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Five Decades of Agricultural Development in Bangladesh: A Success Story Powered by the Dream of Bangabandhu

Jahangir Alam Khan[a]

Abstract

Bangladesh recently observed the centennial of birth of Bangabandhu Sheikh Mujibur Rahman, the architect of our independence in 1971 and the Father of the Nation. It coincided with the celebration of the Golden jubilee of independence. Five decades had elapsed since independence leaving an imprint on the country's journey on the road to development. Among the many dreams that Bangabandhu cherished for the newly born country, the dream to bring about revolutionary changes in the agriculture sector was his most coveted one. During this period, Bangladesh's economy underwent amazing transformation; particularly its agriculture sector. This paper describes important strategies that Bangabandhu put in place to promote development in the agriculture sector during the first few years of his regime since independence and those that were implemented so far in the sector. Evidence shows significant growth rates had been achieved in all sub-sectors of agriculture during the last fifty years. However, the pace of transformative changes needs to be scaled up to confront the challenge of boosting food and nutrition security of the country in the coming years. The paper outlines suggestions for future development of the agricultural sector in Bangladesh.

Key Words: Bangabandhu, Independence, Golden Jubilee, Agriculture, Food security, Sustainability

Introduction

The foundation for the amazing transformation of Bangladesh's agriculture was laid at the dawn of independence by Bangabandhu Sheikh Mujibur Rahman, the architect of our independence and the Father of the Nation. In the wake of independence Bangladesh inherited a poor economy with a big margin of food shortage. Bangabandhu called for achieving self-sufficiency in food production and took revolutionary measures for agricultural development. First of all, he ensured the constitutional rights of the farmers. Article 14 of the constitution states, "It shall be a fundamental responsibility of the state to emancipate the toiling masses—the peasants and workers--and backward section of the people from all forms of exploitation." Article 16 of the constitution states, "The state shall adopt effective measures to bring about a radical transformation in the rural areas through the promotion of an agricultural revolution."

In Bangladesh and elsewhere in the world, agriculture is the art and science of farming. It is an occupation concerned with cultivating land, raising crops, livestock, trees and fisheries. It is the source of producing food for people and generating employment and

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income for them. Agriculture is the key driver of the growth of Bangladesh economy. According to the estimates of BBS, the contribution of the agricultural sector to GDP stood at around 13 percent in FY 2020-2021. The growth of the industrial and the service sectors is substantially supported by the agricultural sector. Moreover, the agricultural sector absorbs around 40% of the total labour force of the country and earns about 7 percent(including leather) of the total export revenue. As the main source of economic linkages in rural areas, it plays a fundamental role in reducing poverty. Recent evidence shows that one percent increase in agricultural output reduces poverty by about 0.4 percent. As a result, the economic and social development of Bangladesh depends largely on the development of agriculture. It is in this context that Bangabandhu's call for an agricultural revolution five decades ago was timely for achieving food security and alleviating poverty in the country.

Bangabandhu as the head of the government and head of the state got only about three and a half years to rebuild the country. In this short period he directed all efforts at increasing agricultural production in the country. Initially he implemented redistributive land reforms imposing a ceiling of ownership upto 100 bighas (33.3 acres) of land and exempted farmers from payment of land revenues up to 25 bighas (8.3 acres) of land. He withdrew one million certificate cases against farmers for nonpayment of loans. Bangabandhu's reforms also touched agricultural research and extension with establishment of new institutions and reorganization of the existing ones. On his watch, separate ministries were created for fisheries and livestock and for jute for efficiently harnessing growth potentials of relevant commodities. Bangabandhu took steps to provide generous government subsidies for agricultural inputs and price support for farm outputs to increase farm profits. During this period, irrigation facilities were expanded, high-yielding varieties (HYVs) were introduced and cooperative farming was encouraged. Bangabandhu's Government ensured the highest allocation of 31 percent of the total outlay for agriculture and rural development during the first five year plan. Bangabandhu visited Bangladesh Agricultural University in February 1973 where he asked agricultural graduates to go to the field to work with farmers for doubling food production. He urged farmers to bring every inch of land under cultivation. In his speech, Bangabandhu laid down his vision for agricultural development in the country. The progress that Bangladesh achieved now in the agriculture sector, which is widely acclaimed all over the world, is testimony of farsightedness of Bangabandhu's vision. The fulfillment of Bangabandhu's vision in the changed socio-economic context of the country is a continuing task which is being carried out under the guidance of Prime Minister Sheikh Hasina, eldest daughter of the Father of the Nation.

Agricultural Growth

Agricultural sub-sectors are broadly classified as crops, livestock, forestry and fisheries. The gross domestic product (GDP) coming from these subsectors are regarded as agricultural GDP. The share of agricultural GDP to total GDP of the country was about 50 percent in 1973-74. It has declined to 13 percent in 2020-21 because of the rapid increase in the share of manufacturing, industry and service sectors to the national

GDP. But total agricultural production continued to increase to cater the needs of the growing population of the country. Agricultural growth was recorded at around 7 percent in 1972-73 that decelerated to around 2.5 per cent per year during the 80s. Over the past decade agricultural growth in the country hovered at about 3.9 percent per year. At the same time, the total GDP of the country experienced a growth rate of about 7 percent per year. Per capita income of the country increased to US$2,591 in 2020-21 from about US$100 in the early 1970s. The incidence of poverty declined to about 20 percent from the peak of 80 percent after liberation. Agricultural growth contributed significantly to the overall growth of the economy and general well-being of the people of Bangladesh.

Structure of Agricultural Subsectors

Bangladesh agriculture is dominated by the crop sub-sector. Until the late 1980s, farmers were concentrating more on crop production, particularly on rice production. It was due to incentives provided by the state to favour rice production in a race to maintain growth in the production of the staple food at pace with population growth. Farmers' response to the government's policy was enthusiastic. Many converted low lying areas traditionally used for fish production into rice producing areas. However, there has been a change in the incentive structure that has led to a shift of preference in recent years for agricultural diversification. Consequently, the share of crop sub-sector to total agricultural GDP has declined to 50.64 percent in 2019-2020 from 78.9 percent in 1979-80, while the combined share of livestock, forestry and fisheries has increased to 49.36 percent from 20.10 percent over the same period (Table 1). The change in the share of agricultural GDP was remarkable for the fisheries subsector.

Table 1: Change in the composition of real agricultural GDP (%) over time

Subsectors	1978-79 to 1979-80 (average)	2019-20
Crops	78.9	50.64
Livestock	7.43	10.74
Forestry	6.57	12.28
Fisheries	7.09	26.34

Source: GOB (2020b) and previous issues.

Crop subsector

Agricultural land use by crops over time shows an increase in rice acreage but a decline in acreage for jute and sugarcane (Table 2). The area under potato and vegetables has also increased. However, the extent of crop diversification is low (Alam, 2005) because cereals alone occupy little more than 74 percent of the cropped area of the country. The extent of coverage of HYV seeds now accounts for about 80% of rice and 100% of wheat and maize areas, which were below 10% immediately after independence in 1971. The consumption of chemical fertilizers has also increased significantly over time from

1.3 mmt in 1984-85 to 5.9 mmt in 2019-20, but the unbalanced use of fertilizers has led to a deterioration of soil health.

Table 2: Agricultural land use by crops over the census years

Crops	% of gross cropped area		
	1983-84	1996	2008
Aus	23.6	14.5	8.35
Aman	36.6	36.9	30.75
Boro	9.6	21.4	33.14
Total rice	69.8	72.8	72.24
Wheat	4.1	5.3	2.11
Jute	5.4	4.5	3.58
Sugarcane	1.2	1.1	0.72

Source: BBS.

There has been a significant increase in production of different crops in the country over the last five decades. The production of food grains increased from about 100 million tons in 1971-72 to 454 million tons in 2019-20, giving an average growth rate of 3 percent per year. This was much higher than the world rate of 2.4 percent per year. In spite of a high population growth rate of about 2 percent per year, the per capita availability of food increased from 456 grams in 1972 to 522 grams in 2000 and 687 grams in 2020. Other than foodgrains, production of vegetables, potatoes and fruits has also increased significantly. Bangladesh is a small country but occupies third position in rice and vegetables production, second in jute production, seventh in mango, eighth in potato and guava, and second in jackfruit production in the world.

Bangladesh is currently said to be a surplus country in rice production.The country has recently exported about 50 thousand tons of rice to a SAARC country. This does not mean that there is no shortage of food in Bangladesh. Evidence shows that there is still some deficit in food production and the gap is met through imports.The average quantity of food grains imported per year was 5.04 million metric tons for the last ten years (2010-11 to 2019-20). In 2020-21, the country imported 6.7 million metric tons of which 1.36 mmt was rice and 5.34 mmt was wheat. The requirements for foodgrains import increased in bad harvest years and declined in good harvest years. The import payments for other agricultural commodities, such as spies, oil seeds, edible oil, pulses and sugar increased sharply over time. It is expected, however, that the food deficit would be met from an increase in domestic production in the near future.

Export of agricultural commodities from Bangladesh has increased significantly over time. The country exportedprimary commodities of US$ 1 thousand 5 hundred 6 million in the 2020-21 financial year which was only about 2 hundred million per year in the early 1970s. The share of primary commodities in the total export earnings has declined due to sharp increase in export of readymade garments and knitwear. Nevertheless, the absolute amount of export receipts from primary products has increased significantly over time due to increase in export volume and diversification of products.

Land Utilization Pattern

After independence, Bangladesh had 59 percent of approximately 14.8 million ha of total land under cultivation. With the increasing population pressure, cultivable area has been reduced and now stands at 53.5 percent of the total land area. The remaining areas are covered by water bodies, human settlement, forests, and roads etc. The land available for cultivation has shrunk mostly because of urban and residential encroachment. During the period from 1983-84 to 2008, cultivable land of the country has declined by 0.74 percent per year.

Currently, the forests occupy 17.52 percent of the land area. This figure is 1.52 percent higher than that of 16 percent in 1974. However, in reality, this may not be the case (BARC, 2012). The actual tree-covered area is reported to have fallen much below the estimated level.

The country’s arable land area is estimated at 8.24 mha. This is composed of 28.40 percent single cropped area, 47.57 percent double cropped area, 15.53 percent triple cropped area and 8.52 percent cultivable waste and currently fallow. Over time, the double and triple cropped areas have increased with the innovation and adoption of new technology in agriculture. The cropping intensity is currently estimated at 197 percent. It was 151% in 1970 (Table 3). The increase in cropping intensity is largely attributed to high pressure on land for attaining food security. The current cropping intensity ratio of the country can be favorably compared with that of other regions of the world. The recent data shows that the world average cropping intensity is 113%, much below the intensity of cropping achieved by farmers in Bangladesh.

Table 3: Intensity of cropping in Bangladesh

Year	Cropping intensity (%)
1969-70	151
1979-80	153
1983-84	170.84
1996	173.95
2008	172.64
2010	181.00
2020	197.00

Source: BBS and Department of Agricultural Extension, Dhaka.

Irrigation Coverage

Irrigation affects the land use pattern of a country significantly. It facilitates adoption of high yielding crop varieties leading to increases in crop yield and also multiple cropping. Currently, about 63 percent of the cultivated area is irrigated and about 69 percent of the farm holdings are reported to have been irrigating their land (Table 4). The irrigation coverage of the country has significantly increased over time. FAO (1999) estimated that about 86 percent of the cultivable land in Bangladesh can be brought under irrigation. It means that the country has further potential for crop intensification. There are also problems of excess water (flooding) in some periods of the year and water scarcity in other periods.

Table 4: Irrigation coverage in Bangladesh according to different Agricultural Censuses

Coverage (%)	1983-84	1996	2008
Farm holding reporting irrigation	43.3	64.2	68.62
Irrigated area to cultivated area	19.9	48.3	62.96

Source: BBS

Currently, groundwater and surface water cover 77 percent and 23 percent, respectively of the total irrigated area. About 70.0 percent of the irrigated area is covered by Boro rice, grown during January-May. Aman rice, wheat and potato cover about 9.02 percent, 5.24 percent and 5.25 percent, respectively of the total irrigated area. The remainder of the crops including vegetables and sugarcane cover only about 11 percent. At present, the amount of pumping out of groundwater from the aquifers greatly exceeds the amount of recharge resulting in lowering of groundwater levels at alarming rates (BARC, 2012). This has created environmental problems in some areas of the country.

Climatic Condition

The climate of Bangladesh is generally sub-tropical in the north to hot humid in the south. Southwest monsoon influences the climate during June to October. During winter, the climate is controlled by the northeast monsoon from November to March. The summer is hot and humid and the winter is mild.

Several studies indicate that the climate is changing and becoming more unpredictable every year in Bangladesh. One of the most significant impacts of climate change is the rise of sea level. The sea level has risen by 17 to 20 centimeters over the last century. Sea level rise affects agriculture in three ways, i.e., by salinity intrusion, by flooding and by increasing cyclone frequency and its depth of damage. Combined effects of these three factors decrease agriculture production in the coastal zone.

Climatically, Bangladesh is one of the most vulnerable and risk-prone countries in the world. It contributes only 0.3% to global CO_2 emissions, but bears the most dangerous consequences of climate change. Evidence of some selected countries on the basis of total greenhouse gas (GHG) emissions in 2010 shows that more than 52 percent of total global greenhouse gas (GHG) emission is contributed by only five countries (China, United States, Russia, India and Japan), but they are not the worst sufferers.

Due to global warming, the average temperature of Bangladesh is likely to increase 1 degree Celsius by 2030, 1.4 degree Celsius by 2050 and 2.4 degree Celsius by 2100. As a result, natural hazards like floods, droughts, cyclones and salinity intrusion are likely to be aggravated by climate change and sea level rise. Flood and water logging in the central region, flash-flood in the northeast region, drought in the northwest and southwest region, and salinity intrusion and coastal inundation in the coastal regions would be a more acute problem in future. All of these will have an extra bearing on the agriculture sector.

Livestock subsector

Livestock population in Bangladesh is currently estimated to comprise 25.9 million cattle and buffaloes, 30.0 million goat and sheep, and 356.32 million poultry (DLS, 2020). The annual growth rate of large animals was worked out at 0.63 percent between 1983-84 and 2008. The growth rate of small animals was calculated at 0.78 percent. Chicken and duck population showed a significant increase over that period with an annual growth rate of 2.42 percent (GOB, 2010). Bangladesh now produces 10.68 mmt milk, 7.67 mmt meat and 17364 million eggs per year. The country has achieved self sufficiency in meat and egg production but remains deficit in milk production (Table -5). The deficit accounts for 30 percent or 4.5 million metric tons (mmt). Consequently, the country has to depend on milk imports to satisfy its domestic demand. The expenditure on import of milk and milk products increased from US$106 million in 2009-10 to US$366 million in 2019-20, the average being US$258 million per year from 2009-10 to 2019-20.

Table 5: Production, requirements and deficits of livestock products (2019-20)

Products	Total production	Total requirement*	Total deficit/surplus (percent)
Milk (mmt)	10.68	15.20 @ 250 ml/day/head	(-) 4.52 (29.74)
Meat (mmt)	7.67	7.30 @ 120 gm/day/head	(+) 0.37 (5.08)
Eggs (mn)	17364.0	17326.0 @ 104 number/year/head	(+) 38.00 (0.22)

Source: DLS, 2020; mmt = million metric ton; mn = million number

Bangladesh has a relative density of livestock population well above the averages for many other countries in the world. It occupies 12th position in cattle and 4th position in goat population on a global scale. But the production per animal and bird is very low. This is attributed to prevalence of widespread livestock diseases, acute feed shortage, poor genetic quality of livestock species, and their low productivity.

Bangladesh produces about 25 crore square meters of hides and skins per year of which 64.8% is contributed by cattle alone.The contributions of buffaloes, goat and sheep to total quantity are 2.2%, 31.8% and 1.2%, respectively. The export value of leather and leather products was US$692.6 million in 2012-13 that increased to US$1285 in 2020-21. But the prices of raw hides and skins at home have drastically declined. Besides, there is significant wastage at the field level. This requires improvement in management and deserves attention of the policy makers.

Fisheries subsector

The fisheries sub-sector in Bangladesh is broadly divided into inland and marine fisheries. The country is very rich in inland water bodies which include rivers, canals, *beels*, floodplain, ponds, *baors* and lakes. Total inland waters are estimated to cover 4.7 million hectares of which about 83 percent are open waters and 17 percent closed waters. The country also has a long coastal belt of 480 km. The economic zone extends up to 200 miles from the coastline. The marine water area is estimated to be 16.6 million hectares which accounts for about 77 percent of the total water resources available to the country.

There are 260 species of freshwater fish and 63 species of shrimp and prawn available in Bangladesh. Some of the freshwater fish species have, however, become locally extinct. The number of marine fish species is 475, of which 65 are exploitable for commercial purposes. In addition, there are 25 species of edible tortoises, 11 species of marine crabs, 4 species of freshwater crabs and 3 species of edible lobsters. Bangladesh thus has a substantial natural as well as physical and biological resource base for stimulating fish production both for nutritional and commercial purposes. Nevertheless, these resources have not, so far, been exploited to their optimal level.

Table 6: Fish production (lakh metric tons) in Bangladesh

Fishery type	Production (lakh metric tons)	
	1983-84	2019-20
Open waters	4.72 (62.68)	12.50 (27.87)
Closed waters	1.17 (15.54)	25.57 (57.01)
Total Inland waters	5.89 (78.22)	38.07 (84.88)
Marine waters	1.64 (21.78)	6.78 (15.12)
Grand Total	7.53 (100.00)	44.85 (100.00)

Bracketed figures are percentages of total fish production.

The gross production of fish shows an increasing trend, rising from 7.53 lac metric tons in 1983-84 to 44.85 lac metric tons in 2019-20 (Table-6). The annual growth rate of total fish production was calculated at 4.96 percent over the 36 years. The highest growth rate was observed for closed water fisheries (8.57%) followed by marine water (3.94 percent) and open water (2.70 percent) fisheries. Over time, the contribution of closed water fisheries has significantly increased mainly due to modern fish culture. Hilsa production in Bangladesh has broken all records in recent years. The country occupies the top position in Hilsa capture on a global scale. Bangladesh harvested about 5.5 lac tons of Hilsa fish in 2020-21.The observed growth rate was over 4 percent in recent years. Hilsa production increased gradually because of the ban on fishing in the sea, and on catching jatka.

Fisheries sub-sector contributes 1.20 percent to the nation's foreign currency earnings. Bangladesh exports quality frozen shrimp and other fish and fish products to EU, USA, UK, Japan, France, Hong Kong, Singapore, Saudi Arabia, Sudan and other countries. In FY 2020-21, the country earned US$465.17 million by exporting shrimp and frozen fish. The export of fish and fish products is gradually increasing and there is high demand for fish meal for livestock (poultry, cattle farming) and aquaculture sub-sectors which will require more supply of fish in future.

Forestry subsector

Total forest land area of the country is currently estimated at 2.60 million hectares. Of this, 2.2 million hectares (84.6 percent) is Government owned and the remainder is privately controlled land scattered all over the country. Table 7 shows that 53.8 percent of the total forest area are hill forests and unclassified state forests, 3.8 percent are plain land *Sal* forests and 15.4 percent are village forests, tea and rubber gardens. The Sundarban forest land (mangrove forests) in Bangladesh accounts for 27 % of the total forest area. Out of 64 districts, 28 districts had no public forest in the past. But now almost all the districts have been brought under forest coverage through the social forestry programme.

Table 7: Forest area in Bangladesh by type

Forest type	Area (mha)	% of total forest area
Sundarban Mangrove Forest	0.7	27.0
Hill Forest and Unclassified State Forest	1.4	53.8
Plain Land *Sal* Forest	0.1	3.8
Village Forest, Tea and Rubber Garden	0.4	15.4
Total	2.6	100.0

It has been suggested that around 25 to 30 percent of the total land area of any country should be kept under forestry in order to maintain an appropriate ecological balance. In Bangladesh, only about 17 percent of the total land area is under forest or potential forest land. The forest area is said to have increased from 16 percent in 1974 to 17.5 percent in 2008-09 due to social and participatory programs of the Government and NGOs. This area is not, however, covered with trees. Recent statistics of SAARC countries shows that only 11.04 percent of the total land area of Bangladesh is covered with trees compared to 23.11 percent in India, 25.36 percent in Nepal, 85.8 percent in Bhutan and 29.19percent in Sri Lanka.

The Forest Department controls all classified state forests (67 percent of total state owned forests) and the local authorities (District Councils of three hill districts, namely Bandarban, Khagrachori and Rangamati) administers the unclassified state forests (33% of total state owned forests). Natural forests in Chittagong belt and Madhupur belt have been heavily depleted. Trees are felled, but not replaced immediately. Influential people take such deforested land on lease for industry or other purpose. Because of land scarcity, there is forest depletion due to urbanization, industrialization and road construction. Lack of initiative by FD for immediate afforestation is the vital cause of reducing forest areas. Local people also fell trees, sometimes within and sometimes beyond the knowledge of FD staffs. They are poor people and they do it for survival. The poverty-stricken people living around the forests are involved in ruthless illicit felling of the resources. Hill tribes have access to USFs for practicing shifting cultivation where uncontrolled felling of trees has continued over the years, leading to soil erosion and degradation of land in these areas.

Forests supply a variety of products, such as timber, firewood, bamboo, golpata, sungrass, honey, wax, fish and raw materials for industries. The total production of forest products has been declining over the years. Thus, the demand and supply gap has continuously widened. Currently, only about 61% of the government-controlled forest is productive. However, this area has been so over-exploited that the present tree cover area has come to the minimum level. Widespread destruction, clearing of forestland for homestead and agriculture, low priority to agro-forestry etc., have been the common scenario of this country that undermined the success of forestry activities.

Sustainable Agriculture

Sustainability is defined as the practice of reserving resources for future generation without any harm to the nature and other components of it. Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable agriculture consists of environmentally-friendly methods of farming that allow the production of crops or livestock without damage to human or natural systems.

Of the UN's 17 Sustainable Development Goals (SDGs), Goal 2 has specific focus on promoting sustainable agriculture. Specific targets for Goal 2 include ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture.

Agriculture in Bangladesh has changed dramatically, since independence. Food productivity soared due to new technologies, mechanization, increased chemical use, specialization and government policies that favored maximizing production. These developments have had many positive effects and reduced many risks in farming, but there have also been significant costs. Prominent among these are topsoil depletion, groundwater contamination, decline of family farms, increasing costs of production, reducing farmers' profit, and the disintegration of economic and social conditions in rural communities. A growing concern has emerged during the past few years to question the role of the agricultural establishment in promoting practices that contribute to these social problems. Now a day, this concern for sustainable agriculture is getting increasing support and acceptance within mainstream agriculture. Not only does sustainable agriculture address many environmental and social concerns, but it offers innovative and economically viable opportunities for growers, laborers, consumers, policymakers and many others in the entire food system. The following issues are very important for ensuring sustainable agriculture in Bangladesh.

1. Optimum use of land resource
2. Land zoning
3. Planned housing
4. Productive use of fallow lands
5. Austerity in acquisition of land
6. Intensive crop production
7. Extensive coverage of farm mechanization
8. Minimize yield gap
9. Introduce eco-friendly and stress tolerant varieties
10. Maintain biodiversity
11. Diversify agriculture
12. Develop non-crop agriculture (NCA)
13. Develop quality breed and feed for livestock
14. Preserve water bodies
15. Intensify fish culture
16. Ensure optimal use of water resources
17. Maintenance, preservation, and extension of forests
18. Ensure extension services for agro-forestry
19. Minimize cost of production
20. Develop agro-processing
21. Achieve gender equality
22. Ensure commercialization of agriculture
23. Introduce good agricultural practices
24. Promote use of quality agricultural inputs
25. Increase farm income
26. Increase public investment in agriculture

Conclusion

The dream of Bangabandhu for achieving higher food production and ensuring food security in the country has largely been achieved over the last five decades. But there are areas that need improvement and intervention for further development of the agricultural sector. Bangladesh plans to become a high middle income country by 2031 and a high income country by 2041. Meanwhile, the SDG targets compel the country to end poverty and hunger by 2030. This will require a high growth rate of GDP from 8 to 10 percent per year. Agricultural sector has to grow by 4 to 5 percent per year in order to support high GDP growth and increasing demand for food. It is possible to achieve such a high growth in agricultural production through proper utilization of land and other resources available in the country. In that case, the present cultivation practices have to be made more intensive and dynamic in near future. Moreover, environmental and sustainability issues have to be taken care of properly. A major challenge would be to frame policies, create institutions and human resources, and develop technologies that make the two goals more compatible. Recent experiences suggest that agricultural development can eradicate poverty and hunger together without making any compromise with sustainability issues. But the challenges are versatile and needs to address in a comprehensive and participatory manner. Farming has become a less remunerative occupation in these days. Farmers are suffering from lack of confidence in farming. They have to be supported by the state to make them interested in intensive farming. For that reason, a much higher investment in agriculture would be required and farming has to be considered as a sector of top priority. Input subsidy has to be increased. Provision has to be made for output subsidy. Budgetary allocation for research and extension has to be increased to about 10 percent in near future from the current 1.5 percent of agricultural GDP.

Bangabandhu made a call to respect farmers. His eldest daughter Prime Minister Sheikh Hasina also made a call to respect them. This should be incorporated in our agricultural policy. This will help recognize agriculture as a respectable profession in the country.

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Non-conventional Methods of Alginates Extraction from Seaweed: Influence on Properties and Application

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Abstract

Alginates are natural linear polysaccharides of brown seaweed cell walls, which is highly biocompatible that confers huge interest for the food, biotechnology, cosmetics, and pharmaceutical industries. Different conventional methods are being used to extract alginates from brown seaweed for several decades although these methods have some limitations in terms of yield, properties, and application. Very recently, some non-conventional methods such as Microwave-assisted Extraction, Ultraviolet assisted Extraction, Enzyme assisted extraction have been getting popularity serving time-saving, non-destructive, quantitative, and cost-effective facilities which have enormous potential to overcome major drawbacks of conventional methods and is also successfully applied to the extraction of alginates. These methods have several advantages like higher yield, higher processing speeds, lower solvent consumption, etc. However, there is no comprehensive information on non-conventional methods of alginates extraction and their influence on properties and application. Therefore, the present review aims to give an outline of the available non-conventional methods of alginates extraction and their effect on compositional properties, functional properties, and biological properties. In addition, higher extraction efficiency of nonconventional methods of alginates extraction also is discussed.

Keywords: Alginates, microwave assisted extraction, ultra sound assisted extraction; enzyme assisted extraction.

1. Introduction

Seaweed or Macroalgae is a large and diverse group of plants, which can be unicellular and multicellular organisms. Seaweeds are classified into three groups depending on their pigmentation and chemical composition: brown (Phaeophyceae), red (Rhodophyceae) and green (Chlorophyceae) (Mišurcová et al. 2014). Brown algae becomes an important topic in research as it is a rich source of bioactive molecules such as polysaccharides, proteins, fatty acids, amino acids, dietary fiber, vitamins, minerals, sterols, pigments, polyphenols, etc. These bioactive compounds possess a broad spectrum of biological activities like anti-inflammatory, anti-oxidative, anticoagulant,

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anti-aging, antithrombotic, anti-cancer, anti-viral, and antibacterial (Zhao et al. 2018; Rafiquzzaman et al. 2013; Rafiquzzaman et al. 2015a, Rafiquzzaman et al. 2015b). Polysaccharides, one of the most important groups of bioactive compounds, significantly contribute to the biological potential of brown algae. Over the last decade, increasing interest has been observed about different types of polysaccharides in brown algae cell walls, including fucoidans, alginates and laminarins, which can be greatly influenced the biological applications in functional foods, cosmeceutical and pharmaceutical products (Jiao et al. 2011).

Alginate is one of the potential polysaccharides of brown seaweeds that can form heat-stable gels with some divalent metals. It is an ionic polysaccharide consisting of β -D-mannuronic acid (M) and α -L-guluronic acid (G). These units can be arranged as homogeneous blocks MM or GG and alternate as MG as randomly distributed in a linear chain. The proportion of these three types of blocks and the seaweed source influenced the physical properties of alginates. MG ratio of alginates determines gelling properties and viscosity; high G means higher gelling properties and high M means higher viscosity. Alginates are mostly used in industries to give consistency (viscosity) or to form gels. It is used in textile prints, baked foods, beer foam stabilizers, pill disintegrators, welding rods, bandages and dental impression material, among many others. Alginates are now also used for medicinal purposes like lower cholesterol levels, treat gastric ulcers, and inhibit the granulation of mast cells (Nagaoka et al. 2000). More recent applications are as proteins carriers (Coppi et al. 2001), metal interchangers (Davis et al. 2004; De Stefano et al. 2005), textiles (Goren š ek and Buko š ek, 2006), yeast immobilization (Pajic-Lijakovic et al. 2007), microbeads (Schuldt and Hunkeler, 2007), UV ray absorption (Tavares- Salgado 2007) and control of ulcerative colitis (Alireza-Razavi et al. 2008). By using many different conventional methods alginates were extracted from brown seaweed for several decades. However, they have some limitations in terms of extraction efficiency like lower alginate yield, time consuming, required higher amount of solvent etc. The extraction process should be time-saving, non-destructive, quantitative, and cost-effective. To achieve higher extraction efficiency some advanced non-conventional extraction methods are being developed and have been developed. Microwave assisted Extraction, Ultraviolet assisted Extraction, Enzyme assisted extraction are the most studied non-conventional extraction methods for alginate extraction. In recent years, these methods have shown enormous potential to overcome major drawbacks that outcome from conventional techniques, being also successfully applied to the extraction of alginates (Figure 1). These methods have numerical advantages like higher yield, higher extraction speeds, lower solvent consumption, etc. Compositional properties, functional properties, biological properties of alginate are also influenced by these non-conventional extraction methods compared to the conventional method. Table 2 summarized the influence of non-conventional extraction methods on different properties of alginates.

2. Microwave Assisted Extraction (MAE)

2.1 Extraction Method

Microwave Assisted Extraction (MAE) is one of the most popular and cost-effective extractions available to date. There are two main types of MAE, classified as open and closed vessel systems (Kadam et al. 2013). The closed vessel system is used for the extraction of targeted compounds at higher temperatures and pressure but has potential explosion risks (Heng et al. 2013; Grosso et al. 2015). Thus, MAE with an open vessel system is more preferable. This vessel system is used for extraction carried out under atmospheric pressure conditions (Kubrakova and Toropchenova, 2008). Heat is generated directly within the material by ionic displacement of dissolved ions and/or dipole rotation of polar solvent. Non-polar compounds are not heated when exposed to microwaves. An effective cell wall rupture will occur as a result of rapid internal heating during MAE which releases the intracellular compounds into the extraction solvent (Yuan and Macquarrie, 2015a). Cuticular layer destruction is also stimulated by microwave radiation (Rodriguez-Jasso et al., 2011). MAE has been successfully used for the isolation of polysaccharides and various bioactive compounds from seaweeds and other plants (Yuan et al. 2018; Dang et al. 2018; Magnusson et al. 2017; Chen et al. 2017).

MAE extraction efficiency depends on few factors like power and frequency of the microwave, extraction time, concentration of solvent, characteristics of the matrix, ratio of solid to liquid, extraction pressure, number of extraction cycles, and most important properties of the solvents and temperature (Tatke and Jaiswal 2011; Heng et al. 2013). MAE shows more effective results in terms of extraction time, less solvent, higher extraction rate and lower cost, over the conventional method of extraction of compounds (Delazar et al. 2012; Ganzler et al. 1986). Rapid heating (in few seconds) of the targeted matrices can be gained through microwave irradiation which causes the direct generation of heat within the matrix through friction and collisions between molecules. But in the conventional extraction method, it heats only at the surfaces of the matrix and subsequently heating is by conduction from the surfaces to the core of the matrix particles which consume more time and energy (Grosso et al. 2015). MAE requires 3 times lower solvent volume when considering method efficiency is much lower than the conventional method (Yuan and Macquarrie, 2015a).

Internal pressure builds inside the cell of plant material as the quick elevation of temperature occurs from microwave energy penetration. The high interior pressure may destroy the cell wall of plant material and release bioactive compounds into solvents easily (Chan et al. 2016). Reduction of mechanical strength in MAE and dehydration of cellulose promotes the solvent to penetrate into the cellular channels as a result of high temperature which facilitates the improvement of extraction yield (Sun et al. 2016). Higher crude extract yield does not mean higher amounts of bioactive compounds, there is a possibility of higher amounts of impurities which can explain higher yields obtained by conventional methods compared to MAE in others research (Yuan and Macquarrie, 2015a; Okolie et al. 2019). These contradictory results may vary in differences in extraction protocols, extraction conditions, algae species, harvest time and origin (Okolie et al. 2019). In the work of Silva et al. (2015) it was demonstrated that the determination of the optimal acid pretreatment conditions for *Saccorhiza polyschides* is 40 mL of 0.1M HCl per g of dried seaweed with constant stirring at 20ºC during 14 h which significantly enhanced the yield of alginates in MAE.

2.2 Influence on Yield

Extraction parameters influence the polysaccharides yield like microwave power, irradiation time, temperature and pressure in MAE and these parameters should be optimized. In MAE optimal conditions at 10 min, 90 ºC, 800 W was found by Cao et al. (2018) and 20 min, 70 ºC, 600 W by Ren et al. (2017). Polysaccharides extraction yield increased significantly with increased time, temperature and power in case of *Sargassum pallidum* and *Sargassum thunbergii*. Yuan and Macquarrie (2015b) viewed a parallel trend for time and temperature influence on *Ascophyllum nodosum*polysaccharides, where the utmost yield was achieved at 120 ºC for 15 min. The alginate yield of the alginate only process was 23.13%, which is about 5% higher than that from the biorefinery process (18.24%). They drew a conclusion there was some loss of alginate during the first fucoidan extraction step, but the majority of alginate could still be recovered in the extraction step. Compound solubility, diffusion rate and mass transfer in the solvent may improve with increasingtemperature which reduces the viscosity and surface tension (Fayad et al. 2017). Ruslan et al. (2019) investigated in *Sargassum sp.* that the highest yield of sodium alginate (37.13%,) was obtained at power level 80 where the yield at power 90 level yield was decreased (23.36%). This is because the process of extracting the MAE strategy can increase the breakdown of cell walls due to the microwave radiation beam in *Sargassum sp*. Ruslan et al. (2019) also investigated the time variation, the highest yield (37.13%) was obtained in the extraction for 16 minutes, while the lowest yield (25.76%) was in 18 minutes extraction. Table 1 summarized the comparison of alginate yield between Conventional and Nonconventional MAE extraction methods.

2.3 Influence on Composition

MAE extracted polysaccharides showed higher concentration of sulfate groups (Okolie et al. 2019; Ren et al. 2017). Chhatbar et al. (2009) studied that Poly-mannuronic acid (PMA) and the poly-guluronic acid (PGA) ratio of MAE extracted polysaccharides from *Sargassum wighitii* was M/G 0.38, which was similar to that (M/G 0.39) obtained by the conventional method. Ruslan et al. (2019) found variation of water content, ash content, viscosity depending on extraction time frame in the compositional study of MAE extracted sodium alginate from *Sargassum sp*. The water content of sodium alginate extraction for 16 minutes showed low water content (14.43%) and the highest water content (18.74%) in the extraction for 18 minutes in the MAE method. The ash content of sodium alginate extraction results in the range of 14-21% which meets quality standards alginate. Sodium alginate extracted by MAE for 18 minutes shows the highest viscosity (95.00 cps) while the lowest viscosity (15.00 cps) in the extraction for 16 minutes. Yuan and Macquarrie, (2015b) found a similar and high M/G ratio (1.5) in

MAE extracted alginate from *Ascophyllum nodosum* with compaering biorefinery process and alginate only process.

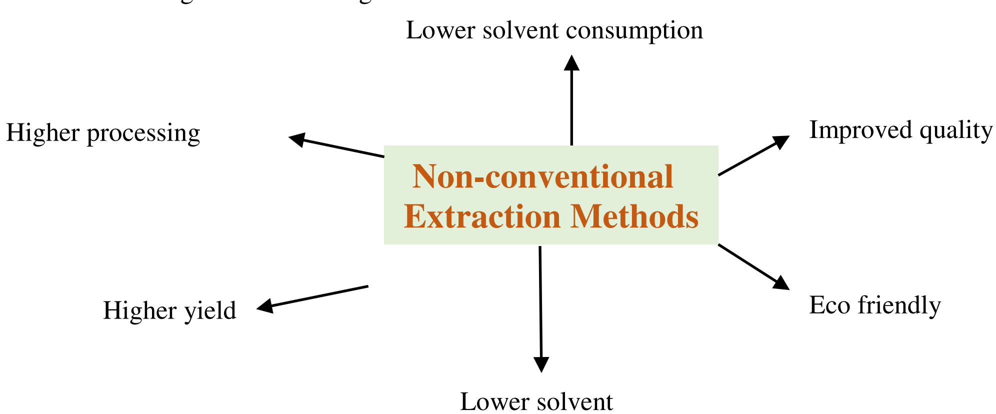
2.4 Influence on Structure

Polysaccharides obtained by MAE have lower molecular weight (Okolie et al. 2019; Ren et al. 2017). Yuan and Macquarrie (2015b) also found variation in molecular weight of MAE extracted alginate from *Ascophyllum nodosum,* the molecular weight of alginate from alginate only process was 195.3 kDa and from biorefinery process was only 75.13 kDa. This reduction may occur due to the acid treatment and extra heating during the first fucoidan extraction, which might cause partial depolymerization of the alginate. Ruslan et al. (2019) studied the Fourier-transform infrared spectroscopy (FTIR) analysis of MAE extracted alginates from *Sargassum sp*, where FTIR spectra results showed the presence of hydroxyl (- OH) functional groups at wave numbers 3448.7 cm^{-1} and 1620.21 cm^{-1}; C-H bond at 2931.8 cm^{-1}; alkene group at 2337.7 cm^{-1}; sodium (Na) bond at 1419.61 cm^{-1}; carbonyl group at 1095.57 cm^{-1} and carboxylic and ketone groups at 1033.85 cm^{-1}.

2.5 Influence on Application

MAE extracted polysaccharide showed higher hydroxyl radical scavenging activity and antioxidant activity as well as potential hypoglycemic activity (Ren et al. 2017). This may be due to the lower molecular weight and higher sulfate groups content of extracted alginate. Yuan and Macquarrie (2015a) also found higher antioxidant activity due to lower molecular weight after studying MAE extracted alginate from *Ascophyllum nodosum.* They also found that the M/G ratio influences the gelling process and characteristics of alginate gels. Rigid gels were formed from alginate with a low M/G ratio and elastic gels are obtained from alginate with a high M/G ratio (Torres et al. 2007).

Figure 1.: Advantages of non-conventional extraction methods.



3. Ultrasound Assisted Extraction (UAE)

3.1 Extraction Method

Sound waves beyond the audible frequency range (typically, >20 kHz) are known as Ultrasound (Chandrapala et al. 2013). The UAE method is more efficient, inexpensive, simple in comparison to conventional methods and even microwave-assisted extraction (MAE) and supercritical fluid extraction (SFE) methods (Kadam et al. 2013; Chandrapala et al. 2013). Among the novel techniques, UAE is the most practical for the industrial level because UAE is recognized as a simple, faster, higher yield as well as cheaper among the novel methods of extraction (Hanjabam et al. 2019). This method can also be used in combination with other non-conventional technologies, like MAE or EAE (Alboofetileh et al. 2018b). Ultrasound allows greater penetration of solvent into the sample matrix which increases the contact surface area between solid and liquid phase (Rostagno et al. 2003). and the solute can also fast diffuse from the solid-state to the solvent. Higher cell walls disruption, particle size reduction and better contact between solvent and target compounds occurred in UAE as it generates physical forces such as shear, shockwaves, micro jets and acoustic streaming (Ying et al., 2011). This method can significantly increase the extraction yield and reduce extraction time (Grosso et al. 2015).

Efficiency of UAE is largely influenced by various factors like temperature, ultrasound power, time, solvents to solids ratio and characteristics of the compounds to be extracted. Therefore, it is important to optimize the extraction conditions. The study of temperature impact on polysaccharide yield can be done by temperature-controlled UAE equipment. Youssouf et al. (2017) studied the effect of temperature in a range of 30–90ºC and Alboofetileh et al. (2018b) in a range of 70–90ºC. respectively. Youssouf et al. (2017) determined that the extraction yield of alginates was influenced by algae/water ratio, pH and the time of exposure to ultrasounds from *Sargassum binderi* and *Turbinaria ornata*.

3.2 Influence on Yield

Youssouf et al. (2017) investigated the UAE experimental conditions as algae/ water ratio of 10 g/L, pH 12, ultrasounds for 40 minutes and ultrasound power 150 W, which resulted in the highest extraction yield of alginates (54%). UAEfacilitated more alginate yield in 15–30 minutes with ultrasound assistance, where conventional extraction methods permit to obtain 25% alginate yield in 2 h. Thus, the time of the extraction of alginates was significantly reduced. They also demonstrated that the extraction yield of UAE extracted alginate increased linearly with temperature increase and maximum result at 90 ºC. Higher temperature reduced the surface tension and solvent viscosity and increased the vapor pressure which favored the extraction. Cavitation bubbles intensify cellular damage, promote intracellular polysaccharides extraction and improve extraction yield in UAE method where cavitation bubbles form easily (Zhu et al. 2015). The extraction yield of alginates also improved by increasing the ultrasound power from 75 W to 150 W in the case of *Sargassum binderi* and *Turbinaria ornata* (Youssouf et al. 2017). Notwithstanding, hydroxyl radicals can be generated which lead to chemical decomposition by acoustic cavitation in greater ultrasound power (Zhu et al. 2015). Increasing extraction time also showed linear relation with alginate yield as well as fucoidans until they reached plateau at 40 and 30 min separately (Alboofetileh et al. 2018b; Youssouf et al. 2017). Youssouf et al. (2017) noted that pH also had a positive correlation with alginate yield where high pH leads to the formation of water-soluble sodium alginate. Table 1 summarized the comparison of alginate yield between Conventional and Nonconventional UAE extraction methods.

3.3 Influence on Composition

Flórez-Fernández et al. (2019) investigated the influence of sonication time or UV treatment duration on the composition of UAE extracted alginates extraction from *Sargassum muticum*. They found the alginates composition and their gelling capacity markedly influenced by sonication time. They clearly noticed that increasing sonication time has a positive relation with mannuronic acids and M/G ratio, but guluronic acids exhibited a reverse trend. Furthermore, they demonstrated that the strength of the gel can be improved by changing the ratio of M/G with the help of ultrasound. They experimented that the minimum ratio of M/G of alginates treated at 135 kHz was 1.34. UAE extracted alginates did not show variation in terms of sulfate content compared with conventional methods (Alboofetileh et al. 2018b), while some reported higher sulfate concentration obtained by UAE (Hanjabam et al. 2019) and some even lower.

3.4 Influence on Structure

Flórez-Fernández et al. (2019) found that sonication time or UV treatment duration influenced the molecular weights of UAE extracted alginate. A wider range of molecular mass weights at lower mass/charge (m/z) values could occur due to sonication time above 20 min led. While Youssouf et al. (2017) investigated the influence of extraction time during extracting alginates from *Sargassum binderi* and *Turbinaria ornate*. They found Ultrasound allowed the reduction of extraction time by 4 times without affecting the chemical structure and molar mass distribution of UAE extracted alginates. Different ultrasonic frequencies may affect the properties of sodium alginate which is studied by Feng et al. (2017). He found that the molecular weight gradually increased with the increase of the ultrasonic frequency. The molecular weight of the untreated alginates was 1.927×105 g/mol, but the molecular weight of the ultrasound-treatedalginates was gradually increased from 3.50×104 g/mol to 7.34×104 g/mol with the increase of the ultrasonic frequency. And in case of molecular numbers also show a similar trend, where the untreated alginates molecular number was 4.852 ×104 g/mol, but the molecular number of ultrasound-treated alginates was increased and then decreased with the increase of the ultrasonic frequency. At 40 kHz ultrasound frequency UAE extracted alginates showed the maximum value of molecular number was 9.988×104 g/mol. Flórez-Fernández et al also studied the FTIR analysis of UAE extracted alginates from *Sargassum muticum*. He confirmed it as alginates as major signals were found around 3300–3400 cm−1 (O=H groups in the hydrogen bond of the molecules), weak bands at 2900 cm−1 (C=H), 1600 cm−1 (carboxylate O=C=O asymmetric stretching and

C=O asymmetric stretching vibrations of uronic acids), 900 cm−1 (α L guluronic), 810 cm−1 (β mannuronic acid), 880 cm−1 (C1–Hvibration of the β mannuronic acid), 1260 cm−1 could be attributed to the sulfate (S=O) groups.

3.5 Influence on Application

The quality and properties of alginate largely depend on the M/G ratio which determines the application of alginates. Higher mannuronic acids containing UAE extracted alginates have low viscosity which is more flexible and useful to produce polyelectrolyte complexes and nanoparticles and are also widely used in paper, dyeing, or textile industries. High guluronic acids containing UAE extracted alginates have high viscosity which is useful to obtain resistant gels for cosmetic and food applications. The stability of alginates could be enhanced by ultrasound. Flórez-Fernández et al. (2019) clearly illustrated that sonication time has a positive relation with mannuronic acids and M/G ratio, but guluronic acids exhibited a reverse trend in UAE extracted alginates from *Sargassum muticum.* They also found that sonication influenced the gelling capacity of alginates. Feng et al. (2017) found molecular weight and molecular number were increased with the increase of the ultrasonic frequency during studying the effects of ultrasound on properties of sodium alginate. UAE extracted alginates hydrophobic interaction and interfacial activity was increased by ultrasound treatment at 135 kHz. This study may help to explore the effect of ultrasound on UAE extracted sodium alginate which improves the physical properties of sodium alginate as food additives, enzyme and drug carriers.

Table 1. Comparison of alginate yield between Conventional and Nonconventional extraction methods.

Extraction Method Type	Seaweed Species	Origin	Extraction Method	Yield (%dry weight - d.w.)	Reference
Conventional Extraction Method	*Sargassum angustifolium*	Bushehr, Iran	Water Extraction	3.30	Borazjani et al. (2017)
	Colpomenia Peregrina	Caspian Sea, Noor, Iran.	Acid Extraction	3.40	Rostami et al. (2017)
	Sargassum turbinarioides	Nosy Be, Madagascar	Acid Extraction	10%	Fenoradosoa et al. (2010)
	Chnoospora sp.	Fort-Dauphin	Alkaline Extraction	9.2%	Andriamanantoanina and Rinaudo (2010)
	Cystoseira trinode *Sargassum latifolium*	Egypt	Acid Extraction	3.3%, 4.3%	Larsen et al. (2003)
	Saccorhiza polyschides	Angeiras beach, Portugal	Microwave-assisted extraction	from 7.5 to 23.8%	Silva et al. (2015)

Non Conventional Extraction Method	*Ascophyllum Nodosum*	Shetland, UK	Microwave-assisted extraction	18.2%	Yuan and Macquarrie (2015b)
	Sargassum sp.	Gulf of Bima, Indonesia	Microwave-assisted extraction	37.13%	Ruslan et al. (2019)
	Sargassum binderi *Turbinaria ornata*	Mauritius	Ultrasound assisted extraction	27%	Youssouf et al. (2017)
	Sargassum angustifolium	Bushehr, Iran	Enzyme-assisted extraction	Cellulase- 3.47 Alcalase - 3.50	Borazjani et al. (2017)
	Colpomenia Peregrina	Caspian Sea, Noor, Iran.	Enzyme-assisted extraction	Alcalase-3.8% Cellulase-6.6%	Rostami et al. (2017)

4. Enzyme Assisted Extraction (EAE)

4.1 Extraction Method

Some enzymes are capable of cell wall degradation while some other enzymes can cause partial degradation of desirable polysaccharides into smaller fragments. These enzymes are generally used for Enzyme assisted extraction (EAE) of polysaccharides. Plant cell walls consist mainly of cellulose, hemicellulose and lignin make a complex and heterogeneous structure (Abdul-Khalil et al. 2016). Moreover, seaweed cell walls and cuticles are more complicated compared with land plants in terms of physical and chemical characteristics. Seaweed cell walls and cuticles consist mainly of a chemical mixture of sulphated and branched polysaccharides associating with proteins and various bound ions like calcium and magnesium (Polne-Fuller M and Gibor A, 1987). This physical barrier is the main obstacle to extract bioactive compounds or polysaccharides from seaweed (Wijesinghe and Jeon, 2012). For that reason, these complex cell walls breaking down is necessary to extract the targeted compounds. EAE method offers low cost, higher extraction yield, faster extraction rate, less solvent usage, lower energy consumption and is also an eco-friendly method compared with conventional methods (Nadar et al. 2018). EAE method also facilitates the conversion of water-insoluble materials into water-soluble materials (Kadam et al. 2013; Grosso et al. 2015). In addition, the EAE method maximizes the antioxidant and antiviral activities of bioactive compounds while improving extraction yield significantly at the same time (Kulshreshtha et al. 2015).

Commercial carbohydrate hydrolytic enzymes and proteases are mainly used for seaweed polysaccharides extraction. Conventional chemicals have limitations in extraction of fucoidans and alginates as they are closely associated with cellulose and proteins. But commercially available carbohydrate hydrolytic enzymes and proteases have higher capability to break down the complex seaweed cell wall and release the target seaweed polysaccharides (fucoidan and alginate) without significant degradation

(Charoensiddhi et al. 2016). Some of the commercially available enzymes are: (i) Viscozyme (mixture of carbohydrase), (ii) Alcalase (protease), (iii) Celluclast, (iv) Termamyl (amylase), (v) AMG (amyloglucosidase), and (vi) Ultraflo (multiactive β-glucanase) (Chaminda et al. 2015). The extraction efficiency of the EAE method mainly depends on pH, Temperature, type of solvent (water or buffer with appropriate pH), proportion of enzymes substrates to enzymes, agitation, etc.

4.2 Influence on Yield

Alcalase showed better cell wall degradation in EAE method (Alboofetileh et al. 2018a) Borazjani et al. (2017) studied that alcalase and cellulase extracted alginate yield showed a further small increase up to 3.50% comparing water and acid method in case of *Sargassum angustifolium*. While Rostami et al. (2017) demonstrated that Cellulase treatment increased alginate yield up to 6.60% but Alcalase did not improve alginate yield in comparison with conventional water extraction (3.8%). Research by Hammed et al. (2017) revealed that sulfated polysaccharides yield was influenced significantly by extraction stages, hydrolysis time, and enzyme concentration. Table 1 summarized the comparison of alginate yield between Conventional and Nonconventional EAE extraction methods.

4.3 Influence on composition

Borazjani et al. (2017) studied that protease and carbohydrase enzymes extracted alginates have lower amounts of protein contaminations as well as polyphenols compounds in case of *Sargassum angustifolium*. Alcalase and cellulase enzymes extracted alginates possess higher levels of purity and their functional properties are more reliable. The ratio of M/G did not change significantly in enzymatic extraction. Rostami et al. (2017) also stated that alcalase and cellulase extracted alginates have higher purity and lower chemical contamination of polyphenols and proteins the lower molecular weight. EAE extracted sulfated polysaccharide from *Sargassum horneri* resulted highest polysaccharide yield, the highest sulfate content and the lowest protein content by cellulase while AMG, Viscozyme and Alcalase showed downtrend (Asanka et al. 2017).

4.4 Influence on Structure

Borazjani et al. (2017) also found that alcalase extracted alginates possess low molecular weight while cellulase extracted alginates showed greater amounts of low molecular weight from *Sargassum angustifolium*. Chemical structure of EAE extracted alginates was not changed subsequently with employment of different pretreatments. Charoensiddhi et al. (2016) reported as the molecular weight of the extracted polysaccharides from Ecklonia radiata was reduced in EAE method by 20–50% comparing with conventional methods as enzymes hydrolyse certain bonds within alginate and fucoidan molecules. Rostami et al. (2017) illustrated FT-IR analysis of EAE extracted alginates from *Colpomenia peregrina* as follow; presence of characteristic wavenumbers of polysaccharides peaks at two regions of 800-1200 cm^{-1} and 3400 cm^{-1}, hydroxyl groups O–H indicated by the broad and strong signals at 3302 cm^{-1}, C–H stretching indicated by the small absorption signals at 2932 cm^{-1}, at 1604 cm^{-1} (carboxyl groups COO-) carboxyl groups (COO-) in alginates are also presented by signals at 1406 cm^{-1}.

4.5 Influence on Application

Alcalase and cellulase enzymes extracted alginate's functional properties are more reliable as they possess higher levels of purity in terms of protein contaminations as well as polyphenols compounds (Borazjani et al. 2017; Rostami et al. 2017). Alcalase treated alginate stimulated macrophage cells to release nitric oxide, anti-inflammatory cytokines and pro-inflammatory cells as it showed immune enhancer capability. DPPH radical scavenging activity resulted in maximum EAE extracted. So, antioxidant activity was increased in EAE method (Borazjani et al. 2017). Rostami et al. (2017) also reported Alcalase and Cellulase extracted alginate resulted in higher DPPH radical scavenging activity and higher reducing power. Celluclast extracted sulfated polysaccharide from *Sargassum thunbergia* resulted in higher DPPH radical and hydrogen peroxide scavenging activity was assured by Kang et al. (Kang et al. 2019).

Table 2. Influence of non-conventional extraction method on different properties of alginates.

Extraction Method	Influence on properties	Reference
Microwave-assisted extraction	Microwave extracted alginate's M/G ratio was similar to that obtained by the conventional method.	Chhatbar et al. (2009)
	MAE extracted polysaccharides possess lower MW and higher concentration of sulfate groups.	Okolie et al. (2019)
	MAE extracted polysaccharide show higher hydroxyl radical scavenging activity and higher antioxidant activity.	Ren et al. (2017)
Ultrasound assisted extraction	Alginate composition and gelling capacity greatly influenced by Sonication time.	Flórez-Fernández et al. (2019)
	Extraction time reduced 4 times in UAE method without affecting molar mass distribution and the chemical structure.	Youssouf et al. (2017)
	Gel strength of alginate can be improved the by changing the M/G ratio through ultrasound.	Feng et al. (2017)
	Alcalase extracted alginate from *S. angustifolium* was more purified with lower protein and polyphenols.	Borazjani et al. (2017)

Enzyme-assisted extraction	Enzyme treated alginates showed higher antioxidant activity.	(Rostami et al. 2017)
	Cellulase led to the highest sulfate content in alginate.	Asanka et al. (2017)
	EAE reduced molecular weight of the extracted alginate.	Charoensiddhi et al. (2016)

5. Further Challenges Regarding Nonconventional Extraction Methods

Appropriate extraction method selection is a critical decision. Different factors need to be considered like extraction time, cost, solvent types, volume of solvent, recovery rate and greenness of the method for extraction of alginates or any polysaccharides in an appropriate method. Every method has its advantages and disadvantages whether it is conventional or non-conventional. Among all conventional extraction methods, water assisted extraction is a simpler and easier method to extract alginates from various types of macroalgae. But this method may result in degradation of alginates and bioactive compounds as it requires long processing time with high temperature. Contrarily, non-conventional extraction methods are being used to extract alginates from different brown seaweeds efficiently. These non-conventional extraction methods facilitate different advantages like less solvent consumption, shorter treatment time, high extraction yields and also enriched the quality of different properties. UAE can be used alone or combined with conventional extraction methods as it is cheap, effective, simple, and reproducible. But the UAE method is highly dependent on matters and presence of dispersed phase which may reduce the effectiveness of this method. While MAE closed systems possess a risk of explosion as it requires high pressure and temperature. Open MAE system overcomes the explosion risk but it is less precise and requires longer extraction time (Tatke and Jaiswal, 2011). Moreover, microwave heating may have negative effects on bioactive compounds and reduce the recovery of non-polar compounds. EAE can be called the greenest method as it extracts polysaccharides from brown seaweeds without use of any harmful chemical and organic solvent. But this method becomes costly and less economical as it requires excessive buffering (Adalbjörnsson and Jónsdóttir, 2015; Heo et al. 2005; Sari et al. 2016). Though MAE, EAE, UAE methods have higher extraction efficiency and improved alginates in quality but limitedly use in mass production and industries. These methods need skilled people and the initial investment cost is higher. So, researchers and academicians need further studies to make optimized and simple methods regarding safety, implementation cost, sustainability to extract alginates from various brown seaweed effectively.

6. Conclusion

Natural polysaccharides including alginates nowadays become regular use in different sectors like textile, pharmaceutical, food and beverage, and also in biotechnology. Alginates possess various biological functions and become a potential ingredient for cosmeceutical, functional foods, and pharmaceutical products. The market demand for functional foods has increased in the last two decades and is increasing rapidly. Advanced extraction techniques like Microwave-Assisted Extraction (MAE), Ultraviolet Assisted Extraction (UAE), Enzyme Assisted Extraction (EAE) are limited to laboratory research. Therefore, the development of a simple and reliable method for alginates and other marine polysaccharides extraction the standard extraction procedure attains a great interest. According to this review, it can be concluded that there is a lack of information about the non-conventional methods for extracting alginates, use of these methods on large scale, and influences on properties and application, which all warrant further research and innovation.

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Options for reduction of nitrogen loss from rice field in Bangladesh

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Abstract

Rice is the most important option to meet the food demand for the ever-increasing population of Bangladesh and nitrogen is needed the most for potential rice production. However, NH_3 volatilization, de-nitrification and leaching loss of N reduce the nitrogen use efficiency by up to 70%. On the other hand, optimum reactive N (NH_4^+-N and NO_3^- -N) synchronized with other essential plant nutrients is the prime need for increasing crop production and reducing the environmental pollution as well. To increase the NUE, soluble salts of Ca, Mg and K, combined use of organic and inorganic fertilizers, deep placement of USG and slow-release fertilizers reduce 8.8-13.1, 8.82- 12.6, 28-88, 65-96% NH_3 volatilization loss, respectively. Less degree of flooded soil and clay soil reduce nitrate leaching. The use of low N input rice variety without compromising quality and yield should be introduced to reduce N loss through optimum use of nitrogenous fertilizers. Plant growth promoting *Azospirillum*, *Azotobacter* and *Rhizobium* control the N loss through the production of auxins, cytokinins, gibberellins and ethylene as well as a supplement from N fixation. Traditional soil tests, soil test kits, rapid plant tissue tests and leaf color charts help to reduce N loss through optimum use of N fertilizers timely. Reduction of NH_3 volatilization and inhibition of nitrification processes can supply sufficient reactive N (NH_4^+-N and NO_3^- -N) and reduce other reactive nitrogen (ammoniacal NH_3, NO_2, NO and N_2O gases) in the environment. Finally, knowing the weather conditions for effective nitrogen fertilizer application time and amount, congenial soil properties and water conditions by using artificial intelligence (AI) technologies can help to reduce N loss and increase rice production.

Keywords: Reducing nitogen loss, Rice field of Bangladesh, A review.

1. Introduction

Bangladesh is an agro-based country. Rice is the staple food for about 166 million people in the country. The population growth is about 2 million per year, and if the population increases at this rate, the total population will reach 238 million by 2050 (Streatfield and Karar, 2008). An increase in total rice production is required to feed this ever-increasing (337% from 1950-2022) population (Figure 1a). Nitrogenous fertilizers use increased with the increase of time (Figure 1b) except sometimes for DAP. Bangladesh is suitable for year-round rice cultivation. The production of rice is greatly influenced by nitrogen. Because of its high mobility in the environment, urea-N, in particular, has very low efficacy in rice cultivation; often falling between 30 and 40% and occasionally falling even lower (Cao et al., 1984; Choudhury and Khanif, 2004). Ammonia volatilization, de-

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nitrification, and leaching loss of N create some problems, such as reduced available N forms (NH_4^+-N and NO_3^--N) in the soil.

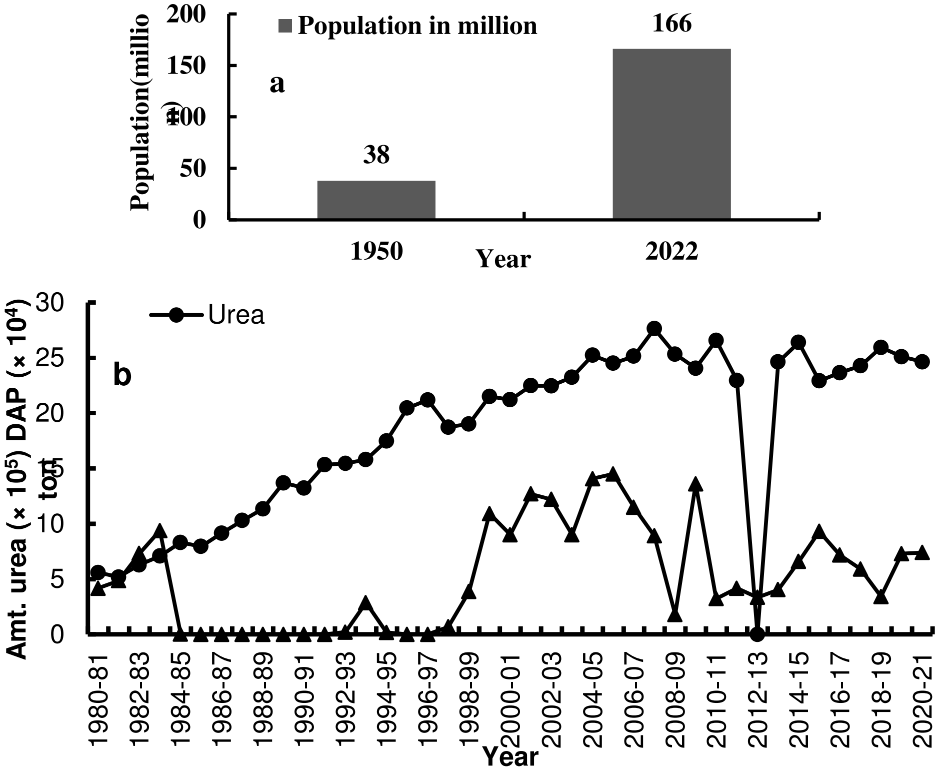

Figure 1. Showing the status of population trend (a) and use of nitrogenous fertilizers (b) in Bangladesh (BBS, 2022)

Nonetheless, it produces ammonia, nitrous oxide, and nitric oxide gases, which create environmental pollution. Nitrous oxide absorbs infrared radiation and contributes to global warming and depletion the stratospheric ozone layer. Agricultural systems produce about 70% of global N2O, which has 300 times more powerful global warming potential than that of CO2, and it is the third most important contributor to global warming (Hungate et al., 2003). N2O level in the atmosphere is increasing at an alarming rate and expected to quadruple by 2050 (Philippot and Hallin, 2011; IPCC, 2014) unless measures are taken to reduce such emissions. On the other hand, the deposition of nitric oxide and ammonia in terrestrial and aquatic ecosystems can lead to acidification, eutrophication, shifts in species diversity, and effects on predators and parasite systems. The leaching of nitrate in groundwater is another catastrophe for human that is exacerbated by the leaching of nitrate. Leaching out of the soil, reactive nitrogen can reach groundwater and surface water bodies, making them unfit for human consumption or use. Additionally, eutrophication in coastal environments is encouraged by reactive nitrogen, which can have a detrimental effect on fish stocks and biodiversity. Combined use of soil organic matter and organic manures or through the application of N fertilizers in effective ways can ensure the optimum supply of NH4+-N and NO3–-N. The optimum supply of NH4+-N and NO3--N to synchronize with crop plant demand via biological and anthropogenic sources governs the role of reactive N in food production (Cheng et al., 2022). In order to increase rice production and lessen environmental pollution, ideal levels of NH4+-N and NO3--N are required. In rice production, farmers apply large amounts of N fertilizer to maximize yield, but only 20–50% of N is taken up by the crop. The resulting loss of the applied N, which is a mobile nutrient leads to increased water and land pollution and greenhouse gas (GHG) emissions (Pan et al., 2016). An appropriate N management strategy is essential to increase nitrogen use efficiency (NUE) and crop yields (Herrera et al., 2016). In light of this, choices are required to investigate the ideal quantity of plant-available reactive N (NH4+-N and NO3--N) by minimizing the loss of N from volatilization, de-nitrification, and leaching pathways.

2. Methodology

The paper is based on the review and use of secondary information published in journals, research magazines, scientific reports, books, proceedings, and training manuals available in the studies conducted by various researchers, institutions, and organizations. The review focused primarily on literature searching and was restricted to articles and report papers published. Published articles were searched and identified from different electronic databases such as the library, Web of Science, AGRIS, Research Gate, Science Direct etc. Based on the review objectives and content types, articles and published reports were retrieved from databases, mainly focusing on empirical results reported on N loss through different pathways. Following a critical review data and literature were compiled and discussed on effective ways and recommendations made to minimize N loss and reduce environmental pollution.

3. Results and Discussion

3.1 Ammonia volatilization

3.1.1 Factors affecting on ammonia volatilization

Ammonia volatilization is affected by a number of factors, such as nitrogen fertilizer management methods (dosage, fertilizer varieties and application time), soil properties (pH and soil type), and climatic conditions such as temperature, sunshine length, and wind speed (Liu et al., 2020). Wang et al. (2018) reported that ammonia volatilization (AV) is one of the most dominant pathways, accounting for 10–50% of the N loss from paddy fields. Rice plants mainly take up NH_4^+-N, which requires less energy for converting ammonium nitrogen to amino acid than nitrate-N. The ammonia volatilization process happens in moderately to slightly acidic soils, although losses are higher in alkaline soils. On the other hand, carbon dioxide-consuming algae and other aquatic biota increase the pH of the floodwater through their photosynthetic activities, which leads to substantial losses of N by ammonia volatilization. The degree of ammonia volatilization depends on the nature of nitrogenous fertilizers. Ammonium fertilizer directly dissociates to NH_4^+, whereas urea fertilizer is decomposed by catalytic hydrolysis to produce NH_4^+-N ions. Ammonium is loosely bound to the water body and converted to non-ionized ammonia (NH_3), which escapes from the water as gas. Loss from ammonia volatilization in flooded soils ranges from negligible to almost 60% of the applied N.

3.1.2 Options for reducing ammonia volatilization

Some options are available to reduce ammonia volatilization in the soil-water system (Table 1 and Figure 3). These include the application of soluble salts of calcium, potassium, and magnesium, use of urease and algal inhibitors, deep placement of nitrogen fertilizers, and use of modified forms of urea and slow-release fertilizers. Efficient irrigation techniques like non-flooding controlled irrigation, dry–wet alternate irrigation, rice intensification (Uphoff et al., 2011), saturated soil culture, and ground cover systems have been proposed as water-use efficient irrigation management methods and have decreased nitrogen loss from paddy fields by 20–40% (Peng et al., 2011).

3.1.2.1 Soluble salts of calcium, potassium, and magnesium

Urea is converted to ammonium carbonate in soil, and this ammonium carbonate is susceptible to NH_3 volatilization. In this regard, nitrate or chloride of calcium, magnesium, and potassium salts with urea can reduce ammonia volatilization. Potassium reduces NH_3 volatilization loss indirectly by increasing calcium carbonate precipitation by replacing Ca^{++} from the exchange complex in high Ca^{++} soil. Application of coated calcium carbide along with urea significantly improved the fertilizer N recovery by the crop (24.4%) and reduced the unaccounted for fertilizer- N (47.6%) over that of sole application of urea (Bandyopadhyay and Sarker, 2007). Christianson et al. (2004) discussed that a mix of KCl or KCl-coated urea performed lower NH_3 volatilization than urea alone. The addition of Mg salts effectively reduced NH_3 volatilization loss from the surface applied urea and thus increased N recovery (Yang et al., 2008; Foster and Zakaria, 1986).

3.1.2.2 Urease and algal inhibitors

Urea is converted to ammonium carbonate after hydrolysis by the urease enzyme. This transformation of N leads to the availability of high concentrations of ammonium ions in the floodwater, which are lost through ammonia volatilization when the pH of the floodwater rises due to the photosynthetic activity of algae. The application of urease inhibitors limits urease activity at the soil surface and allows urea to move into the deeper soil layer before hydrolysis. Released ammonium also remains in the cation exchange complex in the soil (Ohnemus et al., 2021). The urease inhibitors phenyl phosphorodiamidate (PPD) and N-(n-butyl) thiophosphoric triamide (NBPT) reduce successful ammonia volatilization loss. The application of urease inhibitors like hydroquinone and phenylenediamine also increases the agronomic efficiency of urea-N due to reduced ammonia volatilization loss in flooded rice soils. Algal inhibitors can retard the growth of algae, which contributes to the rise of soil pH and thus can reduce ammonia volatilization loss. Freney et al. (1995) found that the application of an algal inhibitor (copper sulfate + terbutryn) decreased ammonia volatilization loss, increasing rice yield of 0.3–0.6 t ha^{-1}. Rawluk et al. (2001) reported that ammonia volatilization loss was decreased by 28–88% due to NBPT application with granular urea. The addition of the urease inhibitor PPD along with urea ($120\,kg\,N\,ha^{-1}$) reduced the urease activity by 45% (Modolo et al., 2018). The addition of the urease inhibitor PPD along with urea reduced the ammonia loss by 12–22 kg N ha^{-1} (De Datta, 1985). Thiourea, hydroquinone, 2–4 dinitro phenol, and boric acid are also the beneficial effects of urease inhibitors.

3.1.2.3 Deep placement of nitrogen fertilizers and use of modified forms of urea

Deep placement of N fertilizers in the anaerobic soil zone is an effective method to reduce volatilization loss (Mikkelsen et al., 1978). N use efficiency is higher when fertilizer is placed at a 10-cm soil depth (De Datta 1981). Deep placement of USG performed better than the conventional split-broadcast method (Hossain and Sarker, 2020). A liquid urea injector is used to inject dissolved urea into the upper soil layer at 5–6 cm soil depth and is effective in reducing ammonia volatilization loss, increasing grain yield, and fertilizer N recovery. Different sources of N fertilizer are now available on the market for commercial use. Prilled urea is commonly used for rice production as nitrogenous fertilizer. The mean diameter of PU is 1.5 mm. USG (urea super granule) is a modified form of urea whose diameter is 11.5 mm. USG is superior to PU for rice cultivation (Hossain and Sarker, 2020). Azollon is a urea-formaldehyde condensation product containing 38% N. The performance of PU, ULG, USG, and Azollon in wetland rice culture was evaluated in a field experiment at BRRI (Choudhury et al., 1994). Considering grain yield, USG is significantly superior to PU and azollon, whereas ULG has a slight edge over PU but is not statistically different. Total N uptake increases significantly in ULG- and USG-treated plots compared to the conventional PU-treated plots. USG and ULG are superior to PU in respect of agronomic efficiency and apparent recovery of added N (Choudhury et al., 1994).

3.1.2.4 Use of slow-release fertilizers

Slow-release nitrogen fertilizers are considered a potential way to improve the efficiency of N fertilizers as well as reduce the possibility of N loss through volatilization. Slow-release fertilizers like sulfur-coated urea (SCU), neem-cake blended urea (NBU), and lac-coated urea (LCU) reduce ammonia volatilization loss. Research results indicate that SCU reduces ammonia volatilization loss which results in higher fertilizer N efficiency (De Datta, 1985). Some researchers prove that SCU performance is better than PU in response to NUE (De Datta, 1981). Blended PU with neem-cake produces a slow release, which increases NUE (Sharma and Prasad, 1980). USG placement at 8–10 cm depth is effective for reducing ammonia volatilization loss of N.

3.2 Factors affecting on de-nitrification process

De-nitrification occurs in the flooded rice soils following the nitrification of ammonium into nitrate (NO_3). Nitrification occurs at a distance of 0–2 mm from the root surface, while de-nitrification occurs at a distance of 1.5–5.0 mm (Arth and Frenzel, 2000). NO_3^- is reduced by a series of steps to nitric oxide (NO), nitrous oxide (N_2O), and nitrogen (N_2) gases by de-nitrification processes, which are then released into the atmosphere. In wetland rice soils, de-nitrification primarily occurs in the reduced soil layer devoid of oxygen (O_2). In the absence of O_2, NO_3^--N is used as an electron acceptor by the facultative anaerobes during the oxidation of soil organic matter and other organic manures (Kennedy, 1992). The magnitude of de-nitrification loss may vary from negligible to almost 60% of the applied N depending on urea application and crop establishment methods (Buresh and De Datta, 1990; Xing and Zhu, 2000). Fillery and Vlek (1982) reported that de-nitrification losses from N fertilizer were 5–10% in continuously flooded rice-cropped soils while in fallow soils the loss was around 40% of the applied N. Prolonged waterlogged conditions discourage the nitrification process, and as a result, N_2O emissions are reduced by the de-nitrification process (Islam et al., 2020). ^{15}N tracer study indicates that the de-nitrification rate is higher in underground saturated soils under rice cultivation compared to soils under wheat cultivation (Xing et al., 2002).

3.2.1 Factors affecting the reduction of de-nitrification losses

Successful nitrification processes inhibit the de-nitrification and leaching loss of N from rice fields (Table 1 and Figure 3). Retained ammonium ion in the soil-water system is readily converted to nitrite, then to nitrate through the nitrification process. The nitrate ion is subject to losses through de-nitrification and leaching. De-nitrification follows the nitrification process. As a result, N de-nitrification loss is postponed or reduced by the control nitrification process. De-nitrification losses can be reduced by using nitrification inhibitors like dicyandiamide (DCD), iron pyrite, nitrapyrin, phenylacetylene, encapsulated calcium carbide, terrazole, etc. (Carrasco et al., 2004; De Datta, 1981; Freney et al., 1995). The use of encapsulated calcium carbides significant reduces de-nitrification process. Denitrification losses can also be decreased by the deep placement of urea fertilizer (Fillery and Vlek, 1982). Among the greenhouse gases, nitrous oxide is produced by the de-nitrification process in agricultural soil. Plant residues with high polyphenol and protein binding capacity reduce nitrous oxide emissions. Nitrogen dynamics-related microorganisms are responsible for changing one step to another step of N forms in soil. Slow release fertilizer has a high ability to inhibit N transformation activity, which improves nitrogen use efficiency for crop production. But even now, farmers in Bangladesh do not use this type of fertilizer for crop production. In this regard, researchers and extension personnel of the Department of Agriculture Extension (DAE) should motivate farmers to increase the use of slow-releasing fertilizers.

Table 1. N loss reduction by different processes

N loss reduction by different approaches	References
NH_3 volatilization	
» Reduce NH_3 volatilization from 8.4% to 13.1% with cation/N ratio of 2.00	Khanif and Wong, 1987
» Organic–inorganic compound fertilizers reduce ammonia volatilization by 8.82–12.67% compared to conventional fertilizers.	Nascimento et al., 2013
» NH_3 volatilization loss is decreased by 28–88% due to NBPT application with granular urea. Urease inhibitor PPD along with urea reduces the ammonia loss by 12–22 kg N ha^{-1}	De Datta, 1985
» Algal inhibitor (copper sulfate+terbutryn) decrease ammonia volatilization loss resulting an increase in rice yield by 0.3 – 0.6 t ha^{-1}	Freney et al., 1995
» USG point placement is 65–96% while it is only 32 –55% with the conventional PU broadcasting due to lower amount of ammonia volatilization loss	Cao et al., 1984; Schnier et al., 1990
» Ammonia volatilization loss rate reduces 11.53–25.33% lower under the sulfur-coated urea (SCU) compared to conventional urea.	Liu et al., 2020
» Paraffin-coated phosphogypsum granulated urea reduces 35% N loss up to 28 days after submersion in water compared to urea fertilizer	Yu and Bogang, 2019
» A combination of controlled released nitrogen and non-flooding controlled irrigation reduces 14.0 – 17.1% N loss over flooding conditions	Xu et al., 2012
De-nitrification	
» Denitrification losses of fertilizer N are 5–10% in continuously flooded rice-cropped soils, while in the fallow soil the loss was around 40% of the applied N	Fillery and Vlek, 1982
» Denitrification reduces from negligible to 46% of the applied N depending on the deep placement of USG application and crop establishment methods	De Datta, 1985; Xing and Zhu, 2000
Leaching	
» Soil and weather variables such as precipitation and coarse-textured soils are usually associated with higher NO_3^- leaching losses	Cameron et al., 2013; Huddell et al., 2020

3.3 N loss through leaching

Ammonium and nitrate forms of nitrogen are lost through leaching (Table 1 and Figure 3). The nitrate form is lost easily due to its negative charge, while the positively charged ammonium form is usually adsorbed to the negatively charged soil clay lattice. The leached nitrate joins the groundwater through the percolation of water through the soil column under gravity. The magnitude of fertilizer-N leaching varies depending on soil condition and the method of fertilizer application (Xing and Zhu, 2000).

3.4 Use of plant–growth promoting microorganisms in reducing nitrogen losses

Nitrogen fertilizer losses by different mechanisms can be minimized by reducing the amount of applied fertilizer N and increasing the efficient use of N by the rice plant. Plant growth-promoting microorganisms like *Azospirillum, Azotobacter and* and *Rhizobium* can reduce the use of urea-N by growth promotion through the production of auxins, cytokinins, gibberellins, and ethylene (Dobbelaere et al., 2003) (Figure 3). The use of plan-growth promoting microorganisms can increase plants' capacity to utilize fertilizer N efficiently. *Azospirillum* and *Rhizobium* inoculation can increase ammonium uptake by rice plants (Biswas et al., 2000). So, plant-growth-promoting microorganisms are used in rice cultivation that can reduce the environmental pollution problems due to N losses.

3.5. Use of mass media and easily accessible soil test kits, rapid plant tissue test, and leaf color chart to the farmer-'s' level for reducing N loss

Different soil test protocols and mass media can help optimum use of nitrogenous fertilizers and increase rice production (Figure 3). A leaf color chart (LCC) is a cheaper method used for determining the timing and amount of N fertilizer application in rice crops. Farmers can easily use the LCC to qualitatively assess the foliar N status of rice crops and adjust N application for a large area. So, LCC is a more useful, simple, and cheaper method for Bangladesh farmers for N management in rice. By using LCC, farmers can save 25 kg of nitrogen per hectare without any reduction in yield. N application through the LCC test can save 40% of N. The Leaf color chart (LCC) is an ideal tool and environmentally friendly to optimize nitrogen use efficiency irrespective of the amount of N applied. Traditional soil test results are not available to the farmer levels. In this regard, soil test kits can be easily supplied to the farmers of Bangladesh. So, a soil test kit can help with the optimum use of nitrogenous fertilizer for crop production. Farmers can also easily use the rapid plant tissue test to qualitatively assess the foliar N status of their rice crop and adjust N application for a large area. Rapid plant tissue testing is a more useful, simple, and cheaper method for the farmers of Bangladesh to manage N in rice. Mass media, such as radio, television, and other popular media, disseminate the benefits of the above-mentioned technologies for the judicial use of nitrogenous fertilizers in rice fields.

3.5 Use of low N input rice varieties

Rice varieties with low N input are one way to cut down on N loss and enhance the environment (Figure 3). The lower dose of N fertilizer increases crop quality without compromising yield performance. In this regard, BINAdhan-17 is a low N input rice variety for the T. aman season. It is needed 30% less N compared to other T. aman varieties. More researches should be conducted to develop low N input rice varieties to combat environmental pollution caused by NH_3, NO, N_2O gases, and NO_3^- leaching.

3.6 Use of artificial intelligence for reducing nitrogen loss

An artificial intelligence (AI) system selects different options for reducing N loss and the suitable crop with the optimal date of sowing and harvest for the specific area, which helps to improve crop yield and decrease the use of water, fertilizers, and pesticides (Figure 2). To improve the accuracy of application, precision farming aims to match agricultural methods to agro-climatic conditions (Hossain, 2021). AI also helps with effective soil management practices. A thorough understanding of the different soil types and conditions helps increase agricultural output and protect soil resources. It is the use of operations, practices, and treatments to improve soil performance. Management-oriented modeling (MOM) minimizes nitrate leaching and improves crop production. An artificial neural network (ANN) model accurately predicts and classifies soil structure, monthly mean soil temperature, soil moisture, and nutrients following erosion. It also predicts soil texture and enzyme activity. A remote sensing device integrated into a higher-order neural network is used to describe and estimate the dynamics of soil moisture (Elshorbagy and Parasuraman, 2008). By sensing soil factors (soil type, PH, nitrogen, phosphate, potassium, organic carbon, calcium, magnesium, sulfur, manganese, copper, iron, depth, temperature, rainfall, and humidity), as well as meteorological parameters, crop prediction methodology is used to determine the right crop (Snehal and Sandeep, 2014). SRC-DSS can be classified according to associated risks (Lopez et al., 2008). Support vector machine (SVM): ANN also detects low levels of nitrogen in the soil for judicious application of nitrogenous fertilizers (Karimi et al., 2006).

Activities for successful use of AI technologies in reducing N loss

»Trained up extension, research, NGO‘s and farmers for using AI technologies
» Create facility of AI supporting tools and infrastructures
» Collaboration with CGIAR for satellite image and big data facilities
» Provide aids, reliefs, tax holidays, crop insurance and other incentives for farmers
» Develop community based farming system
» Strengthening crop zone based farming system
» Accumulation and generate big data from national and international organizations

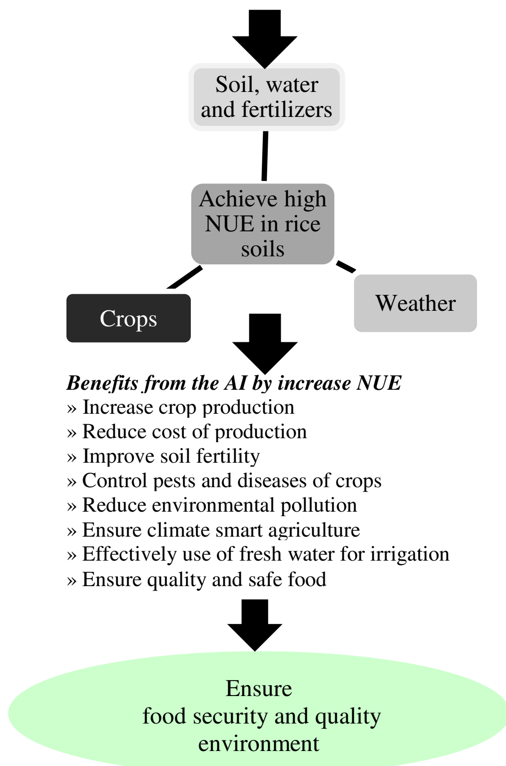

Figure 2. Use of AI to ensure food security and quality environment through reducing N loss in irrigated rice soils (adapted from Hossain and Islam, 2022)

ANN captures weather as a factor to determine the effective fertilization practices that can help to increase NUE and rice yield (Snehal and Sandeep, 2014). ANN also confirms the above 90% success rate in detecting crop nutrition disorders (Song and He, 2005).

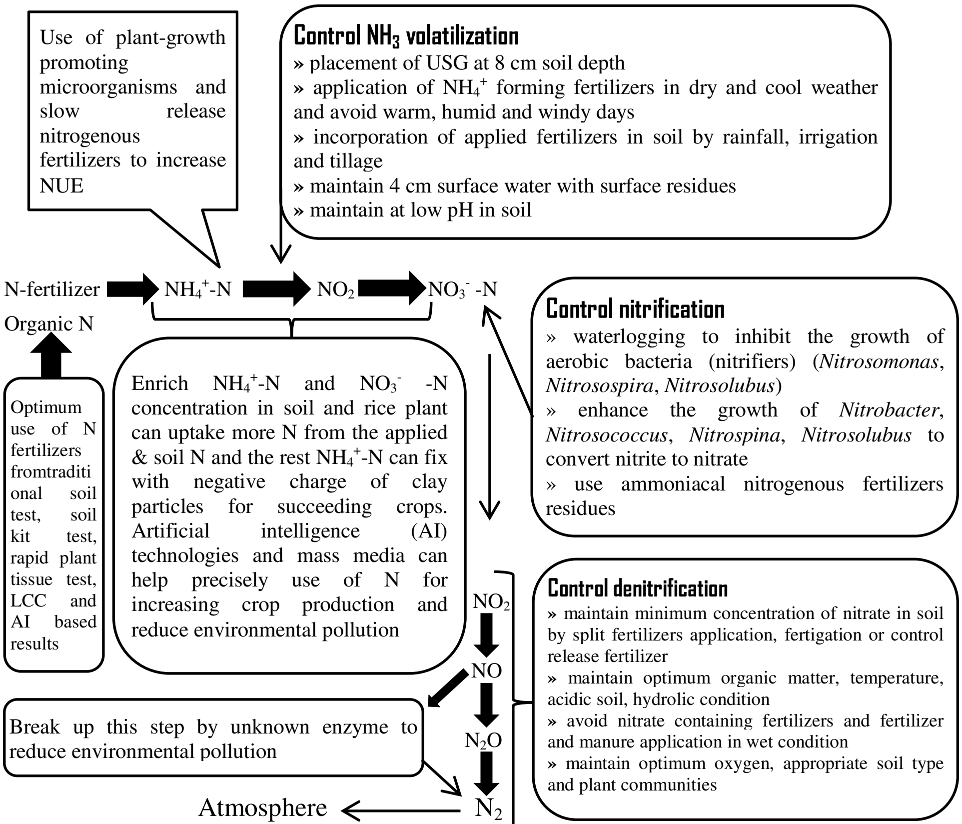

Figure 3. The conceptual model for increasing NUE and reducing environmental pollution

Boosting rice production and reducing environmental pollution inhibit the N loss pathways (NH_3 volatilization, nitrification, de-nitrification, and NO_3^- leaching) (Yao et al., 2020; Li et al., 2018; Ma et al., 2019).

3.5 Conclusions

N loss from ammonia volatilization, de-nitrification, and leaching can be stopped but can be minimized through adoption of certain management practices. Application of soluble calcium, magnesium, and potassium chloride or nitrate salts, use of urease and algal inhibitors, deep placement of nitrogen fertilizers, use of modified forms of urea, and use of slow-release fertilizers are all methods for lowering ammonia volatilization losses. De-nitrification losses can also be reduced by the use of nitrification inhibitors, deep placement of N fertilizers, use of slow-release fertilizers, and application of plant residues having high polyphenol content and high protein binding capacity. Leaching losses can be reduced by increasing water-use efficiency, using slow-release fertilizers and nitrification inhibitors, puddling the rice fields, planting catch and cover crops, and using crop residues in situ. Plant growth-promoting microorganisms partially supply the N to ensure the optimum rice yield and reduce environmental pollution.

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Threatened Fish Genetic Resources and Biological Diversity of the Baluhar Baor Wetland in Bangladesh

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Abstract

The Baluhar Baor is an oxbow lake, occupying an area of 282 ha, belongs to Kotchandpur Upazilla under the district of Jhenaidah, Bangladesh. Unlike other baor wetlands, Baluhar Baor ecosystem is also important as natural breeding and grazing habitat for many indigenous large, medium and small fish species. This wetland was being well managed by GoB through concerned department (DoF) and Ministry (MoFL) under World Bank funded project entitled "Oxbow Lake Project-1 (OLP-1)" during 1979 – 1985 and DANIDA/IFAD funded OLP-2 projects during 1988 – 1997 in view of increasing the fish production and uplift the socio-economic condition of the fishers' living surrounding to the baor area. Afterwards, at the end of these two projects, mainly the baor was managed by the Baor Manager of DoF with the help of local fishermen. The study was conducted in winter season to assess the effect of such management and dry season on the overall fisheries resources and biological diversity of existing fish species in the wetland ecosystem of the baor. In this study, Focused Group Discussion (FGD) and direct interviews of different stake holders viz. Key Informant Interview (KII), FGDs, Personal Interview (PI) of individual fishermen and local inhabitants were carried out within Kotchandpur Upazilla area covering two villages viz. Kagmari and Ramchandrapur. From this study, the present status of fish biodiversity of Baluhar Baor was thoroughly assessed, where there are only 48 species are presently available, which have listed by the stakeholder's discussion at FGD of Fisher Groups and interviews with KIIs and PIs and local fishermen. Among the 48 species identified in the survey, 15 species (31%) are Commonly Available Species (CAS), 14 species (29.16%) are Moderately Available Species (MAS), 13 species (27.08%) are Less Available Species (LAS), and 06 species (12.50%) are Rarely Available Species (RAS). Both LAS and RAS can be categorized as vulnerable species, which means they will be close to threatened or critically endangered within a few years unless action is taken to reverse the trend. Therefore, it is important to follow and adopt the exact agreements were made between DoF and Fisher Groups to restore the concern of existing baor habitat and conserve the indigenous fish biodiversity of the wetland ecosystem.

Keywords: Baluhar Baor wetland, Oxbow lake, Fish genetic resources, Biological diversity.

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Introduction

Bangladesh is specifically rich in inland fishery resources having vast water bodies in the form of many rivers, canals, haors, floodplains, beels (natural depressions), lakes, man-made ponds and estuaries. Among those the Baors ie. Oxbow lakes, are potential and peculiar form of inland water bodies, these are the dead arms of a river in the moribund delta as in the case of the Ganges (Abdullah-Bin-Farid et al. 2013). It is reported that there are about 600 oxbow lakes in four greater districts of Jessore, Faridpur, Khulna and Kustia (Hasan 2003; Biswas et al. 2009). The total area of those baors is 8556 hectare (DoF 2011). The greater Jessore district having the major concentration of these baors, therefore, Baluhar Baor belongs to Kotchandpur Upazila of newly established Jhenaidah district. Unlike other baor wetlands, Baluhar Baor ecosystem is also important as natural breeding and grazing habitat for many indigenous large, medium and small fish species. Since many years people living to the adjacent localities of the baor were used to harvest fish for their family consumption and earning their livelihoods by selling those fish in the local markets. Afterwards, in view of increasing the fish production and uplift the socio-economic condition of the fisher groups of people, a World Bank funded project entitled "Oxbow Lake Project-1 (OLP-1)" was implemented during 1979 to 1985 by the Department of Fisheries (DoF), Ministry of Fisheries and Livestock, Govt. of Bangladesh. From that time OLP-1 project was implemented with 6 baors including Baluhar Baor. After the completion of OLP-1 project, Oxbow Lakes Project 2 (OLP-2) had been started and institutionalized the fisheries management to the fishers themselves by ensuring their participation in the management process during 1988 to 1997 (initially supported by DANIDA/IFAD as a project). Under this project, there were 23 Baors including Baluhar Baor. Therefore, a tota of 29 Baors have been operated under "Oxbow Lake Project 1 programme (6 Baors)" and "Oxbow Lake Project 2 programme (23 Baors)" for increasing fish production and to uplift the socio-economic condition of the fishers (Ahmed et al, 2006). Among these baors, Baluhar Baor is the largest occupying an area of 282 ha. There are six adjacent villages and fishermen living in these villages were fully dependent on this baor for their livelihood. Only licensed fishermen were permitted to harvest fish. License was issued by baor management authority. Mainly the baor was managed by the Baor Manager of DoF with the help of local fishermen (Abdullah-Bin-Farid et al. 2013).

To enhance fish production, Baluhar Baor Management agreed to stock along with existing rani fish (non stocked existing indigenous fish species of the baor) some commercially important fast growing endemic and exotic carp species (locally called Raja fish) viz. rohu, *Labeo rohita*; catla, *Catla catla*; mrigal, *Cirrhinus mrigala*; kalbasu, *Labeo calbasu*; grass carp, *Cteropharyngodon idella*; scalled common carp, *Cyprinus carpio* var. communis; mirror carp, *Cyprinus carpio* var. specularies; and silver carp, *Hypopthalmichthys molitrix* respectively at the ratio of 13%; 12%; 12%; 14%; 7.5%; 7.5% and 34%. Total stocking of carps remains in the baor around 750,000 individuals (Abdullah-Bin-Farid et al. 2013). As per Baluhar Baor Management rules, all fishermen living at adjacent villages were allowed permitted to fish carp species received their licences. A total 288 fishermen were given fishing licence for fishing in the baor. By the

DoF Baor Management Authority, two types of licenses were provided, one, for carp and rani fish harvesting and another, for harvesting of rani fish only. In each fishing season, harvesting of carps plus rani fish normally start during November – Decembr and over by June. There are three locally adopted methods carp fishing is practiced at the baor area viz. komor fishing (brush shelters), kochal fishing (seining) and chak fishing (triangle trap made by bamboo frame with net) (Biswas et al. 2009, Apu and Middendorp 1998 and Das and Bandayapaddaya, 2000). Under the fishing management system of Baluhar Baor, DoF side provides all production inputs. Fishermen are participated with their nets, boat, komor materials and labors. During distribution of share, government take sixty percent which in turn added to revenue sector and fishermen receive forty percent share from the total fishing money. As per fishing agreement, fishermen can harvest rani fish throughout the year in the baor and take all selling money. Carp species harvesting, a pre-set fishing schedule time to be maintained. Fishermen are not allowed to harvest the stocked species in the baor outside this fishing schedule. Baluhar Baor Management and involvement fisher groups in fishing in the baor could be a model for other wetland management practices in Bangladesh.

This paper aims to highlight a part of the studies were conducted under a GoB funded project of Department of Bangladesh Haor and Wetland Development (DBHWD), Ministry of Water Resources (MoWR), GoB for protecting the haor and other wetland resources implemented by the Institute of Water Modelling (IWM), Bangladesh. The broad objectives of the study were to assess the overall fisheries resources and fish biodiversity issues of the Baluhar Baor through public consultation and interviews with the targeted stakeholders.

Materials and Methods

The study periods

The present field surveys and studies have been conducted from 28 November to 01 December, 2019 in Baluhar Baor, Kotchandpur, Jhenaidah. Due to decision of IWM project implementing authority, there was an opportunity to conduct such survey in winter season only rather than in summer season.

Location of Baluhar baor wetland

The Baluhar Baor is an oxbow lake; belongs to Kotchandpur Upazilla under the district of Jhenaidah, Bangladesh (Fig. 1). The baor is situated within 23°27′ to 23°50′ North latitude and 88°55′ to 89°05′ East longitudes. The total area of Baluhar Baor is about 282 hectares having an average depth of 5.88 ± 0.701 meter (Islam, 2013).

Figure 1. Map of Baluhar Bar at Kotchandpur, Jhenaidah

Sites for conducting the study

As entire Baluhar Baor area belong to Kotchandpur, Jhenaidah, thetefore only Kotchandpur was covered during this study. In this Upazila the survey spots were at Kagmari and Ramchandrapur villages. The survey and study sites adjacent to Baluhar Baor is shown in Table 1.

Table 1. List of survey and study sites of Baluhar Baor area

Name of the Baor	Upazilas	Spot/village/lake sites
Baluhar Baor	Kotchandpur	Kagmari
	Kotchandpur	Ramchandrapur

Data collection

The surveys and studies were conducted in Baluhar Baor at the aforementioned sites for collection of data through Focus Group Discussion (FGD) and direct interviews of different stake holders viz. Key Informant Interview (KII), FGDs, Personal Interview (PI) of individual fishermen and local inhabitants only. For data collection, consultation and interviews were made using several sets of pre-structured and pre-tested questionnaires.

Survey methodology

Focus Group Discussion (FGD)

In Baluhar Baor area, the Survey Team organized first FGD of Fisher Groups having 30 persons with the assistance of Baor Manager at the adjacent baor village ie. Kagmari, Kotchandpur Upazila. In this consultation, discussion was maily focussed on the overall fisheries resources and biodiversity matters of the baor with the gathered fisher groups. On the following day the 2nd FGD of 40 members Fisher Groups was organized at the surrounding village Ramchandrapur, where detail discussion and public consultation shared with the group members. Similar to all other consultations and group interviews of other wetlands, in Baluhar Baor the team used same questionnaire for all FGD groups, major crucial points covered as follows: i)During the season quantity and type of fish resources presently available/not available at harvesting and existing status of fish biodiversity in the baor; ii) Present fishing practices and type of crafts and gear used during this season; iii) Major reasons of declining catch, fish biodiversity and degrading aquatic habitat; IV) Impact of catch and biodiversity declining over fish trade and marking as well impact on consumers; V) Suggestive mitigating measures for improvement of catch, fish availability at the landing centers and local markets; VI) Suggestive mitigating measures for conservation of fish biodiversity and natural breeding grounds and habitat.

Personal Interview (PI)

During this survey, the Team performed 6 PIs of fishermen and local inhabitants at the adjacent Kagmari village and 5 PIs at Anuhadi village, Ramchandrapur, under the Kotchadpur Upazila, Jhenaidah.

Informant Interview (KII)

The survey team made KII with Baor Manager Mr. K.M. Siddiqur Rahman along with the training instructor Mr. Abul Kalam Azad of Department of Fisheries (DoF) and discussed about DoF’s baor management aspects and it’s impact on restoration of fisheries resources and fish biodiversity conservation at Baluhar Baor.

Results and Discussion

Assessment of existing fish genetic resources and status of fish biological diversity

From this survey and study, the present status of fish biodiversity of Baluhar Baor was assessed, where there are only 48 species are presently available, which have listed by the stakeholder’s discussion at FGD of Fisher Groups and interviews with KIIs and PIs and local fishermen during this winter season (Table 2). Among the 48 species identified in the survey, 15 species (31%) are Commonly Available Species (CAS), 14 species (29.16%) are Moderately Available Species (MAS), 13 species (27.08%) are Less Available Species (LAS), and 06 species (12.50%) are Rarely Available Species (RAS)

(Fig. 2). Both LAS and RAS can be categorized as vulnerable species, which means they will be close to threatened or critically endangered within a few years unless action is taken to reverse the trend.

Table 2. List of fish species are presently available during winter season in Baluhar Baor wetland.

Serial number	**Commonly Available Species (Local Name)**	**Moderately Available Species (Local Name)**	**Less Available Species (Local Name)**	**Rarely Available Species (Local Name)**	**Not Available Species (Local Name)**
1	*Puntius ticto* (Tit Punti)	*Anabas testudineus* (Koi)	*Puntiius sp.* (Bagha punti)	*Monopterus cuchia* (Kuchia)	*Labeo calbasu* (Kalibaush)
2	*Puntius sophore* (Jat Punti)	*Oreochromis mossambicus* (Mozambic Tilapia)	*Mystus tengara* (Bujuri Tengra)	*Mystus aor* (Air)	*Wallago attu* (Boal)
3	*Mystus vittatus* (Tengra)	*Nandus nandus* (Meni)	*Colisa lalia* (Lal Khalisha)	*Notopterus chitala* (Chittal)	*Puntius sarana* (Sar punti)
4	*Colisa fasciatus* (Large Khalisha)	*Channa striatus* (Shoal)	*Channa orientalis* (Chang)	*Osteobrama cotio* (Dhela)	*Macrobrachium rosenbergii* (Golda Chingri)
5	*Colisa chuna* (Chuna Khalisha)	*Channa marulius* (Gozar)	*Macrognathus pancalus* (Guchi Baim)	*Pseudeutropius atherinoides* (Batashi)	*Silonia silondia* (Shilon)
6	*Channa punctatus* (Taki)	*Chanda nama* (Lamba chanda)	*Macrognathus aculeatus* (Tara Baim)	*Ailia coila* (Kajuli)	*Mystus cavasius* (Gulsha)
7	*Parambassis ranga* (Gol chanda)	*Clarius batrachus* (Magur)	*Macrognathus armatus* (Baro Baim)	-	-
8	*Heteropneustes fossilis* (Shing)	*Hyporamphus limbatus* (Ekthuta)	*Lepidocephalichthys guntea* (Gutum)	-	-
9	*Glossogobius giuris* (Baila)	*Notopterus notopterus* (Foli)	*Xenentodon cancila* (Kakila)	-	-
10	*Amblypharyngodon mola* (Mola)	*Chela phulo* (Chela)	*Tetraodon cutcutia* (Potka)	-	-
11	*Labeo rohita* (Rui)	*Aplocheilus panchax* (Pach Chokha)	*Ompok bimaculatus* (Pabda)	-	-
12	*Catla catla* (Catla)	*Gaduasia chapra* (Chapila)	*Esomus danricus* (Darkina)	-	-
13	*Cirrhinus cirrhosis* (Mrigal)	*Macrobrachium malcolmsonii* (Kalo Icha)	*Labeo bata* (Bata)	-	-
14	*Ctenopharyngodon Idella* (Grass carp)	*Macrobrachium sp.* (Chingri)	-	-	-
15	*Cyprinus carpio* (Common carp)	-	-	-	-
Total #	15	14	13	6	6

Note: Commonly Available Species = CAS**;** Moderately Available Species = MAS; Less Available Species = LAS; Rarely Available Species RAS; Not Available Species = NAS

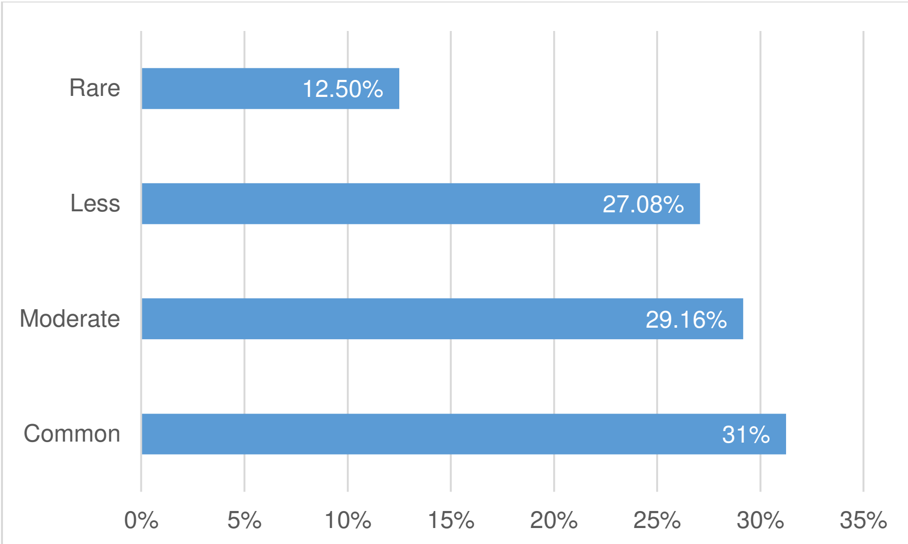

Figure 2. Comparative proportion (shown as Bar Chart) of fish species availability during winter season at Baluhar Baor wetland

It is reported that a total of 72 species of freshwater fish species were identified, distributed among 48 genera, 23 families and 11 orders at Baluhar Baor including 8 carp species released by the Baluhar Baor Management authority since beginning of implementing Oxbow Lake Project-1 (OLP-1(Islam, 2013). It is estimated in this study from the Table 16 that fish biodiversity presently remained 65.6% fish (only 42 indigenous rani fish species excluding introduced raja fish species, ie. carps and tilapia species) out of total 64 rani fish (excluding introduced carp species) at Baluahr Baor and other 37.4% rani fish species either lost or disappeared forever from this water body. A comparative proportion of presently available fish species of Baluhar Baor is shown graphically in Fig. 2.

Present surveys and studies revealed that due to serious deterioration of natural habitat of the baor resulted declining the fisheries resources and fish biodiversity in this baor. Among the causes identified behind this fish biodiversity declination in the baor are; release of carp species, kata fishing practice, heavy growth of aquatic weeds and vegetation, use of harmful insecticides and pesticides at the surrounding agricultural crop lands become a source of chemical pollution during rainy season, decreasing of water depth, low water velocity, reduction of connection with the river canals and adjacent beels due to heavy siltation and sedimentation, poor implementation of Govt. fishing rules and regulations in the baor etc. are prominent. No other studies have yet been made and reported before regarding fish biodiversity issues of Baluhar Baor or other baor ecosystem.

Present fishing practices and use of fishing crafts and gear

The fishing practices in Baluhar Baor are little bit different than other wetlands. As it has been mentioned above that especially for carp fishing three locally adopted methods are commonly used viz. komor fishing, kochal fishing (seining) and chak fishing (triangle trap made by bamboo frame with net). But while discussion and consultation with Fisher Groups in 2 FGDs and interviews with PIs taken placed, it was cleared that mostly rani fish and some carps are harvested using a number local and traditional fishing crafts and gears. It was recorded that among the fishing nets, the gill net, the cast net, the seine net and the pushnet (ie. Thela Jal) for harvesting most of the both rani fish and carps harvesting as well. On the hand, the rectangular bamboo trap is used for harvesting small prawn species and hook and line (ie. Lar norshi and Chip borshi) are used for fishing catfish, climbing perch and snakehead fishes.

Potential causes and challenges of fish biological diversity and habitat degradation

The survey team has identified and listed a number of potential causes for declining fisheries resources and biological diversity of fish species at the wetlands of Baluhar Bao. The listed major causes are as follows; i) High fishing pressure and over fishing in the baor; ii) Use of illegal fishing gears like current jal, Ber jal etc. by the unauthorized local fishermen; iii) Release and culture of carp species within the baor indirectly affect the habitat of SIS species; iv) Heavy growth of aquatic weeds like water hyacinth, water lily, lotus etc. in the baor directly detrimental to the existing fish species by causing water quality deterioration; v) Decreasing of water depth, low water velocity, reduction of connection with the river canals and adjacent beels due to heavy siltation and sedimentation; vi) Kata fishing also responsible for fish biodiversity declination; vii) Poor implementation of Govt. fishing rules and regulations in the baor; viii) Use of insecticides and pesticides at the surrounding agricultural crop lands become a source of chemical pollution during rainy season due to surface run off to the baor water body cause a great threat to fish biodiversity; ix) Lack of sufficient number of fish sanctuaries; x) Fishing by dewatering in the shallow areas of the baor become a cause of SIS habitat destruction; xi) Baor area encroached by the local people for agricultural farming that's why the total area of the baor decreasing day by day; xii) Climate changes causes rising temperature, drought, less rainfall etc. which are negatively affect the fish biodiversity of the baor ecosystem; xiii) Socio-economic conditions of fishermen around the baor are very marginal. Majority of them are landless people and desperately depends on the baor for their livelihood.

Recommendations for conserving of fish genetic resources and biological diversity

On the basis of public consolations in a number of FGDs and interviews with DoF Baor Manager as KII and quite a good number of fishermen and local inhabitants conducted during the survey at Baluhar Baor, the Survey Team suggested some mitigating measures for fisheries resources and conservation of fish biological diversity at the baor ecosystem. These measures and recommendations are as follows:

- More fish sanctuaries/brush shelters need to be established inside the baor area to enhance natural breeding of SIS and other indigenous fish species.
- Dredging of baor area is extremely required to keep optimum water depth to minimize less rain fall and draught season for better growth of stocked and naturally bred SIS species.

- Banning of wild fish catch need to be restored during June – July months, during that time the fishermen should be provided alternative income opportunities like Govt. Hilsa Fisheries conservation and management program.
- Illegal fishing nets and gears should strictly be prohibited in baor fishing by the local fishermen.
- Any influence by musclemen and other political activists in baor management must be controlled by the appropriate Govt. authority(s).
- The baor should be brought under community-based fisheries management to maximize sustainable production.
- As District Fishery Officer vs DoF Baor Manager are the sole controlling authority of the baor, they must strictly follow all the Govt. Rules and Regulation for proper conservation of baor Fisheries Resources and Fish Biodiversity by imposing BMP system to manage the wetland.

Conclusion

Baluhar Baor as Oxbow Lake wetland was being well managed by GoB through her concerned department (DoF) and Ministry (MoFL) under World Bank funded project entitled "Oxbow Lake Project-1 (OLP-1)" during 1979 – 1985 and DANIDA/IFAD funded OLP-2 projects during 1997 – 1988 – 1997 in view of increasing the fish production and uplift the socio-economic condition of the fisher groups of people living surrounding to the baor area. Fisher groups were the sharing partners under an agreement for fishing activities. As per fishing agreement, fishermen can harvest rani fish throughout the year in the baor and take all selling money. Carp species harvesting, a pre-set fishing schedule time to be maintained. Fishermen are not allowed to harvest the stocked species in the baor outside this fishing schedule. Baluhar Haor Management and involvement of fisher groups in fishing in the baor could be a model for other wetland management practices in Bangladesh. After the end of project periods, Baluhar Baor is being running under the Baor Manager of DoF, but it is not very clear how much care could have been undertaken by present management. There might be some laps and gaps for managing the baor ecosystem presently. Therefore, it is important to follow and adopt the exact agreements were made between DoF and Fisher Groups to restore the concern of existing baor habitat and conserve the indigenous fish biodiversity.

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Assessment of Spawning Season of Guntea Loach, *Lepidocephalichthys guntea* in Bangladesh

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Abstract

Guntea loach, *Lepidocephalichthys guntea* is a commercially important freshwater fish species in Bangladesh. The present study demonstrates to assess the spawning season of *L. guntea* in the old Brahmaputra River, Bangladesh with an aim of its sustainable conservation through induced breeding and aquaculture practices. Sample of *L. guntea* were collected each month throughout the study period from January to December 2018. Spawning season was determined based on monthly gonadosomatic index (GSI) values and observation of ovarian developmental stages based on external features of the ovaries of this species. Monthly mean percent of GSI values of females ranged from 2.61 to 12.57. The lowest mean GSI value for females was 2.61 in November and the highest was 12.57 in June. Based on the mean GSI of both male and female breeders, it was noticed that both male and female maturity trends were more or less similar. GSI values of both male and female were high in June, while low during the other months of the year. According to the monthly GSI, the study apparently determined that the spawning season of *L. guntea* began from March to June having peaked in June. External features of female gonadal condition observation concluded that the spawning season of *L. guntea* was from May to August since the spawning stage was found during these months. Nevertheless, the findings will be useful for initiating sustainable management and conservation of the *L. guntea* in the old Brahmaputra river and surrounding aquatic ecosystems of Bangladesh.

Keywords: Gonadosomatic index, *Lepidocephalichthys guntea,* Sexual maturity, Spawning season

Introduction

Bangladesh is blessed with huge open water resources with a wide range of aquatic diversity. Biodiversity is also enriched, comprising almost 260 freshwater fish species. But due to mainly decline and degradation of wetland resources, the share of inland capture fisheries has been reduced remarkably during recent past decades (Hossain *et al.*, 2012). At present, decline of species diversity is a burning issue in Bangladesh. The main reasons for such decline are overfishing, construction of unplanned embankments,

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sedimentation, habitat modification, environmental changes, destruction of breeding and nursing grounds, pollution from agricultural, domestic and industrial wastes (Ahamed *et al*., 2018). For sustainable fish production, efficient culture, management practices and conservation of biological diversity of aquatic species should be maintained to overcome this situation.

The inland water is inhabited by 293 species of indigenous fin fishes (DoF, 2012). The large numbers of small fish species are still available in both open and closed inland waters. Ali (1997) listed 143 species of SIS such as Darkina, Punti, Mola, Taki, Koi, Tengra, Gulsa tengra, Guchi, Gutum,Tara baim, Kajuli and Chanda etc. in Bangladesh. Among them the Guntea loach, *Lepidocephalichthys guntea*is one of the important fish in Bangladesh. The IUCN red list status of this species is not evaluated. Considering the importance of this species in nutritional, economic and biodiversity point of view, the conservation and propagation are essential

Guntea loach, *L. guntea* (Hamiltion, 1822), a fish species belonging to the family Cobitidae under the order Cypriniformes, is well known as a SIS in Bangladesh, and is locally known as Gutum. It is available in Pakistan, Northern India, Bangladesh, Nepal, Myanmar, Thailand, and the Salween basin. This fish species is most commonly found in shallow, slow-moving sections of streams or calm habitats such as swamps, haor water bodies, oxbow lakes, and paddy fields. These are often heavily-vegetated or littered with submerged roots, branches and leaf litter, with substrates composed of soft mud or silt (Hasan *et al*., 2017). *L. guntea* is well regarded as a quality food containing high amounts of protein, fat, carbohydrate, minerals and vitamins.

An understanding of the reproductive biology of a species is a central aspect of providing sound scientific advice for fisheries management. It's reproductive biology that in large part determines productivity and therefore a population's resilience to exploitation or perturbation from other human activities (Banik *et al*., 2012). The importance of quantifying productivity in terms of reproductive potential (RP) and recruitment, as well as the difficulty in doing so, have long been recognized. Reproduction in fish is the process by which species perpetuated and by which in combination with genetic change, characteristics for new species appear (Lagler, 1949). Life story characteristics, which include size at sexual maturity, reproductive life span may differ according to populations (Hossain *et al*., 2012). Other life story characteristics i.e., reproductive characteristic is fecundity, spawning season and frequency, distribution of ovum diameter, frequency of maturation or maturity stages and oocyte formation (Chen *et al.,* 1990). Knowledge of the state of maturity of individuals in a population is useful and estimation of annual egg production of a fish is considerably important in studies of population dynamics to understand recruitment and manage populations properly and effectively (Muchlisin *et al*., 2010). Moreover, this small indigenous fish species is maintaining a stable and static condition of aquatic food chain thus the biodiversity of our open water ecology have been in smooth form.

Spawning season helps to determine when and at which length the fish should be protected and it is, therefore, important for the proper management and conservation of fish stocks. In order to assessment and management of fish stocks, spatial and temporal changes of number and weight in stock should be studied. Reproduction is the initial point of those changes. Reproduction in fishes is the process by which species is perpetuated and by which in combination with genetic change, characteristics for new species appear (Lagler, 1949). The reproductive strategy of a species is a characteristic feature that is usually firmly associated within that species (Morgan, 2008).

For efficient fish culture and management practices it is important to know the spawning season of fish. Determination of the breeding season is an essential part of biological investigations of fishes. Spawning season and fecundity determination have been important components of the biological basis of management for fish and fisheries. Knowledge on reproductive biology of fish is essential for evaluating the commercial potentialities of its stock, life history, culture practice and management of its fishery (Islam *et al.,* 2012). In order to achieve success in fish culture, it is important to assess the breeding cycle with fecundity of cultivable fishes.

In spite of the enormous economic and nutritional importance of Guntea loach, *L. guntea* to the rural people and fishing community, a little study on its reproductive biology has been done in Bangladesh. The knowledge of spawning season and size is important to examine some aspects of reproductive biology of *L. guntea* that will be essential to increase the wild stock of this species. Therefore, this research is conducted to determine the spawning season of the fish to know the accurate spawning season of this valuable species and it is possible to design the culture management and conservation steps for this species.

Materials and method

Location of study site

The samples were collected from the old Brahmaputra river in Bangladesh. The Brahmaputra river is one of the three major rivers of Bangladesh, with a total length of 2,900 km. The old Brahmaputra river was once the main flow of the Brahmaputra-Jamuna river system. The old Brahmaputra river is an important source of fisheries. It is an important fish breeding and spawning area. A numerous number of freshwater fishes are available in this river and Guntea loach, *L. guntea* is an important species among them.

Sample collection of L. *guntea*

The study was conducted for a period of one year from January to December 2018. Fishes were collected randomly with gill and fine meshed seine nets in order to ensure all size groups of *L. gnutea* population in the catch. A total of 100 fish were collected each month in a year. At the time of sampling, individuals were collected randomly and preserved with 10% neutralized formalin in small containers as soon as possible to eliminate the possibility of decomposition of fish, which would degrade gonad quality of female and male individual. Finally, formalin preserved sample was brought to the laboratory.

Measurement of standard length and body weight

Formalin preserved individuals were washed with tap water and then absorbed the water with tissue paper. Standard length (SL) was measured from the tip of the snout to the last vertebra in which part folding makes a crease in the tail. Standard length was measured with the help of a measuring scale. Body weight (BW) was taken with the help of an electric balance.

Gonad collection and sex determination

The body cavity of fishes was opened carefully by scissors and gonads were extracted with forceps carefully. Other constitutional units such as muscles, fat tissues, digestive organs and blood veins were taken away properly. Both left and right gonads were measured together as gonad weight (GW) to the nearest 0.001 g. After measurement both male and female gonads were preserved with 10% formalin in small vials with proper labels.

Gonadosomatic Index (GSI)

Gonadosomatic index (GSI) value is defined as the percentage of gonad weight to the total weight of fish. It is often used to follow the reproductive cycle of a species over the year at monthly or less intervals. The index comprehends that a gonad increases in size with its increasing maturity compared with the mass of the gonad to the total mass of the animal. Determination of gonadosomatic index (GSI) is a method to employ for estimating the spawning season of a species. The gonadosomatic index of each fish specimen in the study was calculated as GSI = (GW/ BW) * 100, where GSI, GW and BW were perceived as gonadosomatic index, gonad weight and body weight respectively (Hossain et al., 2017).

Observation of ovarian external features

The structure and general feature of the ovaries as well as month wise size, shape and color of female gonads of *L. guntea* were studied during sample collection and preservation. External features of both ovaries were observed by empirical observation and microscope at low magnification (x20). Percent occurrence of the most advanced gonad stage in a particular period indicates perfect spawning season.

Results

Standard length

Histograms using standard length (SL) data of each month specimens was constructed and all histograms of monthly samples were displayed vertically along with the progression of time. Male specimens SL ranged from 43 to 86 mm (Table 1 and Figure 1) over the study period. The minimum SL occurred in June and maximum in January, April and May. The study considered male having length range of 40-55 mm as small size group, 55-65 mm medium size group and male ranging from 65-75 mm indicated as large size group and male ranging from 75-90 mm as very large size group. Male collected in January ranged from 50-82 mm SL, where four size groups, *i.e.,* small, medium, large and very large were present. There was a small size group of males measured in samples of January, February, June, July, August, September and December when SL varied from 50-82, 49-79, 43-75, 50-74, 50-81, 53-71 and 46-86 mm, respectively. Only medium and large groups of males were caught almost every month and their SL ranged from 55-65 mm and 65-75 mm. Very large size group of males were collected in January, February, March, April, May August, October, November and December, where SL ranges of March, April, May, October and November were 63-80 mm, 61-86 mm, 62-86 mm, 55-79 mm, respectively.

In the case of females, SL ranged from 50-92 mm (Table 1 and Figure 2) over the study period. The investigation classified females into three size groups based on standard length. Females having a length range of 50-60 mm were small size group, 60-70 mm was medium size group, and females ranging from 70-80 mm was large size group and 80-95 mm very large size group. Female fish collected in January ranged from 56-85 mm SL, where four size groups, *i.e.* small, medium, large and very large were present. Medium, large, very large size groups were found in almost every month when SL varied from 55-88 mm in February, 67-92 mm in March, 69-92 mm in April, 67-92 mm in May, 55-80 mm in June, 50-82 mm in July, 50-85 mm in August, 52-80 mm in September, 55-82 mm in October, 51-83 mm in November, 50 to 80 mm in December. The small group was observed in January, February, June, July, August, September, October, November and December.

Table 1. Collection record of *Lepidocephalichthys guntea* sample from the old Brahmaputra river in Bangladesh

Sampling months	Total fish no.	No. of Male	Size ranges		No. of female	Size ranges	
			SL (mm)	BW (g)		SL (mm)	BW (g)
January	88	33	50-82	1.87-10.44	55	56-85	2.86-11.95
February	100	29	49-79	1.87-6.43	71	55-88	2.54-10.24
March	100	56	63-80	3.19-7.40	44	67-92	3.97-13.50
April	94	62	61-86	3.76-7.53	32	69-92	4.79-10.42
May	99	25	62-86	3.16-7.11	74	67-92	3.68-10.57
June	100	82	43-75	0.86-4.31	18	55-80	1.86-9.40
July	100	30	50-74	1.40-5.28	70	50-82	1.41-8.17
August	100	47	53-81	1.46-7.77	53	50-85	1.66-8.72
September	100	16	55-71	2.06-4.82	84	52-80	1.88-7.61
October	100	42	55-79	2.53-5.99	58	55-82	2.28-8.13
November	100	8	55-68	2.19-4.38	92	51-83	2.21-8.63
December	100	32	46-86	1.53-6.02	68	50-80	1.78-7.97

Note: SL= Standard length, BW= Body weight

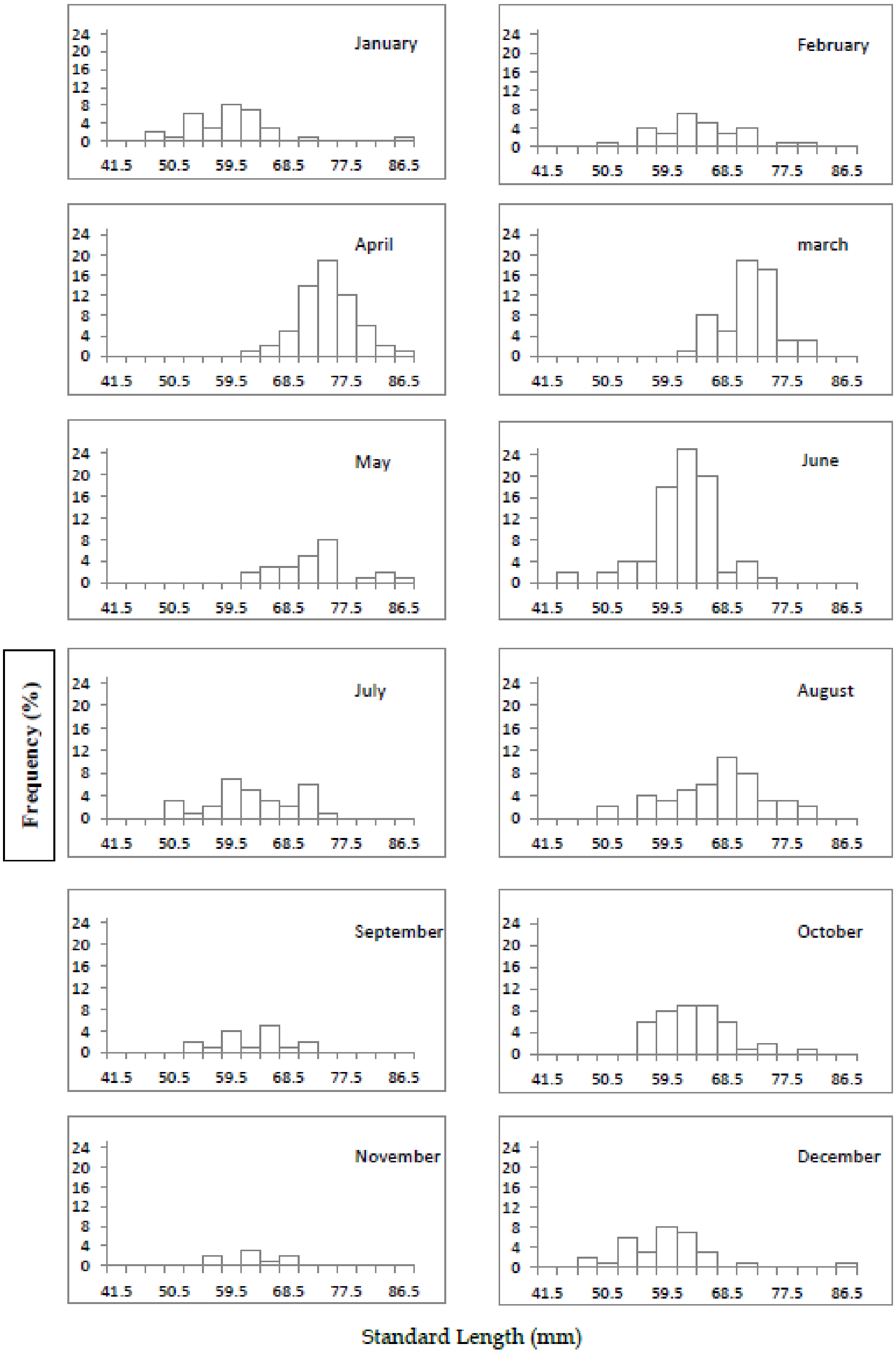

Figure 1. Frequency distribution of standard length in male of *L. guntea*

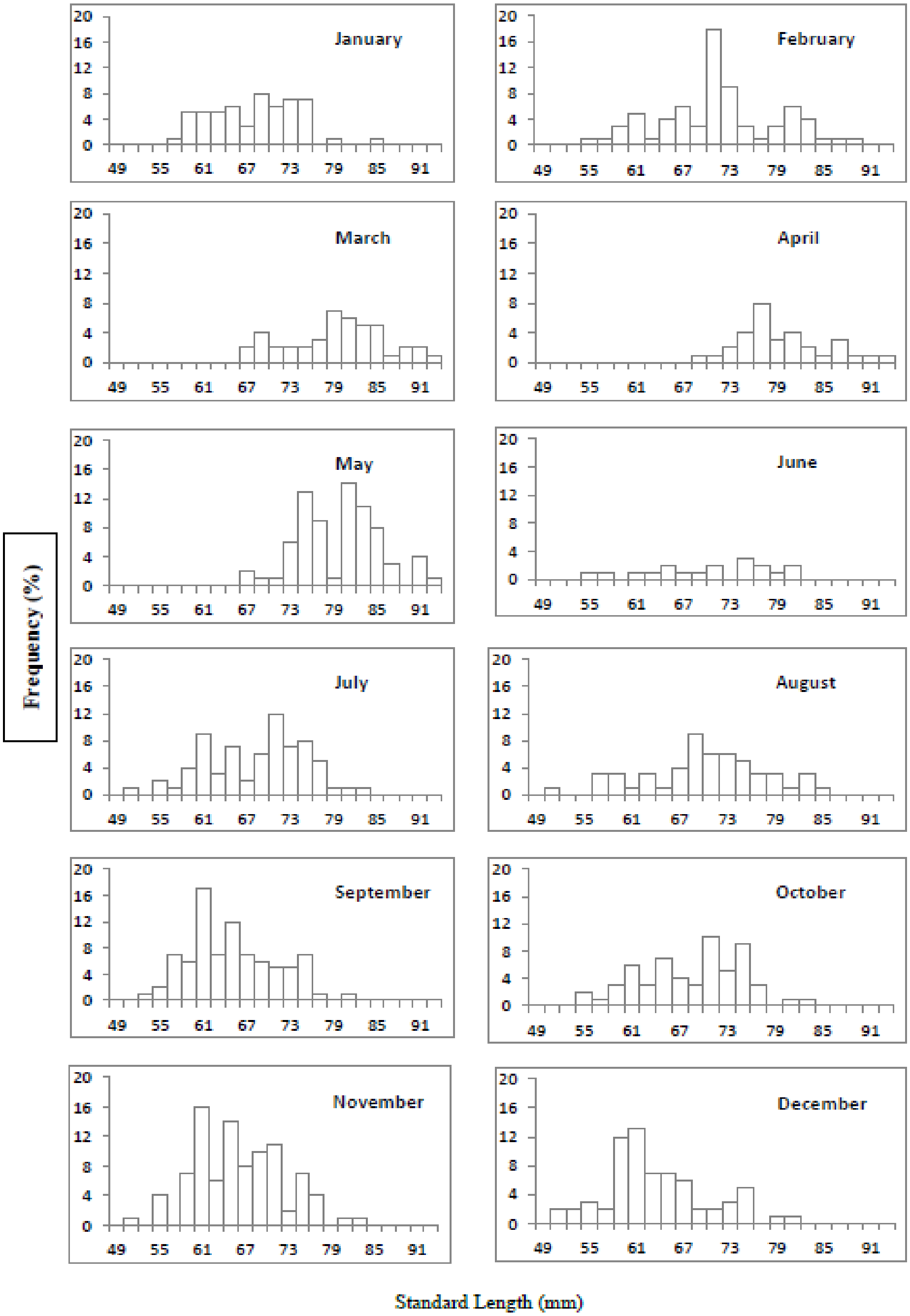

Figure 2. Frequency distribution of standard length in female of *L. guntea*

Body weight

Body weight of male was taken throughout the sampling period, which ranged from 0.86-10.44 g (Table 1 & Figure 3). The study assigned male having a weight range of 0.5-3 g as small size group, 3-6 g medium size group, 6-9 g as large size group and male ranging from 9 to 10 g BW very large size group. Small size groups of male specimens were collected in January, February, April, May, June, July, August, September, October, November and December, and BW ranged from 1.87-10.44, 1.87-6.43, 3.76-7.53, 3.16-7.11, 0.86-4.31, 1.40-5.28, 1.46-7.77, 2.06-4.82, 2.53-5.99, 2.19-4.38 and 1.53-6.02 g, respectively. Medium size found almost every month. Only large and very large size groups were available in the catch of March, April, May, August, and December their BW varied from 3.19-7.40 g. Large size groups were available in March and very large size groups found in January.

In the case of female individuals, body weight was measured throughout the sampling period, which was ranged between 1.41 g and 13.50 g (Table 1 & Figure 4). The minimum BW was recorded in July and the maximum was in March. The study designated females having a weight range of 1-3 g as small size group, 3-7 g as medium size group, 7-10 g as large size group and female ranging from 10 to 14 g was very large size group. Female specimens collected in October belonged to only the medium size group and body weight varied from 12.18 to 27.29 g. More or less medium and large size groups of female specimens were collected in all months of January, February, March, April, May, June, July, August, September, October, November and December having BW ranges were 2.86-11.95, 2.54-10.24, 3.97-13.50, 4.79-10.42, 3.68-10.57, 1.86-9,1.41-8.17, 1.66-8.72, 1.88-7.61, 2.28-8.13, 2.21-8.63, 1.78-7.97g, respectively. Small size group of females were found in January, February, April, May, June, July, August, September, October, November and December. Only a very large size group of females were available in January, February, March, April and May samples.

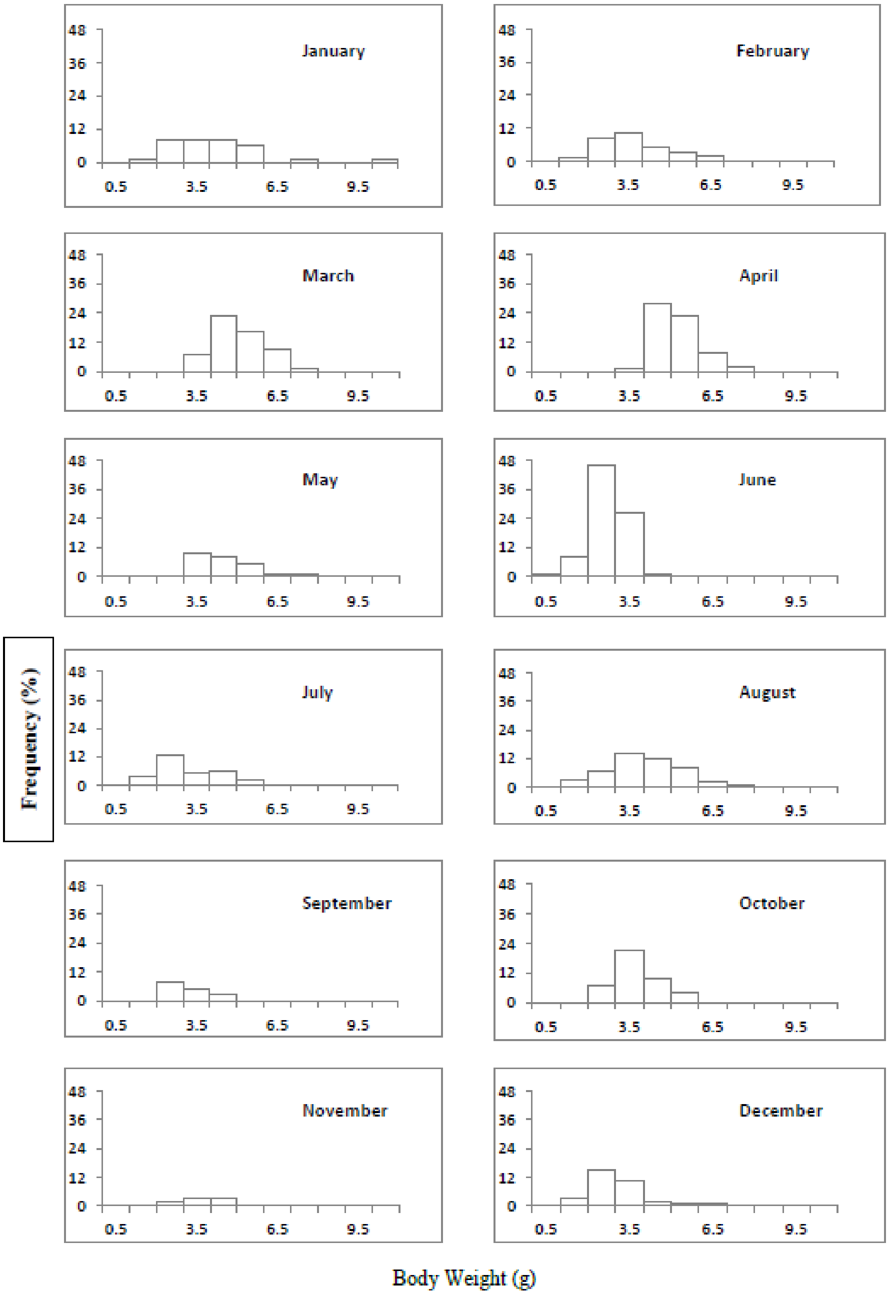

Figure 3. Frequency distribution of body weight in male of *L. guntea*

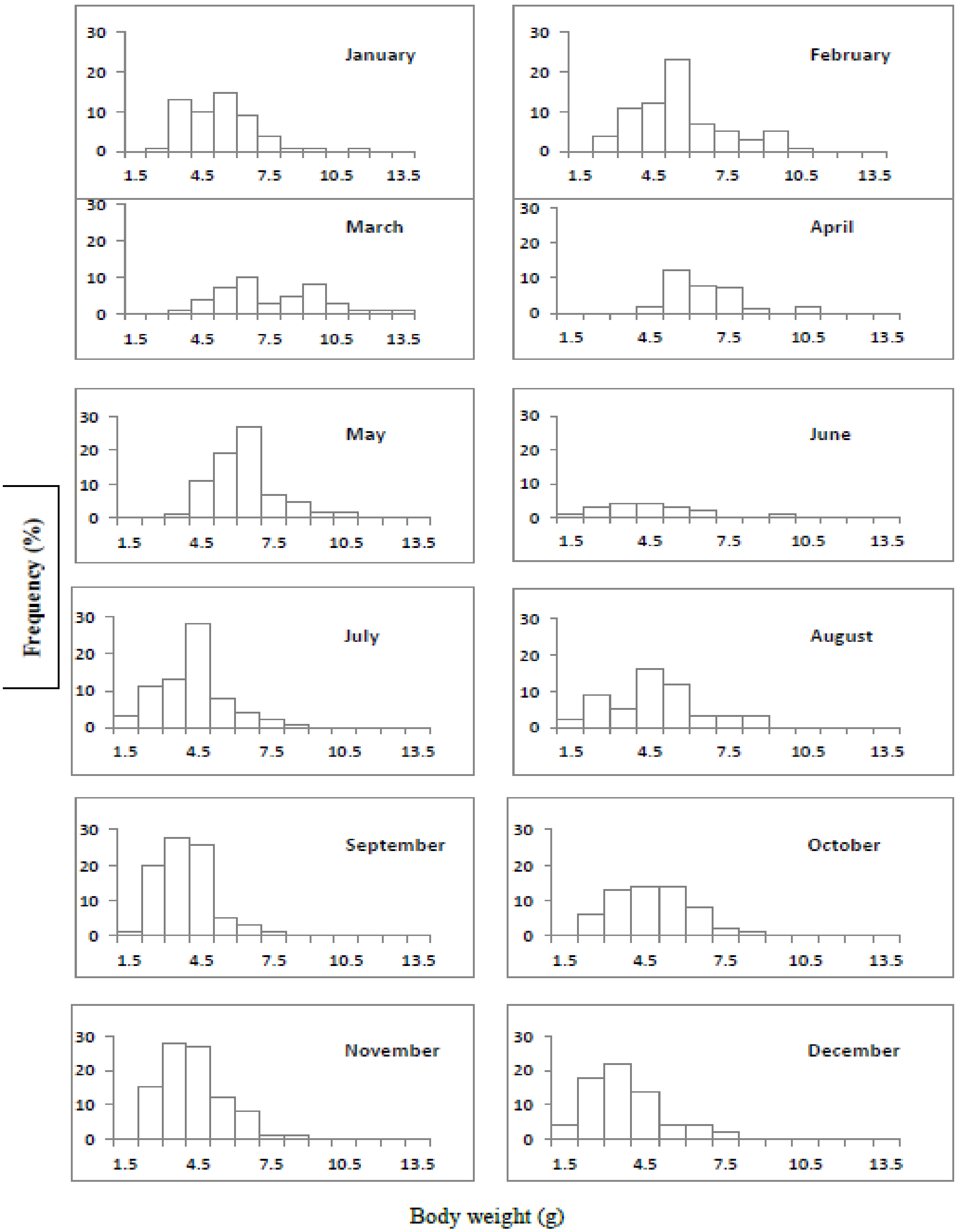

Figure 4. Frequency distribution of body weight in female of *L. guntea*

Gonadosomatic index

Gonadosomatic index (GSI) of every individual of male and female was calculated separately at each month's sample over the study period (Tables 2 & 3). Monthly percent GSI values of all male and female individuals were graphed as histogram separately and all the histograms were displayed vertically, which are shown in (Figures 5 & 6) according to males and females. In the case of male individuals, GSI varied throughout the sampling period which ranged between 0.17-2.65. The minimum GSI occurred in April, and the maximum was in October. The study considered male having GSI range of 0-0.5 were assigned to small size groups, 0.5-1 was medium size group, and male GSI ranging from 1-2 was large size group and male GSI ranging from 2-3 was very large size group. Male collected in February, March, April, May, August and September having very large size group of GSI which varied from 0.41-1.14, 0.20-0.84, 0.172-0.79, 0.26-1.01, 0.47-1.98 and 0.38-1.34, respectively. GSI values were in January, February, May, June, July, September, October, November and December having large group size and ranged from 0.38-2.14 in January, 0.26-2.33 in June, 0.24-2.42 in July, 0.26-2.65 in October, 0.41-1.94 in November and 0.62-1.91 in December. These values in these months were higher than those of other months in the year. Small and medium size groups according to GSI of male are found in almost every month of the year.

In the case of females, individual percent GSI varied throughout the sampling period, which ranged between 0.38 and 31.85. The study considered female having GSI range of 0-7 was assigned to small size group of GSI, 7-15 was medium size group of GSI, and female GSI ranging from 15-25 was large size group of GSI and 25-32 was very large size group of GSI female collected in March, April, May, June, July, August and September having more or less large and very large size of GSI, their values varied from 0.42-15.15, 0.75-17.86, 3.24-21.39, 2-27.02, 0.38-31.85, 0.69-27.91 and 0.94-17.12, respectively. Medium and small size was found in almost every month that ranges from 1.32-4.82 in January, 0.90-10.60 in February, 0.98-8.05 in October, 1.12-9.43 in November 0.66-6.01 in December. Based on individual GSI value in March, April, May, June and July were showing the fishes were in the progress of increasing gonad weight. Monthly mean percent GSI of females fluctuated as well and they ranged from 2.61 to 12.57, where the minimum mean GSI was estimated in November and the maximum in June.

Table 2. Month-wise gonadosomatic index of male *L. guntea*

Month	No of fish examined	GSI range	Mean GSI
January	33	0.38-2.14	0.88
February	29	0.41-1.14	0.75
March	56	0.20-0.84	0.48
April	62	0.17-0.77	0.46
May	25	0.26-1.01	0.49
June	82	0.26-2.33	0.73
July	30	0.24-2.42	1.12
August	47	0.47-1.98	1.14
September	16	0.38-1.34	0.91
October	42	0.26-2.65	0.86
November	8	0.41-1.94	0.84
December	32	0.62-1.91	1.05

Table 3. Month-wise gonadosomatic index of female *L. guntea*

Month	No of fish examined	GSI range	Mean GSI
January	55	1.32-4.82	2.80
February	71	0.90-10.60	3.48
March	44	1.42-15.15	6.48
April	32	0.75-17.86	10.05
May	74	3.24-21.39	12.55
June	18	2-27.0219	12.57
July	70	0.38-31.85	3.68
August	53	0.69-27.91	4.17
September	84	0.94-17.12	4.56
October	58	0.98-8.05	2.65
November	92	1.12-9.43	2.61
December	68	0.66-6.01	3.76

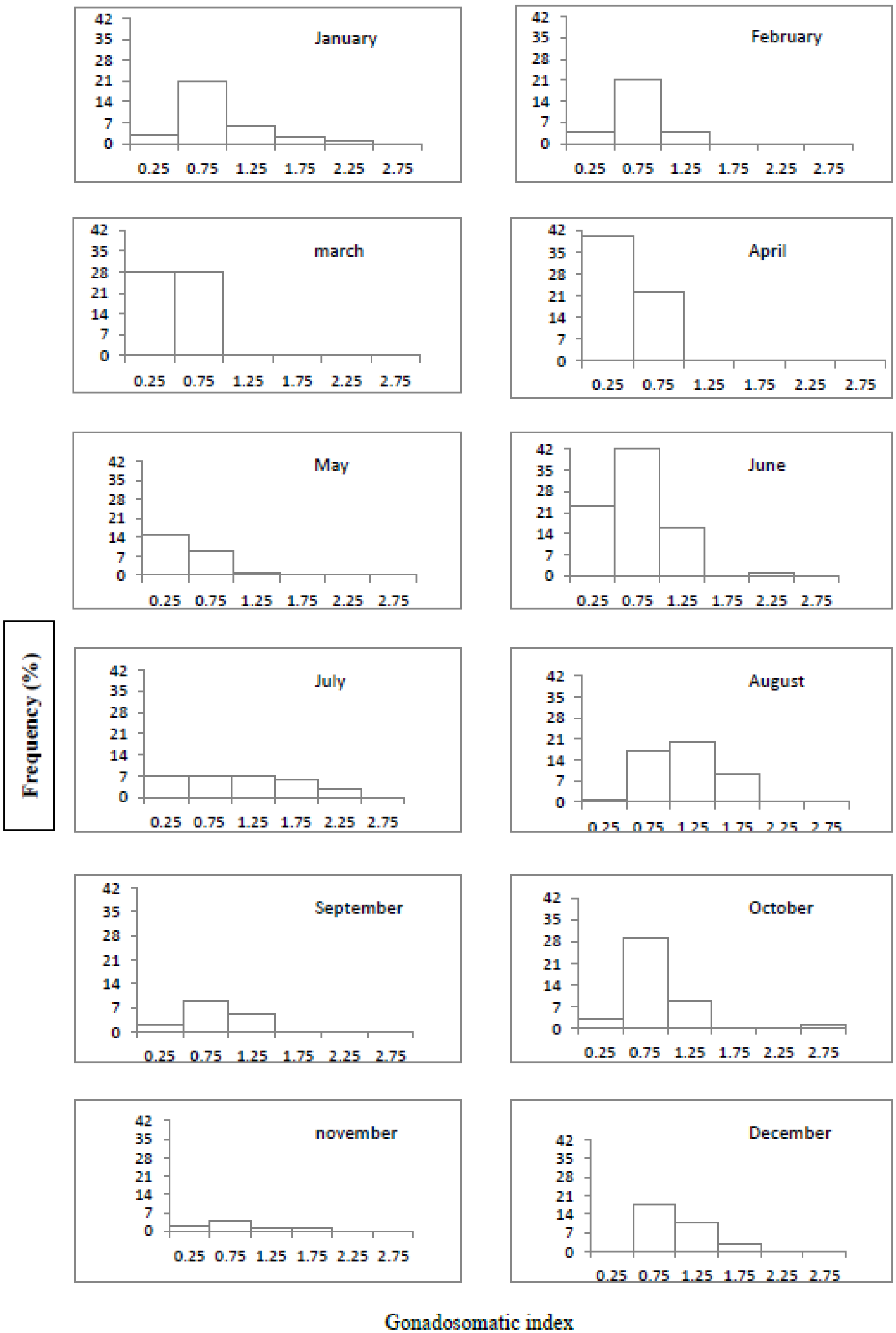

Figure 5. Frequency distribution of gonadosomatic index in male of *L. guntea*

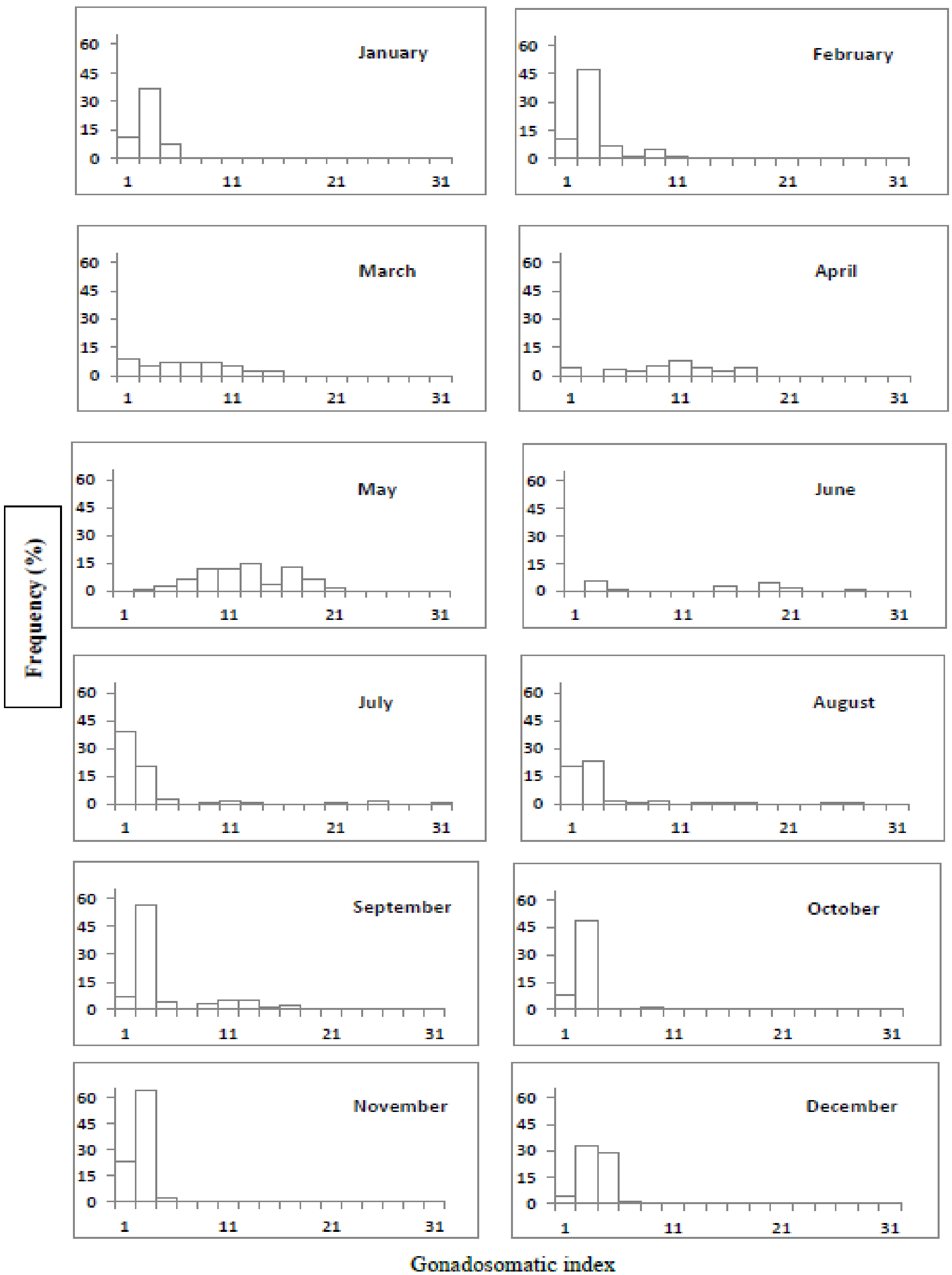

Figure 6. Frequency distribution of gonadosomatic index in female of *L. guntea*

Discussion

Information about gonadal maturation and the breeding season of a species makes subsequent studies on spawning frequency of its population easier, which is important for stock management. Proper assessment and management of exploited stocks is widely reliant on the accurate assessment of the maturity condition of fish, a broadly used tool by the fisheries biologists (Rahman et al. 2018). Though histological assessment of fish gonad is considered as one of the most reliable techniques for evaluating the maturity of individual fish, various macroscopic and biological index are also commonly used as rather easy and cost-effective method for describing maturity condition where histological observation facilities is lacking (Lowerre-Barbieri et al. 2011). However, spawning of fish occurs during a particular phase of the reproductive cycle. Some of them breed once a year while some at regular intervals throughout the year.

GSI is used by many scientists to successfully assess the maturity of individual fish (Hossain et al. 2012, 2017; Rahman et al. 2018). In the current study, the gonadosomatic index (GSI) values of males and females were evaluated month wise to determine the reproduction period of *L. guntea.* The GSI is considered as an indicator of the breeding season of *L. guntea*, which showed a clear pattern for one spawning season from March to June. In the present study, standard length of male *L. guntea* individuals collected over the study period ranges from 43 to 86 mm and the body weight varied from 0.86-10.44 g, those of females were from 50-92 mm and 1.41 and 13.50 g respectively. In addition, gonadosomatic index ranged from 0.172-2.653 in males and 0.383 - 31.852 in females. The peaks of GSI index values might be due to completion of maturity. The gonadosomatic index increases with the maturation of fish, being maximum during the period of peak maturity and declining abruptly thereafter, when fish become spent (Hossain et al. 2017).

During the present study, it was observed that the percentage of mature males and females was highest from February to September. Based on the mean percent of gonadosomatic index of both male and female, it was noticed that both male and female maturity trends were more or less similar. In this study, GSI values of both male and female were high in June and it remains until September, while there are low in other months. However, various studies corroborate the significance of temperature and other ecological factors in controlling gonadal maturation and reproduction in fish (Ridha et al. 1998). Taking peak monthly percent GSI, the study approximately considered that the spawning season of *L. guntea* was from March to June with a peak in June.

Conclusion

The current study provided some basic information on spawning season of *L. guntea* that will help further detailed studies and also contribute to determining basic information. Therefore, the information provided in this present study would be useful for the sustainable management and conservation of *L. guntea* in the old Brahmaputra river and surrounding aquatic ecosystems.

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Agricultural Extension in Bangladesh: Current Status/System and Challenges

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Abstract

Bangladesh has achieved tremendous success in crop production due to strong collaboration between research and extension agencies including private and non-governmental organizations. The factors attributed towards increasing production include irrigation facilities followed by fertilizers and pesticides as well as varietal improvement of different crops. Bangladesh is now self-sufficient in food and nutrition. Fish and meat production including eggs also increased keeping pace with population growth. The main challenges now include climate change and natural disaster, excessive use of fertilizers and pesticides leading to soil degradation and human health. Bangladesh has moved into smart agriculture through providing real-time support to the farmers through virtual media. It is expected that by 2030 Bangladesh will be able to achieve related SDG goals due to combined efforts of research, extension, private sector and NGOs.

Keywords: Agricultural Extension, Current Status, Current System, Challenges

Introduction

Bangladesh has achieved tremendous progress in crop production over the last 50 years. Crop production of six major crops namely Aus, Aman, Boro, wheat, jute and potatoes has increased significantly since 1970-71. According to BBS (2018), the rice production, which is the main crop of Bangladesh, has increased from 10.868 million metric tons in 1970-71 to 34.71 million metric tons in 2014-15. The average yield of rice in 1970-71 was only 1.096 ton per ha but in 2014-15 it was increased to 3.041 ton per ha. Jute was one of the main foreign currency earning crops. During 1970-71, jute used to grow in 0.91 million ha of land that provided 6.8 million bales of fibres with average of 7.472 bales per ha but in 2014-15 the area coverage was reduced to 0.67 million ha but yielded 7.5 million bales with average of 11.15 bales per ha. It means that though area was reduced the production per ha increased from 7.47 to 11.15 tons per ha. Similar trend was observed in potato. During 1970-71 the area coverage for growing potato was 0.259 million ha producing about 0.849 million tons of potato with an average of 3.28 tons per ha. But during 2014-15, the potato production area was increased to 0.47 million ha with total production of 9.25 million tons and average yield increased from 3.28 tons/ha to 19.65 tons/ha. Same is the case for wheat which was grown in only 0.126 million ha in 1970-71 that gave 0.1099 tons of yield with average yield of 0.87 tons/ha but in 2014-15 the area is expanded to 0.437 million ha with total yield of 1.348 million tons and average yield being 3.086 tons/ha

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(BBS, 2018). In vegetable production, Bangladesh ranks 3rd in the world (Financial express, 2021). Same is the case with fisheries and livestock.

Fish production up until 1990 was not encouraging. During 1973-78, Bangladesh produced only 0.64 metric tons of fish (Planning Commission, 1978). The lower production was attributed to weak institutional capacity and lack of skilled manpower (Buiyan and Rahman 1991). Fish production had been growing at around 5 percent per annum over the last two decades (Awal and Uddin, 2021). As per Department of Fisheries, Bangladesh produced only 2.44 million metric tons of fish which included capture, culture and marine fisheries. It gradually increased to 4.621 million metric tons in the year 2020-21. Hilsha production in 2006-07 was 0.075 million metric tons but now it is 0.273 million metric tons (Department of Fisheries, 2023). It may be mentioned that Bangladesh ranks third in inland open water capture production and fifth in World Aquaculture Production (Awal and Uddin, 2021)[c]. In Tilapia production Bangladesh is 4th in world and 3rd in Asia.

In case of livestock and its products, Bangladesh produced 9.923 million metric tons of milk during 2018-19, meat 7.514 million metric tons and eggs1.171 billion eggs. Livestock is one of the fastest growing industries in Bangladesh, contributing about 1.90 percent to the GDP and 16.52 percent to the agriculture sector in FY 2021-22. Due to government support, improved medical care, artificial insemination to increase production, the use of automation and technology in firms, and increased investment, the number of livestock is constantly increasing and the growth of the sector is accelerating. In FY 2021-22, the total amount of livestock in Bangladesh exceeded 43 crores. Due to this Bangladesh is now self-sufficient in meat production and can meet the population demand for 830 grams of meat per capita (Hasan 2023).

During 1977, Bangladesh had 22 million bovines while in 2008 it was increased to 26 million; poultry was 73.7 million which was increased to 137 million (Rahman, et al. 2014).

Role of extension services in success of agriculture sector

For crops, vegetables and fruit trees, the national agricultural extension agency in Bangladesh is the Department of Agricultural Extension (DAE). Beside DAE, Bangladesh Agricultural Development Corporation is also a national agency which support farmers with inputs like seeds of different crops. Previously, the BADC was also involved in distribution of fertilisers and irrigation facilities. Some of the roles were shared with private sector in distribution of fertilizer, insecticides and water and now BADC is involved only in seed production and distribution. BADC is also involved in quality planting materials production of fruit trees. Besides public extension system, there are several private organizations who are also involved in extension services using business development model. Engagement of private sector in agricultural extension began from 1993 through granting permission by the Government for selling agricultural inputs and irrigation equipment. The private extension agencies include NGOs and private companies.

Some national and international NGOs provide support to the poor and extreme poor for building capacity for livelihood improvement through increasing agricultural production which includes crops, vegetables, fruit trees, fish production, poultry and livestock. According to Umali and Schwartz (1993) the prime objectives of privatized extension is offering the right message to the right users at right time in the course of a demand driven service system that efficient also. Private extension services operate in business development method and they are responsive to clients as well as competitive in service provision. They address the problem in way that ensure their own survival through benefit to the clients. So, in addition to marketing their products, they also create market demand (Adejo et al., 2012). In the beginning, private companies were limited to agro-chemicals and seeds of vegetables. Afterwards, they expanded their scope to dairy, poultry and fisheries enterprises. The private companies have promoted their business through demo to show increased return using their inputs (Rashid, et al. 2012)[d]. Leading private companies are Lal Teer Seed Ltd, Mollika Seeds, Aftab Farm, Supreme Seeds, etc. The pesticides and fertilizer companies are supplying agrochemicals through their dealers all over the country. They provide embedded extension services during selling their produces.

Many of the poor and small farmers could change their economic conditions through such support. They stated with household level activities but gradually scaled up with development of technical knowledge and skill. The NGOs provided them free inputs while private sector. Usually, they adopt farmer field school approach including exchange visit (Arannayk Foundation, 2022). Some NGOs adopt business model to ensure sustainability of their business and development of farmers without economic consideration. Seed companies, pesticide dealers, fertiliser dealers and companies involved in contact farming belong to this group.

There is still another group of NGOs that provides microcredit support to the poor and extreme poor. They develop their skill from training from either NGOs or Ministry of Youth and get loan from NGOs to start their business. Though some banks provide microcredit support but due to complex system of having loan, the poor farmers prefer to take loan from NGOs. It is known that out of 250 kinds of activities for which Grameen Bank provides loan, maximum loan is distributed for agriculture and among agriculture mainly livestock (Grameen Bank, personal communication). Same is the case with brac and other large NGOs like TMSS, Uddipan, etc (Rashid, et al. 2012).

The critical factors that limit agricultural production include water, fertilisers, quality seeds, land, cash and technologies. It means that there are two types of NGOs: some works to support livelihood through building capacities of the target groups on technologies and inputs. The other group consider that if the farmers are provided with cash, they can best use their knowledge and skill in improving their livelihood. According to the World Bank, there are about 400 NGOs who are directly involved in agricultural activities (World Bank, 2016). Some of the NGOs providing agricultural extension services include BRAC, CARE-Bangladesh, RDRS, TMSS, KHI, etc.

While public extension agencies are commodity based, the NGOs provide integrated extension services on all four sub-sectors. The NGOs usually takes value chain approach while the public sector works on value chain of identified crops.

The activities of private companies who are engaged in fertilisers and pesticides provide embedded advisory services during marketing their products. For example, during selling fertilisers or insecticides, they advise the customer doses of pesticides in specific crops, quantity of fertilisers to be applied on specific crops, etc. The same is valid for crops and livestock. The public sector organizations have highly qualified professionals and sub-professionals for advisory services but the number of staffs are not enough to reach to all the households. Therefore, public sector extensionists can't reach to the mass while the NGOs or private companies grabbed it as opportunity as well as service though there are complaints about over use of fertilisers and insecticides which are affecting our environment in general and soil and human health as well as biodiversity in particular.

It is recognised that for effective extension of technologies, both public and private sector should work very closely. Private sector uses the knowledge of public sector extension professionals in training. The NGOs are especially highly skilled in facilitation process in training while public sector uses mostly teacher-student approach. The private companies promote their products through establishing demonstration plots. Some of the private companies include Lal Tir Seed Limited, Syngenta, ACI, Supreme Seed Company, Mollika Seeds, BRAC seeds, Kustia Seed Stores, etc. Besides national companies, there are multinational companies as well (Uddin and Qijie, 2013).

Role of research in knowledge generation

It must be acknowledged that success of extension agencies, be it public or private depends largely on new knowledge. The knowledge is usually generated by the research organizations. There are now 12 agricultural research organizations under National Agricultural Research System. The apex body of the NARS is the Bangladesh Agricultural Research Council. It is noteworthy to mention that BRRI has developed more than 100 high yielding rice varieties (including six hybrid rice) during the last few decades (BRRI, 2019). Efforts were made to popularize those modern varieties among the farmers in different seasons. The BRRI developed modern rice varieties (MVs) and technology packages played the key role in boosting annual rice production in Bangladesh from 9.93 million tons in 1972-73 to nearly 38.66 million tons annually in 2018-19 (Islam, et al. 2019). Almost 91% of the total rice production in Bangladesh comes from high yielding modern rice varieties (FPMU, 2019). Similarly, Bangladesh Agricultural Research Institute has developed more than 600 technologeis on cereals, oil seeds, pulses, tuber crops, vegetables, fruits, flowers, spices, fibre crops and others (BARI, 2023). Other research institutes have also developed thousands of technologies.

To strengthened linkages between research and extension, the agricultural extension policy has suggested mechanism of coordination both at field level as well as at the central level (NAEP, 1996).

The NATCC is headed by the Chairman, Bangladesh Agricultural Research Council (BARe) and comprises representatives of all research and extension agencies at national level. The member secretary is the Additional Director (Monitoring), Field Services Wing, DAE. The NATCC meets as and when required, but at least once each season

Dynamics of extension approaches

Agricultural extension service started with training and visit (T&V) method. New knowledge about any technology used to be transferred to farmers by the extension professional. After the training, the farmers were expected to execute the knowledge in their field. The block supervisor from the DAE was responsible for monitoring and provide further support to the farmers. The Block Supervisor had to report back to the Agriculture Officer. The costs associated with visit was borne by the project supported by the World Bank during 1980s. After two decades of functioning T&V model, it didn’t sustain due to completion of the World Bank Supported project in 1990’s (Anderson et al, 2006).

As mentioned earlier, T&V system supported individual farmer. After T&V, the system of meeting *group of farmers* was initiated in mid-1990s. The T&V was top-down but the group approach was bottom-up as it started with planning where participation of farmer was ensured. Considering positive impact of group approach, government has developed a **New Agricultural Extension Policy (NAEP)** in 1996. The NAEP focused on the extension support to all categories of farmers, decentralised planning, demand-led extension services, strengthening extension-research linkage, and coordination at each echelon of administration (UADC, DDCC, ATC and NTC). Strategies for implementing NAEP included formation of different coordination committees at national level down to local levels so that the research issues are identified from the field and technologies generated from the research institutes reach to the farmers through extension agencies. These coordination committees are:

1. National Agricultural Technical Co-ordination Committee (NATCC) at the national level
2. Agricultural Technical Committee (ATC) at the regional level
3. District Extension Planning Committee (DEPC) at the district level
4. Upazila Agricultural Extension Co-ordination Committee (UAECC) at the upazila level
5. DAE/NGO Liaison Committee for homestead production.

With the implementation of NAEP in 1997 the conditions of service delivery of the DAE improved with respect to *bottom-up planning,* identification of research issues, dissemination of technologies to the field, monitoring and evaluation and strengthening research extension linkages including linkages with NGOs. Unfortunately, the coordination activities could not be continued for long beyond project period. Government could not provide necessary fund and hence, alternative approach was sought. The main limitation of the approach was donor and project dependence.

Farmer Field School Approach

The Farmer Field School (FFS) approach was developed in the late 1980s in Indonesia. This agricultural extension method was originally designed to build capacity of the rice farmers on the concept of biological control, and to familiarize them with Integrated Pest Management (IPM). Following the success of this practical and participatory method of learning, it quickly spread to other countries. In Bangladesh, the first Farmer Field Schools were organized in the early 1990s, assisted by the FAO inter-country program for IPM in rice. After initial positive experiences, several other donors (UNDP, CARE-Bangladesh and DANIDA) started projects to spread IPM to hundreds of thousands of farmers through IPM Farmer Field Schools. All these projects included season-long Training of Trainers courses to develop skilled FFS facilitators. Through this continuous support over the past ten years, Bangladesh now has a huge capacity to implement FFSs, especially in the DAE.

Immediately after phasing out T&V system, the DAE and fisheries and livestock department started farmer field school approach. The main approach of the Farmer Field Schools is learning-by-doing, putting farmers at the heart of learning and decision-making around new agricultural techniques. The FFS integrates different components such as sustainable agriculture practices, market engagement, gender and equity, food and nutrition security, empowerment and monitoring and evaluation to build the knowledge, skills, and practices of farmers.

The FFS ensures that the communities, preferably existing communities participates in season-long training on any specific crop that starts before, during, and after the cropping season ensuring that learning and other activities are done in real time without requiring extra commitments from already time-constrained farmers. It is based on adult learning principles that offer practical lessons through participatory approaches. Farmers can then translate this learning and adapt it into their own fields, creating ownership and sustainability of adoption. Monitoring and evaluation are done by the farmers though project staff make sample check to be sure that they are in track. They learn calculating costs, and profit and loss and to use this information to make decisions based on their specific circumstances.

Though FFS started with biological control of rice, it subsequently encompassed homestead issues such as vegetable and fruit gardening, group formation, social issues, livestock, poultry and fish-farming.

Since 2006, around three million poor people (representing more than 500,000 households) in rural Bangladesh have benefitted directly from new knowledge and techniques related to agricultural production and nutrition provided through FFS. It also had spill-over effects who learned from the neighbor.

FFS has benefited poor farmers. The households have reduced their vulnerability and increased intake of most food items significantly more than control village households. Likewise, FFS households estimate that their probability of being hit by food shortage has decreased from 20% before FFS to 11% after FFS, compared to a slight decrease from 31% to 30% within control village households (Danida, 2008).

The impact of FFS on household income was highly significant. While income in FFS households on average increased from BDT 52,000 before FFS (2007) to BDT 72,000 after FFS participation (2010), the increase within control village households within the same period was only from BDT 47,000 to BDT 57,000. The income increases within FFS households is most significant for the households with the lowest income levels. The impact of FFS on production diversification is highly significant. The total number of agricultural products produced is significantly larger for FFS households than for control village households. When costs are compared with benefits from the FFS interventions at household level, it shows a pay-back time of less than a year from the investment.

Though the FFS is also donor and project dependent approach, much of the knowledge has already been spilled to the farmers and through farmers-to-farmers knowledge sharing, the program is sustaining. Almost all the NGOs involved in livelihood activities adopted FFS approach and hence with some changes in approach it is still sustaining.

Beside extension supports either by DAE, DLS or DoF, some other factors also contributed in food production and storage. Since 2011, the Integrated Agricultural Productivity Project financed by the World Bank has trained 300,000 farmers and improved irrigation system of 27,500 ha of land. The project supported adaptation and mitigation of heat-tolerant, drought-tolerant and saline-tolerant crops, improved soil health management, and diversification out of rice production (World Bank 2016).

The Modern Food Storage Facilities Project (MFSFP), initiated in 2007 helped Bangladesh to procure rice from the international markets, expands and improves grain storage infrastructure and strengthens the management of grain stocks. It helped Bangladesh to absorb shock of food security, especially for its poorest and most vulnerable citizens, from natural disasters and external shocks.

Upgradation of Agricultural Extension Policy through inclusion of e-extension services

With introduction of e-extension service, the agricultural Extension has further improved its efficiency. The e-extension service provides real-time support to the farmers through online information. This is in line with National Agricultural Extension 2020. The DAE has updated its mission and made its vision more effective of the changing time. This policy document is very much aligned with the revised with the revised Agriculture Policy 2018. The DAE has 3500 Agriculture Graduate with 15,000 diploma agriculture who works directly with the farmers and provide extension services either to the group or individual farmers.

Major Challenges of Crop Agriculture in Bangladesh

With increasing population and development of economy of Bangladesh agricultural land is decreasing due to land use conversion. The cropping intensity is more than 190 and hence there is real challenge of fertility management of soil. Due to climate change, there is change in rainfall pattern. Farmers are compelled to use underground water but it has always a negative impact on environment. Government is providing high subsidy in fertilizers, which may reduce over time. Natural hazards is also a challenge which impair harvesting or crop damage in the field. Sometimes people don't get right price on agricultural crops, especially the robi crops. Many of the small farmers don't use technologies to understand soil fertility for determining fertilizer doses; rather they use more fertilizers that the crop needs resulting in soil degradation. These are some of the major problems of agriculture.

Similar is the case with fisheries, poultry and cattle rearing. The farmers are using more chemicals in feeds. The residual effects of such chemicals are harmful to the consumers.

Conclusion

Despite being very small country area and burgeoning in population, over the past 50 years since its independence Bangladesh has been able to feed the people with its own production. The success is attributed to conducive government policy, involvement of private sector and above all the most resilient farming communities having their own knowledge of farming system. With combined efforts, Bangladesh's is now third in rice and vegetable, second in jute and jackfruit, sixth in potato, seventh in mango and guava production. This could be achieved due to research and extension policy support from the government. The research organizations have generated technologies and extension agencies played vital role in disseminating the technologies to the field. This has made the country almost self-sufficient in agriculture.

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Trends and Opportunities of Biofortified Crops in Bangladesh

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Abstract

This article explored the prospects and opportunities of biofortified crops in Bangladesh. In 2016, only 499 tons of biofortified zinc rice seeds were consumed by the farmers and the demand for such seeds increased to 6,358 tons in 2022. Biofortified breeder seed production started with only 50 kg in 2013, which has been increased to 41,650 kg in 2021-22. Increase in breeder seed production of biofortified rice indicates that the demand for cultivating biofortified zinc rice is increasing. The seeds are produced by private seed companies and BADC. As of now, 138 seed companies have included zinc rice seeds in their business portfolio compared to 91 in 2020-21. Out of 10 zinc rice varieties, the demand for BRRI rice 74 is most preferred by the growers of Barisal region. BADC, Supreme Seed Company Ltd., ACI seed, BRAC seed, Krishibid seed, Ispahani seed, Vai Vai Traders, National AgriCare Import & Export Ltd are pioneers in marketing of zinc rice seeds. Development of climate smart biofortified crop varieties and creating mass awareness will further scale up local production and procurement of biofortified zinc rice in Bangladesh that will greatly support food and nutritional security. Both public and private sectors should work together to scale up production of biofortified crops.

Keywords: Trends and opportunities, Biofortified crops, Bangladesh

Introduction

Any crop developed through breeding for having higher amounts of a particular micronutrient than standard crops is known as biofortification" (Codex Alimentarius Commission, 2017). Dr. Howarth Bouis, the father of HarvestPlus, introduced the term biofortification. HarvestPlus is a program of the International Food Policy Research Institute (IFPRI) and it leads the program of biofortification for improving the nutrition and public health by developing and promoting biofortified food crops that are rich in vitamins and minerals.

In biofortified crops, target micronutrient(s) is absorbed by the plant during growth and transfer to edible parts through physiological and biochemical reactions; on the other hand, fortification involves physically mixing of a desired chemical micronutrient(s) to the food before cooking. In terms of economics, biofortification is cost effective as the biofortified crop varieties needs no additional mixing of micronutrient. The growers can grow biofortified crop varieties without any additional costs or labour. Biofortification acts as a complementary to food diversity and fortification for alleviating micronutrient deficiency.

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Conventional plant breeding approach acts as the principal way of achieving biofortification in staple crops in many countries of the world, although agronomic practices and transgenic methods can also be deployed.

Biofortified Crop Development

Bangladesh is a pioneer in developing biofortified zinc rice. Bangladesh Rice Research Institute (BRRI) developed the first biofortified zinc rice variety, BRRI dhan62, through conventional breeding, in 2013. As of now BRRI developed seven biofortified zinc rice varieties – BRRI dhan62, BRRI dhan64, BRRI dhan72, BRRI dhan74, BRRI dhan84, Bangabandhu dhan100 and BRRI dhan102. Bangladesh Institute of Nuclear Agriculture (BINA) has developed one biofortified zinc rice variety - Binadhan-20 and Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) has developed two biofortified zinc rice varieties – BU Aromatic Hybrid dhan1 and BU dhan2 (Ref). Zinc content in the ten biofortified zinc rice varieties ranged from 19 to 27 mg per kg clean rice compared to 10 – 15 mg per kg of the regular high yielding rice varieties (Ref). However, all the biofortified zinc rice varieties may not equally satisfy the prosumers and consumers exigencies in all over the country. Some international development partners such as BMGF, DFID, World Bank, European Union, GAC (Global Affairs Canada) supported for awareness building and distribution of free seeds of biofortified zinc rice in Bangladesh. HarvestPlus in Bangladesh underpins dissemination of biofortified zinc rice varieties through partnering with NARS, DAE, BADC, NGOs and private sectors. An integrated effort of the NARS, DAE, BADC, NGOs and private sectors delivered seeds of biofortified zinc rice to 6,000 households in 2013, which increased gradually and reached about 0.5 million (510,646) by 2022 (Ref).

Year	Breeder Seed Produced (MT)	Number of Seed Companies received seeds
2005-06	77.93	82
2010-11	124.27	752
2015-16	177.71	1172
2020-21	193.03	996
2021-22	218.72	718

Table 1: Breeder seed production of all BRRI developed varieties with the number of seed companies)

Seed Production Trend

BRRI has increased the production of breeder seeds as the demand increases. Table 1 shows the breeder seed production information of all rice varieities of BRRI. In 2005-06, about 78 MT seeds were produced and distributed among 82 seed companies. The production increased gradually, which reached about 219 MT in 2021-22 and 718 seed companies received and multiplied accordingly. Out of the 718 seed companies, 138 companies produced breeder seeds of zinc rice in 2021–22 (Ref).

Role of HarvestPlus in Seed Delivery

HarvestPlus partially funded BRRI for breeder seed production of biofortified rice varieties. Bangladesh Agricultural Development Corporation (BADC) and private seed companies purchased breeder seeds from BRRI for production of foundation seeds, certified seeds and TLS seeds. Harvest Plus development partners are engaged in promoting and facilitating the marketing of biofortified zinc rice varieties. HarvestPlus also support the NGOs and seed companies for wider promotion and demand creation of biofortified zinc rice varieties. It is evident from Figure 1 that BRRI has increased production and supply of breeder seed of zinc rice.

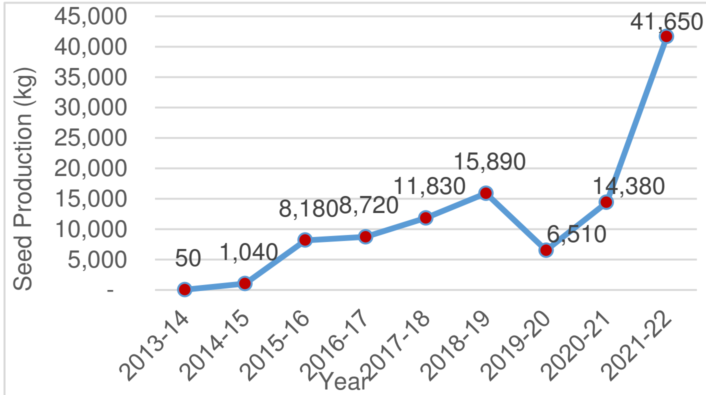

Figure 1: Production of breeder seeds of biofortified zinc rice

HarvestPlus initiated facilitating biofortified zinc rice seed marketing in Bangladesh since 2019. Figure 2 represents the increasing trend in biofortified zinc rice seed production and marketing. In 2019, about 1,591 MT seeds of zinc rice were produced which gradually increased to 6,358 MT in 2022. This is 4% of the national total seed supply. A total of 138 seed companies have included zinc rice seeds in their seed business portfolio.

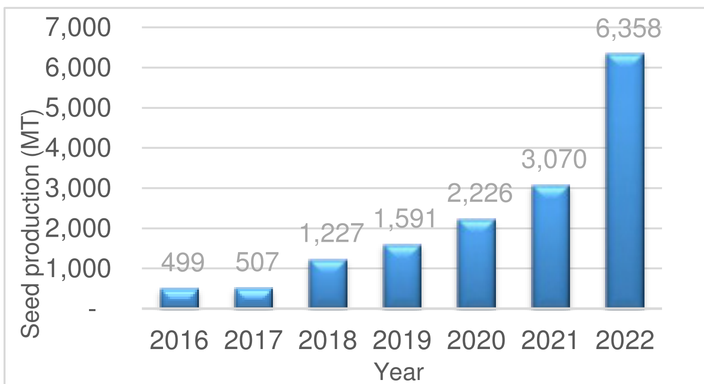

Figure 2: Biofortified zinc rice seed production (in ton) trend from 2016 to 2022

BRRI dhan74 is a potential bold grain type biofortified zinc rice variety for Boro season. BRRI dhan74 yielded 7.5 – 8.5 t/ha in different areas of Bangladesh and in single Boro rice area it yielded up to 11.0 t/ha (Ref). Although it is bold grain type variety, its higher achievable yield led its acceptability in the low-lying fields where farmers prefer to grow hybrid rice. Increasing trend of seed production by BADC depicts its adoption and growth trends in the country. In 2016-2017, BADC produced 1.8 tons seed of BRRI dhan74 that increased to 72 tons in 2017 – 2018, 425 tons in 2018 – 2019 and in 2022 – 2023 it increased to about 3,444 tons (Ref). BRRI dhan74 showed its demand by millers of flattened rice and millers who can deliver rice to government procurement systems. BRRI dhan84 is the highest zinc rich rice varieties which contains 27.6 ppm zinc, 10.1 ppm iron and 9.7% protein (Ref). Its grain quality is medium with brownish color. It gives an average yield of 6.5 tons per hectare after 140 days of maturity (Ref). BRRI dhan84 has the potential to reach more and more people as it is similar to mega variety BRRI dhan28.

The remarkable positive growth of zinc rice can be attributed to the integrated extension approaches by the active public and private sector agencies as well as underpinning seed marketing approach.

HarvestPlus has been working in Bangladesh since 2013, to help developing and delivering biofortified rice seed to farmers, through strong partnership with National Agricultural Research Systems (NARS), department of Agricultural Extension (DAE), Bangladesh Agricultural Development Corporation (BADC), NGOs and private seed companies. Public and private seed companies are engaged in production and marketing of zinc rice seeds all over the countries and gave support for enhancing the marketing of the seeds. A major cause of rapid adoption of zinc rice is the extension program of DAE and private sector seed vendors. Engaging seed dealers, retailers for creating awareness has also helped mass adoption. HarvestPlus patronized Small and Medium Seed Producers Association (SMSPA) and South West Seed Producers Association (SWSPA) model in the south-western districts of Bangladesh for setting example of sustainable seed entrepreneurship with more than 300 small and medium seed enterprises. NGOs and small and medium seed companies as well as business entities have been provided technical support and subsidy to develop seed enterprise. HarvestPlus had long-term formal & informal partnerships with BRRI, DAE, seed associations, seed companies, NGOs, ICM/IPM clubs and farmer groups.

The farmer's adoption of zinc rice has been increased due to the supports of government agencies and private sectors. Media also worked very positively to raise awareness.

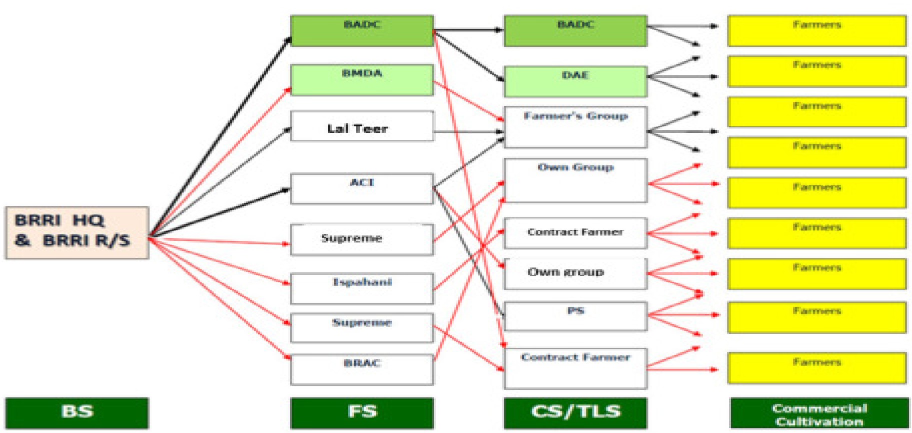

Figure 3: An example of seed flows through BRRI rice seed net

Private sector and NGOs also contributed in popularizing the varieties substantially. Ensuring good prices of rice and direct procurement of paddy from farmers were arranged to create demand for zinc rice. Location specific adaptive experiment and demonstration has been established through the DAE, private sector and NGOs to show the performance and popularize the variety. HarvestPlus utilized many of the seed network members of BRRI seed net, who receive Breeder Seed from BRRI (Bashar et al 2005; Salahuddin & Bashar: 2017). Adequate coordination and information sharing systems helped to seed production and marketing status of different varieties. A great movement of variety dissemination took place in Bangladesh, silently, since 2013, when a joint public, private, NGOs and farmers effort started to work in a participatory manner with support as catalytic role from the HarvestPlus program.

Conclusion

The increasing trend of zinc rice seed production shows that there is a huge scope for zinc rice seed business in Bangladesh. Considering nutrition security, relevant NARS Institutes should strengthen research on biofortified crop development. Crop development, seed production and dissemination of nutrient rich and climate smart crop varieties will play an important role in enhancing food security as well as nutritional security in the country. Enhancing biofortified zinc rice procurement by the government will help to meet the demand for their safety net programs such as school feeding program, VGD, VGF, etc. Awareness creation, extensive promotional activities and demonstration activities are essential for rapid dissemination and adoption of new rice varieties. Zinc rice will be able to play an important role in food and nutrition security in the country, if it is possible to ensure subsequent growth and marketing of zinc rice seed production by BADC and the seed companies.

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Agriculture: How is it changing with time?

Indrajit Roy[a]

Introduction

When a country changes, climbing the ladder of economic development, which means more industrialization, urbanization, and infrastructure building; the society as a whole experiences the wave of transformation. Of all the sectors of the economy, agriculture best captures the change of times, and along with it changes in the society and societal relationships among various groups in the society. It is because the sector produces food, which is the most basic item for sustaining any human society. As a result, all aspects of making food available to consumers along the supply chain from its production, processing, storage, transportation, and delivery to markets draw many actors. Change happens faster in any endeavour where many actors have the opportunity to interact intensively. It happened in Bangladesh, too, where the agriculture sector underwent dramatic changes over the past four decades. The key factor that drove this transformation includes the national policy of achieving food self-sufficiency pursued by all successive governments since independence. The policy supported introduction of new farming technologies and sustained investment in the sector to help farmers continue food production more productively and efficiently. The changes that followed in the agriculture sector were accelerated by economic growth of the country spurring changes in rural livelihoods.

Keywords: Rice farming, pesticides, small holders, structural change

Structural changes in farming in Bangladesh

According to official sources, the contribution of the agriculture sector to national GDP in Bangladesh is consistently declining. It declined from 14.06 percent in 2015-16 to 11.50 percent in 2021-22 (Bangladesh Economic Review, Ministry of Finance, 2021-22). That doesn't mean the agriculture sector is producing less; it is producing more, but the relative weight of other sectors like industry, manufacturing, services, and external trade in an ever increasing size of the GDP is rising. It is a phenomenon that can be logically expected as the economy is on a high growth path recording 7.25 percent GDP growth in FY 2021-22. But the decline of agriculture's share in GDP isn't matched by a proportionate decline in the share of the population engaged in the sector to derive a livelihood. The sector still employs a large number of the labour force. According to data of agricultural censuses conducted in Bangladesh in 1983-84, 1996, 2000, and 2019, the total number of households more than doubled over the period 1983/84 - 2019 with the number of non-farm holdings increasing much faster than farm households (Table 1). In 1983-84, of the total 13.8 million holdings, 10 million (72.7%) were farm households. Although the

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number of farm households increased to 16.9 million in 2019, its share in total households declined to 47.5 percent in 2019. It means about 47 percent of the total population is currently engaged in agriculture seeking to make a living from their lands.

So, the spin-off effect of ongoing industrialization and diversification of the economy in terms of creating employment opportunities is still limited to keep a balance between the agriculture sector's progressive decline in the share of national GDP and the decline in the share of the number of people engaged in agriculture. It is a significant barrier to moving out of the trap of being a permanently developing country. As we have noted between 1983-84 and 2019, the total number of households increased 157 percent keeping pace with population growth over this period. It had an effect on the size of operational holdings. Farm holdings increased but became smaller. Small farms, which vary in size between 0.05 and 2.49 acres, increased their share in total farm holdings from 70.3 percent to 91.7 percent. The share of medium farms (2.50 - 7.49 acres) declined from 24.7 percent to 7.7 percent and also that of large farms (larger than 7.5 acres) declined from 4.9 percent to 0.6 percent. The share of holdings owning no land slightly decreased from 9.6 percent in 2008 to 8.0 percent in 2019.

Over the period 1983/84 - 2019, the average operating size of a farm holding decreased from 2.26 acre to 1.29 acre and the net cultivated area per farm reduced by half from 2.26 acre to 1.1 acre. The share of agricultural labour households (agricultural wage is the main income source of the households) in total households decreased from 39.8 percent to 25.9 percent. However, in the farm group, the share of households whose main source of income is agricultural labour wage increased from 31.1 percent to 34.5 percent.

Table 1. A snapshot into structural changes of farming in Bangladesh, 1983-2019

Number of holdings	1983-84	1996	2008	2019	**Change, %**
TOTAL	13817646	17828187	28695763	35552296	157.3
Non-farm	3772347	6029945	13512580	18670539	394.9
Farm	10045299	11798242	15183183	16881757	68.1
Share of holdings (%)					
Total farm holdings	72.70	66.18	52.91	47.48	-34.7
Small farm (0.05-2.49 acres)	70.34	79.87	84.39	91.70	30.4
Medium farm (2.50-7.49 acres)	24.72	17.61	14.07	7.7	-68.9
Large farm (7.50 acres & above)	4.94	2.52	1.54	0.6	-87.9
Owning no land			9.58	8.02	
Operated area (acre)					
Farm holdings	22678464	19957144	22305008	21727934	-4.2
Per farm holding	2.26	1.69	1.47	1.29	-42.9
Net cultivated area (acre)					
All farm holdings	20157564	17771339	19070749	18636434	-7.5

Number of holdings	1983-84	1996	2008	2019	**Change, %**
Per farm holding	2	1.5	1.26	1.1	-45.0
Agriculture Labour households					
Total number	5495300	6401453	8844402	9200895	67.4
Percent of all households	39.8	35.9	30.82	25.88	-35.0
Number in non-farm group	2375551	3381101	3930357	3374609	42.1
Percent in non-farm group	62.97	56.07	29.09	18.07	-71.3
Total number in farm group	3119749	3020356	4914045	5826286	86.8
Percent in farm group	31.06	25.6	32.37	34.51	11.1

The statistics listed above tells about the trend of changes taking place in the agriculture sector. Fragmentation of the operating holding is going on in all farm categories. Large farms are decreasing in size falling into the medium farm category; the same trend is evident in the medium farm category resulting in the increase of farms in the small farm category. The average size of the farm holdings is decreasing. Smallholder farming, always a characteristic feature of Bangladesh agriculture, is now more dominant. More than 90 percent of the farms engaged in crop production are small farms with the size of the holdings ranging from 0.05 acre to 2.49 acre. As we will see, there are signs that indicate the dwindling size of Bangladesh's small farms is affecting agricultural growth through input use efficiency which is transmitted to cost of production and ultimately profitability of farming.

The Government is pumping substantial resources in the agriculture sector, which maintains a steady increase, to subsidize the cost of inputs aimed at helping farmers lower the cost of production and increase their profit margins. More recently, the Government has adopted a targeted approach of helping specific categories of small farmers by providing them free of cost packages of improved seeds and fertilizer needed to cultivate a crop on their plots in the cropping season. So far, the trend of dwindling farm size hasn't posed a problem for the government to direct its support through subsidizing the cost of chemical inputs and irrigation water. But it is becoming a constraint to supporting these farms with appropriate farm machinery aimed at cutting significantly the cost of production and increase profitability of farming.

The Government's ambitious BDT32 billion farm mechanization support programme launched two years ago, under which the Government subsidizes up to 70 percent cost of machinery, couldn't make much headway, according to a press report (The Daily Star, 12 February 2023). As it turned out, the use of machinery on fragmented plots wasn't cost-effective. The alternative was some form of land consolidation. The Department of Agricultural Extension piloted a model of this approach named "Synchronised Farming" (a cultivation method in which the same variety of rice was planted in one large field, 50 to 60 acre, by machine. All field operations from seedbed preparation to harvesting were performed simultaneously by machines) in 61 districts.

Despite the advantages demonstrated (38 to 40 percent increase in output harvested per unit of cultivated area), farmers are still not fully convinced about the merit of this approach because it requires doing away with the land borders separating individually-owned plots to create a larger field in order for machinery to work at economy of scale. In a society, where land ownership is considered sacrosanct and often violent clashes happen to protect their own land from encroachment by others, farmers' suspicion can be easily understood. To overcome the constraint on efficient utilization of productivity enhancing external inputs posed by land fragmentation, group farming has been tried in Bangladesh under various donor-supported agricultural projects. But few of these groups could maintain their existence upon withdrawal of project support. There are signs that indicate the ongoing structural change in the agriculture sector, whereby farm holdings are being fragmented and becoming smaller in size are affecting efficient utilization of external inputs in rice cultivation.

Rice cultivation

Rice is the staple food crop in Bangladesh which still accounts for the overwhelming majority of the total cropped area in the country. Its share in the total cropped area was >71.9 percent in 2019 - 2020 slightly declining from >76.6 percent in 2011-2012 thanks to expansion of cultivation of non-rice crops such as vegetables and maize (BBS, Yearbook of Agricultural Statistics, 2021). The changes that took place in rice cultivation in Bangladesh illustrate the trends of change in the overall crop sector.

Table 2. Changing scenario of rice growing in Bangladesh over the period 1980/1990 - 2009-2021

Parameter	1980-1990	1991-2000	2001-2008	2009-2021	2016-2021
Area under rice (average, million ha)	10.34	10.23	10.67	11.44	11.45
Annual growth rate, %	0.11	0.65	0.87	0.08	0.01
Production of rice (average, million tonne)	15.28	19.42	26.59	34.81	36.41
Annual growth rate, %	2.56	3.33	3.32	1.19	2.24
Yield (average, t/ha)	1.47	1.89	2.49	3.04	3.15
Annual growth rate, %	2.45	2.67	2.97	1.1	1.2

Source of data (BBS, Yearbook of Agricultural Statistics, from 2012 to 2021; FAOSTAT for the Period 1980-1990 to 2001-2008)

Over the four decades, production of rice (milled) more than doubled, increasing from 15.28 million tonnes, average for the period 1980-1990, to 34.81 million tonnes, average for 2009-2021. Production grew faster in the first two decades, at 2.56 percent in 1980-1990 and 3.33 percent in 1991-2000. Growth in production started tapering off since the beginning of 2000s with annual growth rate remaining almost stagnant at 3.32 percent in 2001-2008 and decreasing to 1.1 percent in 2009-2021. Intensity of rice cropping steadily increased over the four decades. It is evident from the increase in rice cropped area from the average 10.34 million hectares (mha) in 1980-1990 to 11.44 mha average for the period 2009-2021 with growth rates slowing during the past decade. But the net cultivated area decreased by 7.5 percent from 20,157,564 acres in 1983-84 to 18,636,434 acres in 2019 (Table 1). Average yield of rice (milled) more than doubled from 1.47 t/ha in 1980-1990 to 3.04 t/ha in 2009-2021. Over the first three decades, yield growth maintained an upward trend with annual growth rates increasing from 2.45 percent in 1980-1990 to 2.97 percent in 2001-2008 followed by sluggish growth in 2009-2021 with annual growth rate declining to 1.1 percent.

Table 3 provides a deeper insight into the changing trend of rice growing by disaggregating annual rice production over the period from 2009-2010 to 2020-2021 by growing seasons typical for Bangladesh - Aus, Aman, and Boro -varying in climatic resources, atmospheric temperature, solar radiation, rainfall and availability of irrigation.

Table 3. Scenario of annual rice production disaggregated by rice growing seasons, 2009/2010 -2020/2021

Parameter	Aus	Aman	Boro
Area (million ha)			
Average	1.077	5.600	4.760
Range	0.942 - 1.305	5.530 - 5.679	4.707 - 4.859
Annual growth rate (%)	0.9	0.0	0.01
Share (%) of the total rice area, range	8.66 - 11.15	47.91-50.73	40.67 - 42.38
Production (million tonne)			
Average	2.411	13.391	19.004
Range	1.709 - 3.285	12.207 - 14.438	18.059 - 19.885
Annual growth rate (%)	4.1	1.4	0.657
Share (%) of the total rice production, range	5.34 -8.73	37.69 - 40.38	52.87 - 56.48
Yield (tonne/ha)			
Average	2.23	2.39	3.911
Range	1.736 - 2.516	2.155 - 2.573	3.835 - 4.135
Annual growth rate (%)	3.2	1.4	0.649

(Source of data: BBS, Yearbook of Agricultural Statistics, 2012 to 2021)

As evident from Table 3, the Aman season had the highest share (47.9 to 50.7 percent) in total annually cropped rice area with the average 5.6 million hectares for the period 2009/2010 - 2020/21. Boro season, the most favorable rice growing environment, accounts for 40.7 - 42.4 percent of the rice area with an average of 4.76 million ha during this period. In both seasons, growth in rice cropped area remains stagnant. In the Aus season rice area has increased at 0.9 percent annually with its share in total rice area increasing from 8.7 percent to 11.1 percent. Of the three seasons, Boro is the most productive contributing 52.9 percent to 56.5 percent to annual rice production with an average of 19.88 million tonnes for the period 2009/2010 - 2020/21. In the Aman season, the average production amounted to 13.39 million tonnes with its contribution to annual rice production varying in the range from 37.7 percent to 40.4 percent.

However, growth in rice production is slowing with the lowest for Boro season with annual growth rate at 0.66 percent and for the Aman season at 1.4 percent over the period 2009/2010 - 2020/2021. In contrast to sluggish growth in Boro and Aman season, rice production in Aus season maintains an upward trend increasing at 4.1 percent annually. As a result, its share in total rice production has increased from 5.7 percent to 8.3 percent during this period. In terms of yield (production per unit area), the highest was harvested in the Boro season with an average of 3.91 tonnes/ha over the past decade followed by 2.39 tonnes/ha in the Aman and 2.23 tonnes/ha in the Aus season. In both Boro and Aman seasons, growth in rice yield is decelerating, which should be a cause of concern, declining to 0.65 percent per year in the Boro and 1.4 percent in the Aman season. In contrast, rice yield in the Aus season increased faster at 3.2 percent annually.

Table 4. Contribution of HYVs and Hybrids in rice cultivation by growing seasons, 2009/2010 -2020/2021

HYV	Aus	Aman	Boro
Share of rice area cropped in the season (%)			
Range	65.8 - 91.8	66.6 - 81.7	78.6 - 85.7
Annual growth rate (%)	2.5	1.8	-0.5
Share of rice production in the season (%)			
Range	77.0 - 95.8	77.0 - 89.6	76.45 - 80.97
Annual growth rate (%)	1.7	1.3	-1.3
Yield (t/ha)			
Average (Range)	2.464 (2.032 - 2.724)	2.698 (2.491 - 2.829)	3.885 (3.734 - 4.038)
Annual growth rate (%)	2.4	1.1	0.6
Hybrid			
Share of rice area cropped in the season (%)			
Range			5.90 - 8.39
Annual growth rate (%)			3.6
Share of rice production in the season (%)			
Range			15.39 - 23.73
Annual growth rate (%)			2.9
Yield (t/ha)			
Average (Range)			4.72 (4.66 - 4.82)
Annual growth rate (%)			0.0

Yield advantage over the HYVs (%)			
Average (Range)			21.5 (15.4 - 25.7)
Annual growth rate (%)			-4.0

(Source of data: BBS, Yearbook of Agricultural Statistics, 2012 to 2021)

Of all the inputs used in rice production, quality seeds of high yielding varieties (HYVs) contribute the largest share to increase in yield. Seed encapsulates the genetic yield potential of the variety. The main role of other inputs is to create conditions that allow achieving yields as close to the genetic yield potential of the seed as possible. In Bangladesh, the green revolution began with the introduction of HYVs in the Boro season. As a result, the coverage of HYVs used to be highest in the Boro season. But since 2018-2019, growth in the coverage of rice areas by HYVs in the Aus season exceeded that of the Boro season.

As evident from Table 4, the share of rice cropped area covered by HYVs in the Boro season recorded a negative growth at 0.5 percent annually decreasing from the highest 85.7 percent in 2012-2013 to 78.6 percent in 2020-21. Because with the advent of hybrids (first generation seeds, used as planting material, obtained from crossing two selected parents with potential to exhibit heterosis, a genetic phenomenon that provides yield advantage over self-pollinated seeds used in HYV cultivation) since the late 1990s, many farmers started switching to cultivation of hybrids instead of HYVs in the Boro season. So, the decline in the coverage of HYVs in the Boro season was compensated for by an increase in the coverage of hybrids. The extent of coverage of the Boro area by hybrids increased from 5.9 percent in 2009-2010 to 8.4 percent in 2020-2021 at 3.6 percent per year during this period. In the Aman season, expansion of HYVs occurred steadily with 81.7 percent coverage of the Aman cropped area in 2020-21 increasing at 1.8 percent over the period 2009/2010 - 2020/2021. The expansion of HYVs in the Aman season occurred mainly by bringing more areas under HYV cultivation where local transplanted and broadcast Aman varieties used to be traditionally grown. During this period the share in total Aman area decreased from 8.4 percent to 4.2 percent for broadcast Aman and from 25.0 percent to 14.1 percent for local transplanted Aman. As indicated above, HYV expansion was dramatic in the Aus season recording a 2.5 percent annual growth during this period.

The trend of the change in the coverage of rice areas by HYVs was also reflected in the trend of relative composition of annual rice production by growing seasons. The share of HYVs in annual rice production disaggregated by growing seasons over the period 2009/2010 - 2020/2021 recorded annual growth at negative 1.3 percent for the Boro; 1.3 percent for the Aman; and 1.7 percent for the Aus season . The share of hybrids in rice production in the Boro season increased at 2.9 percent annually reaching 23.3 percent in 2020-2021 (Table 4). Average yield of HYVs during this period was 2.464 tonnes/ha in the Aus season; 2.698 tonnes/ha in the Aman; and 3.885 in the Boro season. The yield of hybrids varied in the range 4.66 - 4.82 tonnes/ha with an average of 4.72 tonnes/ha. Growth in HYV yields during this period was almost stagnant in the Boro season at 0.6

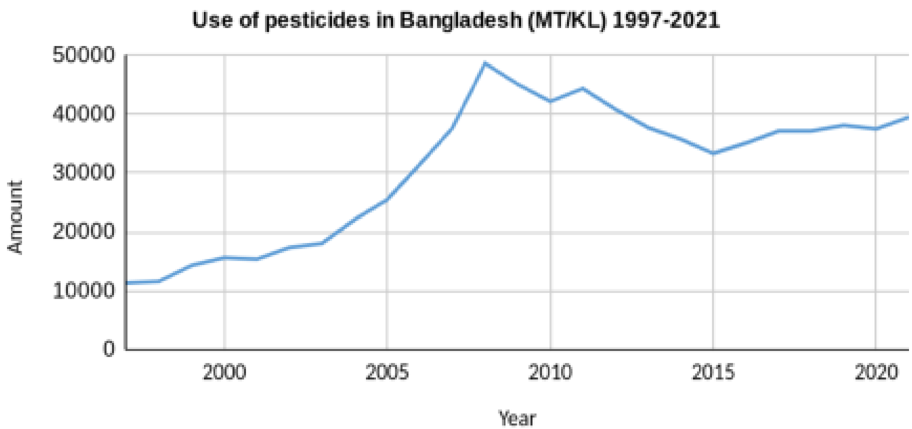
percent per year; 1.1 percent in the Aman season; and 2.4 percent in the Aus season. The scenario with yield growth in the Boro season was equally disappointing for hybrids recording stagnant growth. As a result, the yield advantage the hybrids exhibited relative to HYVs at the beginning declined at 4.0 percent per year from 25.7 percent in 2009-2010 to 15.4 percent in 2020-2021. In view of the declining yield advantage of hybrids, additional investments that farmers make in adopting hybrid cultivation become questionable in terms of cost effectiveness.

On the basis of what has been discussed above, the single most important issue that needs reiteration is sluggish/stagnant growth in HYV/hybrid yields in Boro and Aman seasons. These two seasons together contribute 93. 0 percent of annual rice production in Bangladesh. For now, there is momentum in HYV cultivation in the Aus season, but it is not the major rice growing season to make a meaningful difference in the overall scenario of rice production. Poor growth in yield endangers sustainability of rice cultivation in Bangladesh in an era when rice growing environments across all ecosystems are being stressed by the impacts of ongoing climate change. Ideally, yield growth rates across all rice ecosystems should not only equal but also exceed those of the past century to offset the current and future stresses imposed by climate change and create new basis for accelerating growth in rice production keeping pace with population growth. It is in this context that we need to examine the root causes of stagnation of yield growth given the fact that public investments are on the rise to ensure that farmers can afford buying quality seeds, fertilizer, irrigation equipment, agricultural machinery and other inputs to continue increasing food production. We also need to look into what needs to be done to relieve the constraints on future yield growth at desired rates - breed new generation of HYVs with high yield potential and multiple characteristics to cope with current and future environmental stresses; faster diffusion of those varieties to farmers; accelerating varietal replacement at the farm level; improving efficiency of the use of external inputs in rice cultivation; disaster risk reduction (by promoting Climate-Smart Agriculture technologies) to improve resilience against recurrence of extreme climate events; soil management to improve natural fertility of soils, and other options. It would be also important to examine whether fragmentation of cultivated land into smaller units is affecting efficiency of utilization of purchased inputs.

Pesticide use in crop production

Chemical pesticides were among the inputs the use of which began in Bangladesh in the wake of the Green Revolution. However, unlike other inputs, pesticides stand out by their wide ranging negative effects on the natural environment; diversity of plant, animal, and microbial organisms that play important roles in providing natural ecosystems services vital for agricultural production, and, most importantly, public health. There are numerous scientific studies available that document these effects highlighting how pesticides kill other beneficial insects which are natural enemies of many crop pests; pollute soil and water bodies and enter the food chain causing serious illnesses when people consume foods treated with excessive amounts of pesticides. These studies based on their findings recommend to authorities various alternative measures to restrict the use of pesticides.

However, the reality is that far from decreasing, the use of pesticides in agriculture in Bangladesh is rising keeping pace with intensification of crop production. The amount of pesticides consumed in agriculture was 11,367 MT/KL in 1997. It was a time when the GR was still the paradigm of agricultural research and development. As evident from the chart below, pesticide use was increasing, maintaining a steady upward trend hitting the highest level at 48,690 MT/KL in 2008 followed by a declining trend until 2015 (33, 372 MT/KL). Since 2016, pesticide use again started increasing which reached 39,543 MT/KL in 2021 (data source: Bangladesh Bureau of Statistics, Statistical Yearbook of Bangladesh, various years) despite the fact that the GR has been officially abandoned and Sustainable Intensification (SI), advocated by the Food and Agriculture Organization (FAO) of the United Nations has been embraced as the new paradigm of agricultural R&D. Over the past 25 (1997-2021) years, the annual growth rate of pesticide use was 5.2 percent surpassing overall agricultural growth rate in this period.



In addition to officially reported imports, a significant amount of unapproved and banned pesticides enter the country through illegal cross-border trading. How do pesticides end up when they are applied to crop fields? That, to a large extent, depends on how they are applied. Chemical pesticides are toxic compounds. They are inherently hazardous with varying levels of toxicity; pose a threat to non-target organisms and the environment into which they are released. In true sense, there is no absolutely safe use of pesticides. To minimize unintended negative effects of pesticide application, standard operating procedures (SOPs) are developed that specify the dose of application of each product, protective measures to be taken during application, time of application, intervals between successive applications on the same crop; cut-off time of the last application from the harvest time; a tolerance level (maximum residue limit) for the presence of pesticide residues on food deemed to be safe, and some other aspects.

But pesticide application following SOPs requires field monitoring and technical oversight from regulatory agencies. But in Bangladesh in absence of adequate regulatory control, pesticide use is indiscriminate, excessive and violates basic safety precautions. As a result, some of the pesticides applied on the crop is retained in the soil, some is carried into streams, canals, rivers degrading the ecosystem and entering the food chain impacting food safety. There are studies that show indiscriminate and excessive use of pesticides in crop production in Bangladesh. A field survey conducted by Cornell University in 2020 found a 5-fold increase in the use of all agricultural pesticides (insecticides, herbicides and fungicides) between 1990 and 2010). In this same study the use of insecticides was reported to have increased more than 20-fold during this period.[b]

But the troubling question is why, despite well-documented cases of excessive, inappropriate use of pesticides, its use is increasing and being diversified in Bangladesh. It poses a threat to long-term sustainability of smallholder-dominated farming of Bangladesh. Use of chemical pesticides isn't the only tactic available for pest control. There are other non-chemical options, for example, baits, light traps, biological control using natural enemies of crop pests and other approaches, to which scientists are drawing the attention of authorities to do more for their large-scale expansion to cut the use of chemical pesticides. There is considerable experience accumulated in promoting non-chemical methods for pest control. As far back as in 1981, the well-known Integrated Pest Management (IPM) was introduced in Bangladesh with the support of FAO in the first phase of FAO's inter-country programme (ICP) on IPM in rice crop.

Since then, while pesticide use rapidly expanded, alternative IPM-based approaches progressed at snail's pace. One reason might be the rapid increase in the number of stakeholders in pesticides than in IPM-based non-chemical approaches. Honestly, the stakeholders in IPM are only a few including researchers, extensionists, environmentalists and the farmers who have been trained in IPM. But pesticides have a broad spectrum of stakeholders because of enormous opportunities for business and making profits. As a result, over the past 30 years pesticide use in Bangladesh has grown into an industry. The change in marketing approach of rebranding pesticides as crop protection chemicals also helped in expansion of pesticide consumption. More than 5,500 of various pesticide products are officially registered for use on agricultural crops in Bangladesh. Currently 22 companies produce and sell pesticide products in Bangladesh.[c] Unlike pesticides, promotion of non-chemical approaches including IPM require closely working with farmers, making them aware of the wide-ranging threats that chemical pesticides pose and training them in IPM. But fragmentation of land holdings and increase in the number of smallholder farmers with smaller size of operated land is a barrier to promoting this approach.

Conclusion

Bangladesh Agriculture underwent dramatic transformation over the past four decades. It was driven by introduction of modern technologies in the sector and their faster diffusion

b (Source:https://bteggplant.cornell.edu/2022/08/16/pesticide-use-in-bangladesh-provides -a-strong-justification-for-bt-eggplant/).

c (source:https://news.agropages.com/News/NewsDetail---41543.htm#:~:text=Currently%2C%2022%20companies%20produce%20pesticides,of%20pesticides%20to%20the%20markets.).

to farmers supported by public sector investment in agricultural research, extension and input supply to farmers. Transformation of agriculture was also influenced by sustained economic growth which brought about structural changes in farming and rural livelihoods. The share of small farms increased and that of medium and large farms declined which had implication for adoption of modern technology and input use efficiency.

Major success story of this period was achieving self-sufficiency in staple food through ramping up domestic food production and using agricultural growth as engine to support economic development of the country in the early years of independence. Rice production during this period more than doubled with the major contribution coming from the increase in yield growth rates. This process was driven by transformation of traditional agricultural ecosystems into irrigated rice ecosystem in the Boro season, where high-yielding varieties were introduced and their coverage was rapidly expanded with significant government subsidies on modern production inputs - seeds, fertilizer, irrigation, agricultural machinery, pesticides, and other inputs. High-yielding varieties were subsequently developed for rainfed rice ecosystems (Aman/Aus) and introduced which now accounts for majority of rice areas in these ecosystems. Government's policy and input support played a large role in rapid expansion of HYV cultivation in the Aus season in the past decade.

However, robust growth rates of rice yields and production characteristic of the past century at the height of the Green Revolution have slowed since the turn of the century as the long-term impacts of climate change on agriculture started becoming evident. Resilience of smallholder agriculture and rural livelihoods to climate change is becoming fragile due to increase in frequency of extreme climate events (floods, droughts, cyclones) and transformation of crop growing environments. Over the past decade, growth in yield of high yielding varieties in Boro and Aman seasons has become sluggish and almost stagnant. With such growth rates in yield, it will be difficult to sustain increase of rice production on a high growth path to meet future demand for rice. A negative trend is increase in application of pesticides as intensity of rice cropping continues. Among other negative impacts, it works toward degradation of environment.

General Instruction for Preparation of Manuscript

Articles dealing with the past activities, present status and future guidelines in one or more disciplines of agriculture will get priority. Original research works, both fundamental and applied will also receive priority. The articles, in addition to being on research results, should preferably be on policy, management, advancement and frontier issues of research, extension and economic aspects.

The topics will cover current and future scenarios for improvement of sustainability of the fragile eco-system, food security, natural resource management, input distribution & management, nutrition, agribusiness, climatic risk management, human resource development and economic implications of rapid globalization obtaining since the recent past. The retrospects and prospects of agricultural improvement *vis-à-vis* the constraints hindering progress of agricultural development etc, are burning topics needing elaborate analysis and synthesis for the policy makers , teachers, researches, extensonists, service providers, marketing agents, NGOs and private sector entrepreneurs.

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9. **References:**

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