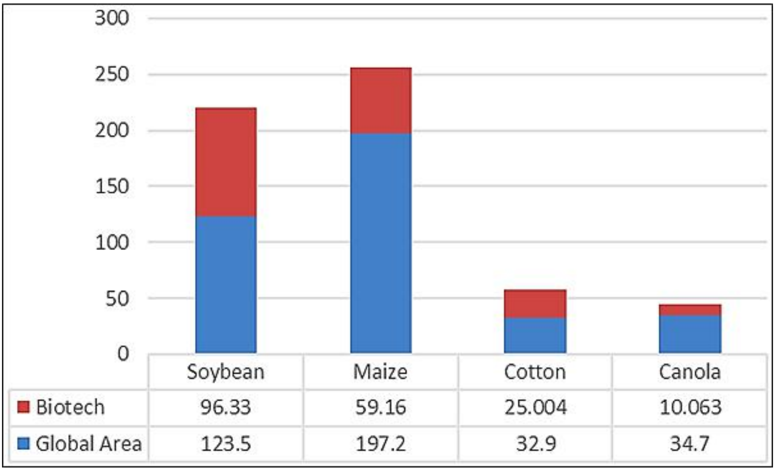


**Fig 1:** Top 4 Biotech crops against their global adoption rates (mha; million hectares)

## 5. Global value of transgenic crops

The six principal countries that have gained the most economically from biotech crops, during the first 21 years of commercialization of biotech crops, 1996 to 2016 are USA (US$80.3 billion), Argentina (US$23.7 billion), India (US$21.1 billion), Brazil (US$19.8 billion), China (US$19.6 billion), Canada (US$8 billion) and others (US$13.6 billion) for a total of US$186.1 billion (Brookes and Barfoot, 2018).

## 6. Safety and benefits

- No untoward incidents related to food/feed safety, environment or pest resistance in the last decades of their commercial cultivation.
- Significant increase in yield.
- Reduction in use of chemical pesticides.
- Social, economic and environmental benefits.

The benefits of GM crops to farmers and consumers can continue to be available if there is continuous implementation of science-based regulations, which should focus on the benefits of agricultural productivity along with environmental conservation and sustainability and most importantly to the poverty stricken and malnourished large portion of the world population who need improvement in their state of living.

## Regulation of genetically modified crops

The products derived from biotechnology processes are to be regulated stringently as per regulatory framework as “novel products”. The focus of regulation should be on the expression of traits developed transgenic and not on the method followed to genetically engineer the crop. An important ethical part of regulation should be making sure that the laws and regulations concerned with GM crops should prioritise innovation with promoting sustainability. The GM crops used as food are of major concern to consumers in terms of public acceptance. Social and economic interests should be considered for risk regulation while weight against health and safety at the end usage. The framework of regulation on GMOs varies between countries, with the most marked differences in the regulations by US and Europe. It is upon each country to introduce appropriate procedures requiring environmental impact assessment of its proposed projects that are likely to have significant adverse effects on biological diversity with a view to avoid or minimize such effects allow for public participation in such procedures. The stringent regulations carried by the concerned countries checked the irrelevant and unreasonable production of transgenic crops. Europe approved and grows relatively fewer transgenic crops while the exception is seen in Spain, where one fifth of Maize is genetically engineered.

In Indian regulation context, three Ministries/Departments deal with application of biotechnology in agriculture:

1) Ministry of Agriculture.
2) Ministry of Environment and Forests.
3) Department of Biotechnology, Ministry of Science and Technology.

Ministry of Environment and Forests, Government of India undertakes the legislative framework on agro biotechnology. Under the Environment (Protection) Act, 1986, the Ministry of Environment and Forests has legislated the Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Micro Organisms/ Genetically Engineered Organisms or Cells, 1989, or in short, the Rules, 1989. These rules and regulations cover the areas of research as well as large scale applications of the GMOs and such products throughout India. The rules have also defined competent authorities and the composition of such authorities for handling of various aspects of the rules. There are six competent authorities as per the rules (Fig. 2).

- Recombinant DNA Advisory Committee (RDAC).
- Review Committee on Genetic Manipulation (RCGM).
- Genetic Engineering Approval Committee (GEAC).
- Institutional Biosafety Committees (IBSC).

- State Biosafety Coordination Committees (SBCC).
- District Level Committees (DLC).

Out of these, the three agencies that are involved in approval of new transgenic crops are:

- IBSC set-up at each institution for monitoring institute level research in genetically modified organisms.
- RCGM functioning in the DBT to monitor ongoing research activities in GMOs and small-scale field trials.
- GEAC functioning in the MoEF to authorize large-scale trials and environmental release of GMOs.

The Recombinant DNA Advisory Committee (RDAC) constituted by DBT takes note of developments in biotechnology at national and international level and prepares suitable recommendations. The State Biotechnology Coordination Committees (SBCCs) are set up in each state where research and application of GMOs are contemplated, coordinate the activities related to GMOs in the state with the central ministry. SBCCs conduct monitoring of the transgenic functions and therefore authorised to inspect, investigate and to take regulatory punitive action in case of violations. Similarly, District Level Committees (DLCs) are constituted at district level to monitor the safety regulations in installations engaged in the use of GMOs in research and application.

**Recombinant DNA guidelines, 1990**

With the advancement of research in biotechnology initiated by various Indian institutions and industry, Department of Biotechnology had formulated Recombinant DNA Guidelines in 1990. These guidelines were further revised in 1994 to cover R&D activities on GMOs, transgenic crops, large-scale production and deliberate release of GMOs, plants, animals and products into the environment, shipment and importation of GMOs for laboratory research.

**Guidelines for research in transgenic plants, 1998**

In 1998, DBT brought out separate guidelines for carrying out research in transgenic plants called the Revised Guidelines for Research in Transgenic Plants. These also include the guidelines for toxicity and allergenicity of transgenic seeds, plants and plant parts. These guidelines cover areas of recombinant DNA research on plants including the development of transgenic plants and their growth in soil for molecular and field evaluation. The guidelines also deal with import and shipment of genetically modified plants of research purposes. The regulations require consideration of all relevant matters. The researcher should provide scientific data which includes information on the nature of the novel trait, its stability in plant, all test data pertinent to environmental and human risks evaluation and assessment; and protocols that direct to preventing the establishment and subsequent spread into the environment of the genetic material compromising the allele frequency through end user selection therefore contingency and monitoring plans to minimize any adverse effect of an unintended movement outside the confined release site such as pollution of the gene pool of cultivated crops and pollution of off-farm organisms and causing gene contamination.

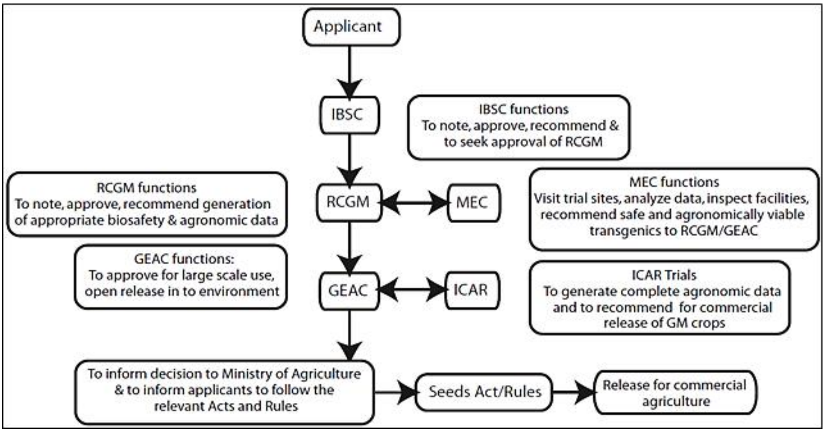


**Fig 2:** Procedures involved in the approval of GM crops in India

## Labelling issues

India, along with a number of other countries, has supported the mandatory labelling of GM food by Codex. Out of the two options under discussion by Codex i.e. Option 1 requires labelling when the products obtained through biotechnology differ significantly from the corresponding food as regards the composition, nutritional value or intended use and Option 2 require the declaration of the method of production for food and ingredients composed of or containing genetically modified/engineered organisms and food or food ingredients produced from, but not containing, genetically modified/engineered organisms if they contain protein or DNA resulting from gene technology or differ significantly from the corresponding food. The labelling of food derived from biotechnology is a major issue for India as its delegation at the CCFL has been seeking to achieve mandatory labelling as set out in Option 2. However, Option 2 has also raised a number of issues of concern including the enforcement, methodology, economic cost, consumer perception and difficulties likely to be faced.

GMOs are regulated in the United States under the Coordinated Framework for Regulation of Biotechnology, published in 1986 with a focus on the nature of the products rather than the process in which they are produced. The US is not a party to the Cartagena Protocol on Biosafety and thus there are no legislation that is specific to GMOs. As a signatory but a non-party to the parent Convention on Biological Diversity, it cannot become a party to the Protocol. It has participated in meetings as a non-party observer, however. The three main agencies involved in regulating GMOs are the US Department of Agriculture's Animal and Plant Health Inspection Service (APHIS), the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA). A series of polls found that public understanding of biotechnology was relatively low and that consumers were relatively unaware of the extent to which their foods included genetically modified ingredients. This could also be due to the recent findings that several scientific organizations in the United States have reported studies and statements covering the safety of GMOs indicating no safety risks compared to conventionally bred crops/organisms (American Medical Association, 2000). In fact, there is no law in the US requiring that GMO foods or foods with GMO ingredients be labelled to so indicate.

European Union regulation on GMOs, in particular has been unable to keep up with new discoveries in the field of biotechnology. As a result, a significant legal uncertainty makes the law itself very much unclear and ineffective. However, the EU and the rest of the Europe strictly regulate the use of GMOs.

It is illegal in Norway to commercialise with intention to sell or promote food or feed derived from GMOs, such as genetically modified plants. The legal framework of EU aims to protect human and animal health and the environment by introducing a safety assessment of the highest possible standards at the EU level before any GMO is placed on the market. It aims to put in place the harmonised procedures for risk assessment and ensures clear labelling of GMOs places in the market in order to enable consumers to make an informed choice. It also ensures the traceability of GM crops commercialised.

In Canada the Canadian Food Inspection Agency (CFIA) is responsible for monitoring genetically modified plants and approving as food regulated by Food and Drugs Act (2003). Health Canada is mandate to authorize them to be sold commercially and foodstuff. Pre-market evaluation to assess the safety and nutritional adequacy of novel foods proposed for sale is conducted. The country also regulates the research purposes by setting out rules and conditions for how they are to be conducted which are timely assessed by government scientists to ensure the trials do not endanger the environment. According to Health Canada, it is a “seven to ten-year process to research, develop, test and assess the safety of a new GM food” before it can be approved.

**International protocols**

Two major international protocols address genetically modified organisms, the Cartagena Protocol of 2000 and the Nagoya-Kuala Lumpur Supplementary Protocol of 2010. They are attached to the Convention on Biological Diversity of 1993. They are applicable only to transboundary actions; they do not apply to use or transit of GMOs within countries.

**Cartagena protocol**

The major international instrument on genetically modified organisms (GMOs) is the Cartagena Protocol on Biosafety to the Convention on Biological Diversity. The Protocol was adopted on January 29, 2000 and became effective on September 11, 2003. It was designed to safeguard and protect both biological diversity and human life from any harmful effects of organisms modified by technology. The Protocol has a participation of 166 parties at present where it is applicable; the United States is not a party.

The protocol stands with its objective which is “to contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health and specifically focusing on transboundary movements”.

The Cartagena Protocol on Biosafety declares that the parties, in reaching a decision on import under the protocol or under its domestic measures implementing the protocol, may take into account “socio-economic considerations arising from the impact of living modified organisms on conservation and sustainable use of biological diversity. The Protocol also contains provisions on accidental movement of GMOs across borders, handling and labelling and illegal transboundary transmissions

**Nagoya protocol**

Following years of negotiations over the question of liability for GMO-produced damages, on October 15, 2010, the Nagoya-Kuala Lumpur Supplementary Protocol was adopted on Liability and Redress to the Cartagena Protocol on Biosafety (the supplementary protocol) that provides international rules and procedure on liability and redress for damage to biodiversity and ecosystem resulting from living modified organisms.

It applies to damage from GMOs that cross borders and defines "damage" as an adverse effect on the conservation and sustainable use of biological diversity, taking also into account risks to human health that is measurable or otherwise observable taking into account, wherever available, scientifically-established baselines recognized by a competent authority that takes into account any other human induced variation and natural variation; and is significant.

The Conference of the Parties serving as the meeting of the parties for the Cartagena Protocol serves as the Conference of the Parties to the Supplementary Protocol. The basic principle underlying the Supplementary Protocol is that the polluter has to pay for any damage caused by the organism. An important basic principle is that a causal link must be established between the damage incurred and the GMO in question.

**Benefits**

Upto 17 million farmers (up to 90% were small/poor farmers) in 29 countries who have planted biotech crops attest to the multiple benefits they derived in the last 21 years as follows:

- Increased productivity that contributes to global food, feed and fibre security.
- Self-sufficiency on a nation's arable land.
- Conserving biodiversity, precluding deforestation and protecting biodiversity sanctuaries.
- Mitigating the challenges associated with climate change.
- Improving economic, health and social benefits. (ISAAA, 2017).

GM crops are improved for resistance to diseases, pests and herbicides, tolerance to cold/heat, improved tolerance to drought/salinity and reduced maturation time. Also, there are research activities carried out for increased nutrients, yields, quality and stress tolerance and food with greater shelf life or food with medicinal benefits, such as edible vaccines for example, bananas with bacterial or rotavirus antigens Increased food security for growing. GM crops could address several such problems where the convention and other breeding techniques have failed. With the current event of frequent climate change activities shown by the nature, genetic engineering could develop crops that can withstand environmental stresses such as prolonged water stress or frost.

**Issues and Controversies**

Despite the multiple promises, concerns and questions are raised regarding the safety, socio economic aspects, food and environmental aspects, patenting aspects, market monopoly aspects, increased prices and biodiversity issues nonetheless, the scientists are more likely to perceive GM crops as safe than the common man and the members of the public who see the GM crop food as unnatural with various fears. Health and environmental safety over genetic engineering was emphasized by Kesavan and Swaminathan (2018) with a deep concern for conservation of Biodiversity. Certain writers such as Michael Pollan mentioned that mandatory labelling of GM foods is necessary and criticized the pesticide dependent heavy monoculture farming of some approved GM crops such as glycophosphate tolerant “Roundup-ready” corn and soybeans. Rich biodiversity of the planet Earth would not have come about but for ‘reproductive isolation’ to gene exchange and the genetic engineering, on the contrary has demolished the reproductive isolation. Further, the Mendelian breeding does not fit into the genetic engineering framework in two aspects:

i) Insertion of genes from widely unrelated organisms into the cells of recipient organisms by means other than sexual reproduction.

ii) Adding a gene (DNA) from outside into the recipient genome, thus increasing the DNA content of the cell from outside.

Gene migration among the species utilising the GM crops has become a major concern as there were multiple case of expression and development of anti-vigour complexes in the end users and other related organisms. One of the first reports was that the FlavrSavr tomatoes contained marker genes that gave resistance to the antibiotic kanamycine which is used in medicine and FlavrSavr tomatoes had shown that these had a potential to induce gastro-intestinal lesions/ulcers which might have caused its withdrawn from market in 1998. Another case reported that ‘Beltsville pigs’ showed serious bone deformities as well as severe cardiac problems. Therefore, production of Beltsville pigs was stopped. In the 1990s, yet another case of failure of genetic engineering was that of L-tryptophan. One batch of genetically-engineered L-tryptophan caused death of 37 people and paralysis of about 1500 people notwithstanding several such reports of adverse health effects, the insecticide (BT) and herbicide (HT) transgenic crops. Moreover, the GM crops are mostly held to the intellectual property by the companies even in the countries such as India with an appreciably high number of marginal farmers. The problem could be addressed by open sourcing of GM foods as adopted by Syngenta. The direct action of the public citizens were seen in the past when the protestors destroyed crops trials in 2014 in UK and in 2013 protestors uprooted an experimental plot golden rice in the Philippines.

There have been numerous reports of “unintended effects” in the genetically engineered crops. A very early report of ‘unintended and unimaginable effect’ was reported by Prescott *et al*. (2005) who demonstrated the conversion of an enzyme alpha-amylase inhibitor-1 from common bean (*Phaseolus vulgaris*) into an allergen upon the engineering of gene for alpha-amylase inhibitor into pea (*Pisum sativum*) genome.

There were also reports on committing suicide by the resource-poor cotton farmers having lost their crop and livelihood. Gutierrez *et al.* (2015) reported that annual suicide rates in rainfed areas are directly related to increases in Bt cotton adoption (i.e. costs). The high inputs cost needed by the farmers for chemical pesticides once the Bt-cotton becomes susceptible to the borer pests and also the resource-poor farmers have to buy seeds for sowing the subsequent season at high cost from the company. Further, the inputs such as chemical fertilizers, irrigation, weeding etc., tremendously enhance the cost of cultivation. The successive failures of the series of Bt cotton varieties namely Bollgaurd(s) and expenditure on the quintessential inputs to be given manufactured by the concerned organisations incurred high expenditures but failed the farmers in returning the least of the expenditure resulted in multiple farmer suicides.

The prerequisite for the safety assessment of genetically modified food products is to assess if the food is ‘substantially equivalent’ to its natural counterpart. They are tested for limited set of components such as toxins, nutrients or allergens that are present in the unmodified food. Therefor deployment of GM crops must encompass the whole process of technology development from pre-release risk assessment to post-release monitoring. The positive and negative effects of GM crops will vary with location and context and monitoring will require a new model of working in order to inform actions at the farming system level. (FAO, 2005)

## Conclusion

Based on this reviews, it can be concluded that the fate of GM crops might take a positive turn considering the fact that conventional breeding takes long time to bring favourable changes in the traits while GM crops do it in few months without much labour. It has gained large scale commercialization and acceptance. In fact, many people believe that the next green revolution in agriculture will be credited to biotech/GM crops. But despite the promised benefits, global negative reaction to GM crops ranges from mild unease to strong opposition. The acceptance of the GM crops among farmers is still a challenge regarding few notable failures in India. Therefore, it is important to regulate GM crops in every aspect and understand vividly the production processes involve is producing them.

Summing up in the words of M.S. Swaminathan, "GM foods have the potential to solve many of the world's hunger and malnutrition problems and to help protect and preserve the environment by increasing yield and reducing reliance upon chemical pesticides. Yet there are many challenges ahead for governments, especially in the areas of safety testing, regulation, industrial policy and food labelling".

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# Chapter - 7
# Internet of Things in Agriculture

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# Chapter - 7

## Internet of Things in Agriculture

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**Abstract**

The Internet of Things (IoT) is a network of connected devices that can send and receive data without the need of human interaction. Devices, sensors, clouds, big data and data are all part of it. Traditional embedded systems are integrated with small wireless micro sensors, control systems with automation and other components to form a huge infrastructure. Wireless communication, micro electro mechanical devices and the Internet have all been used to create new things on the Internet. It's a web-based network of network objects that may be accessible through the Internet. Smart homes, wearables, smart cities, smart grids, industrial internet, connected car, connected health, smart retail, smart supply chain and smart farming are all examples of Internet of Things applications. The Internet of Things (IoT) has the potential to boost productivity and open up a vast worldwide market. The integration of wireless sensors with agricultural mobile apps and cloud platforms aids in the collection of significant environmental data such as temperature, rainfall, humidity, wind speed, pest infestation, soil humus content and nutrient levels.

**Keywords:** Agriculture, internet of things, precision agriculture, weather forecasting, wireless sensor networks (WSN)

### Introduction

The Internet of Things (IoT) is a network of networked devices that can efficiently transfer data even without human intervention. Agriculture has become increasingly popular and important as a result of rapid technological advancements. For the growth of farming, several tools and techniques are available. According to the UN Food and Agriculture Organization, the world would need to produce 70% more food in 2050 than it did in 2006 to feed the world's rising population. Farmers and agricultural companies are turning to the Internet of Things for analytics and increased production capacities in order to meet this demand. The Internet of Things (IoT) does have the capacity to enhance productivity and open up a vast worldwide market. Many agricultural industries are turning to IoT technology for smart farming to improve efficiency, productivity, global market and other qualities like minimal human intervention, time and cost. The Internet of Things (IoT) is one of the most effective and important techniques for developing problem-solving solutions. IoT is made up of a variety of components, including sensors, software, network components and other electronic devices. It also increases the effectiveness of data. IoT allows data to be sent over a network without the need for human intervention. Smart homes, wearables, smart cities, smart grids, industrial internet, connected car, connected health, smart retail, smart supply chain and smart farming are all examples of Internet of Things applications. Agriculture is the backbone of India's economic development. Climate change is the most significant challenge that traditional farming faces. Heavy rainfall, the most intense storms and heat waves, rainfall patterns and other climatic change effects are just few. Productivity suffers as a result of these factors. Climate change has ramifications for the ecosystem, such as seasonal changes in plant life cycles. In order to increase productivity and reduce barriers in the agricultural field, innovative technologies and techniques such as the Internet of Things must be used. The Internet of Things (IoT) is now revolutionizing the agriculture industry, allowing farmers to compete in the face of major hurdles. IoT provides farmers with a lot of information and expertise about current trends and technologies. IoT sensors that can provide farmers with data on crop yields, rainfall, insect infestation and soil nutrition are extremely beneficial in production and provide exact data that can be utilized to enhance agricultural operations over time. With its real-time, accurate and shared properties, the Internet of Things will alter the agricultural supply chain and serve as a crucial tool for ensuring a smooth flow of agricultural logistics. The Internet of Things (IoT) has the potential to boost productivity and open up a vast worldwide market. The integration of wireless sensors with agricultural mobile apps and cloud platforms aids in the collection of major ecological parameters such as temperature, rainfall, humidity, wind speed, pest infestation, soil humus content and nutrient levels.

**Internet revolution**

Internet of boffins (1969-1995)

Internet of geeks (1995-2000)

Internet of masses (2000-2007)

Mobile internet (2007-2011)

Internet of things (2012 & beyond).

**Definition**

The Internet of Things (IOT) is inter-networking of physical devices like electronics, sensors, software and network components.

It has ability to transfer data and collection of data over a network without requiring human-to-human or human-to-computer interaction.

Term was proposed by Kevin Ashton in 1999

**Layers of IOT**

1) Sensor, Connectivity and Network Layer.
2) Gateway and Network Layer.
3) Management Service Layer.

**1. Sensor, Connectivity and Network layer**

RFID tags and sensors constitute this layer. Wireless Sensor Networks are made up of sensors, RFID tags and other wireless Sensor Networks (WSN). The devices have finite storage capacity and have small processing speed. We have many sensors for various uses, such as temperature sensors for collecting temperature data, water quality sensors for analyzing water quality and moisture sensors for determining the moisture content of the atmosphere or soil, among others.

**2. Gateway and Network layer**

Gateways are in capable of forwarding data from the Sensor, Connectivity and Network layers and passing it on to the next layer, the Management Service Layer. This layer involves a vast storage capacity in order to store the massive amounts of data collected by sensors, RFID tags and other devices. Different types of network protocols are used by different IoT devices. All of these protocols must be combined into a single layer. This layer is responsible for managing of combining different network protocols.

**3. Management service layer**

This layer is responsible for the management of IoT services. The Management Service layer is responsible for managing of securing IoT device analysis, data analysis (stream analytics, data analytics) and device management. Data management is required to extract the necessary information from the large amounts of raw data acquired by sensor devices in order to provide a useful result from all of the data. This action is performed in this layer. In addition, many situations require immediate action. By abstracting data, extracting information and regulating the data flow, this layer helps in this course of action.

**IoT and related technologies for agriculture**

1) **Wireless Sensor Network (WSN)**

It is a network of sensor devices that can communicate, sense and compute information gathered from a monitored field via wireless networks using tiny devices. The data is transmitted through multiple nodes and connected to other networks, such as wireless internet, via a gateway. These networks are used to monitor physical or environmental factors such as sound, pressure and temperature and to transfer data to a central point over the network.

2) **Radio-frequency identification (RFID)**

Rfid is a technique that uses radio waves to record the presence of an object.

Rfid is made up of two parts.

**1)** Electronic tags are used to store data.

**2)** Rfid reader allows reading and writing of these tags.

3) **Big Data Analytics**

Big data analytics tools are used to handle huge amount of data transmitted from IoT devices.

4) **Cloud computing**

Cloud computing refers to the ability to access computing resources through the Internet, as rather than traditional systems in which computer hardware is physically located on the user's premises and any software applications are installed on that local hardware.

**Applications of IOT in different areas**

Smart home-100%

Wearables-63%

Smart City-34%

Smart grids-28%

Industrial internet-25%

Connected car-19%

Connected Health-6%

Smart retail-2%

Smart supply chain-2%

Smart farming-1%

**IOT Application in agriculture**

1) Crop water management
2) Pest management and control
3) Drones application
4) Weather forecasting
5) Green house monitoring
6) Hydroponics

**1. Crop water management**

In most cases, the farmer pumps water to more or less to cultivate the field. This could result in water wastage or insufficiency to the crops. When the moisture level rises or falls, it sends a notification to the farmer. Water supply for irrigation can be simply managed by connecting humidity sensors, water valves and a monitoring system. Sensors that monitor soil moisture are known as humidity sensors. Water valves automatically supply water to the field without the need of human intervention. Additionally, any leakage in the water lines can be detected. Farmers can access all data using their cell phones.

**Advantages**

- Least wastage of water.
- Water consumption in the field can be tracked.
- In drought areas the crop water management could be done efficiently and unauthorized water consumption is detectable.

**Smart water meters**

Smart connected metres having this ability of notifying users about water levels and usage can help prevent water waste and under use. Smart sensors in farms can also alert farmers in real time on the moisture level in their fields, preventing water from deteriorating. Depending on the requirement for irrigation and the amount of the water resource, the metre can be turned on or off automatically.

**Soil moisture sensor**

A sensor that will sense the moisture level in the land (sand) called soil moisture sensor.

**Making irrigation smarter**

Water supply at the right time, in right quantity and at the right place plays a vital role in the plant’s growth.

**2. Pest management and control**

To avoid such a situation, the agriculture internet of things has a system that uses PIR sensors to detect pest movement. Farmers can utilize this information to lessen the damage caused by pests. Pest control sensors would be useful in this situation. The sensors track insect behavior, population and environmental conditions as well as plant growth. Pesticides are automatically sprayed onto the field based on this data, at the precise location and in the appropriate quantity, to disrupt pests at the beginning. It would be possible to keep track of the pest's attack on the crop, the amount of pesticides used and how much crop production was damaged. Implementing IoT in the field minimizes pesticide use and keeps crops healthier.

**Passive infrared sensor**

A PIR based motion detector is used to sense movement of people, animals or other objects.

**Arduino**

To perform an operation, both the soil moisture sensor and the passive infrared sensor is connected to the Arduino. Arduino will use the Internet shield to transfer data to the database and in the event of an emergency, it will use the GSM module to send a message to the user.

**3. Drones in agriculture**

Drones are formally known as aerial vehicle which is essentially a flying robot. It can be controlled by either pilot from the ground or it can be autonomous. In current scenario it is also being used for surveillance, weather monitoring, spraying.

**1. Soil and field analysis**

They generate precise 3-D maps for early soil analysis and useful in planning seed planting pattern. Drone-driven soil analysis gives data for irrigation and nitrogen management after planting.

**2. Planting**

Drone-planting systems can save up to 85% on planting costs. These systems shoot pods containing seeds and plant nutrients into the soil, giving the plant everything, it tries to sustain.

**3. Crop spraying**

Drones can scan the ground and spray the appropriate amount of liquid, regulating distance from the ground and spraying in real time to ensure even coverage. Reduces the amount of chemicals that enter into the groundwater, increasing efficiency. In fact, experts estimate that drones can accomplish aerial spraying up to five times faster than traditional machinery.

**4. Crop monitoring**

Images had to be requested ahead of time, could only be taken once a day, and were inaccurate. Furthermore, services were extremely expensive and image quality suffered on sometimes. Time-series animations may now depict the exact evolution of a crop and show inefficiencies in production, leading to better crop management.

**5. Irrigation**

Drones equipped with hyper spectral, multi spectral, or thermal sensors can detect areas of a field that are dry or in need of improvement. Drones can also calculate the vegetation index, which describes the relative density and health of the crop and reveal the heat signature, which is the amount of energy or heat the crop emits, once the crop is growing.

**6. Health assessment**

Assessing crop health and spotting bacterial or fungal infestations on plants is critical. Drone-carried devices can detect which plants reflect various quantities of green light and near-infrared light by scanning a crop with both visible and near-infrared light. This data can be used to create multispectral images that track plant changes and indicate their health. Furthermore, once a disease has been identified, farmers can more accurately apply and monitor treatments. These two options improve a plant's ability to resist disease.

**4. Weather forecasting**

The Arduino Uno in an IoT-enabled weather monitoring system measures four weather parameters using four sensors. Temperature, humidity, light and rain level sensors are among the sensors available. These four sensors are wired straight to the Arduino Uno. These weather characteristics are calculated by Arduino and displayed on an LCD monitor. The parameters are then sent to the Internet. We may send these weather parameters data to the cloud using internet connectivity via a Wi-Fi module via wireless communication using the Internet of Things.

## Advantages

- IOT weather monitoring system project using Arduino is fully automated. It does not require any human attention.
- You can get a prior alert of the weather conditions. Suppose you are planning to visit a place and you want to know the weather parameters over that place, then you can just visit a website IOT portal.

## Monitor and Control of Greenhouse Environment

IOT is used to measure temperature, humidity, light and soil moisture, among other things. These parameters are displayed on LCD by the microcontroller. Sensors detect temperature, humidity and light, while two thin metal rods or metal wires measure soil moisture. Temperature sensor output is amplified and sent to Analog to Digital Converter ADC with the other three sensors. Using relay interface and motor drivers, the microcontroller controls these parameters and keeps them below predetermined levels. Temperature, humidity, light and soil moisture values are send to a computer through a serial port. Hyper terminal can be used to display these values on a PC.

1) **Sensors:** Temperature, humidity and light sensors are used to detect temperature, humidity and light, respectively. To detect soil moisture, metal thin rods or wires are utilized. These sensors detect the parameters and produce a voltage output that corresponds to it.
2) **Amplifier:** Because the sensors' output voltage is in millivolts, it must be increased to a range of 0 to 5 volts. This is usually done with a linear amplifier.
3) **ADC:** The main component is a microcontroller that only receives digital input. (0 and 5 volts) However, because the amplifier's output is analogue, it must be converted to digital before being sent to the microcontroller. For this, an ADC is used to convert the analogue output from the amplifier to the digital output that will be sent to the microcontroller.
4) **Microcontroller:** This is our project's CPU (central processing unit). The following are some of the functions of a microcontroller:

i) Reading the ADC's digital input, which is derived from the temperature and light sensors.

ii) Sending this data to LCD so that the values of temperature and light can read.

iii) Managing variables such as temperature and light, as well as turning on and off the necessary relays.

iv) Using a serial connection to send temperature and light information to a computer.

5) **Relay:** Two relays are usually employed. When the temperature rises above the set point, the first one will switch on. When the humidity level rises above the desired level, the second relay will activate. (For example, if the intended temperature is 35 degrees Celsius and the desired humidity is 50%, Relay 1 will turn on when the temperature is 36 degrees Celsius or higher and Relay 2 will switch on when the humidity is 51 or higher.

6) **DC Motors:** Two 12 volt DC motors are often used. When the light level rises above the threshold, one DC motor will turn on. When the soil moisture level falls below the threshold, another DC motor will be activated.

7) **PC Interfacing:** PC interfacing is used for sending the values of temperature and light to pc when the key is pressed.

## 5. Hydroponics

Hydroponics is a subset of hydroculture, which is the method of growing plants without soil in a water solvent utilizing mineral nutrient solution. Only the roots of terrestrial plants are exposed to the mineral solution, or the roots are supported by an inert media like perlite or gravel. In hydroponics, nutrients can come from a variety of areas, including by-products from fish waste, duck manure and regular fertilizers. The sensors will keep the microclimate in the green houses or poly-houses under control. All of the sensors sent data to the Arduino, which was digitalized and shown on the LCD. We will be able to take the necessary steps as a result of this.

### The benefits of internet of things

**i)** **Increased production:** Crop treatment, such as proper planting, watering, pesticide application and harvesting, has a direct impact on production rates.

**ii)** **Water conservation:** Water is only used when and where it is needed, due to weather predictions and soil moisture sensors.

**iii)** **Real-time data and production insight:** Farmers could see production levels, soil moisture, sunlight intensity and other factors in real time and to help them make better decisions.

iv) **Lower operation costs:** Automating plantation, treatment and harvesting procedures can reduce resource consumption, human error and total costs.

v) **Improved product quality:** Analyzing production quality and results in relation to treatment can teach farmers how to change operations to improve product quality.

vi) **Accurate Farm and Field evaluation:** Tracking production rates per field over time enables detailed forecasting of future crop yield and farm value.

vii) **Improved livestock farming:** Sensors and machines can detect reproduction and health events in animals early. Geofencing and location tracking can help in livestock management and monitoring.

viii) **Remote monitoring:** Using an internet connection, local and commercial farmers can monitor various fields in multiple locations around the world. Decisions can be taken instantly and from any location.

**Disadvantages of the internet of things**

1) **Compatibility:** There is currently no standard for sensor tagging and monitoring. A standardised notion, such as USB or Bluetooth, is necessary, which should not be difficult to implement.

2) **Complexity:** With complex systems, there are various ways for them to fail. For example, you and your spouse may both receive notifications that the milk supply is running low and you may wind up purchasing the identical item. As a result, you'll have twice as much as you need. Or there's a software bug that causes the printer to order ink many times when just one cartridge is needed.

3) **Privacy/Security:** With IoT, privacy is a major concern. All data must be encrypted so that information about your financial state or how much milk you drink isn't shared with coworkers or friends. Data regarding your financial state or how much milk you drink isn't widely shared at work or among friends.

4) **Security:** The programme could be hacked and your personal information could be exploited. The options are limitless. You could be put at risk if your prescription is modified or your account information is stolen. As a result, the consumer is responsible for all safety hazards.

**Programs based on the internet of things**

1) **The Chaman (Coordinated horticulture assessment and Management using geo informatics):** This project aims to use satellite remote sensing data to estimate the acreage and yield of horticulture crops. The programme generates horticultural development action plans using GIS (Geographical Information System) technologies and remote sensing data (site suitability, infrastructure development, crop intensification, orchard rejuvenation, aqua-horticulture, etc.). CHAMAN also conducts research in the areas of horticulture crop condition studies, disease assessment and precision farming.

2) **The KISAN Initiative (Crop Insurance using Space technology and geo-informatics):** Crop cutting experiment planned using high-resolution remote sensing. To create more accurate agricultural yield forecasting models. To provide a block-level yield estimate. To create/test a method/index for index-based insurance. The initiative aims to improve crops by combining space technology and geoinformatics (GIS, GPS and Smartphone) with high-resolution data from drone-based imaging.

3) **NADAMS** (**National Agricultural Drought Assessment and Management using geo-informatics):** Since its establishment in 1990, NADAMS has been providing agricultural drought data at the state, district and sub-district levels, including the prevalence, severity, persistence and intensity of agricultural drought. Using remote sensing, operational drought assessment during the kharif season. Drought warnings are issued (normal, watch and alert) and drought declarations are issued (mild, moderate and severe).

**Constraints for usage of IOT in agriculture in India**

- Farmers who are small and marginal (fragmentation of land holdings) is very difficult to purchase high-cost technologies.
- Expensive.
- E-illiteracy is a term that refers to a lack of knowledge.
- A lack of understanding of Internet of Things (IoT) technologies.
- Inadequate infrastructure.

**Suggestions**

- Conducting skill-development programmes in place.

- Providing Subsidies.
- Farmers' organisations (farmers' interest groups, FPOs, etc.)
- Agriculture's line departments working together.

**Research evidences**

**1. A low-cost automatic irrigation controller driven by soil moisture sensors in wheat**

The controller schedules irrigation based on indications from the soil. The PIC microcontroller is heart of the controller circuit. The dielectric constant of the soil is measured using two dielectric capacitance sensors attached to the controller in order to assess its volumetric water content and thus the necessity to irrigate.

Acquire input from sensor 1.

↓

Convert the analog input to digital.

↓

Retrieve the digital value and store it in register 1.

↓

Acquire input from sensor 2.

↓

Convert the analog input to digital.

↓

Retrieve the digital value and store it in register 2.

↓

Add the two registers, register 1 and register 2.

↓

Divide the sum of two registers by 2.

Compare the quotient against the threshold (FC) and decide whether to irrigate (or) not.

**2. Optimization and Control of hydroponics agriculture using IOT**

The relative humidity in the air is sensed, measured and intelligence by a humidity sensor (or hygrometer). The temperature of the air is measured by a temperature sensor. The soil pH and light intensity are measured using a pH level sensor and a light sensor, respectively. Users can see detailed information on humidity, light intensity and water level. They can also decide whether or not to turn on the air pump, water pump, or lamp remotely based on the information.

### 3. Internet of things based expert system for smart agriculture

Expert systems (ES) are sophisticated computer programmes capable of solving problems. Sensors have been installed in the fields to collect data on temperature, humidity, soil moisture and leaf wetness. The XBee-802 communication module can communicate to a microcontroller. The gateway serves as a link between the sensor nodes and the server. It can communicate with the sensor wirelessly and via USB with a computer.

### 4. Harita priya-IoT based crop advisory model for groundnut crop

In 2014-15, the Government of Andhra Pradesh launched the HARITA (Harmonized Information of Agriculture, Revenue and Irrigation for a Transformation Agenda) initiative.

HARITA-PRIYA (Precision Technology for Agriculture) is a C-DAC pilot study to use cutting-edge sensor-based technologies for:

- Real-time collecting of micro-climatic data from farmers' fields.
- Timely assessment of crop status.
- Personalized Agro-advisory services to farmers.

## Conclusion

Smart farming will benefit from the Internet of Things. IoT is used in several aspects of farming to increase time efficiency, water management, crop monitoring, soil management, insecticide and pesticide control and so on. It also reduces human effort, simplifies farming procedures and aids in smart farming. IoT assists farmers in making better decisions.

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# Chapter - 9
# Role of Remote Sensing in Agricultural Crop Management


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# Chapter - 9

## Role of Remote Sensing in Agricultural Crop Management

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**Abstract**

With the advancement of technology now many operations are feasible and with ease we can directly and indirectly we can perform many things with best results. Doing things remotely is saving lot of time and efforts over the years. In horticulture now it's possible that we can remotely observe our crops and take required actions for best crop production.

Scientists with the Agricultural Research Service (ARS) and various government agencies and private institutions have provided a great deal of fundamental information relating spectral reflectance and thermal emittance properties of soils and crops to their agronomic and biophysical characteristics. This knowledge has facilitated the development and use of various remote sensing methods for non-destructive monitoring of plant growth and development and for the detection of many environmental stresses which limit plant productivity. Coupled with rapid advances in computing and position locating technologies, remote sensing from ground, air and space-based platforms is now capable of providing detailed spatial and temporal information on plant response to their local environment that is needed for site specific agricultural management approaches. This manuscript, which emphasizes contributions by ARS researchers, reviews the biophysical basis of remote sensing; examines approaches that have been developed, refined and tested for management of water, nutrients and pests in agricultural crops; and assesses the role of remote sensing in yield prediction. It concludes with a discussion of challenges facing remote sensing in the future.

**Keywords:** Satellites, plants, deficiency, sensors, climate change, irrigation, fertilization

## Introduction

Horticulture crops are really important for every country because many sectors directly depend on it for example: nation's finance, health, employment, self-dependability, food and nutritional security. For efficient use of horticulture land resources we need to make sure that the factors on which horticulture productions rely on should be taken care of. These factors are; soil characteristics, climate change, irrigation and fertilization etc. To keep track of these things beforehand with the help of new technology and techniques we can assure our country with maximum crop production which can lead to new agriculture achievement.

New technologies can be used for a number of applications like crop inventory, crop condition, crop production forecasts, fruit quality, leaf area index, crown cover, for detection of the growth and health of horticultural crops, drought and flood damage assessment, range and irrigated land monitoring and management. The out lining of orchards and spatial analysis using geospatial technology can provide additional information for management and decision making for successful application of site-specific crop management (SSCM), determination of fruit yield, quantification and scheduling of precise and proper fertilizer, irrigation needs, application of pesticides for pest and disease management and has potential for increasing net returns and optimizing resource. High-resolution multispectral satellite imagery was used to develop viticulture decision support products related to monitoring of field uniformity, vine balance and irrigation planning. Crop yield is perhaps the most important piece of information for crop management in precision agriculture. Despite the commercial availability and increased use of yield monitors, most of the harvesters are note quipped with them. Moreover, yield monitor data can only be used for after-season management, whereas some problems such as nutrient deficiencies, water stress, or pest infiltrations should be managed during the growing season. RS imagery obtained during the growing season has the potential not only for after-season management but also for within-season management. Additionally, field maps derived from RS imagery can be used as an alternative when yield monitor data are not available.

## Remote sensing

### Definition, principles and advantages

RS is a general term for gathering data from a distance. This extremely basic definition suggests that the human eye, the human ear, disposable cameras, radar, sonar and satellite sensor arrays will all fall under the classification of RS devices. This involves sensing and recording reflected or emitted energy and processing, analysing and applying that information for precise yield. The fundamental feature of RS is the detection of radiant energy emitted by various objects whether it is in the form of acoustical energy (sound) or electromagnetic energy (light, infrared heat, ultraviolet and microwaves). RS technology from ground, air or space-based platforms are capable of providing detailed spectral, spatial and progressive information on vegetation health and vigour and it has significant crop yield estimation applications. Many types of sensors including aerial photographs, airborne multi-spectral scanners, satellite imagery, low and high spatial and spectral resolution and ground based spectrometer measurements collect electromagnetic information. The spatial data can now be more easily collected and recorded with the observation tools such as yield monitors, airborne optical RS and soil-sensing instrumentation enabling the horticulturists to make more informed decisions related to desired productivity outcomes.

Spatial resolution is a measure of the smallest object detectable on the ground. The number of available image-forming pixels in the sensor itself and its distance from the ground, contribute to determining the pixel-size on the ground and the overall image footprint. The smallest object that can be directly detected by the sensor is 30 m (Landsat) or 20 m (SPOT) in each dimension. Temporal resolution or, more simply, revisit-frequency is an essential attribute of any sensor when used for commercial monitoring or management purposes.

### Spectral response of plant leaves

As leaves expand, mature and senesce, physiological and morphological changes occur that affect their spectral properties. The interaction of radiation with plant leaves and hence the magnitudes of spectral reflectance, spectral absorbance and spectral transmission, depends not only on the wavelength but also on a range of structural (tissue density, presence, absence, or distribution of waxes, hairs, or air spaces) and chemical characteristics such as chemical composition (proteins, lipids, starch, cellulose, nitrogen and oils), leaf age, leaf thickness, leaf structure, leaf water content, pest and disease attack, water deficiency, nutrient deficiency, etc. Variations in shape and composition of molecular structures in plant leaves will ultimately determine whether a photon will be absorbed, resulting in a slight energetic gain or be "reflected," giving the leaves the colour that we perceive.

**Spectral response of crop**

Reflection of radiation from vegetation depends on the radiation properties of the individual components of the vegetation like leaves, stems, soil, water, canopy architecture or spatial organization relation to the angular distribution of the incident radiation and the orientation of the sensor, together with scattering of radiation by the underlying soil that penetrates the canopy, biomass concentration, plant assimilation condition, photosynthetic apparatus capacity etc. stages and phenology of many horticultural crops are not well understood and tend to be difficult to generalize as a result of wide variations in varieties, planting densities and cultural practices. Vegetation reflectance involves four different and complementary points of view which have led to distinct works:

a) The reflectance of plant parts (single organs pigments).

b) Reflectance of sets (canopies).

c) Nature and state of the plants.

d) Structure and texture of the set.

**Spectral reflectance properties of soils**

Compared with plants, the spectral signatures of most agricultural soils are relatively simple. They usually exhibit monotonic increases in reflectance throughout visible and NIR regions. High soil water and high organic matter contents generally cause lower reflectance while dry, smooth surfaced soils tend to be brighter. Occurrence of specific minerals in soil has been associated with unique spectral features (*e.g.*, higher red reflectance in the presence of iron oxides). In the SWIR, soil spectra display more features than those observed in shorter wavelengths but are still dominated by water content, litter and minerals. The presence of crop residue causes significant changes in reflectance properties compared to bare soil, as well as from partial plant canopies. Therefore, it is important to account for residue when observations are being made across a range of soils and crop production practices application of various remote sensing approaches to soil management, especially as it pertains to definition of zones for crop management, is reviewed in detail.

**Emitted thermal radiation**

All objects on the Earth's surface emit radiation in the thermal-infrared (TIR) region of the spectrum (8 to 14 mm). This emitted energy, which is proportional to the absolute surface temperature of an object, has proven very useful in assessing crop water stress because the temperatures of most plant leaves are mediated strongly by soil water availability and its effect on crop evapotranspiration (Jackson, 1982). Following Tanner's (1963) observation that plant temperatures often differ substantially from air temperature, ARS researchers examined environmental determinants of crop temperature and began to speculate on ways to use the latter for monitoring water stress. When infrared thermometers became affordable and more widely available in the mid-70s, ARS scientists who had been using thermocouples to measure plant temperatures, quickly adopted the new technology and developed a number of non-contact methods for assessing water status and predicting crop yields over wider regions.

**Exogenous factors affecting remote observations**

It is important to recognize that remote assessment of crop growth and plant response to environmental stress is by no means as simple or as straight forward as identifying chemicals *in vitro* via their spectral absorption features. Optical and thermal properties of plant canopies change with stage of growth due to age of individual tissues and architectural arrangement of organs are also strongly affected by illumination and viewing angles, row orientation, topography, meteorological phenomena and other factors not directly related to agronomic or biophysical plant properties. A significant challenge for agricultural remote sensing applications is to be able to separate spectral signals originating with a plant response to a specific stress from signals associated with normal plant biomass or the background "noise" that is introduced by exogenous non-plant factors. Results from multiple crops across a number of different locations indicate that general relationships between spectral properties and plant response are achievable.

**Water management**

Poor irrigation timing and insufficient applications of water are ubiquitous factors limiting production in many arid and semi-arid agricultural regions. As a consequence, considerable ARS research has focused on remote sensing strategies for determining when and how much to irrigate by monitoring plant water status, by measuring rates of evapotranspiration and by estimating crop coefficients.

**Plant water status**

ARS scientists have proposed, refined and tested a number of non-invasive, thermal indices for determining whether plants are meeting transpiration demands of the atmosphere and inferring plant water status from that measurement. Although they vary in complexity as well as the amount of ancillary meteorological and crop specific parameters that are required, each index is based on plant temperatures that can be obtained remotely using infrared radiation thermometers or thermal imaging devices.

Thermal plant water stress indices typically provide adequate lead time for scheduling irrigations in regions where supplemental water is needed to grow a crop. However, successful application of the technique depends on sufficient evaporative demand by the atmosphere, adequate water holding capacity of the soil and irrigation depth. The TIR is less practical for scheduling irrigations in mesic areas, where lower evaporative demand reduces temperature differences between well-watered and stressed plants. Under these conditions, measurement errors and variation in plant temperatures due to fluctuations in wind speed can obscure the water stress signal (Keener and Kirchner, 1983; Stockle and Dugas, 1992; Wanjura and Upchurch, 1997). But even in humid regions, thermal techniques can provide useful information when crops are exposed to a prolonged dry spell or when spatial variation in soils causes stress in portions of the field (Feldhake and Edwards, 1992; Feldhake *et al.*, 1997; Sadler *et al.*, 1998, Sadler *et al.,* 2000). Ben-Asher *et al.*, (1992) found thermal indices less useful for managing micro-irrigation drip systems where the amount of soil water replenished at each irrigation was relatively small compared with the daily requirements of the crop.

Thermal indices can overestimate water stress when canopy cover is incomplete and sensors view a combination of cool plant and warm soil temperatures. For ground-based measurements, this problem can be minimized by restricting observations to the transpiring foliage elements or by using an oblique viewing angle.

**Evapotranspiration (ET) and crop coefficients**

Approaches for assessing the spatial and temporal dynamics of ET have been developed and tested by ARS scientists at field, farm and regional scales. These techniques typically combine ground-based meteorological observations with remote measures of reflected and emitted radiation and then estimate latent energy (LE) exchange as a residual in the energy balance equation. For cloud-free days, the near instantaneous, remote estimates of LE obtained near midday with data from satellites or aircraft can be converted to daily values with reasonably good accuracy, these techniques hold considerable promise for estimating water use over broad areas, but applications have been hampered by lack of thermal sensors with suitable temporal and spatial resolution on satellite or aircraft platforms.

**Salinity stress**

Salts in soils and irrigation water are important factors limiting productivity in many croplands (Rhoades *et al*., 1989). Remedial solutions require mapping of affected areas in space and time. This can be accomplished using remote sensing measurements which identify contaminated soils by their unusually high surface reflectance factors or by detecting reduced biomass or changes in spectral properties of plants growing in affected areas. Significant correlations exist between mid-season VIs and final yields of cotton and sorghum crops which are affected by salinity stress at sub-field spatial scales. Studies have also shown an increase in canopy temperature of plants exposed to excessive salts in irrigation water, suggesting the possibility of previsualize detection of stress which could be remedied by increasing the leaching fraction or switching to a higher quality of water.

**Nutrient management**

Efficient management of nutrients is one of the main challenges facing production agriculture. Here, remote sensing is providing field-scale diagnostic methods that will enable detection of nutrient deficiencies early enough to avoid yield or quality losses. When interfaced with variable rate sprayer equipment, real-time canopy sensors could supply site specific application requirements that lessen contamination of surface-or groundwater supplies and improve overall nutrient use efficiency (Schepers and Francis, 1998).

**Nitrogen**

Ample supplies of nitrogen (N) are essential for modern crop production. However, N is often over-applied without regard to crop requirements or potential environmental risk just to insure that adequate levels are present for the crop. A case in point involves corn grown in the upper Midwestern United States where synchronizing N applications to coincide with maximum crop uptake is desirable but tissue testing of leaves is not widely employed for determining crop needs and thus fields are often over fertilized.

### Other nutrients

Monitoring symptoms caused by other nutrient deficiencies can be problematic because they rarely occur uniformly across a field and often need to be distinguished against background variation in canopy density. Osborne *et al*. (2002a; 2002b) have conducted research which shows usefulness of hyperspectral data in distinguishing differences in N and P the leaf and canopy level, but the relationships were not constant over all plant growth stages. Adams *et al*. (2000) have detected Fe, Mn, Zn and Cu deficiencies in soybean leaves using both leaf fluorescence and hyperspectral reflectance techniques that evaluate leaf chlorosis based on the shape of the reflectance spectrum between 570 and 670 nm. The increased availability of hyperspectral imaging sensors and advanced analysis tools like partial least-squares regression and spectral mixing techniques mentioned earlier will facilitate studies to extend this concept to the canopy level.

### Pest management

Remote sensing lends itself exceptionally well to the detection of anomalous locations within a field or orchard that have been differentially affected by weeds, diseases, or arthropod pests. In fact, more than 35 years ago, ARS scientists were using aerial color-infrared photography for this purpose and relating their findings to laboratory spectra of pest damaged leaves.

### Weeds

Weeds represent a large management cost to growers because they compete with crops for water, nutrients and light, often reducing crop yield and quality. Inappropriate or poorly timed herbicide applications can also have unintended side effects on crop performance and the environment. Thus, in recent years there has been a shift away from uniform, early season weed control options towards approaches that rely on using herbicide-ready crops and applying post-emergence herbicides only as needed. This strategy has generated increased interest in using remote sensing to define the extent of weed patches within fields so they can be targeted with variable rate ground and aerial spray rigs. Such approaches avoid applications to weed free areas, reducing herbicide usage and potential contamination of ground water without compromising weed control.

## Arthropod and Nematode pests

Demonstrated remote sensing methodologies for identifying and managing insect, mite and nematode populations include detecting actual changes in plant pigments caused by pest presence, monitoring plants for damage done by the pests and identifying areas susceptible to infestation. In what are now considered classic studies, ARS scientists used color-infrared (CIR) photography and supporting hyperspectral reflectance data to identify trees in citrus orchards that were infested with brown soft scale insects (*Coccus hesperidum*). They were able to monitor changes in infestation levels because the honeydew excreted by the scale insects was an excellent growth medium for a sooty mold fungus that had very low reflectance in both the visible and NIR wavelength regions and tended to accumulate as the season progressed (Gausman and Hart, 1974).

Cook *et al.* (1999) used multitemporal NIR videography to monitor the seasonal progression of the southern root knot nematode (Meloidogyne incognita Chitwood) and its associated soil-borne fungi complex in kenaf (*Hibiscus cannabinus* L.). Of course, areas of reduced plant vigor could conceivably be caused by a number of factors unrelated to pests, so it is likely that additional spectral, spatial and temporal clues, provided within the context of a decision support system, will be required to uniquely identify the problem.

## Disease

Examples in which ARS employed remote sensing technology for detecting crop disease and assessing its impact on productivity include using CIR photography to identify circular areas affected by cotton root rot, *Phymatotrichum omnivorum* and to estimate yield losses caused by black root disease in sugar beets. Cook *et al.* (1999) also demonstrated the potential for aerial video imagery to detect *P. omnivorum* in kenaf, a crop whose tall growth habit makes it almost impossible to survey from the ground.

## Yield prediction

Yield is a very important end-of-season observation that integrates the cumulative effect of weather and management practices over the entire season. Remote sensing approaches can provide growers with final yield assessments and show variations across fields. In this respect, they are similar to combine-mounted yield monitors that are a key component of precision agriculture. But remote measurements differ in that they also can be taken frequently during the season, providing temporal information on growth rates and plant response to dynamic weather conditions and management practices. There are two general approaches to using remote sensing for yield assessment. The first is a direct method, in which predictions are derived totally from the remote measures. The second is indirect, whereby remotely sensed parameters are incorporated into computer simulations of crop growth and development, either as within-season calibration checks of model output or in a feedback loop used to adjust model starting conditions or processes.

**Advantages of remote sensing over yield monitors**

For many crops, combine-mounted yield monitors have become the de facto standard for assessing within-field variability and determining zones for precision crop management. Yet there is a growing pool of information indicating that combine-derived yield maps may fail to accurately depict the spatial structure of plant yields within a field and seldom show the true extremes in variability. Likewise, the capability to diagnose or manage a specific yield-reducing stress is limited with the end of-season maps that yield monitors produce. The increased availability of aircraft-based sensor systems with improved spatial and spectral resolution and the potential to obtain data several times during the season have prompted scientists to use remotely sensed imagery as a proxy for a yield map generated by a combine. Pre-harvest estimates of plant productivity enable growers to delineate management zones and to make earlier and better-informed marketing decisions. Pre-harvest imagery also facilitates directed field scouting for precise diagnosis of stress and, where possible, enables growers to take timely remedial actions.

In general, reliability of imagery to estimate yields decreases as the time before harvest increases because there is more opportunity for factors like drought, nutrient deficiency, insect infestation and disease to impact yield.

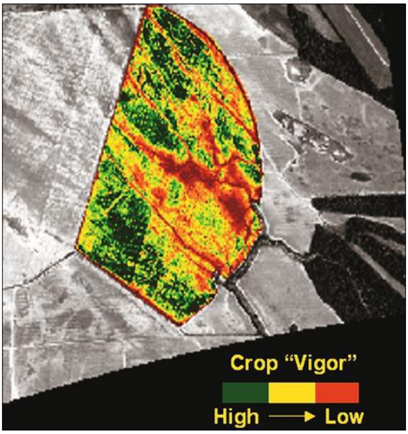


**Plate 3:** Multispectral imagery of an 81-ha Mississippi cotton field in which spatial variation in plant growth is represented by different colors. Areas with more vigorous plant growth (green) are more likely to attract and support high populations of tarnished plant bugs (*Lygus lineolaris*). (Image courtesy of ITD Spectral Visions, Stennis Space Center, Mississippi and ARS, Genetics and Precision Agri-culture Research Unit, Mississippi State University)

Yields of rain-fed crops can be more difficult to estimate using remote sensing because water stress at certain critical growth stages can cause irreversible loss in yield potential. As was found during the Large Area Crop Inventory Experiment, it is likely that imagery collected several times throughout the season will improve yield predicting capabilities.

## Other aspects of crop management

### Plant population

Plant density is an important variable affecting productivity in many systems. Populations vary with planter performance, soil parameters, weather, field slope and aspect, seedling disease, etc. Too dense a stand can result in barren plants without marketable fruit or a canopy more susceptible to disease or attractive to arthropod pests. Variable-rate planters now make it possible to adjust seeding rate to compensate for emergence variations or achieve densities that are better matched to site-specific soil characteristics within the field.

One goal of commercial remote sensing providers is to offer reliable, early season estimates of plant density which would enable growers to identify seedling diseases or insect infestations, to decide on the need for replanting, to plan herbicide and fertilizer needs and to interpret end-of-season yield maps. The sensor estimated plant spacing at the early growth stage with an error of 3 per cent and at harvest with a 6 per cent error. In field tests, filtering algorithms were able to remove the effects of narrow beam interruptions due to small weeds, but large corn leaves were a source of error.

Ideally, multispectral imagery taken shortly after emergence could be used to determine plant populations for management purposes. In practice, however, the seedling plants are usually too small and their signal is overwhelmed by that of the soil. Acquiring imagery very early in the day (*i.e.,* large solar zeniths) or with off-nadir viewing angles offers a potential solution to plant detection at low leaf area levels. As more sensitive sensors are deployed and techniques for calibration and removing effects of changes in soil background improve, capabilities for accurate assessment of early season plant density should improve.

**Growth Regulators and Defoliants**

Growers are increasingly using chemical plant growth regulators such as mepiquat chloride (Pix®) as a means for manipulating plant growth to facilitate mechanical harvesting and encourage early maturity. In the late 1970s, aerial CIR photography was used by ARS scientists to monitor the effectiveness of defoliants used to reduce late-season fruiting and decrease the number of overwintering pink bollworms.

**Overall Challenges and Opportunities**

Twenty years ago, in a seminal essay on the potential use of remote sensing for making day-to-day farm management decisions, stressed the overall importance to the grower of

1) Timeliness.
2) Frequency.
3) Spatial resolution of data.

Most of his observations remain relevant today. There have been substantial improvements in instantaneous field of view but very few farmers presently have access to regular images of their farms and even when they do, slow turnaround of the processed product continues to be a problem.

Despite these shortcomings, there is no question that remote sensing technologies will permeate many aspects of farming in the future. Grower acceptance will increase as products with higher spatial and temporal resolution become more affordable. That, in turn, will reduce costs, encouraging better coverage and faster image delivery. Building grower confidence will also require that remote sensing providers pay greater attention to calibration issues, convert imagery to reflectance and standardize on optimum wavelengths and data collection techniques. This will result in a more consistent product that tells the same story from year to year and brings value-added information to overall farming operations.

The sheer quantity of spectral, temporal and spatial information contained in a sequence of remotely sensed images offers unique opportunities for monitoring and managing agricultural resources at both the local and global scales. At the field and farm level, historic imagery could be combined with crop calendars, heat units, precipitation records and yield monitor data to develop maps showing areas that are prone to water stress, nutrient deficiency, or pest problems under a particular environmental scenario. Current imagery could then be used in decision support systems to provide early warning of yield reducing stress. With variable rate technology becoming more widespread, such information would be invaluable to producers within their decision-making framework. Archived satellite imagery also provides scientists and policy makers with an opportunity to monitor the impact of global change on world agriculture. Growers seeking an equitable, scientifically based method for assessing their environmental stewardship or credits for carbon sequestration could likewise use imagery to document their achievement.

## Conclusion

Modern management of agricultural resources is a complex endeavour that is now benefiting from a convergence of technical advances in information sciences, geographic positioning capabilities and remote sensing systems. Much of the fundamental research relating spectral properties of soils and crops to agronomic and biophysical parameters has been accomplished by ARS researchers working collaboratively with NASA and university scientists in a variety of programs over the past four decades. Many aspects of crop management have already begun to benefit from applications of remote sensing technology. As growers gain more confidence in its use, additional opportunities will present themselves. The future brings tremendous prospects for integrating the spatially and temporally rich information provided through remotely sensed multi- and hyperspectral imagery with the capabilities of management-oriented crop simulation models.

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# Chapter - 10
# Applications of Remote Sensing for Assessing Stress


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# Chapter - 10

## Applications of Remote Sensing for Assessing Stress

**Raja Ram Bunker, Vinay Kumar Kardam and Suresh Kumar Sabal**


### Abstract

Remote sensing is a powerfull technique which is used in numerous fields, including geography, land surveying and most Earth Science disciplines (for example, hydrology, ecology, oceanography, glaciology, geology). It may be split into “Active" remote sensing (i.e., when a signal is emitted by a satellite or aircraft and its reflection by the object is detected by the sensor). Passive" remote sensing (i.e., when the reflection of sunlight is detected by the sensor). Application of remote sensing in agriculture is *viz.*, Identification, area estimation and monitoring, crop nutrient deficiency detection, soil mapping, crop condition assessment, agricultural draught assessment, reflectance modeling, crop yield modeling and production forecasting. And further more application of remote sensing in horticulture is *viz.*, crop insurance, soil moisture, crop stands, crop conditions, crop classification, crop area estimation, crop canopy measurement, yield estimation, detecting pest and disease occurrence, monitoring abiotic stress. Techniques of Remote Sensing which is used in its applications, Methods for monitoring indicators of vegetation condition and it also assessed stress (Detection of plant water stress using remote sensing). Spectral indicators of plant chlorophyll content, plant water content, predawn leaf water potential and Leaf chlorophyll fluorescence also assessed by the using of remote sensing. It also has military, intelligence, commercial, economic, planning and humanitarian applications.


**Keywords:** Remote sensing, satellite, reflection, forecasting, assessment

### Introduction

Remote sensing (Remote-Something which is far away & Sensing-Getting information or getting data) is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on-site observation. Remote sensing is used in numerous fields, including geography, land surveying and most Earth

Science disciplines (for example, hydrology, ecology, oceanography, glaciology, geology). It also has military, intelligence, commercial, economic, planning and humanitarian applications.

**Remote sensing**

“Remote sensing" generally refers to the use of satellite- or aircraft-based sensor technologies to detect and classify objects on Earth, including on the surface and in the atmosphere and oceans, based on propagated signals (e.g. electromagnetic radiation (EMR) A combination of oscillating electric and magnetic fields propagating through space and carrying energy from one place to another; electromagnetic radiation is generally classified by its wavelength.

It may be split into active and passive remote sensing “Active" remote sensing (i.e., when a signal is emitted by a satellite or aircraft and its reflection by the object is detected by the sensor). “Passive" remote sensing (i.e., when the reflection of sunlight is detected by the sensor) or Active sensors have its own source of light or illumination. In particular, it actively sends a pulse and measures the backscatter reflected to the sensor. But passive sensors measure reflected sunlight emitted from the sun. When the sun shines, passive sensors measure this energy.

**Remote sensing process**

i) Energy source or illumination-provides electromagnetic energy to target of interact.

ii) Radiations and the atmosphere-energy travels from its source to target, it comes with and interact with atmosphere it passes through this interaction may take place second time as energy travel from target to sensor.

iii) Interaction with target-once energy makes its way to target it interact, depend upon target and radiation.

iv) Recording of energy by sensor-energy is scattered or emitted from the target and collected by sensor (sensor-A device that converts electromagnetic radiation into an electrical signal that can be recorded, displayed and analyzed). This records electromagnetic radiation.

v) Transmission, reception and processing-energy recorded by sensor has to be transmitted in electric form, to receiving station where data is processed to images.

vi) Interpretation and analysis-processed image that is visually interpreted is used to extract information from target.

vii) Application-final element of remote sensing image is extracted from target to understand it and help in solving of problems.

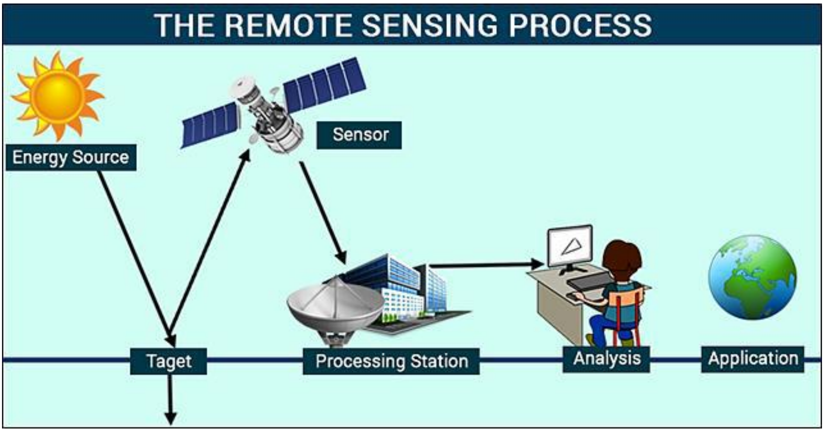


**Fig 1:** Process of Remote Sensing

**Application of remote sensing in agriculture**

- Identification, area estimation and monitoring.
- Crop nutrient deficiency detection.
- Soil mapping.
- Crop condition assessment.
- Agricultural draught assessment.
- Reflectance modeling.
- Crop yield modeling and production forecasting.

**1. Identification, area estimation and monitoring**

The specific requirement of climate and soil conditions coupled with the specialized management practices, make the distribution of plantation crops rather more localized in comparison to other agricultural crops. The identification, estimation of growing stock, analysis of distribution and monitoring at regular intervals are major aspects in plantation crops

**2. Crop nutrient deficiency detection**

The nutrient deficiency in plants affects the colour, moisture content and internal structures of the leaves and as a result their reflecting power changes.

### 3. Crop condition assessment

The physiological changes that occur in a plant due to stress may change the spectral reflectance characteristics resulting in the detection of stress amenable to remote sensing techniques. Crop monitoring at regular intervals during the crop growth cycle is essential to take appropriate measures and to asses information on probable loss of production

### 4. Soil mapping

Advancements in space technology opened application possibilities of remote sensing in soil mapping Soil properties have also been inferred from optical and microwave data using physically-based and empirical methods.

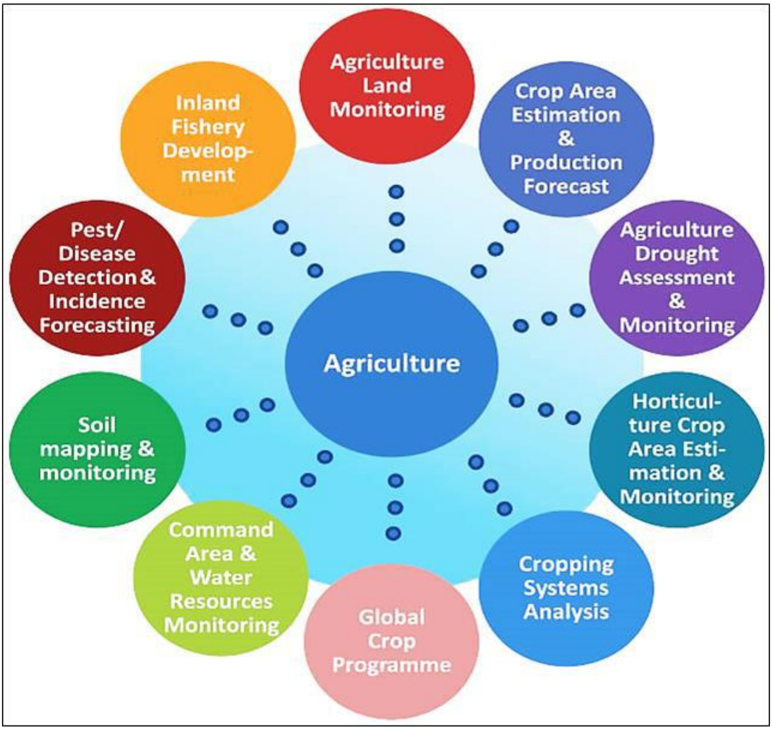


**Fig 2:** Application of remote sensing in agriculture

### 5. Agricultural drought assessment

Drought assessment is yet another area where in remote sensing data has been used at operational level. The district level drought assessment and monitoring using NDVI generated from NOAAAVHRR data helps in taking timely preventive and corrective measures for combating drought.

## 6. Crop yield modeling and production forecasting

The information on production of crops the harvest is very vital to the national food policy planning and economy of the country. Reliable crop yield estimate is one of the most important components of crop production forecasting.

### Application of remote sensing in horticulture

- Crop insurance.
- Soil moisture.
- Crop stands.
- Crop conditions.
- Crop classification.
- Crop area estimation.
- Crop canopy measurement.
- Yield estimation.
- Detecting pest and disease occurrence.
- Monitoring abiotic stress.

## 1. Crop insurance

Due to an obvious effect of global warming and climate change, the climate has become very much unpredictable and destructive; in such circumstances crop insurance can be a blessing to the farmers who are victims of crop failure due to sudden change in weather condition. But there are also instances of insurance fraud. To check this, insurance companies can use the red and infrared bands of satellite images in combination of NDVI (Normalized Difference Vegetation Index) and verify seeded crops to catch fraud.

## 2. Soil moisture

Soil moisture is an important contributing factor of the water cycle, weather forecasting, draught and floods and Remote sensing technique can be useful in determining soil moisture status using active and passive sensors from space. Active sensors illuminate their target and record the backscatter thus resulting in high spatial resolution but low accuracy on the other hand passive sensors measures naturally radiated electromagnetic waves which is highly accurate but with poor resolution. To achieve an optimized solution, harnessing best of both the processes NASA, (National Aeronautics and Space Administration) USA (United States of America) has launched a project namely Soil Moisture Active Passive (SMAP).

## 3. Crop stands

Remote sensing is very useful to identify crop stands and thus to tally the area under crop stand and its production

## 4. Crop classification

To classify horticultural crops from other bushes, shrubs and trees with green leaves which have almost similar spectral signatures that of the other healthy vegetation, multispectral photography is very much useful to distinguish this species from each other by the colour pattern exhibited by them [4]. Unsupervised clustering for image segmentation is a method through which the fruits and nut trees can be distinguished from forest vegetation having similar spectral characteristics specially areas with unexpected land covers [8].

## 5. Crop area estimation

Area and production of crops like potato which grows in large areas in contiguous fields can be estimated with over 90% precision [7] Horticultural crops usually face big ups and down both in its production and consumption as a result, it has a very unstable market and price. That's why reliable statistics regarding area and production of horticulture products is essential for market planning and export of produces. Remote sensing here plays a very important role to assess the supply scenario Estimating area under mango orchards with trees which are more than five years age can be estimated easily but that is not the case with younger mango trees due to over lapping of spectral signatures [12]. Mulberry at an early stage of the season produces similar spectral signatures that of other vegetable crops but at later stage shows some separation [7].

## 6. Crop canopy measurement

Crop canopy of horticultural crops is very important as its volume determines the amount of fertilizer, pesticide and any other chemicals to be applied besides canopy volume also indicates crop health condition as well as about the expected yield [10, 11].

## 7. Yield estimation

Remote sensing is a very useful tool to estimate the yield of different annual crops but again so far its use has been very limited for fruit trees and vegetables [6, 12]. Few studies are there like Prediction of processing tomato yield using a crop growth model and remotely sensed aerial images and relationship studies between modified normalized difference vegetation index and leaf area index for processing tomatoes [14]. Yang, estimated cabbage physical parameters and estimated cabbage yield using aerial photography and reflectance spectra. Whitney and Zaman [13, 15] mapped citrus groves using automated ultrasonic system and a sensor-based automatic yield monitoring system.

## 8. Detecting pest and disease occurrence

Pest and diseases are the two main causes of production and consequently economic losses in horticultural industry. It has been proved that remote sensing can be a useful tool for early detection of diseases and identifying, managing pests and nematodes by detecting changes in plant pigments, leaf skeletonizing caused by pest damage and identifying plant susceptible areas [12, 5]. Johnson developed an airborne multispectral digital imaging system related crop canopy reflectance and canopy density under various degrees of phylloxera stress. Seasonal progression of the southern root knot nematode (*Meloidogyne incognita* Chitwood) and soil borne fungi complex in kenaf (*Hibiscus cannabinus* L.) an associate, was monitored using multi temporal NIR videography by Cook [3, 1]. Borengasser, demonstrated that when citrus canker lesions developed on citrus leaves, spectral reflectance of leaves changed in the wave length range of 600-700 nm. In 1999, Hahn developed a prediction model for mango anthracnose and late blight disease in tomato using NIR (Near Infra-Red) band.

## 9. Monitoring abiotic stress

Remote sensing is a powerfull technique to monitor plant responses towards different abiotic stresses like draught, flooding, salinity, temperature fluctuations etc. For example if any abiotic stress causes inhibition of chlorophyll production, then an increase in reflectance will be observed for weakly absorbed wavelengths[12]. [2]Carter showed that for plants suffering from stress-induced chlorosis, higher reflectance will be detected in the 690-700 nm range. Very recently an institute called Mahalanobis National Crop Forecast Centre (MNCFC) under Department of Agriculture & Cooperation, Ministry of Agriculture has been established and with this application of remote sensing is institutionalised in India. Through this institute, ISRO implements two of its programmes of crop forecasting and draught assessment besides other programmes related to assessment of agricultural activities [9]. Indian Satellite sensors such as AWiFS, LISS-III/IV are being used by National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO) for inventory of fruits, vegetables, plantation crops, crop health, disease mapping, yield modeling and year to year changes, site suitability and post-harvest studies. Indian Space Research Organisation

(ISRO), the country's space agency has launched several sensors/satellites which help to develop various national level agricultural applications using remote sensing data. The department of Agriculture and Farmers' Welfare has recently launched a new project namely Coordinated Horticulture Assessment using Management using Geoinformatics, in short CHAMAN, to use geo-spatial applications for the assessment and management of horticultural crops such as onion, potato and mango. This is a project, started for assessment and development of Horticulture through Remote Sensing and geo-informatics Under the Mission of Integrated Horticulture Development (MIDH), the Department of Agriculture, Cooperation and Farmers' Welfare. This was implemented by Mahalanobis National Crop Forecast Centre (MNCFC) in collaboration with ISRO Centres (SAC and NRSC) and 12 state horticulture departments, NHRDF, IMD, ICAR Centre and State Remote Sensing Centres. It was implemented at a cost of Rs. 13.38 crore for duration of three years starting 2014 till 2017. The objectives of this programme is to estimate area and production of 7 horticultural crops (Potato, Onion, Tomato, Chili, Mango, Banana and Citrus) in 12 major states in 180 districts and thus to generate action plans for horticultural development (site suitability, infrastructure development, crop intensification, orchard rejuvenation, aqua-horticulture, etc.) using satellite remote sensing data and GIS (Geographical Information System) tools. Other components include geospatial applications for horticultural development and management planning (site suitability, post-harvest infrastructure, crop intensification, GIS database creation, orchard rejuvenation, aqua-horticulture). The programme CHAMAN also targets conducting different research activities on horticultural crop condition studies, diseases assessment and precision farming.

**Techniques of remote sensing and its applications**

- Conventional radar is mostly associated with aerial traffic control, early warning and certain large scale meteorological data.
- Doppler radar is used by local law enforcements monitoring of speed limits and in enhanced meteorological collection such as wind speed and direction within weather systems in addition to precipitation location and intensity. Other types of active collection include plasmas in the ionosphere.
- Interferometric synthetic aperture radar is used to produce precise digital elevation models of large scale terrain (RADARST, TerraSAR-X, Magellan).

- Laser and radar altimeters on satellites have provided a wide range of data. By measuring the bulges of water caused by gravity, they map features on the seafloor to a resolution of a mile or so.
- By measuring the height and wavelength of ocean waves, the altimeters measure wind speeds and direction and surface ocean currents and directions.
- Ultrasound (acoustic) and radar tide gauges measure sea level, tides and wave direction in coastal and offshore tide gauges.
- Light detection and ranging (LIDAR) is well known in examples of weapon ranging, laser illuminated homing of projectiles.
- It is used to detect and measure the concentration of various chemicals in the atmosphere, while airborne LIDAR can be used to measure heights of objects and features on the ground more accurately than with radar technology. Vegetation remote sensing is a principal application of LIDAR.
- Radiometers and photometers are the most common instrument in use, collecting reflected and emitted radiation in a wide range of frequencies. The most common are visible and infrared sensors, followed by microwave, gamma ray and rarely, ultraviolet. They may also be used to detect the emission spectra of various chemicals, providing data on chemical concentrations in the atmosphere.
- Stereographic pairs of aerial photographs have often been used to make topographic maps by imagery and terrain analysts in trafficability and highway departments for potential routes, in addition to modelling terrestrial habitat features.
- Simultaneous multi-spectral platforms such as Landsat have been in use since the 1970s.
- These thematic mappers take images in multiple wavelengths of electro- magnetic radiation (multi-spectral) and are usually found on Earth observation satellites, including (for example) the Landsat program or the IKONOS satellite.
- Maps of land cover and land use from thematic mapping can be used to prospect for minerals, detect or monitor land usage, detect invasive vegetation, deforestation and examine the health of indigenous plants and crops, including entire farming regions or forests.

- Landsat images are used by regulatory agencies such as KYDOW to indicate water quality parameters including Secchi depth, chlorophyll a density and total phosphorus content. Weather satellites are used in meteorology and climatology.
- Hyperspectral imaging produces an image where each pixel has full spectral information with imaging narrow spectral bands over a contiguous spectral range. Hyperspectral imagers are used in various applications including mineralogy, biology, defence and environmental measurements.
- Within the scope of the combat against desertification, remote sensing allows to follow up and monitor risk areas in the long term, to determine desertification factors, to support decision-makers in defining relevant measures of environmental management and to assess their impacts

**Methods for monitoring indicators of vegetation condition (Spatial and temporal scales of monitoring)**

- It is a site-based monitoring programmes having a long a history of application and still being commonly used today.
- It involves selecting sites from within homogenous patches of vegetation of the same community type and site history.
- The majority of site-based assessments are quadrat-based where detailed information is collected about the compositional, structural and functional attributes of a site.
- In some cases landscape metrics have also been added into overall measures and benchmarked scores are combined to give an overall condition index for individual patches of sampled vegetation.
- It predominantly measure structural and compositional indicators of vegetation condition, with less emphasis on indicators of function.

**Assessed stress by utilising remote sensing (Detection of plant water stress using remote sensing)**

These technologies acquire many hundreds of spectral bands across the spectrum from 400 nm to 2500 nm, using satellite, airborne or hand-held devices. The spectral characteristics of vegetation are governed primarily by scattering and absorption characteristics of the leaf internal structure and biochemical constituents, such as pigments, water, nitrogen, cellulose and lignin. Pigments are the main determinants controlling the spectral responses of leaves in the visible wavelengths. Chlorophyll pigment content in particular is directly associated with photosynthetic capacity and productivity. Reduced concentrations of chlorophyll are indicative of plant stress.

### Spectral indicators of plant chlorophyll content

In stressed vegetation, leaf chlorophyll content decreases, thereby changing the proportion of light-absorbing pigments, leading to a reduction in the overall absorption of light.

These changes affect the spectral reflectance signatures of plants through a reduction in green reflection and an increase in red and blue reflections, resulting in changes in the normal spectral reflectance patterns of plants. Thus, detecting changes from the normal (unstressed) spectral reflectance patterns is the key to interpreting plant stress.

### Spectral indicators of plant water content

Plant water content at the leaf and canopy scales is often estimated using specific spectral reflectance bands and spectral reflectance indices from near infrared, middle infrared (MIR) and short-wave infrared (SWIR) regions of the electromagnetic spectrum.

NIR and MIR spectral bands are highly correlated to water content of vegetation and soils. Spectral bands from these regions have been used to delineate stressed trees from non-stressed trees. In these regions of the electromagnetic spectrum, leaf water content has been remotely assessed using bands 1550 nm to 1750 nm MIR reflectance increased with decreasing leaf water content.

### Predawn leaf water potential

Predawn leaf water potential measurements, often undertaken with a pressure chamber, are useful for determining plant water stress.

At predawn, xylem water potential has equilibrated with soil water potential after a night of negligible transpiration. At this time, plant water potential is usually at its minimum for the day. The pressure chamber is most commonly used for estimating leaf water potential, having the advantage of simplicity, reliability, instantaneous measurements, low capital cost and portability.

It is commonly used as a plant water stress indicator and has also been used to describe the water status of different species within a habitat.

## Leaf chlorophyll fluorescence

Chlorophyll fluorescence measurements can be described using the typical phases of a temporary fluorescence signal or transient. Therefore, this photosynthetic apparatus has been recognised as being a good indicator of stress and stress adaptation of a plant and is associated with the measurement of chlorophyll fluorescence. Also, because changes in chlorophyll fluorescence may occur before any physical signs of tissue or chlorophyll deterioration are manifested in the plant, stress can be detected before the onset of physical damage.

## Conclusion

With the launch and continuous availability of multi-spectral (visible, near-infrared) sensors on polar orbiting earth observation satellites (Landsat, SPOT, IRS, etc.) remote sensing (RS) data has become an important tool for yield modeling. Remote sensing research has identified several individual spectral bands and vegetation spectral reflectance indices which have been used to detect plant water stress. Depending upon the scale at which an investigation is being undertaken, it is recommended that a practical approach to assessing plant water stress is adopted through the use of at least one ground-based measurement.

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