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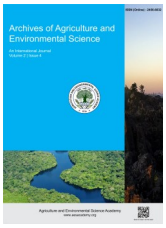

ORIGINAL RESEARCH ARTICLE

Profitability of pineapple intercrops in Madhupur upazila of Tangail district of Bangladesh

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ABSTRACT

Pineapple intercropping is a smart and sustainable agricultural practice for enhancing farm profitability and land use efficiency in Bangladesh. This study was conducted to analyze the socioeconomic characteristics and loan profile, determine the profitability, and assess the problems and constraints faced by the farmers in pineapple intercrop production in Madhupur upazila of Tangail district in Bangladesh. Primary data were collected from 90 randomly selected farmers across five villages in the study area. The study focused on three specific intercropping patterns: pineapple-aroid, pineapple-ginger, and pineapple-turmeric, with 30 farmers representing each group. The data were analyzed using tabular and profitability analysis methods. Findings reveal that the majority of farmers were middle-aged (30–64 years), primarily engaged in agriculture, with an average family size of 5.42. Most respondents belonged to the middle-income group and cultivated an average of 85 decimals of land. A significant portion of farmers received agricultural loans and demonstrated high repayment performance. All three intercropping patterns were economically viable, with a total cost per hectare of Tk. 697540.06 (US$ 5837.15) for pineapple-aroid, Tk. 720526.62 (US$ 6029.51) for pineapple-ginger, and Tk. 724033.85 (US$ 6058.86) for pineapple-turmeric. The corresponding net returns were Tk. 963130.66 (US$ 8059.67), Tk. 1206978.03 (US$ 10100.23), and Tk. 1017049.40 (US$ 8510.87), while the Benefit-Cost Ratio (BCR) stood at 2.38, 2.68, and 2.40, respectively. Although pineapple intercropping is profitable, farmers encounter significant challenges, such as high input costs and pest infestations. The government and relevant authorities must take essential actions to address the challenges and limitations encountered by farmers.

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INTRODUCTION

The majority of people in Bangladesh, an agriculturally based nation, depend on agriculture either directly or indirectly for their living. Agriculture is considered the backbone of the country's economy and plays a crucial role. Agriculture accounted for 11.02% of Bangladesh's GDP in Fiscal Year 2023–2024 (BER, 2024). Rice, jute, potatoes, maize, and wheat are among the major commodities that are grown on the nation's incredibly fertile terrain. Furthermore, a variety of fruits, vegetables, and seasonal minor crops are grown all year round, significantly boosting food security and rural livelihoods. The pineapple is one of the most important fruit crops among these. Every year, Bangladesh produces a variety of pineapples. Giant Kew, Honey Queen, and Ghorasal are the three main types that are most commonly grown in Bangladesh (Hossain & Islam, 2017). Since

pineapple thrives in tropical regions with warm, humid climates, Bangladesh's weather and soil are ideal for growing the fruit. 15°C to 32°C is the optimal temperature range for its growth (Hossain & Islam, 2017). Pineapple is grown across Bangladesh, especially in the mountainous regions where the temperature and soil are particularly ideal. The districts of Tangail, Mymensingh, Gazipur, Sylhet, Moulavibazar, Chittagong, Bandarban, Khagrachari, and Rangamati are among those that cultivate it extensively. The Tangail district's Madhupur upazila is notable among these areas for its significant pineapple cultivation. It encompassed 49% of all pineapple-growing territory and 59% of the nation's production (Hossain & Islam, 2017). Pineapple is extensively cultivated in July, all over Madhupur upazila in the Tangail district of Bangladesh. June, July, and August are the peak months for pineapple harvesting in Bangladesh (Jahan *et al*., 2024). According to The Business Standard (2024), pineapples cultivated in Tangail's Madhupur Garh region are now formally recognized as a Geographical Indication (GI) product. According to the Department of Agriculture Extension (DAE) in Tangail, Madhupur is a vital region for pineapple growing in the nation, yielding a significant quantity of pineapples valued at Tk700 crore yearly, according to an article published in the Business Standard (2024).

A delicious tropical fruit, pineapple is prized for both its high nutritious content and its pleasant flavor. It is high in vitamins and low in fat and sodium (Hossain *et al*., 2015). Pineapple is mostly eaten as a fresh, ripe fruit in Bangladesh. Its substantial nutritional and therapeutic significance is well known (Uddin *et al*., 2022; Hasan *et al*., 2023). Production of pineapple shows an upward trend in Bangladesh. A total of 39583 acres (16025 hectares) of land was cultivated, yielding 234493 metric tons of pineapple during the 2009–2010 periods (Hossain & Islam, 2017). After bananas and mangos, pineapples are the third most popular fruit in Bangladesh in terms of total cultivated area (BBS, 2022). Around 2.40 lakh tons of pineapples were produced on 7550 hectares of land in Tangail during the fiscal year 2021–2022, according to Shakil (2023). The Tangail district alone accounted for 63% of Bangladesh's 2022 pineapple production, which totaled 206,164 metric tons (BBS, 2023) (Mankhin *et al*., 2024). Bangladesh can leverage its surplus pineapple cultivation to produce canned pineapple. By meeting local demand, the country can also explore opportunities in the international market (Biswas & Nishat, 2019). However, the area under cultivation and total pineapple production in Bangladesh and Tangail has both shown a declining trend from 2020–21 to 2022–23. Tangail's production has decreased from 127795 to 123572.88 metric tons, while the country's production has decreased from 208141.88 to 196735.74 metric tons (BBS, 2023). Tangail continues to lead the nation in pineapple output despite this downturn.

Pineapple intercropping means planting a second crop next to pineapple to make the most of the area and make more money. Pineapple is a long-lasting, wide-spaced crop that can grow in partial shade. Short-season vegetables and spicy crops like aroid, ginger, turmeric, and others are good intercrops, especially when the pineapple is still growing. In Bangladesh, growing short-duration crops alongside long-duration pineapple plants are known as pineapple intercrop agriculture. This is a custom in places like Madhupur and Tangail. Papaya, bananas, ginger, turmeric, and aroids are examples of common intercrops. Because intercrops add to cash flow and promote food security, this technique diversifies income and boosts total farm productivity and profitability. Intercropping is a crucial technique for growing pineapples that greatly improves land use efficiency and raises farmers' income by enabling multiple crops to grow simultaneously on the same plot of land. As a result, many farmers in Bangladesh have implemented intercropping practices to optimize pineapple cultivation returns. In order to maximize land utilization and income, pineapples can be grown alongside a number of short-cycle crops, including bananas, ginger, and turmeric. Perennial tree species that can be grown with it include citrus, papaya, mango, and coffee, particularly in the early stages of tree orchard development (Santen, 2021). Smallholder farmers are increasingly turning to intercropping because it helps them meet a range of home needs and provides yield consistency, which gives them a yield advantage over solitary cropping. Pineapple is a significant cash crop in Tangail's hilly Madhupur district. Because it is a long-duration crop that typically takes 15 to 18 months to mature and is grown with broad spacing, it offers an excellent option for intercropping. Farmers in this region can easily plant short-duration crops alongside pineapple during its early growth phases to optimize land utilization and boost overall farm productivity (Khan *et al*., 2023). In this area, intercrops such papaya, bananas, aroids, ginger, turmeric, jackfruit, and others are commonly used. Both pineapple monocrop and pineapple intercrop production are profitable in Madhupur upazila; however, the latter is more profitable than the former. In Madhupur upazila, almost 80% of pineapple growers intercrop pineapple with aroids, papaya, bananas, ginger, and turmeric (Sultan *et al*., 2018). Farmers in the Madhupur region now have a more lucrative and sustainable choice thanks to this intercropping technique, which also enhanced net returns and the benefit-cost ratio.

Several problems with pineapple intercrops in Bangladesh were brought to light by earlier research. In contrast to solitary cropping, a study by Khan *et al.* (2023) showed that a mix of pineapple, papaya, and mukhikachu produced greater equivalent outputs. In their research, Hasan *et al.* (2010) found that growing pineapple alongside other crops increased growers' profits. They discovered that the main crops grown as intercrops with pineapple in Madhupur upazila of Tangail district were turmeric (*Curcuma longa*), ginger (*Zingiber officinale*), kachu (*Colocasia esculenta*), and jackfruit (*Artocarpus heterophyllus*). In Modhupur upazila in Bangladesh's Tangail district, a study by Akter *et al.* (2020) estimated the economic efficiency of pineapple production in Bangladesh's Madhupur upazila, which is part of the Tangail district. They discovered that the pineapple farm's mean cost efficiency was 82.61%, indicating that growers in the study area were not entirely cost-efficient.82.61% in the research area, pineapple farmers had the chance to reduce expenses

without sacrificing productivity. In the Tangail district of Bangladesh, Hoque *et al.* (2019) found that pineapple-papaya, pineapple-banana-arum, and single pineapple farming were all profitable. However, pineapple-papaya agriculture was much more profitable than the other two cropping patterns. According to Deb *et al.* (2021), 57.0% of pineapple growers in Bangladesh's Moulvibazar area had a medium level of understanding of contemporary pineapple production techniques, compared to 28.0% who had little knowledge and just 15.0% who had a high level. In their research, Uddin *et al.* (2022) discovered that the Tangail district of Bangladesh's adoption of pineapple production was influenced by labour availability, income, loan availability, and agricultural expertise. According to Datta *et al.* (2023), the main obstacles faced by farmers in Moulvibazar district were a lack of labour, damage to animals, natural disasters, loan availability issues, low seed quality, costly fertilizer, and insufficient fertilizer. Kehinde *et al.* (2021) discovered that the budgetary study indicated pineapple production was lucrative, with a Benefit-Cost Ratio (BCR) of 2.31 in Osun State, Nigeria. There is still a need for a more thorough analysis that focuses exclusively on pineapple intercropping systems, despite the fact that many studies have looked at the profitability and cultivation methods of pineapple in Bangladesh, particularly in Madhupur upazila. Assessing the economic feasibility of such systems is both pertinent and required, given the growing significance of improving agricultural income and optimizing land usage. These were the research questions derived from the above discussion: Which socioeconomic circumstances are relevant to the sample's farmers? What was the loan profile of the respondents? What is the profitability of the three specific intercropping patterns—pineapple-aroid, pineapple-ginger, and pineapple-turmeric? What were the problems and constraints faced by the pineapple intercrop farmers? The present study, therefore, seeks to analyze socioeconomic characteristics and credit behaviour of the respondents, determine the profitability of three specific intercropping patterns—pineapple-aroid, pineapple-ginger, and pineapple-turmeric within Madhupur upazila, and assess the problems and constraints faced by the intercrop farmers. The findings are expected to assist farmers, agricultural planners, and policymakers in promoting sustainable and income-generating practices in one of the most pineapple-intensive regions of the country.

MATERIALS AND METHODS

Five villages under the Madhupur upazila of the Tangail district in Bangladesh—Danokbandha, Gobdia, Kakraid, Mohishmara, and Ausnara were the sites of this study. The Simple Random Sampling approach was used to pick 90 farmers, 30 from each of the Pineapple-Aroid, Pineapple-Ginger, and Pineapple-Turmeric groups. Using a pre-tested interview plan, direct personal interviews were used to gather primary data. To get rid of mistakes in the survey schedule, the gathered data was carefully examined, revised, and categorized. In order to examine socioeconomic parameters and determine the costs and returns related to pineapple intercrop farming, the tabular technique was utilized to determine sum, average, and percentages. Gross margin, net return, and benefit-cost ratio were used to analyze profitability on a per-hectare basis.

Analytical techniques and models

The study utilized analytical tools aligned with its specified objectives. Descriptive statistics and budgetary approaches are two of the analytical tools.

Budgeting method application

The budgeting method was applied to assess the profitability of pineapple intercrop cultivation. The budgeting index reflects both the total revenue and net profit. The gross margin, as defined by Yusuf *et al.* (2016), is calculated by subtracting the total variable costs of production from the gross revenue.

Budgetary analysis employed for the purpose of this study may be quantitatively represented as; Gross Margin (GM) = Total Revenue (TR) – Total Variable Cost (TVC)

It is rewritten by a formula as:

$$GM = \sum_{i=1}^{n} P_i Q_i - \sum_{j}^{m} Y_j X_j$$

Where,

GM = Gross margin in Taka

Pi = Price of output (pineapple, intercrop, and by-product) in Taka

Qi = Quantity produced per hectare (pineapple, intercrop, and by-product)/piece/kg);

Yj = Unit price of input j in Taka

Xj = Quantity of input j used for producing output i.

Net return analysis: To determine the net return of pineapple intercrop cultivation the following equation was used:

$$\pi = P_y Y - \sum_{i=1}^{n} (P_{xi} X) - TFC$$

π = Net return (Tk./ha); P_y = per unit price of the product (Tk./piece/kg); Y= Quantity of the production per hectare (piece/kg); P_{xi} = Per unit price of i^{th} inputs (Tk.); Xi =Quantity of the i^{th} inputs per hectare (kg); TFC= Total fixed cost (Tk.); i=1,2,3……., n (number of inputs).

RESULTS AND DISCUSSION

Age distribution of the sample respondents

Age distribution impacts various types of social and economic behaviors. The financial requirements and earning potential of younger people may differ from those of older groups. The age of a farmer also plays an important role in the farming activities and management. According to some researchers, there are significant differences between younger and older farmers'

approaches to farming. In the present study, the sampled farmers were classified into three groups according to age, such as i) 15 to 29 years; ii) 30 to 64 years; and iii) 65 years and above.

Table 1 presents that, in pineapple-aroid cultivation, 6.67% of the farmers were aged 15-29 years, 70% were within the 30-64 years' age group, and the remainder were in the 65 years and above category. For pineapple-ginger cultivation, 3.33% of the farmers belonged to the 15-29 years' group, 76.67% were aged 30-64 years, and the remaining farmers were in the 65 years and above category. In the case of pineapple-turmeric cultivation, about 6.67% of the farmers were aged 15-29 years, 80% were within the 30-64 years' age group, and the rest of the percentage belongs to the 65 years and above age group. Bonna & Akter (2023) also found that most of the pineapple growers were middle-aged (31-50 years old) in the study area. Therefore, it is found from the table that the majority of farmers in all three groups were between the ages of 30 and 64, which is thought to be the most productive time frame for farming. This indicates that middle-aged farmers are essential to the production of pineapples, whereas younger and older age groups participate in the industry at comparatively lower rates.

Family size

The term "family size" refers to the number of people living in the respondents' household and having meals from the same kitchen under the administration of a single head of the family. It essentially indicates how many family members each respondent has. The national average family size of Bangladesh is 4.260 members (HIES, 2022). Based on family size, the farmers were classified into three categories. i) up to 4 members; ii) 5-6 members; and iii) more than 6 members. From Table 1 it can be seen that in the case of pineapple-aroid cultivation, about 30% of farmers had small families, 50% had medium families, and 20% had large families. Among pineapple-ginger cultivators, the majority belonged to the medium family size group, which was 43.33% of total respondents. In pineapple-turmeric cultivation, 50% of respondents were in the small family size group, while 26.67% and 23.33% of the respondents belong to the medium and large family size groups, respectively. The average family size across the study area was 5.42 persons per family, and most respondents in all three categories fell into the medium family size group, with the exception of pineapple-turmeric cultivators, who had the smallest family size. According to Datta *et al.* (2020), the average family size of pineapple farmers in the Sreemangal upazila of the Moulvibazar district in Bangladesh is five members.

Educational level

Education enhances farmers' productivity, efficiency, management, and sustainability by promoting modern techniques, better resource management, and adaptive responses to challenges. In Bangladesh, where agriculture is a key economic sector, educating rural communities is essential for modernization, though low literacy remains a major barrier to improved productivity. In this study, to evaluate the respondents' educational levels, the literacy level was divided into five groups: i) illiterate, ii) primary (grades 1–5), iii) secondary (grades 6–10), iv) higher secondary (grades 11–12), and v) graduate and above. People who are unable to read or write were categorized as illiterate. Table 1 shows that, among all three groups of pineapple intercrop cultivators, a significant proportion of respondents were illiterate. The percentages of illiteracy among pineapple-aroid, pineapple-ginger, and pineapple-turmeric cultivators were

Table 1. Socioeconomic characteristics (age, family size, education and household income).

Items	Pineapple-aroid		Pineapple-ginger		Pineapple-turmeric	
Age (years)	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
15-29	2	6.67	1	3.33	2	6.67
30-64	21	70	23	76.67	24	80
65 and above	7	23.33	6	20	4	13.33
Total	30	100	30	100	30	100
Family size						
Small family (up to 4)	9	30	11	36.67	15	50
Medium family (5 to 6)	15	50	13	43.33	8	26.67
Large family (Above 6)	6	20	6	20	7	23.33
Total	30	100	30	100	30	100
Average family size = 5.42						
Literacy level						
Illiterate	10	33.33	8	26.67	10	33.33
Primary (1-5)	5	16.67	7	23.33	6	20
Secondary (6-10)	8	26.67	6	20	9	30
Higher Secondary (11-12)	3	10	2	6.67	3	10
Graduate and above	4	13.33	7	23.33	2	6.67
Total	30	100	30	100	30	100
Average annual income						
Low income (< Tk.100000) (US$ 836.82)	12	40	13	43.33	11	36.67
Middle income (Tk. 100000- Tk. 200000) (US$ 836.82–US$ 1673.64)	16	53.33	12	40	15	50
High income (> Tk. 20000) (US$ 1673.64)	2	6.67	5	16.67	4	13.33
Total	30	100	30	100	30	100

Source: Field Survey, 2024 (US$ 1= Tk.119.50).

33.33%, 26.67%, and 33.33%, respectively. In the case of pineapple-aroid cultivators, the second largest group was the secondary level of education. The percentages for primary, higher secondary, and graduate and above levels of education were 16.67%, 10%, and 13.33%. Among pineapple-ginger cultivators, the percentage of respondents with primary and graduate and above education was 23.33% each, while those with a secondary and higher secondary education accounted for 20% and 6.67%, respectively. In the case of pineapple-turmeric cultivators, the percentages of respondents at different education levels were 20% for primary, 30% for secondary, 10% for higher secondary, and 6.67% for graduate and above. Bonna & Akter (2023) found in their study that almost all farmers were literate, and more than 25.51% of them had primary education in the same study area.

Average annual household income

In this study, the sampled respondents were classified into three categories according to income, such as i) low income (< Tk. 100000) (US$ 836.82), ii) middle income (Tk. 100000-Tk. 200000) (US$ 836.82–US$ 1673.64), and iii) high income (> Tk. 20000) (US$ 1673.64). From Table 1, it can be seen that in the case of Pineapple-aroid cultivators, 53.33% of respondents were from the middle-income group, whereas the sample respondents from the low- and high-income groups were 40% and 6.67%, respectively. In the case of pineapple-ginger cultivators, the maximum numbers of the respondents were from the low-income group and middle-income group, which were 43.33% and 40%, respectively, and the rest belonged to the high-income group. And in the case of pineapple-turmeric cultivators, the respondents belonged to low, middle, and high income groups, which were 36.67%, 50%, and 13.33%, respectively.

Loan received by the sample respondents

Agricultural loans provide essential financial support to farmers for purchasing seeds, fertilizers, equipment, and other farming necessities. Timely access to loans enables farmers to reduce risks, handle seasonal expenses, and ensure a stable income. In this survey, it was found that about 63.33% of respondents from pineapple-aroid cultivators, 56.67% of respondents from pineapple-ginger cultivators, and 50% of respondents from pineapple-turmeric cultivators received loans from different banks, financial institutions, and different informal sources. The sources are Bangladesh Krishi Bank (BKB), Agrani Bank PLC, Sonali Bank PLC, Grameen Bank; Informal Sources., and informal sources.

Interest rates of the different sources

As of November 2023, interest rates on agricultural loans were approximately 10% in Bangladesh (Bangladesh Bank, 2025). This resulted from the June 2023 removal of the lending rate cap by the Bangladesh Bank. Bangladesh Krishi Bank (BKB) is the largest lender in the agricultural sector of Bangladesh. It provides a 9% interest rate for the loanee, while Grameen Bank, Agrani Bank, and Sonali Bank provide interest rates of 20%, 10%, and 10% for the loanee, respectively (BB, 2025). In this survey, we found that a significant amount of loans was obtained from money lenders, who charged high interest rates.

Repayment of the loan

Table 2 represents that the principal amounts received by the pineapple-aroid cultivators from BKB, Grameen Bank, Agrani Bank, Sonali Bank, and other informal sources were 1395000 Tk. (US$ 11673.64), 386000 Tk. (US$ 3230.13), 350000 Tk. (US$ 2928.87), 360000 Tk. (US$ 3012.55), and 340000 Tk. (US$ 2845.19), respectively. And after one year the interests became 125550 Tk. (US$ 1050.63) for BKB, 77200 Tk. (US$ 646.03) for Grameen Bank, 35000 Tk. (US$ 292.89) for Agrani Bank, 36000 Tk. (US$ 301.26) for Sonali Bank, and 51000 Tk. (US$ 426.78) for informal sources with respective interest rates of 9%, 20%, 10%, 10%, and 15%. Pineapple-ginger cultivators received amounts from BKB, Grameen Bank, Agrani Bank, and other informal sources of 1020000 Tk. (US$ 8535.56), 570000 Tk. (US$ 4769.87), 1050000 Tk. (US$ 8786.61), and 430000 Tk. (US$ 3598.33), respectively. And after one year the interest became 91800 Tk. (US$ 768.20) for BKB, 114000 Tk. (US$ 953.97) for Grameen Bank, 105000 Tk. (US$ 878.66) for Agrani Bank, and 64500 Tk. (US$ 539.75) for informal sources at 9%, 20%, 10%, and 15%, respectively. Pineapple-turmeric cultivators received 874000 Tk. (US$ 7313.81) from BKB, 200000 Tk. (US$ 1673.64) from Grameen Bank, 1080000 Tk. (US$ 9037.66) from Agrani Bank, 100000 Tk. (US$ 836.82) from Sonali Bank, and 680000 Tk. (US$ 5690.38) from other informal sources. And after one year the interests become 78660 Tk. (US$ 658.24) for BKB, 40000 Tk. (US$ 334.73) for Grameen Bank, 108000 Tk. (US$ 903.77) for Agrani Bank, 10000 Tk. (US$ 83.68) for Sonali Bank, and 102000 Tk. (US$ 853.56) for informal sources at 9%, 20%, 10%, 10%, and 15%, respectively. In all cases, the repayment rate was nearly 100%, demonstrating effective use of loans and responsible financial behaviour by the cultivators.

Pattern of loan utilization by the respondents

Proper loan utilization is essential for achieving the goals of both borrowers and lending institutions, as well as contributing to the overall economic growth of the country. In this case, only a 12-month borrowing period was considered because it can be difficult to remember financial transactions that are more than a year old. The percentage of loan utilization patterns of the respondents is shown in Table 3. About 47.37% of the loan funds of pineapple-aroid cultivators were used for only seedling cultivation, 10.53% for both seedling cultivation and business investments, and 42.10% for non-agricultural purposes such as livestock purchases, debt repayment, land recovery, and house repairs. Pineapple-ginger cultivators used 52.94% of their loans for growing seedlings; while 23.53% each was spent on growing seedlings, business investments, and other non-agricultural needs. In contrast, pineapple-turmeric cultivators allocated 40% of their loans to seedling growing and business investments, 33.33% to non-agricultural purposes, and only 26.67% to seedling cultivation.

Table 2. Amount received and paid by the respondents.

Cropping pattern	Item	BKB	Grameen Bank	Agrani Bank	Sonali Bank	Informal
		Amount (Tk.)	Amount (Tk.)	Amount (Tk.)	Amount (Tk.)	Amount (Tk.)
Pineapple- Aroid	Principal amount received by the respondents (Tk.)	1395000 (US$ 11673.64)	386000 (US$ 3230.13)	350000 (US$ 2928.87)	360000 (US$ 3012.55)	340000 (US$ 2845.19)
	Interest after one year (Tk.)	125550 (US$ 1050.63)	77200 (US$ 646.03)	35000 (US$ 292.89)	36000 (US$ 301.26)	51000 (US$ 426.78)
	Total amount (Tk.)	1520550 (US$ 12724.27)	463200 (US$ 3876.15)	385000 (US$ 3221.76)	396000 (US$ 3313.81)	391000 (US$ 3271.97)
	Repayment by the respondents (Tk.)	1520550 (US$ 12724.27)	463200 (US$ 3876.15)	385000 (US$ 3221.76)	396000 (US$ 3313.81)	391000 (US$ 3271.97)
	Repayment performance (percentage)	100	100	100	100	100
Pineapple-Ginger	Principal amount received by the respondents (Tk.)	1020000 (US$ 8535.56)	570000 (US$ 4769.87)	1050000 (US$ 8786.61)	-	430000 (US$ 3598.33)
	Interest after one year (Tk.)	91800 (US$ 768.20)	114000 (US$ 953.97)	105000 (US$ 878.66)	-	64500 (US$ 539.75)
	Total amount (Tk.)	1111800 (US$ 9303.77)	684000 (US$ 5723.84)	1155000 (US$ 9665.27)	-	494500 (US$ 4138.08)
	Repayment by the respondents (Tk.)	1111800 (US$ 9303.77)	684000 (US$ 5723.84)	1155000 (US$ 9665.27	-	494500 (US$ 4138.08)
	Repayment performance (percentage)	100	100	100	-	100
Pineapple-Turmeric	Principal amount received by the respondents (Tk.)	874000 (US$ 7313.81)	200000 (US$ 1673.64)	1080000 (US$ 9037.66)	100000 (US$ 836.82)	680000 (US$ 5690.38)
	Interest after one year (Tk.)	78660 (US$ 658.24)	40000 (US$ 334.73)	108000 (US$ 903.77)	10000 (US$ 83.68)	102000 (US$ 853.56)
	Total amount (Tk.)	952660 (US$ 7972.05)	240000 (US$ 2008.37)	1188000 (US$ 9941.42)	110000 (US$ 920.50)	782000 (US$ 6543.93)
	Repayment by the respondents (Tk.)	952660 (US$ 7972.05)	240000 (US$ 2008.37)	1188000 (US$ 9941.42)	110000 (US$ 920.50)	782000 (US$ 543.93)
	Repayment performance (percentage)	100	100	100	100	100

Source: Field Survey, 2024 (US$ 1= Tk.119.50).

Table 3. Pattern of loan utilization by the respondents.

Items	Pineapple-aroid		Pineapple-ginger		Pineapple-turmeric	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Seedlings growing	9	47.37	9	52.94	4	26.67
Seedlings growing, Investment in the business	2	10.53	4	23.53	6	40
Seedlings growing, Purchasing dairy cow, Poultry purchasing, Repayment of old debt, Recovery of mortgaged out land, Repairing of houses	8	42.10	4	23.53	5	33.33
Total	19	100	17	100	15	100

Source: Field Survey, 2024.

Profitability of pineapple intercrops

Economic profitability is a key factor in decision-making for farm -level production. It can be assessed through gross margin, net return, and the ratio of return to total cost. In this survey, cost items were classified into two major categories, i.e., (a) variable cost and (b) fixed cost. Variable cost items for production are the cost of seedlings/seeds, land preparation, fertilizers, manure/cow dung, mulching, weeding, harvesting and labour, hormones and vitamins, and insecticides and pesticides. And the fixed cost items are land cost and interest on operating capital. All the cost items were taken into account in calculating the per-hectare profitability of pineapple intercrops. Total cost was estimated by adding variable costs and fixed costs. The land value was determined based on its opportunity cost per hectare for an 18-month cropping period. The cost of land use was considered as the land's cash value. According to the data, the land use cost was the same (Tk. 123564/US$ 1034) for pineapple-aroid cultivation, pineapple-ginger cultivation, and pineapple-turmeric cultivation. Interest on operating capital was calculated over a period of 18 months (1.5 years) using an interest rate of 10%.

Tables 4 - 6 show that the per hectare total costs of pineapple-aroid cultivation, pineapple-ginger cultivation, and pineapple-turmeric cultivation were found to be Tk. 697540.06 (US$ 5837.15), Tk. 720526.62 (US$ 6029.51), and Tk. 724033.85 (US$ 6058.86), respectively, in the present study area. Total return was calculated by multiplying the total amount of product and by-product with the respective per unit price. The average yield of pineapple was 29180.11, 26626.95, and 26174.18 pieces per hectare for pineapple-aroid, pineapple-ginger, and pineapple -turmeric cultivation, respectively. At a market price of Tk. 30 per piece, the total income from pineapple alone was Tk. 875403.30 (US$ 7325.55), Tk. 798808.50 (US$ 6684.58), and Tk. 785225.40 (US$ 6570.92) per hectare for the respective cultivation types. The average yields of aroid, ginger, and turmeric were 5249.73 kg, 2312.55 kg, and 7239.03 kg per hectare, respectively. At market prices of Tk. 84 per kg for aroid, Tk. 320 per kg for ginger, and Tk. 80 per kg for turmeric, the total revenue from these intercrops amounted to Tk. 440977.32 (US$ 3690.18), Tk. 740016.00 (US$ 6192.60), and Tk. 579122.40 (US$ 4846.21) per hectare, respectively. In addition, the income from by-products was Tk. 344290.1 (US$ 2881.09) for pineapple -aroid cultivation, Tk. 388680.15 (US$ 3252.55) for pineapple-ginger cultivation, and Tk. 376735.45 (US$ 3152.59) for pineapple-turmeric cultivation. The average total return per hectare was Tk. 1660670.72 (US$13896.83) for pineapple-aroid cultivation, Tk 1927504.65 (US$16129.75) for pineapple-ginger cultivation, and Tk. 1741083.25 (US$14569.73) for pineapple-turmeric cultivation.

Gross margin was calculated by deducting the total variable cost from the gross return. Per hectare gross margins were found to be Tk. 1126780.77 (US$ 9429.13), Tk. 1372216.76 (US$ 11482.98), and Tk. 1182471.46 (US$ 9895.16) for pineapple-aroid, pineapple-ginger, and pineapple-turmeric cultivation, respectively. Correspondingly, the net return per hectare was Tk. 963130.66 (US$ 8059.67) for pineapple-aroid cultivation, Tk. 1206978.03 (US$ 10100.23) for pineapple-ginger cultivation and Tk. 1017049.4 (US$ 8510.87) for pineapple-turmeric cultivation. It was calculated by deducting the total cost from the gross return. The Benefit-Cost Ratio (BCR) was found to be 2.38 for pineapple-aroid cultivation, indicating that every one-taka investment yielded a return of Tk. 2.38. For pineapple-ginger cultivation, the BCR was 2.68, while for pineapple-turmeric cultivation; it stood at 2.40- both reflecting profitable returns on investment. Khan *et al.* (2023) found that the pineapple intercrop in Madhupur upazila of Tangail district in Bangladesh was profitable, and per hectare gross return was Taka 703,700 (US$5888.70), and the benefit-cost ratio was 2.04. Hazari *et al*. (2024) discovered that the production of pineapple as a monocrop was economically viable in the Tripura district of India, evidenced by a BCR ratio of 2.15. Based on the above discussion, it can be cautiously concluded that pineapple intercropping is a profitable practice. Incorporating pineapple with compatible crops like aroid, ginger, and turmeric maximizes land use while also improving farmers' income, lowering production risks, and encouraging sustainable farming methods.

Table 4. Per-hectare average cost and return of pineapple-aroid cultivation.

Item	Unit	Quantity/ha	Price/Unit (Tk.)	Total costs (Tk.)
Variable costs				
Pineapple seedlings	Piece	33174.67	5	165873.35 (US$ 1388.06)
Aroid seed	kg	598.87	78	46711.86 (US$ 390.89)
Land preparation	Tk.			21153.99 (US$ 177.02)
Fertilizer costs				
Urea	Kg	1361.98	27	36773.46 (US$ 307.73)
TSP	Kg	1079.21	27	29138.67 (US$ 243.84)
MoP	Kg	866.89	20	17337.8 (US$ 145.09)
Gypsum	Kg	133.75	22	2942.5 (US$ 24.62)
Manure/cow dung	Tk.			7008.84 (US$ 58.65)
Mulching	Tk.			25917.05 (US$ 216.88)
Weeding	Tk.			42355.05 (US$ 354.44)
Harvesting & labor cost	Tk.			133165.40 (US$ 1114.35)
Hormone & vitamin	Tk.			4792.56 (US$ 40.11)
Insecticides & pesticides	Tk.			719.42 (US$ 6.02)
total variable cost	Tk.			533889.95 (US$ 4467.69)
Fixed costs				
Land use cost	Tk.			123564 (US$ 1034)
Interest on operating capital	Tk.			40086.11 (US$ 335.45)
Total Fixed Cost	Tk.			163650.11 (US$ 1369.45)
Total Cost (A+B)	Tk.			697540.06 (US$ 5837.15)
Returns				
Pineapple	Piece	29180.11	30	875403.3 (US$ 7325.55)
Aroid	Kg	5249.73	84	440977.32 (US$ 3690.18)
By-product	Piece	68858.02	5	344290.1 (US$ 2881.09)
Total return	Tk.			1660670.72 (US$13896.83)
Gross margin (D-A)	Tk.			1126780.77 (US$ 9429.13)
Net return (D-C)	Tk.			963130.66 (US$ 8059.67)
BCR (D/C)				2.38

Source: Field Survey, 2024 (US$ 1= Tk.119.50)

Table 5. Per-hectare average cost and return of pineapple-ginger cultivation.

Item	Unit	Quantity/ha	Price/Unit (Tk.)	Total Costs (Tk.)
Variable costs				
pineapple seedlings	Piece	30441.91	5	152209.55 (US$ 1273.72)
ginger seed	Kg	312.56	300	93768 (US$ 784.67)
land preparation	Tk.			20389.92 (US$ 170.63)
Fertilizer costs				
Urea	Kg	1442.32	27	38942.64 (US$ 325.88)
TSP	Kg	1171.85	27	31639.95 (US$ 264.77)
MoP	Kg	898.74	20	17974.8 (US$ 150.42)
Gypsum	Kg	164.08	22	3609.76 (US$ 30.21)
Manure/Cow dung	Tk.			13788.83 (US$ 115.38)
Mulching	Tk.			25536.35 (US$ 213.69)
Weeding	Tk.			48691.08 (US$ 407.45)
Harvesting & labor cost	Tk.			102745.20 (US$ 859.79)
Hormone & vitamin	Tk.			4590.17 (US$ 38.41)
Insecticides & pesticides	Tk.			1401.64 (US$ 11.73)
Total variable cost	Tk.			555287.89 (US$ 4646.76)
Fixed costs				
Land use cost	Tk.			123564 (US$ 1034)
Interest on operating capital	Tk.			41674.73 (US$ 348.74)
Total Fixed Cost	Tk.			165238.73 (US$ 1382.75)
Total Cost (A+B)	Tk.			720526.62 (US$ 6029.51)
Returns				
Pineapple	Piece	26626.95	30	798808.5 (US$ 6684.58)
Ginger	Kg	2312.55	320	740016 (US$ 6192.60)
By-product	Piece	77736.03	5	388680.15 (US$ 3252.55)
Total return	Tk.			1927504.65 (US$ 16129.75)
Gross margin (D-A)	Tk.			1372216.76 (US$ 11482.98)
Net return (D-C)	Tk.			1206978.03 (US$ 10100.23)
BCR (D/C)				2.68

Source: Field Survey, 2024 (US$ 1= Tk.119.50).

Table 6. Per-hectare average cost and return of pineapple-turmeric cultivation.

Item	Unit	Quantity/ha	Price/Unit (Tk.)	Total Costs (Tk.)
Variable costs				
Pineapple seedlings	Piece	30853.60	5	154268 (US$ 1290.95)
Turmeric seed	Kg	792.11	72	57031.92 (US$ 477.25)
Land preparation	Tk.			21669.96 (US$ 181.34)
Fertilizer costs				
Urea	Kg	1374.35	27	37107.45 (US$ 310.52)
TSP	Kg	1258.82	27	33988.14 (US$ 284.42)
MoP	Kg	933.43	20	18668.6 (US$ 156.22)
Gypsum	Kg	161.09	22	3543.98 (US$ 29.66)
Manure/Cow dung	Tk.			7493.51 (US$ 62.71)
Mulching	Tk.			43287.87 (US$ 362.24)
Weeding	Tk.			56177.61 (US$ 470.11)
Harvesting & labor cost	Tk.			119926.23 (US$ 1003.57)
Hormone & vitamin	Tk.			4393.39 (US$ 36.76)
Insecticides & pesticides	Tk.			1055.13 (US$ 8.83)
Total Variable Cost	Tk.			558611.79 (US$ 4674.57)
Fixed costs				
Land use cost	Tk.			123564 (US$ 1034)
Interest on operating capital	Tk.			41858.06 (US$ 350.27)
Total Fixed Cost	Tk.			165422.06 (US$ 1384.28)
Total Cost (A+B)	Tk.			724033.85 (US$ 6058.86)
Returns				
Pineapple	Piece	26174.18	30	785225.4 (US$ 6570.92)
Turmeric	Kg	7239.03	80	579122.4 (US$ 4846.21)
By-product	Piece	75347.09	5	376735.45 (US$ 3152.59)
Total return	Tk.			1741083.25 (US$ 14569.73)
Gross margin (D-A)	Tk.			1182471.46 (US$ 9895.16)
Net Return (D-C)	Tk.			1017049.4 (US$ 8510.87)
BCR (D/C)				2.40

Source: Field Survey, 2024 (US$ 1= Tk.119.50).

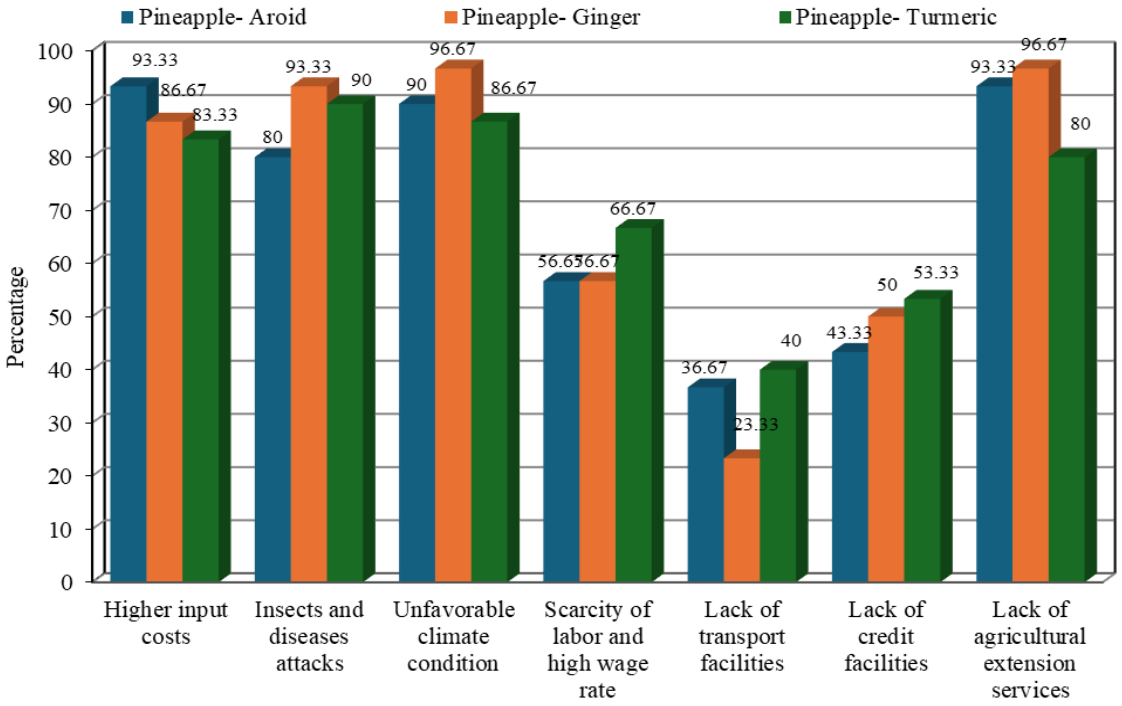

Figure 1. *Problems and constraints of pineapple intercrop cultivation ranked by the respondents (Source: Field Survey, 2024).*

Problems and constraints faced by the respondents

Figure 1 shows that higher cost of inputs was a major challenge, reported by 93.33% of pineapple-aroid, 86.67% of pineapple-ginger, and 83.33% of pineapple-turmeric cultivators. This constraint prevented many farmers from applying the recommended quantities, thereby lowering productivity. Insect and disease attacks were also prevalent, significantly affecting crop yields and increasing production costs, with 80%, 93.33%, and 90% of farmers from the respective groups identifying it as a serious concern. Unfavourable climatic conditions were identified as a significant issue by 90% of pineapple-aroid farmers, 96.67% of pineapple-ginger farmers, and 86.67% of pineapple-turmeric farmers. Additionally, labour scarcity and high wage rates, particularly during harvesting, posed significant challenges for 56.67% of both pineapple-aroid and pineapple-ginger cultivators and 66.67% of pineapple-turmeric cultivators. Poor transport facilities affected 36.67% of pineapple-aroid, 23.33% of pineapple-ginger, and 40% of pineapple-turmeric cultivators. Furthermore, limited access to credit facilities restricted farmers' ability to invest in quality inputs and modern techniques, with 43.33%, 50%, and 53.33% of pineapple-aroid, pineapple-ginger, and pineapple-turmeric farmers, respectively, citing this as a constraint. Lastly, about 93.33% of pineapple-aroid, 96.67% of pineapple-ginger, and 80% of pineapple-turmeric cultivators reported the lack of agricultural extension services as a critical barrier. Extension office needs to provide more and effective training facilities to the pineapple farmers for profitable production (Datta *et al.*, 2020). Uddin *et al.* (2022) identified elevated input costs, insufficient preservation and processing facilities, and inadequate operational capital as the primary challenges affecting the production, value addition, and marketing of pineapple, respectively.

Conclusion

This study demonstrates that pineapple intercropping with aroid, ginger, and turmeric is a profitable and sustainable farming practice in Madhupur upazila of Tangail district in Bangladesh. All three systems generated substantial net returns with favourable benefit-cost ratios, reflecting that intercropping significantly enhances land use efficiency and farm income compared to mono-cropping. Among the patterns, pineapple-ginger provided the highest profitability, while pineapple-aroid and pineapple-turmeric also ensured considerable economic benefits, making them attractive options for smallholder farmers. Despite its profitability, several challenges remain. Farmers reported high input costs, insect and disease attacks, unfavourable climate conditions, scarcity of labour with high wage rates, poor transportation facilities, limited access to credit, and inadequate extension services as major constraints. To solve these difficulties, it is important to provide timely input support, improve pest control, make loan programs more accessible, and improve extension services. By promoting pineapple intercropping, it is possible to enhance rural livelihoods and contribute to sustainable agricultural development in Bangladesh.

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DECLARATIONS

Author's contribution statement: Conceptualization, FHT and

MAR; methodology, MAR; software, FHT; validation, FHT, MAR MAK and EJ; formal analysis, FHT; investigation, MAR; resources, FHT; data curation, FHT; writing—original draft preparation, FHT; writing—review and editing, MAR, MAK and EJ; visualization, FHT; supervision, MAR; project administration, FHT; funding acquisition, FHT. All authors have read and agreed to the published version of the manuscript.

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