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Efficacy of wish pond-aquaponics system in mitigating water pollution and safe food production

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Abstract
The experiment was conducted for 108 days from 27 September 2016 to 11 January 2017 in Bolashpur, Pagla Bazar and Boyra, the peri-urban areas of Mymensingh sadar to assess the integration effect of aquaponic system with wish pond concept in producing safe food by addressing water pollution associated with wish pond alone. Juvenile tilapia (*Oreochromis niloticus*) of 5.97 ± 1.36 cm and 4.73 ± 3.97 g and walking catfish (*Clarias batrachus*) of 6.93 ± 1.35 cm and 2.77 ± 1.88g initial size were stocked at the rate of 100 fish/pond. Commercial floating pellet feed were used at a rate of 10% body weight of fish. Survival rate, total production of fish and vegetables were higher (84%, 18.78 tons/ha/108 days and 58.64 tons/ha respectively) in wish pond-aquaponics system than the wish Pond system (78%, 15.80 tons/ha/108 days and 47.07 tons/ha). Nutrient loads were significantly lower in wish pond-aquaponics system at the end because of utilization by the plants therefore performed better than the wish pond system in maintaining water quality.

Keywords: Wish pond**,** Aquaponics, water pollution, Fish, vegetables, small pond

1. Introduction

Wish pond (derived from the words ‘water’, ‘fish’ and ‘pond’) is a new concept of small scale fish farming at the homestead level. The term was first coined by WorldFish and Stung Treng Fishery Administration and the Culture and Environment Preservation Association in 2011 [1]. Its aim was to improve the uptake of small-scale aquaculture by communities with limited experience in fish culture in Stung Treng Province in northeast Cambodia. Initially, Wish pond was targeted towards the households having limited space to construct large fish pond, such as peri-urban households [2]. However, the system was pollution prone. Farmers exchanged the water in their ponds six times on average in both cycles. The water often had a strong odor, characteristic of poor water quality resulting from overfeeding and accumulation of fish metabolites. In addition, the water was opaque and hence the fish could not be seen. It was therefore difficult to determine the condition of the fish, the actual mortality, size distribution, signs of disease, etc. Farmers observed high fish mortalities after harvesting and transportation to the market, a result of feeding fish shortly before harvesting. Farmers also fed fish during water exchange and other activities that may have imposed stress on the fish. Some diseases occurred 2–3 days after stocking the fingerlings, indicating the possibility of inappropriate handling of the fish, as well as transfer of hatchery water to the pond. They went through the *Clarias gariepinus* culture and on average, farmers produced 70 ± 39 kilograms of fish at harvest, from which 61 ± 40 kg was sold and 9 ± 6 kg was consumed by the households. [1].

In this situation aquaponics can be a great tool to handle the pollution drawback of wish pond system. Aquaponics is an integrated fish and vegetable culture system which has been designed to provide an artificial and controlled environment that optimizes the growth of fish and hydroponic vegetables, while saving water resources and acts as safe guard for the environment [3]. In aquaponics, the integration of fish and plants result in a polyculture that increases diversity and yields of multiple products where fish and vegetables are grown in a mutually beneficial and symbiotic relationship [4]. Through this system water is being filtered automatically and ensures clean water for fish to grow. So that if the two systems are combined together, drawbacks of the wish pond system can be overcome. The study was conducted with a view to mitigating the environmental problem of wish pond by combining aquaponics for safe food production.

2. Materials and Methods

2.1 Study Site

The experiment was conducted with ten household families in Balashpur, Boira and Pagla bazar, the peri-urban areas of Mymensingh sadar, Bangladesh from 27 September 2016 to 11 January 2017. A questionnaire was made to collect some related information from the participants to know their basic knowledge on fish culture, aquaculture systems, home gardening, and their household and economic condition. Among the participants, 4 were males and rest 6 was females, their average age was 40.8 (±9.31) years. Five farmers were selected for wish pond-aquaponics and another five for wish pond system only. After selection of families different type of materials such as- plastic sac bags, plastic containers, trays, wires, pipes, water pumps, electrical instruments, nylon nets, tripals, bamboos, gravels etc. were collected from 'Mymensingh Bazar' and suppliers.

2.2 Preparation of wish pond system

After having the reconnaissance survey data, the wish pond was constructed in the farmer's yard measuring 2.1 x 1.5 x 0.3 m^3. The soil available from digging pond was compiled with some ingredients such as ½ kg urea, ½ kg tsp, ½ kg murate of potash, ½ kg wheat flower and 1 liter molasses to enhance the vegetable productivity. Then the soil was filled into the sac bags and placed them around the pond to have a strong embankment. Following the sac bag setup at the pond side, a tripal and polythene lining was placed inside the pond to facilitate and increase water holding capacity. Some bamboo splits and pillar was used to tie the bag to keep in place and then water was added. Some ponds were filled with nearby pond water and some were filled with municipality supply water. The system was fenced with nylon net to protect the vegetables from the domestic birds and animals. Machas were also constructed for the blackthorns like bean, gourd and in addition bamboo stick was placed to support the vegetables not falling in the water. In Cambodia the wish pond system consisted of concrete tanks (3 meters x 4 meters x 1.2 meters) [1]. The preparation procedure was a new concept in the present experiment to reduce the set up cost.

2.3 Preparation of aquaponics system

Aquaponic set up were linked with four wish pond systems available with electricity and security. Six food grade plastic containers (20 L) were used to facilitate the aquaponics vegetable production. A twenty watt aquarium filter pump was used to pump the water from the wish pond to the containers where brick lets were used as grow bed and vegetable saplings were planted. The brick lets were supposed to filter the fish water and naturally accumulated microbes would convert the ammonia to nitrite and then nitrate to make the water safe for the fish and provides food for the vegetable plants [25].

2.4 Planting vegetable saplings and stocking of fish

Different types of seasonal vegetables such as- brinjal, water gourd, cabbage, cauliflower, tomato, water spinach etc. were planted in different sacs. They were planted both on the top of the sac and beside the sac by making small hole on the sac wall. In aquaponics system, vegetable plants were planted through the bricks and gravels. Tilapia (*Oreochromis niloticus*) and walking catfish (*Clarias batrachus*) juveniles were released at the rate of 100 fish in each pond. Commercial floating pellet feed containing 30% protein was used to feed the fish twice daily. Feed was given at the rate of 10% body weight of the fish.

2.5 Sampling and harvesting of fish and vegetables

Sampling of fish was done monthly. In every sampling, ten fishes were sampled randomly caught from the pond by using a fine mesh net. Length and weight of the fish were measured and the data were recorded in the computer. Vegetable harvesting was a continuous process. Water spinach was harvested after 15 days of plantation. Other vegetables were harvested between 55-60 days. Following the harvesting process, their amount and numbers were recorded. The fish and vegetables were finally harvested after 108 days of experiment.

2.6 Sampling of water

Water samples were collected from the fish pond in ½ liter water bottle. The water samples were collected twice during experimental period, first at the starting period and then at the end of the experiment. After the collection of samples they were brought to the Humboldt Soil Testing Laboratory in Soil Science Department at BAU for measuring total-N, electric conductivity (EC), hydrogen carbonate (HCO3), potassium (K), sulfur (S), sodium (Na) and phosphorus (P) [14].

2.7 Statistical analysis

Collected data were loaded in the computer for statistical analysis. One way ANOVA was done with the collected data. Comparison between treatment means was carried out by Duncan's test to analyze the significance of variation between the treatment means. All statistical analyses were carried out by MS Excel 2010 version and Excel-Stat software. The outcomes were presented in tabular and graphical forms.

3. Results and Discussion

3.1 Water quality parameters

At the beginning of the experiment, water temperature range was 26.5 to 28.7ºC on 05^{th} October, 2016. In November the temperature started to get low and in January (winter) the range was 16.5-18.5ºC. Temperature was more or less similar in both the systems during the study period. Swan [5] suggested that the suitable ranges of water temperature would be 24-32ºC for aquaculture. For walking catfish culture suitable water temperature would be 29 ± 1°C [6]. Losordo *et al.* [7] found that suitable range of temperature for optimal tilapia growth was 27-29ºC. Tyson and Simonne [8] suggested that for tilapia production optimum temperature usually ranged from 28-32ºC. So that during the study period temperature range was suitable for walking catfish and tilapia production.

pH is one of the most important factors in aquaculture that represents the acidity alkalinity condition of a water body. Successful production is vastly depends on it. DoF [9] noted that suitable pH range for fish production is 6.5 to 8.5. Srivastava *et al.* [6] recorded water pH of 7.2 ± 0.2 for walking catfish culture. In case of tilapia production pH ranges from 6.0 to 8.5 [8]. On the other hand plants have the best growth at pH 6.0 to 6.5 in aquaponic system [10], whereas the pH tolerance of plants ranges between 5.0 to 7.6 depending on species[11]. In the present experiment, the range of pH was varied from 7.82 to 8.26 in October and in January it was 7.82 to 8.30 among all of the participant families. In wish pond system mean value of pH was 8.03 ± 0.15 and 8.17 ± 0.07 in October and January respectively, whereas in wish pond-aquaponics System it was 7.84 ± 0.30 and 8.08 ± 0.24. Wish pond-aquaponics System has lower pH than the wish pond system because regular water filtration kept the water clean and ensures less pollution. It helps in reducing ammonia content of water and keeps the water pH within the favorable range for fish production.

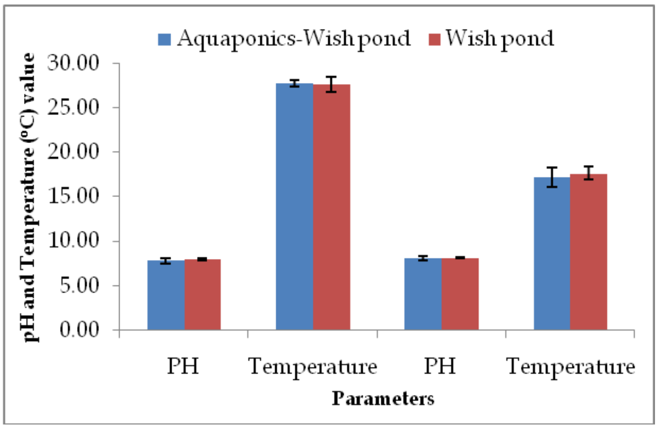

Fig 1: pH and temperature was recorded in Wish pond and Wish pond-aquaponics system during the experiment

3.2 Nutrient loads of pond water in both the systems

EC is the measurement of electrical movement through the water. Though EC cannot move through pure water, it may happen when any salt is dissolved in water because of its (+) charged cations and (-) charged anaions. Argo [12] stated that the EC will be higher when greater amount of salt will dissolve in water. Rakocy *et al.* [13] noted the value of EC was 500 µs/cm during okra production in aquaponic system. In the present study, significantly higher mean value of EC was found in wish pond-aquaponics system (700.67 ± 11.78) than the Wish pond system (640.29 ± 9.78) µs/cm. This might happen due to having higher salt content (Table 1) in the wish pond-aquaponics water because of having good number of fish within a small pond area.

In case of total-N there was no significant difference between the two systems but the amount is lower in wish pond-aquaponics system (4.87 ± 0.88) than the wish pond system (5.40 ± 0.78) mg/L.

Significantly lower amount of P (0.24 ± 0.03), K (4.11 ± 0.70) and S (4.50 ± 0.40) was found in wish pond-aquaponics system than the wish pond one (0.59 ± 0.08, 9.25 ± 1.78 and 5.03 ± 0.48) mg\L. It indicates the utilization of nutrients by the plants [13]. But the HCO3- and Na were significantly higher in wish pond-aquaponics system (328.38 ± 8.78 and 62.88 ± 3.98) than the wish pond system (282.34 ± 6.78 and 53.92 ± 4.78) mg\L, because the plants may require a little amount of sodium for their growth and they didn't take up the carbonate at significant level [14]. A similar result was obtained by Salam *et al.* [15].

Midmore *et al.* [16] stated that the suitable range of total-N was 3.5-5, whereas Swan [5] found it 3.0 mg/L in his experiment. Present result is slightly higher than the former studies because of having higher number of fish in a small area. Boyd [17] stated that 0.20 to 1.15 phosphorus range is good for aquaculture. Midmore *et al.* [16] found this range 0.50 to 0.80. So that present findings are in suitable range.

Table 1: Water quality and fish production parameters in both the systems

Parameters		Wish pond-aquaponics system	Wish pond system	Level of significance	LSD (0.05)	CV (%)
Nutrient loads	EC (µs/cm)	700.67 ± 11.78a	640.29 ± 9.78b	**	0.417	1.61
	HCO3- (mg/L)	328.38 ± 8.78a	282.34 ± 6.78b	**	0.199	2.57
	Total-N (mg/l)	4.87 ± 0.88a	5.40 ± 0.78a	NS	0.619	16.19
	P (mg/l)	0.24 ± 0.03b	0.59 ± 0.08a	**	0.001	14.56
	K (mg/l)	4.11 ± 0.70b	9.25 ± 1.78a	**	0.001	20.25
	S (mg/l)	4.50 ± 0.40b	5.03 ± 0.48a	*	0.429	9.27
	Na (mg/l)	62.88 ± 3.98a	53.92 ± 4.78b	*	0.426	7.53

**= Significant at 1% level of probability, *= significant at 5% level of probability and NS= non-significant

3.3 Fish growth and production

The mean initial length of both walking catfish and tilapia were more or less similar for both the systems. There was no significant difference between them (Table 2 and 3). After 108 days of rearing significant percent length and weight gain, specific growth rate and survival rate was found for walking catfish. Higher specific growth rate was found in wish pond system (1.45 ± 0.00) than wish pond-aquaponics system (1.22 ± 0.0) but in case of survival rate the result was just opposite (71 and 84%). Significantly higher production of walking catfish was found in wish pond-aquaponics system (10.29 ± 1.0) than the wish pond system (8.91 ± 1.0 tons/ha/108 days). Nath *et al.* [18] carried out an experiment and found the survival rate 83.33 and 36.67% T_1 and T_2 respectively after 113 days of rearing. Nur [19] found the total production of walking catfish was 5.25 tons/ha/110 days with 90% survivability. Result of the present study is higher than the former study.

In case of tilapia, specific growth rate was higher in wish pond-aquaponics system (1.30 ± 0.07) than the wish pond system (1.26 ± 0.07) and there was significant difference. But significantly higher survival rate (91%) and production (8.49 ± 1.03 tons/ha/108 days) was found in wish pond-aquaponics system than the wish pond system alone (76% and 6.89 ± 1.08 tons/ha/108 days). Rakibullah [20] has conducted research in the Fisheries Field Laboratory of BAU campus and found that survival rate of tilapia was 83.54–93.75% in the ponds. Rana *et al.* [21] obtained tilapia production of 28 tons/ha/90 days in ponds feeding with experimental diets which is higher than the present study. Though satisfactory survival rate of tilapia was found within the systems, production performances was not as expected. This might be due to lower temperature in winter (November to January), genetic problem in the tilapia fry and some other problems which could not be identified during culture period.

Significantly higher fish production (total) was found in wish pond-aquaponics system (18.78 ± 2.41) than the wish pond system (15.80 ± 2.13 tons/ha/108 days). Other fish growth parameters were also better in wish pond-aquaponics system. Because the water filtration facility of wish pond-aquaponics system keeps the water clean and pollution free for fishes. So that, fish get favorable water quality for their regular growth and production. On the other hand, in winter when the water temperature falls down, the growth of fishes also decrease significantly. In this situation, regular water flow of wish pond-aquaponics system helps in regulating water temperature as well as some other factors related to the temperature. Wish pond-aquaponics system is more convenient than wish pond system in terms of maintaining water quality and fish production.

Table 2: Growth performances of walking catfish in both the systems

Growth Parameters	Walking catfish				
	Wish pond system	Wish pond- aquaponics system	Level of significance	LSD (0.05)	CV (%)
Mean Initial Length(cm)	6.65 ± 0.78	6.63 ± 0.70	NS	0.658	11.16
Mean Final Length (cm)	16.75 ± 1.7	15.85 ± 1.3	NS	0.211	9.77
Mean Length Gain (cm)	10.11 ± 1.78	9.22 ± 1.48	NS	0.422	16.94
Percent Length Gain (%)	152.04 ± 7.78	139.02 ± 6.70	*	0.53	4.99
Mean Initial Weight (g)	2.69 ± 0.17	2.65 ± 0.23	NS	0.071	7.57
Mean Final Weight (g)	40.04 ± 2.78	39.70 ± 3.78	NS	0.057	8.32
Mean Weight Gain (gm)	37.37 ± 2.80	37.22 ± 3.08	NS	0.699	7.89
Percent Weight Gain (%)	1236.31 ± 19.78	1409.05 ± 21.48	**	0.739	1.56
Specific growth rate (%)	1.45 ± 0.00	1.22 ± 0.0	*	1	5.99
Survival Rate (%)	71	84	*	0.432	6.1
FCR	2.5	2.25	NS	0.01	5.59
Production (tons/ha/108days)	8.91 ± 1.0	10.29 ± 1.0	*	0.971	11.2

**= Significant at 1% level of probability, *= significant at 5% level of probability and NS= non-significant

Table 3: Growth performances of tilapia in both the systems

Growth Parameters	Tilapia				
	Wish pond system	Wish pond-aquaponics system	Level of significance	LSD (0.05)	CV (%)
Mean Initial Length (cm)	5.97 ± 0.70	5.97 ± 0.80	NS	0.579	12.59
Mean Final Length (cm)	10.97 ± 1.88	11.22 ± 1.03	NS	0.01	13.66
Mean Length Gain (cm)	4.98 ± 1.70	5.30 ± 0.44	NS	0.01	2416
Percent Length Gain (%)	83.67 ± 5.98	87.67 ± 4.70	NS	0.251	6.28
Mean Initial Weight (g)	4.73 ± 0.28	4.73 ± 0.41	NS	0.0001	7.42
Mean Final Weight (g)	28.07 ± 1.98	29.88 ± 2.70	NS	0.048	8.17
Mean Weight Gain (g)	23.35 ± 2.08	25.16 ± 2.93	NS	0.1	10.48
Percent Weight Gain (%)	493.67 ± 6.70	532.33 ± 7.40	**	0.686	1.38
Specific growth rate (%)	1.26 ± 0.07	1.30 ± 0.07	NS	1	5.47
Survival Rate (%)	76	91	*	0.1	6.37
FCR	2.29	2.21	NS	0.01	4.37
Production (tons/ha/108 days)	6.89 ± 1.08	8.49 ± 1.03	*	0.85	13.72
Total Production	18.78 ± 2.41a	15.80 ± 2.13b	*	0.61	13.15

**= Significant at 1% level of probability, *= significant at 5% level of probability and NS= non-significant

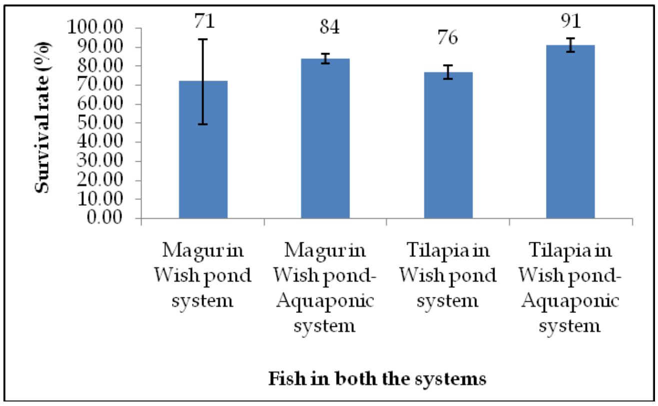

Fig 2: Survival rate of walking catfish (magur) and tilapia in both the systems

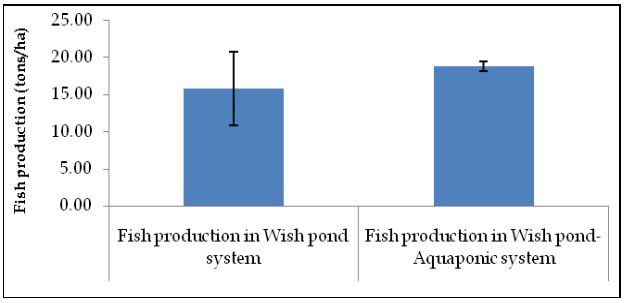

Fig 3: Total fish production in both the systems

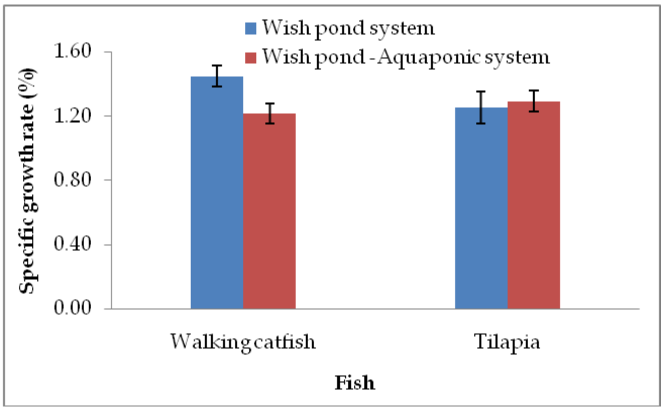

Fig 4: Specific growth rate of fish in both the systems

3.4 Vegetable Production

Vegetable production was from two different systems during the study period. Among them, vegetable of wish pond-aquaponics system got continuous nutrition from fish water. Here fish waste was used as fertilizer to the plants. Another system was out of fertilization. Chabok and Amoli [22] got an average yield of 22-30 tons/ha cauliflower in their experiment. In the present study higher cauliflower yield was found in wish pond-aquaponics system (24.06 ± 3.59) than the wish pond system (22.94 ± 5.63 tons/ha) which is similar to the previous study. Ogbodo *et al.* [23] found the average cabbage head yield range of 5.5 - 7.7 tons/ha in their study

and mentioned that the findings was lower than the world average yield range of 10.0 - 40.0 tons/ha. In another study Sajib *et al.* [24] got the maximum yield of cabbage was 57.16 tons/ha and the lowest yield was 38.48 tons/ha. During the study period production of cabbage was 32.74 ± 4.58 and 33.19 ± 5.71 tons/ha in wish pond and wish pond-aquaponics system respectively. Present findings are much higher than Ogbodo *et al.* [23]. Though the production is lower than the maximum yield of Sajib *et al.* [24], it fulfills the world average yield range mentioned in Ogbodo *et al.* [23].
Salam *et al.* [25] found that the total tomato production was 49.67 tons/ha. At the present study production of tomato in wish pond and wish pond-aquaponics system was 50.10±7.56 and 63.04±6.25 tons/ha respectively, which is quite similar to the former study but higher in wish pond-aquaponics system.
Bethe *et al.* [26] got the total production of water spinach was 128 tons/ha in her aquaponic study. Present study shows that higher production of water spinach was found in wish pond-aquaponics system (150.44±10.39) than the wish pond system (97.05±33.28 tons/ha). Though Bethe *et al.* [26] had the same system, stocking of higher fish and larger surface area ensures the higher production of water spinach within the system.
From the above discussion it can be concluded that the overall production was higher in wish pond-aquaponics system than the wish pond system alone. The main reason behind this difference is the continuous nutrient availability of plants during their growth period. In wish pond-aquaponics system, fish waste water went to the vegetable growing media where the plants bacteria convert ammonia into nitrate [25]. This nitrate was used as the plant nutrients. As a result the production was higher within this system than the other one.

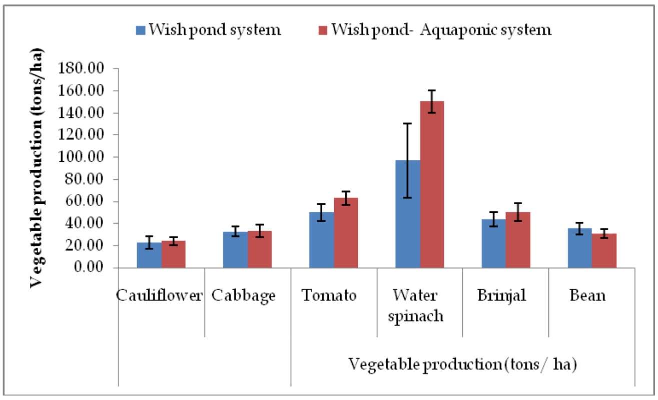

Fig 5: Vegetable production in both the systems

4. Conclusion

The present study concludes that wish pond system is pollution prone; hence, water was exchanged twice during the 108 days of experiment period. Integration of water filtration system (aquaponics) improved the water quality; therefore, increased fish production than the Wish pond system. The system produced vegetables without fertilizer and ensured clean water for fish growth. Vegetable consumption has increased in the families than the neighbors. The system proved environmental friendly and easy to handle; therefore, these can be combined and implemented in water deficit harsh areas, in regional as well as international context.

5. Acknowledgements

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