4. Pasture management with broad range of forage crops

5. Avoiding fallowing by growing off-season cover crops

3. INTEGRATED NUTRIENT MANAGEMENT

Integrated nutrient management (INM) is the practice of maintaining soil fertility through utilization of all possible sources of nutrient supply (organic manures, composts, bio-fertilizers and inorganic fertilizers) by using them in integrated manner. It draws following benefits:

1. It keeps in equilibrium the readily available, slowly available and fixed forms of nutrients.

2. Physical, biological and chemical health of soil is maintained.

3. It maintains continuous nutrient supply to crops in terms of time and space by synchronizing plant demand with soil and applied nutrient pools.

4. Minimize nutrient losses and avoids soil and water pollution by fertilizers.

Major components of INM:

1. Organic Manures:

a) In-situ organic manuring

This is the soil manuring at site. It has 2 sources:

i. In-situ animal manuring

Usually practiced in areas where cattle, sheep buffalos, and goats are reared in the open lands and later on their dung is ploughed down into the soil.

ii. In-situ plant manuring (green manuring)

It is the growing of green manure crops (guara, dhaincha, berseem, sunhemp, and senji) then incorporating them into soil at the time of flower initiation.

b) Ex-situ organic manuring

Plant and animal wastes from agriculture and agro-industrial sources such as:

i. Livestock and human waste

ii. Crop residues, tree waste

On an average, crop residues contain about 1.5% K_2O, 0.6% P_2O_5, and 0.5% N.

iii. Urban and rural wastes

- Urban and rural composts
- sewage and sludge

Rural and urban waste on an average contains about 0.8-1.2% K_2O, 0.5-1.0% N, and 0.4-0.8% P_2O_5.

iv. Agro-industries by products

- Wheat and rice mills waste
- Bagasse and press mud
- Saw dust

2. VERMI-COMPOST:

Vermi-composting is a process where worms are used in transforming agricultural and kitchen waste, and city garbage into valuable fertilizer products. Usually, vermicompost contains 0.4-0.9% N, 0.2-0.3% P_2O_5 and 0.2-0.5% K_2O, and lot of micronutrients.

There are following advantages of using vermicompost:

1. It improves soil fertility as well as physico-biochemical properties of soil.

2. It adds considerable amounts of micronutrients to soil.

3. Rich in growth promoters and enzymes.

5. Maintains soil pH to neutral range thus helps in keeping nutrient availability.

6. Quality, shelf life and nutritive value of horticultural crops is enhanced.

7. Al toxicity is reduced.

3. Biofertilizers:

Biofertilizers are the microbial rich organic materials manufactured to get benefits from a number of biological processes such as biological N fixation, nutrient solubilization, growth promoting hormones carried out by living micro-organisms.

Kinds of biofertilizers

a) Nitrogen Fixing Biofertilizers

These biofertilizers contain nitrogen fixing bacteria and blue green algae that add plant available N to the soil by after fixing atmospheric nitrogen.

i. Rhizobium

Rhizobium is specific to crop and used for inoculation purpose in legumes crops. Rhizobium bacteria fix atmospheric nitrogen in especially in legumes, however in some non-legumes it also fix atmospheric nitrogen. Act on pulses like mash, moong, arhar, pea, lentil, chickpea and others like soybean, groundnut, berseem, and lucerne etc. Rhizobium can fix 50-150 kg N/ha/season and increase yield 10-30%. It is needed in areas where a particular legume crop has not grown earlier or is being grown after 3-4 years. Twenty grams of culture is required to inoculate 1 kg seed of pulse crop. Crop inoculation groups along with their rhizobium species and legume crops have been listed in Table 11.2.

Table 11.2.: Major cross inoculation groups with inoculants and host plant

Cross inoculation group	**Rhizobium species**	**Legume host**
Pea group	*R. leguminosorum*	pea, sweet pea
Alfalfa	*R. meliloti*	sweet clover
Clovers	*R. trifoli*	clover/berseem
Bean group	*R. phaseoli*	all beans
Soybean group	*R. japonicum*	/soybean
Lupine group	*R. lupini*	lupins
Cow pea group	*R. species*	cowpea, gram, arhar, urd, moong, groundnut

ii. Azotobacter

Azotobacter is non- symbiotic, free living and aerobic nitrogen fixing bacteria mostly used on a limited scale found in close association with vegetable crops. Besides vegetables it is also effective for sugarcane, cotton, cereals and millets. It can fix about 15-25 kg N/ha/season and causes about 10-15% increase in yield. Azotobactor is reported to synthesize growth promoting substances like IAA, IBA, NAA, cytokinins , and GA, B-vitamins which help in plant growth promotion. Azotobactor synthesizes antibiotic substances which has effective control against various fungal infections that are caused by Alternaria & Fusarium, viral and bacterial diseases of crop plants. It mineralizes tricalcium phosphate and thus increases uptake of P in plant. It has been reported that in rice and wheat yields were increased by 5-31 and 16-30%, respectively with azotobacter culture. This can be applied in the fields either by seed inoculation, seedling inoculation, pelleted seeds, pre-inoculated seed or granular soil inoculants. Of these, seed and seedling inoculation are common, effective and easy. In seed inoculation, carrier based culture as per need and it is mixed with water of 500 mL/packet to form slurry adding 10% sugar and 40 percent gum arabica. Required quantity of seed is then mixed with slurry to form uniform coating of seed with inoculants. Two kilograms of the culture is mixed with 25 kg FYM and broadcasted in the field uniformly before sowing. The roots of seedlings can be dipped in azotobacter slurry prior to transplantation.

iii. Azospirillum

This species is also crop specific and commonly useful for cereal. The crops responding to azospirillum are maize, barley, wheat, rice, oats, sorghum, pearl millet and forages. Roots of these crops excrete organic substances (exudates) which are good source of carbon and energy for azospirillum and stimulate its multiplication. It can enhance crop yield by 14-20%. It can fix about 20-25 kg N/ha/season. Application procedure is same as for azotobacter**.**

iv. Blue-green algae

These are cyanobacteria, free-living organisms. They are photosynthetic nitrogen fixers (they use energy derived from photosynthesis to fix atmospheric N). The BGA anabaena inhabits cavities in the leaves of floating fern Azolla and fix nitrogen in lowland rice. The Azolla-anabaena complex is a significant non symbiotic system without nodule formation. The common Azolla specie is *Azolla pinnata*. The BGA can be cultured in small pits and used as an inoculum in rice fields at 12 to 15 kg ha^{-1} or mass multiplied in cropped area assimilated into the soil before planting.

BGA boosts rice production (up to 50 %) under an-aerobic conditions by fixing nitrogen and release of plant growth regulators for crop. They are reported to fix 20-25 kg N/ha/season. It can improve texture of soil by increasing organic contents and amino acids, produces organic acids that solubilize P precipitates, Ca which ameliorate soil, growth promoting substances, vitamins for rice and oxygenates the field impounded water to prevent accumulation of reduced iron and sulphates which are injurious to root growth. Blue green algae conserve nitrogen and carbon and converting the sodium clay into calcium clay. Under laboratory conditions about 12-34% decrease in soil salinity through mat has been reported (*Anabaena torulasa*). BGA produce the compounds responsible for "Earthy" odors detected in soil. Some BGA secrete mucilaginous substances which bind soil particles into soil aggregates.

v. Azolla

Azolla is applied in rice field at the rate of 7.5 kg/ha as a green manure. It is allowed to grow in flooded conditions for 2-3 weeks before transplanting, after that water is allowed to drain and azolla is mixed with cultivation in the field. As a double crop 10-50 q/ha of azolla (hybrid azolla at 60 kg/ha) is induced in the field about 1-1.5 week after rice transplanting. It forms a thick mat on water. Azolla can double its biomass in 3-5 days and assimilate 30-80 kg N/ha.

b) Phosphorus mobilizer biofertilizers

i. Phosphate solubilizers: Phosphorus solubilizing bacteria has ability to solubilize soil phosphate and increase P availability by secreting organic acids. These bacteria belongs to genera *Pseudomonas* and *Bacillus.* Some P solubilizing fungi also belongs to genera *Penicillium* and *Aspergillus.* Inoculation of seedlings or seeds with microphos biofertilizers can provide around 30 kg P_2O_5. These microorganisms secrete organic and inorganic acids such as malic acids, citric acid, formic acid, acetic acid etc. They reduced soil pH and caused dissolution of bound form of phosphorus. Bacillus grows on sulphur in soil and sulphuric acid is synthesized which dissolves phosphate from rock phosphate and make it available for plant use.

ii. Phosphate absorbers: Mycorrhizae are mutualistic symbiosis or association between roots and fungi present in soil. These are the member of kingdom Basidiomycetes, Zygomycetes and Ascomycetes. Vesicular-arbuscular mycorrhiza (VAM) increase the P nutrition along with its mobility. Through VAM plants are able to take P from soil zone not visited by root system. The VAM has also been reported to improve the uptake of zinc, copper and water. VAM are formed by association of phycomycete fungi and most of the agricultural crops. They store P as phospholipids. VAM inoculums can be prepared by mixing finely chopped roots of VAM infected host in sterile soil. Maize, sorghum and other grasses are suitable host for VAM inoculation. VAM culture can be used for all crops including grasses, legumes and cereals.

c) Organic matter decomposing bio-fertilizers

Insoluble contents of organic matter are cellulose and lignin and delay the composting process. Cellulose decomposing microorganisms are Chaetomium, Trichoderma, Aspergillus, Penicillum fungi and bacteria such as Cellulomonas, Clostridium, Cytophaga, Arthrobactor, and Actinomycetes, Nocardia and Streptomyces. Lignin decomposing fungi are cephalosporium, Humicola, etc. The decomposition of lignin is done by fungi.

Problems in Biofertilizers

1. Unawareness of biofertilizers
2. Unavailability of biofertilizers .
3. Poor quality biofertilizers or biofertilizers of expired date.
4. Transport and storage conditions that destroy the microbial

3- INORGANIC FERTILIZERS

Improved cultivars demand large quantities of nutrients due to their high yield potential. As such, low analysis organic manures and biofertilizers are not in a position to meet the nutrient needs of the crop. Until all the available resources of organic manure are fully tapped, there is need for supplementing at least part of plant nutrients, through inorganic fertilizers. It reported that inorganic fertilizers efficiency increased by its integration with organic manures and bio fertilizers. This will also reduce the environmental pollution.

4. SUSTAINABLE UTILIZATION OF WATER RESOURCES

A. Ground water use consistent with aquifer recharge

Ground water has a good source of irrigation water. However, much of the present practices of utilization are not sustainable because they largely depend upon luxurious use of water. The decline in ground water levels in certain areas has resulted in decrease in well yield, failure of wells/tube wells, increased pumping costs and higher consumption of energy and ingress (intrusion) of sea water in coastal areas. Thus, depletion of ground water needs to be arrested by:

i. Integrated approach for control of declining water table

1. Reduced ground water draft through

1. Enhancing surface water supply by developing new projects, inter zonal transfer of water, storage of surplus water, and renovation of water course,
2. Crop diversification,
3. Optimizing water use in rice fields,
4. Minimizing the gap between demand and supply,