Present status of Dark green bulrush [*Scirpus atrovirens* (Wild.)] cultivation at Tala Upazila of Satkhira District

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A B S T R A C T

Dark green bulrush [*Scirpus atrovirens* (Willd.)] cultivation has become a potential driver of socioeconomic growth in Tala Upazila of Satkhira District, Bangladesh during October to December, 2024. This study explores the current cultivation practices adopted by local farmers. A total of 41 respondents were selected using snowball sampling, and a descriptive and diagnostic research design was followed to analyze the data. The majority utilize traditional methods suited to wetland ecosystems, with 65.9% of them relying on a combination of irrigation and natural rainfall . Most growers are marginal farmers operating on small landholdings, with an average investment of approximately BDT 50,000 per hectare. Despite limited resources, all surveyed farmers reported that cultivation of Dark green bulrush is profitable. On average, they obtain over 700 bundles per hectare, each fetching around BDT 150 in local markets. The study also reveals that a considerable number of cultivators have undergone training programs and possess substantial knowledge regarding crop management. Their primary motivation for cultivating this crop is income generation. The findings suggest a growing interest and positive outlook among farmers in this crop, driven by its economic benefits. Promoting Dark green bulrush cultivation under current practices is contributing meaningfully to the livelihood improvement of small-scale farmers in this coastal region. The study highlights its emerging role in strengthening rural income and supporting economic resilience. Continued encouragement of such initiatives may play an important role in promoting locally adapted and income-generating agricultural practices across the region.

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Introduction

In the southwest coastal region of Bangladesh, particularly in Satkhira District, a perennial sedge plant locally known as "Mele" (মেলে), scientifically named *Scirpus atrovirens* (Willd.) and commonly referred to in English as Dark green bulrush, has become an emerging component of local agricultural systems (EarthOne, 2025). As a wetland-adapted grass species, Dark green bulrush is gaining increasing attention for its ecological adaptability and economic potential, particularly in regions affected by waterlogging, salinity intrusion, and other forms of environmental stress (Akène, 2025). Its ability to grow under wet, saline, and flood-prone conditions renders it particularly suitable for cultivation in the coastal ecosystems of Bangladesh. The species not only contributes to soil stabilization and wetland preservation but also serves as a raw material for traditional mat weaving, which plays a vital role in rural household economies (Sanka, 2009). Given these multiple utilities, the plant is gradually being recognized as a promising element in the portfolio of climate-resilient agricultural practices. In Bangladesh, especially in the

southwestern coastal belts like Tala Upazila of Satkhira District, recurring climate hazards such as tidal surges, saline intrusion, riverbank erosion, and heavy rainfall-induced flooding have significantly disrupted traditional crop cultivation. As a result, many local farmers have sought alternative livelihood options that are both environmentally suitable and economically viable. Within this context, the cultivation of Dark green bulrush has emerged as an adaptive strategy for marginal and smallholder farmers. Its compatibility with low-lying wetland areas and minimal input requirements has further contributed to its appeal. Studies such as Rahman *et al.* (2018) have emphasized the species' potential role in sustainable development, climate change adaptation, and livelihood diversification in coastal ecosystems. However, despite such promise, its cultivation remains under-researched and poorly documented in the academic and policy literature.

Field observations and preliminary interviews with farmers in the Tala region suggest that while many cultivators are adopting Dark green bulrush cultivation due to its economic returns, they often rely on traditional knowledge and manual practices passed down through generations. Most production activities occur in wetland environments, with a majority of farmers depending on natural rainfall or a combination of rainfall and surface irrigation. While the crop is recognized for its resilience and utility, comprehensive scientific studies evaluating its agronomic practices, economic viability, and social relevance are scarce. Additionally, there is a limited understanding of the socio-economic profiles of its cultivators, their level of technical knowledge, and the actual benefits they derive from this crop in the context of broader livelihood strategies. Despite anecdotal reports of profitability and suitability in marginal lands, scientific data on current cultivation practices, yield trends, and market integration are largely lacking. This presents a critical research gap that warrants systematic investigation. Recognizing the need to generate evidence-based insights on this emerging crop, the present studywas undertaken. The study seeks to document and analyze the existing cultivation methods, investment levels, farmer perceptions, and socio-economic conditions associated with Dark green bulrush production in the region. In doing so, it aims to build a knowledge base that can inform future agricultural planning, extension services, and policy formulation targeted at saline and waterlogged agroecosystems.

The research question guiding this study is: What are the current cultivation practices and socio-economic conditions influencing the cultivation of Dark green bulrush in Tala Upazila, Satkhira District? This question is designed to explore the extent to which this crop is integrated into local farming systems and to identify the key agronomic and economic factors associated with its cultivation. To address this research question, the study has outlined the specific objective: to assess current cultivation practices of Dark green bulrush in Tala Upazila of Satkhira District. By addressing this objective, the research intends to offer baseline data that can be used for future comparative studies and serve as a reference for stakeholders, including agricultural researchers, extension professionals, and policymakers. It is anticipated that the findings will contribute to enhancing the visibility of Dark green bulrush as a viable component of climate-resilient agriculture in Bangladesh's coastal regions.

Methodology

Locale of the study: A descriptive survey design was employed in this research to collect comprehensive and systematic data from respondents across multiple villages within Tala Upazila, specifically Krishnonagar, Bathuyadanga, Horinkhola, and Sonabadhal. This design was chosen because it allows for the collection of diverse opinions and experiences from a targeted population, making it particularly effective in exploring the current practices, perceptions, and challenges related to the cultivation of Dark green bulrush (*Scirpus atrovirens*). These villages represent a cross-section of the broader agroecological and socio-economic characteristics of the southwest coastal region, allowing for a more holistic understanding of the opportunities involved in introducing or expanding the cultivation of this native wetland species. The location and layout of these villages are depicted in Figure 1 to provide a visual representation of the study area.

Population and sampling: The target population of this study included farmers and individuals engaged in the cultivation and processing of Dark green bulrush in the selected areas of Tala Upazila, Satkhira district. A purposive sampling technique was employed to ensure that participants had direct involvement and experience with Dark green bulrush, thereby providing relevant

and meaningful data for the study. A total of 41 respondents were selected from multiple villages within the research area.
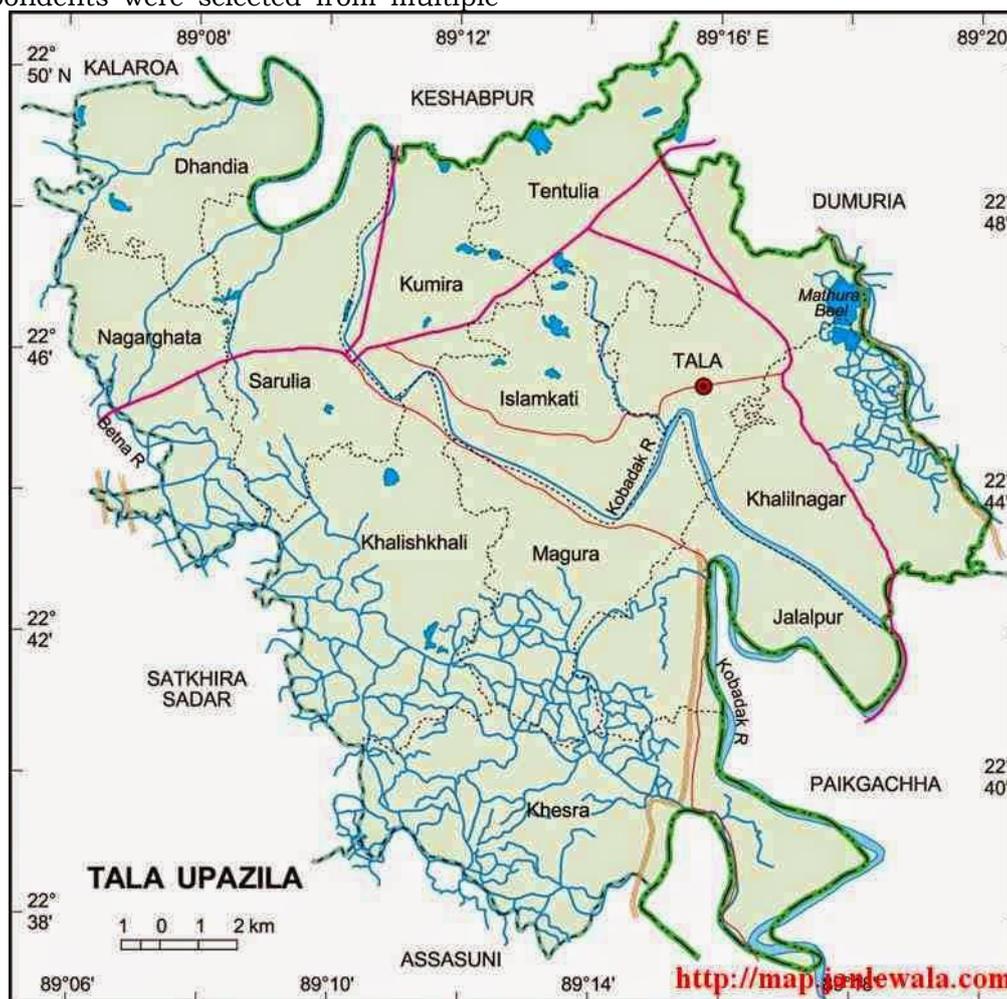

Fig. 1. Map showing Tala Upazila of Satkhira District.

Selection of variables: The primary objective of this research was to assess the current status of the cultivation of Dark green bulrush.

    a.   Land type
    b.   Cultivation method
    c.   Water supply method
    d.   Farm size
    e.   Actual area of cultivation
    f.   Experience
    g.   Cultivation cost
    h.   Possible benefit
    i.   Agricultural training
    j.   Knowledge
    k.   Cropping pattern
    l.   Purpose of cultivation
    m.   Average yield
    n.   Selling price
    o.   Soil, water and fungi data

Measurement of variables

The study gathered detailed information on thirteen key variables related to the cultivation of Dark green bulrush through an interview schedule. Land type was categorized as lowland, wetland, or other, while cultivation method was identified as traditional, modern, or a combination of both. Water supply management was determined through rainfed, irrigation, natural water bodies, or other sources. Farm size and actual ownership area were measured in hectares and categorized using BBS (2017) classifications. Experience in cultivation was recorded in years and grouped into low (≤5), medium (6–10), and high (>10). Cultivation cost and possible benefit were recorded in BDT per hectare, with cost grouped into minimum (<95,000), medium (95,000–200,000), and maximum (>200,000). Training was measured by the number of related sessions attended and categorized from none to high (>4). Knowledge on cultivation was assessed through five structured questions with scores ranging from 0 to 10 and classified into low (≤3), medium (4–6), and high (>6). Cropping pattern over the past five years was

documented seasonally (Kharif 1, Kharif 2, and Rabi) to identify trends and potential integration with Bulrush. The purpose of cultivation was captured through options like income generation, household need, hobby, or incentive. Average yield was reported in bundles per hectare and categorized into four ranges (<200 to >600 bundles), while selling price per bundle was classified into four groups ranging from less than 50 BDT to more than 150 BDT.

To evaluate the environmental conditions influencing the growth and survival of Dark green bulrush, soil, water, and abnormal plant samples were systematically collected from the cultivation site. Soil samples were analyzed for pH, electrical conductivity (EC), organic carbon (C), available phosphorus (P), exchangeable potassium (K), and available nitrogen (N) using established scientific protocols. Water samples were collected monthly and tested for pH, EC, and total dissolved solids (TDS) to monitor seasonal variations in water quality. Abnormal plant samples were also collected to investigate potential environmental stressors affecting plant health. These procedures were designed to generate reliable data on the physicochemical characteristics of the site, providing valuable insights into how environmental factors influence plant development and cultivation success. The interview schedule for this study was meticulously developed based on the research objectives, incorporating input from farmers, organizations, and the research supervisor through preliminary interviews

and revisions. Data collection was conducted via face-to-face interviews from October 5 to December 7, 2024, using the finalized schedule. To ensure data reliability and respondent comfort, rapport-building measures were taken, and supplementary methods such as Key Informant Interviews (KII) and Focus Group Discussions (FGD) were employed. The collected data were systematically processed, compiled, and tabulated according to pre-defined categories for clarity and ease of interpretation. Quantitative analysis involved descriptive statistics (frequency, mean, standard deviation).

Results and Discussion

The primary objective of this chapter is to present and interpret the key findings derived from the study. The results are systematically organized and discussed in alignment with the specific objective of the research: an assessment of the existing cultivation practices of Dark green bulrush.

Land type

According to Table 1, a significant proportion of respondents cultivated Dark green bulrush in wetland areas, with 39.0% (16 out of 41 respondents) indicating this preference. Lowland areas were the second most common land type used, reported by 36.6% (15 respondents). A relatively small number of farmers practiced cultivation in medium land and highland areas, each accounting for 12.2% of the total respondents (5 each).

Table 1. Distribution of the respondents according to their land type for Dark green bulrush cultivation.

Characteristics	Categories	Score	N=41		Range		Mean±SD
			F.	%	Min.	Max.	
Land Type	Lowland	-	15	36.6	-	-	-
	Wetland		16	39.0			
	Medium land		5	12.2			
	Highland		5	12.2			

[F.=Frequency, %=Percentage, SD=Standard Deviation, Min.=Minimum, and Max.=Maximum] (For all Tables)

The calculated mean score for land type use was 2.00, with a standard deviation of ±1.00, indicating a moderate spread in land type selection among the respondents. The range of land type scores extended from a minimum of 1 to a maximum of 4, signifying that all four land categories—lowland, wetland, medium land, and highland—were represented in the study.

The results highlight that wetlands and lowlands together account for over 75% of the total land types used for Dark green bulrush cultivation. This dominant preference suggests that the species favors areas with high soil moisture retention and seasonal water accumulation, which are characteristic of wetland and lowland ecosystems. These conditions are particularly important for the growth and fiber quality of

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Dark green bulrush, which naturally thrives in hydrophytic environments. The presence of a small group of farmers cultivating in medium land and highland areas might indicate experimental practices or adaptation due to land unavailability, but it also points to potential limitations in productivity due to suboptimal water availability and soil texture in those terrains. The standard deviation further supports a moderately diverse choice of land type, though concentrated toward more water-retentive categories.

The findings scientifically affirm that wetlands and lowlands are the ecologically suitable and most preferred land types for cultivating Dark green bulrush in the study area. These ecosystems provide the ideal hydrological conditions necessary for the successful establishment and growth of the crop. The limited use of medium land and highland areas underscores the crop's dependency on moist and saturated soils.

Cultivation method

Table 2 presents the distribution of respondents based on their selected method for cultivating Dark green bulrush. The majority, comprising 65.9% of the respondents, reported using the traditional method. In contrast, a smaller proportion, 19.5%, adopted the modern method of cultivation. Additionally, 14.6% of the respondents employed a combination of both traditional and modern practices. The data indicate that traditional cultivation practices dominate the farming approach for Dark green bulrush in the study area. This preference may reflect farmers' strong reliance on indigenous knowledge, resource constraints, lack of access to modern technologies, or uncertainty regarding the outcomes of modern interventions. The relatively low adoption of modern methods (19.5%) suggests several possible barriers, such as insufficient extension services, inadequate training, high input costs, or limited awareness of improved techniques. Meanwhile, the 14.6% who integrated both systems may represent a transitional group—farmers exploring new methods while still grounded in traditional approaches. This blend of practices implies a potential openness to innovation, provided that supportive measures are put in place, such as demonstrations, financial assistance, and institutional support.

Table 2. Distribution of the respondents according to their cultivation method for Dark green bulrush cultivation.

Characteristics	Categories	Score	N=41		Range		Mean±SD
			F.	%	Min.	Max.	
Cultivation Method	Traditional Method	-	27	65.9	-	-	-
	Modern Method		8	19.5			
	Combination of both		6	14.6			

The findings reveal a clear dominance of traditional methods in Dark green bulrush cultivation, signifying a low penetration of modern agricultural practices in the study area. This could limit the overall productivity, profitability, and sustainability of the crop under changing climatic and environmental conditions. The limited adoption of modern or integrated methods highlights the need for targeted agricultural extension programs, training, and awareness campaigns. Promoting adaptive, resource-efficient, and climate-resilient technologies—particularly those customized for wetland and saline-prone areas—could encourage more farmers to adopt or combine modern practices with traditional wisdom.

Water supply method

Table 3 reveals the distribution of respondents based on their preferred water management practices for cultivating Dark green bulrush. Among the 41 respondents, the majority, 65.9%, reported using a combination of both irrigation and rainfed systems. In contrast, 17.1% relied solely on rainfed methods, while another 17.1% exclusively utilized irrigation (from canals, ponds, or other sources). The data suggest that the combined use of irrigation and rainfed systems is the most widely adopted strategy among farmers. This preference reflects a practical adaptation to uncertain and uneven rainfall patterns, which are common in Bangladesh, particularly in coastal and saline-prone areas. By

integrating both water sources, farmers can better ensure the continuity of water supply, reduce risk, and maximize the survival and growth potential of soft-stem Dark green bulrush (Edwards *et al.*, 2020; Hunter *et al.*, 2000). The equal representation of farmers relying exclusively on either rainfed or irrigation methods indicates the diversity of

water resource access and infrastructure in the area. Farmers with dependable access to canals, ponds, or stored water may opt for irrigation, whereas those in more remote or low-resource settings may depend solely on rainfall.

Table 3. Distribution of the respondents according to their water supply method for Dark green bulrush cultivation.

Characteristics	Categories	Score	N=41		Range		Mean±SD
			F.	%	Min.	Max.	
Water Supply	Rainfed	-	7	17.1	-	-	-
	Irrigation		7	17.1			
	Irrigation & Rainfed		27	65.9			

The findings clearly demonstrate that a combined water management approach is the most preferred and practical method for Dark green bulrush cultivation in the study area. This integrated system offers a strategic advantage by enhancing water availability and mitigating the impacts of irregular rainfall, which is a common feature of Bangladesh's climate.

The adoption of a combined method not only enhances resilience to climatic variability but also contributes to more consistent crop performance and yield. Therefore, efforts to improve access to small-scale irrigation infrastructure, such as community-managed canals or water harvesting systems, should be encouraged. At the same time, training programs on integrated water resource management can further strengthen farmers' adaptive capacity and long-term productivity.

Farm size

Table 4 presents the distribution of respondents based on their farm size allocated for Dark green bulrush cultivation. The findings indicate that a vast majority 90.2% of the respondents fall under the marginal farmer category, with 37 out of 41 participants cultivating the crop on very small landholdings. The remaining 9.8% are small-scale farmers. Notably, there were no respondents in the landless, medium, or large farm categories. The farm sizes among respondents range from 0.0209 hectares to 0.8028 hectares, with a mean value of 0.08 ha and a standard deviation of 0.13. This suggests that the land distribution is heavily skewed toward the lower end of the scale, with very few outliers managing slightly larger plots.

Table 4. Distribution of the respondents according to their farm size for Dark green bulrush cultivation.

Characteristics	Categories	Score	N=41		Range		Mean±SD
			F.	%	Min.	Max.	
Farm Size(ha)	Landless	<0.02	0	0	0.0209	0.8028	0.08±0.13
	Marginal	0.02-0.2	37	90.2			
	Small	0.2-1	4	9.8			
	Medium	1-3	0	0			
	Large	>3	0	0			

The dominance of marginal farmers among the respondents clearly highlights the land scarcity issue in the study area. These farmers cultivate Dark green bulrush on small and fragmented plots, often constrained by limited access to arable land and capital resources. This trend is particularly evident in coastal saline-prone regions, where land availability and quality are both restricted due to waterlogging,

salinity, and river erosion. The absence of medium and large-scale farmers in this dataset suggests that Dark green bulrush cultivation has not yet been adopted on a commercial scale. It remains largely a subsistence-level or supplementary activity, possibly due to its limited market integration, lower perceived profitability, or lack of institutional support.
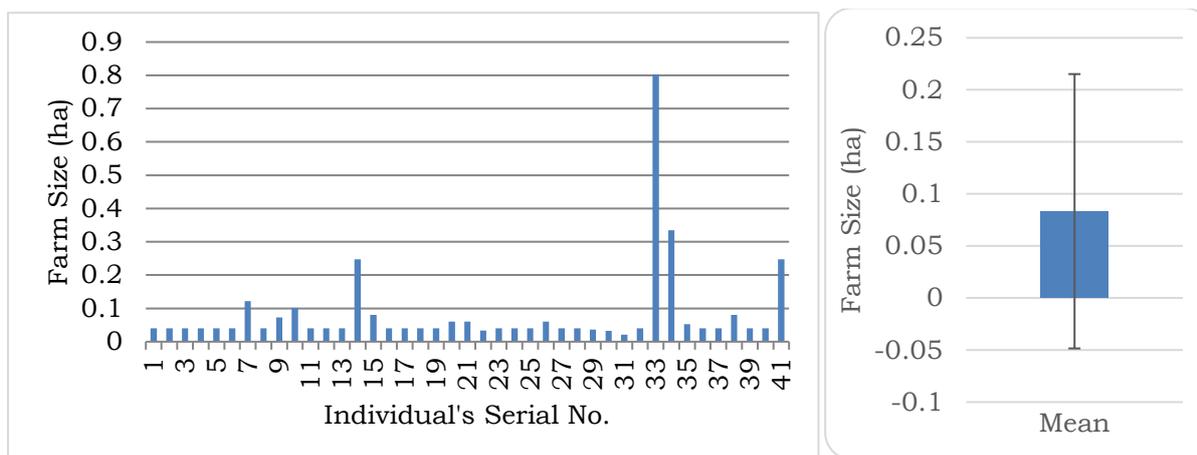
Fig. 2. Farm size for Dark green bulrush cultivation (ha).

Figure 2 illustrates the distribution of farm sizes among the respondents engaged in Dark green bulrush cultivation, expressed in hectares. The analysis reveals that the majority of farmers fall within the marginal category, highlighting the dominance of small-scale landholdings in the study area. The farm sizes ranged from a minimum of 0.0404 ha to a maximum of 0.8028 ha, with a mean of 0.0834 ha and a standard deviation of 0.1318, indicating a concentration of farms at the lower end of the scale and limited variation in land size. This pattern reflects the structural constraints of land access in coastal regions, where fragmentation, salinity, and environmental vulnerability restrict the expansion of cultivable land. The predominance of very small farms underscores the need for targeted support to improve the productivity and livelihoods of marginal farmers involved in Dark green bulrush cultivation.

Actual area for Bulrush cultivation

Figure 3 presents the distribution of actual land ownership among the respondents, with land size converted into hectares for uniformity. The data indicate that the landholding sizes vary widely, ranging from 0.0000 ha to 0.9347 ha. Notably, one respondent out of 41 was completely landless, emphasizing the presence of extreme marginalization even within this already vulnerable group. This broad variation highlights the unequal access to land resources among Dark green bulrush cultivators.
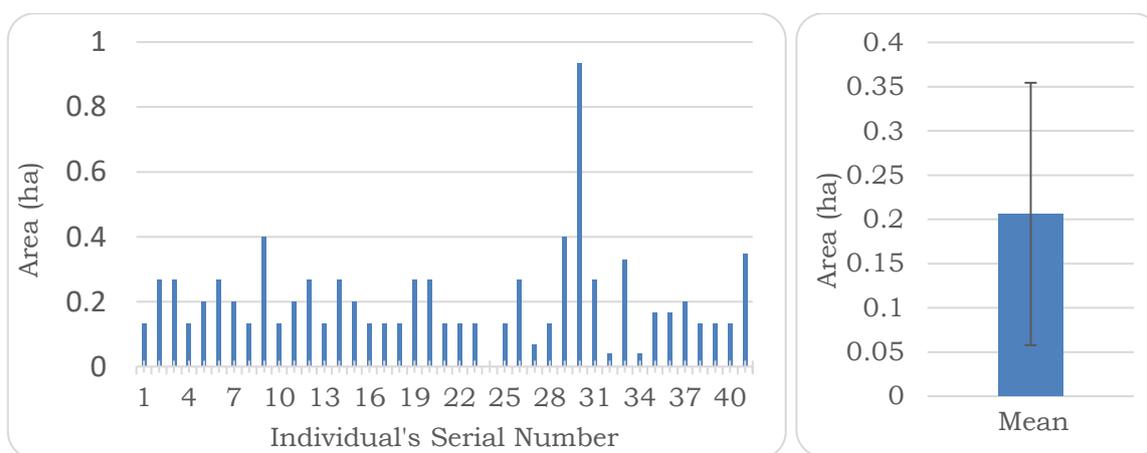

Fig. 3. Actual ownership areas of farmers (ha).

The presence of landless farmers also suggests that some individuals may be cultivating borrowed or leased land, pointing to potential issues in land tenure security and long-term investment in cultivation. Scientifically, such a skewed distribution of land ownership reflects systemic socio-economic disparities and has significant implications for the scalability and sustainability of Dark green bulrush cultivation in coastal saline areas. Addressing land access and ownership issues could be critical for enhancing productivity and ensuring equitable development in these regions.

Experience

Table 5 presents the cultivation experience of respondents in growing Dark green bulrush. The data clearly indicates that a vast majority (97.6%) of the farmers have prior experience in cultivating this plant, with most having 3 to 4 years of hands-on involvement. Specifically, 40 out of 41 respondents reported previous cultivation experience, while only one respondent (2.4%) had no prior exposure. This strong prevalence of experienced farmers suggests that Dark green bulrush cultivation is not a new or unfamiliar practice in the study area.

Table 5. Distribution of the respondents according to their experience in Dark green bulrush cultivation.

Characteristics	Categories	Score	N=41		Range		Mean±SD
			F.	%	Min.	Max.	
Experience (years)	Yes	-	40	97.6	1	40	-
	No		1	2.4			

The widespread experience also reflects a growing local knowledge base, which can play a crucial role in improving practices, addressing challenges, and promoting the crop's potential as an adaptive livelihood option in the coastal saline zone. Scientifically, this finding indicates a foundation for further capacity building and technology dissemination, as most farmers are already acquainted with the crop and are likely to adopt improved methods more readily.

Cultivation cost (and, support from annual income)

Table 6 illustrates the distribution of respondents according to their cultivation cost per hectare (in BDT) for Dark green bulrush production. The data reveal that the majority of farmers (75.6%) incurred a medium level of cultivation cost, ranging from BDT 95,000 to 200,000 per hectare. A smaller segment (14.6%) of respondents reported high cultivation costs exceeding BDT 200,000, while only 9.8% of farmers managed their cultivation with lower costs (below BDT 95,000). The overall cultivation cost per hectare ranged from BDT 44,950 to BDT 296,400, with a mean cost of BDT 153,499.68 and a standard deviation of BDT 56,817.52. This substantial variation in cost suggests a moderately diverse expenditure pattern among farmers, likely influenced by factors such as farm size, availability of resources, labor cost, and intensity of input use. The findings imply that most farmers invest a moderate amount in Dark green bulrush cultivation, which may reflect a balance between input affordability and expected returns. The higher standard deviation indicates economic disparity among farmers and highlights the need for cost optimization strategies and financial planning support, especially for smallholders with higher cost burdens.

Table 6. Distribution of the respondents according to their cultivation cost for Dark green bulrush cultivation.

Characteristics	Categories	Score	N=41		Range		Mean±SD
			F.	%	Min.	Max.	
Cultivation Cost (BDT ha^{-1})	Minimum	<95000	4	9.8	44950	296400	153499.68 ± 56817.52
	Medium	95000-200000	31	75.6			
	Maximum	>200000	6	14.6			

Scientifically, this cost distribution also provides baseline information for evaluating the cost-benefit ratio and for designing interventions aimed at improving resource use efficiency in the context of sustainable cultivation of Dark green bulrush in saline-prone regions (Beetle, 1950).
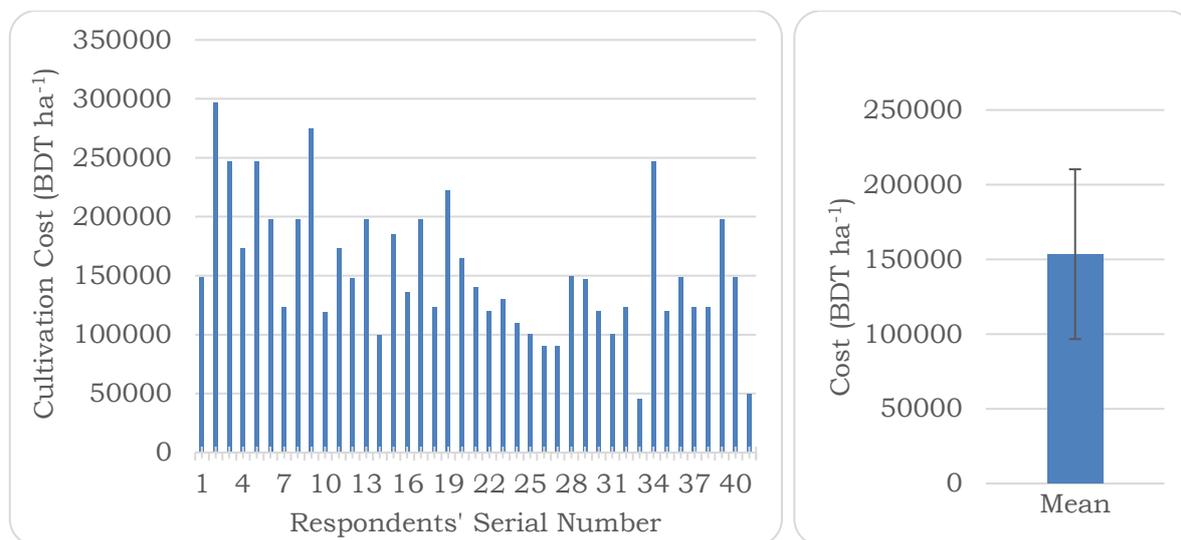
Fig. 4. Cultivation cost for Dark green bulrush cultivation (BDT ha^{-1}).

The findings reveal that most farmers (75.6%) incur a moderate level of cultivation cost ranging between BDT 95,000 and BDT 200,000 per hectare (Fig. 4), indicating a substantial but manageable financial investment in Dark green bulrush cultivation. A smaller proportion of farmers spend either significantly higher or lower amounts, which reflects variability in input use, scale of operation, and access to resources. The average cost of BDT 153,499.68 with a standard deviation of BDT 56,817.52 suggests a moderately wide variation in cultivation practices among respondents.

The annual family income data of the 41 respondents indicates a diverse range of earnings derived from multiple sources, including agriculture, livestock, fisheries, and business. The total annual family income ranged from a minimum of BDT 20,000 to a maximum of BDT 95,000 (Fig. 5). Agriculture was the most common source of income, supplemented notably by livestock and fisheries in many cases. Some respondents also relied on small business activities. A few families were entirely dependent on a single income source, particularly agriculture or livestock, while others exhibited more diversified income patterns. Overall, the data highlights the modest and varied economic backgrounds of Dark green bulrush cultivators, with most families earning below BDT 80,000 annually.
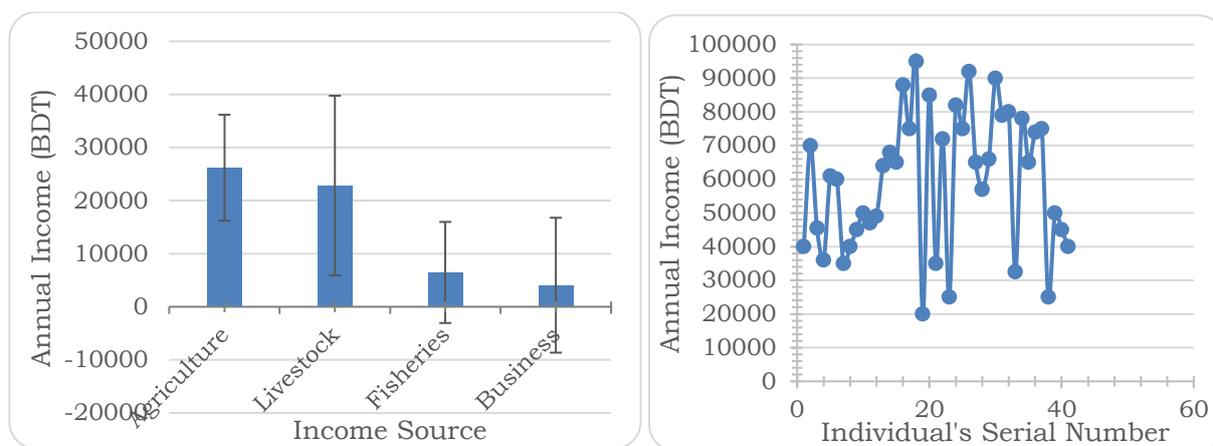

Fig. 5. Annual family incomes of respondents.

The annual family income, which ranges between BDT 20,000 and BDT 95,000 for most respondents, plays a critical role in determining their capacity to bear the cost of Dark green bulrush cultivation. Given that the average cultivation cost per hectare is BDT 153,499.68, it is evident that the income of many farmers falls significantly short of covering these expenses independently. As a result, farmers likely rely on external support such as loans, community sharing, informal borrowing, or

cost-sharing arrangements to manage cultivation. The gap between income and cultivation cost underscores the economic vulnerability of these farmers and highlights the need for financial assistance or subsidized inputs to sustain their agricultural activities.

Possible benefit

Figure 6 illustrates the estimated benefit per hectare derived from Dark green bulrush cultivation among the respondents. All 41 farmers unanimously stated that cultivating

Dark green bulrush was profitable. When their profit estimates were standardized per hectare, the benefit ranged from BDT 40,000 to BDT 494,000, with a calculated mean benefit of BDT 174,948.09. This wide range reflects variability in cultivation scale, input use, yield, and market price, yet the uniformly positive response underscores the crop's strong potential for economic gain. Despite differing levels of investment and landholding, even farmers with limited resources were able to generate a substantial surplus from cultivation.
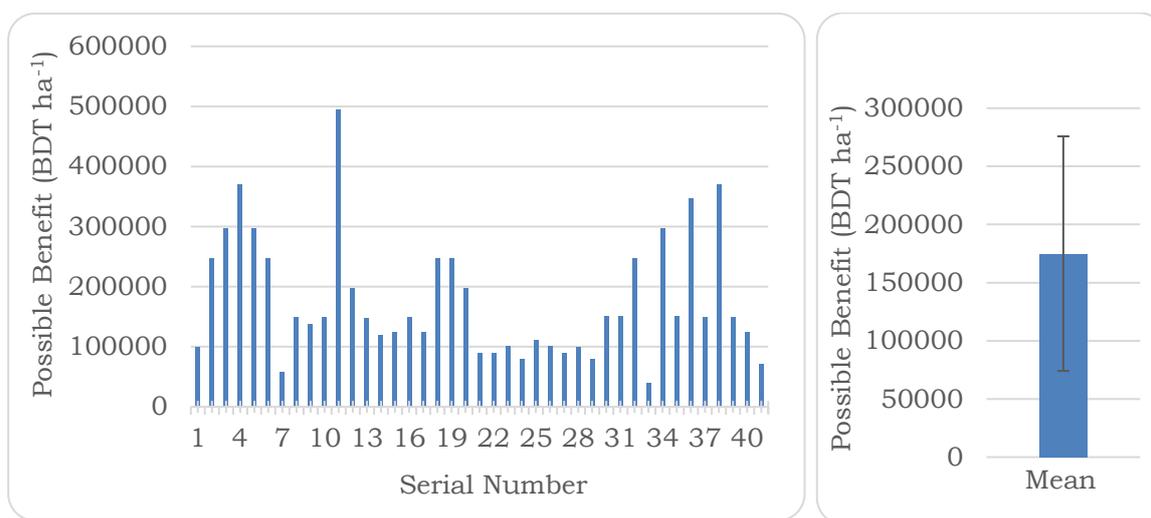

Fig. 6. Possible benefits for Dark green bulrush cultivation (BDT ha^{-1}).

These findings strongly suggest that Dark green bulrush is a highly profitable crop, especially for marginal and small-scale farmers seeking alternative income-generating options in saline-prone and waterlogged regions. The high average return not only demonstrates the crop's financial viability but also underscores its potential contribution to rural income diversification and poverty reduction. Therefore, with proper training, input support, and market linkage, the cultivation of Dark green bulrush could be scaled up as a climate-resilient and economically rewarding livelihood strategy in vulnerable coastal areas.

Agricultural training (and, Bulrush cultivation training)

Table 7 provides a summary of the types of agricultural training received by respondents, all of which were organized and sponsored by the Mukti Foundation. Among the four training programs offered, the most widely attended was "Floormat Making and

Marketing", which was completed by 80.48% of the respondents. This training ranks first in terms of participation, indicating strong interest in the income-generating potential of value-added products from Dark green bulrush. The second most attended training was "Disability Inclusive Disaster Risk Reduction (DIDRR)", with a 46.34% participation rate. This suggests moderate awareness-building efforts related to inclusive disaster preparedness. The third most common was "Rights and Advocacy Training, attended by 34.14% of respondents, indicating some engagement in social empowerment and awareness. The least attended training was "Leadership Training", with only 19.51% participation, pointing to a gap in the development of community leadership among farmers. The duration of each training ranged between 2 and 3 days, with most held for 2 days except the Leadership Training, which lasted 3 days.

Table 7. Distribution of the respondents according to the types of Agricultural Training received.

Serial	Name of Training	Duration (Days)	Frequency	%	Rank
1.	Floormat Making and Marketing	2	33	80.48	1st
2.	Leadership Training	3	8	19.51	4th
3.	Rights and Advocacy Training	2	14	34.14	3rd
4.	Disability Inclusive Disaster Risk Reduction (DIDRR) Training	2	19	46.34	2nd

The data reveal that skill-based training, particularly those directly linked to economic outcomes such as floormat production and marketing, drew the highest engagement. This indicates that farmers prioritize training with tangible livelihood benefits. Meanwhile, the lower participation in leadership and advocacy-related trainings suggests a potential area for further development in building farmers' capacity for organization, collective action, and policy engagement. The limited duration of training sessions may also constrain deep learning and retention, although it may have improved accessibility. Overall, the training programs have had a positive impact by enhancing technical, marketing, and disaster awareness skills, but more focus on empowering farmers through leadership and rights-based education is essential for sustainable community development and climate resilience in the region.

Table 8 presents the distribution of respondents based on whether they have received training specifically in Dark green bulrush cultivation. The findings reveal that a significant majority 82.92% of the respondents had received formal training related to this crop. In contrast, only 17.08% of the respondents had not participated in any such training programs. This indicates a relatively high level of exposure to cultivation-related guidance and skill development among the surveyed farmers. The high percentage of trained farmers suggests that there has been a commendable effort by relevant stakeholders (such as NGOs or agricultural departments) in disseminating knowledge and techniques associated with Dark green bulrush cultivation. Training can significantly influence farming outcomes by improving understanding of best practices, pest and disease management, input optimization, and market linkage.

Table 8. Respondents' training on Dark green bulrush cultivation.

Categories	Frequency	%
Training Received	34	82.92
No Training Received	7	17.08

The remaining 17.08% of untrained farmers may reflect challenges in outreach or accessibility and could benefit from future inclusive training initiatives. The data scientifically support the conclusion that training plays a crucial role in equipping farmers with the necessary skills to successfully cultivate Dark green bulrush. With over 80% of respondents already trained, the potential for improved productivity and profitability is high. However, targeted efforts are needed to bridge the remaining training gap, ensuring that all farmers, especially marginalized and remote individuals, have access to capacity-building opportunities. Widespread, inclusive training can thus serve as a catalyst for sustainable adoption and upscaling of this promising crop in saline-prone coastal regions.

Knowledge on Bulrush

Table 9 presents the distribution of respondents based on their knowledge scores pertaining to Dark green bulrush cultivation. The results show that a substantial majority (78.0%) of the respondents fall into the high knowledge category, suggesting a strong understanding of the crop's agronomic practices, management techniques, and overall cultivation process. An additional 22.0% of respondents possess medium knowledge, while, notably, no respondents were classified under the low knowledge category. The knowledge score ranged from 5.00 to 10.00, with a mean score of 7.48 and a standard deviation of 1.14. This relatively high mean score, along with a moderate level of variability, indicates that most respondents are well-informed, though there is still some room for enhancing knowledge

among those in the medium category. The dominance of high knowledge scores reflects successful dissemination of cultivation-related information, possibly through training programs, experience sharing, or

extension activities. This high knowledge level is crucial, as it directly influences the adoption of best practices, input efficiency, and productivity.

Table 9. Knowledge of the respondents on Dark green bulrush cultivation.

Characteristics	Categories	Score	N=41		Range		Mean±SD
			F.	%	Min.	Max.	
Knowledge (score)	Low	≤3	0	0	5.00	10.00	7.48±1.14
	Medium	4-6	9	22.0			
	High	>6	32	78.0			

The absence of low-knowledge respondents suggests effective knowledge outreach, although the presence of medium-level knowledge farmers implies that targeted interventions could still be beneficial for further strengthening technical capacities. The findings confirm that the majority of farmers engaged in Dark green bulrush cultivation possess a high level of knowledge, which is a critical factor for ensuring sustainable and productive agricultural practices. This strong knowledge base likely contributes to the perceived profitability and successful adoption of the crop. However, continuous education and refresher training sessions could help uplift those with medium knowledge and ensure uniform understanding across the farming community. Investing in knowledge-building remains a key strategy for optimizing cultivation outcomes in this promising sector.

Last five years cropping pattern

From 2019 to 2024, the cropping pattern in the studied area reveals a clear distinction between seasonal crop preferences, primarily influenced by local agro-ecological

conditions. The region follows two main agricultural seasons: Kharif (15th March to 15th October) and Rabi (16th October to 14th March) (Table 10). Dark green bulrush was introduced in the Kharif season starting in 2021, with 20 farmers initially adopting it. Its cultivation steadily increased over the years, reaching 25 farmers in 2022, 30 in 2023, and 36 in 2024. Notably, this crop was not cultivated during the Rabi season in any year. On the other hand, rice was consistently cultivated by all 41 surveyed farmers during every Rabi season from 2019 to 2024, with no cultivation during the Kharif seasons. This pattern is largely due to the water-stagnated conditions of the area, making rice cultivation more viable during the drier Rabi period. The data indicate a growing diversification in the cropping system, with farmers increasingly incorporating Dark green bulrush into the Kharif season while maintaining rice as a staple Rabi crop. This dual-season approach reflects strategic adaptation to environmental conditions and highlights the evolving agricultural practices aimed at optimizing land use and ensuring year-round productivity.

Table 10. Last five years' cropping pattern of the farmers.

Year	Categories	Frequency	
		Season	
		Kharif 1 and Kharif 2 (March-October)	Rabi (October-March)
2019		0	0
2020		0	0
2021	Dark green bulrush	20	0
2022		25	0
2023		30	0
2024		36	0
2019		0	41
2020		0	41
2021	Rice	0	41
2022		0	41
2023		0	41
2024		0	41

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The findings reflect a strategic adaptation of farmers to the prevailing agro-ecological conditions of the study area, particularly the issue of seasonal water stagnation. The consistent cultivation of rice by all 41 respondents during the Rabi season over six years indicates that rice remains the most reliable and suitable crop under the given conditions, especially when water stagnation recedes. In contrast, the absence of rice cultivation during the Kharif season highlights the limitations imposed by excessive water accumulation during this period. The introduction of Dark green bulrush in 2021 marks a significant shift in the cropping pattern, indicating efforts by farmers to utilize the waterlogged Kharif season more effectively. The gradual increase in the number of farmers cultivating this crop from 20 in 2021 to 36 in 2024 demonstrates growing acceptance and possibly favorable economic or agronomic returns. The exclusive cultivation of Dark green bulrush during the Kharif season, coupled with rice cultivation in Rabi, shows a complementary pattern that allows farmers to make productive use of both seasons without overlap. The cropping pattern observed from 2019 to 2024 reflects a well-adapted, seasonally driven agricultural system. Farmers are effectively leveraging seasonal variations by cultivating rice in the water-stagnated Rabi period and increasingly integrating Dark green bulrush during the Kharif season. This evolving dual-season strategy indicates a trend toward diversification and resilience, potentially enhancing food security and sustainable livelihood opportunities in the region.

Purpose of cultivation

Table 11 presents data on the motivations behind the cultivation of Dark green bulrush among farmers. The findings reveal that 100% of respondents cultivated Dark green bulrush primarily for income generation, indicating its strong role as a source of supplementary earnings. In addition, 90.24% of the farmers also cited the fulfillment of household needs as a secondary objective. Interestingly, none of the respondents reported cultivating the crop for reasons such as personal interest (hobby) or due to any form of external incentive or subsidy. The data clearly suggest that Dark green bulrush cultivation is driven by practical and economic considerations. Its role in enhancing household income makes it an attractive option for farmers, especially in areas where livelihood diversification is crucial. The fact that a significant majority also associate it with meeting family needs further emphasizes its functional value in rural livelihoods. The absence of hobby or incentive-driven cultivation implies that the adoption of this crop is entirely need-based and not influenced by recreational interests or policy-driven support mechanisms.

Table 11. Respondents' purpose for Dark green bulrush cultivation.

Characteristics	Categories	Score	N=41		Range		Mean±SD
			F.	%	Min.	Max.	
Purpose (score)	Income Generation	-	41	100	-	-	-
	Fulfillment of Family need		37	90.24			
	Hobby		0	0			
	Incentive		0	0			

The cultivation of Dark green bulrush is a strategically motivated practice, rooted in economic necessity and household utility. Its adoption reflects a rational decision by farmers to diversify income sources and enhance livelihood resilience. The crop's relevance as a dependable means of income and family sustenance underlines its potential for broader promotion in similar agro-ecological zones, particularly in regions seeking sustainable livelihood strategies without relying on external incentives.

Average yield of Dark green bulrush

Table 12 presents data on the average yield of Dark green bulrush cultivation as reported by the respondents. All farmers confirmed that their yields exceeded 600 bundles per cultivation cycle. Each bundle typically contains 60 to 80 individual plants, indicating substantial biomass production. The maximum recorded yield was 810 bundles, while the minimum yield reported was 650 bundles, demonstrating relatively consistent and high productivity across respondents. The uniformly high yield figures suggest that Dark green bulrush performs

well under the existing agro-ecological conditions of the study area. The narrow range between the minimum and maximum yields indicates a degree of consistency in cultivation practices and environmental suitability. Such productivity levels imply that the crop is not only viable but also capable of delivering substantial returns to farmers, particularly when cultivated at scale (Kim et al., 2016).

Table 12. Average yield of Dark green bulrush cultivation per ha.

Characteristics	Categories	Score	N=41		Range		Mean±SD
			F.	%	Min.	Max.	
Average Yield (Bundles ha^{-1})	Less than 200 Bundles	-	0	0	650.00	810.00	712.63 ± 30.58
	200-400 Bundles		0	0			
	401-600 Bundles		0	0			
	More than 600 Bundles		41	100			

The reported yields of Dark green bulrush underscore its potential as a high-yielding crop with consistent performance. With yields consistently above 600 bundles, the crop demonstrates both economic and agronomic viability. These results further reinforce the crop's suitability for income generation and justify its increasing adoption among farmers in the region.
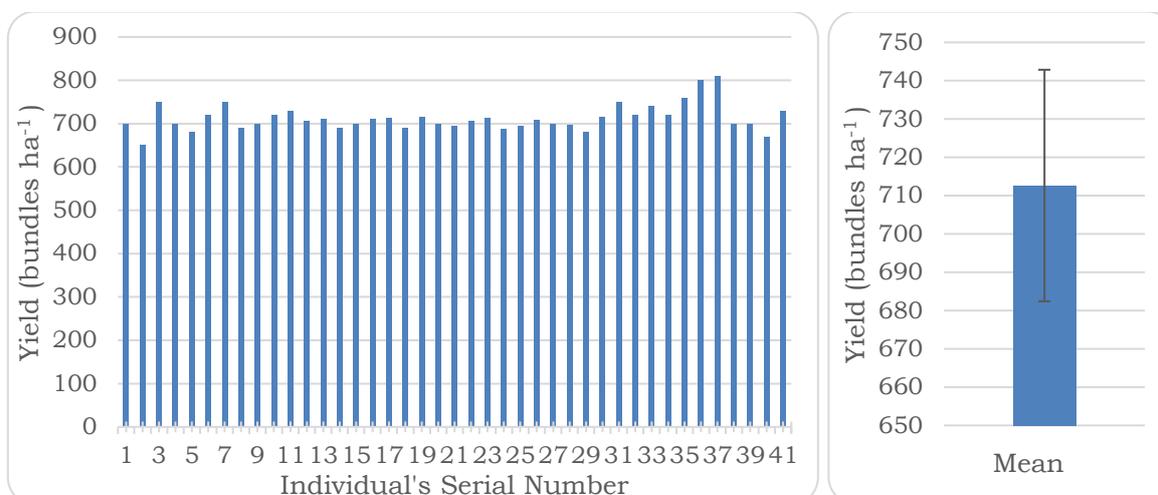

Fig. 7. Average yield of Dark green bulrush (Bundles ha^{-1}).

The average yield of Dark green bulrush among the respondents was reported to be 712.63 bundles, with a standard deviation of 30.58. This relatively low variation around the mean indicates a high level of consistency and uniform productivity across the farming population (Fig. 7). The mean yield figure reflects the strong performance of Dark green bulrush under local cultivation conditions. The modest standard deviation suggests minimal disparity in yield outcomes among farmers, implying that most respondents are achieving yields close to the average. This consistency points to uniform agronomic practices, favorable growing conditions, and possibly a good understanding of the crop's requirements among cultivators.

The consistently high average yield of Dark green bulrush, coupled with a low standard deviation, confirms the crop's reliability and suitability in the study area. These findings highlight the crop's potential for scalable and sustainable cultivation, reinforcing its role as a dependable source of income and agricultural productivity for local farmers.

Selling price of Dark green bulrush

Figure 8 illustrates the selling price of Dark green bulrush, expressed in Bangladeshi Taka (BDT) per bundle. According to respondent data, the market price per bundle ranges from BDT 100 to BDT 190, depending on various factors such as market demand and quality. The average selling price reported was BDT 150 per bundle, indicating a moderately high market value for the crop.
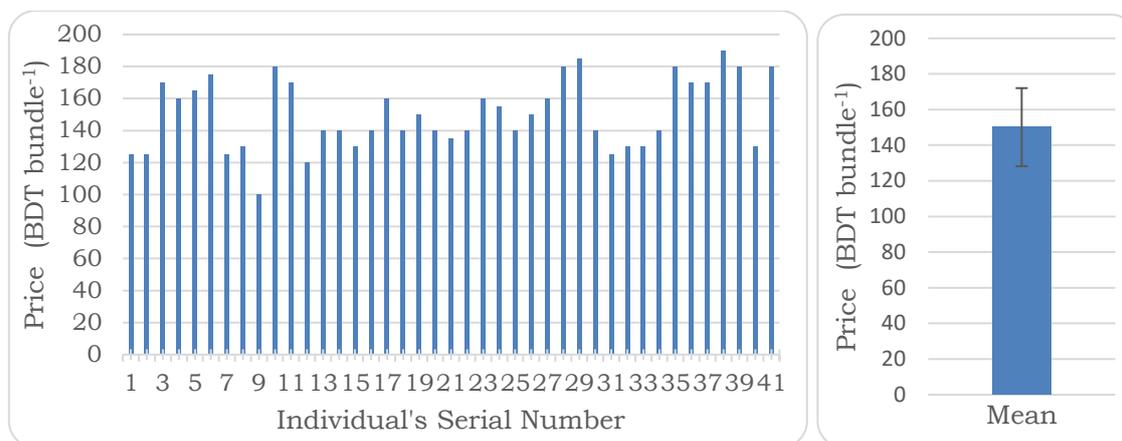
Fig. 8. Selling price of Dark green bulrush (BDT bundle^{-1}).

The variation in selling price reflects the influence of market dynamics, yet the average price of BDT 150 suggests that Dark green bulrush holds a stable and economically viable position in the local market. This price point, combined with consistently high yields, positions the crop as a profitable choice for smallholder farmers. The relatively broad price range also suggests opportunities for increased profitability through improved quality, marketing strategies, or better access to markets. The average selling price of BDT 150 per bundle demonstrates that Dark green bulrush has strong market potential and offers a reliable income stream for farmers. Given its favorable price and yield performance, the crop is well-positioned to contribute to enhanced livelihood security and rural economic development in the region.

Soil quality, water quality and plant disease status of the study sites

Soil, water, and abnormal plant samples were systematically collected from the Dark green bulrush cultivation site to assess the physicochemical status of the environment using standard scientific methods. Soil samples were analyzed for pH, electrical conductivity (EC), organic carbon (C), available phosphorus (P), exchangeable potassium (K), and available nitrogen (N) following established protocols. Water samples were collected monthly and tested for pH, EC, and total dissolved solids (TDS) to observe seasonal variations in water quality. These measurements provided critical insights into the environmental conditions affecting plant survival and growth.

(a) Soil quality: Soil quality analysis was conducted to evaluate key physicochemical properties, including pH, EC, organic carbon, available phosphorus, exchangeable potassium, and available nitrogen, to assess soil fertility and suitability for Dark green bulrush cultivation (Fig. 9).

Soil pH: The soil pH values of the bulrush cultivation plots ranged from 6.7 to 6.8, indicating slightly acidic to nearly neutral conditions. This pH range is generally favorable for most wetland species, including *Scirpus atrovirens*, as it supports microbial activity and nutrient availability without causing toxicity or nutrient lock-up. Despite these seemingly suitable pH levels, other factors such as waterlogging and nutrient deficiency may still restrict effective nutrient uptake and plant growth. Therefore, while pH itself may not be a major limiting factor, it interacts with other soil constraints that impact overall soil health.

Electrical Conductivity (EC) of Soil: The EC values of the soil samples ranged from 430 µS cm^{-1} to 440 µS cm^{-1}, classifying the soils as low to moderately saline. While these values do not reach thresholds commonly associated with severe salinity stress, they can still impact sensitive crops or stress plants during vulnerable growth stages. For Dark green bulrush, especially at the seedling stage, these EC levels could reduce germination rates and root development. Moreover, prolonged saturation and poor drainage may amplify the impact of salinity over time. EC management strategies, including improved drainage and appropriate mulching, could mitigate the risk of salt buildup.

Organic Carbon: The organic carbon content in the soils was relatively low, ranging from 1.4728% to 1.8103%. These values reflect poor organic matter content, which directly affects soil fertility, structure, and water

retention capacity. Low organic matter reduces the soil's ability to buffer pH and salinity changes and limits microbial activity crucial for nutrient cycling. In wetland ecosystems where organic-rich substrates are typically expected, such low values indicate degradation or poor organic input. Incorporating compost, decomposed vegetation, or organic amendments could enhance soil health and support better bulrush growth.

Available Phosphorus (P): Available phosphorus levels across the soil samples were found to be between 2.1 and 2.97 ppm,

which is below the optimal threshold for most crops. Phosphorus plays a vital role in root development and energy transfer, and its deficiency severely limits seedling establishment and early growth phases. In wet, anaerobic soils, phosphorus often becomes less available due to chemical fixation. These low P values, in combination with water saturation, suggest that phosphorus is a key limiting nutrient for bulrush survival and productivity. Phosphate fertilization using water-soluble or slow-release forms may help improve plant response.
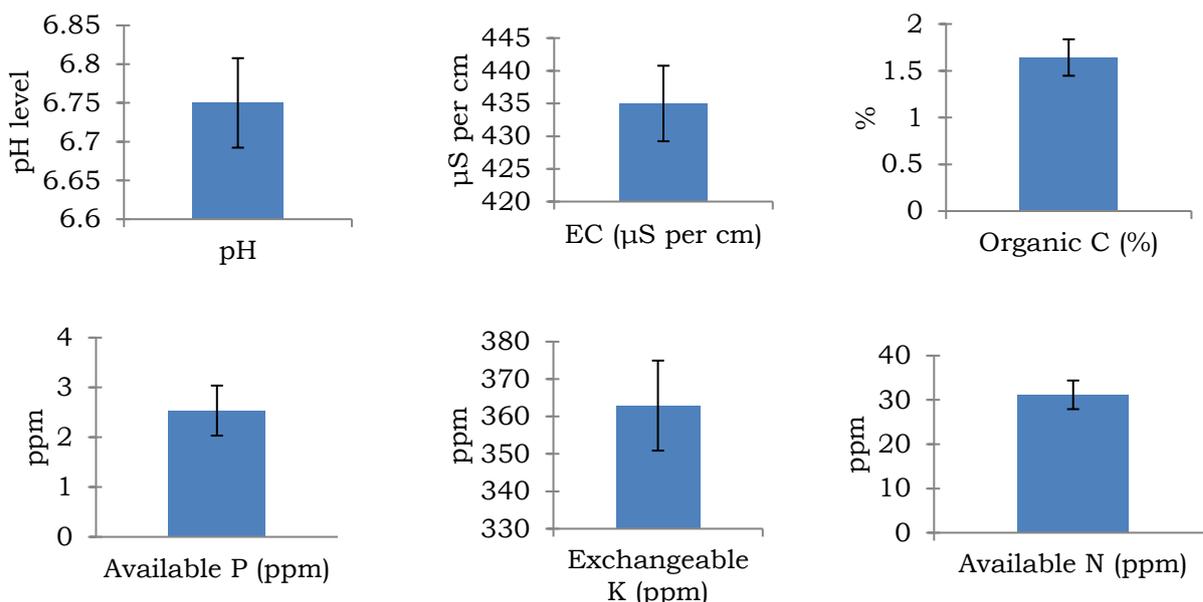
Fig. 9. pH, EC, organic C, available P, exchangeable K and available N of different soil samples.

Exchangeable Potassium (K): The exchangeable potassium values were also inadequate, ranging from 373.33 to 352.50 ppm. Potassium is essential for water regulation, enzyme activation, and stress resistance. In saline-prone, waterlogged soils, potassium deficiency can become more pronounced due to leaching or competition with sodium ions. The low K levels observed here may contribute to the poor vigor and low biomass of the surviving bulrush plants. Potassium supplementation through muriate of potash (KCl) or organic sources like wood ash could restore balance and improve plant health.

Available Nitrogen (N): Available nitrogen concentrations were observed between 33.95 and 28.35 ppm, falling below ideal levels required for vigorous vegetative growth. Nitrogen is critical for chlorophyll synthesis and shoots elongation, and its deficiency results in pale leaves and stunted plants.

Given the leaching-prone nature of wetland soils and the observed waterlogging in the area, nitrogen loss is expected through denitrification and runoff. This deficiency may be one of the major causes behind the 30–40% plant survival rate in only a few plots. Application of organic matter, green manure, or slow-release nitrogen fertilizers could help improve nitrogen availability.

(b) Water quality: Water quality analysis was performed by measuring pH, electrical conductivity (EC), and total dissolved solids (TDS) across different months to assess seasonal salinity fluctuations and their potential impact on bulrush cultivation (Fig. 10).

Water pH: The water pH values recorded over different months varied between 6.986667 and 6.796667, indicating neutral to slightly acidic conditions. These values are suitable for irrigation and support the availability of

most essential nutrients. For bulrush cultivation, this pH range does not present any direct chemical constraints and is considered safe. However, when combined with fluctuating salinity levels, even neutral pH water can carry risks if salts accumulate over time.
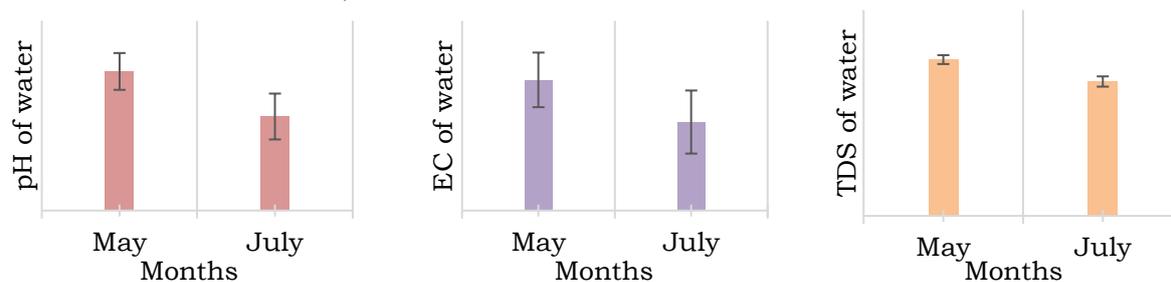

Fig. 10. EC, pH and TDS of different water samples in different months.

Water EC and TDS: The water electrical conductivity (EC) values ranged from 28.5333 to 28.2000 μS cm^{-1}, and the total dissolved solids (TDS) ranged from 7.6 to 6.5 ppm across months. These fluctuations indicate periodic salinity stress, likely due to tidal intrusion or seasonal waterlogging. High EC and TDS values during specific months can negatively affect seedling establishment and plant physiology. The intermittent nature of water salinity in this region requires careful timing of planting and possible freshwater harvesting to minimize salt stress during critical stages.

(c) Disease status: No severe or devastating fungal diseases were empirically observed in the Dark green bulrush cultivation plots during the study period (Plate 1). However, the prevailing environmental conditions characterized by high humidity, poor drainage, and prolonged stagnant water are known to favor the development and spread of fungal pathogens. Although specific fungal diseases affecting *Scirpus atrovirens* are not well-documented in the region, these stress-prone conditions suggest a potential risk for future outbreaks, particularly if plant health and soil conditions continue to deteriorate. Regular monitoring and preventive measures are therefore recommended to minimize the possibility of fungal infections (Boyd and White, 2010).

Fungal image 1   Fungal image 2

Plate 1. No devastating fungal growth was evident in the laboratory.

The empirical laboratory findings indicate that the soil at the cultivation site is low in organic carbon, available nitrogen, phosphorus, and potassium, despite having a favorable pH range and moderate salinity. Water quality showed seasonal fluctuations in salinity, with elevated EC and TDS levels during certain months, posing stress risks to plant growth. While no significant fungal diseases were detected, the high humidity and stagnant water conditions create a potentially conducive environment for future infections. These combined factors suggest that soil nutrient management, improved drainage, and regular monitoring are essential for successful Dark green bulrush cultivation.

Conclusion

The findings of this study highlight that Green Bulrush cultivation offers significant potential as a sustainable livelihood strategy, especially for marginalized and women farmers in the wetlands of Tala Upazila, Satkhira. Despite facing various challenges, farmers mostly women continue to grow this crop using traditional techniques, relying mainly on rainwater and manual irrigation. The crop's high average yield of 712.63 bundles, even on small landholdings, reflects its suitability and resilience in the region. However, to fully harness the potential of green bulrush, the study emphasizes the need for strategic interventions. Priority should be given to improving water management infrastructure to address the challenges posed by prolonged waterlogging and inconsistent rainfall. In addition, the introduction of appropriate modern cultivation methods and tools can enhance productivity and reduce labor intensity. Better market access and value-chain development are also essential to ensure fair prices and income security for farmers. Finally, strengthening the role of agricultural extension services and institutional support is crucial to building farmers' capacity, disseminating knowledge, and providing timely guidance. Overall, while green bulrush already plays a vital role in supporting rural livelihoods, especially among disadvantaged groups, its long-term viability depends on integrated support systems and policy attention to promote sustainable and inclusive agricultural development in southwestern Bangladesh.

Acknowledgments

Conflict of Interests

The authors declare that there is no conflict of interest regarding the conduct, authorship, or publication of this research. No financial, institutional, or personal relationships have influenced the work presented in this study. All aspects of the research, including the design, data collection, analysis, and interpretation, were carried out independently and objectively. This declaration is made in the interest of full transparency and to uphold the integrity of the research process.

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