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Profitable Production of Fish (*Pangasius sutchi*) and Vegetables without any Chemical Fertilizers and Pesticides in a Recirculating Gravel Media based Aquaponic System

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ABSTRACT

Unlike traditional farming, in an aquaponic system, the waste created by the fish provides necessary nutrients for the plants while nutrient uptake by the plants improves the water quality for the fish. Study was carried out in an Aquaponic unit of Jalandhar District, Punjab. There are four fish rearing tanks which are cemented from base and sides. Tanks are lined from base and sides with the help of high density polyethylene sheet. There were nine vegetable beds next to the fish tanks and a sump. Vegetable beds are embedded with light weight expanded clay aggregates and it is acting as biological and mechanical filter for the system. The total plant growing area is 2,193.75 square feet and total fish-rearing area is 262.29 square feet. Total system is under a greenhouse. No chemical fertilizers, pesticides or growth regulators are used. Benefit cost ratio of the system from second year is 1.33. From the observations it is concluded that with proper choices of plants, fish, proper consideration of air temperature, FCR and component ratio, recirculating gravel media based aquaponic system can operate successfully and may serve as a complementary method of intensive production system under indoor condition for Indian farmers.

Keywords Gravel media based aquaponics, Hydroponic, *Pangasius sutchi*, vegetables, Component ratio.

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INTRODUCTION

Aquaponic systems (Fig. 1) are recirculating aquaculture systems that incorporate the production of plants without soil. The waste created by the fish provides necessary nutrients for the plants while nutrient uptake by the plants improves the water quality for the fish. Recirculating systems are designed to raise large quantities of fish in relatively small volumes of water by treating the water to remove toxic waste products and then reusing it. Unlike traditional farming, in an aquaponic system there is a constant flow of water and more constant supply of nutrients for the plants.

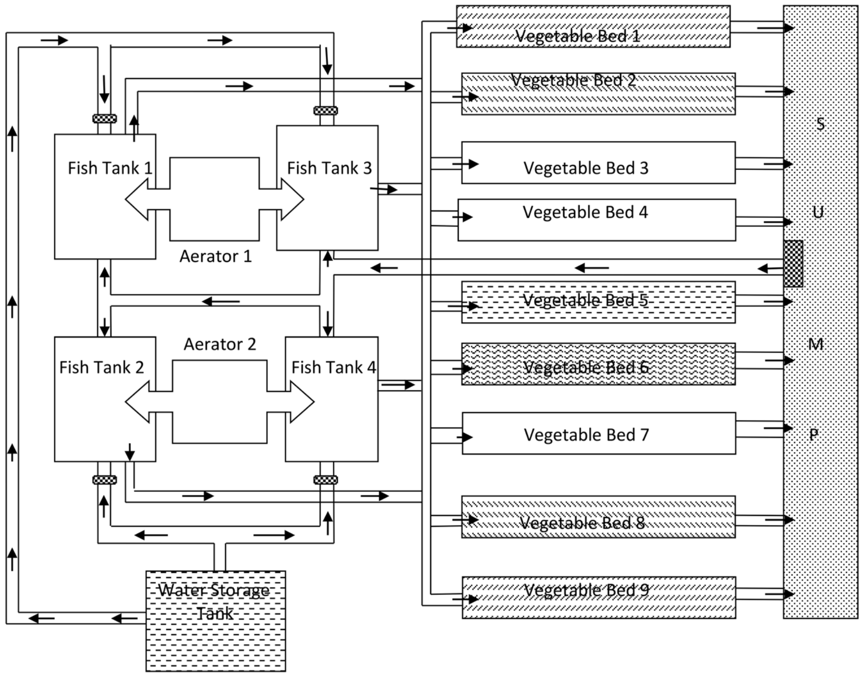

Fig. 1. Layout of the aquaponic unit.

High surface area provides more space for the growth of nitrifying bacteria (Driver and Rinehart 2010, Blidariu and Grozea 2011). Grow bed material choices require careful analysis of the surface area, price and maintainability considerations. The stocking density of 1.4 kg/m^3 of Koi carp, *Cyprinus carpio* var *Koi* along with spinach, *Beta vulgaris* var *bengalensis* at a density of 28 m^2 was optimum in aquaponics system. Nutrient removal and water quality was found better in aquaponics treatment than the treatment without plants (Hussain *et al*. 2014). Optimum fish to plant component ratio was 1:2 in the production of common carp and mint in aquaponics system (Shete *et al.* 2015). In Nile tilapia and catfish polyculture, several water quality parameters improved, such as dissolved oxygen, ammonia and nitrate. Meanwhile, Orthophosphate tends to be similar both in aquaponics system and control (Hasan *et al*. 2017). Commercial production in aquaponic system seems a very appropriate for aquaculture and agriculture improvement (Mashaii *et al*. 2021). Population of India and the world is increasing at exponential rate, area of cultivable land and volume of water is decreasing day by day. In this context, aquaponic can provide a suitable complementary high density culture method both for fish and vegetables. Also the production of crops and fish in India is highly dependent on rainfall. When the rainfall is low, the production of food as well as fish is affected adversely. Water and soil are two important natural resources, the scarcity of which is going to be acute in the coming years (Datta 2015, Datta *et al*. 2018). Conventional agriculture needs to increase its independence from chemical fertilizers and pesticides, which have a serious impact on the natural ecosystem (Kocira *et al*. 2020). All these points have drawn the attention to take the present work.

MATERIALS AND METHODS

The study was carried out in an Aquaponic unit at village Lambra, District Jalandhar, Punjab during October 2018 to March 2019.

Fish rearing tanks

There are four fish rearing tanks which are cemented from base and sides. The dimensions are 4 x 5 x 1.5

Fig. 2. Pipes pumping water from fish tanks to the vegetable beds.

meters i.e. water volume is 30,000 L/tank. The tanks are lined from base and sides with the help of high quality, high density, UV resistant polyethylene sheet of thickness 500 GSM and weighing 40 to 50 kg as per 100 sq meters sheet per tank. The water is from tube well and motor is operated on every 10 days interval to add 4000 L of freshwater in four tanks, according to the demand. No degassing unit and clarifier are used in this system, which is a modification over the primitive model of aquaponics. The water from the fish tanks (Fig. 2) is continuously being circulated within the vegetable beds via the PVC pipelines (110 mm diameter or 4 inches) arranged systematically. The water from the fish tanks is pumped @ 6 kg/cm^2 and subsequently to the vegetable beds with pipes of 63 mm diameter, 4 kg/cm^2. Nine outlet pipes are there to add water in nine trenches. The water passes from a mesh inside the pipe to eliminate any solid waste acting as mechanical filter and prevent fish from coming out in pipes.

Aerators

Two aerators of 80 watt power each (with 20 outlets each) are used for aeration. Each tank has got ten aerator tubes to ensure sufficient aeration throughout the day. The aerators have the output of 80 L per h.

Stocking, feeding and harvesting

5000 fingerlings of *Pangasius sutchi* are stocked per fish tank. So, a total of around 20,000 fish fingerlings are stocked in four tanks. They are fed twice a day at the rate of 2.5 to 3% of their body weight. The maximum biomass of fish a system can support without restricting fish growth is called critical standing crop. Operating a system near its critical standing crop uses space efficiently, maximizes production and reduces variation in the daily feed input to the system, an important factor in sizing the hydroponic component. In this system, once the stocking is done, the fish is fed properly twice a day and harvested completely after 6 months. No partial harvesting or stock splitting is carried out. In general, the critical standing crop in aquaponic systems should not exceed 0.50 pound/gallon (226.8 g/3.78 L). This density will promote fast growth and efficient feed conversion and reduce crowding stress that may lead to disease outbreaks. Therefore, the goal of the design process is to reduce labor wherever possible and make operations as simple as possible. The commercial feed (Growfin of Growl) was used. To maintain pH, liming was done occasionally.

Solid removal

Main outlet pipes taking out water from the rearing tanks were lined inside by a micro screening mesh to allow the passage of solids and particulate matter of specific size in the vegetable beds thereby retaining the fishes in the tank. This leads to mechanical filtration in first step. Secondly, the clay aggregates forming the gravel bed for vegetables further act as filters.

Vegetable beds

There were nine vegetable trenches or beds next to the fish tanks. The dimension of each trench was 3.25 feet x 75 feet approx and 9 inches deep. The total area of the greenhouse unit including tanks, vegetable beds and pathways was 18 x 40 meters i.e. 720 m^2. The trenches were lined entirely with Polyethylene sheet of thickness 500 GSM and without any soil bed. The trenches were packed with stone particles of various sizes, which form the gravel bed for the growing of plants. The bed was embedded with light weight expanded clay aggregates of sizes 18 to 25 mm in vertical system and it acting as biological and mechanic filter for the system. The weight of gravel requires strong support structures. It was subject to clogging with suspended solids, microbial growth and the roots that remain after harvest. The resulting reduction in water circulation, together with the decomposition of organic matter, leads to the formation of anaerobic zones that impair or kill plant roots. The small, plastic tubes used to irrigate gravel. 90 cm diameter pipes were used for vertical system plantings. The PVC pipes were holed and small pockets were filled with pots having clay aggregates and 16 mm pipes were used for drip irrigation in addition to 4 mm pipes for drop wise flow. The PVC pipes were holed up in a systematic manner and joined to form vertical stands (Fig. 3) which hold small baskets embedded with clay aggregates, planted with seedlings and were used for vegetable cultivation with water from fish tanks. The outlet from aerator was added in the stand to create turbulence in water and to supply proper aeration to the system. The water flow in the vegetable beds was regulated by knob on the pipes. The vegetables planted in the trenches were Spinach (*Spinacea oleracea*), Chinese lettuce (*Lactuca sativa* var. *angustana*), Leaf lettuce (*Lactuca sativa*), Iceberg lettuce (*Lactuca sativa* var. *Capitata*), Capsicum (*Capsicum annuum*), Cherry tomato (*Solanum lycopersicum*), Beet root (*Beta vulgaris*), Broccoli (*Brassica oleracea*), Strawberry (*Fragaria ananassa*), Mint (*Mentha*), Coriander (*Coriandrum sativum*), Parsely (*Petroselinum crispum*), Orange Bell pepper (*Capsicum annuum*), China cabbage (*Brassica rapa*).

Biofilteration

A major concern in aquaponic systems is the removal of ammonia, a metabolic waste product excreted through the gills of fish. Nitrifying bacteria (*Nitrosomonas* and *Nitrobacter*) grow as a film (referred to as biofilm) on the large surface areas of clay aggregates or they adhere to organic particles. Biofilters perform optimally at a temperature range of 77 to 86^0F, a pH range of 7.0 to 9.0, saturated DO, low BOD (< 20 mg/L) and total alkalinity of 100 mg/L or more.

Fig. 3. Vertical stands showing plantation and arrangements of water pipes.

Nitrification is a reaction, consuming 7.14 units of alkalinity per unit of ammonia oxidised. Therefore, an alkaline base must be added frequently, depending on feeding rate, to maintain relatively stable pH value. Nitrification efficiency is affected by pH. The optimum pH range for nitrification is 7.0 to 9.0. The pH of a solution affects the solubility of nutrients, especially trace metals. Essential nutrients such as iron, manganese, copper, zinc and boron are less available to plants at a pH higher than 7.0, while the solubility of phosphorus, calcium, magnesium and molybdenum sharply decreases at a pH lower than 6.0. Compromise between nitrification and nutrient availability is reached in aquaponic systems by maintaining pH close to 7.0. Nitrification is most efficient when water is saturated with dissolved oxygen level near 80% saturation (6 to 7 mg/L). Media such as clay aggregates/stones provide sufficient substrate for nitrifying bacteria and generally serve as the sole biofilter.

Sump

Water flows by gravity from vegetable beds to a sump (Figs 4, 5), which is the lowest point in the system. The sump contains a pump or pump inlet that returns the treated culture water to the rearing tanks. There is only one pump to circulate water in this aquaponic system. The sump is the only tank in the system where the water level decreases as a result of overall water loss from evaporation, transpiration, sludge removal and splashing. An electrical or mechanical valve is used to automatically add replacement water from a storage reservoir. Municipal water is not used unless it is de-chlorinated. Surface water is avoided because it may contain disease organisms. A water meter is used to record additions. Unusually high water consumption indicates a leak. The water from the vegetable bed drains in a pit of dimension 12 x 2 x 1 meters (24 m^3) at the last end of the system. A pump of 320 watts is installed, which pumps the water into a central pipeline of 110 mm diameter, 6 kg/cm^2, from where the water is again poured in the four tanks by 50 mm diameter PVC pipes. The water gets collected in the terminal pit and the suspended particles are allowed to settle for some time and upper water keeps on circulating back to the system.

Fig. 4. Light weight expanded clay aggregates.

Fig. 5. Sump showing water drained from vegetable beds.

The pathways in between the vegetable beds are utilized by adding nursery beds to the area and Swiss chard (Kashmiri Palak) seeds are planted in it. The nursery beds are filled with coco peat as the growing media. The pots have small clay pebbles as growing media and beet root have been planted in it.

Component ratios

Another key design criterion is the ratio between the fish rearing units and hydroponic components. The key is the ratio of daily feed input to plant growing area. If the ratio of daily feeding rate to plants is too high, nutrient salts will accumulate rapidly and may reach phytotoxic levels. Higher water exchange rates will be required to prevent excessive nutrient buildup. If the ratio of daily feeding rate to plants is too low, plants will develop nutrient deficiencies and need more nutrient supplementation. Fortunately, hydroponic plants grow well over a wide range of nutrient concentrations. In this aquaponic system, the surface area of the hydroponic component is large compared to the surface area of the fish-rearing tank. The unit has a ratio of 8.36:1. The total plant growing area is 2,193.75 square feet and the total fish-rearing surface area is 262.29 square feet.

Plant growth requirements

For maximum growth, plants in aquaponic systems require 16 essential nutrients. Three of the macronutrients—carbon (C), oxygen (O) and hydrogen (H) are supplied by water (H_2O) and carbon dioxide gas (CO_2). The remaining nutrients that are absorbed from the culture water are nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P) and sulfur (S), chloride (Cl), iron (Fe), manganese (Mn), boron (B), zinc (Zn), copper (Cu) and molybdenum (Mo). Maintaining high dissolved oxygen level in the culture water is extremely important for optimal plant growth, especially in aquaponic systems with high organic load. Hydroponic plants are subjected to intense root respiration and draw large amounts of oxygen from the surrounding water. If dissolved oxygen is deficient, root respiration decreases. This reduces water absorption, decreases nutrient uptake and causes the loss of cell tissue from roots. Root respiration, root growth and transpiration are greatest at saturated DO levels (Rakocy *et al.* 2017).

RESULTS AND DISCUSSION

Water quality parameters

Different chemical parameters of water e.g. pH, dissolved oxygen, alkalinity, hardness, ammonia, nitrite, nitrate of the aquaponic system were analyzed as per standard methods (APHA 2012) and are presented in Table 1.

Table 1. Chemical parameters of water at the start and after 3 and 6 months.

Parameters	Initial reading	Reading after 3 months	Reading after 6 months
Temperature (^{0} C)	24.90	17.00	27.00
pH	7.50	7.80	8.00
DO (mg/L)	7.00	8.50	10.00
Alkalinity (mg/L)	230.00	170.00	115.00
Hardness (mg/L)	270.00	280.00	295.00
Ammonia (mg/L)	0.30	0.50	0. 40
Nitrite (mg/L)	0.05	0.15	0.08
Nitrate (mg/L)	15.00	24.00	32.00

Temperature: Average ambient temperature during the experimental period was minimum 17.0 ± 1.00 and maximum 27.00 ± 1.40. Water temperature in the fish tank was found to be around 2^{o}C lowered than the air temperature. Due to green house effect inside the unit, the temperature of air was one degree more than outside. The temperature suitability of water for *P. sutchi* is 15 to 39^{o}C, as it is a hardy fish which can tolerate high temperature.

pH: The pH range of 7.0 to 8.0 is optimum for the growth of *Pangasius sutchi*. The overall pH of the water in fish tank remained in the alkaline range fluctuating 7.5 to 8.0.

Dissolved oxygen: Dissolved oxygen showed a gradual increase from 7 mg/L to 8.5 mg/L in first three months and finally increased to 10 mg/L after six months. Firstly, Tubewell water is used as a source of water in tanks, it is very low in dissolved oxygen content. Secondly, water is also not added from a height to set up turbulence, as a way to diffuse atmospheric oxygen in it. Thirdly, as the system is under greenhouse, no phytoplankton growth is there in the cemented polyethylene sheet lined tanks, hence, no photosynthesis and so no diurnal fluctuation of the oxygen level occurs in water. So in order to maintain a high oxygen level, two aerators of 80 watt each are continuously being operated.

Alkalinity: Alkalinity of the water is its capacity to neutralize acid and it is characterized by the presence of carbonates and bicarbonates of Ca^{2+}, Mg^{2+} and Fe^{2+} ions. Permissible limit of alkalinity for culture is 100 to 250 mg/L of water. In this system, it lies in desired range i.e. 130 mg/L. Alkalinity drops from 230 mg/L to 170 mg/L and finally to 115 mg/L at the end of six months. As it is known that, nitrification is a reaction, consuming 7.14 units of alkalinity per unit of ammonia oxidised. Therefore, with the increase in nitrification process, ammonia gets oxidized and thereby decreases alkalinity gradually.

Hardness: Permissible limit of hardness is 200 to

400 mg/L for fish culture. In this system, hardness lies in the desired range. Hardness was found to increase gradually from 270 mg/L to 295 mg/L within six months of the culture period.

Ammonia: Ammonia in the waters affects the survival rate of fish. Toxicity of ammonia increases with pH because at higher pH most of the ammonia is in gaseous form. The decrease in pH, decreases its toxicity due to the conversion of ammonia into ammonium ion, which is less toxic than gaseous form. Permissible limit of ammonia nitrogen (NH_3-N) is less than 0.1 mg/L and ammonium ion (NH_4-N) is 1.5 mg/L. *P. sutchi* being a hardy fish can tolerate ammonia concentration up to 0.5 mg/L. Ammonia increased from 0.3 mg/L to 0.5 mg/L during first three months followed by a decrease to 0.4 mg/L in the next three months.

Nitrite: Nitrite represents an intermediate form during nitrification and de-nitrification reactions of nitrogen. It is very unstable and gets converted into either ammonia or nitrate depending upon the conditions prevailing in the water. The permissible limit of nitrite nitrogen is less than 0.05 ppm. Nitrite increased from 0.05 mg/L to 0.15 mg/L during first three months and then dropped to 0.08 mg/L as nitrification process speeded up. *P. Sutchi* being a hardy fish can tolerate nitrite concentration of 0.2 mg/L.

Nitrate: Nitrate represents the highest oxidized form of nitrogen. The most important source of nitrate is biological oxidation of organic nitrogenous substances produced indigenously in water. The high amount of nitrate denotes the aerobic conditions and high stability of wastes. The permissible limit of nitrate nitrogen is less than 40 ppm. *P. sutchi* is cultured in high stocking density, thus more nitrogenous waste is produced. So, Nitrate content showed a gradual increase from 15 mg/L to 24 mg/L in the first three months and then reached 32 mg/L in subsequent months. The nitrate is absorbed by the growing plants as nutrient, thereby reducing its concentration in fish tank. High amount of nitrate shows that the system can hold more number of plants to utilize the nitrate content so produced. The nitrification process runs well since there is an interaction among fish, plants and nitrification bacteria. The protein from the feed is decomposed into the simple compound by converting bacteria such as Nitrosomonas that converts ammonia into nitrite and Nitrobacter that converts nitrite into nitrate; this nitrate is further used by vegetable plants as a nutrient, resulting in the balance of nitrogen in the aquaponics system. At this condition, the good quality of water is maintained, supporting fish growth through the use of feed.

Table 2. Fish feed composition – Growel's Growfin starter feed.

Component	Quantity
Crude protein	38 % (min)
Crude fat	6% (min)
Crude fiber	3% (max)
Moisture	11.5% (max)
Energy	2750 kcal/kg (min)

Composition of fish feed: The composition of feed is shown in the Table 2. Crude protein content was maintained in the feed as 38% for generation of sufficient quantity of nitrogenous metabolites in the system and to sustain the vegetable plants. The feeding rate was 3% of the average body weight in the first three months, moving to 2.5% the average body weight in the next three months. Feeding schedule is shown in Table 3. Feed are given 2 to 3 times when fishes are small (15 to 50g) and 1 to 2 times when fishes are grown (more than 500g).

Growth performance and nutrient utilization by the fish

Length and weight of fish were taken at the start of the experiment and at different intervals to know the growth performance and nutrient utilization of fish. The observations are presented in the Table 4. The initial average weight of 20 numbers of *Pangasius sutchi* fishes of average length 11.84 cm was found to

Table 3. Feeding schedule.

Average body weight (g)	Average feed (g/fish)	No. of feedings / day	Recommended feed size (diameter in mm)
15 - 50	3	2 - 3	3
50 - 100	4.5	2 - 3	3
100 - 250	six	2 - 3	4
250 - 500	8	2 - 3	4
500 - 750	9	1 - 2	5
750 - 1000	10	1 - 2	5
1000 - 1500	10	1 - 2	6
>1500	11	1 – 2	6

Table 4. Growth and nutrient utilization by *Pangasius sutchi*.

Growth period	Initial weight (g)	Final weight (g)	Weight gain (g)	FCR	FER	PER	SGR %
Phase I (3 months)	36.65	197.95	161.3	2.7	0.37	1.02	0.81
Phase II (next 3 months)	197.95	729.25	531.3	2.7	0.37	1.02	0.81
Overall duration (6 months)	36.65	729.25	692.6	2.7	0.37	1.02	0.81

be 36.65 g. Within three months the average weight of fish increased to 197.95 g and it attained 729.25 g in six months. There is a gradual increase in weight with increase in length of the fish with time. The growth and nutrient utilization of the fish is studied during six months interval. The average weight gain per fish was found to be 692.6 g. Feed Conversion Ratio (FCR) was found to be 2.7. Feed Efficiency Ratio (FER), Protein Efficiency Ratio (FER) and Specific Growth Rate (SGR) were found to be 0.37, 1.02 and 0.81 % respectively.

The food conversion ratio (FCR) of a fish affects the amount of waste produced. A fish with an FCR of 1.0 is more efficient than a fish with an FCR of 2.0, it takes half as much food to get the same weight gain in the first fish (FCR=1.0). If a fish's FCR is low (e.g. 1.0), than more of the available nutrient in food is going into building body mass in the fish, so less nutrient is released by the fish as waste and less plant growth may be supported. So, if grown on the same food (with the same protein content), the fish with the lower FCR (1.0) should theoretically produce less nitrate nutrient waste than the fish with a higher FCR (Lennard 2012). So higher production of fish in the aquaponic system requires a fish with low FCR value and if we want higher production of plants, we have to use fish with higher FCR values. FCR value of the experimental fish *Pangasius sutchi* for the formulated feed used in the present experiment was found to be 2.7.

Growth of vegetable plants

Growth of vegetable plants was taken when the plants were sown till the end of the study or before the plants wilted. Average growth of all plant per day is presented in Table 5. The selection of plant species adapted to hydroponic culture in aquaponic greenhouses is related to stocking density of fish tanks and subsequent nutrient concentration of aquacultural effluent. Lettuce, herbs and speciality greens (spinach, lettuce) have low to medium nutritional requirements and are well adapted in this aquaponic system. The growth per day of Cherry Tomato was seen to be maximum (2 cm/day), followed by Spinach (0.91 cm/day), Broccoli (0.75 cm/day), Mint (0.66 cm/day), Coriander (0.58 cm/day), Leaf Lettuce (0.55 cm/day) and Capsicum (0.5 cm/day). Parsely (0.41 cm/day) and Iceberg (0.18 cm/day) showed a little less growth comparatively. Vegetables are harvested from the vegetable beds time to time as they grow. Spinach,

Table 5. Growth of vegetable plants.

Plant	Initial length (cm)	Final length (cm)	Net growth (cm)	Days	Average growth/day
Spinach	5	32.5	27.5	30	0.91 cm
Leaf lettuce	8	24.5	16.5	30	0.55 cm
Iceberg lettuce	7	12.5	six	30	0.18 cm
Capsicum	30	45	15	30	0.5 cm
Cherry tomato	15	75	60	30	2 cm
Beet root	5	17.5	12.5	30	0.41 cm
Broccoli	7.5	30	22.5	30	0.75 cm
Mint	2	22	20	30	0.66 cm
Coriander	2.5	20	17.5	30	0.58 cm
Parsley	2.5	15	12.5	30	0.41 cm

Table 6. Production of plants in vegetable beds.

Vegetables	No. of (Total) plantings	Percentage of plantation	Production (per month)
Spinach	8,000	66.94	80 kg
Leaf lettuce	1500	12.55	60 kg
Iceberg	100	0.83	30 kg
Capsicum	800	6.69	70 kg
Cherry tomato	400	3.34	200 kg
Beet root	100	0.83	35 kg
Broccoli	150	1.25	50 kg
Mint	200	1.67	60 kg
Corriander	100	0.83	30 kg
Parsley	400	3.34	110 kg
Bellpepper	200	1.67	40 kg
Total	11,950	100	765 kg

Mint, Coriander, Leaf Lettuce are harvested every week, whereas Tomato, Capsicum, Beet root, Bell Pepper are harvested every month. Total production of vegetables per month was 765 kg (Table 6). The vegetables are free of any fertilizer, inorganic sprays, pesticides and other chemicals. The fingerlings grow into pleasant smelling, shiny fishes which is sold at a good price. In Jalandhar, the produce is being sold in E-Rasooi and Mink Organics food stores.

Economics

The economics of aquaponic systems depends on specific site conditions and markets. It would be inaccurate to make sweeping generalizations because material costs, construction costs, operating costs and market prices vary by location. Economics of the system is presented in Table 7.

First year: Total Expense - Non recurring and Recurring cost = Rs 20,39,000/-
Total value of produce after 6 months = 16 lakhs
Profit = Produce sale – recurring cost = Rs 16,00,000 – Rs 20,39,000= (-) Rs 4,39,000/-

Second year: Renovation cost (5% depreciation) = Rs 71,250/-
Total expense = Rs 71,250 + Rs 6,14,000 = Rs 6,85,250/-
Profit = Produce sale – total expense = Rs 16,00,000 - Rs 6,85,250 = Rs 9,14,750/-
Benefit cost ratio = 1.33

Table 7. Economics of the aquaponic unit.

Non recurring cost (Fixed cost) (Rs)		
1.)	Evacuation of tanks	4 lakhs
2.)	Aerators (two)	50,000
3.)	Pipes and fittings	80,000
4.)	Gravel bed	80,000
5.)	Tubewell (2HP)	80,000
6.)	Green house	6 lakhs
7.)	Tiles	70,000
8.)	Vertical stands (three)	45,000
9.)	Horizontal stands set up	20,000
Total fixed cost		14,25,000
Recurring cost (operational cost) (Rs)		
1.)	Fish seed	64,000
2.)	Electricity	20,000
3.)	Fish feed	5 lakhs
4.)	Vegetable seeds	25,000
5.)	Manures / minerals/ neem sprays	5,000
Total recurring cost		6,14,000
Value of produce after 6 months		
1.)	Fish *Pangasius sutchi*	12 lakhs
2.)	Vegetables	4 lakhs
Total sale		16 lakhs

CONCLUSION

The plants with low volume and girth of root are good for the system as the root requires less area in the grow bed to support the growth of plant. During summer months, the water temperature of the system should be maintained to prevent the wilting of the plants due to damage of roots. Humidizers must be used to maintain air temperature in summers. Regular monitoring of the water quality parameters may be done to ensure better FCR of the feed used. It can be concluded that with proper consideration of water parameters (e.g. pH, ammonia, nitrate, dissolved oxygen), FCR of fish, component ratio of fish tank and grow bed should be continuously monitored for the gravel media based aquaponic system to operate successfully and serve as a complementary method of intensive production system under indoor condition for Indian farmers.

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