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Perspective research

The village Kalshimati: Lifting out of multidimensional poverty

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ABSTRACT

Kalshimati, a village located in Sherpur Upazila under Bogura distirict of Bangladesh is the place where a good many poor people live with low living standard signifying the presence of various deprivations due to multidimensional poverty. The paper describes an ongoing action research project designed and launched by Rural Development Academy, Bogura to lift the village out of multidimensional poverty, develop a replicable model and find out the drawback of the application of Multidimensional Poverty Index (MPI). MPI is the central idea of framing the project from setting intervention strategy to implementation, monitoring and evaluation.

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Introduction

Leaving no one behind—a value asserted in Sustainable Development Goals (SDGs) points to inclusive development which is neither possible nor desirable in a society sick of poverty. Poverty is first and foremost an issue to be addressed to ensure inclusive development. The spirit of inclusive development reflected in the dream of Bangabandhu Sheikh Mujibur Rahman, the Father of the Nation. He said that every citizen of Bangladesh would have food, home, education and an improved life. The population living below the national poverty line in 2019 was 20.5 percent (MOF, 2021). The target set in the 8th Five Year Plan is to drop the poverty rate to 7.4 percent (GED, 2020). Multidimensional Poverty Index (MPI) based estimation shows that 14.5 percent in urban and 27.4 percent in rural areas were MPI poor in 2020 (OPHI and IsDBI, 2021). However, the nation is hopeful of a poverty free future as the present government has given the highest priority to poverty reduction and set it at the forefront of national development. There is a firm commitment in Bangladesh 'Perspective Plan 2041' to eliminate absolute poverty by 2041, bring down the national poverty rate below 3% and ensure minimum living standard for all the citizens by 2041 (GED, 2020).

To translate the dream of Bangabandhu into reality, the honorable Prime Minister Sheikh Hasina has launched ten special development initiatives. These are My House My Farm, Digital Bangladesh, Housing Project, Women's Empowerment, Electricity for All, Community Clinic and Child Development, Social Safety Programme, Environmental Protection, Education Assistance Programe, and Investment Development. The initiatives bear testimony to the visionary and futuristic leadership of honourable Prime Minister. They are profoundly contributing to eradicate poverty and achieve the status of a high-income nation by

Table 1. Global MPI, Dimension, Indicator, Deprivation Cut off and Weights.

Dimension	Indicator/ weight	Deprivation cut off (deprivation if living in the household under)	SDG Area
Health (1/3)	Nutrition (1/6)	Any person under 70 years of age for whom there is nutritional information is under nourished.	SDG 2
	Child Mortality (1/6)	A child under 18 years has died in the household in the 5 years period preceding the survey.	SDG 3
Education (1/3)	Years of Schooling (1/6)	No eligible household member has completed 6 years of schooling.	SDG 4
	School Attendance (1/6)	Any school aged child is not attending school up to the age at which he or she would complete class 8.	SDG 4
Living Standard (1/3)	Cooking Fuel (1/18)	A household cooks using solid fuel such as dung, agriculture crop, shrubs, wood, charcoal or coal.	SDG 7
	Sanitation (1/18)	The household has unimproved or no sanitation facility or it is improved but share with other households.	SDG 6
	Drinking Water (1/18)	The households' source of drinking water is not safe or saved drinking water is a 30 minutes or longer work from home and round trip.	SDG 6
	Electricity (1/18)	The household has no electricity.	SDG 7
	Housing (1/18)	The household has inadequate housing materials in any of the three components: floor, roof or walls.	SDG 11
	Asset (1/18)	The household does not own more than one of these assets: radio, TV, telephone, computer, animal cart, bicycle, motorbike or refrigerator and does not own a car or track.	SDG 1

Source: Alkire et al. (2020).

2041. 'My Village My Town' another well timed development concept for Bangladesh aims at creating urban modern amenities in rural area, and thus checking unintended rural to urban migration and utilizing the full potential of rural area. Notwithstanding the poverty eradication efforts mentioned above, there is scope to extend thinking over the poverty issue from researchers' view point.

Household Income and Expenditure Survey (HIES 2016) conducted by Bangladesh Bureau of Statistics (BBS) determines the percentage of the total population living below the poverty line in Bangladesh. Through this survey, the national poverty status of Bangladesh has been projected. According to HIES 2016, the estimated rate of national poverty was about 20.5% while the extreme poverty was about 10.5% in 2019. However, this survey was unable to measure the poverty rate of a particular village or identify the rural poor population for a particular area. Various governments with the help of World Bank have taken initiative to identify poor families in their country conducting survey to identify ultra-poor. Since the real income of each family is not possible to know, this type of project tries to identify ultra-poor families by using some proxy variable and calculate the Proxy Mean Test (PMT) score of each household. But identifying ultra-poor families with this method is complicated to calculate accurately. Recently Multi-Dimensional Poverty Index (MPI) has been popular for determining poor in a country which is introduced by University of Oxford and UNDP recently. Every year UNDP has published the Global MPI. MPI can determine the poor or non-poor household finding the deprivation aspects based on non-economic factors. MPI is an analytical tool to identify the most vulnerable poor, revealing poverty patterns within countries and over time, enabling policy makers to target resources and design policies more effectively.

This method is a smart and easier to select the poor household in a particular area and household. However, the global MPI is calculated according to dimension stated below:

According to Human Development Report 2021 of UNDP population in multidimensional poverty in Bangladesh is 24.1 percent and about 39.23 million people are considered as MPI poor. According the UNPD latest report people of Bangladesh are still deprived at higher rate in cooking fuel, year of schooling, sanitation, housing and assets (Table 2).

Rationale of the action research

There are a good number of terminated and ongoing projects aiming at eradicating poverty. For example, Chars Livelihoods Programme (CLP), Comprehensive Village Development Programme (CVDP). Most of them adopted an income based approach to define poverty line and select beneficiaries. One limitation is that some poor people are bypassed due to the beneficiary selection criteria. For example, many eligible people will not be selected as beneficiary if priority is given to place such as people living in char area, certain level of income, particular profession, indigenous people, cooperative based approach etc.

Literature shows that the projects used education and health assistance, housing, asset and cash transfer, training and microcredit as intervention strategies. Another limitation in this regard is that the poverty was not widely reflected beyond income or monetary dimension. Non-monetary dimension of the poverty includes but not limited to health and education services, life and non-life insurance, improved sanitation and safe drinking water, consumption of electricity and use of clean fuel for decent life.

Rural Development Academy (RDA), Bogura sets a research question relating to poverty reduction strategies applied by various development projects. The question is: With consistency and without any logical contradiction, is there any need of poverty reduction intervention strategy apart from ones adopted in aforesaid development initiatives? RDA, Bogura has launched an action research project entitled "Poverty free Model Village" to answer the question. The central thrust of the project is to address multidimensionality and dynamism of poverty felt by the poor. In strict relevance to the

Table 2. Multidimensional Poverty Index: changes over time based on harmonized estimates for Bangladesh.

Sl No	Subject	2014	2019
	Population in multidimensional poverty		
1	Headcount (%)	37.6	24.1
2	Headcount	58,040,000	39,236,000
	People who are multidimensional poor and deprived in each indicator		
1	Nutrition (%)	16.4	8.7
2	Child mortality (%)	2.3	1.3
3	Years of schooling (%)	25.3	16.6
4	School attendance (%)	9.5	6.5
5	Cooking fuel (%)	35.9	22.8
6	Sanitation (%)	28.2	15.3
7	Drinking water (%)	4.1	1.4
8	Electricity (%)	23.8	4.6
9	Housing (%)	35.8	22.8
10	Assets (%)	26.2	15.9

Source: Human Development Report 2021 (UNDP 2021).

Table 3. Demographic analysis of Kalshimati villages.

Sl No	Subjects	Numbers/Percentage
1	Total population	1374
2	Total households	387
3	Female	682
4	Male	692
5	Percentage of population under 18 years	24.67
6	Percentage of youth (18-35 years)	27.22
7	Percentage of population middle age (36-60 years)	39.45
8	Percentage of population above 61 years	8.66

key idea, Multidimensional Poverty Index (MPI) has been applied in designing the action research. MPI method can capture non-monetary multi-dimensionality of the poverty. Besides, income aspect has been given equal importance. Hence poverty can be analyzed from a comprehensive viewpoint. MPI reflects the deprivation or poverty experienced by each member of a household, and thus providing a deep and complete picture of household poverty. Poverty status can be monitored during implementation phase in a systematic way. The way MPI based project works can contribute to achieve SDGs 1, 2, 3, 4, 6, 7 and 11 simultaneously. This action research will follow MPI, a non-income approach, together with income approach. Thus, an effort has been made to overcome the limitations of previous projects. With a motto—no one left behind—the aim of this action research is to identify the deprivation factors and to provide intervention as such in order to ensure sustainable poverty free area.

Objectives of the study

The broad objective of the action research is to transform the MPI poor households (sore 33 and above) into MPI non-poor (score below 33) and make their status sustainable above poverty line. The precise objectives are as follows:

a. Lift the households out of poverty or deprivation through indicator wise intervention;
b. Increase income of households through income generating activities;
c. Identify advantage and disadvantage of MPI in poverty reduction; and
d. Develop a model of poverty reduction in the light of implementation and evaluation experience of the action research.

Study location and baseline survey

The study is being conducted in the village Kalshimati situated in Sherpur Upazila of Bogura District. The village, being in the vicinity of RDA,

Table 4. Status of educational qualification in Kalshimati village.

Sl No	Educational Qualification	Number of persons	Percentage
1	Can sign/can read and write	179	13.03
2	Illiterate	251	18.27
3	Hafez/madrasa education	10	0.73
4	Primary	326	23.73
5	Lower secondary	310	22.56
6	Secondary (SSC)	104	7.57
7	Higher secondary	103	7.50
8	Graduation	60	4.37
9	Post-Graduate	31	2.26
	Grand Total	**1374**	**100.00**

Table 5. Status of Land ownership of households based on MPI Score in Kalshimati village.

Land Size (acre)	MPI Score						
	0-0.19	**0.20-0.32**	**0.33-0.49**	**0.50-1.00**	**0-0.32**	**0.33-1.00**	**0-1.00**
0.00-0.00	10	35	79	37	45	116	161
0.00-0.20	5	24	32	9	29	41	70
0.21-0.49	10	12	25	10	22	35	57
0.50-1.00	13	23	15	8	36	23	59
1.01-2.00	7	9	14	1	16	15	31
2.01-above	5	0	4	0	5	4	9

Note: Considering land ownership of cultivable agricultural land and non-agricultural land.

Bogura and a residence of a good number of poor people is an ideal one to choose for the pilot study. RDA has conducted an apps based census and qualitative investigation to study the feasibility. The analysis has been performed to calculate MPI score of every household of the village and select the beneficiaries. Training needs, the possibility of additional income generation and the potential of making village resources more productive have also been analyzed through qualitative and quantitative inquiries.

Result and discussions

The Baseline Survey was conducted by Rural Development Academy, Bogura in the village of Kalshimati in October 2021. This survey can be treated as census because every household was taken into account. The total population of the village at the time of the survey was 1374 and the number of households was 387. 66.67 percent

Table 6. Status of occupations of households member in Kalshimati village.

SL No	Name of Occupations	Number of population	Percentage
1	Children	196	14.26
2	Disabled	2	0.15
3	Unemployed	41	2.98
4	Student	204	14.85
5	Housewife	434	31.59
6	Day labor (agriculture/non-agriculture)	75	5.46
7	Driver (rickshaw/van/auto rickshaw/ truck/ nachimon)	39	2.84
8	Mechanic (van, plumbing, mason, electrician/carpenter/ others)	33	2.40
9	Village doctor and lsp	5	0.36
10	Handicraft/tailoring	5	0.36
11	Imam/priest	3	0.22
12	Farmer	190	13.83
13	Business	53	3.86
14	Government job	18	1.31
15	Private job	73	5.31
16	Expatriate	3	0.22
	Total	**1374**	**100.00**

Table 7. Multidimensional poor and non-poor based on MPI score in Kalshimati village.

Poor/Non Poor	MPI Score	Population	Headcount (%)	Number of Household	Average Family size
MPI Non Poor	0.00-0.19	169	12.30	50	3.4
MPI Non Poor (Vulnerable)	0.20-0.32	382	27.80	103	3.7
MPI Poor	0.33-0.49	573	41.70	169	3.4
MPI Poor (Severe Poverty)	0.50-1.00	250	18.20	65	3.8
MPI Non Poor	0.00-0.32	551	40.10	153	3.6
MPI Poor	0.33-1.00	823	59.90	234	3.5
Total	**0.00-1.00**	**1374**	**100.00**	**387**	**3.6**

of the total population of the village is between 18 and 60 years of age (Table 3). Only 21.70 percent of the people in the village are educated with secondary school certificate or above, which means that the village lags far behind in terms of education (Table 4).

The seven families in the village have no homestead area or agriculture or non- agricultural land. Besides, 161 households do not have at least one decimal of agricultural and non-agricultural land. According to the definition of landless, 288 families in this village and 75 percent of the total houses are marked as landless. Out of 288 landless families, 192 MPI poor families can be identified as landless and 96 families are landless even though they are MPI Non poor. In this case, even though the MPI Non poor, all these families and landless families are at risk (Table 5).

Although the number of unemployed is less in rural areas, it is more in low income population. Table 6 shows that about 63.63 percent of the total population of the village is dependent i.e. dependent on other family members. 24.31 percent of the people are engaged in farming and private employment. 10.7 percent of the people work as driver or mechanics or day laborers. There are 434 housewives in this village and the number of handicraft sewing business and village doctors is very low. Poverty alleviation in the area may be possible if various income-generating trainings are arranged for unemployed people, including housewives.

The global MPI measure identifies those who are close to the one-third threshold, that is, individuals are vulnerable to multidimensional poverty if they are deprived in 20% to 33.33% of weighted indicators. The measure also specifies a higher poverty cutoff to identify those in severe poverty, meaning those deprived in 50% or more of the dimensions. Based on this concept we

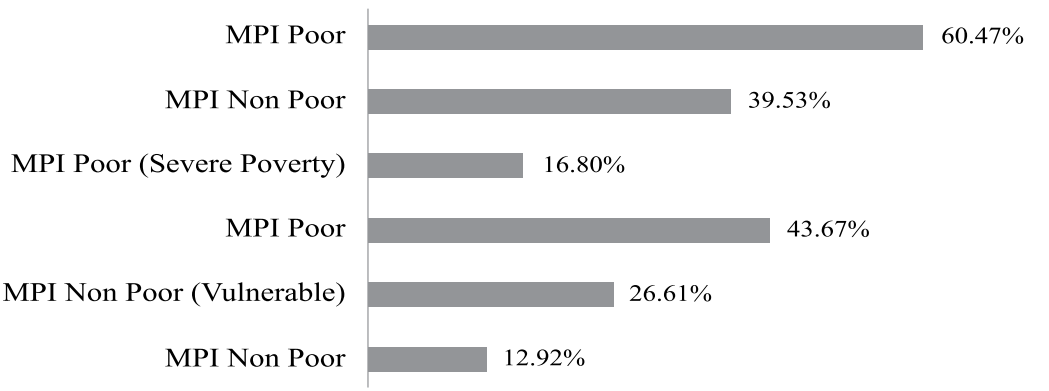

Figure 1. Percentage of Poor and Non-poor Household based on MPI Score in Kalshimati Village.

Table 8. Indicator wise number of deprived household of village Kalshimati.

Indicator	Number of deprived household based on MPI Score						
	MPI Non Poor	Vulnerable	MPI Poor	Severe Poverty	MPI Non Poor	MPI Poor	
	0.00-0.19	0.20-0.32	0.33-0.49	0.50-1.00	0.00-0.32	0.33-1.00	0-1.00
Nutrition	3	9	28	24	12	52	64
Reproductive Health	1	8	19	37	9	56	65
Years of Schooling	12	82	162	64	94	226	320
School Attendance	0	1	9	13	1	22	23
Cooking Fuel	7	22	113	50	29	163	192
Sanitation	13	31	114	47	44	161	205
Drinking Water	4	13	35	18	17	53	70
Electricity	0	0	14	7	0	21	21
Housing	25	96	154	63	121	217	338
Asset	4	7	68	27	11	95	106

have calculated the number of MPI Poor, MPI Non Poor, MPI Non Poor but Vulnerable, MPI Poor but Severe Poor household and population.

Table 7 shows that there are 234 MPI poor households with a total number of 823 members whereas 153 households with 551 household members are MPI non-poor in Village Kalshimati. All the MPI poor households and MPI Non Poor but Vulnerable household have been considered as beneficiaries or target people. Figure 1 show that 60.47 percent households of Kalshimati village are considered as multidimensional poor and 39.53 percent households are treated as Non MPI poor. Table 7 shows that 59.90 percent headcount MPI poor in Kalshimati village whereas according to headcount multidimensional poverty in Bangladesh is 24.1 percent (HDI Report 2021). According to this data, we find that the people of Kalshimati village are more than double the national poverty multidimensional poor. Table 8 shows the number of households deprived in different indexes.

In Bangladesh, the General Economics Division of the Ministry of Planning, BBS and UNDP has given importance on reproductive health instead of child mortality and incase of nutrition indicator 0-4 year's old child was considered during MPI survey (Reduction MP in Bangladesh, 2020). During the baseline survey in the Kalshimati village child mortality data and nutrition information for each person has been collected. However, the method that was used for Bangladesh when calculating the multidimensional poverty index is used here.

In the case of Kalshimati village, deprivation has been calculated on various indicators of the multidimensional poverty index. In the case of unimproved housing, 56.07 percent is MPI poor and 31.27 percent is MPI Non poor households, which means that total 87.34 percent of households are deprived from improved housing (Figure 2) . In the case of unimproved housing, we calculated differently from the global MPI. In Global MPI, any one of the roofs, walls and floors of the house is considered as deprivation if it is improved. But in the case of Kalshimati village, if the floor is muddy, it is not identified as an improved house. If the floor of a house is made of mud with many concreted walls, that household has been placed in the category of deprivation. This initiative has been taken to declare this village as smart village in future.

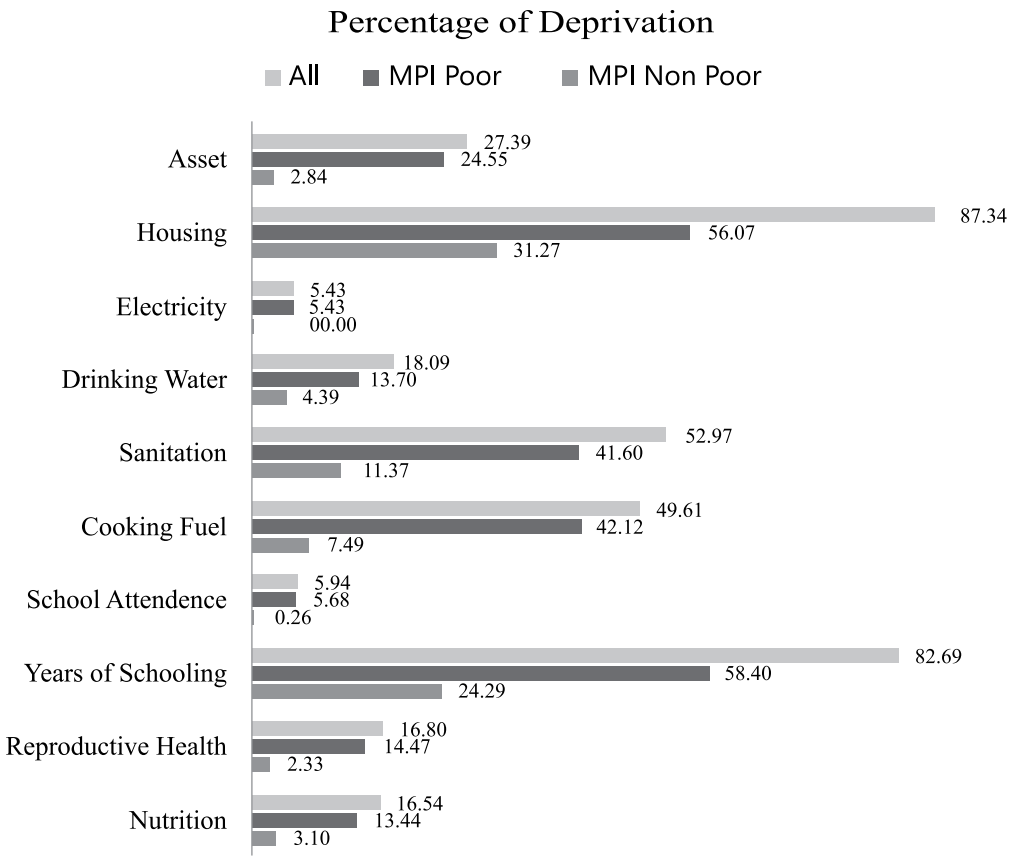

Figure 2. Indicator wise percentage of deprivation household of Village Kalshimati.

In the case of sanitation, 41.6 percent MPI poor and 31.36 percent MPI Non poor households are deprived. In case of cooking fuel, 42.12 percent MPI poor households are deprived. In this village year of schooling, 82.69 percent of the total households are deprived and 58.40 percent MPI poor household are deprived (Figure 2).

Analysis of deprivation indicators in the Multidimensional Poverty Index shows that rural poverty alleviation will be possible if effective measures are taken to alleviate deprivation with special emphasis on these indicators of assets, housing, sanitation, education or training, drinking water, insurance and cooking fuel.

Intervention strategy and implementation mechanism

The importance of non-income and income aspects in addressing the poverty cannot be overstated. They are mutually reinforcing. The project has given equal importance to them for eradicating poverty. Therefore, two types of intervention—indicator based and income generating—need to be identified and implemented as such. The following indicator based and income generating interventions have been identified after carefully conducted feasibility study.

(i) **Indicator Based**: The households who are poor or deprived in one or more indicator will be given treatment or intervention so as to uplift them above the poverty line. To put it another way, if a household's score in a given indicator is poor (MPI score 0.33-1.00), particular intervention will be provided to transform the household into non-poor (MPI score below 0.20). Such interventions include:

a. Awareness building on reproductive and child's health, nutrition, primary health care, hygiene and sanitation, importance of

education, superstition, child marriage and child and women violence.

b. Increase the access of beneficiary households to government and non-government health, education, sanitation and other service providing institutions.
c. Take necessary actions to ensure safe drinking water, electricity, standard home and sanitation and improved stove for cooking. Solar power run water supply will be established, where necessary.
d. Take necessary action to help the beneficiary households so that they can bear educational expense of their members. Mid day meal delivery system will be introduced at primary schools to ensure school attendance.
e. Make old home and rehabilitation center in project area for homeless senior habitants
f. Establish recreational park, organize sports and cultural ceremony for the villagers.
g. Motivate the beneficiaries to build specially designed model house to ensure quality living standard.

(ii) **Income Generating**: It refers to the interventions aiming at increasing household's income and eradicating the deprivations. Such interventions include:

a. Establish community based goat, cattle, and fish and poultry farms. Necessary Infrastructure will be built. Beneficiaries will be provided with goat, cattle, fish and poultry on a condition of paying half price.
b. Help the beneficiaries to become entrepreneur by providing training, assets transfer and credit support.
c. Organize village fair and establish market linkage to extend market facility particularly for the entrepreneurs and the villagers at large.
d. Tree plantation and vegetable gardening in homestead.
e. Utilize the opportunity of increasing income in optional occupation beside the main occupation.
f. Make natural resources (pond, forest, unused and abandoned land) of project area more productive.
g. Extend health insurance, life insurance, non-life insurance and banking services to the beneficiaries.
h. Take necessary actions to provide training and credit supports to those who can ensure employment in countries other than Bangladesh.
i. Take actions to promote rural tourism in the project village.
j. Assist to establish on and off farm small and medium industries in the village.

Apart from those, there will be a team consisting of a minimum number of 50 youth. They will be named after Champion and will be given training, credit and advisory services to be entrepreneur. They will get the privilege to flourish their ideas through the incubation center of "Poverty Free Model Village Lab". The team would be encouraged to work voluntarily to alleviate the poverty from the village and would shape the initiative into a social movement. Consulting partners such as GED of Planning Commission, BBS and Bristol University of UK would be engaged in assessing the project impact in experimental setting.

Conclusion

Poverty is a never ending reality. An all out and sustainable approach therefore, needs to be considered. MPI could be an effective tool, albeit not a way out. MPI offers a well developed and comprehensive concept of poverty and a quantitative method to monitor the progress. The learning and experience can enrich policy makers, researchers and practitioners to engineer context specific dynamism and multidimensionality of poverty. The crucial part of this study is to develop a replicable model that can be helpful to combat against poverty in Asian context.

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Original Research

Organic banana production in a selected area of Bangladesh: Assessment on financial profitability and farmers' livelihood

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ABSTRACT

The study was conducted to estimate the profitability of organic banana production, to assess the factors affecting the adoption of organic banana, and to evaluate the impact of adopting organic banana production on farmers' livelihood. Two villages, namely Jalchatra and Jangalia of Madhupur Upazila in Tangail district, were selected for the study. A total of 40 respondents was interviewed using multi stage sampling technique to collect the primary data. Profitability analysis, logit regression model, and sustainable livelihood framework were used to analyze the data. The BCR of organic and inorganic banana farming was found as 1.55 and 1.63, respectively. Household size, educational level, farm income, and non-farm income had a significant influence on the adoption of organic banana farming by the farmers. The study also found a remarkable improvement that took place in the farmers' livelihood capitals after the adoption of organic banana production. For increasing the production of organic banana, a regular and adequate supply of organic fertilizers and insecticides should be ensured to the growers on time at fair prices. Extension services should be extended to farmers to accelerate the production of organic banana. The study also recommends introducing organic friendly agriculture policy, broadcasting in media on the harmful effects of conventional agriculture, farmers' trainings, and participatory researches for nourishing farmers' knowledge about the importance of adopting the organic approach in banana production.

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Introduction

The economic development of Bangladesh largely depends on agricultural sector. For a huge population of nearly 165 million people, the country has only 8.2 million hectares of arable land (Hassan, 2011). In adequate supply of nutrients, lessening soil organic matter, and soil erosion are intensively hindering the sustainable agricultural improvements (MoA, 2008). Fertilizer consumption in Bangladesh has amplified by more than 1.6 million tonnes from 1994-95 to 2006-07. However, the demand for urea fertilizer has only increased by about 1.0 million ton over this period. Pesticide usage increased from 7,350

tonnes in 1991 to 16,200 tonnes in 2001 (MoA, 2008), more than doubling over a decade. Though the continuous application of chemical fertilizers contributed to boost the crop production,this led to environmental degradation in many ways such as topsoil depletion and degradation, reduced soil microbial activities, groundwater contamination, etc. Consequently, prominent focus is now given on the using of organic energy inputs in agricultural and industrial sectors to reduce environmental pollution (Mishra, 2005).

The organic agricultural approach evades synthetic inputs and genetically modified organisms, reduces air, soil, and water pollution, and optimizes the health and productivity of the ecosystem. Zero usage or reduced usage of chemical fertilizers and pesticides can diminish the adverse effects of environmental adulterations. Applying organic energy inputs potentially result in sustained soil productivity by the means of improving soil's physical, chemical, and biological properties. However, organic farming is still a subject of experiment in Bangladesh except a few cases. Evidence on food production in organic manner in Bangladesh has been found at closely 0.2 million hectares of land (IFOAM, 2005), which renders only 2% of the country's total cultivable land. During the past decade, only 100 of the country's conventional farms had chosen the practice of organic agriculture.

Banana is a high-demand fruit crop in Bangladesh for its nutritional value and year-round availability. It seemed that crop production, particularly banana production, increased after the adoption of chemical agriculture and technology. Organic banana is included in land-use portfolios for almost every accepted risk level with proportions from 1% to maximally 32%, even if the same high uncertainty as for conventional banana is simulated for organic banana. A more realistic, lower simulated price risk increased the proportion of organic banana substantially to up to 57% and increased annual economic returns by up to US$ 187 per hectare. That is, uncertainty is a key issue for adopting organic banana. In practice, however, the adoption of sound practices, such as organic farming, is still limited due to the economic attractiveness of conventional agriculture and government policies that continue to encourage the use of synthetic inputs. Indeed, assessing the ecological and economic trade offs between organic and conventional farming, and identifying the economic perspectives from which the adoption of organic banana farming could be advantageous forms a major challenge.

The organic production of banana provides benefits not only for the environment and human health but also for the socio-economic situation of farmers. The socio-economic and agroecological aspects of organic farming have been explained in a number of pieces of literature. Dhar et al. (2020) carried out a study on organic shrimp farming status in Bangladesh. They confirmed the sustainability of organic shrimp production from consuming energy, protecting the environment, economic feasibility, and social/political equity. Uddin and Dhar (2016) assessed the impact of practicing conservation agriculture on farmers' livelihood status in Bangladesh and revealed significant improvement in farmers' livelihood after adopting such practice. Somasundaram et al. (2014) examined the eco-friendly nutrient management practices for banana in India associated with improved soil's physical, chemical, and biological properties, resulting in a better supply of plant nutrients, which led to good crop growth and yield. Mukul and Rahman (2013) evaluated the profitability of banana stakeholders in Bangladesh and revealed that the benefit-cost ratio for producers, wholesalers, and retailers were 1.40, 1.30, and 1.41, respectively.

The literature review indicates that most of the studies dealt with profitability and environmental impacts of organic banana production, and sustainability of organic agricultural production. However, there is a lack of evidence of how organic banana production affects farmers' livelihood as a profitable business. The specific objectives of this study are as follows: i) to calculate the comparative profitability of organic and inorganic banana production, ii) to identify the factors affecting the adoption of organic banana farming, and iii) to assess the impact of adopting organic banana farming on farmer's livelihood.

Materials and methods

Study area, sample selection, and data collection

The study was carried out at Madhupur Upazila of Tangail district. A total of 40 farmers was selected from Jalchatra and Jangalia villages using the multistage sampling technique. At first, a total of 83 farmers was identified purposively who were engaged in organic banana production. Among them, 40 farmers were interviewed randomly for the purpose of data collection. Primary data were collected using a structured interview schedule from July to September, 2019. The draft interview schedule was pre-tested with 20 respondents before finalizing. Besides the personal interview, two focus group discussions (FGDs) were also conducted. Secondary data and information having relevance with this study were also collected from different reports, published documents, Bangladesh Bureau of Statistics, Bangladesh Economic Review, online sources, journals, newspapers, and other organizations.

Analytical technique

The primary data were analyzed with a combination of the following mathematical and statistical techniques:

Profitability analysis

The profitability of organic and inorganic banana production was measured in terms of gross return, gross margin, net return, and benefit-cost ratio (undiscounted). The calculation of each parameter was done as an average of the data collected from the sample farmers. The formulas needed for the calculation of profitability were discussed as follows (Dillon and Hardaker, 1993; Stigler, 1994):

$GR = P \times Q$

$GM = GR - TVC$

$NR = GR - (TFC + TVC)$

$BCR = GR \div (TFC + TVC)$

Where, GR = Gross return (Tk./ha); P = Sales price of the product (Tk./no.); Q = Yield (no./ha); GM = Gross margin (Tk./ha); TVC = Total variable cost (Tk./ha); NR = Net return (Tk./ha); TFC = Total fixed cost (Tk./ha); and BCR = Benefit cost ratio.

Factors affecting adoption of organic banana production

To identify the factors influencing the adoption of organic banana production by the farmers in the study areas, logistic regression analysis (i.e., logit model) was used. Simple linear regression analysis is usually based on the assumption that the dependent variable is continuous. A very important and applicable method of analyzing the dichotomous response variable is the logit model. Since the dependent variable in this study is a dichotomous response variable, the following logit model was used not only to identify the factors but also to predict the probability of success (Gujarati, 2003):

Table 1. Average measurements of the independent variables.

Independent variables	Average measurements
Household size (no.)	4
Age of household head (years)	38
Educational level of household head (years of schooling)	9
Farm size (ha)	0.27
Farm income (Tk./year)	51,263
Non-farm income (Tk./year)	32,570
Extension contact (% of farmers)	
Yes	57.5
No	42.5
Farming experience (years of farming)	23

Source: Authors' estimation, 2019.

$Z_i = \ln[P_i \div (1 - P_i)] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + E_i$

Where, P_i is the probability of adoption and non-adoption of organic banana production; $P_i = 1$ indicates adoption and $P_i = 0$ indicates non-adoption; Z_i = Probability of adopting organic banana production; X_1 = Household size (no.); X_2 = Age of household head (years); X_3 = Educational level of household head (years of schooling); X_4 = Farm size (ha); X_5 = Farm income (Tk./year); X_6 = Non-farm income (Tk./year); X_7 = Extension contact ($P_i = 1$ indicates having extension contact and $P_i = 0$ indicates having no extension contact); X_8 = Farming experience (years of farming); β_0 = Intercept; β_1 to β_8 = Regression coefficients of the independent variables; and E_i = Error term.

The independent variables included in this logit model were identified by reviewing literatures of similar kind which include Njeru (2016)and Uddin et al. (2016). Table 1 shows the average measurements of the identified factors.

Impact of producing organic banana on farmers' livelihood

The impact of producing organic banana on farmers' livelihood was measured by presenting the assets in sustainable livelihood framework (SLF), also known as asset pentagon considering five types of livelihood capitals (i.e., human, social, natural, physical, and financial capitals) (DFID, 2000) (Figure 1). Changes in the asset position were discussed based on the transformation and improvement of the livelihoods of the farmers. To evaluate whether there was livelihood improvement through adopting organic banana production, each respondent was asked to indicate his/her option regarding level of improvement (i.e., 'increased', 'decreased' and 'constant') on a total of seventeen (17) indicators of the livelihood capitals (Uddin and Nasrin, 2013). The asset pentagon was used for visual presentation of overall asset possession by the farmers after adopting organic banana production, and demonstrate inter-relationships among the assets as well. The shape of the pentagon displayed schematically the variation (i.e., 'increased', 'decreased' and 'constant') in farmer's access to assets as the outcome of producing banana using organic approach.

Data analysis and interpretation

Before analyzing the data, the data and information collected from field surveys, interviews, discussions and communications were scrutinized, classified, edited and coded. Quantitative data were entered into computer using Microsoft Excel and tabulated accordingly. Qualitative data were first coded and converted into quantitative type in order for them to be

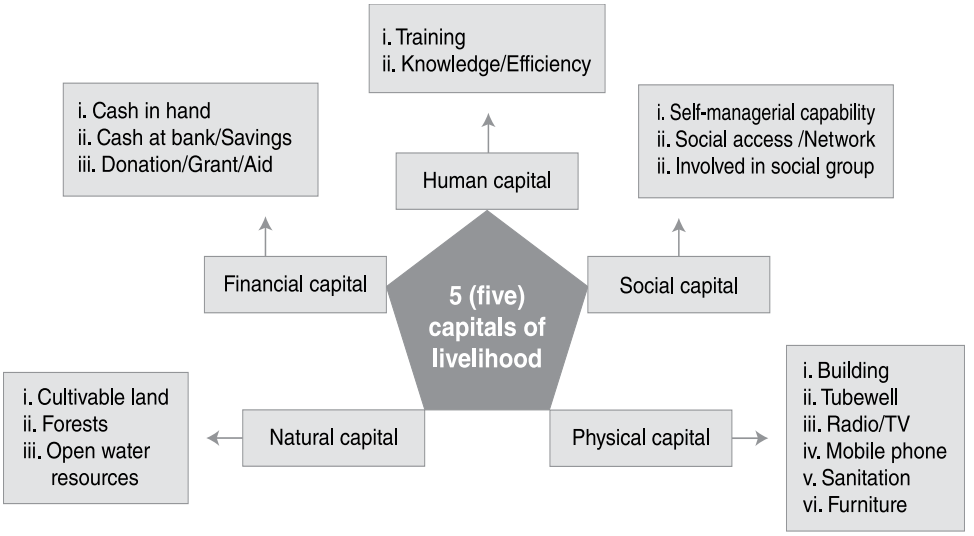

Figure 1. Sustainable livelihood framework.

computed and then, the analysis was done. After completing the pre-tabulation task, a list of tables was prepared and finally, tabulated data were analyzed by the authors to be interpreted on the basis of the objectives of the research. The mathematical and statistical analyses were computed by using Microsoft Excel v.2013, SPSS v.22 and STATA v.12.

Results and discussion

Financial profitability of organic banana production

The profitability of organic banana production was measured in terms of gross return, gross margin, net return, and benefit-cost ratio. Variable and fixed costs were taken into deliberation to estimate the total cost of production. Variable costs included human labor, power tiller, seedlings, fertilizers (organic/inorganic), irrigation,

Table 2. Cost of organic and inorganic banana production.

Items	Unit	Organic banana			Inorganic banana		
		Quantity/ ha	Price (Tk./unit)	Total value (Tk./ha)	Quantity/ ha	Price (Tk./unit)	Total value (Tk./ha)
Variable cost							
Human labor	Man-days	100	300	30,000	120	300	36,000
Power tiller				7,650			8,500
Seedlings	No.	445	15	6,675	900	12	10,800
Fertilizers							
Inorganic fertilizers							
Urea	Bag	15			20	850	17,000
TSP	Bag	800			12,000		
MoP	Bag	15			18,000		
$ZnSo_4$	Packet	1200			1,500		
		10					
		150					
Organic fertilizer							
Compost	Kg	45.84	60	2,750			
Cow dung	Kg	80	50	4,000			
Vermicompost	Kg	5.36	40	214			
Irrigation				5,000			8,000
Insecticides		26.4	250	6,600	34	250	8,500
Cost of fence				5,000			5,000
Interest on operating capital				6,000			6,000
Others				4,500			4,000
A.Total variable B.cost				78,390			135,300
Fixed cost							
Land use cost				12,000			12,000
C.Total fixed Cost				12,000			12,000
Gross cost (A+B)				**90,390**			**147,300**

Source: Authors' estimation, 2019.

Table 3. Return from organic and inorganic banana production.

Return of crop production	Quantity	Price (Tk./ha)	Total value (Tk./ha)	Quantity	Price (Tk./ha)	Total value (Tk./ha)
	Organic banana			Inorganic banana		
Output (no./ha)	400	350	140,000	800	300	240,000
Gross return (GR)			140,000			240,000
Gross margin (GR-VC)			61,610			104,700
Net return (GR-GC)			49,610			92,700
BCR (GR/GC)			1.55			1.63

Source: Authors' estimation, 2019.

insecticides, fencing, and interest on operating capital,and fixed cost included land-use cost.

Table 2 shows that the total variable cost of organic banana production was Tk. 78,390/ha and that for inorganic banana production was Tk. 135,300/ha. The total fixed cost for both cases was estimated at Tk. 12,000/ha. The total cost of organic and inorganic banana production was found as Tk. 90,390/ha and Tk. 147,300/ha, respectively. As shown in Table 3, gross return from organic banana production was Tk. 140,000/ha, and that from inorganic banana production was Tk. 240,000/ha (Table 6.5). Net return from organic and inorganic banana production was estimated at Tk. 49,610/ha and Tk. 92,700/ha, respectively. The BCR of organic and inorganic banana farming was found as 1.55 and 1.63, indicating that banana production in both organic and inorganic manner is profitable. Similar to this finding, Bellamy (2013) also found organic banana to have less productivity than banana-coffee intercropping in Costa Rica. Though less productive,the adoption of organic farming as a form of conservation agriculture can considerably improve the soil and environmental condition adversely affected by excessive chemical fertilizer application (Uddin et al., 2017).

Factors affecting adoption of organic banana production

A logit model was used to simulate the factors influencing the farmers' adoption of organic

Table 4. Factors determining organic banana production by the farmers.

Variables	Coefficient (β)	Standard error	t value	Level of significance	Odds ratio
Household size (X1)	-0.934**	0.876	-1.07	0.024	0.393
Age (X2)	-1.691	0.735	-2.30	0.236	0.184
Educational Level (X3)	2.427***	0.680	3.596	0.000	11.325
Farm size (X4)	0.145	0.571	0.254	0.130	1.156
Farm income (X5)	0.062*	0.618	0.100	0.074	1.064
Non-farm income (X6)	-1.224**	0.642	-1.91	0.021	0.294
Extension contact (X7)	0.753	0.747	1.01	0.313	2.123
Farming experience (X8)	0.536	0.724	0.740	0.460	1.709
Constant	0.429	1.244	0.344	0.730	1.536
R^2 value	0.72				
F-value	42.65				

Note: ***, ** and * indicate significant at 1%, 5% and 10% level, respectively.

Sources: Author's estimation, 2019.

banana production. Four out of eight variables included in the model were significant in explaining the variation in adopting the organic banana approach in the study areas, which were as follows: household size, educational level, farm income, and non-farm income (Table 4). Therefore, the estimated equation is as follows:

$$Z_i = 0.429 - 0.934X_1 - 1.961X_2 + 2.427X_3 + 0.145X_4 + 0.062X_5 - 1.224X_6 + 0.753X_7 + 0.536X_8$$

The estimates of coefficients indicate that household size had a negative but significant (at 5% level) impact on the probability of adopting organic banana production by farmers. The regression coefficient of household size is -0.934, which presented that the remaining other factors held constant, adoption of the organic banana production was negatively influenced by -0.934 units, for one-unit increase of adopting this production by banana farmers. The farmers having large families face relatively fewer problems in practicing organic banana farming. In the case of large families, the family members can help in different farming activities and other income-generating activities more than small families. The educational level had a positive and significant (at 1% level) effect on the probability of adopting organic banana farming.

The regression coefficient of the educational level was 2.427, which implies that the remaining other factors constant, adoption of the production was positively influenced by 2.427 units for one unit increase in educational level. One possible

Table 5. Changes in livelihood capitals of the farmers after adopting organic banana production.

Livelihood capitals	Change after adoption (%)		
	Increased	Decreased	Constant
Human capital			
Training	75.0	12.5	12.5
Knowledge/Efficiency	60.0	25.0	15.0
Social capital			
Self-managerial capability	40.0	45.0	15.0
Social access/Network	72.5	20.0	7.5
Involved in the social group	45.0	27.5	27.5
Natural capital			
Cultivable land	45.0	35.0	20.0
Forests	15.0	7.5	75.0
Open water resources	10.0	20.0	70.0
Physical capital			
Building	30.0	5.0	65.0
Tube well	50.0	5.0	45.0
Radio/TV	22.5	10.0	67.5
Mobile phone	60.0	10.0	30.0
Sanitation	60.0	15.0	25.0
Furniture	45.0	5.0	52.5
Financial capital			
Cash in hand	72.5	12.5	15.0
Cash at bank/ Savings	35.0	5.0	62.5
Donation/Grant	70.0	5.0	25.0

Source: Field survey, 2019.

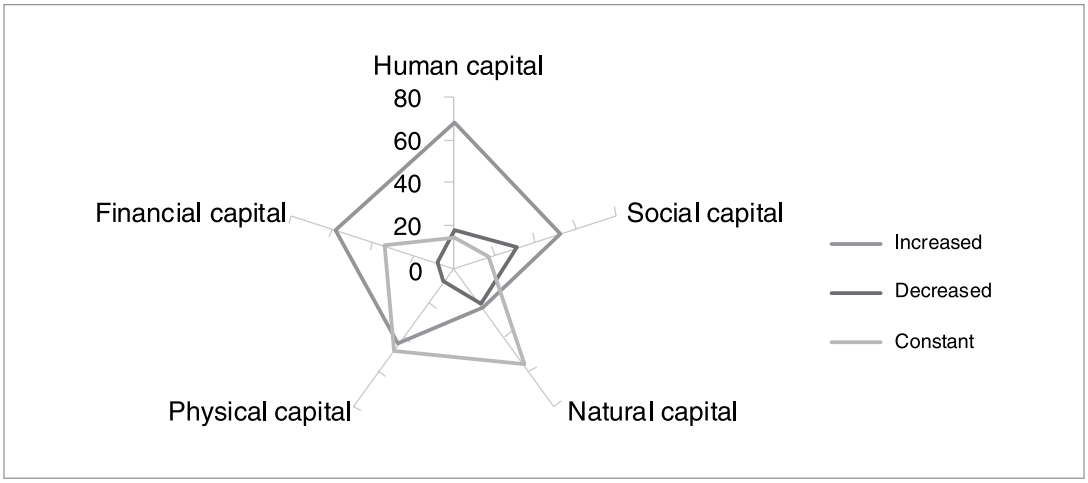

Figure 2. The overall change in farmers' capital ownership after adopting organic banana production.

explanation for this could be that the higher the educational level of farmers, the better they are adopting organic banana production. Farm income also positively affected adopting organic banana production,which was statistically significant at the 10% level. The regression coefficient of farm income was estimated at 0.062, which means, holding other variables constant, if the farm income increases by one unit, the adoption would increase by 0.062 units. Non-farm income negatively affected the probability of adopting the production, and this variable was statistically significant at the 5% level. The regression coefficient of non-farm income was estimated at -1.224, which means, holding other factors constant, if the non-farm income increases by one unit, the adoption of the production would increase by -1.224 units. In addition to these factors, a survey in the Dominican Republic (FAO, 2017) reported that high market demand, better market prices, availability of resources, and NGO support could also influence organic banana farming.

The coefficient of multiple determination (R^2) of the model was 0.72 which indicated that about 72% variation in farmers' decision adopting organic banana production can be explained by the independent variables included in the model. The F-value was 42.65 and it was significant at 1 percent level implying that all the independent variables were important for explaining the variation in farmers' decision adopting organic banana production (Table 4).

Impact of adopting organic banana farming on farmer's livelihood

Table 5 and Figure 2 demonstrate the impact of adopting organic banana farming on farmers' livelihood through changes in the capital ownership (i.e., human, social, natural, physical, and financial capitals) of sustainable livelihood framework (DFID, 2000). Changes in capital ownership are discussed as the transformation and improvement of the livelihood of the respondents.

Human capital appears in the generic framework at a household level as a livelihood asset, that is, as a building block or means of achieving livelihood outcomes. The access to human capital for organic banana farmers increased by 67.5% on average after adopting organic banana production, especially training by 75.0%, and knowledge or efficiency by 60.0% (Table 5). In terms of social capital,the self-managerial capability of organic banana farmers decreased by 45.0%, but the social access and involvement in the social group were increased by 72.5% and 45.0%, respectively. There is a wide variation in the resources that make up natural capital, from intangible public goods such as the atmosphere and biodiversity to divisible assets used directly for production (trees, land, etc.).

Overall, access to natural resources by organic banana farmers was mainly unchanged after adopting organic banana production (Table 5). The changing state of physical assets confirmed that the average access of organic banana farmers to physical capital increased by 45.0%, where the access of using radio or television was nearly the same as before but the access of using mobile phones and sanitation increased by 60.0% in the study areas. The access to financial capital for organic banana farmers was also increased. Though the cash in hand increased by 72.5%, cash at the bank or savings was mostly constant. Donation or grant was increased by 70.0% for organic banana farmers. Overall, a remarkable improvement took place in the farmers' livelihood after adopting organic banana production (Figure 2). Manna et al. (2021) and Udin (2014) also confirmed that organic farming could improve farmers' livelihoods through increasing income, food security, and risk mitigation in India.

Conclusion

The study concluded that organically producing banana was profitable and contributed to the livelihood improvement of the farmers in the study areas. To increase organic banana production, a regular and adequate supply of organic fertilizers and insecticides should be ensured to the growers on time at fair prices. Reasonable market prices of organic banana should be ensured by increasing available storage facilities and establishing various food processing industries. Positive steps should be taken to improve the study area's transport and marketing facilities. Farmers adhered to traditional production practices in the study area and had no training on organic banana cultivation. So, extension services should be extended to farmers to accelerate organic banana production. Improved technologies are needed to enable farmers to grow more organic banana on limited land with reduced cost of cultivation. To reduce the use of chemicals in banana production, the study forwarded some important recommendations like, quality seed/sucker production at the farm level, introducing an organic friendly agriculture policy, broadcasting in media the harmful effects of conventional agriculture, strengthening farmers' training at farm level, and participatory research for the promotion of organic banana production.

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Original Research

In vitro regeneration of *Gerbera jamesonii* through callus culture

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ABSTRACT

A high frequency shoot organogenesis and plant establishment protocol has been developed for Gerbera jamesonii from ex vitro leaf derived callus. The optimal callus was developed on Murashige and Skoog (MS) basal medium supplemented with 0.4 mgL^{-1} 6-benzylaminopurine (BAP), 4.0 mg L^{-1} α -naphthalene acetic acid (NAA) and 3% (w/v) sucrose. Two callus types differing in their structures and growth rates were observed. A friable and non-chlorophyllous callus with high growth rate appeared at the cut surfaces of the explant, and a compact chlorophyllous callus. The rate of shoot bud regeneration was positively correlated with the concentration of growth regulators in the nutrient media. The explants were highly responsive (83.3%) in a medium containing 2.0 mg L^{-1}NAA and 1.0 mg L^{-1} BAP after three weeks of callus transfer to a medium. Regenerated plantlets were transferred to soil where they grew normally with a survival rate of 95%. This protocol offers rapid build up of selected clones and opens up prospects for using biotechnological approaches for gerbera regeneration and improvement.

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Introduction

Gerbera (*Gerbera jamesonii*) belongs to sunflower family *Asteraceae* and is a popular ornamental plant with commercial importance used as a decorative garden and container plant, or mostly as cut flowers. Gerbera has gained popularity in the past few years in many countries of the world and it is in great demand in the floral industry as cut flower as well as potted plant due to its attractive color, long vase life, and ability to rehydrate after long transportation. The most commercial cultivars are propagated through vegetative means by multiplication through divisions of clumps; however, the multiplication by this method is too slow to be commercially viable.

To commercialize this crop and to meet the growing demand for planting material, tissue and organ culture techniques are being used as alternative methods for propagation in many countries. Most of the work has been carried on plant regeneration by adventitious organogenesis from capitulum, shoot tip, leaf, petiole and other parts of the plant.

Because of genetic variability within the *Gerbera* genus is limited, the breeding potential for new flower colors and patterns such as resistance to biotic or abiotic stresses is also limited. However, cultivar improvement for these and other traits through genetic transformation looks promising. Elooma et al. (1993) used

Agrobacterium tumiefaciens mediated transformation to introduce an antisense gene for chalcone synthase into 'Terra Regina'. Nowak et al. (1997) introduced the Gus and NPTII marker genes into five gerbera cultivars.

In the previous work, adventitious gerbera shoots were generated primarily from shoot tips, flower buds of greenhouse grown plants, the pith of rhizome, *in vitro* leaves and *in vitro* petioles. One necessary pre-requisite for obtaining genetically transformed plants is an effective and reliable protocol for long-term regeneration from single cells. Callus establishment and regeneration of shoots were reported by Ruffoni and Massabo (1991) in shoot tip, Miyoshi and Asakura (1996) from the ovule, Orlikowska et al. (1999) from in vitro petioles, Huang et al. (2001) from the shoot tip, stem and in vitro petiole. They found frequent browning of the media with slow and unstable regeneration in few cultivars. However, there has so far been no report on callus regeneration and subsequent recovery of the plants from *ex vitro* leaves. For successful transformation, it is important that regeneration be maintained over a relatively long period, in which organogenetic calli are first produced from single transformed cells, after which shoots can be regenerated from the calli. In the gerbera, directly regenerated shoots were either not transformed or not stably transformed (Orlikowska and Nowak, 1997). Therefore, the use of an effective long-term protocol for indirect regeneration would increases the chances of obtaining transgenic gerbera plants. This work documents the effects of growth regulators and long term shoot regeneration from the calli obtained from ex vitro leaves of two gerbera cultivars.

Objective of the study

The objective of the study was to develop an appropriate protocol for in vitro micropropagation of *Gerbera jamesonii* and its field level establishment in specific Barind environmental condition.

Materials and methods

Plant material

Tissue culture plants of *Gerbera Jamesonii Souvenir* (GJS) and *Gerbera Jamesonii Transvaal Daisy* (GJTD) were obtained from Jhikargacha, Jashore. These plants were grown under polyhouse in farmer's field. GJS is a cut flower variety which produces flowers with long stalks of 60 cm and a flower diameter of 13 cm, whereas GJTD is a dwarf potted variety, produces a 40 cm flower stalk and has a flower diameter of 9.0 cm. The explants size 5.0 mm x 5.0 mm, were cut transversely to the mid rib from mature leaves (3rd leaf from top). They were washed thoroughly with water for 15 minutes, disinfected with 70% ethanol for 40s, and surface sterilized with filtered 0.1% mercuric chloride. After 10 minutes, explants were rinsed three times with sterilized distilled water, blotted on sterile filter paper and 15 explants were plated with adoxial surface in contact with the medium (25ml) in 100-mm petri dishes.

Culture media and experimental conditions

Callus were regenerated on Murashige and Skoog (1962) MS basal medium supplemented with 3% sucrose, 1% agar agar and different concentrations (0, 0.2, 0.4, 1.0 and 4.0 mg L^{-1}) of α–naphthalene acetic acid (NAA) and 6-benzylaminopurine (BAP). The culture media were adjusted to pH 5.7 and sterilized at 121°C for 15-20 minutes. After the positioning of the explants, the petri dishes were sealed with para film to minimize water loss. The cultures were maintained at 23°C under 60 µmol m^{-2} s^{-1} fluorescent illumination with a 16 hour photoperiod.

After four weeks, the initiated calluses were placed on MS medium supplemented with different concentrations (0, 1, 2 and 4 mg L^{-1}) of NAA and BAP for initiation and proliferation of shoots. Shoot cultures were raised in culture tubes (1.5 cm diameter x 15 cm length) containing 10 ml medium. After eight weeks the shoot height was measured (from the base to the highest point of the upper leaf) and then transferred to NAA, IAA or hormone-free normal MS medium for rooting.

Table 1. Initiation frequency and compact calluses from ex vitro leaves of gerbera on MS medium with NAA and BAP.

Growth hormones (mg/L)		Initiation frequency of calluses (%)*					
		Av101			AV108		
NAA	BAP	Total calluses	Friable calluses	Compact calluses	Total calluses	Friable calluses	Compact calluses
0	0 to 4	0	0	0	0	0	0
0.2	0	0	0	0	0	0	0
0.2	0.2	2.7	2.7	0	3.1	1.5	1.6
0.2	0.4	5.4	5.4	0	6.6	4.8	1.8
0.2	1.0	16.2	13.5	2.7	15.6	12.5	3.1
0.2	4.0	15.3	12.2	4.1	15.4	9.1	6.3
0.4	0	0	0	0	0	0	0
0.4	0.2	28.4	21.6	6.8	26.6	18.1	8.5
0.4	0.4	25.7	18.9	6.8	23.9	15.2	8.7
0.4	1.0	16.3	12.2	4.1	15.4	9.3	6.1
0.4	4.0	8.1	8.1	0	9.9	7.6	2.3
1.0	0	0	0	0	0	0	0
1.0	0.2	58.1	33.8	15.2	53.7	28.1	25.6
1.0	0.4	50	31.1	18.9	56.9	28.6	28.3
1.0	1.0	28.4	20.3	8.1	38.7	20.3	28.3
1.0	4.0	14.9	14.9	0	17.2	12.0	18.4
1.0	4.0	14.9	14.9	0	17.2	12.0	5.2
4.0	0	0	0	0	0	0	0
4.0	0.2	60.8	40.5	20.3	63.5	33.2	30.3
4.0	0.4	94.6	60.8	33.8	95.0	57.2	37.8
4.0	1.0	43.2	31.1	12.1	52.3	29.7	22.6
4.0	4	4.1	4.1	0	16.4	12.1	4.3

*Data represents mean of 20 replications/treatment: repeated three times.

Transfer to soil

Agar was carefully washed from the regenerated plantlets with well-established root system before transfer to the pots (15 cm) filled with a mixture of cocopeat and compost (1:1 v/v). Plantlets were maintained under high relative humidity (80 ± 10%) for 3 weeks. Acclimatized plants were kept under a natural photoperiod and a temperature of 24 ± 2 °C.

Observation of cultures

Twenty petri dishes/tubes were used per treatment and each experiment was repeated three times. All cultures were examined periodically and visual observations of any morphological changes were recorded. The data pertaining to the percentages of cultures responding to callusing, percentage of organogenetic calluses per culture, mean number of shoot bud/ culture, mean percentage of rooting and number of roots/ shoot were statistically analyzed by the post-Hoc Duncan's multiple range test (Marascuilo & McSweeney, 1977). The average figures followed by the same letter were not significantly different at $p < 0.05$ levels.

Results and discussion

The classical findings of Skoog and Miller (1957) reported that organogenesis in tissue culture governed by the balance of auxin and cytokinin in the medium cannot be demonstrated universally due to the explant sensitivity or the original content of the endogenous growth regulators. It is strongly advocated here that such reports constitute a basic work for a more complete characterization of callus induction and early organogenesis. The development processes of gerbera callus required both cytokinins and auxins. No callus was induced when explants were cultured on BAP or NAA free medium (zero/ normal MS). Callus formation from explants was observed 3 weeks after culture initiation in the cut edges of the explants (Figure 4). The frequency of callus formation is shown in Table 1. The frequency of callus induction reached 60–95% at high concentrations of NAA and low concentrations of BAP. Two callus types differing in their structures and growth rates were observed. Afriable and non- chlorophyllous callus (Figure 1) with high growth rate appeared at the cut surfaces of the explant and a compact chlorophyllous callus (Figure 2) with low growth rate was formed directly from whole explants. Only this second type of callus contained adventitious shoot primordia. However, such cultures showing initial stages of differentiation did not develop further on the same medium. Fewer compact calluses than friable calluses were initiated on all the media. A high frequency of callus initiation was obtained only in the MS medium supplemented with 1 or 4 mg L^{-1} NAA; the highest callus initiation was obtained after culture in MS medium with 4 mg L^{-1} NAA and 0.4 mg L^{-1} BAP (95%). Direct formation of short shoots was observed in this medium at low frequency (3%). Total growth of the callus did not vary with different cultivars; however, the type of callus varied with the cultivars.

The cv. GJS produced more friable non-chlorophyllous callus and a less compact chlorophyllous callus than GJTD. The results of this study agreed with those of Pierik and Segers (1973), showing that the induction of callus-formation by cytokinin was promoted by the addition of an auxin, especially by indole–3 butric acid, the most effective cytokinin being BAP. Further it is also supported by Huang et al. (2001) where they found MS+BA 1.0 mg L^{-1} + IBA 0.05 mg L^{-1} was suitable for the induction of callus from shoot tip, stem and petiole.

Other than this, different types of callus like a high thickness with a cluster of 15-20 cells, very high thickness and clusters of medium size 30-50 cells, high thickness with clusters of medium size of 15 cells and single cells; medium thickness with big clusters of more than 50 cells were observed in different treatments (data not shown), however, their frequency was low. Ruffoni and Massabo (1991) also observed this type of different calli in suspension cultures of gerbera with growth hormones like BAP, 2ip, 2, 4-D, pCPA and IBA.

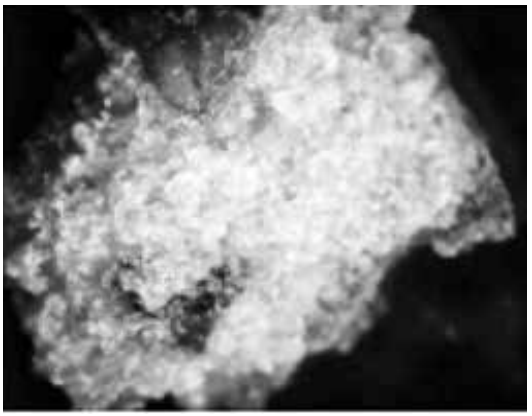

Figure 1. A friable and non-chlorophyllous callus.

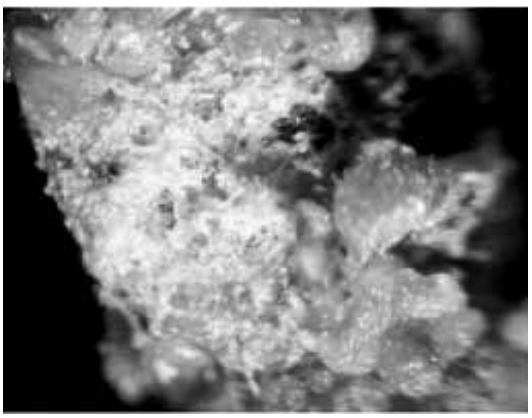

Figure 2. A compact and chlorophyllous callus.

Table 2. Formation, multiplication rate and height of shoot formed from compact calluses of gerbera.

Growth hormones (mg/L)		**Shoot characteristics***					
		Shoot frequency (%)		Number of shoots/callus		Shoot height (cm)	
NAA	BAP	AV101	AV108	AV101	AV108	AV101	AV108
0	0	0	0	0	0	0	0
0	1	12.5 a	15.3 a	1 ± 0.3 a	2.1 ± 0.2a	0.5 ± 0.1a	0.35 ± 0.1a
0	2	12.5 a	17.6 a	1 ± 0.3 a	1.4 ± 0.1a	0.75 ± 0.2a	0.4 ± 0.1a
0	4	12.5 a	23.1 a	1 ± 0.2 a	2.3 ± 0.2a	0.6 ± 0.1a	0.5 ± 0.1a
1	0	0	0	0	0	0	0
1	1	41.7 e	41.7 d	5.1 ± 0.7c	3.2 ± 0.2b	4.5 ± 0.3c	3.1 ± 0.2c
1	2	29.1 d	49.1 e	3.9 ± 0.7 b	5.1 ± 0.3c	4.1 ± 0.7c	2.1 ± 0.2b
1	4	16.7 b	26.7 b	1.6 ± 0.6 a	4.1 ± 0.2c	3.2 ± 0.4b	2.0 ± 0.1b
2	0	0	0	0	0	0	0
2	1	83.3 h	63.1 f	9.9 ± .0.1 e	11.1 ± 0.9e	4.9 ± 0.6c	2.1 ± 0.1b
2	2	66.7 g	60.2 f	7.5 ± 1 d	14.3 ± 0.5e	3.7 ± 0.4c	2.7 ± 0.2c
2	4	58.3 f	63.3 f	5.9 ± 0.8 c	7.2 ± 0.3d	3.7 ± 0.6c	2.9 ± 0.2c
4	0	0	0	0	0	0	0
4	1	12.5 a	41.5 d	2 ± 0.7 a	4.0 ± 0.2c	1 ± 0.3a	1.5 ± 0.1b
4	2	20.8 c	36.0 c	2.8 ± 0.5 b	6.0 ± 0.3d	2.1 ± 0.3d	1.7 ± 0.2b
4	4	33.3 d	37.2 c	2.6 ± 0.7 b	3.5 ± 0.2b	2.5 ± 0.3b	1.2 ± 0.1b

*Data represents mean of 20 replications per treatment: repeated three times.

To induce shoot formation the compact callus obtained after culture in MS medium with 4.0 mg L^{-1} NAA and 0.4 mg L^{-1} BAP was transferred to MS media with different concentrations of NAA and BAP. The frequency of shoot formation and the numbers and heights of developed shoots are given in Table 2. Shoots appeared to develop directly from adventitious primordia already formed in the compact callus.

A mean having the same letter in a column were not significantly different by Post- Hoc Multiple Comparison test $p < 0.005$ level.

The media containing only BAP induced translucent short shoots with a lower frequency. With up to 2 mg L^{-1} NAA in the medium, BAP had a negative effect on shoot development, multiplication rate and the height of the shoots. In contrast, increasing the BAP concentration in the medium had a positive effect when combined with a high NAA concentration (4 mg L^{-1}). Jerzy and Lubomski (1991) observed the highest number of shoots from 8–11 on medium with 10 mg L^{-1} BAP from in vitro leaf, but the shoots were frail, concise and showed vitrification symptoms. On a medium with lower levels of BA (1 and 2 mg L^{-1}) they observed one to three shoots. Barbosa et al. (1993) reported the establishment of shoots in vitro from a young capitulum in 3.0 mg L^{-1} BAP, while, Henrique et al. (1994) got the best results from a capitulum at 3.0 and 9.0 mg L^{-1} BAP. However, in contrast to these studies Vardja and Vardja (2001) observed the tendency of vitrified shoots in high concentrations of BAP and recommended not using BAP in gerbera multiplication. The highest percentage of multiple shoot formation (83%) occurred three weeks after GJS callus transfer on a medium with 2.0 mg L^{-1} NAA and 1.0 mg L^{-1} BAP (Figure 5). After four weeks of culture, a complex mass of multiple shoots was formed. After eight weeks the shoots, when separated from the callus and transferred to the same medium, multiplied more rapidly and the cycle was repeatable.

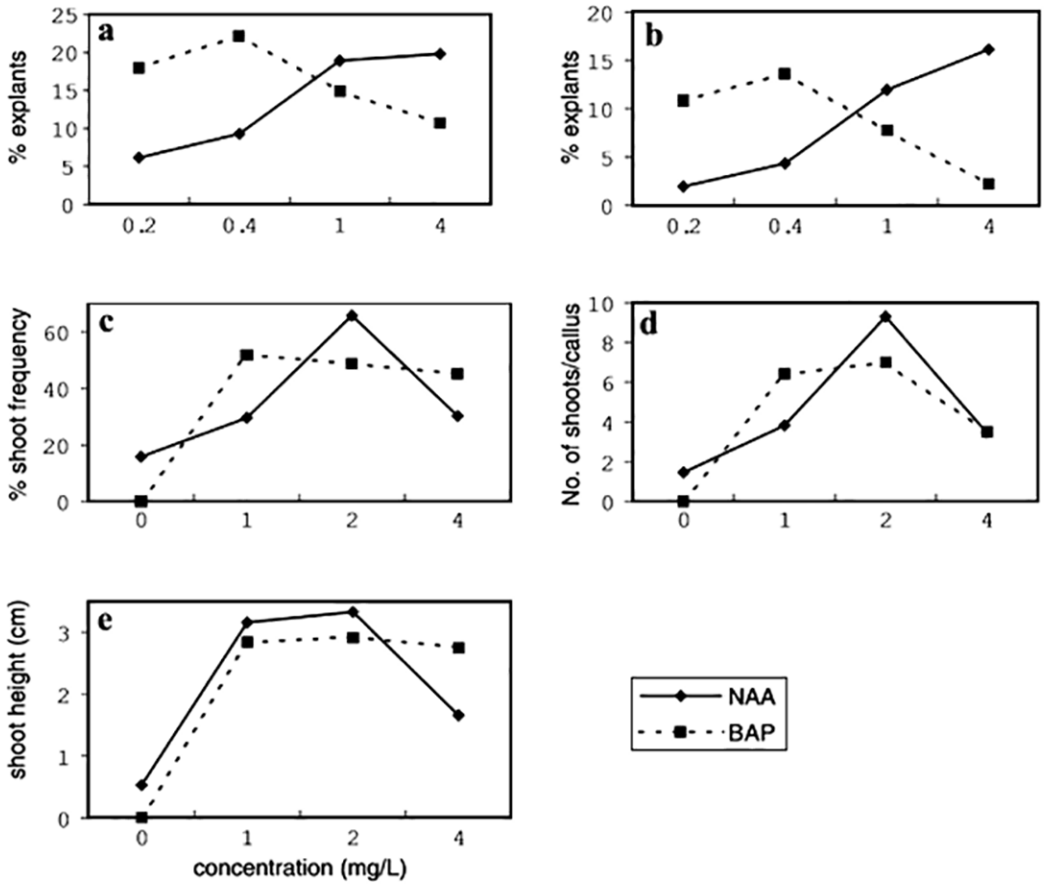

Figure 3. Cumulative effect of NAA and BAP on induction of friable callus (a), compact callus (b), shoots frequency from callus (c), number of shoots/callus (d), shoot height from callus (e).

No appreciable difference in the shoot multiplication rate was observed during several repeated cycles. No shoot development was obtained from the friable callus. Blakesley and Lenton (1987) reported that cytokinins were usually added to tissue culture media to stimulate axillary or adventitious shoot development. The type and concentration of cytokinin had profound effects on shoot multiplication. Rates of multiplication of gerbera shoots in vitro are much slower in the presence of natural zeatin (Z) than the synthetic cytokinin (BAP). These differences in growth response may be related to the rate of metabolism of zeatin and BAP observed in callus cultures. The highest regeneration ability rate of 83.3 and 63.3% was obtained in GJS and GJTD, respectively.

The number of shoots regenerated per explant was highest for cv. GJTD, ranging from 1 to 14.3 shoots while regeneration was lower for cultivar GJS with 1 to 10.6 shoots per explant; this difference may be due to the high production

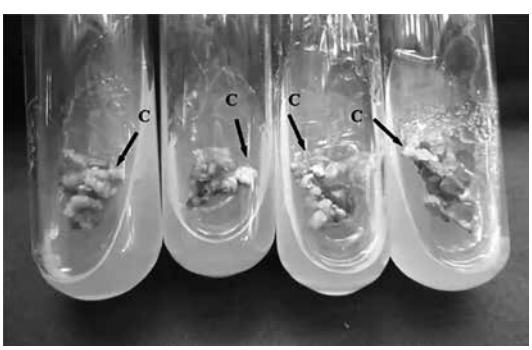

Figure 4. Growing callus (c) from the cut area of leaf/ leaves explants.

Table 3. Rooting from multiple shoots of gerbera (After how many weeks?)

Growth hormones (mg/L)	Characteristics of plantlets*			
	Average number of roots/shoot		Shoot height (cm)	
	AV101	AV108	AV101	AV108
0	1.3	1.3	3.8± 0.6	2.9± 0.4
NAA 1	3.6	4.1	5.6± 0.3	3.3± 0.3
2	3.8	3.9	6.8± 0.3	4.5± 0.4
3	4.8	3.8	4.2± 0.4	6.2± 0.3
4	4.0	4.2	4.1± 0.3	4.1± 0.3
IAA 1	4.1	4.3	3.9± 0.3	3.1± 0.4
2	4.8	4.9	4.2± 0.2	3.5± 0.2
3	5.2	6.1	6.2± 0.4	4.3± 0.2
4	5.1	4.2	4.1± 0.1	4.1± 0.1

* Data represents mean of 20 replications per treatment in three repeated experiments.

of compact chlorophyllous callus by cv. GJTD. Overall shoot height was more in GJS than in GJTD. The difference in multiplication rate and shoot height may be related to the dwarf genetic nature of the cultivar GJTD. The results of this study agreed with those of Jerzy and Lubomski (1991), Reynoird et al. (1993) and Orlikowska et al. (1999) showing that gerbera regeneration ability is genotype-dependent. Although different cultivars showed varying results, the method followed in this study was effective for these two cultivars.

The effect of NAA or BAP on callus induction was pooled and plotted in graphical form (Figures 3a & 3b). The performance of callus cultures initiated and maintained on medium supplemented with NAA and BAP showed different responses. The concentration of NAA had a profound effect on both friable and compact callus, and as the concentration increased, the amount of callus also increased (Figures 3a & 3b). This is the first report in which NAA was used for the induction of callus in gerbera leaves. However, a reverse trend was observed in case of BAP. As the concentration of BAP increased the amount of friable and compact callus decreased and was found to be lethal at 4.0 mg L^{-1} (Figures 3a & 3b). Huang et al. (2001) in shoot tip and Orilkowska et al. (1999) in petioles also found a low concentration of BAP (1.0 mg L^{-1}) with IBA and IAA, respectively, was best for shoot proliferation. The effect of NAA or BAP on

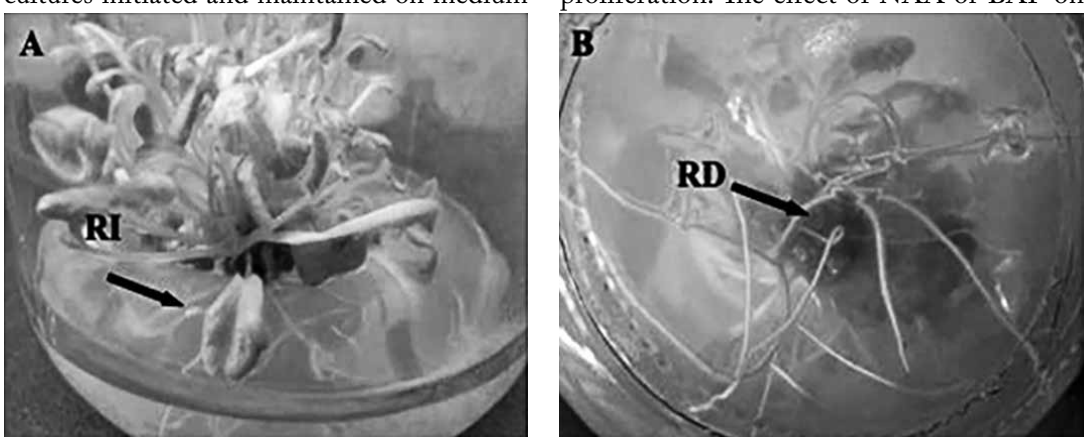

Figure 5. Multiple shoots with root formation from callus.

Figure 6. Rooted plantlet free from agar agar.

shoot proliferation was pooled and plotted in graphical form (Figures 3c, 3d & 3e). When BAP was used as the sole growth regulator in the culture medium without the interaction of NAA, a limited shoot proliferation were observed in few explants, while NAA alone as the sole growth hormone did not initiate any shoot proliferation. Shoot frequency, the number of shoot/callus and shoot height was highest in 2.0 mg L^{-1} NAA and the number of shoots decreased when the level of NAA was increased from 2.0 to 4.0 mg L^{-1}.

To induce rooting, individual shoots from a multiple shoot complex originated from the callus were separated after eight weeks of shoot initiation and transferred to MS medium free of hormones or containing only NAA and IAA (Table 3). In both IAA and NAA the frequency of rooting was 100%. In all media, the first roots appeared after 1–2 weeks of culture and after 4–5 weeks, the root system was well developed. On medium without NAA and IAA, we observed the initiation of single root with secondary root formation, whereas in media with NAA and IAA the formation of multiple adventitious roots without secondary roots was observed. IAA was slightly better than NAA in inducing roots in both the cultivars. Even though we observed the difference in shoot height between cultivars there was no difference found as far as root number is concerned. The greatest shoot height (about 6.8 cm) was observed on medium with 2 mg L^{-1} NAA. Barbosa et al. (1992) also found a better root system in gerbera sprouts at all levels of IAA (0.5, 1.0, 2.0 and 4.0 mg L^{-1}) (Figure 6).

After four weeks of culture, the whole plants obtained were removed from the medium,

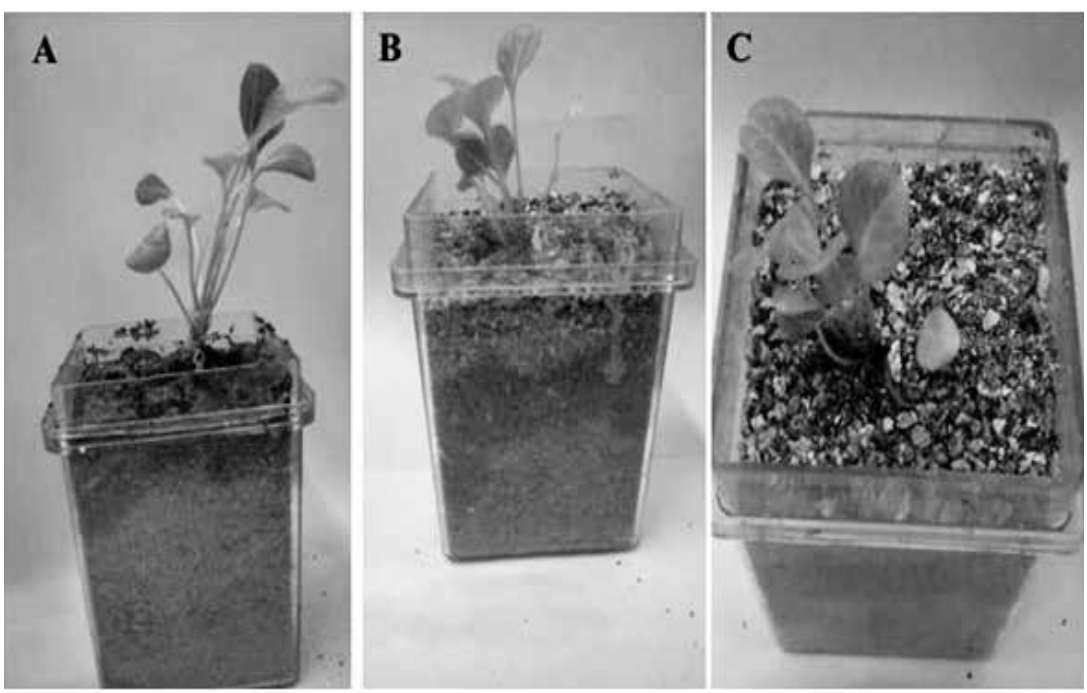

Figure 7. Plantlets transferred to the soil.

transferred to soil, acclimatized for three weeks and subsequently cultivated in a glass house (Figure 7). The success rate of this transplantation was 95%. After three months, rooted shoots had grown to a height of more than 20 cm. We observed no difference in any of the phenotypic characters including flowering among regenerated plants in either of the cultivars.

Adventitious shoot formation in gerbera was reported by Hedtrich (1979). Using in vitro techniques she obtained a small number of adventitious shoots from the leaf blades of only one cultivar. Jerzy and Lubomski (1991) initiated shoot regeneration from petiole and there is a tendency of in vitro petioles to form vitrified shoots at a higher concentration of BAP; in addition, there is a possibility of getting only one to three shoots at a lower concentration. The capability of gerbera ex vitro leaf explants to regenerate 9-11 shoots at a lower concentration of growth hormones in the present paper is the first report, and the method seems to be more effective in inducing non-vitrified shoots.

Conclusion

The present experiment has shown that ex vitro leaves are able to give a callus. From this callus, healthy plants developed, with a high survival rates when transplanted. The protocol is simple, easy to carry out and can produce large number of plants for transformation or mutagenesis or for mass propagation. However, the risk of somaclonal variation should be ascertained before using it form as spropagation. This ability also opens up the prospects of using biotechnological approaches for gerbera improvement.

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Original Research

Household calorie intake and food expenditure relationship: A case in rural Liberia

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ABSTRACT

The food security of households was threatened severely by low agricultural production, global rice price volatility along with international trade disruption as a result of the outbreak of Ebola in 2014 in Liberia. Moreover, decades of war and low investments ravaged Liberia's productive assets. The entire situation negatively impacted the food security and threatened household food consumption expenditure leading to malnutrition and hunger among households. The government intended to study the household's expenditure capability in relation to low calorie intake in order to get important policy inputs. Cross-sectional data of 1,171 households were collected from the Liberia 2014 Household Income and Expenditure Survey (LHIES) and were analyzed by Two-Stage Least Squares (2SLS) regression model. The study finds that a 2% increase in calorie intake was possible if household monthly expenditure increased by 10% on an average. The people having non-farm business had 13% higher calorie intake in a month than the people having no non-farm business. The results are important for the government to know the cost of food or cash transfer policy to deal with the issue. The results are also suggestive of promoting non-farm business, agricultural development as a whole and income generating opportunities for the rural people.

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Introduction

Liberia is a food insecure country. A burning issue is whether the households have the ability to spend for the food so as to provide required calorie intake. The staple food crops of Liberia are cassava and rice. The households engaged in farming live from hand to mouth and their sustenance heavily depends on cassava and rice production. The demand for the staple food has increased manifold due to low agricultural productivity. More than 60% population depends on agriculture and forestry for primary livelihood. Most of the farmers are engaged in cassava production. Since the production of food crop is low, the country is to import 80% of its rice requirement. Consequently, Liberia has been vulnerable to the instability of food price in the world market. Per capita calorie intake declined 18% in a 20 year period between 1980 and 2000. Access to food was getting worse and the cost

of food was rising. Liberia like other developing countries continues to face persistent challenges in producing its staple food and maintain a stable supply of food for the growing population. Hence food security in Liberia should be considered in the forefront of future development strategy (Tefft, 2005).

The food security of households was threatened severely by low production, global rice price volatility along with international trade disruption as a result of the outbreak of Ebola in 2014. Moreover, decades of war and low investments ravaged Liberia's productive assets.

The post war economic constraints together with the outbreak of Ebola Virus Disease in 2014 negatively impacted the food security and threatened household food consumption expenditure leading to malnutrition and hunger among households. Calorie intake is the main determinant of malnutrition among the people. It is needed for the growth and assimilation of micronutrients among children. Inadequate supply of calorie lowers productivity, hinders learning and increases the risk of diseases (Aromolaran, 2004).

The importance of calorie intake coupled with the concern about undernourishment in developing countries has led to increasing number of studies on the determinants of calorie intake. More prominent in the empirical studies is the relationship between income and calorie intake (Abdulai & Aubert, 2004). An increase in child food intake and child nutrition will lead to an increase in labor supply and household food consumption (Fitzsimons et al., 2016). If participation of the poor in economic growth is less than the rest of the population, their nutritional status is likely to suffer proportionally more (Knudsen & Scandizzo, 1982).

Against this background, an important policy input as to the people's health and nutrition could be to investigate the relationship between household food expenditure and household calorie intake. The study assumes a positive linear relationship between household food expenditure and calorie intake and deals the question: with increase or decrease in household food expenditure, what happens to household calorie intake? To overcome the probable long term negative effect on malnutrition and labour supply in rural Liberia, the government intends to study the relationship between household food expenditure and household calorie intake.

Rationale of the study

In Liberia, rural areas were stricken with food insecurity with 60.3% of households having food deficiency. The problem was highly associated with low agricultural productivity, global rice price volatility and outbreak of Ebola in the year of 2014. The food price increased on the one hand and the household's income reduced on the other. Consequently, household's food expenditure capability reduced significantly. For the policy makers, a key policy input was to explore the relationship between household's food expenditure and household's calorie intake. This study attempts to capture the rural picture in South Eastern B, one of the six regions in Liberia. South Eastern B suffered from the highest poverty level estimated at 78.9%. The findings might add insights to policy studies. The government can have the direction as to policy formulation in relevant areas.

Objectives of the study

The study aims at finding out the relationship between household food expenditure and household calorie intake and to explain the variable household calorie intake in relation to other predictor variables.

Data collection

The data used in this study is a cross-sectional data of 1,171 households derived from the Liberia 2014 Household Income and Expenditure Survey (LHIES). Liberia is geographically divided into six regions. One of them is South Eastern B consisting of Rivergee, Grand Kru and Maryland countries. The study focuses on rural areas of South Eastern B region. Localities with a population less than 2,000 are classified as rural. Besides, regardless of population size, county capitals and some important towns are not classified as rural.

The data were collected randomly from LHIES for the following variables:

- Household calorie intake (monthly): This was counted following FAO method;
- Food consumption expenditure;
- Size of household: Each household size has been counted by adult equivalence scale as per the FAO method;
- Education of household head: This was measured by years of education completed by household head;
- Age of household head;
- Gender of household head: 1 = male and 0 = female; and
- Ownership of non-farm business: 1 = engaged and 0 = not engaged

Identification strategy

The study deals with household as unit of analysis. The data were analyzed by Two-Stage Least Squares (2SLS) regression model. The following is the original regression equation.

$Y_{lci} = \beta_o + X\beta_{1fex} + X\beta_{2ehh} + X\beta_{3ahh} + X\beta_{4nfbo} + X\beta_{5g} + \varepsilon$

$Y_{lc\,i\,(}$dependent variable) = log of household calorie intake (monthly)

$X\beta_{1fex}$ (independent variable) = log of household food consumption expenditure in Liberian Dollar (monthly)

$X\beta_{2ehh}$ (predictor variable) = education of household head

$X\beta_{3ahh}$ (predictor variable) = age of household head

$X\beta_{4nfbo}$ (predictor variable) = ownership of non-farm business

$X\beta_{5g}$ (predictor variable) = gender of household head and

ε = random error term

Since the variable, log of household food consumption expenditure, is assumed to suffer from endogeneity problem, the size of household was used as the instrument variable. The first stage and second stage regression equations are as follows:

$X\beta_{1fex} = \beta_o + X\beta_{1hhsize} + X\beta_{2ehh} + X\beta_{3ahh} + X\beta_{4nfbo} + X\beta_{5g} + X\beta_{6pr} + \varepsilon$ ---------- (1)

$Y_{lci} = \beta_o + X\beta_{1fex} + X\beta_{2ehh} + X\beta_{3ahh} + X\beta_{4nfbo} + X\beta_{5g} + X\beta_{6pr} + \varepsilon$ ---------- (2)

$X\beta_{1hhsize}$ in equation—1 was used as instrumental variable and $X\beta_{1fex}$ was regressed on $X\beta_{1hhsize.}$

From stage one and predicted $X\beta_{1fex}$ had been used in equation—2.

Summary statistics

Table 1 presents summary statistics of the study variables. There are seven variables, of which the first two are log transformed. The mean of household calorie intake (monthly), household food consumption expenditure (monthly), household size and education of household head are 5,837.43 kcal, 5,555 Liberian Dollars, 3.28 and 11.24 respectively.

Table 1. Summary statistics of the variables.

Name of variable	Obs	Mean	Std. Dev.	Min	Max
Household calorie intake (monthly)	1,171	200760	512.97	134034	275054
Household food consumption expenditure (monthly)	1,171	8752	319.23	6450	11860
Age of household head	1,171	46.63	11.60	18	81
Education of household head	1,171	11.24	3.63	4	20
Ownership of non-farm business	1,171	0.46	0.50	0	1
Household size	1,171	3.57	1.28	2.23	4.3
Gender of household head	1,171	0.90	0.30	0	1

Results and discussions

To explore the relationship between the log of household calorie intake and household food expenditure, household calorie intake was regressed on the log of household food consumption expenditure in the original regression equation. The results show that there is positive relationship between calorie intake and household food consumption expenditure as indicated by the coefficient of household food consumption expenditure (Table 2).

The result is statistically significant at 1.0 percent significance level and shows that an increase in household food consumption expenditure by 10 percent will increase per capita daily calorie intake by 1.7% percent (Table 2). However, the value of coefficient (0.183) is either underestimated or overestimated due to suspected reverse causation between household calorie intake and household food consumption expenditure. The coefficient is a biased estimation, if this is the case. To address the problem, 2SLS regression model was applied. To confirm about the endogeneity and to know that the result as estimated by Ordinary Least Square is not consistent, augmented regression was performed by including the residuals of each endogenous right-hand side variable, as a function of all exogenous variables (Cong, 2021). The small p value of Residual_ log of household food consumption expenditure in Table-3 indicates that the Ordinary Least Square is inconsistent.

First-stage summary statistics in Table-4 also shows the F test result (36.652) which is higher than any critical value. The result, therefore, confirms the existence of endogeneity. Finally, Durbin (score) chi2 (1) = 0.220984 (p = 0.0123) and Wu-Hausman F (1, 34) = 0.184248 (p = 0.0015) tests substantiate the endogeneity problem.

Since the two step procedure as explained in identification strategy will not provide the exact standard error, one step test was performed (ivregress in Stata package). The result has been presented in Table 5. The table shows that two variables—log of household monthly expenditure and ownership of non-farm business—have positive impact on household calorie intake with statistical significance ($p<0.01$).

The coefficient of log of household food expenditure is 0.217. Since both the variables (household expenditure and calorie intake) are log transformed, the interpretation is: We expect a 2.1% increase in calorie intake when household monthly expenditure increases by 10%. For the ownership in non-farm business variable, the people engaged in non-farm business have 13% higher calorie intake in a month than the people not engaged in non-farm business. Other variables are not found to be statistically significant.

Table 2. Results of original regression.

Variables	Household calorie intake
Household food consumption expenditure	0.183*** (0.0195)
Age of household head	0.0014 (0.0008)
Education of household head	0.0012 (0.0026)
Ownership of non-farm business	0.137*** (0.0026)
Gender of household head	0.0342 (0.0311)
Household size	0.0213 (0.0675)
Constant	4.987*** (0.001)
Observations	1,171
R-squared	0.567

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, $(1.10)^{0.183} = 1.0208$

Table 3. Results of second stage regression.

Variables	Household calorie intake
Log of household food consumption expenditure	0.213*** (0.0018)
Residual_ log of household food consumption expenditure	0.0041*** (0.0021)
Age of household head	0.0011 (0.0008)
Education of household head	0.0012 (0.0025)
Ownership of non-farm business	0.129*** (0.0235)
Gender of household head	0.0351 (0.0281)
Constant	5.637*** (0.000)
Observations	1,171
R-squared	0.63

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, *

Table 4. First-stage regression summary statistics.

Critical values # of endogenous regressors: 1
Ho: Instruments are weak # of excluded instruments: 1

	Adjusted		Partial		
Variable	R-sq.	R-sq.	R-sq.	F (1, 35)	Prob > F
Household food expenditure	0.4402	0.3602	0.1597	36.65265	0.0143

Percentage	5%	10%	20%	30%
2SLS relative bias	-	-	-	-
Percentage	10%	15%	20%	25%
2SLS size of nominal 5% Wald test	16.38	12.96	9.66	5.53
LIML size of nominal 5% Wald test	16.38	12.96	9.66	5.53

Table 5. Results of one step test.

Variables	Log of household calorie intake
Log of household food consumption expenditure	0.213*** (0.0028)
Age of household head	0.0016 (0.0019)
Education of household head	0.0013 (0.0034)
Ownership of non-farm business	0.129*** (0.0266)
Gender of household head	0.0351 (0.0396)
Constant	5.637*** (0.000)
Observations	1,171
R-square	0.63

Note: the robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Conclusion

The production of rice and cassava in rural Liberia was too much lower than usual in 2014. On the other hand, the price of main food soared up due to international trade disruption as a result of Ebola outbreak. The people were getting undernourished. The government was apprehensive of sudden contextual threat coupled with underdeveloped agricultural sector. Low calorie intake causes malnutrition, which in turn negatively affects labour supply and results in inter generational poverty. To address the problem, the government intended to find out people's expenditure ability for the food in relation to calorie intake. The study finds that a 2% increase in calorie intake is possible if household monthly expenditure increases by 10% on an average. The people having non-farm business have 13% higher calorie intake in a month than the people having no non-farm business. The study results are important policy inputs to determine how costly it is for the government to deal with the issue by food or cash transfer. The results are also suggestive of promoting non-farm business, agricultural development as a whole and income generating scopes for the rural people.

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Original Research

Financial diagnosis of selected jute companies in Bangladesh

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ABSTRACT

Jute is well regarded as one of Bangladesh's most significant agricultural, economic, and industrial sectors. It is also an integral part of Bengali history & culture. Unfortunately, this industry is now a days at a standstill caused by repeated losses every year. The focus of this paper is to delve into the financial performance of the selected jute companies listed on the Security Exchange Commission. This study is based on a 10-year ratio study and statistical analysis as well as necessary information from the annual report. Liquidity, profitability, and solvency analysis have been worked out for univariate analysis. Pairwise mean test ratio and correlation matrix have also been used in bivariate analysis to determine the magnitude of association. The financial stability of both the selected companies has exhibited a sluggish trend. Consequently,the financial stability of these jute companies is jeopardized. Different financial indicators are used by businesses to measure their financial status. Firms' liquidity, profitability, solvency, and other indicators have been looked into to provide some financial insights to stakeholders. Concerned authorities must move immediately to address the situation to resolve the issue and thus contribute to the better position of the jute industry. This paper can be a tool for the management of these companies to enhance their economic structure.

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Introduction

Jute, commonly known as 'Golden Fiber', is a significant asset of Bangladesh with a delightful past and an impressive future for Bangladesh. Bangladeshi scientists have effectively mapped the DNA of the jute plant, paving the way for new varieties of the world's most used biodegradable natural fiber (Ahmed, 2010). According to Jahan (2019), when considering jute's environmental, economic and social contributions, it is worth noting that jute plays a significant role in attaining sustainable development.

According to Iqbal (2013), Bangladesh produced approximately 80% of the world's jute until the 1960s, making it the most significant contributor to foreign exchange earnings. Following the liberation war, the Government of Bangladesh acquired control of all the 73 jute mills and formed Bangladesh Jute Mills Corporation (BJMC) to oversee them. The government initially provided Tk. 200 million cash subsidy to the BJMC, which was reduced gradually until it began to profit in 1979-1980; thus, cash support was withdrawn.

Uddin et al. (2014) stated that the glorious days of jute faded significantly due to a variety

of factors, including regular price fluctuation, increased demand for synthetic products, mismanagement, pilferage, managerial vacuum, and other shameless activities rampant in the jute industry, like other sectors of the economy. However, the ability to decode the jute genome sequence is promising a new day. People are becoming more environmentally conscious, and different organizations are working for a better environment,using eco-friendly, biodegradable, and renewable products. Therefore, the market for jute products is growing every day. The key factors for strengthening this sector are professional knowledge, thoughts, innovative ideas, and the discovery of jute, hi-tech equipment DNA.

A financial statement deals with lots of numbers and figures. Financial performance analysis provides a sense of the financial statements so that stakeholders can make decisions. Clausen (2009) used ratio analysis to measure a company's performance. He showed the company's performance in terms of profit compared to sales and assets to make revenue. Investors may feel reluctant to invest when they find ratios indicate poor performance. Financial statements contain a great deal of information that can provide mutual understanding about the firm's activities and performance if adequately examined and interpreted. Trade creditors confine their analysis to the firm's liquidity position. Suppliers analyze the firm's profitability over time and are thus concerned with the firm's solvency and sustainability. Long-term creditors consider the firm's solvency and profitability. The investors emphasize the firm's ability to accelerate profit so that they can visualize what is going or what may happen next (Sina & Matubber, 1998).

The economy of Bangladesh is expanding day by day. The number of public limited companies in the country increases with economic development. Jute is one of the most decisive sectors for the Bangladesh economy. There are only three listed jute companies in Dhaka Stock Exchange and none in the Chittagong Stock Exchange. Financial ratios were used to measure the performance of a limited company in the study of Jahur and Mohiuddin (1995). They used profitability, liquidity, activity, and capital structure ratios to measure operating performance. Many studies have been conducted in different industries to evaluate financial performance, but a few studies have been carried out in the jute industry. Using time-series data and data from 1973 – 2013, Rahman et al. (2017) assessed the future potential of the jute sector of Bangladesh. They examined different factors like growth performance, international competitiveness, profitability, and production efficiency. The findings indicated that performance could be boosted by reducing inefficiency.

Molla et al. (2015) analyzed jute's financial and economic profitability and its main alternative crop Aus, including an assessment of comparative advantage using Policy Analysis Matrix. They concluded that jute was more profitable financially in the study period than Aus in the selected areas of Bangladesh. Sheheli and Roy (2014) investigated jute cultivation status and practices using structured interview schedules from two villages. Though jute cultivation improved the livelihood of concerned people, there are many bottlenecks that should be overcome. Many studies have been carried out to determine the different financial and non-financial factors that can boost or adversely affect performance. Nevertheless,no single effective model has been established that captures maximum variation (Mirza & Javed, 2013).

Financial analysis is a procedure of measuring the association of different financial statement elements to understand the company's position and performance. Solvency and profitability are the primary concern of a long-term creditor, while a short-term creditor considers liquidity. Investors emphasize the firm's earnings, profitability, and risk. Financial analysis is crucial for the company's continuous improvement and overcoming the crisis if any. Analyzing financial position is always an effective tool for any company to strengthen its place in the industry to sustain itself in the competitive world. Information about the jute sector in Bangladesh is not available, and little is known about financial performance. Given the scarcity

of information about the jute sector's financial performance, especially listed companies under Dhaka Stock Exchange Ltd. (DSE), the present study explicitly addressed this research gap. The financial diagnosis of the organization assists its stakeholders in comprehending the current situation of the respective organization, allowing stakeholders to make data-driven decisions. It examines the financial performance of selected companies in the jute industry for ten years and measures profitability, liquidity, solvency, and overall financial soundness. This study used10-year data of selected jute companies that are listed under DSE to analyze the financial performance of the concerned for 2009-2010 to 2018-2019. The paper is wedded to evaluate and compare selected jute companies' financial performance so that policymakers are aware of potential problems dating back ten years which will aid in decision making.

Materials and methods

Data were collected from 2 out of 3 (67%) jute sector companies enlisted in Bangladesh's DSE. One company was excluded from the study due to a lack of data. The study covered 10 years period from 2009-2010 to 2018-2019. Secondary data, annual reports of selected companies of the jute industry, and various studies available through library work,were considered for the study. The viability and reliability of the data is the prime concern for ensuring the quality of this research. The financial and quantitative aspect of the study is based on relevant financial metrics that are suitable to address the research gap. Data were summarized with the help of fourteen ratios, which fall under the three broad categories, i.e., liquidity ratio (current ratio, acid-test ratio, inventory turnover, current assets to fixed assets, networking capital), profitability ratio (gross profit margin, net profit margin, total assets turnover, return on assets, return on equity, earnings per share, operating profit ratio), solvency ratio (debt to total assets, debt to equity). Statistical tools like mean, standard deviation, skewness, kurtosis, maximum, minimum were considered. A pairwise mean test of ratios of two organizations was calculated in bivariate analysis. Variable correlation matrices were also computed.

$$r_{xy} = \frac{n\sum xy - \sum x\sum y}{(\sqrt{n\sum x^2(\sum x)^2})(\sqrt{n\sum y^2(\sum y)^2})}$$

Where,

r = Correlation coefficient
n = Number of observation
x = Independent variables
y = Dependent variable

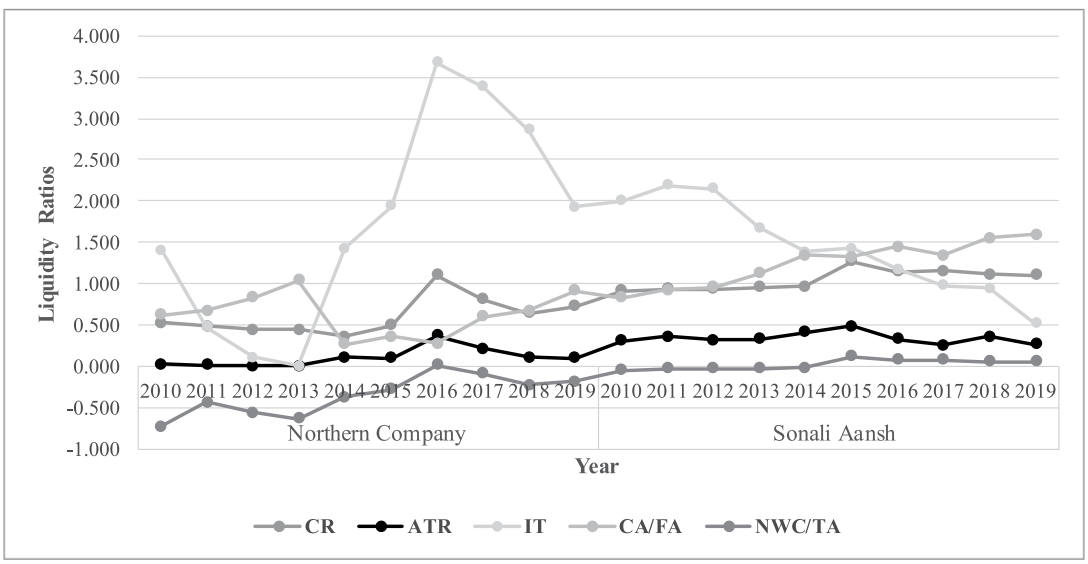

Figure 1. Liquidity ratio of several indicators of two companies.

Results and discussion

A ratio is a numerical relation between two variables under the same unit of measurement. Accounting ratios demonstrate interrelationship among accounting data. Ratio analysis is an effective tool because it is easy to understand and calculate. Moreover, it has a predictive value. A stakeholder can rely substantially on ratio analysis to assess the company's performance and make informed decisions. An excellent way to diagnose financial health is to measure profitability, liquidity, and solvency, best done by ratio analysis.

Liquidity ratio

The liquidity ratio assesses the organization's short-term capacity to pay its obligation and fulfill any emergency for cash. Short-term creditors such as bankers, suppliers, or a person that has provided money, goods, or service are particularly interested in assessing liquidity (Weygandt et al., 2015). Current ratio, quick ratio, inventory turnover, current assets to fixed assets, net working capital to total assets ratio are the most commonly used ratios to measure an organization's liquidity condition. The overall result is shown in Figure 1.

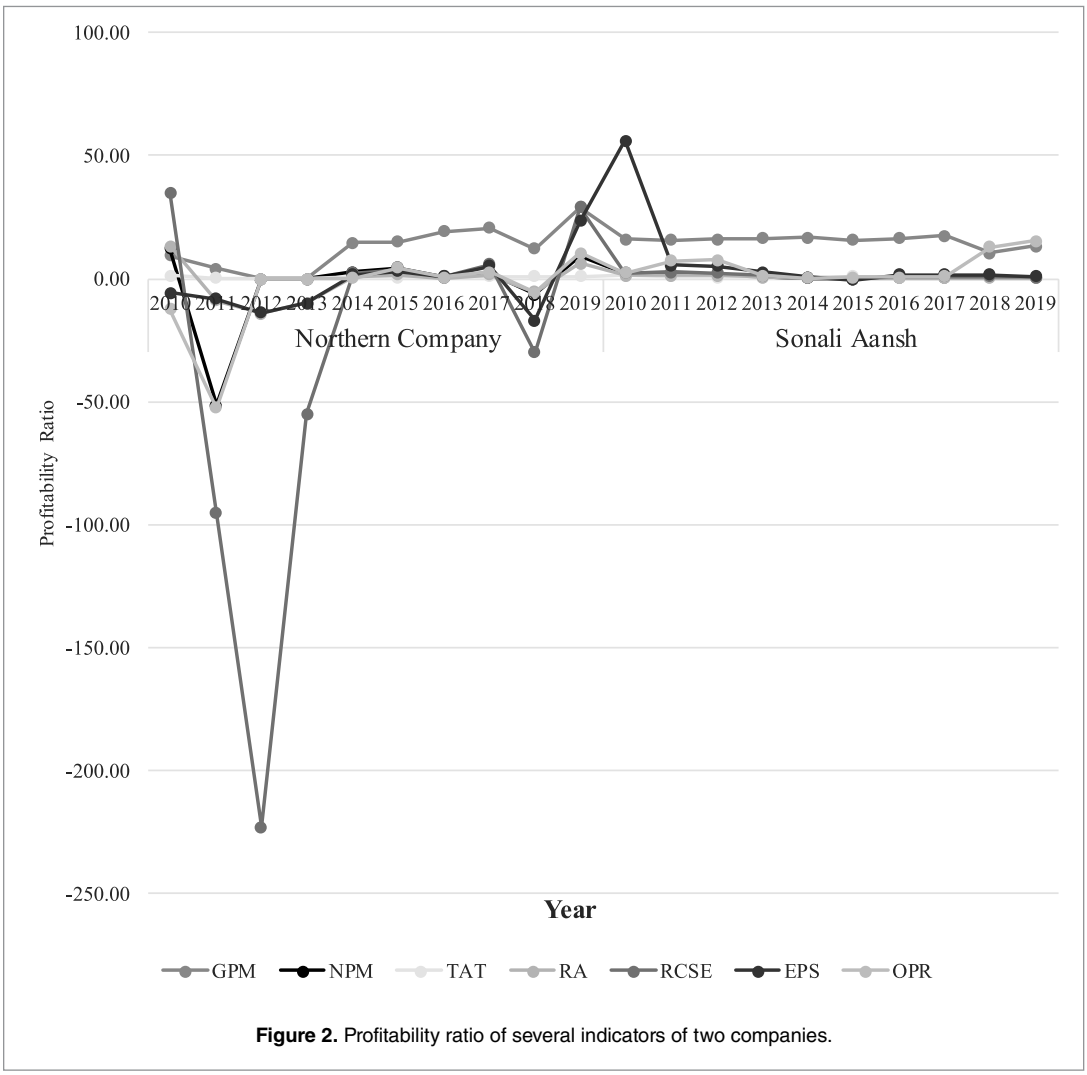

Figure 2. Profitability ratio of several indicators of two companies.

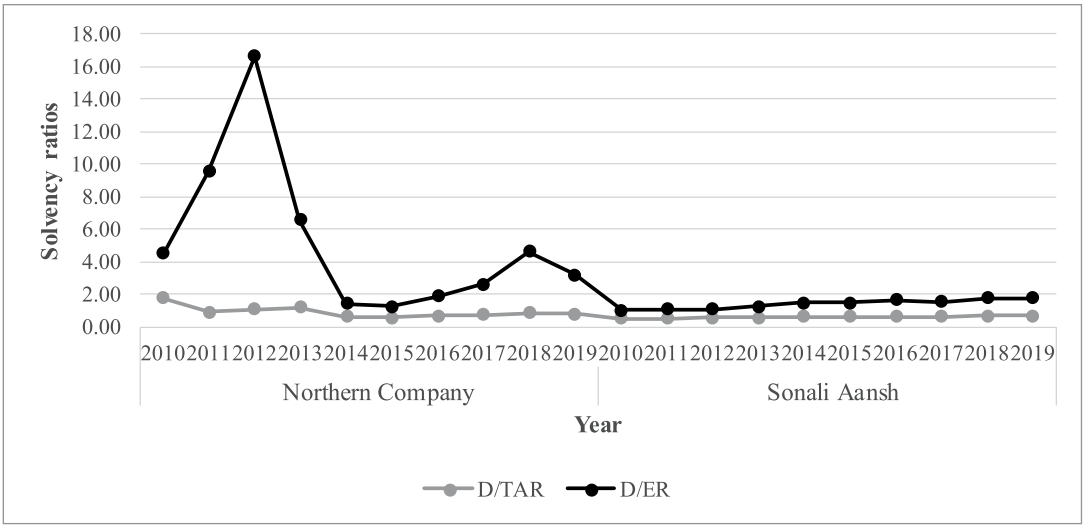

Figure 3. Solvency ratio of several indicators of two companies.

Current ratio

The current ratio is calculated through the divisor of existing assets and liabilities in the current period. Companies frequently use this ratio to measure the company's liquidity and short-term debt-paying ability. A low current ratio indicates the firm's difficulty in meeting short-term commitments. A high percentage may imply the firm's unregulated investment in current assets or under utilizing short-term credit. Though it varies based on the business, a 2:1 current ratio is regarded as excellent. Northern Jute Manufacturing Co. Ltd. (NJMCL) was in a poorer scenario in 2013-14, with a Current Ratio of 0.368, but it increased to a high point after two years (1.09). Sonali Aansh Industries Ltd. (SAIL), on the other hand, experienced an upward tendency over time. The lowest ratio was in 2009-10 (0.909), while the highest was in 2016-17. (1.156). On the other hand, the industry average was 0.826 over the period.

Acid test ratio

The acid test ratio is a quick ratio for displaying an organization's ability to encounter instantaneous short-term obligations from current liquid assets. The acid-test ratio measures the sufficiency of short-term assets to cover its short-term liabilities, and it strongly defines the company's ability to make payments on current obligations. Ideally, this ratio should be 1:1. A higher acid test ratio may dictate undue cash on hand or uncontrolled investment in the business's working capital, which may more profitably be used elsewhere.

Generally, a standard quick ratio provides enough leverage against the liquidity risk in a specific business sector, among other considerations. On the contrary, a lower ratio may ascertain that the institution is at risk of taking too much by unbalancing the ideal buffer of liquid resources. NJMCL faced 0.006 in 2012-13 while the maximum ratio was 0.373 in 2015-16. For SAIL, the acid test ratio was better, ranging from 0.256 to 0.489. The overall average was 0.223, so it can be said that both companies were at the risk of liquid resources.

Inventory turnover (times)

Inventory turnover assesses the liquidity of inventory. It specifies the number of times, on average, the inventory was sold during the period. Low inventory turnover may entail unwarranted savings in inventories, and high turnover may indicate the probability of running out of stock frequently or sales being in a strong position. Two times of inventory turnover ratio for a company is considered good. For NJMCL this ratio spiked in 2015-16 (3.676) while at downfall on 2012-13 with a null value.

Table 1. Summary statistics of liquidity ratio of two companies.

Particulars	Northern Jute Manufacturing Co. Ltd. (NJMCL)				
	CR	**ATR**	**IT**	**CA/FA**	**NWC/TA**
Mean	0.604	0.105	1.721	0.627	-0.346
Industry mean	0.826	0.223	1.582	0.935	-0.162
Median	0.51	0.097	1.677	0.65	-0.322
SD	0.222	0.114	1.303	0.261	0.242
Skewness	1.347	1.601	0.146	-0.051	-0.141
Kurtosis	1.63	2.687	-1.168	-0.953	-0.993
Minimum	0.36	0.006	0	0.27	-0.724
Maximum	1.1	0.373	3.68	1.04	0.02
	Sonali Aansh Industries Ltd. (SAIL)				
	CR	**ATR**	**IT**	**CA/FA**	**NWC/TA**
Mean	1.049	0.342	1.4437	1.2424	0.0237
Industry mean	0.826	0.223	1.582	0.935	-0.162
Median	1.0355	0.331	1.404	1.332	0.019
SD	0.121	0.068	0.558	0.271	0.0592
Skewness	0.462	1.005	-0.064	-0.319	0.259
Kurtosis	-1.06	1.541	-1.002	-1.344	-1.701
Minimum	0.91	0.256	0.52	0.83	-0.045
Maximum	1.27	0.489	2.19	1.59	0.119

On the other hand, SAIL experienced a downward trend on this ratio though it maintained a modest ratio in the beginning period of this study period. It was more than two times from 2009-2010 to 2011-2012 and became 0.522 in 2018-2019. Overall the average for this ratio was 1.58 times. The average inventory turnover ratio for NJMCL was 1.72, and for SAIL was 1.44, which was close to the industry mean.

Current assets to fixed assets

The current asset to fixed asset or fixed asset turnover ratio is a quick measurement of knowing operating performance. It tells only about the effectiveness of management in using its fixed assets. In other words, it helps us describe the company's efficiency briefly to generate sales from its existing fixed assets. NJMCL witnessed the lowest value in 2013-14 (0.266), while it was the highest point in the previous year (1.036). SAIL's operating performance was well with time as it visualized a rising trend (0.826 to 1.594).

Net working capital to total assets

Net working capital to total asset ratio is a liquidity ratio that assesses a company's net current assets or working capital as a percentage of its total assets. The ratio supplements the calculation of a company's financial liquidity. It shows the share of net working capital in funding the inventory and short-term receivables. NJMCL was not in a good position in this matrix as it faced negative results except 2015-2016. SAIL showed positive value after 2013-2014. So, the risk was not at vivid in this regard. For both, planning is crucial to cover up this crisis and take over the company to see a rising sun.

Summary statistics of this liquidity ratio are given in Table 1. SAIL performed comparatively better; mean and median were higher than NJMCL, as standard deviation (SD) was smaller, maximum and minimum were not scattered.

Table 2. Summary statistics of profitability ratio of two companies.

Particulars	Northern Jute Manufacturing Co. Ltd. (NJMCL)						
	GPM	**NPM**	**TAT**	**RA**	**RCSE**	**EPS**	**OPR**
Mean	12.40	-2.74	0.53	-1.49	-32.70	-2.09	-5.26
Industry mean	13.89	-0.92	0.58	-0.5	-15.81	-2.72	-0.21
Median	13.36	1.28	0.57	0.60	1.50	-2.50	0.10
SD	9.36	17.88	0.38	8.22	77.51	11.65	17.61
Skewness	0.20	-2.69	-0.21	0.14	-1.91	0.98	-2.52
Kurtosis	-0.46	7.91	-1.34	-0.22	3.92	1.52	7.03
Minimum	0	-51.52	0	-14.26	-222.89	-17.15	-52.38
Maximum	29.08	12.07	1.06	13.30	34.86	23.29	10.21
	Sonali Aansh Industries Ltd. (SAIL)						
	GPM	**NPM**	**TAT**	**RA**	**RCSE**	**EPS**	**OPR**
Mean	15.38	0.90	0.64	0.49	1.08	7.54	4.83
Industry mean	13.89	-0.92	0.58	-0.5	-15.81	-2.72	-0.21
Median	16.07	0.72	0.53	0.29	0.75	1.68	1.65
SD	2.09	0.69	0.30	0.47	0.94	17.17	5.59
Skewness	-1.92	0.16	0.81	0.62	0.44	3.09	1.04
Kurtosis	3.79	-0.71	0.02	-1.22	-1.06	9.67	-0.33
Minimum	10.30	-0.22	0.23	-0.11	-0.27	-0.60	0.29
Maximum	17.46	1.90	1.21	1.22	2.51	56.11	15.39

Profitability ratio

The degree to which a firm or activity generates profits or financial benefit is profitability. It measures efficiency and the ability to generate revenue over a given period. Seven performance indicators of profitability are shown in Figure 2.

Gross profit margin (GPM)

Gross profit margin is a straightforward measure of profitability performance. The difference between total revenue and the cost of goods sold (COGS) is gross margin. This ratio measures the management team's efficiency in producing gross income for par Taka of cost. The gross profit

Table 3. Summary statistics of solvency ratio of two companies

Variable	Northern Jute Manufacturing Co. Ltd. (NJMCL)		Sonali Aansh Industries Ltd. (SAIL)	
	D/TAR	**D/ER**	**D/TAR**	**D/ER**
Mean	0.899	5.211	0.576	1.388
Industry mean	0.74	3.3	0.74	3.3
Median	0.805	3.85	0.59	1.44
SD	0.35085	4.75839	0.05275	0.28538
Skewness	1.555	1.789	-0.275	-0.095
Kurtosis	2.734	3.321	-1.51	-1.451
Minimum	0.55	1.21	0.5	0.99
Maximum	1.72	16.63	0.64	1.77

Table 4. Pairwise mean test of ratios of two companies.

Company ratios			Northern Jute Manufacturing Co. Ltd (NJMCL)		Sonali Aansh Industries Ltd. (SAIL)	
	Variables	Industry mean	T statistic	p-value	T statistic	p-value
Liquidity Ratio	CR	0.83	-3.16	0.01	5.82	0.00
	ATR	0.22	-3.25	0.02	5.51	0.00
	IT	1.58	0.34	0.74	-0.78	0.45
	CA/FA	0.94	-3.72	0.00	3.58	0.00
	NWC/TA	-0.16	-2.41	0.03	9.91	0.00
Profitability Ratio	GPM	13.89	-0.51	0.62	2.25	0.05
	NPM	-0.92	-0.32	0.76	8.37	0.00
	TAT	0.58	-0.42	0.69	0.25	0.62
	RA	-0.50	-0.38	0.71	6.66	0.00
	RCSE	-15.81	-0.68	0.52	56.93	0.00
	EPS	-2.72	0.17	0.86	1.88	0.09
	OPR	-0.21	-0.91	0.39	2.86	0.01
Solvency Ratio	D/TAR	0.74	1.43	0.18	-9.83	0.00w
	D/ER	3.30	1.27	0.23	-21.72	0.00

margin standard for any enterprise is 20% to 30%. NJMCL witnessed steady growth from 2013-2014 and touched 29% in 2018-2019.

SAIL, on the other hand, experienced a steady decline in profits. As a result, the company struggled to make a profit as time passed. This industry's average gross profit margin was 13.89 percent.

Net Profit Margin (NPM)

Net profit margin is employed to compute the percentage of net income a company produces from its total revenue. This ratio measures an organization's overall profitability, soit is crucial for shareholders. Though a good net profit margin will vary considerably by industry, a general yardstick for net profit margin is around 10%.Northern Jute Manufacturing Co. Ltd. had obstacles until 2013-14. For 2010-11 and 2017-18, it suffered from one of the darkest scenery of net profit on last 10 years' summary. SonaliAansh Industries Ltd. faceda steadily decreasing trend.

Total Asset Turnover (TAT)

The total asset turnover ratio assesses the efficiency of an organization's assets to generate sales. It exhibits the dollar sales generated by each dollar invested in assets 2 times (200%) of this ratio is interpreted assound by some authors for an industrial enterprise. This may also be taken as such for our selected jute companies. Total asset Turnover of NJMCL ranged from 0.376 to 0.898 of 2013-2014 to 2018-2019 time span, while it had a loss in a previous couple of years. SAIL struggled to maintain its total asset turnover and decreased over the years.

Return on assets

The Return On Assets (ROA) measures how much profit a business earns concerning its overall resources. Simply, it measures the efficiency of the organization's assets in generating profits. ROA is calculated by dividing the net income by total assets. 10% to 12% rate of ROA is considered an ideal rate by some authors for industry and can be taken for jute companies. NJMCL strived to perform better in ROA indices during the

period. On the other hand, ROA for SAIL was dangling between -0.11 to 1.22.

Return on common shareholders' equity

Return on common shareholders' equity measures the profitability of an organization from the perspective of common stockholders. It shows each dollar of net income generated by each dollar invested by owners. It is calculated by dividing net income by average common shareholders' equity. SAIL faced slowly moving down as time goes. NJMCL exhibited the most deteriorated value on 2011-12 while it turned back into positive on 2018-19 with too many ups and downs.

Earnings per share (EPS)

Earnings per share represent the net income earned on each share of common stock. It is calculated by dividing net income (minus preferred dividends) by the weighted average number of common shares outstanding over the course of a year. NJMCL had a startling ratio like the other three, whereas SAIL took tortoise steps.

Operating profit ratio

Operating profit measures the profitability of a company considering the variable costs. It helps to determine the company's efficiency in controlling the costs and expenses associated with business operation. Operating profit is usually used as a yardstick mean when comparing different companies belonging to a single sector. NJMCL exhibited sluggish performance before 2013-2014, but after 2017-2018, it seemed to be a landmark. On the other hand, SAIL faced sudden strikes in 2017-2018 and 2018-2019.

Basic statistics are provided in the table two companies under seven ratios. NJMCL faced losses before 2013-14 on several ratios, while SAIL made profits on particular periods. Except for EPS and OPR, maximum output witnessed by NJMCL, yet darkest side also faces this. Comparatively, standard deviation (SD) was more prominent for NJMCL than SAIL. Under skewness, SAIL did not lose as much as NJMCL, so each ratio was positively skewed.

Solvency Ratio

The ability of a business to have enough assets to cover its liabilities is called solvency. It is

Table 5. Correlation matrix of variables.

	CR	ATR	IT	CA/FA	NWC/TA	GPM	NPM	TAT	RA	RCSE	EPS	OPR	D/TAR	D/ER
CR	1	.883**	.818**	-0.244	.776**	0.607	0.157	0.529	0.272	0.357	0.341	0.246	-0.27	-0.373
ATR	.883**	1	.871**	-0.6	.849**	0.622	0.223	0.439	0.273	0.418	0.339	0.345	-0.527	-0.553
IT	.818**	.871**	1	-0.54	.850**	.751*	0.284	.748*	0.471	0.598	0.343	0.346	-0.45	-.672*
CA/FA	-0.244	-0.6	-0.54	1	-0.453	-0.334	-0.065	-0.288	-0.355	-0.376	-0.121	-0.036	0.497	0.55
NWC/TA	.776**	.849**	.850**	-0.453	1	.763*	0.038	0.38	0.145	0.364	0.479	0.298	-.789**	-0.524
GPM	0.607	0.622	.751*	-0.334	.763*	1	0.38	.647*	.657*	.716*	.849**	0.459	-0.489	-.717*
NPM	0.157	0.223	0.284	-0.065	0.038	0.38	1	0.342	0.52	0.394	0.342	.903**	0.116	-0.364
TAT	0.529	0.439	.748*	-0.288	0.38	.647*	0.342	1	.790**	.722*	0.298	0.15	0.117	-0.586
RA	0.272	0.273	0.471	-0.355	0.145	.657*	0.52	.790**	1	.856**	0.59	0.257	0.171	-.704*
RCSE	0.357	0.418	0.598	-0.376	0.364	.716*	0.394	.722*	.856**	1	0.585	0.272	-0.109	-.943**
EPS	0.341	0.339	0.343	-0.121	0.479	.849**	0.342	0.298	0.59	0.585	1	0.411	-0.368	-0.548
OPR	0.246	0.345	0.346	-0.036	0.298	0.459	.903**	0.15	0.257	0.272	0.411	1	-0.237	-0.346
D/TAR	-0.27	-0.527	-0.45	0.497	-.789**	-0.489	0.116	0.117	0.171	-0.109	-0.368	-0.237	1	0.384
D/ER	-0.373	-0.553	-.672*	0.55	-0.524	-.717*	-0.364	-0.586	-.704*	-.943**	-0.548	-0.346	0.384	1

often confused with liquidity, but it is not. The solvency ratio is an essential factor for a business to operate. Long-term creditors and stockholders are specifically interested in a company's ability to pay the interest required to repay the face value of debt at maturity. The most widely utilized solvency ratios are the debt-to-total assets and debt-to-equity ratios. These two indices are graphically visualized in Figure 3.

Debt to total assets ratio

The proportion of total assets provided by the creditors is measured by the debt to total assets ratio. One can calculate the debt to total assets by dividing the total liabilities by total assets. Generally, not more than 50% of an organization's assets should be financed by debt. Debt to total assets was consistent for both companies throughout the period. The debt to equity ratio was good for both companies too.

Debt to equity ratio

The debt to equity ratio shows the percentage of company financing from creditors and investors. It compares the total debt and total equity of a company. If the debt to equity ratio is high, more creditor financing is used than investor financing. NJMCL ran into problems, whereas SAIL managed to stay in the balance.

Bivariate analysis

This study used Pearson correlation for bivariate analysis to exhibit product-moment correlation. Gross profit margin (GPM) showed mostly correlated in number under statistical paradigm, as it was strongly positively associated with almost each profitability ratio (TAT, RA, RCSE, EPS) and two liquidity ratios (IT, NWC/TA). Moreover, inventory turnover (IT) was strongly correlated with three liquidity ratios(CR, ATR, NWC/TA) and two profitability ratios (GPM, TAT). On the other hand, several correlations were inconsequential (CA/FA, EPS, OPR, D/TAR).

Table 5 compared the average with industry mean for two companies. The indicators for NJMCL were not significant. SAIL, on the other hand, performed well in every ratio under financial performance.

Conclusion

This study complies with a dataset of the financial performance of two well-known names in the jute industry: NJMCL and SAIL. This research looks at several indices under the umbrella of a financial indicator. Basic data of each ratio under three pillars based on univariate analysis: liquidity, profitability, and solvency ratio.

NJMCL performed better in different indices of liquidity ratio except net working capital to total assets. The profitability ratios were good too in recent years. The debt to total assets ratio was consistent though fluctuations in the debt to equity ratio in the periods. On the other hand, SAIL comparatively performed well but not on the standard. On bivariate analysis industry comparison is made; meanwhile, SAIL exhibited a significant difference with its ratio to the expected value. The correlation matrix was used to explore further exploration. Statistical tests revealed that certain ratios have no substantial evidence. Due to the lack of availability of additional data, no multivariate techniques could have been used to explore further. In addition, the timespan was not fitted well for further model building. Despite all these, this research can aid policymakers in gaining insight into their financial performance in the face of numerous difficulties. Maintaining standards is also crucial for both companies to tackle hazardous situations.

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Original Research

Profitability and value chain analysis of cut flower in Bangladesh: Exploring value addition among different actors

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ABSTRACT

The study is aimed to analyse the profitability and existing value chain of cut flowers in Bangladesh. The study was conducted at Gadkhali and Panisara Union under Jhikargaccha Upazila in Jashore district and at Shahbag flower market in Dhaka city. Data were collected from respondents through survey schedules from Jashore and Dhaka city. The respondents were selected by applying a convenience sampling technique. The study covered two kinds of cut flowers such as marigold and gladiolus. The channel II is the smallest chain which includes only producer,retailer and consumer but three chains have highest actors, channel III, channel V and channel VII. Among the two kinds of cut flowers per hectare total cost was Tk. 373,246.95 for marigold and Tk. 740,275.98 for gladiolus. Per hectare net return was Tk. 282,475.25 for marigold and Tk. 681,274.02 for gladiolus. The benefit-cost ratio (BCR) for marigold and gladiolus was 1.75 and 1.92 respectively, which indicated that cut flower cultivation was profitable in the study areas. The average estimated marketing cost per hundred flowers was highest for the retailer followed by the local trader and wholesaler. The average estimated value addition per hundred flowers was highest for the retailer followed by the wholesaler and local trader. So, it can be said that cut flower has a huge potential as a larger contributor to the economic development of the country, and the government, the private sector should take proper initiative to establish a wholesale market with modern facilities.

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Introduction

Floriculture becomes popular and emerged as one of the most important and remunerative professions all over the world (Prodhan et al., 2017). At present, it is not only being considered as a symbol of purity and beauty but also a potential revenue earning source (Omar et al., 2014). In Bangladesh, small-scale flower production has initially started in the late seventies by some innovative growers with the production of tuberose. However, from the mid-eighties, large-scale commercial production was started

at Jhikargaccha *Upazila* under the Jashore district (Hasan et al., 2019; Sultana, 2003). Suitable agro-climatic conditions and relatively low capital investment encourage growers to cultivate flowers in Bangladesh (Hasan et al., 2019; Omar et al., 2014). Nowadays, flowers are being cultivated on nearly 6,000 hectares of land in 24 districts of Bangladesh including Jashore, Kushtia, Jhenaidah, Chuadanga, Gazipur, Chattogram, Narayanganj, and Cumilla (Mim, 2020). The major production is concentrated at Gadkhali in Jashore which covered about 70% of total flower production (Daily Asian Age, 2017). About 15 to 20 lakh people are earning their livelihoods directly or indirectly through floriculture. A wide variety of flowers, especially tuberose, gladiolus, rose, marigold, lotus, gerbera, hyacinth, chrysanthemum, lily, etc. are now being commercially cultivated in Bangladesh (Mim, 2020). Most of these flowers are cut flower, a flower or bud that is cut from its bearing plant (Dadlani, 2003). In Bangladesh, the fresh-cut flower business is very popular. Only a few shops were opened in Dhaka city for selling fresh cut flowers in the late 1980s. At present, fresh-cut flowers are sold in most of the cities and districts even the *Upazila* towns of Bangladesh. Flowers are daily auctioned in the morning at Shahbag Avenue, and the Agargaon flower market in Dhaka (Rakibuzzaman et al., 2018). Dhaka is the main center of the flower business in Bangladesh. A large number of flower shops- both permanent and temporary have been developed in and around Dhaka city which can give a picture of the present flower market situation. There are around 2,000 retail shops of flowers in the country. Among these, around half of the retail shops are in Dhaka, while others are in Chattogram, Sylhet, and other district towns (Mou, 2012).

Flower cultivation has been found as a profitable business that assures a higher potential to earn money compared to other crops in Bangladesh (Majira, 2018). Yeasmin (2009) stated that income from floriculture has a remarkable contribution to increasing total household income. Besides, national GDP is largely influenced by the flower sector and it creates employment opportunities and can increase the participation of rural women income-generating activities (Rakibuzzaman et al., 2018; Yeasmin, 2009). Nowadays, the flower has become an important part of our culture. People use the flower on all social, political, and historical occasions (Majira, 2018). Flower farming is an important and profitable enterprise in the agriculture sector of Bangladesh (Jalil, 2007). In spite of the huge potential, the floriculture industry has not been considered a flourishing industry in the agricultural sector (Shaibur, 2020). Demand for flowers especially cut flowers is increasing in the domestic as well as international market (Rakibuzzaman et al., 2018). So, it is necessary to identify the production and profitability status of the cut flower in Bangladesh.

However, most of the studies such as Jahan (2009), Mou (2012), Islam and Rahman (2013), Omar et al. (2014), Usman et al. (2015), Mohiuddin (2016), Amarnath and Vendhan (2017), Ara and Hosen (2017), Das (2017), Prodhan et al. (2017), Rakibuzzaman et al. (2018), and Momotaz and Banik (2020) are conducted on the basis of production and marketing system of cut flowers. Few studies (Bagchi, 2009; Manjira, 2018) are conducted from the perspective of value chain analysis of cut flowers in Bangladesh. There is a dearth of scientific work. The present study emphasizes the issue in order to fill this gap. So, the value chain analysis of cut flowers can add new knowledge in the field of the flower business. Moreover, for market information and improving the performance of the functional activities, value chain analysis is a very essential tool. It helps to identify the costs associated with each activity as well as the value drivers for that activity (Wikinsom, 2013). Also, it helps to identify the existing market chain, weak points in the chain, and actions to add more value (Raj, 2011; Devaux et al., 2018). So, the flower producers and traders at different levels will be benefited from the information generated through this study. The study also provides valuable insights for policymakers of the government and NGOs to

formulate policy. Therefore, this study is aimed to identify the actors in the cut flower value chain, and to examine the value addition by cut flower producers and value chain actors of cut flowers in the study area.

Materials and Methods

Selection of the study area

On the basis of the high concentration of flower cultivation and production, Jashore district is considered as one of the leading cut flowers (such as tuberose, gladiolus, marigold, gerbera) producing zones in Bangladesh(Abdin, 2014; Chowdhury & Khan, 2015; Manjira, 2018; Prodhan et al., 2017; Shaibur et al, 2020). Two Unions, namely Gadkhali and Panisara under Jhikargacha *Upazila* of Jashore district were selected (Figure 1). Shahbag flower market in Dhaka city was selected for collecting data from different levels of intermediaries (Figure 2).

Selection of flower

Rose, tuberose, marigold, gladiolus, gerbera flowers are commercially produced by the farmers in the study area. Among them, marigold and gladiolus were selected for the study. Farmers in the study area cultivate more marigold and gladiolus than other cut flowers. The comparative figure of Jhikargachha flower production in 2011-12 and March 2012-13 showed that marigold production increased from 250 acres to 625 acres, and gladiolus production increased from 225 acres to 940 acres while Gerberas had grown from 15 acres to 50 acres (Tazuddin, 2020).

Selection of the sample and sampling technique

The sampling unit for this study is farmers and traders of cut flowers in the study area. Sample units were selected by applying a convenience sampling technique in order to fulfill the objectives of the study. Twenty cut flower growers were

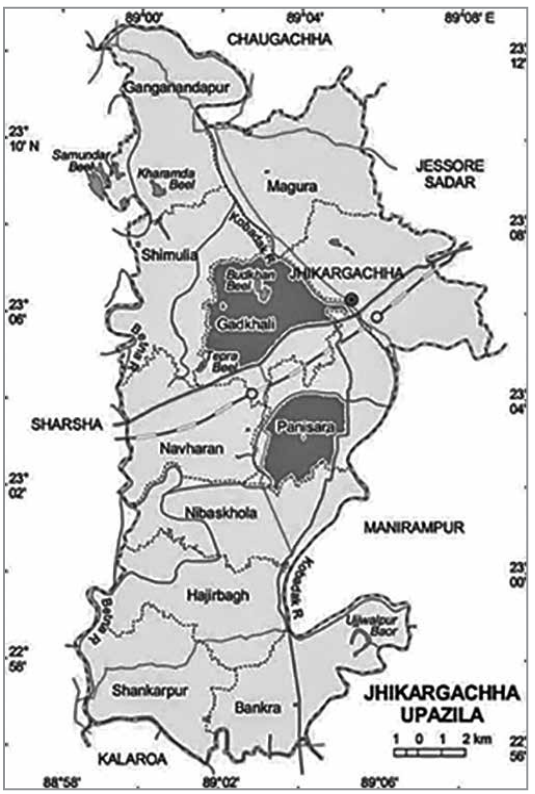

Figure 1. Map of Jhikargachha Upazila of Jashore district; ▲indicates the study areas.

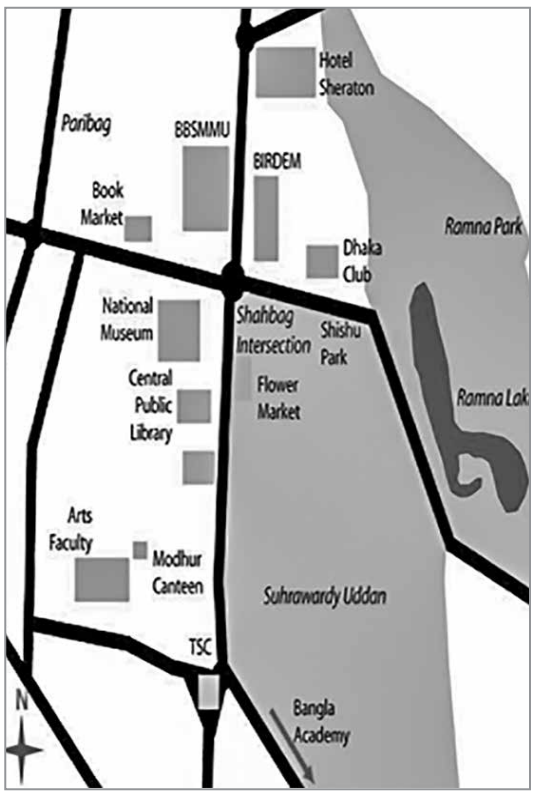

Figure 2. Map of Shahbag flower market, Dhaka.

selected from Gadkhali and Panisara union of Jhikargacha *Upazila* in Jashore district, 10 local traders from the Gadkhali flower market, 10 wholesalers from Gadkhali flower market and Dhaka city, and 10 retailers from Dhaka city were selected for collecting necessary data. Thus the total sample size was 50.

Data collection and analytical technique

Primary data were collected from July to September, 2019 through direct interviews using survey schedules. Data entry was made in computer and analysis was done using Microsoft Excel. This analysis was used to analyse the data by simple statistical measures like sum, percentage, average, and ratio.

Cost and return analysis

The following profit equation was employed to assess the profitability of cut flower production. Several studies such as Bagchi (2009), Mou (2012), and Mandal et al. (2021) used this method in their studies to access profitability.

$\prod = Pm.\ Qm - (TVC+TFC)$

Where,

$\prod$ = Profit of cut flower grower (Tk./ha)

Pm = Price of cut flower (Tk./100 flower/ha)

Qm = Yield of cut flower (no. in '00'/ha)

TVC = Total variable cost of cut flower grower (Tk./ha)

TFC = Total fixed cost of cut flower grower (Tk./ha)

- Total cost of production of cut flower (Tk./ha) = TVC + TFC (Tk./ha)
- Gross return of cut flower (Tk./ha) = Yield of cut flower (no. in '00'/ha) × Price of cut flower (Tk./100 flower/ha)
- Net return of cut flower (Tk./ha) = Gross return of cut flower (Tk./ha) - Total cost of production of cut flower (Tk./ha)
- Benefit-Cost Ratio (BCR) of cut flower

Value chain analysis

- Marketing cost of flower producer (Tk./ha) = Marketing cost (Tk./100 flowers) × yield(/hectare)
- Gross Marketing Margin = Sales price – Purchase price
- Net marketing margin= Marketing margin – Marketing cost
- Value Addition = Gross Marketing Margin
- Value Addition (%) =

$$\frac{\text{Sales price} - \text{Purchase price}}{\text{Purchase price}} \times 100$$

Results and discussion

Value chain of cut flower marketing

Cut flower moves from the point of production to the point of consumption through some actors who form a chain in the flower market in the

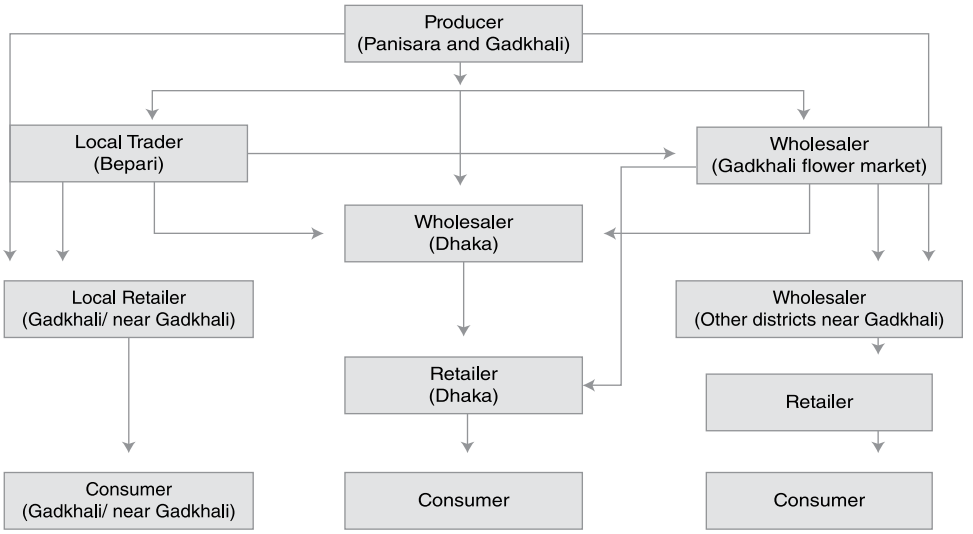

Figure 3. Cut flower value chain map.

study area. There are many actors involved in the value chain of the cut flower (Figure 3).

The following major channels are involved in the cut flower production and marketing:

- Channel I: Producer → Local trader → Retailer (Gadkhali/ near Gadkhali) → Consumer (Gadkhali/ near Gadkhali)
- Channel II: Producer → Retailer (Gadkhali/ near Gadkhali) → Consumer (Gadkhali/ near Gadkhali)
- Channel III: Producer → Local trader → Wholesaler (Dhaka) → Retailer (Dhaka) → Consumer (Dhaka)
- Channel IV: Producer → Wholesaler (Dhaka) → Retailer (Dhaka) → Consumer (Dhaka)
- Channel V: Producer → Wholesaler (Gadkhali) → Wholesaler (Dhaka) → Retailer (Dhaka) → Consumer (Dhaka)

Table 1. Per hectare total (production and marketing) cost of cut flower farmers.

Particulars	Marigold	% of total cost	Gladiolus	% of total cost
1. Variable cost (Tk.)				
Human labor cost	52383.38	21.80	68022.56	9.85
Seed/seedling cost	18315.06	7.62	425568.28	61.60
Fertilizer cost	24853.42	10.34	62040.68	8.98
Irrigation cost	25745.60	10.71	19996.58	2.89
Pesticides/insecticides cost	43079.27	17.93	24611.18	3.56
Miscellaneous cost	8157.02	3.39	3486.58	0.50
Total variable cost	172533.75	71.80	603725.86	87.38
2. Fixed cost (Tk.)				
Land use cost	60000.00	24.97	60000.00	8.68
Interest on operating capital (9%)	7764.02	3.23	27167.66	3.93
Total fixed cost	67764.02	28.02	87167.66	12.62
Total cost of production (Tk.) (1+2)	240297.77	100	690893.52	100
3. Marketing cost of farmer (Tk. per 100 flowers)				
Plucking and assembling	0.81	36.65	5.34	23.64
Transportation	0.49	22.17	4.41	19.84
Market toll	0.13	5.88	2.03	8.99
Grading/ Sorting	0.32	14.48	2.84	12.58
Loading and unloading	0.35	15.84	5.26	23.29
Personal expense	0.11	4.98	2.70	11.96
Total marketing cost	2.21	100	22.58	100
Yield (no. in '00')	60158.00	-	2187.00	-
Marketing cost (Tk./ha)	132949.18	-	49382.46	-
Total cost (Tk./ha) (1+2+3)	373246.95	-	740275.98	-
Total cost (Tk./100 flowers)	6.20	-	338.49	-

Source: Author's own calculation, 2019.

- Channel VI: Producer → Wholesaler (Gadkhali) → Retailer (Dhaka) → Consumer (Dhaka)
- Channel VII: Producer → Wholesaler (Gadkhali) → Wholesaler (other districts near Gadkhali) → Retailer → Consumer
- Channel VIII: Producer → Wholesaler (other districts near Gadkhali) → Retailer → Consumer

Total cost of cut flower farmers

Cost is an important part of running a business successfully. In this study, the cost of production of different cut flowers is estimated per hectare. The cost involved in cut flower production is of two types: variable cost and fixed cost. The variable costs are the costs of using the variable inputs. These costs vary with the level of production. In this study, variable cost items were labor cost, seed/seedling cost, fertilizer cost, pesticides, irrigation cost, and miscellaneous cost. On the other hand, fixed assets are those, which do not change and are incurred even when production is not undertaken.

The fixed cost of cut flower cultivation includes land use cost. Per hectare total production cost of marigold and gladiolus were estimated as Tk. 240,297.77 and Tk. 690,893.52 respectively (Table 1). In cost of production, the highest cost for marigold was incurred for human labour (21.80%), land preparation (24.97%) and pesticides/insecticides cost (17.93%). For gladiolus, the highest cost was incurred for seed/seedling (61.60%), human labor (9.85%), and fertilizer cost (8.98%) in the study area.

Among the marketing cost of farmers, plucking and assembling cost was the highest cost for both marigold (Tk. 36.65) and gladiolus (Tk. 23.64) in the study area. Per hectare marketing cost of marigold and gladiolus were Tk. 132,949.18 and Tk. 49,382.46 respectively. So, per hectare total cost was Tk. 373,246.95 for marigold and Tk. 740275.98 for gladiolus.

The marketing cost (Tk./ha) of marigold (132,949.18) was higher than the marketing cost gladiolus (49,382.46) due to the higher yield of marigold in the study area. And the total cost of gladiolus was higher than the total cost of marigold due to input cost especially seed cost was higher for gladiolus.

Profitability of production of selected flower

Per hectare, gross return for marigold and gladiolus was Tk. 655,722.20 and Tk. 1,421,550.00 respectively; and gross margins per hectare for marigold and gladiolus were Tk. 483,188.45 and Tk. 817,824.14 respectively. So, the net return per hectare for marigold was Tk. 282475.27 and Tk. 681274.02 for gladiolus (table II).

The benefit-cost ratio was 1.75 for marigold and 1.92 for gladiolus, indicating that cut flower cultivation is profitable in the study area. A higher benefit-cost ratio for gladiolus reveals that the cultivation of gladiolus is more profitable than that of marigold. This study is consistent with

Table 2. Per hectare return from the production of selected flower.

No.	Particulars	Marigold	Gladiolus
a.	Yield (no. in '00')	60158.00	2187.00
b.	Price (Tk./ 100 flowers)	10.90	650.00
c.	Gross return (Tk./ha) (a*b)	655722.20	1421550.00
d.	Variable cost (Tk./ha)	172533.75	603725.86
e.	Total cost (Tk./ha)	373246.95	740275.98
f.	Gross margin (c-d) (Tk./ha)	483188.45	817824.14
g.	Net return (c-e) (Tk./ha)	282475.25	681274.02
h.	Benefit-cost ratio (BCR) (c/e)	1.75	1.92
i.	Net return (Tk./100 flowers)	4.70	311.51

Source: Authors' own calculation, 2019.

earlier studies. Bagchi (2009) found that flower cultivation was profitable as the benefit-cost ratio for marigold and gladiolus was 1.87 and 2.02 respectively.

Value addition analysis of different intermediaries

The local trader, wholesaler, and retailer incurred the higher marketing cost for gladiolus than the marigold. Transportation is the highest cost item for local traders (67.38%) and wholesalers (46.20%). Besides, the highest marketing cost item for the retailer was wages of labor which was 25.47% in the study area. The average estimated marketing cost incurred by the local trader, wholesaler, and retailer was Tk. 9.87, Tk. 6.32 and Tk. 41.06 respectively per hundred flowers (Table 3).In this study, the maximum cost items of gladiolus were higher than marigold due to gladiolus need to take special care in case of transporting, assembling, handling, loading and unloading, etc.

The marketing cost incurred by local traders per hundred marigold and gladiolus were Tk. 1.38 and Tk. 18.33 respectively. The net marketing margin by the local traders for these flowers was Tk. 1.42 and Tk. 121.67 respectively. The value added by local traders for marigold and gladiolus was Tk. 2.80 and Tk. 140 respectively (per hundred flowers) due to assembling, transportation, market toll, loading and unloading activities. The percentage of value addition by

Table 3. Marketing cost of value chain intermediaries (Tk. per 100 flowers).

Cost items (Tk.)	Marigold	Gladiolus	All flowers (Average)	Percentage
Marketing cost of local trader				
Assembling	0.28	2.83	1.56	15.81
Transportation	0.80	12.50	6.65	67.38
Market toll	0.18	1.43	0.81	8.21
Loading and unloading	0.12	1.57	0.85	8.61
Total	**1.38**	**18.33**	**9.87**	**100**
Marketing cost of wholesaler				
Transportation	0.36	5.48	2.92	46.20
Market toll	0.47	2.65	1.56	24.68
Loading and unloading	0.33	3.35	1.84	29.11
Total	**1.16**	**11.48**	**6.32**	**100**
Marketing cost of retailer				
Basket	1.59	6.17	3.88	9.94
Refine	0.33	2.96	1.65	4.02
Thread	0.06	0.59	0.33	0.80
Scotch tape	0.00	5.80	2.90	7.06
Salary of staff	0.89	14.57	7.73	18.83
Wages of labor	1.65	19.26	10.46	25.47
Electricity charge	0.25	3.95	2.10	5.11
Cost of water	0.47	1.56	1.02	2.48
Telephone bill	0.41	1.73	1.07	2.61
Rent	1.11	18.77	9.94	24.21
Total	**6.76**	**75.36**	**41.06**	**100**

Source: Authors' own calculation, 2019.

Table 4. Value addition of different intermediaries of selected flower (Tk. per 100 flowers).

Particulars	Local trader			Wholesaler			Retailer		
	M	G	Average	M	G	Average	M	G	Average
a. Average purchase price	10.20	640.00	325.10	12.00	780.00	396.00	14.00	1030.00	522.00
b. Average sales price	13.00	780.00	396.50	14.66	1020.00	517.33	25.60	1350.00	687.80
c. Gross marketing margin (b-a)	2.80	140.00	71.40	2.66	240.00	121.33	11.60	320.00	165.80
d. Marketing cost	1.38	18.33	9.87	1.16	11.48	6.32	6.76	75.36	41.06
e. Net marketing margin (c-d)	1.42	121.67	61.53	1.50	228.52	115.01	4.84	244.64	124.74
f. Value addition	2.80	140.00	71.40	2.66	240.00	121.33	11.60	320.00	165.80
g. Value addition (%)	27.45	21.88	21.96	22.16	30.77	30.64	82.86	31.07	31.76

Note: M indicates Marigold and G indicates Gladiolus.

local traders was 27.45% and 21.88% for marigold and gladiolus respectively. On the other hand, the marketing cost incurred by wholesalers for marigold and gladiolus were Tk. 1.16 and Tk. 11.48 respectively (per hundred flowers) while the value addition for marigold and gladiolus were Tk. 2.66 and Tk. 240 respectively (per hundred flowers) due to transportation, market toll, loading and unloading activities. The percentage of value addition by wholesalers was 22.16% and 30.77% for marigold and gladiolus respectively (Table 3 and 4).

For marigold and gladiolus, the marketing cost incurred by the retailer was Tk. 6.76 and Tk. 75.36 respectively (per hundred flowers) and the net marketing margin was Tk. 4.84 and Tk. 244.64 respectively (per hundred flowers). The value addition for marigold and gladiolus were Tk. 11.60 and Tk. 320 respectively (per hundred flowers). The value is added due to basketing, sorting, scotch taping, management of staff and labor, etc. activities at the retailer level. The percentage of value addition by wholesalers was 82.86% and 31.07% for marigold and gladiolus respectively (Table 3 and 4).

From the calculation of Table 4, it is clear that the average values added by local traders, wholesalers, and retailers were Tk. 71.40, Tk. 121.33 and Tk. 165.80 respectively (per hundred flowers). Moreover, the average percentage of value added by the local trader, wholesaler, and retailer was 21.96, 30.64, and 31.76 respectively (per hundred flowers). This present study found that the value added by the retailers was the highest Tk. 165.80, followed by wholesaler Tk. 121.33 and local trader Tk. 71.40 (per hundred flowers) and it is consistent with the result of Bagchi (2009) who found that the value added by retailers was the highest at Tk. 128, followed by wholesalers Tk. 76 and local trader Tk. 55 (per hundred flowers).However, Manjira (2018) stated that the highest marketing cost was incurred by the Dhaka wholesalers at Tk. 68.2 followed by retailers Tk. 59.7 due to the wholesaler transportation cost and shop rent were higher.

Distribution of cost and net return

Figure 4 shows that the cost incurred by the retailer was highest for both marigold (Tk. 20.76) and gladiolus (Tk. 1,105.36) per hundred flowers. Net return was highest for the retailer (Tk. 4.84) followed by producer (Tk. 4.70), wholesaler (Tk.

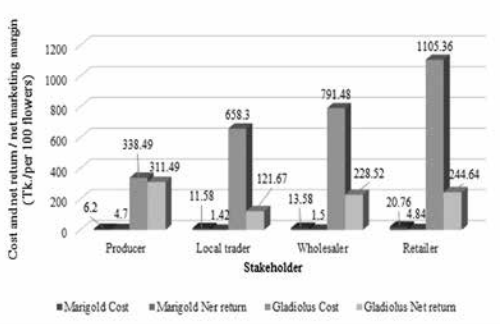

Figure 4. Distribution of cost and net return/net marketing margin received by different stakeholders of marigold.

1.50) and Bepari (local trader) (Tk. 1.42) per hundred marigold flowers. However, we found that per hundred gladiolus flowers net return was highest for the producer (Tk. 311.49) followed by the retailer (Tk. 244.64), wholesaler (Tk. 228.52), and local trader (Tk. 121.67) in the study area.

Conclusion

Cut flower production has been become an important and innovative venture both at the national and international levels. The findings of the study indicate that trading for the cut flower was profitable for different intermediaries in the study areas. Therefore, there is a considerable scope exists to increase the productivity of cut flowers and to develop the value chain. Cut flower cultivation could create employment opportunities for rural people and improve their standard of living. So, it can be said that flower cultivation had wider scope in Bangladesh. Besides, this study can be a base or foundation for conducting further studies on flower value chain analysis and forecasting of cut flower export in Bangladesh. The Government of Bangladesh should provide subsidies on inputs of flowers to encourage the farmers to cultivate flowers and improve their rural livelihood. Moreover, the government need to develop the good transport facilities reducing the spoilage of flowers. Besides, more emphasis should be given to floriculture research.

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Original Research

Commercial cultivation and profitability of medicinal plants in Natore district of Bangladesh

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ABSTRACT

Medicinal plants (MPs) contribute to human, animal and fisheries health, but MP sector faced the most destruction of its species. Commercial MP cultivation is profit, employment and income generating, but it is still now in a rudimentary stage in Bangladesh. So, this study could enhance commercial cultivation of MPs through providing updated information and finding out existing condition of MP sector. A commercially cultivated and dominated cluster of MPs, Laxmipur Kholabaria union of Natore district in Bangladesh was selected as the study area. Ten MPs produced in the union like Amrul, Basok, Ghritokumari, Hostipolash, Kalomegh, Misridana, Oshwagandha, Shotomul, Shimulmul and Tulsi were selected for investigation. Total 60 MP producers were selected randomly from a list of MP producers. The estimated net return per hectare was the highest for Ghritokumari (Tk.21,02,587) and the lowest for Tulsi (Tk.80,257) whereas BCR was the highest for Hostipolash (3.11) and the lowest for Tulsi (1.44). Lack of improved variety, method and technology; lack of producer – outside buyer linkages, unstable demand and supply; absence of MP producers' association; etc. are the major problems for MP cultivation. Finally, government and non-government organizations should come forward with necessary supports for promoting and sustaining the MP cultivation commercially.

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Introduction

Medicinal plants (MPs) are an important part of our natural and cultural wealth. The cultivation and use of MPs have been started probably dates back to the beginning of human civilization. At one time, Bangladesh as a tropical country was very rich in diverse natural MPs and these were collected only from natural sources. Unfortunately, due to over population pressure, over exploitation, deforestation and change in land use patterns, many species of MPs have reached the fate of extinction or severe genetic loss. In addition, the country is facing serious consequences of biodiversity loss from the over use of high toxic chemical inputs in agriculture and the global climate change that are the causes for destroying the MP species. In early 80's, ayurvedic and unani companies procured 80%

of MPs from natural forests and the rest was from import. Now the scenario has changed: 80% are imported and 20% are procured from domestic production (Merry & Shahjahan, 2014). In spite of this inverse situation, Bangladesh is still now blessed with innumerable genetic diversity of MPs. Bangladesh Agricultural Research Institute (BARI) recorded 722 plant species, growing or available in Bangladesh have medicinal values. More than 8,000 plant species are used as MPs in the world. Four thousand plant species are used as MPs in India while in Bangladesh only 700 plants are used. Currently, about 255 MPs are used for preparation of ayurvedic and unani medicine (Mohiuddin, 2014).

Cultivation of MPs contributes significantly to the economy of Bangladesh. Some advantages of MPs cultivation are: traditional healing in MP medicines, higher productivity in small land and can be cultivated year round (Rahman, 2014).Moreover,fertile and suitable land for MPs cultivation, easy production,lower production cost and better quality of production are the other advantages (Buiyan, 2014).But in Bangladesh, majority of the farmers are still now unaware about the profitability of MPs cultivation. So, it is clear that MP cultivation is still in a rudimentary stage. Few farmers are now cultivating MPs with their own initiatives. The commercial cultivation of MPs started in early 1990s mainly in Natore district (Rahman, 2014). But their cultivation is in rudimentary stage yet. Cultivation at company level is sporadic or in patchy form. No prescribed cultivation methods are still practiced. Farmers cultivate in their own way using indiscriminate harvesting and storage methods. Both farmers and different NGOs are cultivating and promoting MPs but it exists in a very small-scale. Bangladesh Forest Research Institute (BFRI) has initiated culture practice of different market demandable MPs in hilly area addressing Good Agricultural Practice (GAP). BFRI is also helping to develop linkage between producers and commercial users (pharmaceuticals). This venture will create an avenue of extending cultivation practice of MPs in greater hill districts as cash crop for alleviating poverty of tribal people. MPs are invaluable resource in the present world. At one time, in Bangladesh these resources were used as curative of various diseases all over the country. Rural poor and ethnic people generally use MPs as a panacea of all ailments. So, modern production practices with an effective business link to the market will be able to return the golden past history of MPs in Bangladesh which will help producers, traders and other parties related to MPs all over the country.

MPs play an important role in the socio-economic and health sectors of Bangladesh. They can create opportunities for alternate income generation. The cultivation of MP can uplift the socio-economic condition of rural and tribal people through occurring diverse ecosystems (Banik et al., 2014). MP cultivation is needed for reducing poverty, increasing employment, development of door step pharmacy, reducing dependency on synthetic drug,meeting demand for raw materials to herbal drug processing companies, reducing soil erosion and enhancing better environment. In this circumstance, to achieve 'Sustainable Development Goals' (SDGs) and to meet demand for pharmaceuticals and various herbal users, cultivation of MPs has no alternative. In human life, the significant of MPs is unlimited. MPs obviously make fundamental contributions to human health, animal and fisheries health, disease control, feed additives, nutrient supplement, healthy food, herbal drink, toiletries, scent, flavour and fragrant, etc. (Merry et al., 2014).

MPs research in Asia continues to receive significant national and international attention, particularly concerning its multiple roles in poverty alleviation and health care support. From the reviews, five key lessons are drawn: Asian MP production systems demonstrate continuous shift from wild gathering to cultivation; sub-regional variations for traditional healing, modern healthcare, and livelihoods support; knowledge on the effect of multi-scale institutional arrangements (formal and informal) on MP management practices is fragmented; very few studies dwell on the challenges of medicinal plants commercialization; and patronisation of law enforcement,

benefit and knowledge sharing, and research and development to serve the interest of medicinal plants production actors (Astutik et al., 2019).

Institutional development and support policy and also expert and expert support are almost absent in this sector in Bangladesh. Some formal advices are generally provided to the MP producers only for maintaining the farmers' contacts through local agriculture office. So, existing institutional development program, expert support and policy support need to be assessed to build a comprehensive favorable agribusiness environment for MP producers' level in the country. Although some research studies were completed earlier on the MP production mainly on the basis of survey and observation, detail and comprehensive agribusiness studies on this sector are essential. Most parts of the study are a new addition in which latest information and data on present condition of the sector were used. The study will provide specific findings for the sector in terms of activities,supply chain, profitability, problems and agribusiness environment. The specific objectives of the study are to determine activities and problems, supply chain and profitability of medicinal plant production enterprises and provide suggestions for policy measures for promoting the enterprises.

Materials and methods

Investigated area

To fulfill the purposes of the study, commercially cultivated and dominated clusters of MPs i.e. Laxmipur-Kholabaria union of Natore Sadar Upazila in Natore district of Bangladesh was selected for collection of primary data. Besides, due to backward and forward linkage actors of MP production enterprise, this union was selected as investigated area for the research work. Ten villages under this union, such as Kholabaria, Kathalbaria, Borobaria, Luxmipur, Ibrahimpur, Dakkhinpur, Gazipur, Hoybatpur, Dorabpur and Chauri are closely situated and for this reason, they were identified as single cluster for the MP production. About 109 types of MPs are produced in the union, of which 10 MPs such as Amrul, Basok, Ghritokumari, Hostipolash, Kalomegh, Misridana, Oshwagandha, Shotomul, Shimulmul and Tulsi were selected as they are produced in large scale in the selected area. Moreover, after completing several field visits properly, the union was selected as investigated areas.

Sampling technique

For collecting the primary data, 60 MP producers out of about 400 in the union were selected as samples. Before the selection of sample units and size, a complete list of sampling units (sampling frame) of MP producers in the union was collected from local Upazila agriculture office. Both purposive and random sampling technique was followed in selecting samples of MP producers.

Data collection and Processing

For the study the primary data were collected from MP producers through face-to-face interview by using questionnaire. The questionnaire was developed based on the basic information collected through FGDs and field visits, and field experience and then finalized by an effective field test. The collected information and data were properly processed with necessary cleaning and editing and finally, the processed data were analyzed by different quantitative and qualitative methods. The collected information data were not recorded by the respondents and generally provided from their memory sources. Secondary data used in the study were compiled from different sources, i.e. journals, reports, documents, websites, books, and handouts, etc.

Period of data collection

The collection period of primary and secondary data collection was normally 1st January 2016 to 31st December2017. Moreover, the survey for the primary data collection using questionnaire was performed in the study area mainly from 1stJuly 2017 to 31st December 2017.

Method of data analysis

To achieve the objectives of the study, the collected data were analyzed by applying the most appropriate available and necessary methods, tools and techniques and in this case, both qualitative and quantitative analysis method

Table 1. Yielded products of cultivated MPs in producers' level.

MPs	Main product	By-product	MPs	Main product	By-product
Amrul	Green root	Residual (motha)	Misridana	Green corn *(dana)*	Residual (motha)
Basok	Dry leaf with stem	-	Oshwagondha	Dry root	Dry seed, dry plant
Ghritokumari	Green leaf	Immature seedling, mature plant	Shotomul	Green root	Dry seed
Hostipolash	Green root	Dry seed	Shimulmul	Green root	-
Kalomegh	Dry full plant	Dry seed	Tulsi	Dry plant excluding root	Dry seed

Source: Field Survey, 2017.

was applied. For data analysis, Microsoft Office Excel was used. The major activities of MP producers were descriptive information which was explained by tabular analysis. For numerical estimation, the basic statistical techniques like mean, sum, minimum, maximum or percentages were used. Moreover, the supply chain mapping technique was applied for determining backward and forward linkages to MP production enterprise. Besides, several financial formulas were used for analysis the profitability of MP production in calculation of gross return, total cost, net return and benefit cost ratio which as follows.

The gross return (GR) of *AP* was calculated by multiplying the total output at the farm gate price. The formula is-

$$(a)GR_i = \sum_{i=1}^{n} p_i * y_i$$

Where

y_1=Quantity of the product; and

p_1 = Per unit price of product.

Gross margin (GM) was measured where variable cost (is deducted from gross return, then net margin (NM) was estimated by deducting fixed costs (from GM. For this purpose, the following equation proposed by Dillon and Hardaker (1993) was used.

$$\mathrm{GM}_i = GR_i - TVC_i$$

Where total cost (TC) includes all types of variable and fixed costs involved in the production process. The total cost was estimated as follows:

$$(b)TC_i = \sum_{j=1}^{n} P_{x_{ij}} x_{ij} + \mathrm{TFC_i}$$

Where $\sum_{i=1}^{n} P_{x_{ij}} x_{ij} = \mathrm{TVC_i}$ =Total variable cost; x_{ij} = Quantity of the j^{th} variable; P_{xij}= Per unit price of the j^{th} variable input; and $\mathrm{TFC_i}$ = Total fixed cost.

$$\mathrm{NM}_i = GM_i - \mathrm{TFC}$$

Then the study analysed benefit-cost ratio (BCR). Here, BCR was computed in the undiscounted level, the formula of undiscounted BCR is:

$$(c)BCR_i = \frac{GR_i}{TC_i}$$

It is accepted from value of BCR that a high ratio value more than one indicates MP production as a profitable enterprise in the study area.

Results and discussion

Activities of MP producers

The activities followed by the producers for cultivation and marketing of the MPs are discussed below.

MP cultivation by producers

The highest number (80%) of producers was involved in the cultivation of Ghritokumari, whereas the lowest (13%) were involved in the Basok cultivation ((based on results of analysis) Due to several factors, like availability of

Table 2. Cultivated area and yield of main products from MPs.

MPs	Cultivated area (dec.)	Yield		Harvest in life (no.)
		Kg/ha		
	Aver	Main product	Aver	
Amrul	5	Green root	14488	One
Basok	4	Dry leaf with stem	16414	Several
Ghritokumari	33	Green leaf	169474	Several
Hostipolash	6	Green root	15975	Several
Kalomegh	5	Full dry plant	3435	One
Misridana	10	Green corn(dana)	7364	One
Oshwagondha	26	Dry root	1717	One
Shotomul	5	Green root	15959	One
Shimulmul	38	Green root	17210	One
Tulsi	3	Dry plant part without root	2458	One

Source: Field Survey, 2017.

cultivable land, high yield and return, facility of selling and return earning year round, the highest number of producers were involved in Ghritokumari cultivation. Overall, some common factors i.e. availability of suitable land, quantity of yield, price of product, scope of product selling in all time, duration of MP life, return of MP production, etc. influenced the producers in involving of MP cultivation.

Land utilisation for MP cultivation

Only 7% of MP plants were grown in homestead area and the rest in other area. More than one-third of own land was cultivated for MP production, while it was 94% for other land. Overall, 41% of cultivated land was utilised for MP cultivation in the study area (based on results of analysis)

Period of MP cultivation

Planting period ranges from mid-March to mid-June for Amrul, Kalomegh, Misridana, Shimulmul and Tulsi, from mid-October to mid-December for Ghritokumari and the whole year for the other plants. The plant life cycle varies from 2 to 31 months being minimum for Shimulmul and maximum for Basok. Moreover,

Table 3. Processed forms and parts of MPs in producers' level.

Name of plant	Parts used/sold	Multi forms	Major forms sold in producers' level
Amrul	Root	Green, dry, dust	Green
Basok	Leaf with stem	Green, dry, dust	Dry
Ghritokumari	Leaf	Green	Green
Hostipolash	Root	Green, dust	Green
Kalomegh	Full plant	Green, dry	Dry
Misridana	Corn (*Dana*)	Green, dry, dust	Green
Oshwagondha	Root	Dry, dust	Dry
Shotomul	Root	Green, dust	Green
Shimulmul	Root	Green, dry, dust	Green
Tulsi	Full plant part without root	Green, dry	Dry

Table 4. Packet size of MP products in producers' level.

MPs	Packet size (Kg)		MPs	Packet size (Kg)	
	Green form	Dry form		Green form	Dry form
Amrul	5 - 40	-	Misridana	1 - 80	-
Basok	-	01 - 80	Oshwagondha	-	1 - 60
Ghritokumari	50	-	Shotomul	5 - 50	-
Hostipolash	1-10	-	Shimulmul	50 -80	-
Kalomegh	-	1 – 5 (in bundle)	Tulsi	-	1 – 10

Source: Field survey, 2017.

almost all the (8) MPs have life span of less than 1 year (based on results of analysis).

Activities of MP cultivation in producers' level

In the study area, different types of activities are done in homestead garden and field for cultivation of MPs. Different sowing/planting materials of MPs are collected by producers from different sources which are: the producers' own source, local MP producers, local seed suppliers, local seedling suppliers and local MP wholesaler-cum-retailers. For cultivation of MPs, land is prepared usually by tilling method. There was no prescribed method for MP cultivation provided by any government or non-government organization. All the methods, the technologies and the doses practiced by the producers were traditionally gained from one another or by generation or innovated from own knowledge and experiences.

It is depicted in Table 1 that among the main products, green root was collected from 4 MPs while others were collected from 1 MP each. In the case of by-products, seed was harvested from Hostipolash, Kalomegh, Oshwagandha, Shotomul, Tulsi; while residual (motha) from Amrul, Misridana and others from 1 MP each. Moreover, green root is the most important main product and immature seedling and matured plant were the most important by-products in the study area.

It is found in Table 2 that area under cultivation of MPs was the largest average of 38 decimals for Shimulmul and the lowest of 3 decimals for Tulsi. Average yield of main product per hectare ranged from the lowest of 1,717 kg of dry root for Oshwagondha to the largest of 169,474 kg of green leaf for Ghritokumari. Basok, Ghritokumari and Hostipolash were harvested several times while the others (Amrul, Kalomegh, Misridana, Oshwagandha, Shotomul, Shimulmul and Tulsi) were harvested one time in the study area. Finally, there is found a positive relationship among area, yield and number of harvest. As each type of MP contains separate and independent characters botanically in its life cycle from other MPs in major terms of life duration, produced product, forms (green, dry), weight and yield of produced products; yields of MPs were differed among one another in the study area.

Processing of MPs in producers' level

Producers sell their products in green or dry forms. Green products are sold after primary processing, while the dry ones are always sold after secondary processing. Various processing forms are mentioned in Table 3.

In Table 3, it is indicated that Amrul, Basok, Misridana and Shimulmul were sold in maximum three forms, that is green, dry and dust; and green form was practiced almost all the MPs. On the other hand, green form was also the highly practiced form for major or single form sale followed by dry form. So, the producers deal with their products in different forms but green form was the dominant for processing MPs in the study area.

Storing, packaging, standardization, grading and transportation of MPs in producers' level

Almost all types of the products are sold locally during harvesting season by the producers. Due to lower demand and price during harvesting; Basok, Kalomegh, Oshwagondha and Tulsi are stored in dry form at producers' house usually within a week to 3 months. Products are usually stored in packet, container or in open form. The packets are plastic bags while the containers are bamboo baskets. No specific standard or grade is maintained by the producers in any stage of selling of their products. Table 4 depicts that packet size of product varies among both types and forms of MPs under study. In both cases, packet varies from 1–80 kg. The highest of 80 kg packet size was found in green Shimulmul and Misridana while it was the same for Basok in dry form.

No specialized transport is used by the producers for carrying their MPs and products. Motor operating van (including electric charging battery) is used by the producers for carrying the plants from field to processing place, but in absence of the road connection the plants are carried by head-loading. In case of selling in local markets, producers usually transport the products by hired motor operating van. Sometimes own by-cycle is also used to carry the products.

Selling of medicinal products by producers

The products are generally sold in either cultivation plot or residence of the producers and in local markets to different kinds of local buyers. Major portions of the products are sold to the wholesaler-cum-retailers and the processors. The rest of the portions is sold to the hoarders, *hawkers/farias* and *hakims/kobirazs*. It was found that processors, hoarders, *hawkers/farias* and *hakims/kobirazs* purchase the products both from cultivation plot and residence, while local

Table 5. Selling price of MP products in producers' level.

MPs	Price (Tk./unit)					
	Main products			By-products		
	Main product	Unit	Ave	By-product	Unit	Ave
Amrul	Green root	Kg	33	Residual (Motha)	Kg	47
Basok	Dry leaf with stem	Kg	82	-	-	-
Ghritokumari	Green leaf	Kg	13	Immature seedling	No.	0.80
	-	-	-	Mature plant	No.	27
Hostipolash	Green root	Kg	75	Dry seed	Kg	1013
Kalomegh	Dry full plant	Kg	97	Dry seed	Kg	1575
Misridana	Green corn *(dana)*	Kg	47	Residual (Motha)	Kg	102
Oshwagondha	Dry root	Kg	203	Dry seed	Kg	1835
	-	-	-	Dry plant	Kg	23
Shotomul	Green root	Kg	53	Dry seed	Kg	1300
Shimulmul	Green root	Kg	23	-	-	-
Tulsi	Dry plant part	Kg	102	Dry seed	Kg	2029

Source: Field survey, 2017.

wholesaler-cum-retailers purchase almost in their shops.

It was found that selling price is fixed by open bargaining without any artificial pressure. Almost all payments are made in cash during transaction.

It is depicted in Table 5that the lowest selling price of Tk. 203/kg is associated with Oshwagondha as main product which is linked with the second highest price of Tk. 1815/kg as by-products. Tulsi receives the highest price as by-product in the study area. So, price variation makes MP market risky for the producers but higher risk is associated with higher prices in the areas under study.

Main activities performed by MP production entrepreneurs identified in present study were land selection and tillage;collection,sowing and planting of seed and seedling;fertilizer application; pest and disease control; irrigation; weeding; processing, packaging, storage, transportation, price fixing, sales promotion of MP products; etc. Sharmin (2004), Shahidullah and Haque (2010), Merry et al. (2014), Mohiudiin (2014), and Rashid et al. (2014) in Bangladesh; Deshpande et al. (2006) and Sivaramane, N. and Kumar, R. (2018) in India, and Hashe et al. (2016) in Ethiopia also mentioned many similar activities in their studies. Major buyers of medicinal plants and products dealt in present study are local MP producers, wholesaler-cum-retailers, processors, hoarders, *hawkers/farias, and hakims/kobirazs*. So, price variation results of the present study are supported by the findings of other studies done previously in terms of buyer and market categories, seasons, selling time, etc.

Supply chain of MP production enterprise

In the study area, a strong and organized supply chain associated with different types of entrepreneurs/actors were found. In the supply chain, nine actors were identified and they are MP producers, seed suppliers, seedling growers, wholesaler-cum-retailers, processors, hoarders, *Hawkers, Kobirazs* and *Ghritokumari* suppliers. Among the actors, MP producers are the principal actor. Apart from the producers, eight entrepreneurs/actors were involved in backward and forward linkages of the supply chain (Figure 1). Seed suppliers and seedling growers were at backward, whereas wholesaler-cum-retailers, processors, hoarders, *Hawkers, Kobirazs* and Ghritokumari suppliers were at forward stage. It is found that several wholesaler-cum-retailers were also involved at backward stage mainly as seed suppliers. All the entrepreneurs/actors and stakeholders involved in the MP production supply chain were shown in Figure 1. The activities performed by the supply chain actors were discussed below.

Local seed suppliers

Local medicinal seed suppliers act as backward linkage actors in the supply chain. They are involved only in purchasing and selling of seeds

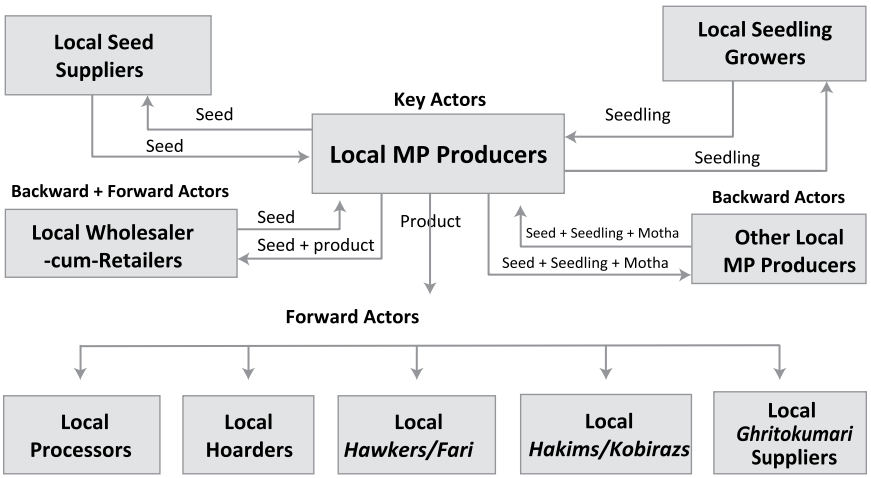

Figure 1. Supply chain of medicinal plants.

Table 6. Total cost of MP cultivation (Average in hectare).

MPs	Total input cost (Tk.)	Total labour & machinery cost (Tk.)	Total opportunity cost (Tk.)	Total cost (Tk./ha)
Amrul	127396	123348	77045	327789
Basok	224122	181563	259023	664708
Ghritokumari	1089743	352982	148564	1591289
Hostipolash	79802	104025	219090	402917
Kalomegh	57734	104048	71707	233489
Misridana	113437	84330	73866	271633
Oshwagondha	69646	81389	71062	222097
Shotomul	109724	139579	153916	403219
Shimulmul	53232	47326	68033	168591
Tulsi	30378	83427	68828	182633

Source: Field Survey, 2017.

locally and create 'possession utility' of the seeds. They collect seeds mainly from the local producers and then sell locally to local MP producers, local seedling growers, outside MP producers and outside medicinal companies.

Local seedling growers

Local seedling growers are also backward linkage actors in supply chain and involved both in growing and selling of the seedlings. Several functions like seed and seedling (immature) collection, seed sowing, seedling planting, input application, intercultural operations, seedling selling, etc. were performed by local seeding growers. The seedlings were always sold from the nurseries by the growers to local and outside producers, local and outside *Hawkers/Farias*, local and outside *Hakims/Kobirazs*, medicinal companies, NGOs and visiting teams/visitors.

Local producers

Producers are the major actors in the supply chain of MP enterprises. The producers involved with cultivation of MPs and marketing of MP products locally. The activities include seed and seedling collection, tillage of land, input application, intercultural operations, plant harvest, and product processing and selling. The producers process the products only for selling, not for value addition. As a result, 'possession utility' of the products is created by the producers through selling. The MPs are sold to local wholesaler-cum-retailers, local processors, local hoarders, local *Hawkers,* local *Kobirazs* and local Ghritokumari suppliers.

Local wholesaler-cum-retailers

Local wholesaler-cum-retailers work at forward linkage of supply chain and operate their business in their own or hired permanent shops in local market. Almost all the activities related to purchasing and selling of the products were performed in the shops. They deal with the products of all forms - green, dry and dust. They collected the products from local plant producers, local processors, and local hoarders and sold the products to local and outside *hawkers/farias,* local and outside *hakims/kobirazs,* outside wholesaler-cum-retailers and outside medicinal companies. They also involved as both forward and backward linkage actors in the supply chain for MP seed business and in this case, they collected seeds from local MP producers and local seed suppliers and then the purchased seeds are sold to the local MP producers.

Local processors

Local medicinal product processors are value adding actors in forward stage in the supply chain and are professionally involved in processing of MP products. All activities of processing are performed in the processors' residences. The product processing is the most physical

Table 7. Gross return of MP cultivation (Average per hectare).

MPs	Product category	Quantity of product		Selling price (Tk./unit)	Product-wise return (Tk.)	Gross return (Tk./ha)
		Unit	Quantity			
Amrul	Green root	Kg	14488	33	478104	582538
	Residual (motha)	Kg	2222	47	104434	
Basok	Dry leaf (with stem)	Kg	16414	82	1345948	1345948
Ghritokumari	Green leaf	Kg	169474	13	2203162	3693876
	Immature seedling	No.	147475	0.80	117980	
	Mature plant	No.	50842	27	1372734	
Hostipolash	Green root	Kg	15975	75	1198125	1251814
	Dry seed	Kg	53	1013	53689	
Kalomegh	Full dry plant	Kg	3435	97	333195	363120
	Dry seed	Kg	19	1575	29925	
Misridana	Green corn *(dana)*	Kg	7364	47	346108	521752
	Residual (motha)	Kg	1722	102	175644	
Oshwagondha	Dry root	Kg	1717	203	348551	405563
	Dry seed	Kg	24	1835	44040	
	Dry plant	Kg	564	23	12972	
Shotomul	Green root	Kg	15959	53	845827	921227
	Dry seed	Kg	58	1300	75400	
Shimulmul	Green root	Kg	17210	23	395830	395830
Tulsi	Full dry plant (excluding root)	Kg	2458	102	250716	262890
	Dry seed	Kg	6	2029	12174	

Source: Field survey, 2017.

hard-working activity among all the activities in MP enterprises. Value is added by processors through 3 types of processing - primary, secondary and tertiary. The processors purchase only green and dry products from the local producers. Then the purchased green and dry products are sold by the processors in green, dry and dust form. This creates 'form utility' of the products. The processed products are sold by the processors to local wholesaler-cum-retailers, local hoarders, local *Hawkers/Farias,* local *Hakims/Kobirazs*, outside traders, and regional and national medicinal companies.

Local hoarders

Local hoarders are mainly involved in storing of MP dry products. Sometimes, they purchase green products and perform drying activities before storing of the products. The products are usually stored in separate rooms of the hoarders' residence. The hoarders are involved only in wholesale business of medicinal products. As storage period of the products depends on market demand and price, the hoarders sell their products throughout the year. The hoarders create 'time utility' of the products. The hoarders purchase products for storage from local plant producers and local processors. They sell to local wholesalers-cum-retailers, outside wholesale traders, and regional and national medicinal companies.

Local Hawkers/Farias

Local *Hawkers/Farias* work at forward linkage in the supply chain. They operate their business

in outside of local areas and stay in different business spots ordinarily for the period of 2 to 5 days in a week or 15 to 25 days in a month. They collect products locally and usually one time in a week or month before they travel to business place. They always sell products in the same form of purchase. They create 'place utility' of the products. The sources of purchase are local wholesaler-cum-retailers, local plant producers, local processors and home supplied (own). They sell the products to local users/patients, local *Hawkers/Farias*, local *Hakims/Kobirazs,* and local retail traders.

Local Hakims/Kobirazs

Local *Hakims/Kobirazs* provide herbal treatment as general village practitioners at their residences. Sometimes they stay in their own shops in local markets. They do not have any formal training about herbal treatment. The *Hakims/Kobirazs* gain knowledge from their self practice and traditionally comes from predecessors, relatives, friends and neighbors who were involved in the herbal treatment practice. They prescribe and supply products as medicine to patients. The patients pay monies for the treatment service and medicine. The *Hakims/Kobirazs* create 'form utility' of the products through converting the products into medicine.

Local Ghritokumari suppliers

Local Ghritokumari suppliers operate their business at forward linkage in supply chain. They are known as agribusiness group under the name of 'Ghritokumary Supply Association'. The group is not formally organized and work together based on verbal agreement. The Ghritokumari suppliers collect Ghritokumari from the producers' plot and supply to the outside buyers of wholesalers, processors, agro-product processing companies and medicinal companies from the local roadside fixed point selected by local Ghritokumari Supplier's Association. Thus, they create 'place utility.' Major activities performed by the Ghritokumari suppliers are purchasing, selling, primary processing, packaging, procurement, transportation, etc.

Dixie et al. (2003) dipicted the MP supply chain and identified different market actors, such as farmers/collectors, shoppers, wholesalers, Bepari, processors, primary processors *(Kobirazs).* Sharmin (2004) showed a marketing channel of MPs comprising seven market players, such as cultivators/growers, wild plant pickers, nursery owners, *hawker, bepari, mahazan* and farmers group. Merry et al. (2013), BFTI (2016), Kop et al. (2006), Hashe et al. (2016) also found such several market actors. Astutik et al.(2019) identified a general market structure of Asian medicinal plants formulating of a large number actors i.e. farmers, local traders (village/local traders, middlemen of big traders), regional traders/wholesalers, national traders, exporters, international markets, importers, distributors/ stores, consumers/end users, traditional markets, traditional healers/herbalists, herbal/pharmaceutical industries, farmers cooperative/association, organizations/institutes (forest/agriculture departments, research institutes, NGOs), gatherers. So, it is found that all the actors identified in the present study were shown partially or fully in the previous studies.

Problems encountered by Producers for MP cultivation

Many problems and constraints encountered by the producers were: absence of high yielding variety (HYV),standard method, technology and instrument/machinery;unknown and non-controlled pests and diseases; insufficient of bank loan; insufficient and inappropriate extension services and training support;lack of local MP producers - outside buyers linkage; low quality of MP seed; scarcity of trained and expert personnel in MP sector;Hampering of irrigation due to irregular electricity supply; absent of effective MP producers' association; risky due to unstable demand, supply and price.

Similar and dissimilar problems and constraints of the present study weremention by Sharmin (2004), Banik et al. (2014), Merry et al. (2013), BFTI (2016), Despande (2006), Dhungyel (2013), Rai (2013), Jayakody et al. (2013), Hung and Chi (2013), Barakoti (2013) and Sivaramane, N. and Kumar, R. (2018) both in home and abroad. But,

all the previous studies mentioned here emphasized production activies of MPs while the present study incorporated production, processing and marketing MPs and MP products, and also GOs and NGOs supports and services, policy and manual which gives an overall image of hindrance for MP sector in Bangladesh.

Profitability of MP production enterprise

For the purpose of profitability analysis, different types of costs and returns associated with MP production enterprise were studied. Total cost was the summation (average) of all individual cost of MP producers whereas gross return was the total (average) sale value of the products. On the other hand, net return of the MP production enterprise was determined from the difference between gross return and total cost and BCR was calculated from gross return by divided total cost. Gross returns and total costs per hectare for all MPs were determined on basis of average life duration for the period of beginning life to ending life till 2016. Input costs, labour and machinery costs, and opportunity costs were major cost items for all MP cultivation. Therefore, for analysis of profitability, all the costs, returns and BCR of all MPs are discussed below.

Total cost for MP production

Total cost of MP production was determined by aggregating all cost items of input cost, labour and machinery cost, and opportunity cost. In Table 6 it is shown that Ghritokumari enterprise experienced the largest total cost of production of Tk.15,91,289 per hectare which was followed by Basok, Shotomul, Hostipolash and Amrul with respective cost of Tk. 664,708, 403,219, 402,917 and 327,789, respectively. The minimum total cost per hectare was estimated for Shimulmul being Tk. 168,591. So, Ghritokumari was the costliest and Shimulmul was the cheapest MP in terms of total cost is the areas under investigation.

Gross return for MP cultivation

Gross return was the sum of total values earned through the sales of all main products, and by-products of the MPs under investigation. The value was determined by multiplying the physical quantity with respective market price. It is found in Table 7 that the highest per hectare gross return was obtained by Ghritokumari (Tk. 3,693,876) and the lowest for Tulsi (Tk. 262,890). So, gross earning capacity of Ghritokumari was the highest and it was the lowest for Tulsi under investigation. The MPs subsequent to Ghritokumari were Basok, Hostipolash, Shotomul and Amrul in term of gross earning capacity.

Net return and BCR of MP cultivation

Net return is the difference between gross return and total cost. Again BCR has been derived by

Table 8. Net return (Average per hectare) and BCR of MP cultivation.

MPs	Gross return (Tk.)	Total cost (Tk.)	Net return (Tk./ha)	BCR	Life duration of plant	
					Duration	Unit
Amrul	582538	327789	254749	1.78	10	Mon
Basok	1345948	664708	681240	2.02	31	Mon
Ghritokumari	3693876	1591289	2102587	2.32	11	Mon
Hostipolash	1251814	402917	848897	3.11	3	Yr.
Kalomegh	363120	233489	129631	1.56	10	Mon
Misridana	521752	271633	250119	1.92	13	Mon
Oshwagondha	405563	222097	183466	1.83	11	Mon
Shotomul	921227	403219	518008	2.28	2	Yr.
Shimulmul	395830	168591	227239	2.35	11	Mon
Tulsi	262890	182633	80257	1.44	8	Mon

Source: Field survey, 2017.

dividing gross return by total cost. All these figures are depicted in Table 8.

Above Table 8 indicates that net return per hectare stands the highest for Ghritokumari (Tk.21,02,587) and the lowest for Tulsi (Tk.80,257). But BCR (undiscounted) stands the highest for Hostipolash (3.11) and it is the lowest for Tulsi (1.44). So, BCR clears that all the MPs under investigation are profitable but profitability of Hostipolash is the highest followed by Shimulmul, Ghritokumari, Shotomul and Basok being the lowest for Tulsi. Again, profitability of MP cultivation maintains on an average a positive relationship with duration of plant life. This study dealt with an elaborate cost and return analysis and found that all the 10 enterprises of MPs were profitable, being some highly profitable and some generated lower profit.

This finding is partially supported by the study of Sharmin (2004) where Ghritokumari, Shimulmul and Misridana were found profitable. Although similarity of cost items was found between the present study and study of Sharmin (2004), the later one did not explain them elaborately. Cultivation of all the MPs investigated under study was estimated as profitable enterprises. Again, Jakusic and Brkic (2020) and Darthiya and Lokanadhan (2020) were also identified the cultivation of some MPs studied in the present study as profitable business but level of the profits determined among the present studies and the previous studies show variations due to difference of study time, locations, crop yields, product prices, cultivation and marketing costs, etc.

Conclusion and recommendations

Commercial production of MPs is an important emerging and growing economic activity of commercial agriculture sector in Bangladesh for specially income and employment generation in rural and urban peoples in year-round. Besides, a huge scope exits to expand markets and demands for medicinal products in country and outside countries. So, in the context of economic importance of the country, promotion and sustainability of commercial MP growing is very essential activity. But, commercial cultivation of MPs in Bangladesh is yet now in negligible stage. Besides, some major problems such as:no supply of high yielding variety (HYV) of MPs and scientific method, technology and instrument for cultivation and marketing activities of MPs; unknown and non-controlled pests and diseases; insufficient extension services, training and bank loan to MP farmers/entrepreneurs, lack of MP producer-outside buyer linkage; insufficient and irregular electricity supply for irrigation; unstable demand, supply and price of MP productsand absent of MP producers' association were identified for MP cultivation.All the MPs cultivation ingestivated under this study were identified as prifitable enterprises.In these consequencies, some recommendations for policy guilines are suggested based on the information, discussion and findings of the present study and existing status of MP sector in Bangladesh.The recommendations are:an intregrated program shoud be developedand some major activities will be implemented under the programby the coordination of GOs and NGOsfor upgrading and sustaining MP commercial production as well as MP producers/entrepreneurs.These activities are: develelop improved HYVs, methods, technologies and instruments/machineries under effective research and entend these to MP producers/ entrepreneurs; formulate appropriate training manual and providetrainig to MP producers and GOs and NGOs personnel as per the manual; increase extension services, provide subsidy and bank loan to MP producer/entreprenerurs; support for organizing MP producers association and making likages between MP producer and outside buyers and markets; establish sales centre and research station under BARI and BFRI and confirm regular electricity supply in MP cultivating areas and prepared an perfect policy manual related to overall management of MP commercial sector (including cultivation, processing, packaging, storage, standardization and grading, transformation, sales and promotion, market, selling and export, etc. for MPs and its products) in Bangladesh.

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Original Research

Impact of vermicompost and cowdung along with chemical fertilizers on yield of rice

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ABSTRACT

An experiment conducted by Bangladesh Academy for Rural Development (BARD) to compare the effects of vermicompost and cowdung and their efficacy in rice field at Tulatoli and Haratoli village, Kotbari, Cumilla, Bangladesh during January 2019 to May 2019. The soil was silty loam in texture having pH 6.55, 1.24% organic C, 0.11% total N, 12.38 ppm P, 0.186 meq/100g K, 8.0 ppm S. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and eight treatments. The treatments were T_0=Control, T_1=100% Recommended Fertilizers, T_2=100% RF + Vermicompost (5 t ha^{-1}), T_3=75% RF + Vermicompost (5 t ha^{-1}), T_4=50% RF + Vermicompost (5 t ha^{-1}), T_5=100% RF+Cowdung (5 t ha^{-1}), T_6=75% RF + Cowdung (5 t ha^{-1}), T_7=50% RF + Cowdung (5 t ha^{-1}). The best perform in term of growth and yield exhibited from the T_2 treatment and T_3 treatment as compared to cowdung with similar dose of RF. The T_2 treatment and T_1 treatment were produced 7.29 t ha^{-1} and 6.25 t ha^{-1} rice grain yield, respectively. Besides, T_5 treatment produced 6.83 t ha^{-1} rice grain yield. Therefore, it may be suggested that vermicompost in combination with chemical fertilizers might be used by the farmer to, restore soil fertility and better yield.

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Introduction

Agriculture has been a key driver of economic and rural development in the country, accounting for about 14% of GDP and employing more than 40% of the workforce (8th Five Year Plan, Bangladesh). With the introduction of modern high yielding crop varieties and intensive management practices including irrigation and fertilizer technology the country has made impressive progress in food production over the last few decades (Shah et al., 2008). For example, rice production in Bangladesh increased more than three-fold from 10.8 million tonnes (husked rice) in 1971 to about 34.7 million tonnes in 2015 (BBS, 2018). The overall growth in agriculture along with a distinct progress in rice production has enabled the country to achieve self-sufficiency in cereal production.

A variety of environmental factors influence crop production, including the availability of

necessary nutritional components in adequate quantity and at the proper time, which is critical for crops to achieve their maximum yield potential. Sixteen inorganic elements are known to be essential for the normal growth and development of crop plants. Three macronutrients namely carbon (C), hydrogen (H), and oxygen (O), required in greater quantities by crop plants, are taken up from air and water. So deficiency of these elements is never happen in nature. Plants, on the other hand, take up the other six macronutrients as well as seven micronutrients in ionic form from the soil (s). To get the best crop output, all soil nutrients must be present in sufficient and balanced proportions, as well as in usable form (BARC, 2012). Due to their requirements in larger quantities the deficiency of macronutrients like N, P, K, S, Ca and Mg is very common under intensive crop cultivation. Although micronutrients (Fe, B, Mn, Mo, Zn, Cl, Cu) are required in smaller quantities, the deficiency may happen in soil under intensive crop agriculture, especially under the condition of no or less use of organic manures.

Over the previous few decades, a great deal of focus has been placed on intensive crop farming to achieve self-sufficiency in staple food of the country, almost completely ignoring the issue of sustainability of soil fertility (Moslehuddin et al., 1997). As a result, soils of several parts of the country have severely depleted in terms of nutrients and organic matters. The widespread deficiency of phosphorus, potassium, Sulphur, zinc, boron etc. and organic matter is severely limiting crop production in the country. The organic matter level of about 53% of the country's arable lands is severely low, with less than 1% organic matter. Low organic matter status in Bangladeshi soils is due to intensive crop farming, uneven fertilizer use, little or very little use of organic manures, and depletion of crop residues from the field. According to Witt et al. (1999), the efficiency of fertilizers with nitrogen in Asia is only 20-30 per cent, and in the rest of the world only 45 per cent. In Bangladesh, the input-output balance sheet for nutrients shows a substantial net annual removal of nutrients from our soil, which exceeds 2 million tonnes per year from our arable land (Karim et al., 1994). This is a serious threat on the sustainability of our agricultural productivity. Under the above situation, it is very highly important to minimize nutrient depletion by replenishing them into the soil every year. To minimize the nutrient depletion in soil, it is not enough only to use inorganic fertilizers. It is rather very essential to add sufficient amount of organic manures, which not only add nutrients in soil but also increase the organic matter content of soil.

Farmers in Bangladesh have always used cowdung as a source of organic materials. However, since the introduction of intensive farming and the use of chemical fertilizers, the use of cowdung has decreased. Earthworm vermicomposting is a composting technology that converts complicated organic compounds into a stable, humus-like product (Benitez et al., 2000). It incorporates the cooperation of earthworms and microorganisms to stabilize active organic materials and turn them into a useful soil amendment and plant nutrient source. Because the material goes through the earthworm gut, where substantial change occurs, it is a mesophilic process that is faster than compositing. The resulting earthworm castings (worm manure) are rich in microbial activity and they retain reduced levels of contaminants and a higher saturation of nutrients, plant growth regulators and other plant growth influencing materials produced by micro-organisms including humates and are fortified with pest and root knot nematode repellence attributes as well (Arancon et al., 2005; Grappelli et al., 1987; Shi-wei et al., 1991). Vermicompost contains nutrients in such forms that are readily available to the crops, such as nitrates, exchangeable P, soluble K, Iron (Fe), Calcium (Ca), Magnesium (Mg), etc. (Ludibeth et al., 2012; Tejada et al., 2009). Because of the acceleration of soil microbial development and activity, subsequent mineralization of plant nutrients, and increased soil fertility and quality, vermicompost application to soil is regarded a good management practice in any agricultural production system (Arancon et al., 2006; Ferreras

et al., 2006). Cowdung may be the most suitable material for vermicomposting. Despite the fact that experts claim that vermicompost is better to cowdung in terms of nutrient content, some specific study questions remain. Such as: In what aspects vermicompost is better than cowdung? And in which proportion vermicompost should be used along with chemical fertilizer? That's why this study was taken to find out the nutrient concentration and chemical composition of vermicompost in comparison with cowdung; and to investigate the response of rice to vermicompost and cowdung amendment along with chemical fertilizers at farmer's field.

Materials and methods

Geographical location of the experimental site

The research work was carried out at Tulatoli village, Lalmai-Mainamati Project area in Bangladesh Academy for Rural Development (BARD), Cumilla, Bangladesh. The trial on paddy field was carried out during rabi season (January 2019 to May 2019). Geographically the experimental site is located at 23.4352° N Latitude and 91.1331° E Longitude at an elevation of 12m above the sea level. The site belonged to the Agro-Ecological Zone (AEZ-16) of *Middle Meghna River Floodplain* (FAO & UNDP, 1988).

Nutrient and chemical analysis

Nutrient concentration and chemical composition of vermicompost and cowdung were tested in Professor Muhammad Hossain Central Laboratory, Bangladesh Agricultural University, Mymensingh. After testing nutrient elements like N, P, K, S, organic carbon and moisture content of vermicompost and cowdung were determined. Standard agronomic practices as well as intercultural operations were followed in the experiments under the supervision of the researchers.

Treatments	Composition
T_0	Control
T_1	100% Recommended fertilizer (RF)
T_2	Vermicompost (5 t/ha) +100% RF
T_3	Vermicompost (5 t/ha) + 75% RF
T_4	Vermicompost (5 t/ha) +50% RF
T_5	Cowdung (5 t/ha) + 100% RF
T_6	Cowdung (5 t/ha) + 75% RF
T_7	Cowdung (5 t/ha) +50% RF

Treatments and the yield contributing characters

Three separate field experiments were conducted at farmers' field located at Lalmai-Mainamati project area of Cumilla to evaluate the yield performance of rice under the application of vermicompost and cowdung. Randomized complete block design was followed and the number of replications was three (3). The following treatments were used in the study:

Yield contributing characters

The plot size of each replication of the experiment was 4 x 3 m^2 and the rice variety BRRI Dhan-58 was selected for this experiment. During the field experiments, following yield and yield components of *Boro* rice were recorded:

i. Number of tillers/hill
ii. Number of effective tillers/hill
iii. Panicle length (cm)
iv. Number of grains/panicle
v. Number of sterile spikelets/panicle
vi. Thousand grain weight (g)
vii. Grain yield (t/ha)

Table 1. Chemical composition of vermicompost and cowdung.

Nutrient elements	Vermicompost	Cowdung
Organic carbon (%)	19.60	12.40
Nitrogen (%)	2.10	0.78
Phosphorus (ppm)	1.919	1.212
Potassium (meq./100g)	0.858	0.606
Sulphur (ppm)	0.533	0.263

viii. Straw yield (t/ha)
ix. Biological yield (t/ha)
x. Harvest index (%)

Data analysis

The recorded data were tabulated and the "Analysis of Variance" was done using computer package MSTAT-C program. The means were evaluated using post-hoc analysis with Duncan's Multiple Range Test (DMRT) at the 0.05% level of significance.

Results and discussions

Comparison of nutrient concentration and chemical composition

In general, vermicomposts of all animal/plant based organic wastes are highly potent fertilizers (Hussain et al., 2018). Vermicompost and cowdung were collected from farmer's level. After testing nutrient elements like N, P, K, S, organic carbon and moisture content of vermicompost and cowdung, it was found that vermicompost contains higher level of N, P, K, S, organic carbon as compare to cowdung. Similar trend was found by Alidadi et al. (2014) and Mukta et al. (2015).

Comparative assessment of vermicompost and cowdung

Plant height

The use of vermicompost in association with chemical fertilizers has a considerable impact on rice plant height. At harvest, plant heights ranged between 81.11 and 102.55 cm (Figure 1). Plants treated with vermicompost @ 5 t/ha and 100% RF (T2) had the highest plant height, while control (T0) plants had the lowest (Figure 1). At final harvesting time (102.55cm), the T2 (Vermicompost 5 t/ha + 100 % RF) treatment had the highest plant height, followed by T6 (96.11cm), T1 (95.56cm), T3 (95.33cm), T5 (95.33cm), T4 (94.66cm), T7 (91.44cm), and T0 (81.11 cm). Higher plant height 26.80cm, 52.89cm, 93.55cm and 102.55 cm were obtained at 20, 40, 60 and 80 DAT, respectively from vermicompost + 100% RF (T_2) treated plant as compared to cowdung, chemical fertilizers and control. The increased plant height was ascribed to T_2 might have accelerated the metabolic and physiological activity of the plant and put up more growth by assimilating more amounts of major nutrients and ultimately increased the plant height.

Number of total tillers/hill

Application of vermicompost, cowdung, and chemical fertilizers had a significant impact on total tillers plant-1. Cowdung @ 5 t/ha and 100% RF (T5) treated plants had the highest number of total tillers/hill (16.66), whereas T_0 treated plants had the lowest number of total tillers/hill (13.00). (Figure 2). The result of vermicompost @ 5 t/ha and 100% RF (T_2) was also good, with a score of 15.89. At the 100% RF plot, the total number of tillers was 14.44. This might be due

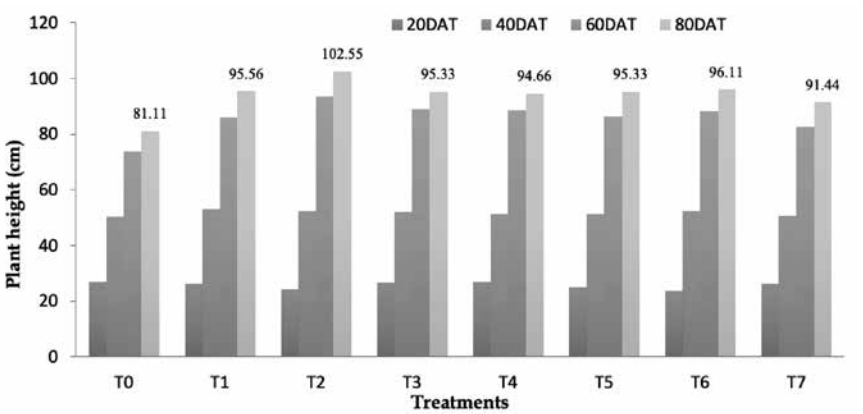

Figure 1. Comparative effect of vermicompost and cowdung on plant height.

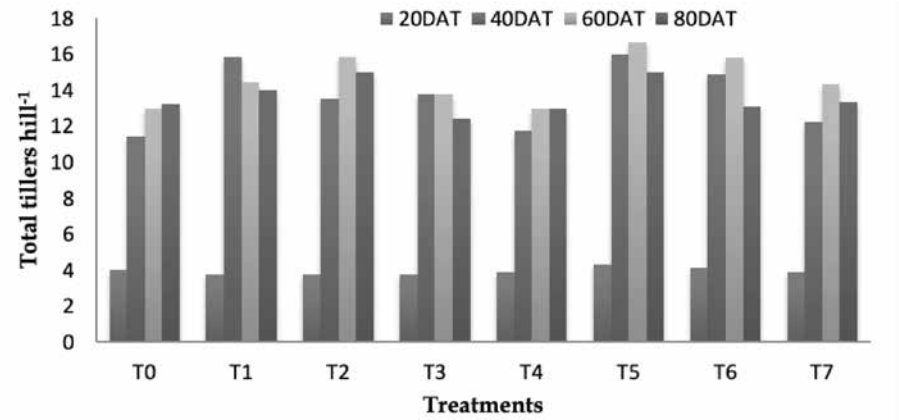

Figure 2. Comparative effect of vermicompost and cowdung on number of total tillers.

to vermicompost application which caused dual benefits of improving the physical environment of rhizosphere region and adequate supply of available nutrients to the plant. The similar results were also observed by Roy et al. (2006).

Number of effective tillers/hill

Effective tillering is primarily dependent on improved soil physical conditions as a result of organic manure application (Usman et al., 2003). Effective tillers have a direct impact on cereal productivity. In cereal cultivation, an effective tiller is the most important factor in increasing grain yield. Application of vermicompost, cowdung, and chemical fertilizers had statistically significant effects on the number of effective tillers per hill (Figure 3). Vermicompost @ 5 t/ha and 100% RF (T_2) yielded the highest total number of effective tiller hill^{-1} (14.96), which was statistically almost identical to T_3 treatment. Control (T_0) treatment yielded the lowest overall number of tiller hill^{-1} (10.36).

Number of non-effective tillers/hill

Non-effective tillers/hill was not significantly influenced by vermicompost, cowdung and chemical fertilizers application. However, numerically the highest number of non-effective tillers/hill (1.66) was obtained from the treatment T_4=50% RF + Vermicompost (5 t/ha) and the lowest number of non-effective tillers/hill (0.65) was obtained from the treatment T_7=50% RF + Cowdung (5 t/ha) as shown in the Table 2.

Panicle length

Panicle length was not significantly influenced by application of vermicompost, cowdung and chemical fertilizers (Table 2). Longest (23.44 cm) panicle was produced from the treatment vermicompost @ 5 t/ha and 100% RF (T_2). Lowest (22.77) panicle length was produced of control (T_0), which was statistically similar with T_3, T_4, T_5, T_6 and T_7.

Number of filled grains/panicle

There was a statistical variation in number of filled grains/panicle due to vermicompost and chemical fertilizers (Table 2). Results showed that highest number of filled grains/panicle was obtained (216.29) from vermicompost @ 5 t/ha and 100% RF (T_2). The lowest number of filled grains/panicle (111.33) was found from control (T_0) treatment. Gradual adequate supply of nitrogen of vermicompost contributed to grain formation which probably increased number of grain panicle^{-1} with increasing nitrogen level. Rama et al. (1989) found significantly higher filled grains/panicle with 40, 80 or 120 kg N ha^{-1}.

Number of unfilled grains/panicle

The effect of vermicompost, cowdung and chemical fertilizers on number of unfilled grains/panicle was not significant. However, numerically the highest number of unfilled grains/panicle (28.55) was found from the treatment T_6=75% RF + Cowdung (5 t/ha) and the lowest number of unfilled grains/panicle (15.77) was found

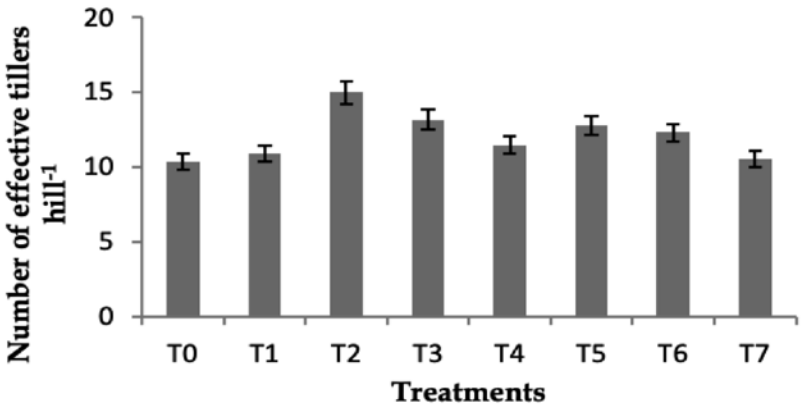

Figure 3. Comparative effect of vermicompost and cowdung on number of effective tillers/hill.

from the treatment T_4=50% RF +Vermicompost (5 t/ha) (Table 2).

1000-grain weight

The 1000-grain weight was not significantly influenced by vermicompost, cowdung and chemical fertilizers application. The highest 1000-grain weight (29.20 g) was obtained from the treatment T_7=50% RF + Cowdung (5 t/ha) and the lowest one (27.06 g) was found from the treatment T_1=100% Recommended Fertilizers (Table 2).

Grain yield

The grain production of Boro rice was significantly affected by different doses of vermicompost, cowdung, and chemical fertilizers. The highest grain yield (7.29 t/ha) was obtained from the treatment T_2=100% RF + Vermicompost (5 t/ha), which was statistically similar to the grain yield (7.09 t/ha) obtained from the treatment T_3=75 % RF + Vermicompost (5 t/ha) and the lowest grain yield (4.66 t/ha) obtained from the treatment T_0=Control (Table 2). The yield of T_3 treatment significantly higher than T_1 and T_5 treatments. Between T_3 and T_5, vermicompost and cowdung were used @ 5 t/

Table 2. Effect of vermicompost, cowdung and chemical fertilizers on yield contributing factors of Boro rice.

Treatment	Number of non -effective tillers/hill	Panicle length (cm)	Number of grains/ panicle	Number of sterile spikelets/ panicle	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
T0	1.33	22.77	111.33f	18.88	27.73	4.66f	6.16e	10.83g	43.04
T1	1.14	23.66	164.33d	22.55	27.06	6.25c	7.98bcd	14.23de	43.91
T2	1.00	23.44	216.29a	24.33	27.77	7.29a	9.18a	16.47a	44.24
T3	0.99	23.99	204.94b	27.11	28.57	7.09a	8.82ab	15.91ab	44.54
T4	1.66	23.89	157.80d	15.77	28.53	5.80d	7.85cd	13.65ef	42.51
T5	1.22	24.55	191.22c	20.88	27.82	6.83b	8.57abc	15.40bc	44.51
T6	1.33	23.55	188.03c	28.55	28.21	6.43c	8.27bcd	14.70cd	43.74
T7	1.29	23.44	127.93e	21.88	29.20	5.35e	7.65d	13.00f	41.18
LSD (0.01)	0.65	1.85	7.29	14.21	2.55	0.24	0.90	0.94	2.79
Level of significant	NS	NS	**	NS	NS	**	**	**	NS
CV%	29.55	3.42	2.45	26.07	5.18	2.22	6.40	3.77	3.68

**=Significant at 1% level of probability, NS = Not significant. In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).

ha but chemical fertilizer used 75% and 100% of the recommended dose respectively. It is very interesting that with 25% less chemical fertilizer T_3 treatment yields significantly higher than the same dose of cowdung i.e. T_5. This may be due to higher microbial stimulation effect of vermicompost and N supplied through gradual mineralization. According to Rani et al. (2001), providing one third or one fourth of the nitrogen as vermicompost boosted plant height, grain production, and yield components in rice.

Straw yield

The straw yield of Boro rice was significantly influenced by various doses of vermicompost, cowdung, and fertilizers. The treatment T_2=100% RF + Vermicompost (5 t/ha) produced the highest straw yield (9.18 t/ha), which was statistically similar to the straw yield (8.82 t/ha) obtained from the treatment T_3=75% RF + Vermicompost (5 t/ha) and the lowest (6.16 t/ha) obtained from the treatment T_0=Control (Table 2).

Biological yield

Biological yield was significantly affected by vermicompost, cowdung and chemical fertilizers application. The highest biological yield (16.47 t/ha) was obtained from the treatment T_2=100% RF + Vermicompost (5 t/ha) which was statistically similar with the result found from the treatment T_3=75% RF + Vermicompost (5 t/ha) and the lowest one (10.38 t/ha) was found from the treatment T_0=Control (Table 2). It occurred due to lack of nutrients in control application.

Harvest index

When the field was treated with varied doses of vermicompost, cowdung, and chemical fertilizers, no significant variation in the harvest index of boro rice was noticed. However, the treatment T_3=75% RF + Vermicompost (5 t/ha) had the highest numerical harvest index (44.54), whereas the treatment T_7=50% RF + Cowdung (5 t/ha) had the lowest (41.18) (Table 2).

Conclusions

The experiment was conducted during the rabi season to compare the effects of vermicompost and cowdung, as well as chemical fertilizers, on rice growth and yield. There was also a comparison of the nutritional content of vermicompost and cowdung. Plant height (cm), total tillers/hill, effective tillers/hill, number of grains/panicle, grain yield (t/ha), straw yield (t/ha) and biological yield (t/ha) all showed statistically significant variation in vermicompost applied plot, but number of non-effective tillers/hill, panicle length (cm), 1000-grain weight (g), number of unfilled grains/panicle, and harvest index (%) did not. The highest value of plant height (102.55 cm), number of total tillers/hill (14.99), number of effective tillers/hill (14.96), number of grains/panicle (216.29), grain yield (7.29 t/ha), straw yield (9.18t t/ha), biological yield (16.47t/ha) and harvest index (44.54%) were received from the treatment T_2=100% RF + Vermicompost (5 t/ha) and the lowest value obtained by control. It can be stated that vermicompost, in combination with chemical fertilizers, outperformed cowdung in terms of yield of Rice variety BRRI dhan 58. When compared to cowdung with a similar dose of RF, the dose @ 5 t/ha vermicompost with 100% RF (T_2) and @ 5 t/ha vermicompost with 75 % RF (T_3) showed the best performance in terms of growth and yield. Although there is no significant yield difference between the T_2 and T_3 treatments (7.29 t/ha and 7.09 t/ha, respectively), there is a substantial difference in the amount of chemical fertilizer needed (25 % less in T_3). We recommend, 5 t/ha vermicompost with 75% RF could be applied for Boro rice cultivation in Bangladesh, taking into account long-term viability and cost-effectiveness.

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