WATER BUDGETING STUDIES ON THE HATCHERY AND NURSERY REARING PRACTICES FOR THE COMMON CARP, *CYPRINUS CARPIO* (LINNAEUS, 1758)

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ABSTRACT

Aquaculture systems are an integral element of rural development and therefore should be environment friendly as well as socially and economically designed. From the economic standpoint, one of the major constraints for the development of sustainable aquaculture includes externalities generated by competition in access to a limited resource. This study was conducted as an investigation into the water requirement for the hatchery and nursery production phases of common carp, *Cyprinus carpio* (Linnaeus, 1758) at the Maharashtra State Fish Seed Farm at Khopoli in Raigad Dist. of Maharashtra during the winter months from November to February. The water budgeting study involves the quantification of water used in every stage of production in hatchery and nursery systems and aimed at becoming a foundation for the minimization of water during production without affecting the yield; thereby conserving water and upholding the theme of sustainable aquaculture. The total water used in a single operation cycle was estimated to be 11,25,040 L. Out of the total water consumed, 4.74% water was used in the pre-operational management steps, 4.48% was consumed during breeding, 62.72% was consumed in the hatching phase, 21.50% was used for hatchery rearing and 6.56% was consumed during conditioning. In the nursery ponds, the water gain was primarily the regulated inflow coming through the irrigation channel. The total quantum of water used in the nursery rearing was 31,60,800 L. The initial filling and regulated inflow formed 42.60% and 57.40% respectively of water gain, while evaporation, seepage and discharge contributed 20.71%, 36.46% and 42.82% respectively to the water loss. The total water expended for the entire operation was 1,21,61,120 L. Water expense occurred to produce a single spawn in the hatchery system was calculated and found to be 0.56 L while the water expended to produce one fry was calculated as 4.86 L. The study fulfills the hydrological equation described by Winter (1981) and Boyd (1985). It also validates the water budget simulation model that can be used for forecasting water requirements for aquaculture ponds (Nath and Bolte, 1998).

Key words: Water budgeting, Hatchery, Nursery rearing, Common carp.

INTRODUCTION

Over the last few decades, aquaculture has taken off in India from a mere subsistence to a profitable commercial enterprise. Indian aquaculture sector has made tremendous growth over the past few decades. Inland aquaculture has emerged as a major fish producing system in India, with the governmental initiatives in the past three decades. Currently the average annual yield is around 2.2 t/ha. India produces over nineteen thousand million fry per year. Necessary capacity for feed production also exists. Carp accounts for over 80% of farmed fish.

Although aquaculture has been the most vibrant and fastest growing food production systems over the last three decades, the impending water crisis is evident in aquaculture as good quality water is becoming scarce, the remaining resource is being polluted and it has become the need of the hour that the scientific community advocates judicious use of water in aquaculture systems. The competition for water quality and quantity has led to conflicts among various sectors; therefore, proper quantification through water budgeting is required for effective management of water resources.

Water budgeting reflects a balance between the inputs and outputs of water to and from the culture system. The inputs include precipitation, runoff, filling and inflow from ground. The outputs include evaporation, overflow and seepage. Water budgeting helps in the assessment of correct minimum water requirement of individual aquaculture species thereby helps in conserving water and reducing the operational costs.

Cyprinus carpio (Linnaeus, 1758) commonly referred to as common carp belongs to the Class *Osteichthyes*, Order *Cypriniformes* and family *Cyprinidae*. Its original home is China, where this fish has been cultured in ponds for many centuries. Today the common carp has been distributed not only in the countries of Asia but throughout the world. The common carp is the most domesticated fish. Common carp hold C/s the fourth position in terms of the largest global production for an individual species with a production of 3.4 million tonnes and ranks first in the most commonly introduced species (FAO, 2006). The common carp is a highly adaptable species found in still and running waters from the cold temperate zone to the tropics. An optimum temperature of 18 to 24°C is required for its natural reproduction (FAO, 1985).

Hence, the impending crisis due to scarcity of good quality water can be overcome by the culture of hardy, less water requiring fishes with proper water budgeting. Although the water requirement for agricultural production systems has been standardized which has resulted in greater water conservation as well as increased profit, yet the water requirement has not yet been established in aquaculture. This study was therefore aimed at estimating the total quantity of water used for hatchery and nursery operation cycles.

MATERIALS AND METHODS

The Maharashtra State Fish Seed Farm, Khopoli is situated at N 18° 47' 10.1" latitude and E 73° 21' 6.4" longitude, at an elevation of 83 m above Mean Sea Level (MSL) in Raigad District of Maharashtra State, India (Fig. 1). It lies at a distance of 89 Km from Mumbai and 74 Km from Pune, 200 m away from the Mumbai-Pune National Highway No.4 and 6 Km from the Mumbai-Pune expressway.

The Maharashtra State Fish Seed Farm, Khopoli was established in the year 1991 and became operational in 1993-94. The layout of the farm is given in the Fig. 2. The farm has a total area of 2.5 ha with a water spread area of 1.5 ha. The site has an office with attached rooms, three living quarters for the staff and a store room for the stocking of fertilizers, feeds and equipments. The infrastructure for fish production includes one Chinese carp hatchery, ten ponds comprising of four stocking ponds totaling an area of 0.85 ha and six nursery ponds of area 0.65 ha of which 0.43 ha (66.15%) only is suitable. The current brood stock capacity is 2100 Kg which has exceeded the total brood stock capacity of

1700 Kg. The spawn rearing capacity of the farm is 195 Lakhs.

The water source for the site is from a canal originating from the Walwan dam, under the jurisdiction of Tata Hydroelectric Project at Lonavla. Water is transferred via underground pipes of 12 inch diameter utilizing gravity flow. It is first passed through a mechanical slow sand filter to clear the water free from impurities and then taken to a chamber wherein the water is diverted into the stocking pond, SP4. The water is again carried forward to another chamber which serves as the inlet for SP2 and SP3. The remaining water is sent to the next chamber and further diverted to ponds NP1, NP2 and SP1. Water from the chamber-2 is transferred via underground pipes of 12 inch diameter to an underground storage tank of 30,000 L capacity The water is pumped from the underground storage tank using two electric pumps of 5 Hp each. One standby diesel pump of 5 Hp is provided in case of power failure. Water is pumped into an overhead tank of 8 m height having a capacity of 30,000 L A bypass pipe diverts the water from the chamber-2 directly into the Chinese hatchery to minimize operational cost.

The hatchery consists of a spawning pool of 8m diameter with a depth of 1.5 m. Two incubation pools of 3.8 m diameter and 1m depth are installed. The water from the overhead tank or bypass from chamber-2 is let into the spawning pool via duck mouths and showers. Spawning pool is used only for water storage. The incubation pool is filled using duck mouths and is used as a site for breeding as well as hatching of eggs. The water from the incubation pool is let out into the fry collection pool or let out through a bypass pipe to the adjacent area.

The breeding system including the tanks, plastic thickets and other materials were disinfected and washed and the tanks were filled before the breeding started. The fishes were injected with ovaprim and released along with males in the ratio of 1:1.5 into the cleaned incubation tank of Chinese hatchery before 11.00 am. The water flow was maintained at 1.4 L/s to meet the oxygen demand. The breeding took 5 to 6 hrs and spawning was completed in this period. Thickets of plastic weighted at the bottom were provided to get attached the adhesive eggs instead of weeds. The plastic thickets application reduces contamination and disease occurrence as well as avoid dissolved oxygen depletion. After spawning, the brood fishes were removed from the tank to avoid damage to the eggs and the flow rate was maintained at 1.4 L/s. Hatching took 70 to 72 hours depending on the temperature. After hatching, the plastic strands were removed and the spawn were transferred after a day to FRP tanks for conditioning for a period of two days. The fry were then transferred to the nursery ponds where they were held for around a month depending on the demand.

The study was carried out with the help of a standard weather station manufactured by Davis Instruments Corporation, California, USA. The station monitors temperature, humidity, wind speed and wind direction, solar radiation, ultraviolet radiation, rainfall, dew point, wind run, wind chill, heat index, THW index, rain rate and degree days.

Water budgeting is a practice which can be used beneficially to account for water stored, entering, and leaving a particular area of interest. In order to maintain a relatively constant water level in a pond, the amount of water entering the pond must be equivalent to the amount of water lost from the pond. The hydrologic equation as described by Winter (1981) and Boyd (1985) is:

$$\text{Gains} = \text{losses} \pm \text{storage}$$

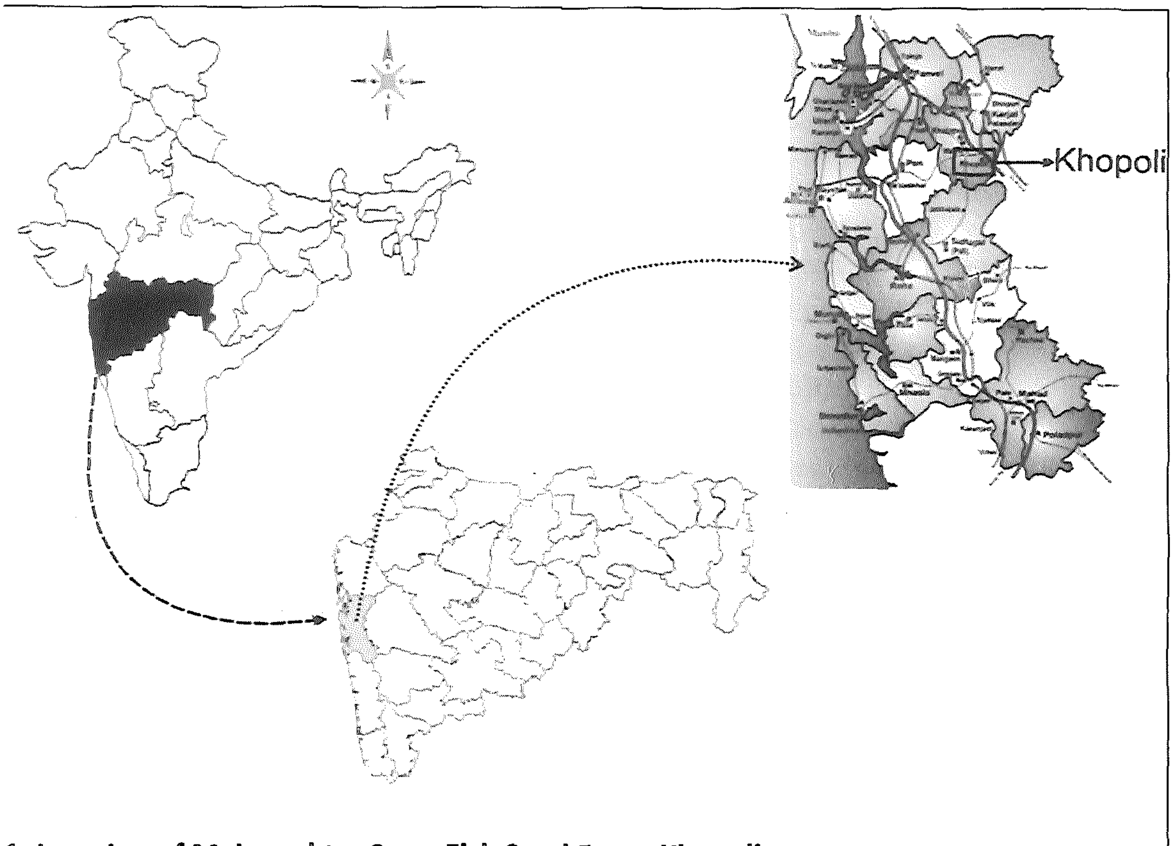

Fig. 1: Location of Maharashtra State Fish Seed Farm, Khopoli

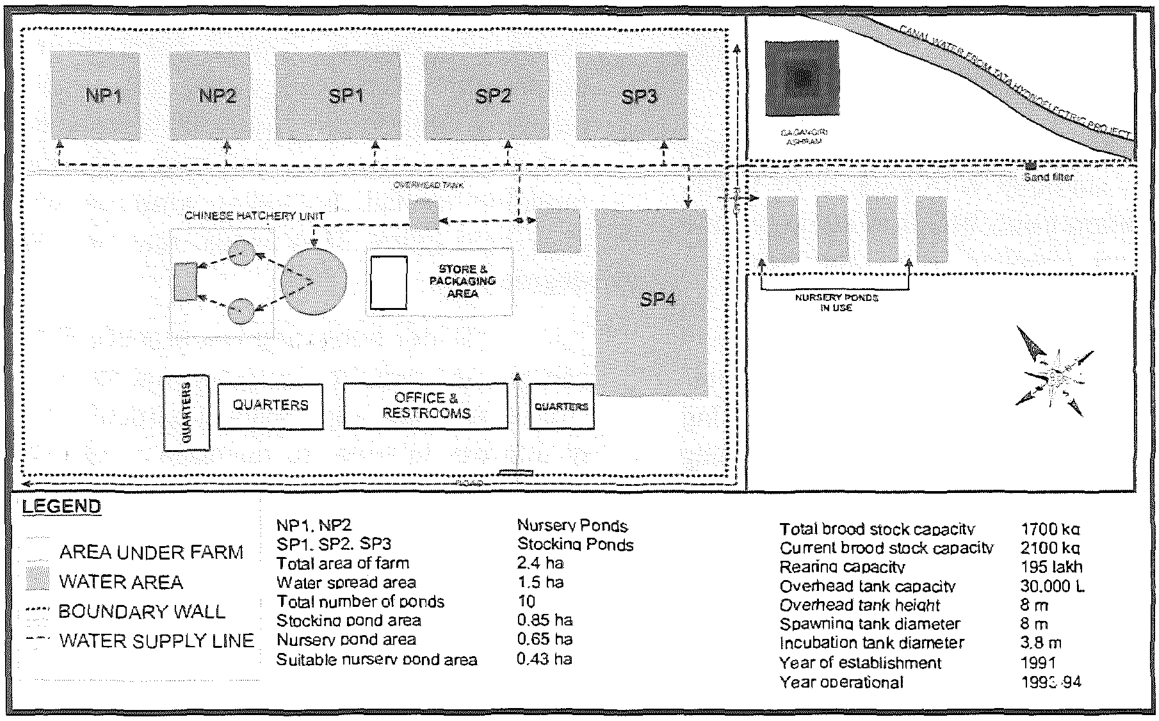

Fig. 2: Layout of the Maharashtra State Fish Seed Farm, Khopoli

Therefore, the water budget for a levee pond is

$P + I + RO = (S + E) + \Delta V$

Where P = precipitation; I = inflow from well, stream, or reservoir; RO = runoff; S = seepage; E = pond evaporation; and ΔV = change in storage volume. Variables are expressed in volume or depth of water. The water budget equation for a watershed pond is

$P + RO = (S + E + OF) \pm \Delta V$

Where OF = spillway overflow.

Inflow in to the pond was calculated based on the formula

$Q = V_m \times A_f$

Where Q= flow rate of water, V_m is the mean velocity of flow and A_f is the cross sectional area of the channel

$V_m = K_f \times V_s$

Where V_s is surface velocity measured with a float, and K_f is a velocity correction factor ranging from 0.65 to 0.8

The total inflow was calculated as

$I = Q \times t$

Where, I is the inflow, Q the flow rate and t is the time of flow

The rain fall measurement was carried out by the installation of a standard rain gauge (Davis Instruments Corporation, California, USA). The period of study did not experience any rain fall. Surface runoffs into the ponds were absent during the experimental period. The evapo-transpiration was computed by the weather station from the daily mean temperature, wind speed, relative humidity, and solar radiation using the Penman-Monteith equation as given below.

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$

Where R_n is the net radiation, G is the soil heat flux, $(e_s - e_a)$ represents the vapour pressure deficit of the air, P_a is the mean air density at constant pressure, c_p is the specific heat of the air, Δ represents the slope of the saturation vapour pressure temperature relationship, γ is the psychrometric constant, and r_s and r_a are the (bulk) surface and aerodynamic resistances.

Seepage can result in ponds that have soils which are too permeable to hold water. Although analysis of soil samples taken prior to pond construction can prevent usage of permeable soils; occasionally the site may be less than satisfactory and permeable soils must be used. In these cases, methods of reducing seepage should be considered. Seepage from a pond was estimated utilizing a variation of the water budget formula using the stage measurement method.

$P + RO = E + S + \Delta H$

Where ΔH = stage change, i.e., change in water level depth (Boyd, 1985).

Due to the difficulty in estimating runoff, it is best to determine seepage during dry periods, when inflow and outflow from the pond are essentially zero (Boyd, 1985). The estimation of seepage can then be simplified to the following formula:

$S = \Delta H - E$

Where, the variables are generally expressed in depth. Stage changes in the pond were made with a staff gauge that has been mounted in the pond. Reported seepage rates from ponds range from 1 mm to more than 25 mm per day (Parsons, 1949; Allred *et al.*, 1971;

Boyd, 1982; Boyd and Shelton, 1984).The seepage rate analysis was performed based on the above calculation. The total seepage loss was calculated based on the following equation

$$S = \frac{As_r}{1000}$$

Water discharge rate was measured using the flow rate measurement through a channel method as in inflow. Hatchery being a partly indoor system, the influence of rain, runoffs and other inputs were assumed to be nil Here, the water consumed was the water being pumped in to meet the water requirement during breeding as well as hatching period.

The total water consumed during one production cycle for the hatchery is calculated using the following equation

$$W_T=W_F+W_B+W_H+W_R+W_C$$

Where, W_T is the total water consumed, W_F is the water used for flushing, disinfection and filling, W_B is the water consumed during breeding, W_H is the water consumed during hatching, W_R is the water consumed during rearing and W_C is the water consumed during conditioning.

In nursery, the influence of climate is evident and the water consumed is calculated based on the hydrologic equation as described by Winter (1981) and Boyd (1985)

$$\text{Gains} = \text{losses} \pm \Delta\,\text{storage}$$

$$P + I + RO = (S + E) + \Delta V$$

The water quality parameters were studied over the period of experiment to assess the production conditions as well as its effect on breeding and water requirement. The breeding of common carp was carried out to produce spawn. The water budgeting studies were carried out both in the hatchery as well as the nursery system and the water required for the production of unit spawn and fry was calculated.

RESULTS AND DISCUSSION

Physico-chemical parameters of soil and water

The Physico-chemical parameters of water analyzed at regular intervals are shown in the Table 1 and that of soil in the Table 2.

Carp breeding

The breeding experiment was conducted from November 2007 to February, 2008. The single hatchery cycle was for a period of 11 days. The spawn was stocked in the nursery ponds and the production obtained is shown in the Table 3.

Table 1: Physico-chemical parameters of water samples

Sl. No.	Parameter	Values observed							
1.	Temperature (°C) a. Air	31.2	30.5	29.0	28.0	27.7	28.0	28.5	30.0
	b. Water	30.0	29.0	27.0	26.0	25.8	26.0	26.5	28.5
2.	pH	7.0	7.0	7.0	7.1	6.9	7.0	7.0	7.1
3.	Salinity (ppt)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
4.	Chloride (mgL^{-1})	27.00	27.00	28.00	28.00	28.00	28.00	29.00	29.00
5.	Alkalinity (mgL^{-1})	39.00	40.00	41.00	41.00	40.00	48.00	48.00	49.00
6.	Hardness (mgL^{-1})	44.00	44.00	45.00	45.00	45.00	48.00	49.00	50.00
7.	Dissolved Oxygen (mgL^{-1})	6.00	6.20	6.20	6.40	6.20	5.00	5.20	5.00
8.	Dissolved free CO_2 (MgL^{-1})	5.20	5.00	5.00	4.80	5.40	6.00	4.00	3.80
9.	Ammonia Nitrogen (NH_4^+-N:mgL^{-1})	0.25	0.25	0.23	0.22	0.27	0.25	0.24	0.25
10.	Nitrite Nitrogen (NO_2-N:mgL^{-1})	0.02	0.03	0.02	0.02	0.02	0.03	0.03	0.04
11.	Nitrate Nitrogen (NO_3-N:mgL^{-1})	0.19	0.20	0.21	0.22	0.20	0.22	0.23	0.24
12.	Phosphate (mgL^{-1})	0.04	0.05	0.05	0.05	0.04	0.05	0.05	0.05
13.	Total organic matter (mgL^{-1})	29.00	30.00	30.00	30.00	30.00	30.00	31.00	31.00

Table 2: Physico-Chemical parameters of soil samples

1.	Soil colour	Black	Black	Black	Black
2.	Soil pH	6.9	7.0	7.0	6.9
3.	Sand (%)	44	40	45	35
4.	Silt (%)	40	35	30	35
5.	Clay (%)	16	25	25	30
6.	Water retention capacity (%)	42	43	41	45
7.	Organic carbon (%)	1.16	1.27	1.15	1.22
8.	Organic matter (%)	2.00	2.18	1.98	2.10
9.	Total Nitrogen (mg/100g)	116.00	127.00	115.00	122.00
10.	Phosphorous (mg/100g)	6.00	6.20	6.00	6.10

Table 3: Spawn production obtained from Maharashtra state fish seed farm, Khopoli

Starting Date	Species	Breeding set (Kg)	Female		Male		Hormone Ovaprim (ml)	Fertilization (%)	Temperature (°C)		Spawn (Lakhs)
			Number	Weight (Kg)	Number	Weight (Kg)			Min	Max	
05/12/2007	*C. carpio*	15	12	15	18	15	10	60	18	32	1
13/12/2007	*C. carpio*	60	65	60	78	70	10	70	18	32	10
24/12/2007	*C. carpio*	90	80	90	95	100	20	65	18	33	17
02/01/2008	*C. carpio*	90	78	90	90	100	20	70	16	33	20
14/01/2008	*C. carpio*	92	80	92	115	110	22	80	15	32	30
23/01/2008	*C. carpio*	90	80	90	112	105	22	70	12	33	27
04/02/2008	*C. carpio*	90	85	90	110	98	30	65	14	35	27
18/02/2008	*C. carpio*	90	84	90	108	92	45	70	15	36	28
Total Spawn											160 Lakhs

Water budgeting

Water used in hatchery

Water used for flushing, sanitation and filling

Water used for flushing = 3,400 L

Water used for sanitizing = 11,340 L

Water used for reflushing = 3,400 L

Water used for filling= 8,505 L

Total water used= 26,645 L

So, total water used for pre-operational management = 26,645 L x 2 tanks = 53,290 L

Water used for breeding

Breeding time = 5 hours

Flow rate = 1.4 L/s

Total water used = flow rate x time = 25,200 L
Total water used in 2 tanks = 50,400 L

Water used for hatching

Hatching time = 70 hours

Flow rate= 1.4 L/s

Total water used = flow rate x time = 3,52,800 L
Total water used in 2 tanks = 7,05,600 L

Water used for hatchery rearing

Rearing period = 24 hours

Flow rate = 1.4 L/s

Total water used = flow rate x time = 1,20,960 L
Total water used in 2 tanks = 2,41,920 L

Water used for conditioning

Conditioning period=48 hours

Shower rate= 0.2 L/s

Total water used= flow rate x time = 34,560 L

Water used for initial filling = 2,355 L Total water used in one tank = 36,915 L

Total water used in 2 tanks = 73,830 L

Total water used in hatchery for a single cycle

Total water used in hatchery = water used for flushing, disinfection and filling + water used for breeding + water used for hatching + water used for hatchery rearing +water used for conditioning = 11,25,040 L

Water used in nursery

The total number of days of operation was 80 days. The spawn was raised to fry of 22 to 25 mm in 15-16 days.

Storage volume

The storage volume of the pond was measured as 13,50,000 L at 75 cm average depth.

Inflow

The inflow rate was calculated as 22 L/s. The initial filling was 13,46,400 L followed by regulated filling @ 12 L/s. The total inflow therefore totaled 31,60,800 L.

Runoff

The runoff was assumed to be zero as there were no rains.

Precipitation

The precipitation in the experimental site was zero for the period.

Discharge

Water was discharged after the entire operation. The total discharge was 13,53,600 L.

Seepage

Seepage rate was measured by the stage measurement method and data collected revealed the average seepage rate as 8 mm/day or 14,400 L/day. The total seepage loss was found to be 11,52,540 L.

Evaporation

Average evaporation rate was found to be 4.55 mm/day or 8,190 L/day. The total evaporation was found to be 6,54,660 L.

Total gain

The total gain was therefore 31,60,800 L.

Total loss

The total loss was found out as 31,60,800 L.

Therefore, Gains = losses ± A storage

Water used per cycle

Water used in hatchery = 11,25,040 L x 8 cycles = 90,00,320 L

Total water consumed in nursery= 31,60,800 L.

Therefore, the total water consumed= 1,21,61,120 L.

Total water expense per unit spawn produced in hatchery

Total spawn production= 160 lakhs

Total water used in hatchery = 90,00,320 L

Water expense = total water used /total spawn production = 0.56 L/spawn

Total water expense per unit fry produced from nursery pond

Average fry production= 40% of total spawn production = 25,00,000

Total water used = 1,21,61,120 L.

Water expended per fry = 4.86 L/fry

CONCLUSION

The total spawn production was 160 lakhs in a total of eight breeding cycles (Table 3). The maximum production from a single cycle was 30 lakhs. During the experiment, a trial was conducted to minimize the water-use by employing showers for water inflow. The carps were allowed to breed in 2500 m^3 FRP tanks with shower delivering water at the rate of 12 L/min. This trial however resulted in increase in the breeding rate and the quantity of spawn produced. The fertilization rate varied between 60-80% which might have been due to the influence of physico-chemical parameters of water as well as the intrinsic factors of fish.

Water use in the hatchery was primarily in the pre-operational management followed by the breeding steps including breeding, hatching, hatchery rearing and conditioning. The total water used in a single operation cycle was estimated to be 11,25,040 L. Out of the total water consumed, 4.74% water was used in the pre-operational management steps, 4.48% was consumed during breeding, 62.72% was consumed in the hatching phase, 21.50% was used for hatchery rearing and 6.56% was consumed during conditioning. The breeding step can be modified by employing showers which will not only reduce water usage but also provide more aeration as well as prevent clumping of the plastic strands resulting in damaged eggs and poor fertilization rate.

The spawn obtained from the hatchery was stocked in the nursery pond of 1800 m^2 area. The water budgeting study was carried out by estimating the water gains and water losses. The total storage volume of the pond was calculated as 13,50,000 L and the water gain was primarily the regulated inflow coming through the irrigation channel. The flow rate was estimated and the initial filling was calculated as 31,60,800 L. The water losses from the pond were mainly due to evaporation and seepage. The total evaporation was found to be 6,54,660 L. The average seepage rate was calculated from the stage measurement studies as 8 mm day^{-1} and the total seepage was measured as 11,52,540 L. The water discharge from the pond was found to be 31,60,800 L. The total quantum of water used in the nursery rearing was therefore 31,60,800 L. Out of the total water gained and lost, the regulated inflow forms 57.40% of gains while evaporation, seepage and discharge contributed 20.71%, 36.46% and 42.82% respectively.

The total water expended for the entire operation was measured as 1,21,61,120 L. Water expense occurred to produce a single spawn in the hatchery system was calculated and found to be 0.56 L, while the water expended to produce one fry was calculated as 4.86 L.

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