Effect of Recirculation Aquaculture System (RAS) on Fish Farming and Vegetables

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Abstract

High density fish farming with Recirculation Aquaculture System (RAS) is one of the advanced technique in fish farming with add-on benefits like agriculture production, less capital intensive and water re-use (recirculation) features as compare to other conventional method like pound or tank based indoor systems. The RAS farming experiment was conducted with tilapia fish and leafy vegetables on bio-bed. The RAS system was consist of fish tank with HDPE (sipolin) plastic paper lining, bio-bed (bio-filter) and water circulation system. During trail it was found that, the bio-bed was effectively established by water circulation system and NH_3 levels in were maintained below 1 PPM in fish tank. The high FCR was mainly fluctuating dissolved oxygen levels during night time, accumulation of particulate (bottom sludge) in fish tank and low quality fish feed formulation. The higher fish mortality was due to excessive handling of fished during weight gain recoding. Even though at first impression it seems trial has recorded high FCR and negative economic value proportion, but if the required system corrections are successfully achieved, the RAS defiantly has a potential of large scale replication in selected agro-climatic region.

Keywords: Recirculation Aquaculture System (RAS), Fish Farming, Vegetables, Tilapia.

Introduction

India stands 2nd in word fish production with annual fish production of about 9.58 million tonnes (2014)[1]. Fish production of country has doubled in past 10 Yrs, which is with direct co-relation with net demand and consumption of fish meat. Increased production & market demand for fish meat is mainly due to development of advanced technology in fish production, catching and increased awareness on benefits of fish meat. Increase in net demand for fish meat also creates extra pressure on natural fish habitats (sea/ rivers) resulting in over harvesting, less production etc. In India around 64 % fish is produced from inland fish farming with annual production of 6.14 million tonnes in 2014. With increased demand for fish meat, scope for inland fish farming is also increasing. It is estimated that only about 40 % of the available area of 2.36 million hectares of ponds and tanks has been put to use and an immense scope for expansion of area exists under freshwater aquaculture [2]. At the same time community and individual (on-farm) water storage units like small check-dams, plastic paper-lined farm tanks are increasing rapidly. In past 5 years nearly 35500 small farm tanks were built in only Maharashtra state with collective water storage of 1775 core lit [3]. These water bodies can be used easily for fresh water fish farming by adopting advanced technologies of this field.

With increasing man made water bodies like small check-dams, farm tanks etc freshwater aquaculture can be profitable venture to farmers as similar to poultry or dairy farming. Conventional know-how for dairy, poultry farming is available for farmers. But techno-economical know-how on inland fish farming practices, like new improved fish breed, equipment's, high density fish farming etc are still not available with farmers in & around western Maharashtra state of India. A demo unit will encourage nearby farmers to learn and adopt fresh water aquaculture as one of additional income source. Hence we referred to literature on small scale fresh-water fish farming and decided to establish demo medal capable of producing handsome income to farmers.

High density fish farming with Recirculation Aquaculture System (RAS) is one of the advanced technic in fish farming with add-on benefits like agriculture production, less capital intensive and water re-use (recirculation) features as compare to other conventional method like pound or tank based indoor systems. Tilapia (Tilapia Sparmanii) is also most preferable fish for high density fish farming due to its wide adoptive nature to change climatic conditions and high Feed Conversion Ratio (FCR). RAS system is also has benefit of converting it into Aquaponics like integrated farming system. A demo unit of RAS system was established at Vigyan ashram (www.vigyanashram.com), Pabal, Pune district of Maharashtra state. This paper gives overview on learning gathered from this experimental demo unit and also put light on future scope of experimentation and adoption of this technology.

Material and Methods

The said demo unit of RAS system was established with system component and specification as -

Fish Tank

A fish tank of about 54,500 lit volume and 1 M standing water depth was constructed by simply digging soil in to rectangular shape. Tank was lined with back colour plastic paper (HDPE 500 micron) polyethylene sheet to stop any percolation losses. This tank was also covered with green shed net film (50 % shed) from top to avoid external dirt material / leaves etc. contamination. The shed-net cover avoids external contamination and allows partial sun-line to percolate in water necessary for phytoplankton's growth. A water level indicator fixed at centre of tank to estimate daily water uses by system.

Bio Bed Preparation

Water from fish tank is circulated through bio-bed for nitrification. Bio-bed prepared by and mixture of sand, gravel and bricks. The bio-bed was 12.45 M long, 4.50 M wide and 0.30 M height was prepared using 200 micron HDPE (sipoline) sheet and layers of red soil bricks , gravels (Stone mortar)and sand at 2:1:1 proportion. A gentle slope provided to bio-bed so as to flow water back to fish tank by gravity. The water is circulated through bio-bed by using micro-sprinkler and drip irrigation system. Bed was planted with spinach and tomato seeds without any soil media.

Water Circulation System

Water from fish tank was circulated to bio-bed through PVC piping system. Fish tank was fixed with 1.5 HP motor open well motor having discharge rate of 12000 LPH. Water passed through screen filter to remove physical impurities to bio-bed which flew back to fish tank by gravity. Flow rate is adjusted in such a way that around 80 % water (i.e. 7000 to 10000 LPH) flows through bio-bed, whereas remaining 20 % fall back to fish tank through by-pass value. The water passing through by-pass value was free-flowed to fish tank in form of waterfall so as to increase water dissolved oxygen level by water flow. The pump was operated for 5 minutes per half hour (30 minutes) by fixing automated on-off switch, so as to maintain desire water flow rate in system and maintain optimum DO (Dissolved Oxygen) and Ammonia (NH_3) levels. Tank bottom sludge (particulate accumulation) was removed by gravity syphon suction pipe.

Water Quality Parameters

Fish tank water was periodically analysed for Dissolved Oxygen (DO) and Ammonia (NH_3) levels. DO (Dissolved oxygen) levels measured by compact aquarium testing kits periodically (make Prerna Lab, Pune) and digital DO meter (Lutron Electronic Enterprise -make). Initially DO levels were measured at higher frequency (2-3 times per day) to adjust water circulation frequency and when system was tuned-up weekly recording were taken for DO. DO levels was maintained around 5 to 7 PPM during day time by adjusting water circulation time, but at the later stage of experiment it was found that DO levels in night use to drop below 1 PPM , creating stress on fish. This was mainly due to respiration activities by phytoplanktons.

Similarly Ammonia (NH_3) accumulation levels were also analysed by using colour-metric scale developed by using Thymol colour creating reactions [4].

Fish Feed and Feeding Frequency

Fish tank loaded with 8.5 kg tilapia fish (around 400 fingerlings with average weight of12.4 Gm/ fish). Fish were fed with frequency of 6 time / day (3 Hr interval between to feeding) during day time. Feeding rate maintained from 7 to 5 % of body weight during different growth stages. During initial growth stages fish fed with shrimp feed with 48 % protein(???) whereas later stages fish fed with self-made fish feed with combination of ground nut oil cake (GOC) and rice bran (1:2) which having protein value about 40.6 % and 9.9 % respectively.

Results and Discussion

(RAS) Experiment

The said experiment was carried out for 12 weeks during January to April 2015 at Vigyan ashram, Pabal (Pune, Maharashtra state). During experiment period fish growth, bio-mass production in bio-bed, water quality parameters were regularly monitored to at specific interval and results are analysed based on fish weight gain and economical outcome. Following are the important observations and finding of experiment as –

Water Circulation System and Quality Parameters

Water from fish tank is circulated in system (bio-bed of 16.80 M^3) so as to maintain water parameters mainly dissolved oxygen (DO) and Ammonia (NH_3) for suitable for optimum fish growth. Water circulation is maintained through open well 1.5 Hp water pump operated at pre-set frequency through automated timer controller. Water is circulated through bio-bed through micro sprinkler system after passing through screen-filter. The flow rate of water circulation through bio-deb is maintained at 7000 to 10000 LPH. Water quality parameters like water Dissolved oxygen (DO), Ammonia (NH_3) are maintained at desire level through water circulation system. Fish tank particulate accumulations were removed by syphoned drain line on daily basis. Details of system design are given in system design details.

Periodical readings were taken for water quality parameters and fish growth. Following are important observations –

NH3 (Ammonia)

Throughout trial NH_3 levels was maintained below 1 PPM. Ammonia (NH3) level was tested by using color-metric scale developed by using Thymol color creating reaction (Loan K D et al,2013). During analysis this was found that water from bio-bed has NH_3 around 0.25 PPM whereas NH_3 in fish tank is in 0.5 to 1.0 PPM. This means bio-filtration system was successfully achieve through sufficient water circulation system in experiment.

Dissolved Oxygen (DO)

During trial period Dissolved oxygen levels in fish tank was maintained in safe zone of 5 PPM during day time. But during night time sudden drop was observed at later stage of experiment. This sudden drop could be due to respiration activities by Phytoplankton's and particulate accumulation in tank. During day time through water circulation system DO was maintained DO level around 5 – 7, but in night times it DO were dropping to below 1 PPM producing stress on fish. As tilapia is air breathing fish, surface breathing fish was frequently observed during early morning hour.

Bio-mass Growth

Bio-bed made up of mixture on bricks, stone mortar and bricks was used to cultivated spinach and tomato crops. Effective root density of bio-bed was around 16 M^3 during trial period. During 90 days of trial, total production of Spinach, Tomato fruits & plant and weeds were measured as net bio-mass production from bio-bed. Total of 164.56 Kg of biomass was harvested from bio-bed (Spinach 24.76 Kg- + Tomato's- 12.22 Kg + Weeds- 149.18 Kg). This biomass was produced purely on soil-less media and without any supplemented growth nutrients. This shows availability of various growth nutrients in fish water and success nitrification process while recycling ammonia from fish tank.

Fish Feeding, Weight Gain (Growth) and FCR-

Fish were fed based on average body weight. shows fish feeding rate maintained as per growth phases during experiment. Fish are fed with, rice bran + ground nut cake (2:1 ratio) feed formulation having approximately 32 % protein content. Feeding rate is maintained between 2 to 7% of body weight. Fish are fed in only day time with feeding frequency 3-4Hr interval between successive feeding.

Substantial amount of fish mortality observed during trial. Overall fish mortality was around 50 % at end of trial. This mortality could be due to handling injury during sampling, fluctuating DO level and same of un-recorded factors like bird, disease attack etc.

Fish growth is recorded at pre-defined time interval by random sampling and weighing of approximately 10 % of total fish density. The table 2 shows, growth data for fish growth and feed conversion ratio (FCR) achieved during experiment. The fish growth was recoded by random sampling at specified interval and average weight of fish is recorded. From table it's seen that-

Experiment started with, phase-I which ran from 20th January to 22 February for 30 days. During this early growth phase tilapia was grown up to 25.72 Gm from initial weight 12.4 Gm recording average weight gain of 13.32 Gm with 2.3 FCR. During this phase fish were fed with rate of 7 % of body weight and with combination of Shrimp feed (purchased from market with 40 % protein) and home-made (rice bran+ ground-nut oil cake with 32 % protein).

In phase-II, which ran for next 15 days, average weight gain of 8.85 Gm was recorded per fish with FCR of 2.1. During this phase, feeding rate was maintained at 6 % of average body weight.

During next 15 day of phase-III, average weight gain of 14.18 Gm was recorded per fish with 4.6 FCR. At end of phase-III substantial fish mortality close to 25 % were observed. This mortality was mainly due to fish handling during harvesting (sampling). During this phase, fish were fed with home-made fish feed with feeding rate of 5% of average body weight.

Phase IV, which ran for next 15 days of experiment, fish grown with 6.3 Gm of average weight gain and FCR of 5.8. But during last phase of experiment, which ran from 9th April to 27th April, we observed negative FCR due to high mortality which was not recorded during experiment. The total mortality recorded at end of experiment was close to 50 %. This un-recorded fish mortality might be due to bird pest attach, handling losses or recording error.

During experiment, FCR was continuously grown from 2.3 of initial phase to 5.8 at later phase. The total weight load of fish tank was grown up to 14600 Gm with fish density of 2.89 Kg/ M^3. Individual fish grown 61.57 Gm from initial weight 12.4 Gm. Overall FCR recorded during experiment were 5.6 as compare to expected FCR of 1.5.

Probable reasons for high FCR and mortality rate in experiment, were as follow –

Accumulation of particulates (sludge) at bottom of fish tank

Fluctuating water dissolved oxygen levels especially during night time to respiration activities by Phytoplankton's.

Low FCR of feed used during trial. (During initial stage (phase-I) of trial shrimp feed with 48% protein was used, which in later stages replaced with Rice bran + GOC feed)

Higher fish mortality during fish weight gain recoding due to excessive handling.

Economics

Total fish mass harvested was 14600 GM from initial input of 400 sampling with FCR of 5.6. The rate of tilapia in local market is around 60 Rs/ Kg. Hence value of fish mass produced during 90 days of trial was Rs.876.00.

Total vegetable outputs received from bio-bed were 24.76 kg of spinach, 12.22 Kg of fresh tomato and 149.18 kg of weeds. In local this produce would fetch 15 Rs/ Kg for Spinach, Rs.10 / Kg for Tomato's and Rs.3/Kg for weed as animal feed. The total value of this bio-bed production was Rs.941.00.

During experiment value of total inputs (except electricity and labour cost) as fish feed was of Rs.2442.7 (81.20 Kg of fish food was used out of which 12.5 Kg shrimp food with Rs.80 /Kg and remaining 68.7 Kg with cost of 21 Rs/Kg).

So by this experiment resulted in to net loss of Rs. 631.7 during 90 days of trial.

Summery and Conclusion

The said RAS farming experiment was conducted for 12 weeks with tilapia fish and leafy vegetables on bio-bed. The RAS system was consist of fish tank with HDPE (sipolin) plastic paper lining, bio-bed (bio-filter) and water circulation system. During experiment it was found that, the bio-bed was effectively established by water circulation system and NH_3 levels in were maintained below 1 PPM in fish tank. Similarly dissolved oxygen levels in water were maintained above 5 PPM during day time, but sudden DO drop observed during night time due to respiration activity by Phytoplankton's.

The fish growth and FCR were not very satisfactory during experiment with high fish mortality. The average recorded FCR during 12 weeks experiment was 5.6 than expected FCR of 1.5. The high FCR was mainly fluctuating dissolved oxygen levels during night time, accumulation of particulate (bottom sludge) in fish tank and low quality fish feed formulation. The higher fish mortality was due to excessive handling of fished during weight gain recoding. The experiment has also showed, need of system modifications particularly fish tank bottom sludge continuous removal system, improvement in fish feed formulation, controlling phytoplankton's growth etc. Even though at first impression it seems trial has recorded high FCR and negative economic value proportion, but if the required system corrections are successfully achieved, the RAS defiantly has a potential of large scale replication in selected agro-climatic region.

Annexure

Table - 1
Fish Feeding Rate During Trial

Feeding Period	Average wt of Fish (Gm)	Total Wt load (gm)	Feeding rate maintained (% body weight)	Calculated fish feed (Gm / Day)	Actual Feeding rate maintained (Gm / Day)
1st & 4th week (Phase I)	21.15	13895.4	7	972.7	700
5th to 7th week (Phase II)	34.73	18878.4	6	1132.7	700
8th & 9th week (Phase III)	53.93	21248.60	5	1062.4	850
10th & 11th Week (Phase IV)	70.82	23024.0	5	1151.2	1000
12th week (Phase V)	21.15	27941	5	1397.1	1000

Table - 2
Fish Weight Gain Record and Feed Conversion Ratio (FCR)

Recording Phase	Initial Average fish weight per fish	Number of fish	Total Fish weight load	Total feeding (Gm)	Feed per fish / Gm	Gross wt gain recorded / fish (Gm)	Total weight load of fish tank (Gm)	Net weight gain of tank (Gm)	FCR achieved
1st & 4th week (Phase I)	21.15	400	8460	21000	52.5	34.73	13895.4	9107.7	2.3
5th to 7th week (Phase II)	34.73	350	13895.4	10500	30	53.93	18878.4	4995.9	2.1
8th & 9th week (Phase III)	53.93	300	18878.4	12750	42.5	70.82	21248.60	2788.50	4.6
10th & 11th Week (Phase IV)	70.82	300	21248.6	15000	50	115.12	23024.0	2588.2	5.8
12th week (Phase V)	115.12	200	23024	7000	35	139.7	27941	4917.0	1.4

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