

Maximizing the Potential of Stunted Fish Fingerlings through Innovative and Sustainable Aquaculture Practices for Enhanced Growth and Production.

ABSTRACT

Aquaculture is an important industry for national economies, but it needs to improve its survival rates through increased technology awareness. Stunted fingerlings, obtained from aged fish, are a practical alternative for stocking in aquaculture due to their higher survival rates and disease resistance. Farmers can produce stunted fish fingerlings by rearing fish at a higher stocking density and feeding them with natural food for a prolonged period.

Farmers use a supplementary feed mixture of Soya Bean Cake, Ground Nut Oil Cake, Rice Bran, and Fish Meal to promote optimal growth. Using feed bags to reduce waste can also help ensure proper growth and reduce costs. Stunting of fish fingerlings has been shown to improve growth and survivability in grow-out ponds, resulting in higher yields. Access to quality fingerlings, market demand, and best management practices are critical for success. Stunted fingerlings could be a practical solution to address the problems of limited fingerling availability and high production costs in aquaculture. Multiple stockings and multiple harvesting are cost-effective methods to increase fish production and enhance pond productivity.

Farmers need to follow best management practices and implement sustainable practices to minimize environmental and community impacts.

Keywords: [Aquaculture, Stunted fingerlings, Sustainable practices, Best management practices, multiple stockings.]

1. INTRODUCTION

Aquaculture plays a crucial role in contributing to the national economy by providing employment and livelihood opportunities to numerous individuals. It is recognized as a robust income and employment generator as it stimulates the growth of subsidiary industries and provides a source of cheap and nutritious food. Presently, aquaculture has emerged as a pivot of growth in the fisheries sector due to diminishing resources, the energy crisis, and

the high cost of fishing. However, awareness of aquaculture technology still needs to improve at the grass-root level, particularly among farmers, who often rely on traditional stocking and fingerlings methods, leading to low survival rates [1].

Stunting is a phenotypic change that can occur in various fish species, including tilapia, catfish, and carp. The development of individuals in stunted populations may be influenced by various ecological factors, such as increased survival from reduced predation and decreased food availability [2,3]. Stunted yearlings have slow growth rates, early maturation, small size, and density-dependent mechanisms that restrict their growth. However, their diminished maximum size has yet to be genetically determined. They are suitable for stocking in ponds or tanks, as they have higher survival rates, are disease-resistant, and can withstand environmental fluctuations, leading to higher yields and income[4].

Jana and colleagues (2020)[5] propose that adopting the method of multiple stocking and multiple harvesting (MSMH) in composite fish farming has the potential to significantly increase fish production by up to 6-10 tons per hectare per year. This method is cost-effective and suitable for small and marginal farmers who can manage the pond for a maximum period of 4 months and start earning within this period, reinvesting the profits for further fish rearing. MSMH also enhances the primary productivity of the pond by releasing noxious gases and mixing bottom nutrients with surface water[5].

Aquaculture can make a significant contribution to the national economy and create livelihoods for a large number of people in the country. By adopting new technologies, such as MSMH, fish production can be increased significantly, making the practice more sustainable and cost-effective.

2. What is a stunted fish fingerling?

The Stunted fish seeds are aged and arrested from attaining their proper growth and development due to high density and minimum food available.

Stunted fingerlings refer to juvenile fish raised in conditions that lack adequate nutrition or space to grow to their full potential. As a result, they remain small in size and need to reach their intended market weight. Fish require various factors, including adequate pond size, a balanced and appropriate diet, proper water conditions, and compatible fish species, to thrive and grow properly. However, when these factors are not met, it can affect their growth and overall health, leading to stunted growth.

Several stressors can impact fish growth and lead to stunting. Crowding and inadequate nutrition are significant stressors in aquaculture practices [6,7]. These stressors

can cause physiological changes in fish, including their defence system [8]. Due to its intensification, diseases have become a significant problem in aquaculture [9, 10].

Recent studies suggest stunted carp fingerlings improve growth and survival when stocked in rearing ponds with optimal conditions [11,12]. These highlights the importance of providing suitable living conditions for fish to prevent stunting and ensure optimal growth and survival rates.

The available information suggests the improved performance of stunted carp fingerling in terms of growth and survival when stocked in rearing ponds with optimal conditions.

3. Why Stunted Fish Fingerling

Stunted fingerlings have become a topic of increasing interest among researchers and fish farmers in recent years due to their potential benefits in aquaculture practices such as,

- i. **Reduced feed requirements:** Stunted fish have a lower metabolic rate and growth rate than non-stunted fish, resulting in lower feed requirements. In a study conducted by Fagbenro and Adesulu (2016) [13], stunted catfish fingerlings required 41% less feed than non-stunted fish of the same age.
- ii. **Higher stocking densities:** Stunted fish can be stocked at higher densities than non-stunted fish due to their smaller size and lower oxygen demand. This allows more fish to be produced in a smaller area, improving production efficiency and profitability. A study by Madsen et al. (2017)[14] found that stunted rainbow trout could be stocked at 50% higher densities than non-stunted fish without affecting growth performance.
- iii. **Reduced cannibalism:** Stunted fish are less likely to cannibalize one another as they are all a similar size. These can reduce mortality rates and improve the overall health of the fish population. A study by Mair et al. (2018)[15] found that stunting tilapia reduced cannibalism and improved survival rates.
- iv. **Reduced disease transmission:** Stunted fish may be less susceptible to certain diseases as their slower growth rate can give their immune system more time to develop. In a study by De Schryver et al. (2017)[16], stunted Nile tilapia had a lower prevalence of *Streptococcus agalactiae* than non-stunted fish.
- v. **Alternative markets:** The commercial market for stunted fish can include alternative markets such as pet food or bait. These can generate additional income for the farmer while reducing waste. In a study by Suantika et al. (2019)[17], stunted barramundi was found to have potential as a raw material for pet food.

Fish farmers in Andhra Pradesh, India, have developed the technology of producing stunted carp fingerlings for stocking in culture ponds [18]. Stunted fish fingerlings are obtained from aged fish, arrested from attaining their proper growth and development due to high density and minimum food available.

Research studies have explored the potential benefits of using stunted fingerlings in aquaculture practices. For instance, a study published in *Aquaculture International* in 2019 investigated the use of stunted fingerlings for stocking culture-based fisheries in Bangladesh, concluding that they could be a suitable alternative to conventional fingerlings due to their higher survival rates and faster growth. Another study published in *Aquaculture Reports* in 2020 explored the potential use of stunted fingerlings in tilapia aquaculture, finding that they could be an effective strategy for maximizing growth and reducing production costs [19,20].

Moreover, recent research has further evaluated the use of stunted fingerlings in aquaculture. One study published in *Aquaculture Reports* in 2020 evaluated the potential use of stunted fingerlings in African catfish aquaculture, finding that they could improve production efficiency[21]. Another study published in *Aquaculture Research* in 2021 investigated the effect of stunting on silver carp's growth performance and survival, concluding that stunted fingerlings could be a viable option for farmers looking to maximize production efficiency [22].

A review article published in *Reviews in Aquaculture* in 2021 examined the various factors affecting stunting in fish and its potential use in aquaculture, highlighting the need for further research in this area[23]. These studies suggest that stunted fingerlings offer several advantages for aquaculture practices, including improved survival rates, faster growth, and higher productivity.

4. Suitable Fish Species Used For Stunted

Stunted fingerlings are fish intentionally kept at a small size for extended periods due to limited resources or space. The selection of fish species for stunted fingerlings can depend on water quality, food availability, and market demand. Recent research has suggested that other fish species can also be considered for stunted fingerling production.

- i. **Tilapia:** According to a study published in the journal *Aquaculture International* in 2021, tilapia (*Oreochromis* spp.) can be a suitable species for stunted fingerlings as they have a high survival rate, are resistant to disease, and can tolerate poor water quality[24].
- ii. **Largemouth Bass:** A study published in the *Journal of Applied Aquaculture* in 2022 suggests that Largemouth Bass (*Micropterus salmoides*) can also be a good candidate for

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stunted fingerlings as they are resilient, adaptable to different water temperatures and have a high feeding rate[25].

- iii. **Yellow Perch:** A study published in the Journal of the World Aquaculture Society in 2020 recommends Yellow Perch (*Percaflavescens*) as a potential species for stunted fingerlings due to their high feed conversion efficiency, good taste, and market demand [26].
- iv. **Channel Catfish:** Channel Catfish (*Ictalurus punctatus*) is another species that can be considered for stunted fingerlings. According to a study published in Aquaculture in 2021, Channel Catfish can grow well in low-nutrient environments and tolerate high-density culture conditions[27].
- v. **Freshwater Fish Species:** According to a study published in 2017 in the Indian Journal of Fisheries, the selection of fish species for stunted fingerlings production in India should prioritize Indian major carps such as Catla (*Catla catla*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus mrigala*), as well as commercially important exotic carps like Silver carp (*Ctenopharyngodon idella*), Grass carp (*Hypophthalmichthys molitrix*), and Common carp (*Cyprinus carpio*). These species are widely used in aquaculture and have a high market demand[28]. The stunted Indian major carp are being cultured in some regions of India because they are believed to have a rapid growth rate after stunting[29].

Choosing the appropriate fish species for stunted fingerlings involves considering crucial factors such as water quality, food availability, and market demand. Seeking advice from local fisheries authorities and experts to identify the most suitable species for a specific location is highly recommended. By doing so, the selected fish species will be better adapted to the environmental and market conditions, leading to a more successful cultivation process.

5. Producing stunted fish fingerlings

Stunting fish fingerlings is still a common practice in aquaculture. It can help eliminate weak and unhealthy seeds and increase the survival rate of healthy seeds for culture purposes. However, producing stunted fingerlings can negatively impact fish welfare and overall production. Therefore, it is important to maintain proper stocking density and provide adequate nutrition to avoid stunting.

Recent studies have shown that stunted fingerlings can be produced by rearing fish fry/fingerlings at a higher stocking density and feeding them with natural food for a prolonged period. For example, Reza et al. (2021)[30] found that a higher stocking density of 150 fry/L for 60 days produced stunted fingerlings of walking catfish (*Clarias batrachus*) with a weight

of 1.75 ± 0.05 g. Similarly, Pal et al. (2022)[31] reported that a stocking density of 300 fry/L and feeding with natural food for 90 days produced stunted fingerlings of Indian major carp (*Labeorohita*) with a weight of 1.30 ± 0.06 g.

On the other hand, maintaining an optimum stocking density and providing regular management practices can lead to higher growth rates in fingerlings. Singh et al. (2021)[32] maintained a stocking density of 150 fingerlings/m² for 150 days and reported a significantly higher growth rate of 2.27 ± 0.03 g/day in fingerlings of Indian major carp (*Labeorohita*).

While producing stunted fingerlings can have its benefits in eliminating weak and unhealthy seeds, it is important to ensure proper stocking density and adequate nutrition to avoid stunting and negative impacts on fish welfare and overall production. Recent studies have shown that stunted fingerlings can be produced by rearing fish fry/fingerlings at a higher stocking density and feeding them with natural food for a prolonged period. However, maintaining an optimum stocking density and providing regular management practices can lead to higher growth rates in fingerlings.

Experimental evidence in marine finfish indicated that the stunted fishes attained compensatory growth with adequate feeding when shifted to favourable conditions. Preliminary results reveal that marine finfishes such as Snubnose pompano and Mangrove red snapper exhibits compensatory growth pattern during post- stunting rearing period in both marine and low saline conditions[33].

6. Seasonality And Availability

Seasonality and availability are significant challenges in aquaculture production. Various innovative approaches have been developed in different regions to overcome these issues.

In Andhra Pradesh, India, carp farmers have developed a system of producing "stunted yearlings" to overcome seasonality and availability problems. In this approach, farmers would purchase seeds during the carp breeding season and stock them at high densities (50,000-100,000/ha), feeding them at 1-2% body weight and rearing them for 6-12 months. After the specified period of confinement, the fish that survive would experience stunted growth and reach a size of around 100-200 grams. This approach has become very popular in the region [18, 34].

A recent study by Das et al. (2020)[35] examined the feasibility of producing stunted yearlings of Indian major carp (IMC) using this approach. The study found that stocking densities and feeding regimes significantly influenced the growth and survival of IMC. A stocking density of 50,000/ha with a feed rate of 2-3% body weight per day was optimal for

producing stunted yearlings of IMC. The study also found that the survival rate of the fish was higher in the stunting process compared to normal rearing.

Another recent study by Saha et al. (2021) [36] evaluated the production of stunted yearlings of *Labeorohita* in earthen ponds. The study found that a stocking density of 40,000 fish/ha with a feeding rate of 2% body weight per day for 12 months resulted in stunted yearlings with an average weight of 96.4 ± 6.5 g. The study also reported that stunted fish had a lower feed conversion ratio and higher survival rate than regular fish.

7. Transportation and Care

Transportation of stunted fish fingerlings is a critical process that requires careful consideration of their unique characteristics and needs. The following steps can be taken to ensure the safe and effective transportation of stunted fish fingerlings:

- i. **Water quality:** Stunted fish fingerlings are more sensitive to changes in water quality than non-stunted fish. Therefore, it is essential to maintain good water quality during transportation. According to the FAO(2015)[37], water should be clean, contaminant-free, and well-oxygenated. The temperature and pH levels of the water should also be maintained within acceptable ranges for the species being transported.
- ii. **Container selection:** The container for transporting stunted fish fingerlings should be appropriate for size and number. The container should have adequate ventilation, be leak-proof, and be made of non-toxic materials. If multiple fish are being transported, they should have enough space to move around without getting crushed or injured. The World Aquaculture Society (2018) [38] recommends using double-layered plastic bags with pure oxygen and no water for short-distance transport of stunted fingerlings.
- iii. **Handling:** Stunted fish fingerlings are delicate and can quickly become stressed or injured during handling. Therefore, it is crucial to handle them with care. Fish should be caught gently and placed into the container without being squeezed or dropped. During transportation, the container should be secured to prevent it from moving around and causing injury to the fish [39].
- iv. **Duration of transport:** The duration of transport should be minimized as much as possible. The longer the transport, the more likely the fish will experience stress and adverse effects on their health. If the transport is expected to take longer, providing additional oxygen to the water or adding aeration devices to the container may be necessary. According to the World Aquaculture Society(2016)[40], oxygen saturation levels should be at least 80-90% during transport.

v. **Inspection:** Before and after transport, it is important to inspect the fish for any signs of stress, injury, or disease. This can help identify and address any issues before they become more serious. According to the FAO(2020)[41], fish should be examined for signs of lethargy, erratic swimming, gasping for air, or other abnormalities.

Transporting stunted fish fingerlings requires careful consideration of their specific needs to ensure safe and practical transport. Farmers have started adopting new methods to reduce stress and mortality rates during transport. One such approach is a conditioning process at least 12 hours before embarkment, which helps prepare the fish for transportation.

Moreover, spacious PVC containers ranging from 2,000 to 3,000 litres in capacity have become increasingly popular. These containers are placed on trucks for easy transportation, and after filling them with water, the conditioned fish seed is stocked within them. Oxygen is supplied through cylinders attached to the truck, ensuring the fish have adequate oxygen during transport. This method has proven effective in mitigating mortality rates during long-distance transport.

Studies have confirmed the effectiveness of using PVC containers with oxygen supply during fish transportation. Ogunremi et al. (2019)[42] investigated the effects of different transportation methods on the survival and growth of African catfish fingerlings. They found that using PVC containers with an oxygen supply resulted in higher survival rates and better growth performance than other methods, such as plastic bags or buckets. Another study by Pal et al. (2021)[43] evaluated the use of a similar transportation method for rohu fingerlings and found that it resulted in low mortality and minimal stress to the fish during transportation.

8. Growing Stunted Fish In Ponds

The minimum grow-out pond size is 0.05 to 0.25 hectares with a depth of 1 to 2 meters. When stocked in the culture pond, stunted seeds can compensate for the growth lost during the stunting period and attain a one kg weight, with almost a 100% survival rate except for mortalities due to other environmental conditions. This technology of stunting fish seed developed by farmers is considered one of the most practical solutions to address the problems related to fish growth and yield.

Recent studies have highlighted the effectiveness of stunting fish for aquaculture production. For example, Singh et al. (2020)[44] studied the production performance of stunted and non-stunted Indian major carp in ponds. They found that stunted fish exhibited significantly higher growth and survival rates than non-stunted fish. Similarly, Biswas et al.

(2021)[45] studied the production of stunted rohu carp in ponds. They reported that stunted fish showed significantly higher feed conversion efficiency and lower production costs than non-stunted fish.

The effectiveness of growing stunted fish in ponds has also been shown in the study by Rahman et al. (2020)[46] in Bangladesh, where stunted rohu fingerlings (stocked at 250,000/ha) in ponds showed improved survival rates, feed conversion efficiency, and biomass production compared to normal fingerlings. Stunting could be a viable strategy for small-scale farmers to increase fish production.

Another study by Azim et al. (2019)[47] in Bangladesh showed the potential of stunting tilapia fingerlings in ponds. The authors found that stunted fingerlings (stocked at 150,000/ha) showed higher survival rates, growth rates, and biomass production than normal fingerlings. Stunting could be a practical solution to address the problems of limited fingerling availability and high production costs.

Stunted fish fingerlings, which have failed to grow normally and have a reduced body size, may experience hormonal changes to compensate for the lack of growth.

- a. **Growth hormone (GH):** GH is a peptide hormone that stimulates growth and development in fish. In stunted fish fingerlings, the growth hormone levels may be elevated to promote growth. Zhang et al. (2020)[48] found that the growth hormone levels were significantly higher in stunted yellow catfish fingerlings than in normal-sized fingerlings.
- b. **Insulin-like growth factor 1 (IGF-1):** (IGF-1) is essential in promoting growth and development in fish. A study by Chen et al. (2021)[49] investigated in the juvenile turbot the effects of dietary protein levels on the expression of genes related to growth and IGF-1 signalling. They found that higher dietary protein levels increased the expression of IGF-1 and other development-related genes. These suggest that dietary manipulation can affect IGF-1 levels and improve fish growth.
- c. **Cortisol:** Cortisol is a steroid hormone released in response to stress. In stunted fish fingerlings, cortisol levels may be elevated due to the chronic stress of living in crowded conditions with limited food resources. Azaza et al. (2019)[50] found that cortisol levels were significantly higher in stunted gilthead sea bream fingerlings than in normal-sized fingerlings.

9. Feeding methodology

Supplementary feeding is essential for optimal growth of fish in ponds. Using locally available feed ingredients such as soybean cake, groundnut oil cake, rice bran, and fish

meal in appropriate ratios can provide a balanced and cost-effective feed for fish. A study by Patel et al. (2021)[51] showed that a feed formulation comprising soybean meal, rice bran, and fish meal resulted in significantly higher growth rates and feed conversion efficiency in Indian major carp.

The size of ponds used by farmers is generally large in Andhra Pradesh. Because of this, the broadcast feeding method resulted in massive wastage of feed and poor growth of fish. Farmers have developed a simple and effective technique of feeding fish through “feed bags” to overcome this problem. Chemical fertilizer bags made of polyethene with a 20-30 kg capacity are commonly used for making feed bags. Small holes at the bottom of feed bags arranged in 2-3 rows are made. Feeding bags are filled with rice-bran and oil cake mixture, tied to bamboo poles, and fixed in the ponds. Fish feed through the holes, which are generally exhausted in less than two hours after suspension. This simple, practical and economical feeding method developed by farmers has helped in many ways:

- i. The technique has reduced feed wastage drastically, and almost all the feeds kept in the bag are consumed directly by fish.
- ii. Feed bags are an excellent indicator to assess the health and growth of the fish. If the feeds provided in the bag are not exhausted within the given period, farmers immediately suspect problems with health and/or water quality.
- iii. The bag-feeding method has given a very effective pathway for treating fish in such large culture ponds.

Farmers use various drugs to feed fish through feed and for external treatment; containers filled with chemicals and perforations are tied close to feeding bags. Dissolutions of chemicals into the water provide an opportunity for treating fish infected with the disease.

There have been several recent studies that have investigated the use of feed bags in fish farming. One study published in the journal *Aquaculture Research* in 2021 evaluated the effectiveness of using feed bags to reduce feed waste and improve the growth of major Indian carp in polyculture ponds. The study found that using feed bags significantly reduced feed waste and enhanced the development of fish (Kumar et al., 2021)[52]. In 2020, the *Journal of Applied Aquaculture* published a study exploring feed bags' use in feeding tilapia within aquaponic systems. According to the study, feed bags helped to minimize feed wastage while improving water quality in the system[53].

A study published in the journal *Aquaculture* in 2022 evaluated the use of feed bags for feeding juvenile yellowtail kingfish in a recirculating aquaculture system. The study found that feeding bags improved growth performance and reduced feed waste [54]. Another study published in the *Journal of Aquacultural Engineering* in 2021 examined using a modified

feed bag design for feeding European sea bass in a recirculating aquaculture system. The study found that the modified feed bag design improved feed efficiency and reduced feed waste while reducing the risk of water quality degradation[55]. Using feed bags in fish farming effectively reduces feed waste and improves fish growth and health.

Following feeding methodology can also play a crucial role in the production of stunted fish fingerlings.

- a. **Restrictive feeding:** Restrictive feeding involves providing fish with limited food, usually below their maintenance requirements. This approach has been used to produce stunted fish fingerlings in several studies. For example, a study by Tan et al. (2020) [56] used a restrictive feeding regimen to produce stunted Chinese sturgeon fingerlings.
- b. **High-energy diets:** High-energy diets, typically rich in carbohydrates and fats, can promote rapid fish growth. However, feeding fish high-energy diets beyond their growth capacity can lead to stunted growth. A study by Ali et al. (2016)[57] used a high-energy diet to produce stunted African catfish fingerlings.
- c. **Imbalanced diets:** Feeding fish with imbalanced diets, such as those deficient in essential amino acids, can also result in stunted growth. El-Haroun et al. (2015)[58] used an imbalanced diet to produce stunted Nile tilapia fingerlings.
- d. **Alternate-day feeding:** Shamseldin et al. (2020)[59] used an alternate-day feeding regimen to produce stunted African catfish fingerlings.

10. Post-stocking Management

Post-stocking management is a crucial aspect of fish farming, and maintaining water quality is one of the essential factors in ensuring the healthy growth and survival of fish. The following table shows the recommended ranges of various physical and chemical parameters for maintaining water quality in the fish pond.

Maintain water quality as given below in the table

Table 1.

Sr. No.	Parameter	Range
Physical parameters		
1	Temperature	20-35oC
2	Colour	Greenish
3	Turbidity in cm	8-20

Chemical parameters		
4	Dissolved oxygen	3-8 ppm
5	pH	7.2-7.5
6	Dissolved CO ₂	4.0- 12.0 ppm
7	Total alkalinity	80 – 150ppm
8	Ammoniacal Nitrogen NH ₄ N	0.2-0.5 (mg/l)
9	Nitrate Nitrogen N ₃ Or N	0.2-0.2 (mg/l)
10	Nitrite Nitrogen NO ₂ - N	<0.014 (mg/l)
11	Phosphorus P ₂ O ₅	0.01-0.5 (mg/l)
12	Iron (Admissible range)	0.05 - 0.02 (mg/l)
12	Manganese (Admissible range)	0.01 - 0.04 (mg/l)

Apart from maintaining water quality, farmers can use ash as a substitute for lime to promote the healthy growth of fish. The use of ash produced from the banana stem as a substitute for lime has become popular among farmers due to the cost and non-availability of lime in remote areas. A banana stem with an alkaline condition can improve water quality, similar to lime[60].

In addition, daily observation of fish in the pond and regular sampling and examination of fish (monthly once) for health checks and disease diagnosis is essential. Sampling and examining fish at the onset of distress, disease outbreak, or mortality can help farmers take timely action to prevent the spread of disease and minimize losses [61].

11. General Precautions

- i. Algal bloom control: Manual algal bloom control is better than chemical application[62].
- ii. If required, Diuron @0.1 - 0.5 ppm (1- 3 gm/ ha /meter depth of water) may be sprayed over the water surface uniformly. Never apply in nursery ponds.
- iii. Maintenance of water quality: Lime is an effective method for maintaining water quality in fish ponds[63].
- iv. Transportation of fish seed: Proper acclimatization and oxygenation during transportation can improve the survival rate of fish seed[64]. While packing for transportation, oxygen should be provided sufficiently depending on the size and number of fish seeds to be carried[65].
- v. Acclimatization is a critical process that needs to be done before releasing fry and fingerlings into culture ponds. It involves gradually introducing the fish to the water and environmental conditions of the culture pond to minimize stress and increase

their chances of survival. The following steps can be taken to acclimate fry and fingerlings:

- a. Prepare the culture pond: Ensure that the culture pond is properly prepared before introducing the fish. The pond should be clean and free from any harmful chemicals or pathogens.
 - b. Gradual temperature adjustment: The water temperature in the culture pond may differ from where the fish were previously kept. Gradually adjust the fish tank's temperature to match that of the culture pond over several hours or days, depending on the temperature difference.
 - c. Gradual salinity adjustment: If the culture pond has a different salinity level than the water where the fish were previously kept, gradually adjust the salinity level of the fish tank to match that of the culture pond over several hours or days.
 - d. Gradual water quality adjustment: Gradually introduce the fish to the water quality of the culture pond. Start by adding small pond water to the fish tank over several hours. Increase the pond water gradually until the fish is fully acclimated to the pond water.
 - e. Monitor the fish: Monitor the fish closely during acclimatization for signs of stress or illness. If any problems are detected, take appropriate measures to address them before releasing the fish into the culture pond.
 - f. According to recent studies, proper acclimatization can significantly improve fish survival and growth rates in culture ponds [66,67]. It is essential to ensure that the fish are gradually introduced to the new environment to minimize stress and prevent mortalities.
- vi. Water bath treatment: A bath treatment with KMnO_4 can reduce the risk of disease transmission during fish seed transfer[68]. A water bath treatment with KMnO_4 @ 1-2 ppm for a minute is essential before releasing the fish seed into the culture ponds.
 - vii. Feed management: Optimal management of feed and manuring is essential for stunted fingerlings[69].
 - viii. Agrimin Forte is a commercial feed additive often used in aquaculture to improve the health and growth of fish. It is a multivitamin and mineral supplement added to the feed at a rate of 10 grams per kilogram [70, 71].
 - ix. Potassium permanganate treatment: Potassium permanganate can control parasites and bacteria in stunted fingerlings ponds[72]. Potassium permanganate @ 1 - 2 ppm is used in stunted fingerlings ponds, followed by liming before the onset of the winter season, and frequent netting should be avoided.

- x. Hardening fingerlings is an important process in aquaculture, as it helps prepare the fish for the conditions they will experience in the grow-out phase. Netting a big mesh-sized net at fortnight intervals is one method used to harden fingerlings [73,74].

Stunted growth in fish can occur due to various reasons, such as poor water quality, overcrowding, disease, inadequate nutrition, and stressful environmental conditions. It is important to avoid putting fish seeds under stressful conditions, as stress can further contribute to stunted growth.

- xi. Stress Management: In order to mitigate stress in fish seeds, the following measures can be implemented:
 - a. Maintain optimal water quality: It is important to ensure that the water quality parameters, including temperature, dissolved oxygen, pH, and ammonia levels, are maintained within the recommended range for the specific species being cultured.
 - b. Avoid overcrowding: Overcrowding can increase competition for food, space, and oxygen, resulting in stress and stunted growth.
 - c. Provide adequate nutrition: To provide adequate nutrition, it is important to ensure that the fish seed is provided with a nutritionally balanced diet that meets their specific dietary requirements.
 - d. Minimize handling and transport: Handling and transport can be stressful for fish seeds, so minimize these activities as much as possible.
 - e. Manage disease: Implement disease prevention and control measures to minimize the incidence and impact of diseases, which can also contribute to stress and stunted growth.

By implementing these measures, the stress levels in the fish seed can be minimized, which in turn can promote optimal growth and development.

12. Fish Production

The stunted fingerlings of rohu show better growth and survivability in grow-out ponds than commonly raised rohu fingerlings under everyday pond management practices. In the North-Eastern region, stunting of earlier year carp seed can be an effective tool to better utilize the potential growth season in polyculture. However, the genetic quality of the seed must be ensured before adopting this technique[75].

When stocked into grow-out ponds at a density of 3,000/ha, stunted fish fingerlings weighing 50-100 g can achieve marketable size (1.0-1.5 kg) within a 5-6 month period with a

high survival rate of 85-95%[28]. Progressive farmers can achieve more than 15 tonnes/ha/year, while the average yield is around 8 tonnes/ha[76].

Recent research has shown that stunting can be a valuable tool for improving fish production in certain situations. A study conducted in India found that stunted rohu fingerlings performed better in growth and survivability when raised in grow-out ponds than commonly raised rohu fingerlings[77]. The study also found that stunted fingerlings stocked at a density of 3,000/ha achieved marketable size within 5-6 months with a high survival rate of 85-95%.

However, it is important to ensure the genetic quality of the seed before adopting this technique, as stunted fish may have reduced genetic diversity and lower resistance to disease[78]. Moreover, following proper pond management practices is crucial to ensure the fish's optimal growth and survival.

13. Multiple Stocking and Harvest

Multiple stockings and harvesting are common in aquaculture to maximize fish production and increase profitability. Several studies have evaluated the effectiveness of this technique.

One study in India found that multiple stockings and harvesting in carp polyculture ponds increased fish production and profitability. The study showed that a stocking density of up to 12000/ha/yr had no adverse effects on the pond's carrying capacity, and regular harvesting and restocking fingerlings could lead to high yields of up to 3500 kg/ha/yr[79].

Another study in Bangladesh evaluated the effects of multiple stockings and harvesting on tilapia production in earthen ponds. The study found that this technique increased tilapia production and profitability, with yields of up to 14.3 tons/ha/yr [80].

It is worth noting that this technique's success relies on various factors, including adequate pond management, access to quality fingerlings, and market demand. Additionally, it is crucial to maintain good water quality and prevent disease outbreaks in the pond.

Multiple stockings and harvests are used in polyculture ponds to maximize fish production. Recent studies have shown that this technique can significantly increase the productivity of aquaculture systems [1].

Here are some additional points to improve the production:

- a. Multiple stockings and harvesting can increase production rates but should be done cautiously. Studies have shown that higher stocking densities can lead to decreased water quality and increased stress on fish, which can negatively impact growth and survival[82].

- b. Regular harvesting and restocking with fingerlings of the same species can help maintain high stocking densities and continuous production in the pond [83].
- c. Proper pond management practices, such as regularly monitoring water quality parameters, maintaining appropriate feeding rates, and controlling the use of inputs, are critical to prevent disease outbreaks and maintain optimal conditions for fish growth [84,85]).
- d. Proper pond maintenance, including periodic draining and debris removal, is essential for preventing problems with high biological oxygen demand (BOD) in the water, which can lead to decreased water quality and negative impacts on fish health [86].

Conclusion

The aquaculture of stunted fingerlings can offer several benefits for fish farmers. It can help overcome the challenges of limited fingerling availability and high production costs, ultimately leading to higher yields and profitability. However, the success of this approach requires adherence to best management practices, including proper pond management, regular monitoring of water quality, and restocking with fingerlings of the same species. Access to quality fingerlings, market demand, and genetic quality is crucial for success. Using stunted fingerlings in aquaculture can improve fish production's efficiency and sustainability while providing economic opportunities for communities.

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Comment [WU2]: References should not be older than 10 years .

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Comment [WU3]: References should follow one pattern and should be cross checked

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