Bulletin No. 23

RAINBOW TROUT FARMING IN INDIA: R & D PERSPECTIVES

Rainbow trout farming in India: R & D perspectives

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Published by:
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PREFACE

In freshwater aquaculture system, coldwater fisheries occupy a unique position in India which is geographically restricted to the Himalayan region from northwestern to northeastern parts including central Himalayas. Rainbow trout is one of the promising cultivable fish species in coldwater and has considerable scope for its expansion. Being a low volume high value commodity, the trout has good potential for domestic consumptions as well as export. In spite of having excellent positive traits, the development and expansion of trout farming in India has yet to be done on large scale. Research and development carried out in India especially by DCFR during the past decade have shown appreciable achievements in trout farming practices. Moreover, the significant increase in rainbow trout production over last decades, and commercial adoption of rainbow trout farming in India indicates growing interest of farmers for trout culture. Aquaculture of trout is intensive type of farming which requires more input resources compared to other species for survival and growth. The feasibility of achieving optimal production depends on a number of factors including seed, feed, health management and environmental consideration. Potential success in trout production requires better governance and significant improvement in the management practices. There are certain technical, social and environmental issues which need attention through strategic planning for developing standards of trout farming for production enhancement and expansion.

Presently the bulk of trout production is contributed by the Northwestern states of India notably Jammu & Kashmir and Himachal Pradesh, while the Northeastern states have to come up for the trout production. In order to give thrust on trout farming and production enhancement in other hill states, the Directorate of Coldwater Fisheries Research, (DCFR), Bhimtal has made concerted efforts towards the development of location specific trout farming practices. However, there is ample scope for further enhancement of trout production in these states through participatory approach.

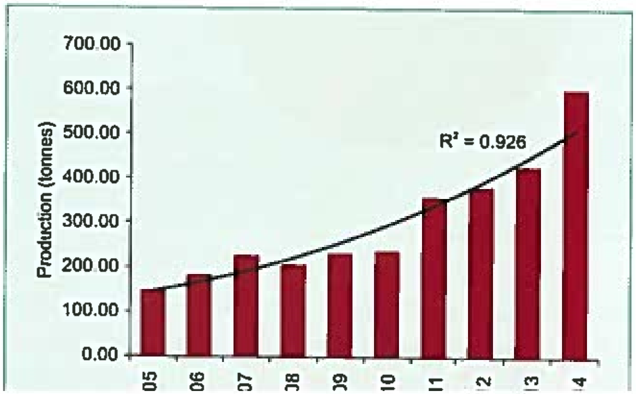
I am sure that present bulletin on trout farming in India will be of immense use to all stakeholders involved in culture and breeding of rainbow trout in the hilly

INTRODUCTION

Rainbow trout (*Oncorhynchus mykiss*) is one of the promising cultivable fish species in coldwater and has considerable scope for its expansion. Being a low volume high value commodity, it has good potential for domestic consumptions as well as export. In spite of having excellent positive traits, the development and expansion of trout farming has yet to be done on large scale. Trout culture is intensive type of farming requiring more input resources compared to other species for survival and growth. The feasibility of achieving required production naturally depends on a number of factors including seed, feed, health management and environmental consideration. Potential success in trout production requires better governance and significant improvement in the management practices.

Rainbow trout (*Oncorhynchus mykiss*) a member of family "Salmonidae" is native to the Pacific drainages of North America ranging from Alaska to Mexico (Ward *et al.*, 2003), and have been widely introduced around the world in regions with cool water temperatures (MacCrimmon, 1971). Presently it is cultured over 69 countries of the world both in southern and northern hemisphere including India. Trout farming in India is over a century old and there are several species of trout but rainbow trout is a species of choice, which is relatively easy to breed and has better growth and maximum cultivable traits (Joshi *et al.*, 2005). This amazingly versatile species can tolerate a wide range of water temperatures (from 0-27°C) and there are numerous freshwater sources in which they can be grown: they thrive in water originating from aquifers, springs and streams – as well as lakes. This species was transplanted in India from Europe by British settlers around the beginning of the last century primarily for sport fishing or recreational angling (Mitchell, 1918). But, since early-nineties the country has taken-up farming of rainbow trout in private sector and the fish is now available for food and farming.

Trout farming has progressed steadily in last 50 years in India and the total trout production in the country was about 147 tonnes during 2004-05 which has increased over four-fold in last ten years, and has reached up to 602 tonnes during 2013-14 (Fig.1). The growth rate of trout production in this duration remained 31.0 percent per annum. Trout ova production also



The trout production infrastructure has also developed steadily in the country in last 30 years and presently around 62 trout farms (under Government sector) with 369 numbers of raceways are spread over seven states in the western, north-eastern and peninsular region of the country. A total of 32 trout hatcheries with an estimated eyed ova production capacity of 13 million are present in the country which have been mostly established by the various state governments. These hatcheries or seed production units cater the need of farmers, private entrepreneurs and also supply to the different government agencies for building their stocks. Moreover, it is estimated that 625 numbers of trout units exist in the private sector mostly located in the Himachal Pradesh, Jammu and Kashmir and Sikkim state.

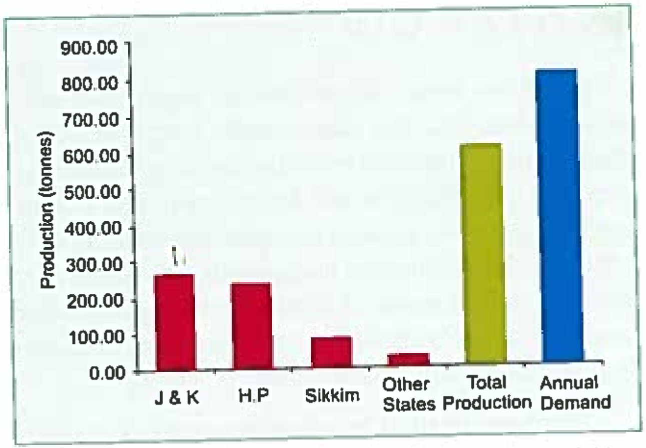


Fig.2: State wise rainbow trout production in India during 2013-14

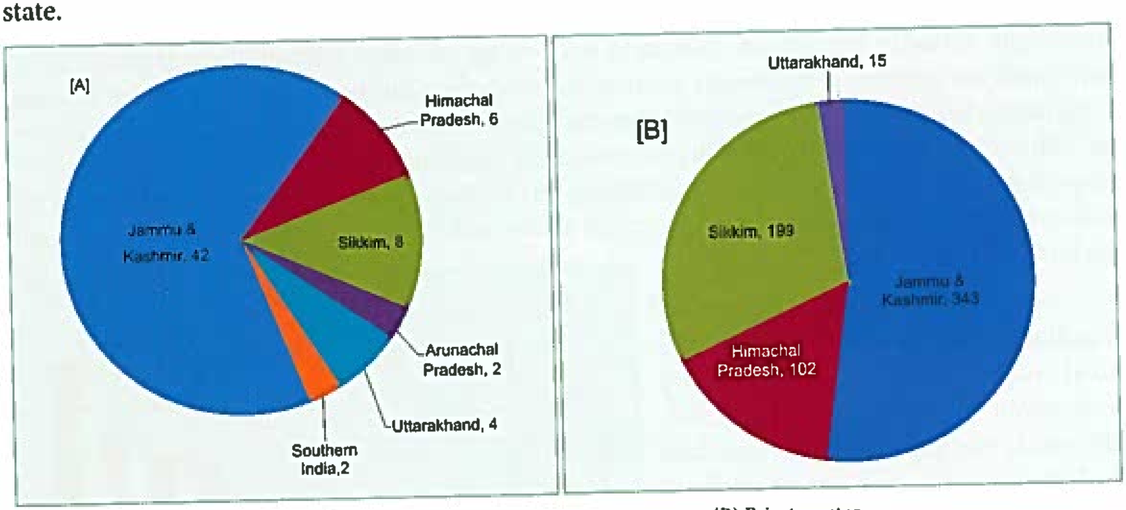


Fig.3: Trout farms in India (A) Government sector (B) Private sector

A good number of fish farmers are still not well aware about the technique of trout farming and its scientific culture practice and hence partially adopting modern culture technology. ... conditions and resources in hill states, the farming has yet to be trout production requires better governance and significant improvement in the management practices through adequate R & D support. In order to achieve the goal of enhancing trout production, it is quite necessary to focus on improving existing technologies or developing new ones for increased and sustained production.

STATUS AND PRODUCTION TREND

Coldwater states have an inherent potential for trout culture due to its suitable climatic conditions like cold and well oxygenated water. Perennial coldwater resources are available in the Himalayan states to adopt trout culture as sustainable livelihood option for local people.

North-Western Himalayan Region

Jammu and Kashmir and Himachal Pradesh are two important states where rainbow trout farming and seed production has progressed on large scale. The State Fisheries Department has consistently worked for the development of trout farming and production enhancement and also established excellent infrastructure for trout grow-out as well as seed production (Hassan and Pandey, 2012). The average production of trout raceways was estimated as 800 to 1000 kg (Dogra and Verma, 2014). At Kokernag trout farm a feed mill of 0.5 t/hr capacity has been installed to fulfill the feed requirement of the government, as well as private trout farmers.

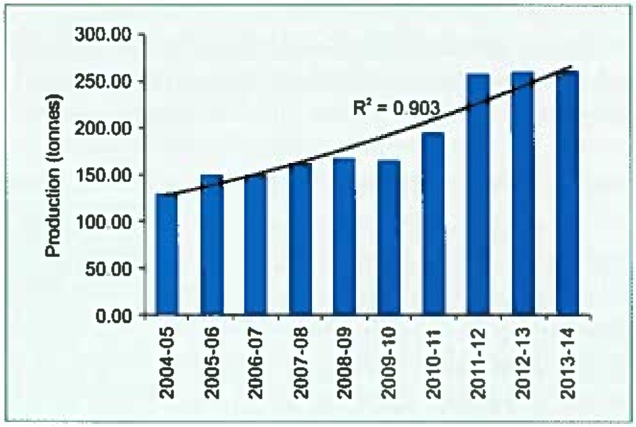


Fig. 4: Trends in rainbow trout production in J&K (2004-05 to 2013-14)

Himachal Pradesh is one of the leading states in rainbow trout farming and seed production in India. With the assistance of Norwegian Government

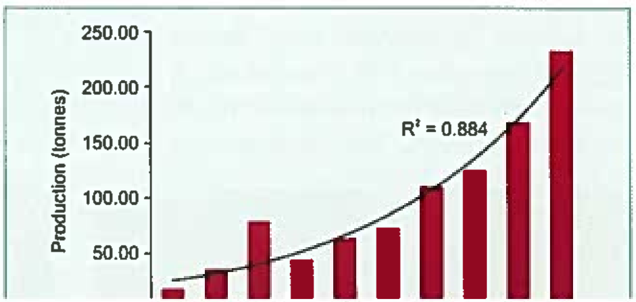


Fig. 6: State trout farm, Patlikuhl

Fig. 7: Trout farm at Dras, J&K

has been possible mainly due to the contribution of the private farmers and entrepreneurs. The private sector has produced 220.56 tonnes of table size rainbow trout during 2013-14 in the state. The state fisheries department has also installed a feed mill having 0.3t/day capacity for the preparation of different types of feed which caters the need of government and private farmers.

North-Eastern Himalayan Region

In northeastern Himalayan states such as Sikkim and Arunachal Pradesh trout production infrastructure as well as trout ova production units in the state were developed with the technical support of DCFR. Sikkim has considerable water resources suitable for rainbow trout farming, and the state has eight farms with 59 raceways. The production of rainbow trout during 2010-11 was around 53.4 tonnes which has significantly increased up to 80 tonnes during 2012-13. The trout seed

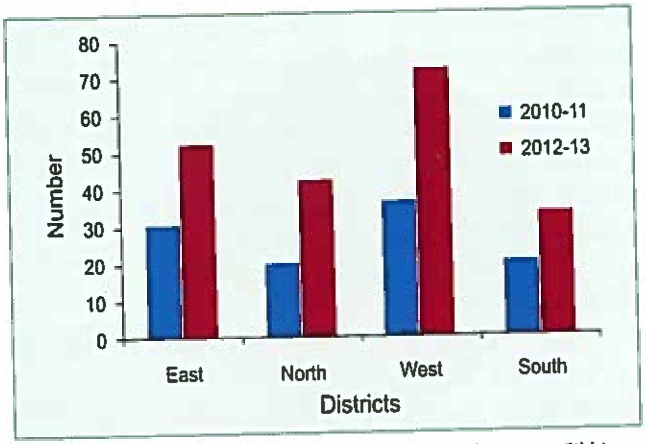


Fig. 8: Trends in rainbow trout adoption by private farmers in Sikkim

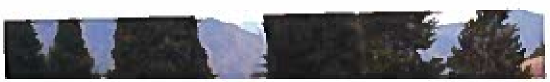


Fig.10: Trout farm and raceways in Sikkim; A. Uttarey, B. Momencho

production during 2011-12 was about 0.4 million (Department of Animal Husbandry, Livestock, Fisheries & Veterinary Services, Sikkim, Annual Report 2010-11). The Directorate has taken all possible initiatives to promote trout culture in the state considering the suitable climatic condition and abundance of water. Brood stock management and seed production have been taken-up on priority over the last four years. Brood stocks of the trout were maintained at State trout farm Uttarey and Yuksom with technical guidance of the DCFR. Although rainbow trout production of Sikkim state is low but a total of 249 farmers have adopted trout farming. In the state of Arunachal Pradesh, trout broodstock and seed production units have been established at two main hatcheries situated at Shergaon of west Kameng and Nuranang in Tawang district with the technical support of DCFR. Shergaon has ova production capacity of 100,000. However, rainbow trout farming is yet to reach private farmers in the state of Arunachal Pradesh. Eyed ova of trout were also introduced in the West Bengal from Kashmir by the state government which miserably remained unsuccessful. In spite of potential in Nagaland trout farming is yet to start. However, there is only one private farm with a mini hatchery at Dzulakia in Kohima district where some stock of trout existed.

Central Himalayas

In central Himalayan region, Uttarakhand is one of the promising states where trout farming has good prospects. In this region, trout culture commenced with the transplantation of eyed-eggs from Kashmir to Talwari and Kaldayani hatcheries. The trout thrived in the hatcheries and some tributaries in the Garhwal but could not survive in Kumaun hills, due to comparatively high summer temperature. The two hatcheries were set up to provide stocking material for the Rivers Pinder, Birehi and Asiganga which were kept in reserve to provide angling pleasure.

the stocks have been successfully raised through various stages of alevins, fry, fingerlings and table size fish. The annual water temperature at the farm ranged between a minimum of 4.5°C in January-February to a maximum of 21.5°C in the months of May/June and for eight months the temperature remained above 18°C. Continuing field experiments, brood stock has now been developed and first successful artificial breeding was carried out in February 2002 at the farm. These trials clearly indicate that with suitable modifications, it is possible to raise trout at marginally higher temperatures prevalent at lower altitudes. This farm also supplies trout seed to different states and local trout growers.

Fig. 11: Trout Raceways at Bairangana trout farm, Uttarakhand

Fig. 12: Trout Raceways and Ova house at Champawat Field centre, DCFR, Uttarakhand

Peninsular India

In Tamil Nadu trout fishery development in the Nilgiri water remained primarily to promote recreational fishing such as angling and sports. Fry and fingerlings produced were mainly stocked in streams, lakes and reservoirs. The trout culture is completely under the domain of State Fisheries Department without any opening to private culturists. Total ova production was around 2 lakh during 2010-11. In Kerala, a trout farm was established in 1941 at Eravikolam and another at Rajamallai. The main focus was to stock the streams for development of sport fishing. Rajamallai hatchery supplies stocking material for stocking in Mudupatty and Kundally reservoirs. A trout hatchery under the control of TATA Tea Company exists at Rajamallai mountain range within a wildlife sanctuary area. The Rajamallai hatchery has 3 broodstock ponds, 3-4 fry rearing tanks and small hatchery with an ova capacity of 48, 000 eggs. The hatchery and farm is maintained by company and running well. Presently no private trout farming is in practice in the southern India. Trout hatchery was constructed in 1909-10 at Avalanche which continued to produce eggs by using brooders from Mukurti stream. The Fisheries department Tamil Nadu took over the management of hatchery in 1958. In 1920, 17000 eyed ova of *Salmo gairdneri irideus* were brought from Kashmir to Avalanche hatchery to stock in various streams of Nilgiris. In February 1968, fresh consignment of 15000 eyed ova

Kodaikanal lake with rainbow fry produced in the Avalanche hatchery. The average weight of rainbow trout in the Southern region ranged between 100-200g (Vass, 2012).

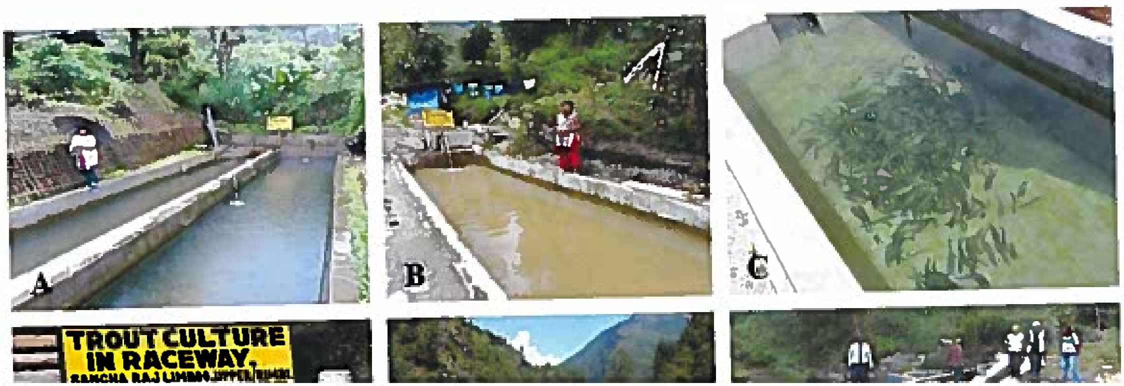
MAJOR R & D INITIATIVES

(i) Culture environments

The DCFR undertook R & D activities to evaluate the growth of the rainbow trout (*Oncorhynchus mykiss*) at different agro-climatic conditions of Himalayan region. At experimental farm, Champawat, Uttarakhand recorded average growth was 200g, 1100g and 2100g at first, second and third year respectively at the thermal regime of 4.5-20°C (Joshi *et al.* 2005). In another field study in central Himalaya, average growth was recorded as 300 g (range 260-400 g) at thermal regime of 5.0-22°C (Vass *et al.* 2010). These observations indicates that rainbow trout farming can be taken up for production of marketable size trout of 240-400g weight within a period of 12 months at marginally higher water temperature range of 10.0-20.0°C in Central Himalayas. The results suggested that higher temperature in mid altitudes of Himalayas can help to maximize yield of rainbow trout, provided farm management practices are optimized. Generally, it takes 12-14 months to attain marketable size (250-260g) in J & K, Himachal Pradesh and Garhwal region of Uttarakhand. However, comparatively better growth of 500-600g was observed in 12 months at state Govt. farm and private farms in West Sikkim. This is due to favourable thermal range of water (14-18°C for 8 months in a year) and availability of sufficient water volume. In Nepal marketable size of 200-300g reach at 14-16 months of culture period with the stocking density of 50 fish/m^2 (Rai *et al.*, 2008, Swar, 2007). Whereas the fish takes approximately 8 months to reach a market size of 300-350g in trout farms of Idaho, U.S.A after being stocked in the raceways as a 4 inch long fingerling (Gempesaw *et al.*,1995). In general, the production level of rainbow trout in Indian conditions is 300-500 kg per raceway having a size of 15mx3mx1m (45m^2) in a period of 12 months duration. However, productivity of 1 t/ raceway or more has been achieved at State Govt. farms and at private trout farms of J & K, Kullu valley of Himachal Pradesh and West Sikkim. This trend of production reflects possibility of raising productivity at suitable environment and sufficient water volume. In present practice, stocking density of 45-50 fish/m^2 has been adopted by the trout growers, which can be increased up to 100 fish/m^2 along with better management practices maintaining sufficient water flow in the raceways. Concrete raceways of various shapes and sizes are used normallv for trout culture.

the water is taken in via a damming of the adjacent water course and water then passes through the farm by gravity (i.e., without use of or only minor use of pump energy). Originally the ponds are constructed directly into the soil of river valleys close to the stream banks. With regard to stocking density, a flow rate of 4 LPS can support up to 20 kg/m^3, though higher volume and higher quality may allow stocking densities as high as 35 kg/m^3. A minimum rate of 500 m^3 per day of water flow is necessary for 1 tonne of trout production (Stevenson, 1987). For achieving success in trout farming, fish of different sizes should be graded time to time. This management avoids competition and cannibalism. The size category for separation might be of 2-5 g; 10-20 g; 50-60 g; and >100 g sizes (Rai *et al.*, 2008). Cost of rainbow trout production has been analyzed which shows that to produce 1 kg of marketable size (200-300g each) of trout the cost remains nearly Rs. 240-300 per kg. Economic analysis of trout culture based on the experiences of the private sector showed that annual rate of return could be nearly 43% of the operational cost. Lamsal *et al.* (2008) evaluated the return on investment in an integrated farm operation in Nepal and found that the return on initial cost was 39%, while the return on operating cost was over 67%. In general, high initial investment for raceways construction could be a constraint for rapid expansion of trout cultivation.

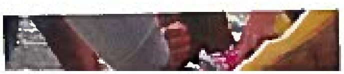
Rainbow trout can survive in water temperatures ranging from 0 to 25°C. The optimum temperature for growth is between 16 and 18°C, but the suitable water temperature range for feeding and growth is 14-18°C, and 9-14°C for the spawning and hatching of eggs. The consistency of environmental conditions with regard to water temperature, volume and quality is very important for trout culture. Trout requires more than 7 ppm dissolved oxygen (DO) (Gibson's 1998). The preferred pH range for trout is between 6.5 and 8.0 with optimum value between 7.0-7.5. At higher pH levels, relatively low level of ammonia can also be dangerously toxic (Bromage and Shepherd, 1990).



(ii) Maturity and Breeding

Rainbow trout normally attains sexual maturity at the age of 3 years. However, males often mature in the second year. The age of sexual maturity is determined by heredity as well as by the farming conditions (e.g., feeding strategy, temperature, light conditions). However, day length is an even more important factor which trigger the timing of sexual maturation. The time of maturation may be controlled by exposing the brood stock to specific light and temperature regimes during the last months before maturation. Exposing the brood stock to increasingly longer days from January until June (18 hours light: 6 hours darkness) with increasing temperature followed by 6 months with shorter and colder days (e.g., 6 hours light: 18 hours darkness) and decreasing temperature may speed up the time of maturation by 3–4 months. The time of maturation may be delayed by using the opposite procedure. Period of the month of December to February is the breeding season with onset of sexual maturity. However, breeding season and breeding period is location specific having different microclimatic conditions especially thermal regime of water and length of photoperiod. At State trout farm, Uttaray (Sikkim) temperature remains comparatively at higher side with the optimal range of 14-18°C for 8 months in a year and rainbow trout mostly breeds during second week of November. In Himachal, rainbow trout breeds earlier than in J&K due the slightly higher thermal regime and other microclimatic conditions. In Uttarakhand, temperature remains 1-3.2°C higher at Champawat than the state trout farm Bairangna (Chamoli) and rainbow trout usually breeds in the first week of January at Champawat, while breeding occurs during the 3rd week of January at Bairangna. The observed age of females producing the highest quality eggs range 4-7 years, and female getting first maturity usually not used for propagation. There is a positive correlation found between egg quantity and individual egg size with increasing size of brood fish. The average egg size of sexually mature females is typically 5 mm (FAO, 2011). The older brood generally lays higher number of eggs/kg body weight. These broods also produce larger eggs. The smaller eggs have low hatchability and small sized alevins with poor survival. The average number of eggs per kilogram of female body weight varies between 1500 to 2000 at different locations. At experimental field farm, Champawat fecundity was recorded as 1402 eggs kg^{-1}.

Natural spawning is not possible with captive rainbow trout so artificial spawning techniques is applied (Rai *et al.*, 2008). The most common method, termed "dry spawning," is to collect milt and eggs and manually mix them in a suitable container. Typically, eggs are collected first and milt is either expelled directly into the egg-containing bowl, or in a separate bowl or subsequently added to the eggs, at which point, fertilization occurs (FAO, 2011). Male brooder having two and six years of age produces the highest quality milt (Basnet *et al.*, 2008). Though it has been stated that milt from a single male can sufficiently fertilize the eggs of two females (Rai *et al.*, 2008), it is also suggested that milt from three or four males must be pooled and can be used to eggs from a specific female now represents one family of full sibs, as all hatching fry have one specific mother and father. The second half of the fertilized eggs represents a separate family of full sibs. However, the two families are half-sibs, as they have the same mother but two different fathers and *vice-versa*. There is a positive correlation between the size of broodstock males and the quantity of milt produced by an individual. After several minutes of mixing milt with stripped eggs, water is added to the milt-egg mixture to allow the process of water-hardening, during which the egg assumes water into the perivitelline space, increasing both its size and its strength. The fertilized eggs are incubated in incubation trays, where clean and cold water must be supplied @ 3-7 L/min. The water used for incubation containing the concentration of dissolved oxygen (DO) 9-10 mg/L resulted better hatching rate and survival. In general, incubation period is 270-310 degree days. At trout farm, Uttarey, Sikkim incubation period was 25-32 days (310 degree days) with better management practices. Hatching period and survival of alevins also depends on water temperature and sufficient water flow in the hatchery. At Champawat, during 2005, the hatching of the stripped eggs completed after 61 days at water temperature 4.5-7.5 °C with a survival rate of 42.6 % (Joshi, 2009). Similarly, during the year 2009, 60% fertilization, 80% hatching and 61% survival of fry to fingerling (Incubation period 58 days) was recorded at water temperature 5-12°C. During the year 2010, 71% fertilization, 72% hatching (Incubation period 54 days) was observed at water temperature 6-14°C. These data revealed that increasing temperature results in better survival and early hatching. Breeding period may also be extended by preparatory hormone dose to the female brooder. In Sikkim, 14 days early maturity in females of the age of 3-4 years was achieved and got maturity during first week of November. Similarly, brooders of the age of 3-5 years showed early maturity (III week of Nov.) than the young brooder of 2-3 years age group (II week of Dec.), which reflects that age also influence the maturity in brooder. The better nutrition to the brooder and sufficient water flow (300 LPM per raceway) results in better breeding performance as fecundity of 1500-1800/kg, fertilization rate 94%, survival up to eyed ova 87%, hatching rate 92% and cumulative survival of 78%. The size of yolk-laden alevin ranged from 15-18mm. Advance alevin started feeding after 11-14 days of hatching. The fry attained average length of 26.0±3.0 mm with corresponding weight of 0.45±0.07g during II week of March. A wooden stripping stand was designed by DCFR for easy stripping operation and to reduce the man power, physical stress on brooder and on breeder during stripping operation. Two people can perform breeding of 120 kg. brooder in 6 hrs without any post stripping mortality, while it is only 70 kg with manual operation. The wide application of the improved technology has resulted in achieving 80-90%



success in several hatcheries in Kashmir, Himachal Pradesh and Uttarakhand. During the first three months adequate nutrition and feeding of fry is required with proper health care. Therefore, the principal factors responsible for fry losses are nutritional deficiencies, diseases and silt load in the nursery raceway. Better quality feeds result in a survival from 50 to 61%, with maximum feed efficiency of 79.9% at 35% crude protein level.

Occurrence of precocious maturation (early onset of puberty) in commercial grow out systems is a prevalent constraint that leads to post-pubertal growth rate, carcass yield, flesh quality, market value and lower return to farmers (Bye and Lincoln 1986; Purdom 1986; Benfey, 1999; Piferrer *et al.*, 2009). Farms adjacent to natural streams or other water sources are subject to escape of domesticated rainbow trout into the wild, which is a serious environmental concern as the escaped fish can contaminate and disrupt the receiving ecosystem (Benfey, 2015). The remedy for overcoming the above farming constraints and slow growth in the existing stock is the induction of reproductive sterility. The most practical and effective way to produce sterile rainbow trout is the manipulation of chromosome sets (Induced polyploidy). A preliminary attempt was made by DCFR to induce triploidy by applying heat shock to newly fertilized trout eggs and the produced triploids are in the early rearing phase.

Fig. 16: Different stages of Egg incubation and larval development of rainbow trout

(iii) Suitable sites for trout farming

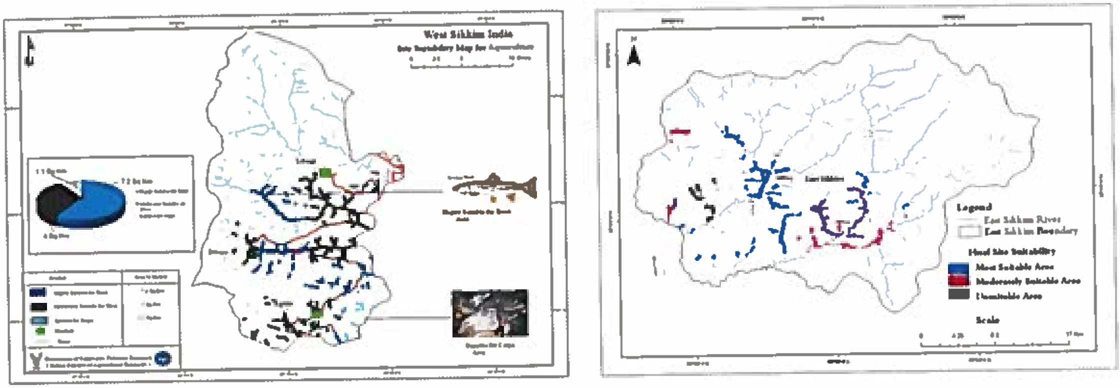


Fig. 17: GIS based site suitability map for West Sikkim and East Sikkim

(iv) Nutrition and Feed formulation

Adequate nutrition, both in terms of quantity and quality, is of utmost importance for the success of any aquaculture operation. For larval and broodstock feeding the requirement of protein is even greater (40-45%). It has been recommended that a diet of no less than 35% crude protein be administered at a rate of 2-3% of bodyweight per day for growout stock of rainbow trout. Use of protein for energy is expensive, thus lipids are primarily included in formulated diets to maximize their protein sparing. Lipids are highly digestible source of concentrated energy. Dietary lipid level as low as 10% has been suggested for rainbow trout on the basis of previous studies. However, weight gain and feed efficiency depressed when diet contains 15% or more lipids. Rainbow trout has an exclusive requirement of n-3 or w3 PUFA in their diet. High protein level in the diet is always resulted an increase in unwanted ammonia excretion. It was observed that diet with 45% and 40 % protein level resulted as 0.12 mg/l and 0.08 mg/l ammonia excretion in the drain water, respectively. But, lowest level of ammonia as 0.05 mg/l was recorded with 35% protein level in the diet.

The nutritional value of the feed depends not only on the quantity but also on the quality of the protein, i.e., its amino acid conformation. Amino acids are the elementary units of proteins. Several amino acids are essential for fish growth and development and, therefore, must be present in the feeds. These amino acids are called essential amino acids. Proximate composition of carcass of fingerlings of rainbow trout reflected that the requirement of Arginine (6.427%) is comparatively higher than the other essential amino acids. Therefore, better utilization of the protein in the diet of trout can be obtained by adding ingredient having more Arginine.

A major researchable issue for trout feeding is the high cost of manufactured pelleted feed acids like lysine and methionine usually occurs. Protein digestibility remains in lower side when diet contain soybean due to anti trypsin factors. Anti-nutritional factor such as trypsin inhibitors may be destroyed or reduced with heat that is applied during the solvent extraction. Heat treatment also reduces phytic phosphorus of soybean and improve digestibility of the plant protein. Solvent extracted soybean meal (SESM) containing 48% protein and has best amino acid profile and is highly palatable, digestible to trout (Digestion coefficient 80%). It also contain Arginine (3.91% of dry basis), an important amino acid for the trout. It is also reported that the total replacement of fish meal by soy protein concentrate (SPC) without negative effect on growth performance and flesh quality of rainbow trout (Kaushik *et al.*, 1995). However, studies conducted at DCFR have shown that the 40% substitution of fish meal with Solvent extracted soybean meal (SESM) is possible which eventually reduce feed cost by about 20% without affecting the growth and feed efficiency. Protein digestibility is reduced in salmonids when diet contains high level of soybean due to its anti-trypsin factor. Current research showed that feed performances and digestibility can be increased with the use of enzymes and balancing amino acid profiles that enhance plant protein use (Hasan, 2001). The manufacturing process may also improve digestibility, inactivate certain undesirable substances present in feedstuffs, reduce the occurrence of molds and bacteria, and improve palatability. High level of soybean also creates waste material in the form of uneaten feed, undigested matter and end product is subject to pollute the recipient environment in the form of increasing level of phosphate and ammonia. Reduction of ammonia excretion can be achieved by adding crystalline DL-methionine to the diet containing high level of soybean meal (Medale *et al.*, 1998). Higher water temperature partially affected the feed intake and dietary protein requirement of the trout, which can be covered by increasing feeding frequency and improving digestibility. Several forms of dry and moist trout feeds are produced by state Fisheries departments (Himachal Pradesh, J&K) and private feed manufacturing companies. The variation in nutrient composition of available trout feeds in the market is much more. More environmentally friendly and low cost diets need to be produced by developing diets with reduced food conversion ratios (FCR) by improving palatability and digestibility of raw ingredients. Mitra (1997) reported that availability of methionine and lysine are recorded higher in earthworm than fishmeal. Considering these facts a comparative study was carried out by DCFR on the effect in the growth of fish fed with diet contained 25% earthworm and 75% farm feed only. Fish fed with farm diet showed better growth than fish fed with diet contained earthworm. The reason might be the earthworm powder was not accepted by fish due to earthworm's unfavorable smell though contained high protein. In absence of suitable starter or dry pellet feed for trout during larval stage, some of the farmers are using egg yolk, followed by boiled goat liver. Since, liver contains very high protein and several other vitamins and minerals, probably it is the substitute of appropriate dry

DCFR has refined this practice and formulated farm made trout diet based on silage prepared with slaughter house waste and fish/poultry offal after incubation with formic acid and is being used for farm trials. Balanced diet, appropriate pellet size, adequate feeding and clean pond environment results in better growth and production.

Feed alone comprised 76% of total variable cost and 40% of the total production cost of trout farming. Therefore, it is required to focus on finding alternate source of protein supplement in trout feed which are locally available at relatively cheaper cost without affecting the growth, survival and quality of trout. Most of the studies on protein requirement of trout have been based on weight gain and feeding efficiency. Previous studies revealed that the dietary protein requirement for trout is in the range of 30-45% on dry basis.

Table 1: Feed and feeding for rainbow trout

Feed type	Approx. Prot./Fat content (%)	Pellet size (mm)	Fish size (g)
Starter/fry	45/14	0.5–1.5	0–10
Growing/fingerling	40/14	2.0 -	10–50
Grow out/yearling	35/17	3.0–9.0	50–1,000
Brood stock	50/10	9.0	1,000–4,000

Fig. 18: Feed mill facility at DCFR, Bhimtal and State Trout farm

(v) Genetic stocks of rainbow trout in India

Based on the historical records of import and time to time translocation of rainbow trout to different parts of the country it can be inferred that more likely three different stocks are present in the country viz. Himachal Pradesh stock, Jammu and Kashmir stock and Munnar hill stock (Southern India). Other states share the rainbow trout stocks from these three stocks which have been brought for either building their new stocks or replacing old stocks. In a recent study (Barat *et al.*, 2015). based on microsatellite markers, it was inferred that, the rainbow trout stock from Munnar, Kerala, in extreme south of India is quite distinct from other four stocks

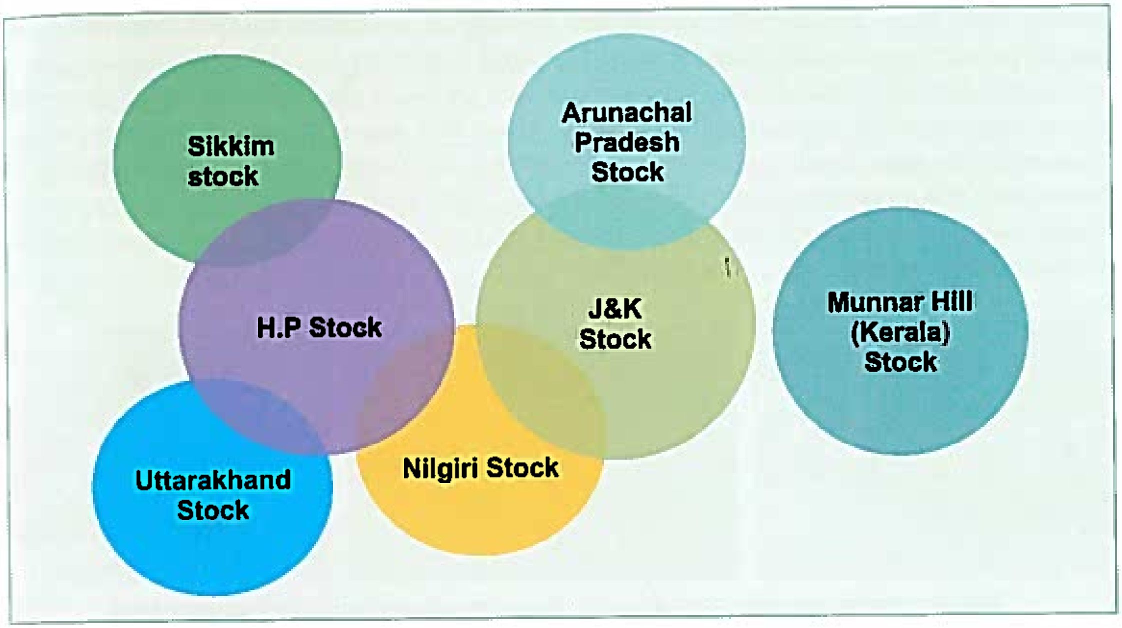


Fig. 19: Differentiation of rainbow trout (*Oncorhynchus mykiss*) stocks present in India based on the historical records of import and time to time translocation in different parts of the country. The figure also indicates sharing of rainbow trout stocks between the states.

(vi) Fish Health Management

Surveillance of rainbow trout farms at different locations observed bacterial diseases like tail rot, gill rot, fin rot and exophthalmia. Skin hemorrhagic ulcers on the caudal regions of rainbow trout were also observed, characterized by deep ulcers and hemorrhagic frayed fins. The causative agent was identified as *Aeromonas hydrophila* (designated RTMCX1). Amplification and sequencing of the 16S rRNA gene (1304 base pair) revealed that the sequence was 99% similar to *A. hydrophila* sub sp. *hydrophila*. This strain exhibited strong ß-hemolytic activity against sheep blood and rainbow trout erythrocytes, and was capable of growing in rainbow trout serum and 0.5-10% NaCl at 4.0-35°C. Mortality was 100% in experimentally-infected fish, with a median lethal dose (LD50) of 1.9×10^4 colony forming units/g body weight. *Aeromonas hydrophila*, RTMCX1 was sensitive to a majority of 27 tested antibiotics, indicating the possibility of controlling this bacterium by antimicrobial compounds. Four strains of *Lactococcus garvieae* (GenBank accession no: KM 604701, KM 604702, KM 604703 and KM 604704) were isolated and identified from diseased rainbow trout in trout farms of Uttarakhand and Himachal Pradesh. Samples were showing typical symptoms of lactococcosis: unilateral exophthalmia, *diclina*. They have characteristics of cottony appearance, elongated zoosporangia and pear shaped primary sporangium. Temperature has a significant effect on the development of fungal infection. Most epizootics occur when temperatures are below the optimum range. However, during incubation of trout eggs it can be observed that higher temperatures increase the chances of infection. Dead eggs are more susceptible to the fungal attack during incubation as *Saprolegnia* is a saprophyte. Rayamajhi and Dhital (2008) state that polluted water, especially during monsoon season, and unhygienic feed are the most likely pathways for disease to enter Nepalese rainbow trout.

Fig. 20: Sampling of diseased fish from trout farms Sikkim

The mass mortality of stocks of rainbow trout was recorded in the year 2003 in state Himachal Pradesh. The causative agent was suggested as a possible irridoviral infection. As the country was lacking diagnostic facility, the agent could not be isolated and characterized. In the year 2009 there was a mass mortality of brown and rainbow trout in state trout farm Bairangna (Uttarakhand). Mortality of fingerlings and brood stocks of rainbow trout weighing 530g to 2500g was recorded in the incident. After this outbreak, a cell culture facility was immediately set up at DCFR and screening of samples started to enable isolation of fish viruses from trout farms. In order to have an effective disease reporting and surveillance system, there are two important projects being handled. National Surveillance Programme on Aquatic

(vii) Environmental issues

As trout farming is progressing in India, environmental concerns related to the aquatic ecosystem also need adequate attention. Flow-through aquaculture systems like raceways and tanks discharge effluents with enhanced concentrations of nutrients and solids. It is well recognized that effluents from trout farm do have impacts on the receiving streams water quality (Riche and Brown, 1996; Boaventura *et al.*, 1997; Green *et al.*, 2002; Pulatsu *et al.*, 2004; Bartoli, *et al.*, 2007) and biotic communities (Selong and Helfrich, 1998; Camargo *et al.*, 2011). Moreover, incidence of pathogenic organisms with antibiotic resistance in effluent water has also been reported (Vaughan *et al.*, 1996; Schmidt *et al.*, 2000). Thus, it is important to evaluate impacts of trout farming on the streams of coldwater regions of India and accordingly effective monitoring, and management measures should be developed. These are pertinent issues which need serious consideration and deliberations for sustainable rainbow trout farming in the country.

(viii) Recirculatory Aquaculture System (RAS)

In view of the environment and sustainable development practices, fish farms are today confronted with water reduction and waste treatment management. Some aquaculture rearing systems, called recirculating systems, can be associated with a treatment loop, for water reuse or water treatment before release (Roque d'orbcastela *et al.*, 2009). Recirculating systems include a number of treatment unit operations depending on the degree of water reuse, the economics and the water quality requirements which mainly depend on the fish species and size. Classically, the recirculating system treatment area is a combination of solid removal (mechanical filtration, decantation), gas control (oxygen supply, CO_2 degassing) and biological processes (ammonia nitrification by biofilter, disinfection by UV). DCFR has taken an initiative and such modifications are in the process of establishing an outdoor water circulatory unit at experimental Field centre, Champawat.

(ix) Processing, Value addition and Marketing

Rainbow trout is one of the most well-known fish in the world, and has a reputation as being a high quality, coveted product that fetches a high price. But, trout farms are distantly located in difficult terrains and have poor accessibility to the markets. At times they are not well connected by road or rail head. Under these circumstances, farmers are either forced to consume the produce by themselves or sell at cheaper prices in local market. Rural domestic consumption cannot be the target of the rainbow trout industry; it must look to areas in which the native and/ or visiting populations have the means for purchase (Swar, 2007). Considering marketing of the product, a "branding" technique, such as labelling the fish "Himalayan rainbow trout" may

Fig. 21: Trout restaurant at Himachal Pradesh

(x) Nutritional values

Rainbow trout has a rich amount of high quality protein with well balanced essential amino acid, polyunsaturated fatty acids and minerals. It also has good quality lipids containing substantial amount of n-3 PUFAs with n3/n6 ratio of 0.77. The moisture, crude protein, crude lipid and ash contents of the rain bow trout are 74.00, 19.44, 5.18 and 1.37%, respectively. Based on moisture and fat contents, the rain bow trout is a medium-fat fish with fat content 5-10% by weight. In total 17 amino acid were identified from the muscles of rainbow trout. Rain bow trout protein had a well balanced amino acid composition. The most abundant amino acid is proline (96.37 mg/g crude protein) followed by Aspartic acid. The free amino acids such as glutamic acid, aspartic acid, alanine and glycine are responsible for the characteristic flavour of fish. Beside the nutritive value, amino acids also provide several health benefits, such as reduction of blood cholesterol, reduction of coronary heart disease and anti-obesity potential. Certain amono acid like aspartic acid, glycine and glutamic acid are also known to play a role in the process of wound healing. Proline, which is one of the major components of human skin collagen together with other amino acids such as glycine, alanine, arginine, serine, isoleucine and phenyl alanine form a polypeptide that will promote regrowth and tissue healing. Tyrosine, methionine, histidine, lysine and tryptophan are considered to act as antioxydants for humans (Singh and Sharma, 2014).

Fatty acids profile showed that total Monounsaturated fatty acids are highest (35.88%) followed by saturated fatty acids (34.51%) and poly unsaturated fatty acid (31.39%). There is a significant amount of palmitic acid (C16:0) as compare to other saturated fatty acids like miristic (C:14:0) and stearic acid (C18:0). Among the MUFAs, oleic (C18:1) and palmitoleic (C16:1) acids were predominant fatty acids, accounting for almost 67.69 and 22.85% of total

Among the minerals analyzed, K is the highest followed by Ca, Na, Fe, Zn, Se and Mn. Trout muscle is reasonably a good source of iron, supplying 5.17 mg/100g muscle. Zinc level of rainbow trout was found to be 1.79 mg/100g muscle which is sufficient to maintain good health in humans. Selenium plays a protective role in preventing carcino-genesis and other chronic diseases and act as an antioxidant in man. The Selenium content (1.66mg/100g) is higher than many other species. In general, rainbow trout is low in fat and calories compared to other meats. A 3-ounce serving of cooked rainbow trout contains 130 calories, 22 g of protein, 4 g fat, 1 g saturated fat and 30 mg of Sodium (Ladewig and Morat, 1995).

(xi) Expansion, Technology dissemination & HRD

(a) Explorations for potential areas

During recent past DCFR made intensive survey of higher altitudinal regions of the Himalayas particularly the Himachal Pradesh, J& K, Arunachal Pradesh, Sikkim and Uttarakhand including cold deserts for exploring possibilities of trout culture in those areas where it does not exist. Under this endeavour, visits were made at Dalan Maidan, Lahul- Spiti, Kullu of Himachal Pradesh; Leh & Laddakh areas of J & K; Sikkim; Tawang, Dirang, Tenga, Chella Pass areas of Arunachal Pradesh; and Munsiari areas of Uttarakhand. However, some sites in the surveyed area have been identified suitable for the construction of raceways having the size of 3x10x1.5 m. This area receive heavy snow fall during winter season from the month of November to April and remain inaccessible during this period. Therefore, the raceways may be protected from heavy snow fall by covering with a tin shed over the raceways.

Fig. 22: Interaction with farmers at Dalang Maidan, Lahul-Spiti

(b) Trout farming in Leh

Initiative for rout farming in highlands of Leh region under Tribal Sub Plan has been taken by DCFR. The programme was initiated after a detailed survey and selected Chushout Shamma village of Chushout block, which is about 20 kilometers from the Leh district head quarters and having a perennial source of water. Fourteen raceways have been constructed by the farmers through technical support of the DCFR for raceway construction, stocking and intercultural activities.

Fig. 24: New trout raceway at Chushout Shamma, Leh

(c) Private trout growers in Himachal Pradesh

A field visit to Kullu and other area of Himachal Pradesh was made during 25 to 29th October, 2013 to identify the problems and prospects of trout farming in the area. An interaction was held with trout growers in Kullu district to identify the problems related to trout farming. The local KVK, Bajoura facilitated the visit to the trout farmers. There are more or less 20 trout growers in the Kullu-Manali districts and most of them are having similar kind of problems.

- Technical guidance for renovation of state trout farms and hatchery infrastructure.
- Broodstock development and maintenance.
- Technical guidance/ demonstration for breeding & larval rearing.
- Technical guidance for establishment of feed mill and feed formulation.
- Awareness/hands on training to departmental personnel and farmers.
- Adopted 42 trout growers of 7 clusters in West Sikkim for farm advisory.
- Construction & renovation of 6 tribal farmer's raceways.
- Technical support for hatchery infrastructure.
- Management of broodstock.
- trout feed requirements and feeding.
- Technical guidance for floating cages and trout rearing in cages.
- Technical guidance for improved raceway design.
- Farm advisory to the adopted farmers for intercultural activities.
- Disease surveillance and health management.

(e) Trainings

A need felt hands on training was conducted for the trout growers of Kullu and Lahaul Spiti district of the Himachal Pradesh in collaboration with CIFT, Cochin and KVK, Bajoura during 11- 13 Dec. 2013. It is an intervention of the DCFR, Bhimtal to popularize the new value added products of the Rainbow trout in tourist places like Kullu, Manali and Lahaul Spiti. Demonstration for the preparation on Trout fillet, trout streak, trout cutlets, trout ball, trout fingers, trout wafers and feed preparation by using trout silage was given to the farmers. Technical knowledge of culture and breeding of the trout was provided by the DCFR. A total of 50 farmers of the distt. Kullu and Lahaul Spiti participated in the training programme and prepared the value added products of trout. This was learning by doing exercise for the participants and they took keen interest in learning different recipes of the trout. A series of training was organized for different stakeholder during 2010-2015 by ICAR-DCFR (Table 2)

Demonstration for filleting

Demonstration for value added products

Fig. 26: Training on processing and value addition of trout in Himachal Pradesh

Fig. 27: Adopted farmers in West Sikkim

Fig. 28: Trout raceways in East Sikkim

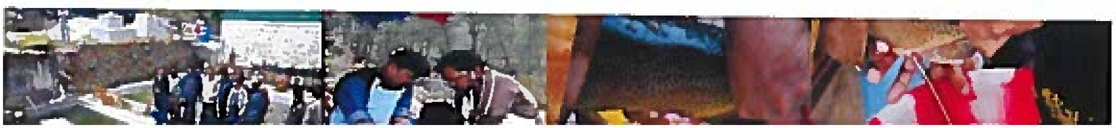


Table 2: Training programme conducted by ICAR-DCFR for farmers and extension functionaries- (2010-15)

Sl. No.	Date	Topic	Nos. of participants	Details
1.	19-23 October 2010	Three pronged fish farming Technologies for hill regions (Dr. D. Sarma)	20	NFDB sponsored, conducted at Itanagar, Fish entrepreneurs/ farmers of Arunachal Pradesh
2.	27th Dec 2010 -3rd Jan 2011	Breeding, Incubation and Rearing of Rainbow Trout (Dr. D. Sarma)	20	Sponsored by Directorate of Extension, Dept. of Ag. & cooperation, Min. of Ag, Fisheries, conducted at Bhimtal/Champawat, Officers/extension functionaries from Arunachal Pradesh/Sikkim/ Uttarakhand.
3.	26-27 Sept, 2011	Training programme for tribal fish farmers in Tirap, Arunachal Pradesh (Dr. D. Sarma)	20	Under TSP, 20 participants, conducted at Deomali Tirap.
4.	14-18 Feb, 2012	Surveillance of Disease in coldwater Aquaculture (Dr. Amit Pande)	25	NFDB sponsored, conducted at Tadong, Gangtok, Department personnel/extension functionaries
5.	9-10 Sept. 2012	Post harvest utilization and value addition of trout (Dr. S. K. Srivastava)	70	Conducted at Champawat jointly with CIFT, Cochin
6.	10-12 Sept. 2012	Fish farming in hills (Dr. N.N.Pandey)	11	Sponsored by ATMA Scheme, Farmers of Distt. Mandi, Himachal Pradesh
7.	9-10 Dec. 2012	Culture and breeding of Rainbow trout (Dr. N.N.Pandey)	23	NEH fund, conducted at Uttarey, W. Sikkim, department personnel/ fish farmers
8.	1-5 Feb. 2013	Coldwater Fisheries management and eco tourism for upliftment of rural livelihood in NEH region (Dr. D. Sarma)	20	NEH fund, conducted at Guhawati, officers of Assam, Manipur, Sikkim, Arunachal Pradesh, Meghalaya, Mizoram
9.	10-12 March, 2013	Training cum exposure visit (Dr. N.N.Pandey)	9	NFDB sponsored State fisheries programme, conducted at Bhimtal, Officers/extension functionaries from Sikkim state

Sl. No.	Date	Topic	Nos. of participants	Details
12.	24-25 Oct. 2013	Coldwater fish farming in Meghalaya: new approaches (Dr. D. Sarma)	100	NEH fund, 100 officers/ students/ extension functionaries of Meghalaya
13.	11-13 Dec. 2013	Culture , Processing and Value added products of Trout (Dr. N.N.Pandey)	50	Under TSP activity, conducted at KVK Bijaura, Kullu, Himachal Pradesh, farmers of Distt Kullu, Lahul spiti
14.	28 Feb- 6 March, 2014	Hands on training on Laboratory procedure diagnosis and control of coldwater fish diseases (Mr. S. Mallik)	14	NEH fund, conducted at Bhimtal, 14 officers/ extension functionaries/ research scholars from NE region
15.	28 Nov- 2 Dec. 2014	Technical know-how for the culture and breeding of Rainbow trout (N.N.Pandey)	25	NFDB sponsored, conducted at Uttarey, W. Sikkim, 25 farmers from Uttarey, Begha, Simphok, Sopakha &Tarbari village49125
16.	20-24 Jan. 2015	Culture and breeding of important coldwater fish species (Dr. D. Sarma)	24	NFDB sponsored, 24 department personnel/ Farmers from Rajeev Gandhi uni. Ita nagar Arunachal Pradesh Rs. 2.5 lakh
17.	10-14 March, 2015	Prevention and control of diseases in Rainbow trout (Dr. S. Malik)	20	NFDB sponsored, conducted at Bhimtal, 20 department personnel/ Asstt. Professors from State fisheries departments (Arunachal Pradesh, Uttarakhand, Manipur & TN)2.5



Fig. 30: Need felt hands on training to the trout growers of Sikkim State

Some important facts on rainbow trout

- Provides excellent opportunity for utilizing the abundant resources of coldwater.
- Small scale trout farming provides a great opportunity for livelihood and nutritional security to the hill community.
- Higher export potential having high demand in international market.
- In addition to the production, ensure increased income and employment through angling tourism, restaurants and related services.
- Grow rapidly and are in demand as a food fish.
- Easy to spawn and their fry remain large in size at first feeding
- Can be fed purely on artificial diet even from first feeding
- Potential success requires better governance and significant improvement in the management practices
- Require cool, clean and well oxygenated continuously flowing water for sustainable production.
- Tolerate a wide range of water temperatures and high altitudinal regions are yet to be brought under trout culture.
- More resistant to certain diseases
- Growth rate depends on water temperature and protein rich feed.
- Attains sexual maturity in 3-4 years of age.
- Can be bred artificially once a year from December to February.
- Technology, knowledge and labour intensive production
- Suitable water temperature range for feeding and growth is 14-18°C and 9-14°C for the

- Intensive production results in the release of organic wastes and soluble inorganic nutrients such as nitrogen and phosphorus
- Phosphorous present in the trout farm discharge water is subject to regulatory restrictions
- Requires high animal protein content in diet
- High cost of manufactured pelleted feed due to the use of costly and scare fish meal.
- Insufficient water supply results in crippled fish larvae, low productivity.
- Non-availability of adequate seed round the year
- Limited infrastructure for hatcheries and trained high quality human resources
- Limited supply of fingerlings and non availability of seed to the farmer round the year
- Less genetic variability, slow growth.
- Need of seed bank and broodstock of improved variety.
- Highly perishable, seasonal, bulky, small scale and scattered production
- Poor market infrastructure and high costs of transportation
- Increase risks of markets due to high input costs and market volatility
- Unlike other fish species, trout solely depends on cost effective feed and quality seed.
- Dead eggs remain more susceptible to the fungal attack during incubation
- Sterile triploids negate inbreeding depression and reduce risk of contamination of wild gene pools.
- Low cost infrastructure and location specific package of practice is required.

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