Model Answers
M.Sc (Semester III)
Major Elective
LZT 303 (A) -Fish Biology
Paper 1: Fish Culture and Fish Pathology

Section A

Q. 1- Answer

(i)- (a)	(ii)- (d)	(iii)- (b)	(iv)- (d)	(v)- (a)
(vi)- (c)	(vii)- (a)	(viii)- (a)	(ix)- (c)	(x)- (c)

Section B

Q. 2- Answer

(a). Pond Fertilization: The process of adding manures to fish pond for increasing maximum carrying capacity is called pond fertilization. The significance of pond fertilization lies in the cultivation and propagation of various fish food organisms in ponds. The fertilizers used in fish culture pond may be of two different types: inorganic and organic.

Organic fertilizers:

- These fertilizers are of animal and plant origin.
- Microbes decompose them to release their K, N, P and C contents.
- **Types :**

(i) Faeces and urine of livestock and poultry- Pig and cattle manure contains large carbon and nitrogen which can be utilized for pond fertilization.

(ii) Green Manures: Nutritive and less fibrous plants such as wild grasses, and few plants belonging to family composite can be used as manure for fish ponds.

(iii) Compost: These are the decayed refuse like roots, twigs and leaves which are decomposed along with animal matter and can be utilized for increasing the productivity of a fish pond.

(iv) Silkworm faeces: Silkworm dregs are rich source of organic matter as well as nitrogen.

Inorganic Fertilizers: These include various inorganic chemicals and can be divided in to following main types:

(i) Phosphorous Fertilizers: considered as indispensible fertilizer, most effective for the growth of algae, application rate is about 25-30 kg/hect.

(ii) Potash Fertilizers: increases the growth of submerged plants, used along with phosphorous fertilizers.

(iii) Nitrogenous fertilizers: used only when pond is newly formed, used along with phosphorous in the ration of 1:4. Different nitrogen fertilizers include liquid ammonia, ammonium sulphate, urea etc.

(iv) Micronutrients: required in traces, mixed with other fertilizers such as slag.

Advantages of using fertilizers in fish ponds:

(i) Improve soil structure, water holding capacity, drainage and base exchange capacity.

(ii) Increase soil fertility of ponds.

(iii) Organic manure converts unusual surplus waste in to useful product.
(iv) They are potential source of micronutrients.

(b) Aquatic weeds: Plants are natural and important components of the aquatic environment. Microscopic plants (algae) form the base of the aquatic food chain. Larger algae and plants provide habitat for fish and food organisms, and all plants produce oxygen as they photosynthesize during the daylight hours. However, excessive growths of these plants can have a detrimental effect on a body of water and its inhabitants. Many shallow, nutrient-rich ponds, lakes, and drainage ditches provide ideal conditions for abundant aquatic weed growth.

Some of the problems caused by aquatic weeds are as follows:

- Interfere with fish culture.
- Stunt or interfere with a balanced fish population.
- Oxygen depletion occurs when plants die and decompose. Photosynthetic production of oxygen ceases, and the bacteria, which break down the plant material, use oxygen in their own respiration. Fish kills by die-offs of algae blooms. Light is blocked thus preventing photosynthesis by any living plants or algae.
- Produce stagnant water areas that are ideal for mosquito breeding.
- Impede water flow in drainage ditches, irrigation canals, and culverts, causing water to back up.

Types of Aquatic weeds:

Algae: Filamentous algae form floating, mat-like growths which usually begin around the edges and bottom of ponds in the early spring.

Flowering Plants: Flowering plants can be grouped into broad categories according to where they are found in a body of water:

Submerged plants are rooted in the bottom sediments and grow up through the water. Flowers or flowering spikes sometimes emerge above the water surface.

Free-floating plants float free on the water's surface. They never become rooted in the soil, and are propagated by sexual and asexual means. They can completely cover the surface of a pond.

Rooted floating plants include water lily and water lotus.

Control of aquatic weeds: The basic control approaches are-

(i) Preventive Measures: Proper design and construction of ditches and channels makes weed control easier in the future. If the banks are leveled and smoothed, hard-to-reach places will be eliminated. Lining canals will help to alleviate water weed problems, too.

(ii) Mechanical Control: Motor-driven underwater weed cutters are available and can be used for the control of many aquatic weeds. Most mechanical control methods fragment weeds. Many weed species can spread and reproduce from these pieces.

Mechanical control is usually slower and more expensive than use of herbicides.

(iii) Habitat Alteration: Certain methods of manipulating or altering the aquatic environment can be effective in controlling aquatic weeds. One of the more successful methods is the drawdown technique in which water levels are lowered over the winter. Exposure of the sediments in the shallow areas of a lake or pond to alternate freezing and thawing action will kill

the underground rhizomes of many aquatic weeds (the majority of aquatic weeds are perennial and come from rhizomes).

(iv) Biological Control: Several species of fish are herbivorous in that their principal diet is aquatic vegetation. One such species, the grass carp is being tested in various parts of the India for control of aquatic weeds.

(v) Chemical Control Methods: Control with Herbicides.

Q. No. 3- Answer

Qualities of culturable species of fishes: Good qualities of cultivable fish species are as follows-

- Fast growth.
- Accepts supplementary feed.
- Resistance to diseases.
- Tolerance to poor water quality.
- Must be popular and marketable within the community.
- Low cost of production.
- Easy to breed in captivity.

Indian Major Carps: The major carps of India fall under three genera, *Catla, Labeo* and *Cirrhinus*. Under the genus *Catla*, the species *C. catla*, under the genus *Labeo* fall the species *L. rohita, L. calbasu, L. fimbriatus, L. bata, L. gonius*, and under the genus *Cirrhinus* fall the species *Cirrhinus mrigala, C. reba, C. cirrhosa*.

(i) *Catla catla:*

Biological Characters:

- Body short and deep, somewhat laterally compressed, its depth more than head length.
- Head very large, its depth exceeding half the head length; body with conspicuously large cycloid scales, head devoid of scales.
- Snout bluntly rounded.
- Eyes large and visible from underside of the head; mouth wide and upturned with prominent protruding lower jaw.
- Upper lip absent, lower lip very thick.
- No barbells.
- Lower jaw with a movable articulation at symphysis, without a prominent process.
- Gill rakers long and fine; pharyngeal teeth in three row, 5.3.2/2.3.5 pattern.
- Dorsal fin inserted slightly in advance of pelvic fins, with 14 to 16 branched rays, the simple rays non-osseous.
- Anal fin short; pectoral fins long extending to pelvic fins; caudal fin forked.
- Lateral line with 40 to 43 scales.
- Grayish on back and flanks, silvery-white below; fins dusky.

Habitat and Biology:

- *Catla* is a eurythermal species that grows best at water temperatures between 25-32 °C.
- The eggs are demersal at first, gradually becoming buoyant. Early-stage larvae remain in surface and sub-surface waters and are strongly phototactic.
- The fry are planktophagic, feeding mainly on zooplankton such as rotifers and cladocerans. Adults feed only in surface and mid-waters.
- *Catla* attains maturity in its second year, performing a spawning migration during the monsoon season towards the upper stretches of rivers, where males and females congregate and breed in shallow marginal areas.
- Since a riverine environment is required, natural breeding does not occur within ponds, even though the species attains maturity; thus hormonal induction is required. Among the three Indian major carps, *Catla* is the most difficult to breed as it requires precise environmental conditions for spawning.
- Under normal conditions *Catla* grows to 1-1.2 kg in the first year, compared to 700-800 g and 600-700 g for *Rohu* and *Mrigal*, respectively. It attends sexual maturity in two years.

Distribution: Jhingran (1968) described the distribution of *Catla catla*, which starts from the Ganga river network in the north to the Krishna River down south of India, Pakistan, Bangladesh and Burma. It is also found in Nepal

(ii) *Labeo rohita*

Biological Characters:

- Body bilaterally symmetrical, moderately elongate, its dorsal profile more arched than the ventral profile.
- Body with cycloid scales, head without scale.
- Snout fairly depressed, projecting beyond mouth, without lateral lobe.
- Eyes dorsolateral in position, not visible from outside of head; mouth small and inferior; lips thick and fringed with a distinct inner fold to each lip, lobate or entire.
- A pair of small maxillary barbells concealed in lateral groove; no teeth on jaws; pharyngeal teeth in three rows; upper jaw not extending to front edge of eye;
- Simple (unbranched) dorsal fin rays three or four, branched dorsal fin rays 12 to 14; dorsal fin inserted midway between snout tip and base of caudal fin; pectoral and pelvic fins laterally inserted; pectoral fin devoid of an osseous spine; caudal fin deeply forked.
- Lower lip usually joined to isthmus by a narrow or broad bridge; pre-dorsal scale 12-16.
- Lateral line distinct, complete and running along median line of the caudal peduncle.
- Lateral line scales 40 to 44; lateral transverse scale-rows six or six and a half between lateral line and pelvic fin base.
- Snout not truncate, without any lateral lobe.
- Colour bluish on back, silvery on flanks and belly.

Habitat and Biology:

- In its early life stages *Rohu* prefer zooplankton, mainly composed of rotifers and cladocerans, with phytoplankton forming the emergency food.

- In the fingerling stage, there is a strong positive selection for all the zooplanktonic organisms and for some smaller phytoplankters like desmids, phytoflagellates and algal spores. On the other hand, adults show a strong positive selection for most of the phytoplankton.
- In the juvenile and adult stages *Rohu* is essentially an herbivorous column feeder, preferring algae and submerged vegetation. Furthermore, the occurrence of decayed organic matter and sand and mud in its gut suggests its bottom feeding habit.
- The nibbling type of mouth with soft fringed lips, sharp cutting edges and absence of teeth in the bucco-pharyngeal region helps the fish to feed on soft aquatic vegetation which do not require seizure and crushing.
- Rohu is a eurythermal species and does not thrive at temperatures below 14 °C. It is a fast growing species and attains about 35-45 cm total length and 700-800 g in one year under normal culture conditions. Generally, in polyculture, its growth rate is higher than that of Mrigal but lower than catla.

Distribution: The main source of literature about the distribution of Rohu is Day (1878 and 1889). He reported that the species is distributed in freshwaters of Sindh and Punjab (Pakistan), through India, Assam, Bangladesh and Burma. He also stated that Rohu is not found in Madras (South India).

Later studies of other workers have mentioned the occurrence of this species in many other places, viz., Sabarmati drainage, in the rivers Narmada, Tapti, Godavari, Mahanadi etc. though it is more common in plains of North India.

Q. No. 4- Answer

Liming: Preparing the fish ponds and treating them with various types of lime, chemical substances rich in calcium (Ca) is called liming. This process improves the structure of the pond soil, improves and stabilizes water quality and makes the fertilizing materials act more efficiently to increase food supply.

Three basic chemicals are commonly used for liming fish ponds:

- calcium carbonate, $CaC0_3$;
- calcium hydroxide, $Ca(OH)_2$, or hydrated lime;
- calcium oxide, CaO, or quicklime.

Liming fish ponds is not always necessary. In certain cases, it may not only be a waste of money but it can also be harmful to fish. In following conditions liming is required:

(a) If the pH of the pond bottom soil is less than 6.5, liming of the bottom soil is justified.

(b) If the pond bottom is very muddy because it has not been regularly drained and dried, liming will improve soil conditions.

(c) If there is the danger of the spread of a contagious disease or if common pests should be controlled, liming can help, especially in drained ponds.

(d) If the amount of organic matter is too high, either in the bottom soil or in the water, liming may be advisable.

(e) If the total alkalinity of the water is less than 25 mg/l $CaC0_3$, liming could be justified.

Liming will have little effect and might be difficult to economically justify if:

- the bottom soil pH is above 7.5;

- the water exchange through the pond is too fast;
- the water pH at the end of the day is 7.5 or above;
- the water total alkalinity is above 50 mg/l $CaC0_3$.

Generally, ponds should not be limed if:

- fertilizers will not be used subsequently, unless the water is very acid;
- natural food is not important, the fish being fed a complete diet;
- the water pH reaches more than 8.5 by the end of the day.

The beneficial effects of liming

The **effects on bottom soil** are:

- **structure** will be improved
- **decomposition of the organic matter** will be accelerated; and
- **pH** will increase.

The effects on pond water are:

- pH will increase and become more stable;
- total alkalinity will increase, providing more carbon dioxide for photosynthesis;
- calcium content will increase, to be used by plants;
- certain toxic substances such as iron compounds will be neutralized and precipitated as
- pH increases; and
- excess organic matter will precipitate, decreasing the demand for dissolved oxygen in
- the pond water.

Q. No. 5- Answer

Composite Fish Culture: Stocking of cultivable fishes of different species which differ in feeding habits in same pond is called composite fish culture or Polyculture or Mixed fish farming

Objectives of Composite Fish Farming:

- All available niches utilized
- Composite fish species do not harm each other
- Production increases 5 – 8 times than monoculture

Composite Fish Culture in India: Following three species of fishes are commonly utilized for composite fish farming in India.

- *Catla catla: Surface feeder, zooplankton*
- *Labeo rohita: Column feeder , omnivore*
- *Cirrihinus mrigala: Bottom feeder , detritivorous*

Stocking Density: Selection of species for stocking depends on-

- nature of soil
- water of ponds
- stocking material
- fish food

Indigenous				**Exotic**		
Catla :	Rohu :	Mrigal :	Common Carp:	Grass Carp:	Silver Carp	
1	1	1	2.5	2.5	2	
1	1	1	2.5	1.5	3	
1.5	3	1	2.5	1.5	3.5	

Stocking Pattern: As far as possible, pond should be stocked with Silver carp, the percentage of which may be 10 to 20 depending on the availability of the seed. *Catla* is also stocked and it is suggested that the combined stocking density of Silver carp and *Catla* should not exceed more than 30 to 35%. Both silver carp and *Catla* feed mainly on surface and thus they are grouped as surface feeders. Growth is normally affected if their proportion in the stock is more than 30–35%. Rohu feeds in the underwater is called a column feeder and does grow well in deeper ponds. Therefore, ponds having more than 3–4 meter depth of water need to be stocked with 15 to 20% of Rohu. In shallow ponds the stocking density of Rohu should not be increased more than 10% of the total stocking density. Bottom feeders such as Mrigal and common carp are stocked at a higher ratio which may together account to about 40–45%. Availability of aquatic weeds in the pond or in the vicinity decides the stocking density of grass carp. It is always desirable to keep 5 to 10% Grass carp, and manage to feed it with aquatic weeds, green vegetables or even with land grasses.

It has been seen in different parts of India that despite higher numbers of Chinese carps used for stocking in Composite fish culture, they have recorded better growth rate than Indian major carps. However, their wide spread use is dependent on the availability of their seed.

Species Interrelationships

Catla and Silver carp

- Catla and silver carp both are planktophage surface feeders, though Catla is predominantly zooplanktophage and Silver carp phytoplanktophage.
- Because of their similar feeding zone and feeding habit it is assumed that their exists some competition between these two species for the same ecological niche.
- Silver carp at double the numbers of that of Catla, the former invariably grew faster achieving weights double that of Catla, at times even more than double.
- Combination can be - 1:1, 1.5:2, 1:3
- Silver carp show better growth

Mrigal and Common carp

- Stocked at equal numbers, growth performance of Mrigal and Common carp appears to be similar in cases where supplementary feed was not supplied adequately.
- However, when supplementary feeds were given in large quantities, Common carp stocked in larger numbers performed much better than Mrigal, indicating its superior capability of utilizing artificial feeds than Mrigal.
- Combination can be 1:1
- Common carp show better growth
- Monthly growth – 147g (Common carp), 76 – 107g (Mrigal)

Grass carp and other fishes

- Association of Grass carp in composite fish culture has an indirect benefit too.
- The excreta consisting of semi-digested vegetable matter, serve as the food of bottom dwellers e.g., Mrigal and Common carp.

- However, Grass carp is also well known utilizer of supplementary feeds like rice polish and oilcakes.
- In order to avoid competition among Grass carp, Rohu, Mrigal and common carp for taking supplementary feeds it is advisable always to provide aquatic weeds in adequate quantity to Grass carp.

Thus the concept of polyculture involves judicious exploitation of all the niches available in the pond. In composite fish culture not only judicious combination of species is required but also proper management techniques, such as preparation of ponds prior to stocking, stocking management, fertilization of the water and supplementary feeding to the fishes are necessary to achieve optimum production.

Q. No. 6 Answer

Categories of exotic fishes:

1. Food fishes: e. g. *Cyprino carpio, Carassius carassius*
2. Game fishes: e. g. *Salmo irrideus, Salmo solar*
3. Larvicidal fishes: e. g. *Gambusia affinis, Lebistes reticulatus*

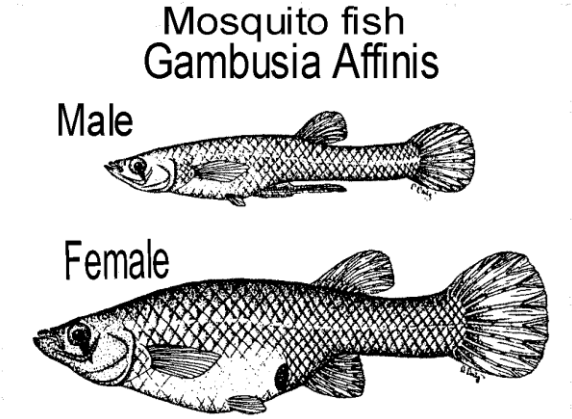
Important larvicidal exotic fishes of India: In spite of an already rich and diverse fish genetic resource of India, more than 300 exotic species have been introduced into the country so far (Jhingran, 1989a). While a vast majority of them are ornamental fishes which remain, more or less, confined to the aquaria, some others have been introduced in aquaculture and open water systems with varying degrees of success. Three larvicidal fishes *viz., Lebistes reticulatus*, *Nothobranchus* sp. and *Gambusia affinis* were introduced for containing the insect larvae in confined waters.

1**. *Gambusia affinis*:** The mosquitofish (*Gambusia affinis*) is a species of freshwater fish, also known commonly as simply mosquitofish or by its generic name, *Gambusia*. Mosquitofish are small in comparison to other fish, with females reaching an overall length of 7 centimeters (2.8 in) and males at a length of 4 centimeters (1.6 in). Females can be distinguished from males by their size and a gravid spot at the posterior of their abdomen.

- The mosquitofish is a member of the family Poeciliidae of order Cyprinodontiformes.
- Mosquitofish are small, dull grey, with a large abdomen, and have rounded dorsal and caudal fins and an upturned mouth towards the surface.
- Sexual dimorphism is pronounced; mature females reach a maximum overall length of 7 centimeters (2.8 in), while males reach only 4 centimeters (1.6 in).
- Sexual dimorphism is also seen in the physiological structures of the body. The anal fins on adult females resemble the dorsal fins, while the anal fins of adult males are pointed. This pointed fin, referred to as a gonopodium, is used to deposit milt inside the female. Adult female mosquitofish can be identified by a gravid spot they possess on the posterior of their abdomen.
- Based on diet, mosquitofish are classified as larvivorous fish. Their diet consists of zooplankton, small insects and insect larvae, and detritus material. Mosquitofish feed

on mosquito larvae at all stages of life. Adult females can consume in one day hundreds of mosquito larvae.

- They are found most abundantly in shallow water protected from larger fish. Mosquitofish can survive relatively inhospitable environments, and are resilient to low oxygen concentrations, high salt concentrations (up to twice that of sea water), and temperatures up to 42 °C (108 °F) for short periods.



2. *Lebistes reticulates:* The *Lebistes reticulates* also known as guppy, million fish and rainbow fish is one of the world's most widely distributed tropical fish, and is one of the most popular freshwater aquarium fish species. It is a member of the Poeciliidae family and, like all other members of the family, is live-bearing.

- Guppies, whose natural range is in northeast South America, were introduced to many habitats and are now found all over the world. Sometimes this has occurred accidentally, but most often as a means of mosquito control.
- Guppies exhibit sexual dimorphism. While wild-type females are grey in body color, males have splashes, spots, or stripes that can be any of a wide variety of colors.The size of guppies vary, but males are typically 1.5–3.5 centimetres (0.6–1.4 in) long, while females are 3–6 centimetres (1.2–2.4 in) long.
- There are around 2-3 generations of guppies per year in the wild. Guppies are well developed and capable of independent existence without further parental care by the time they are born. Young guppies school together and perform anti-predator tactics.
- Guppies' body size is positively correlated with age, and their size at maturation varies highly depending on the predation risk of their habitats.
- Female guppies first produce offspring at 10–20 weeks of age, and they continue to reproduce until 20–34 months of age. Male guppies mature in 7 weeks or less. Total lifespan of guppies in the wild varies greatly, but it is typically around 2 years.
- Guppies reduce their fecundity and reproductive allocation in response to scarce food. When food is abundant, they increase brood size.
- Wild guppies feed on algal remains, diatoms, invertebrates, plant fragments, mineral particles, aquatic insect larvae, and other sources. Algal remains constitute the biggest proportion of wild guppy diet in most cases, but diets of wild guppies vary depending on the specific conditions of food availability in the habitat.

Q. No. 7 Answer

Bacterial diseases in fishes and their treatment:

Erythroderma

- *Pathogen—Pseudomonas fluorescens* is a short, rodlike bacteria with round ends. It measures 0.7–0.75 × 0.4–0.45 μm and exists either singly or in pairs. It is motile with a single polar flagellum, has no gemma, and is gram negative. Agar colonies of *P. fluorescens* are circular in shape, semiopaque, and greyish white.
- *Symptoms and pathological changes* — Symptoms include inflammation, bleeding from the skin, and a loss of scales, particularly on the sides of the abdomen. Blood shot on the fin base, necrosis of the terminal of fins, and red blotches around the upper and lower jaws are also symptomatic of erythroderma. Occasionally, congestion and inflammation along the intestines also occurs.
- *Epidemic situation* — Erythroderma is a common disease of grass carp and black carp and is widespread on all farming sites. Mechanical lesions obtained during stocking or netting allow the bacteria to invade the fish. In addition, wounds may result from fish rubbing against solid objects in the water. Because of these factors, erythroderma is a year-round disease.
- *Prevention* — Complete pond clearing and disinfection and gentle netting, carrying, and stocking are effective preventive measures. A promising method of prevention involves dipping fingerlings in a 5–10 ppm bleaching powder solution for 30 min before stocking. The fingerlings may also be vaccinated.
- *Treatment* — Because the pathogenic bacteria not only infect the skin and the muscle but also invade the blood, medicine should, therefore, be administered both internally and externally.
- Internally, sulphathiazole should be given orally once a day for 6 consecutive days. The 1st-day dose should be 10 g/100 kg fish; the dose for the remaining 5 days is 5 g/100 kg fish. The medicine is mixed with the feed using a binder. Externally, bleaching powder (containing 30 per cent available chlorine) should be spread over the pond to a concentration of 1 ppm.

Enteritis

- *Pathogen —Aeromonas punctata* f. *intestinalis*, which is a short rod-shaped bacteria with two round ends. It measures 0.4–0.5 × 1–1.3 μm and exists mostly in pairs. It has a single polar flagellum, no gemma, and is gram negative. Pathogenicity increases at a suitable water temperature (around 25°C) as water quality deteriorates, as air pressure decreases, and when fish are overfed.
- *Symptoms and pathological changes* — The diseased fish has an expanded abdomen with red blotches; the fins are congested and decayed, the anus is red and swollen, and, when slight pressure is applied to the abdomen, a yellow mucus is released from the anus. The intestinal walls show hyperaemia and inflammation. Cells of mucous membrane ulcerate and drop off, becoming bloody mucus and blocking the intestine. The diseased fish shows a loss of appetite, swims slowly and alone, and soon dies.
- *Prevention* — Maintaining water quality strictly, feeding should be limited and prophylaxis performed regularly.
- *Treatment* — Integrate oral administration with external administration. Externally, bleaching powder should be sprayed into the pond to a concentration of 1 ppm or

quicklime should be scattered over the pond at a dose of 15–25 kg/mu per meter water depth.

Bacterial gill rot

- *Pathogen — Myxococcus piscicolus* is a slender, soft, and easy to coil bacterium. Its length varies greatly (2–37 μm), it is gram-negative,
- *Symptoms and pathological changes* - Diseased fish are black in appearance, especially the head. The gill filaments, which are often covered with mud and mucus, are putrid and pale. In a serious case, hyperemia and inflammation are found on the inside and outside of the opercula. The epidermis of the opercula often rots away leaving a transparent area. Histological studies of bacterial gill rot in grass carp found that it can be divided into chronic and acute types. The chronic disease lasts longer, with prevalent cellular hyperplasia. The acute disease is short with inflammatory dropsy or cell necrosis as the main symptoms.
- *Epidemic situation* — Bacterial gill rot affects grass carp, black carp, bighead, common carp and other fishes; grass carp is the main victim. It is one of the most serious diseases of grass carp, occurring year-round on all fish farms. It seldom appears when the water temperature is below 15°C and begins to occur when the water temperature is above 20°C. Its optimum temperature range is 28–35°C. Therefore, it is more prevalent in the spring, summer, and autumn than in the winter. The disease is often accompanied by enteritis.
- *Control* —When the disease is prevalent, disinfect the pond water and the pond sides weekly with dissolved bleaching powder at a rate of 0.25 kg/mu. For prevention purposes, bleaching powder baskets should be hung around the feeding platforms or bleaching powder should be spread into the pond water to a concentration of 1 ppm.

Q. 8- Answer:

As the name suggests, supplementary feeds do not have to provide a complete, balanced diet alone. Instead they merely add some extra nutrients to those already available to fish from the natural food production in the pond or waterway. Normally, a supplementary feed contributes mostly cheaper carbohydrate rich components. The fish can use these as an energy source, thus freeing more of the protein available from natural food sources to be used for growth. Poorer quality supplementary feeds, which are high in fibre and other components poorly digestible by fish, act more as fertilizers which stimulate production of natural foods in the pond. Thus the distinction between fertilization and supplementary feeding is not always clear.

Sources of supplementary feeds

(a) Plants and animals of aquatic origin

Many of the aquatic plants and animals are valuable foods for either human beings or for livestock. Of these, chestnut (*Trapa natans*) and lotus (*Ipomea aquatica*) are good for human consumption; water hyacinth (*Eichornia crassipes*), hornwort (*Ceratophyllum demersum*), and nariad (*Najas guadalupensis*) are good for cattle, sheep, goats, pigs and poultry; duck weeds (*Potamogeton spp*.) and reed leaves (*Phragmites spp.)* are good, both for farmed animals and for fish.

Of the aquatic animals, the group of wild trash fish is the largest one. Depending on the country, these are utilized either as food for human consumption or feed for farmed animals, including fish. In developing countries, they are seldom utilized as ingredients for fish diets, unless the

production manager forbids the fishermen to take home these fish when they are gathered from the harvested ponds.

(b) Plant and vegetable production

Cereals: The main products of cereal production are grain and seed, while the by-products are straw or stems and/or cobs. With proper handling, there is practically no waste during harvest and/or storage.

By-products of cereals are used as feedstuffs for ruminants or as litter. In fish culture, cereal by-products are used as fertilizers before or after being used as litter.

The utilization of wastes derived from improper harvest and/or storage must be done carefully, because many kinds of dirty, mouldy or rotten seeds are not good for fish. They may cause enteritis or intoxication and therefore their suitability must always be checked locally, by trials.

Root crops: The surplus and uneaten parts of root crops, and the by-products such as leaves and stems, etc., are mainly utilized as feedstuffs for domestic animals. The tubers can be used after processing (by chopping, soaking, cooking, etc.) in intensive and semi-intensive fish production. The waste from tubers is also good for use in animal husbandry as well as in fish culture, provided it is not rotten or mouldy.

Legumes: There is a wide variety of leguminous plants, the main products of which are utilized for human consumption and feed for all kinds of livestock.

The seeds of the green forage plants (alfalfa, clover, etc.), and the pods and leaves of other species, are the by-products.

With proper handling there is little waste. Fresh alfalfa and clovers are good for ruminants, pigs and poultry as well as for herbivorous fish species.

Grasses: Fresh or as hay, these are used mainly as forage for ruminants. Pigs and ducks utilize most of them also. Fresh grasses are good for herbivorous fish especially grass carp.

Oil seeds: Fresh oil seeds are rarely used as feeding material, and when used they can be given only in small quantities due to toxicity. By-products (leaves, hay, stem) are utilized mostly in ruminant farming.

Vegetables: The surplus and the damaged parts of vegetables are good for most farmed animals. By-products (leaves, stems, pods) are utilized as well. In production, harvest and storage there is normally no considerable quantity of waste.

(c) Products of animal husbandry: In animal husbandry the animal itself is the main product, and there are practically no by-products. The waste of animal husbandry, i.e., the manure, is one of the most important traditional materials to raise the productivity of the land, and fish ponds.

The quantity and quality of manure from various animals differ; the ruminants have the poorest and chickens/ducks have the richer manure.

(d) Products of the food industry:

The milling industry: The main products are rarely used as feedstuffs, but all of the by-products are excellent. They are frequently used as energy-rich feeds for pigs, poultry and also for intensive and semi-intensive fish-culture. The wastes (mill sweepings) are good for fish.

Sugar production: The by-products of sugar production are utilized in cattle husbandry and in pig fattening. The wastes from it (lime-mud and sewage) can be utilized on land and in ponds as fertilizer.

Distilleries: The by-products of the different distilleries such as pomace, fresh or dry spent grain, malt germ and yeast, are good feeds for cattle, pigs, poultry and fish.

Vegetable/fruit processing and cold-storage plants: The by-products of vegetable and fruit processing are the various kinds of pomaces, mollasses, seeds, and skins, which either fresh or dry can be used as feedstuffs for ruminants, pigs, poultry and fish.

Slaughtering and meat processing: In slaughter-houses, blood, soft and hard wastes, hooves, horns and feathers can be considered as by-products which are utilized as feedstuffs with or without processing. The sewage of the slaughter-houses can be utilized as material to raise the natural productivity of fish ponds.

Storage:

- Cereal grain is a living material, and the life processes continue even after harvest. Cereal grains take moisture up from the environment, and release it under warmer conditions.
- Like any living organisms, cereal grains respire. In the absence of oxygen, a so-called anaerobic respiration occurs. In principle, this is identical with alcoholic fermentation. This degradation process can be observed in wet grain stored in thick layers.
- The wetter the grain, the more intensive the respiration. Respiration of air-dried grain (with 12–13% moisture content) is practically nil. It becomes marked if moisture content exceeds 15%; the loss in dry matter content is also significant.
- Respiration is also influenced by the temperature of the grain and its environment
- Degradation of grain of high moisture content is caused mostly by intensive respiration. Respiration is the consequence of an enzyme activity which depends on the free moisture content of the grain. If air humidity reaches or exceeds 74%, propagation of moulds starts. Mouldy grain is not only unusable, but can even be toxic. Therefore, during storage the moisture content of grain should not exceed 14%, and air humidity should remain below 70%.

To ensure safe, degradation-free storage conditions, the following measures can be applied:

i. Only air-dry cereals should be harvested; if this is not possible....
ii. Cereals should be dried.
a. if drying is done with warm air, the upper limit of temperature is 82°C with wheat for forage, 65°C with wheat for bread, and 43–48°C with barley and seed barley;
b. Cereals can be dried with cool air.
iii. Chemical preservation is also possible.

Methods of storage

i. During hermetic storage, microbiological processes are inhibited. At a moisture content of 17–22%, few anaerobic bacteria or yeast fungi can propagate. Such storage is generally in silos.
ii. Storage with ventilation. Cool air is blown through pipelines into the stored grain, which causes moisture and temperature to decrease.
iii. Cold storage can substitute for drying, allowing the storage time to be prolonged.
iv. Chemical treatment
a. Freshly harvested grain is treated with propionic or formic acid, then hermetically covered. At pH 2–3, microbiological processes are inhibited.
b. Cereals can be preserved after pre-drying. The specific energy consumption of this process is economic up to a dry matter content of 80%, it is then dramatically reduced. If cereal grain of 20% moisture content is treated with organic acids, energy can be saved and relatively dry grain is obtained.