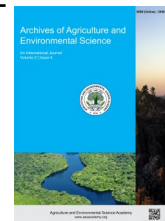




e-ISSN: 2456-6632

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Archives of Agriculture and Environmental Science
Journal homepage: www.aesacademy.org



ORIGINAL RESEARCH ARTICLE



Assessment of fish pond sediments for growth, yield and nutritional quality of Indian spinach (*Basella alba* L.)

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ARTICLE HISTORY

Received: 04 February 2020

Revised received: 26 February 2020

Accepted: 13 March 2020

Keywords

Fertilizers
Growth
Indian spinach
Nutritional quality
Pond Muds/sediments
Yield

ABSTRACT

Integrated farming system is a very effective tool for improving rural economy. Our present study was carried out in different pond dykes of Dumuria upazila of Khulna district, Bangladesh to investigate the effect of different fish pond sediments on growth, yield and subsequently analyze the nutritional quality of Indian spinach. The experiment consisted of two factors viz., pond types (P) (three different ponds growing different fish species: P₁ = prawn and carp, P₂ = prawn and mola, and P₃=prawn, mola and carp) and each pond was cultivated with different fish species with different population densities; and pond sediments (M) (three levels: M₁ = pond dyke soil, M₂ = 50% pond mud and 50% pond dyke soil, and M₃ = 100% pond mud). Physical and chemical properties of three ponds dyke soil as well as sediments were analyzed. Parameters studied on Indian spinach were growth, yield and nutritional qualities. Pond sediments were better quality due to well decomposition and microbial activity of sediments compared to dyke soil of ponds. Organic matter of pond sediment was 2.79 (P₃) and EC was 790 (μc/cm). Plant height was varied from 10 to 19% due to the ponds type and sediment effects. Mostly, the plant growth was found better under the supplement of 100% pond sediments compared to dyke soil (M₁) and mixed soil (M₂). The highest yield was found in P₃M₃ and it was varied from 20 to 25%. Minerals like Ca (%), P (%), and S (mg/100g) were found statistically significantly higher in P₂M₃ compared to other treatments combinations. Nutrition like Vit A and Vit C were the highest (81.33 μg/100 g and 106.14 mg/100 g, respectively) found significantly higher in P₂M₃. Therefore, the pond mud (50% and 100%) can be used to increase the yield and nutrient uptake by the crop which can facilitate to reduce eutrophication and fertilizer for the better environment.

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Citation of this article: Islam, M.A., Jahan, N., Quadir, Q.F. and Haque, S.M. (2020). Assessment of fish pond sediments for growth, yield and nutritional quality of Indian spinach (*Basella alba* L.). *Archives of Agriculture and Environmental Science*, 5(1): 33-39, https://dx.doi.org/10.26832/24566632.2020.050105

INTRODUCTION

Integrated farming is becoming important for the sustainable production of diversified product which are cost effective and friendly environment. Such integration may be observed in the combination of fish farming and crop husbandry. Since, successful management of tropical fish ponds in a balanced manner through fertilizer application and supplementary feed addition is a basic need for the biological optimal fish growth while the

sediment of pond can be a good source of organic matter to improve the soil health as well as for the crop growth and yield (Ihejirika *et al.*, 2012; Li and Yakupitiyage, 2003). Fish feed and fertilization in fish ponds result to accumulation of organic matter (Rahman *et al.*, 2004). Moreover, higher amount nitrogen, higher fractions of phosphate compounds and organic matter are deposited in the sediments of fish ponds; which facilitate to improve the soil condition and reduce the cost through less amount inorganic fertilizer application in the crop land (Olah *et al.*, 1994;

Rahman et al., 2004; Boyd, 1995; Ihejirika et al., 2012; Uwimana et al., 2018).

People are suffering from malnutrition due to lack of balanced diet devoid of nutrient rich vegetables and fruits, good protein sources in the food menu. Yet millions of people who depend on fish to live every day, faced by the fear of food shortage (World Fish Centre, 2002). This leading to a range of negative health outcomes, including anemia, poor growth, rickets, impaired cognitive performance, blindness and neuromuscular deficits (Murphy et al., 2003).

Bangladesh is a land hungry country and its southern part land is mostly converted gher for fish culture especially prawn (*Mollusca rosenbergii*) cultivation. Integration of prawn farming in seasonal rice/paddy fields (ghers) has been successfully implemented and served as a significant source of income to coastal families of southwest Bangladesh. Farmers typically sell the prawns to fetch higher prices in overseas markets; meanwhile family members remain malnourished due to lack of complete protein, vitamins and other minerals in their diet (Milstein et al., 2006). In these areas the land is occupied with crops for eight months, while the rest of the year pond dyke is mostly remained fallow. In areas, some negligible amount vegetables are grown without any nursing. Therefore, integration of pond dyke vegetable culture with fish culture can give the opportunity to avail the diversification of food and help changing the food habit of the local people.

Integration of fish farming and use of effective pond mud for the vegetable cultivation is a new approach for the sustainable environment in Bangladesh. Indian spinach (*Basella alba* L.) is a very popular nutrient rich leafy vegetable under the family Basellaceae. It is widely grown not only in Bangladesh but also in tropical Asia and Africa (Bose et al., 2008). There is an increas-

ing trend in Bangladesh to use inorganic fertilizer for the crop production and the country faces a large fertilizer deficit. Consequently, the share of imported urea increased from 30% in 2005–2006 and 69% in 2010–2011, and the country is almost completely dependent on imports of triple super phosphate (TSP) and muriate of potash (MoP) (Ahmed, 2011). High application rates of inorganic fertilizers have the disadvantage of surface runoff of nutrients to water bodies causing eutrophication which leading to anoxia and even toxic or harmful impacts on fisheries resources, ecosystems, and human health (Bijay et al., 1995; Anderson et al., 2002). Pond sediment is enriched with organic matter, nitrogen, phosphorus, and macro and micronutrients and hence, it can be a potential fertilizer supplement and soil conditioner. Therefore, the aim of the study was to investigate the performance of pond sediments from different fish cultures on the growth, yield and nutritional quality of Indian spinach.

MATERIALS AND METHODS

Location of the experiment

The experiment was conducted during the period from January to May, 2015 to examine the growth, yield and afterwards analyzed the nutritional quality of Indian spinach as influenced by different fish pond sediments. All the experimental units were selected in the areas where freshwater prawn culture is practicing for several years. The experiment was conducted at the different ponds dyke at Dumuria upazila under Khulna district, Southwest part of Bangladesh (Figure 1) to observe proper utilization of sediments of pond on the growth, yield and nutritional quality of Indian Spinach.

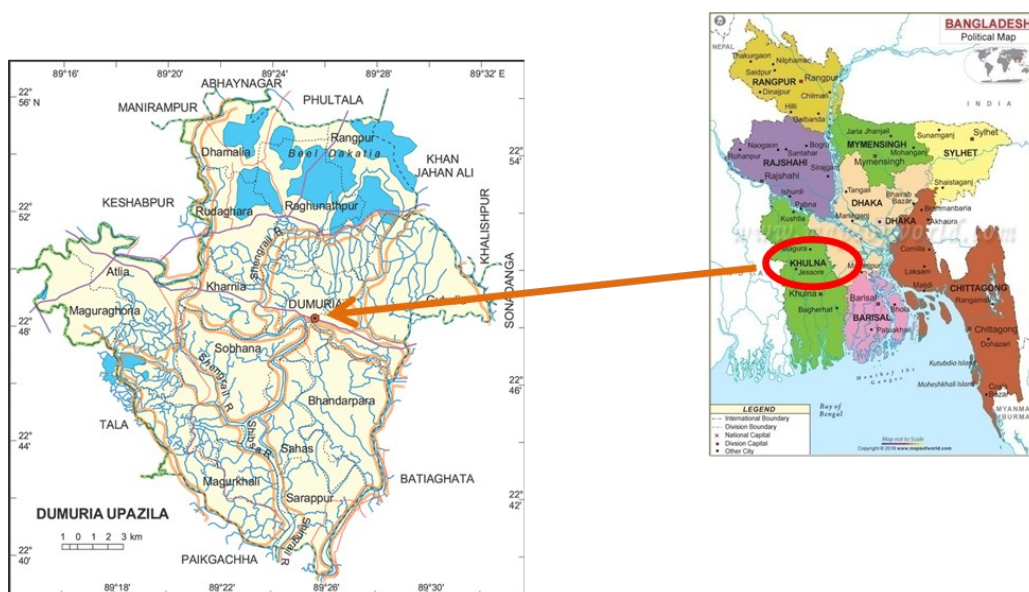


Figure 1. Map of Bangladesh showing Khulna district (Southwest part of Bangladesh) and the Dumuria upazila where the research was conducted (Source: Google).

Experimental design

Two factors experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications and total experimental plots were 27. Factor A was types of pond where number of fishes and species were different in each pond and factor B was the ratio of ponds sediment and dyke soil for the cultivation of Indian Spinach. The treatment combinations for two factors of the experiment are given in Table 1. The size of unit plot was 1.5 m² (1m × 1.5m). Sediments from different ponds and the dyke soil of the respected ponds have been carried to the Soil Science Laboratory of Bangladesh Agricultural University, Mymensingh for chemical analysis. The initial soil properties are presented in Table 2.

Cultivation practices

Selected pond dyke was opened using spade on 25 January 2015 and the soil was mixed with sediments of pond according to the design of the experiment. Indian spinach seeds (green variety) were collected from the seed market and dibbling (3 seeds per pit) was done on 12 February 2015 maintaining the producers recommended spacing (25 cm × 25 cm). Extra seedlings in the same pit were uprooted and used in case of gap filling. Irrigation was given regularly for the germination of seeds as well as for the establishment. Other intercultural operations such as weeding, frequent irrigation, etc. were given at interval according to necessary. Manure or fertilizer was not used in the experiment. Only dyke soil and pond mud/sediments were used to see the effect of dyke soil and mud on vegetable production.

Plant growth and yield analysis of Indian spinach

Plants were randomly selected and tagged as samples for collection of data from the middle of the rows of each unit plot for avoiding border effect. Plant height (cm) was taken from the base to the tip of plant using a meter scale and numbers of leaves were counted during the first harvest of Indian spinach. First harvest (from 10 cm above of plant was considered as edible part) was done after 45 days of seed planting. Length and breadth of largest leaves were measured using meter scale. Fresh weight (g) of each harvested plant (harvesting for consumption after 45 and 60 days after planting) were weighed and calculated per plot (kg) as well as to the unit area. Twig of 10 cm length from selected plants were separated as leaves and stem. Each sample were cut into pieces and was dried in air for 7 days and then kept in an oven at 70°C for 72 hours before taking the dry weight till it was constant. The dry weight was converted in dry matter percentage by the following the formula.

$$\text{Moisture content (\%)} = \frac{\text{FW} - \text{DW}}{\text{FW}} \times 100$$

$$\text{Dry matter (\%)} = \frac{\text{FW} - \text{MC}}{\text{FW}} \times 100$$

Where,

FW= Fresh weight

DW= Dry weight

MC= Moisture content

Table 1. Treatment combination of the experiment.

Factors A (Ponds mud under different species combinations*)			Factor B: Treatment
	Fish	Amount (numbers)	
A (P ₁)	Prawn	80.84 nos /decimal	M ₁ - Dyke soil
	Mola	0 nos/decimal	M ₂ -50 % pond sediments and 50% pond dyke soil
	Carp (Rohu)	4 nos/decimal	M ₃ -100% pond sediments
B (P ₂)	Prawn	80.84 nos/decimal	M ₁ - Dyke soil
	Mola	80.84 nos/decimal	M ₂ -50 % pond sediments and 50% pond dyke soil
	Carp (Rohu)	0 nos/decimal	M ₃ -100% pond sediments
C (P ₃)	Prawn	80.84 nos/decimal	M ₁ - Dyke soil
	Mola	80.84 nos/decimal	M ₂ -50 % pond sediments and 50% pond dyke soil
	Carp (Rohu)	4 nos/decimal	M ₃ -100% pond sediments

Table 2. Physical and chemical properties of dyke soil and pond sediments.

Pond type	Types of soil	pH	EC (µc/cm)	Org M (%)	Total N (%)	P (ppm)	K (ppm)	S (ppm)
P ₁	Pond sediments	6.23	601	1.79	0.09	19.13	114.07	233.2
	Dyke soil	5.98	657	1.59	0.08	12.25	97.27	385.0
P ₂	Pond sediments	6.32	618	1.72	0.08	42.63	150.74	297.8
	Dyke soil	6.78	517	1.57	0.08	36.08	110.8	175
P ₃	Pond sediments	6.60	790	1.92	0.10	50.52	175.18	327.14
	Dyke soil	6.60	494	2.79	0.14	33.23	101.85	113.21

Nutritional quality analysis of Indian spinach

Twigs (twig consisted of leaves and stem) were used for the nutritional quality analysis. Vitamin C was determined by the indophenols dye extraction method. This procedure was based upon the quantitative discoloration of 2, 6- dicholophenol indophenols by ascorbic acid. Vitamin A was calculated using following formula:

$$\text{Beta carotene} = (3.984 \times \text{OD} \times \text{volume}) / (100 \times \text{W sample volume})$$

Phosphorus content of Indian spinach was determined by colorimetric method, following the procedure as mentioned by Jackson (1973). Calcium concentration was determined by EDTA titrimetric method using Na₂EDTA as a complexing agent at pH 12 in presence of calcon indicator (Page et al., 1982). Sulphur concentration was determined turbidimetrically with the help of a digital spectrophotometer (Model: Labtronics LT31) as outlined by Tandon (1995). The iron content was determined by atomic absorption spectrophotometer (Model PG 990) at the wave length of 248.3 nm.

Statistical analysis

Effects of treatments on growth, physiological yield and nutritional quality data were analyzed using analysis of variance (General Linear Model procedure) and Tukey's pair wise comparison test ($P < 0.05$) using Minitab Version 16 (Minitab Inc., State College, PA, USA).

RESULTS AND DISCUSSION

Pond sediments/muds of pond and fish species in ponds effect on plant growth and yield of Indian spinach

The present study was an integrated work of aquaculture and horticulture. Fish number and species were different in different ponds which were conducted by the aquaculture group. This experiment was conducted in pond dyke using the sediments/muds of considering the work of aquaculture. So, output of fish cultivation (May - December of last year) was harvested. Already, the feed of fish and fertilizers given to the pond (the different number of fish species in different ponds) was decomposed. The physical and chemical properties of sediments and dyke soil is shown in Table 2. Muds/sediments of different ponds were used in the dyke of respected pond for the Indian spinach cultivation. Ihejirika et al. (2012) determined the pond sediments quality and used it as supplement of chemical fertilizer for crop production. In our study, statistically significant variation was recorded on growth and yield contributing characters of Indian spinach (Table 3). The longest plant height was found 29.80 cm in P₃M₃ and the lowest plant height obtained in P₂M₁. The similar range of plant height was found in the plot of different ponds dyke where 100% pond sediments were used. Although, no significant difference was found in plant height where as other growth parameters like leaf numbers/plant, leaf length and breadth were shown significant different among the treat-

ment combinations ($P \leq 0.05$). The highest number of leaves, leaf length and breadth were 21.6, 17.2 cm and 12.2 cm, respectively in P₃M₃. It indicates that plant leaf parameters influenced the yield of this crop, because yield per plot was found significantly different (Figure 2). The highest (9.4%) dry matter accumulation was found from P₂M₃ while the lowest was found in P₃M₁ and P₃M₂ (Table 3). Higher dry matter accumulation utilized the nutrient input for plant production and nutrient uptake by plants.

In case of yield, significant variation was recorded due to different level of muds presented in Figure 2. Ponds mud/sediment gave the better growth of plant as well as the yield because of high nutrient are available in the muds compared to the dyke soil. Fish feed decomposed and contain the higher nutritional status for the plant growth like N, P and another macro and micro nutrients (Ihejirika et al., 2012; Rahman et al., 2004). Also, it is reported that this sediment is a good source of nutrient for the crop production and friendly for the environment and soil where crop nutrients are readily available due to well decomposition. Actually, sediments can work as a potential source of fertilizer supplement for the crop product and a new dimension for the sustainable aquaculture-agriculture integrated farming system. In the experiment of aquaculture, farmers were used the fish feed and fertilizers like urea and TSP in the ponds. Those products and phytoplanktons are decomposed which increased the organic matter and other minerals in the muds of pond.

The reuse of pond-mud for the cultivation of vegetables and the aquaculture is a good tool considering the cost-effective methods as well as the supplement of diversified food for the rural poor people considering the nutritional aspects. Applying a high level of both feed and fertilizer gave high positive nutrient balances for the pond and sediments become a good source of nutrients for crop production. It is reported that farmer used 74.69 tonnes feed per hectare of pond assuming that 30% of the nitrogen in the feed is converted into fish flesh and the remainder are deposited as bottom sediments in the pond (Ali and Haque, 2011; Rahman et al., 2004). The bottom sediment is enriched with organic matter, nitrogen, phosphorous, and macro and micronutrients (Rahman et al., 2004) and the value of these nutrients for crop production is potentially high (Voss et al., 1999). In our experiment, pond mud application has given better result for the Indian spinach production compared to the only dyke soil. The similar findings have been found by the work of Verdegem, 2005. He has reported that using pond sediments on the dyke resulted in higher plant yields and improved some of the soil fertility characteristics. Thus, this integrated agriculture -aquaculture (IAA) system has the great potentiality throughout the country (Pervin et al., 2012). Besides, Uwimana et al. (2018) encouraged to promote the use of water and pond sediments as fertilizer for crop production which can be reflected as environmental restoration and sustainable agriculture. Ultimately, this practice could maximize nutrient utilization and decrease the potential for harmful phytoplankton blooms, reduce the dissolved oxygen level and less environmental impacts (Wahab et al., 2008).

Table 3. Combined effect of pond types and pond sediments on growth parameters and dry matter content of Indian spinach.

Treatment combination	Plant height (cm)	Leaf number/plant	Leaf length (cm)	Leaf breadth (cm)	% Dry matter of twig
P ₁ M ₁	24.70	12.60	11.60	7.60	8.10
P ₁ M ₂	26.20	15.10	12.90	7.90	8.20
P ₁ M ₃	29.30	18.60	13.10	8.20	8.40
P ₂ M ₁	21.10	12.50	10.60	6.30	8.00
P ₂ M ₂	21.30	14.60	11.70	6.70	8.30
P ₂ M ₃	29.80	20.30	12.00	7.00	9.40
P ₃ M ₁	23.80	14.70	11.20	8.10	7.80
P ₃ M ₂	25.10	18.30	14.60	11.70	7.80
P ₃ M ₃	29.80	21.60	17.20	12.60	8.50
LSD _{0.05}	9.11	7.32	2.69	2.25	0.212
Level of significance	NS	*	*	*	*

* = Significant at 5% level of probability, NS = Not significant.

Table 4. Combined effect of pond types and pond sediments on the mineral contents of edible part of Indian spinach.

Treatment combinations	Ca (%)	P (%)	S (mg/100g)
P ₁ M ₁	0.56	0.02	2.14
P ₁ M ₂	0.70	0.06	2.25
P ₁ M ₃	1.36	0.10	2.67
P ₂ M ₁	0.69	0.04	1.06
P ₂ M ₂	0.82	0.05	1.83
P ₂ M ₃	1.74	0.13	2.78
P ₃ M ₁	1.07	0.07	1.78
P ₃ M ₂	1.12	0.13	1.99
P ₃ M ₃	1.40	0.15	2.35
LSD _{0.05}	0.08	0.02	0.07
Level of significance	*	*	*

P₁= Pond type A, P₂= Pond type B and P₃= Pond type C; M₁= dyke soil, M₂= 50% pond mud and 50% dyke soil, M₃= 100% pond mud.

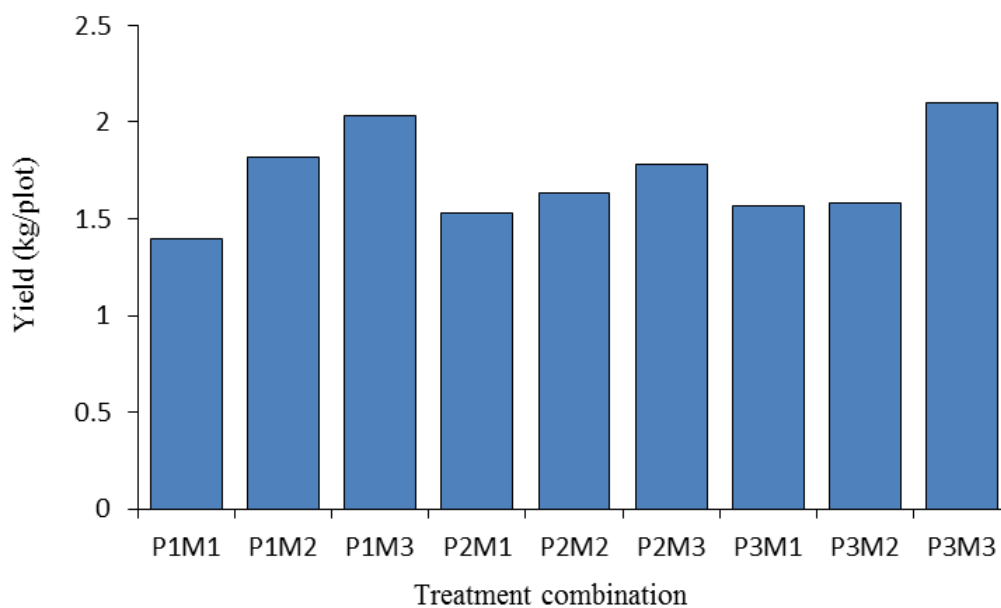


Figure 2. Combined effect of pond types and pond sediments on yield of plot of Indian Spinach. Plot size: 1 m x 1.5m. P₁= Pond type A, P₂= Pond type B and P₃= Pond type C M₁= dyke soil, M₂= 50% pond mud and 50% dyke soil, M₃= 100% pond mud.

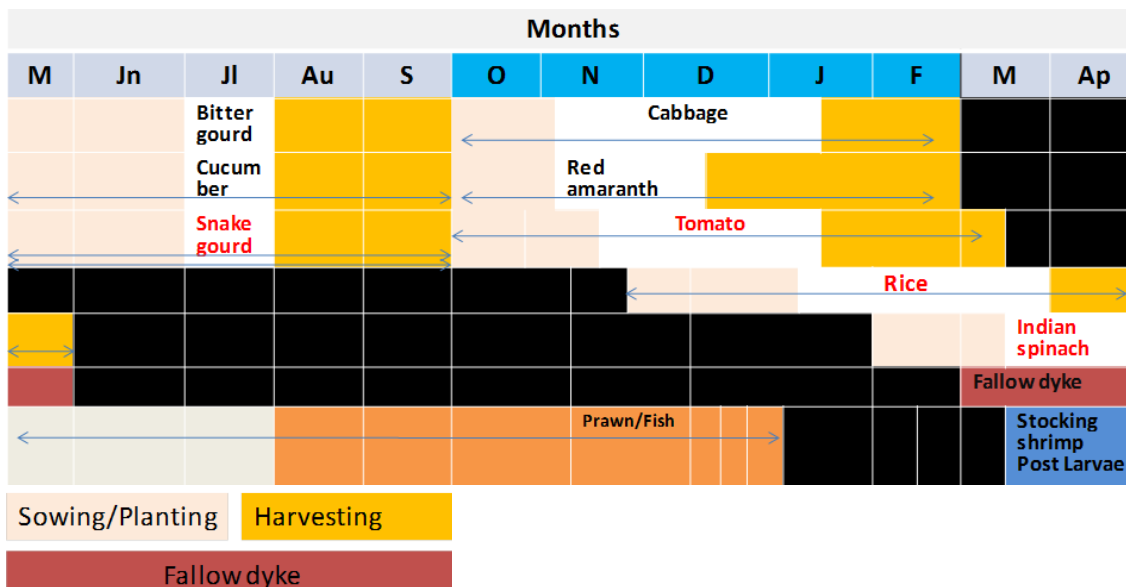


Figure 3. Cropping pattern in the South-western part of Bangladesh.

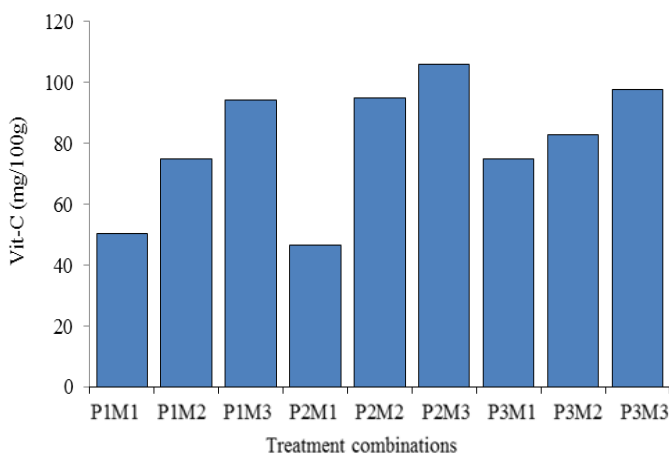


Figure 4. Combined effect of pond types and pond sediments on the Vitamin C content of edible part of Indian spinach. P₁= Pond type A, P₂= Pond type B and P₃= Pond type C M₁= dyke soil, M₁ = dyke soil, M₂= 50% pond mud and 50% dyke soil, M₃= 100% pond mud.

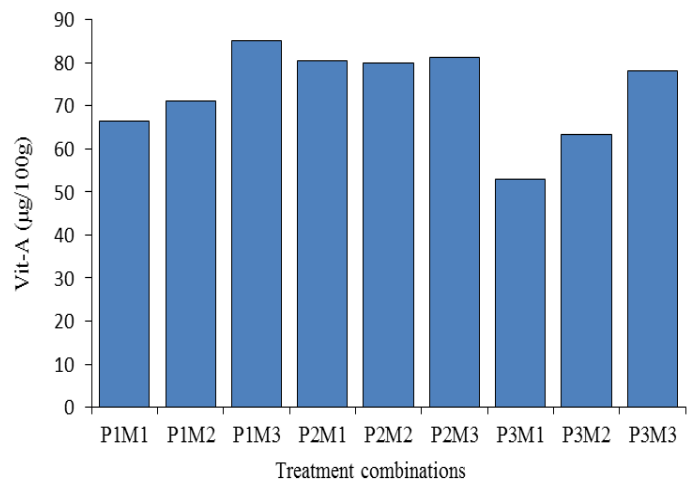


Figure 5. Combined effect of pond types and pond sediments on the Vitamin A content of edible part of Indian spinach. P₁= Pond type A, P₂= Pond type B and P₃= Pond type C M₁= dyke soil, M₁ = dyke soil, M₂= 50% pond mud and 50% dyke soil, M₃= 100% pond mud.

The scenario of the research site (Dumuria Upazila under Khulna district is the Southwest part of Bangladesh) is to cultivation of fish in pond during the July to December in some extension to February. But the rice is cultivated in the pond when pond is becoming dry or less water. In the winter season, farmers are used to grow vegetables without caring to the crops. But, farmers give too much concentration to rice cultivation, also the scarcity of water does not encourage to farmers to grow vegetables after January to April. After May, rainy season is a natural disaster and not convenient for the crop cultivation that is up to September-October. The research site is climate vulnerable area and its cropping pattern was found through visiting the research site and interviewing farmers (Figure 3). So, different fish species cultivation in the same pond and vegetable cultivation introduction can uphold the national security through reducing the use of fertilizer and eutrophication. Because, it is assumed that diversification of fish is decomposing

the sediments and at the same time proper utilization of pond sediments as fertilizers. It is giving the opportunity for consumption of diversified diet of fish and vegetable/crop which can ensure the nutritional security of the household family members (Haque et al., 2016).

Pond sediments/muds of pond and fish species in ponds effect on the nutritional quality of Indian spinach

Plants grown under different treatments were harvested analyzed the mineral and nutritional status from the edible parts of Indian spinach. There are some works conducted to grow vegetables in the dyke area utilizing the pond sediments but no work is found on the nutritional status of crops influenced by pond sediments. In our experiment, minerals like Ca, P and S were analyzed which were found significantly different among the treatment’s combinations (P<0.05) (Table 4). Edible parts of Indian spinach like leaves and stems were analyzed together and

the highest amount of calcium (Ca), phosphorous (P) and sulphur (S) were found 1.74%, 0.13% and 2.78 (mg/100 g), respectively in P₂M₃ and the lowest Ca and P was found in P₁M₁. This result is consistence with the dry matter accumulation in plant parts. On the other hand, 100% pond sediments showed the higher amount of nutrient content compared to the dyke soil.

In case of nutritional analysis, the highest content of Vit A and Vit C of Indian spinach was found 81.33 (µg/100 g) and 106.14 (mg/100 g) in P₂M₃ (Figures 4 and 5). On the other hand, the lowest Vit A was in P₃M₁ and Vit C was P₁M₁. Both of the lowest value was found in the different pond dyke where the soil media was only dyke soil (M₁), no addendum of pond sediments. This highest amount nutrition is consistence the other mineral contents, as well as the growth and nutrient supply to the soil.

Conclusion

Sediments/muds of each pond contain the higher of organic matter and mineral compared to the respected dyke soil. Supply of nutrients to the soil through 100% pond sediments gave the better result on growth and yield of Indian spinach in pond type 3 (P₃) where three type fish species combination were cultivated. On the other hand, higher amount of minerals and vitamins were found in the pond dyke where 100% pond sediments were used. Findings from this experiment indicate that pond sediments application from the pond of different types fish species combination can be useful for increased crop production and nutritional quality of the crop through improved soil quality. On the other hand, these findings can be an exemplary to continue the further work of integrated aquaculture and horticulture to improve the soil health and environment, reduced eutrophication and less chemical fertilizer application for crop production.

ACKNOWLEDGEMENTS

The authors would like to thank USAID-AquaFish Innovation lab to support the work. Also, greatly acknowledge to South-western part household families who allow this work and support to collect data.

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