Program Based Research Grant (PBRG)

Sub-project Completion Report

on
Adaptation and Scaling up Agroforestry for Livelihood Improvement of farmers in Agricultural Ecosystem of Bangladesh

Sub-project Duration
May 2018 to April 2022

Coordinating Organization
On-Farm Research Division
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur-1701

Project Implementation Unit
National Agricultural Technology Program- Phase II Project
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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Abbreviation and Acronyms

ACP	Alternate Cropping Pattern
AEZ	Agro Ecological Zone
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
CP	Cropping Pattern
DAE	Department of Agricultural Extension
DAP	Days after Planting
DAT	Days after Transplanting
FGD	Focal Group Discussion
FRG	Fertilizer Recommendation Guide
FSRD	Farming System Research and Development
FYM	Farm Yard Manure
GEY	Guava Equivalent Yield
GM	Gross Margin
GR	Gross Return
HRC	Horticulture Research Centre
HQ	Head Quarter
IDA	International Development Agency
IFAD	International Fund for Agricultural Development
LEY	Litchi Equivalent Yield
LSP	Local Service Provider
MEY	Mango Equivalent Yield
MBCR	Marginal Benefit Cost Ration
MSFO	Multi Strata Fruit Orchard
NATP	National Agricultural Technology Program
OFRD	On-Farm Research Division
PCR	Project Completion Report
PIU	Project Implementation Unit
SAC	SAARC Agriculture Centre
SRDI	Soil Resources Development Institute
TVC	Total Variable Cost
WB	World Bank

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Executive Summary

Agroforestry system is a dynamic land use system that must get priority to satisfy the demand of the Bangladesh Government for enhancing national agricultural productivity. Livelihood improvement is usually a very complex process and it is a great challenge to improve the livelihood of the farmers of different agro-ecosystems by adaption of agroforestry system in their traditional agricultural system. Therefore, the program was designed and executed under the sub-project entitled "Adaptation and Scaling up Agroforestry for Livelihood Improvement of Farmers in Agricultural Ecosystem of Bangladesh" to adopt the agroforestry system and to scale out the developed technologies of agroforestry system among the farmers of different agro-ecosystems for better utilizing their land resources as well as to increase the productivity and income. The program was coordinated by On-Farm Research Division (OFRD), BARI with two implementing components (OFRD, BARI and Pomology Division, HRC, BARI) at different locations of Plain land, Rainfed, Coastal and Hill ecosystems. The activities of the sub-project were started from May 2018 at 05 (five) Farming System Research and Development (FSRD) sites of OFRD, BARI named Ganggarampur (Pabna), Ajoddhapur (Rangpur), Godagari (Rajshahi), Dumki (Patuakhali) and Telulia para (Bandarban) and at research station of Jashore and Khagrachori district under Pomology Division, HRC, BARI. The project activities were uninterruptly continued from January 2019 to October 2021 under Pandemic situation. A total of 24 of activities were done for maximizing the total productivity from the existing land resources of fourty farmers considering the (i) homestead production system, (ii) crops and cropping system, (iii) on-farm verification trials and (iv) production program in agroforestry system. All components of agroforestry programs such as vegetables, fruits, fooders, spices, high value crops and even cropping patterns were brought under agroforestry system for improving the technological intervention and income from each of the components. Villages under the FSRD sites of the OFRD of the irrespective of locations have been considered under agroforestry activities. On the basis of PRA and base line survey report, farmers need based technologies were intervened among small, marginal and small farmers. The activities were conducted for the improvement of location specific existing fruit based agroforestry system due to rapid extension of fruit orchards at the field level of different ecosystem. Research activities were also conducted at homestead level with existing fruits and non fruits trees and year round vegetables at Pabna, Rajshahi and Patuakhali addressing plain land, rainfed and coastal ecosystem. OFRD Pabna has established some agroforestry activities with the high value crops (Cabbage, Cauliflower, Tomato, and Broccoli etc.), pulse crops (Lentil and Grass pea) and oilseed crop (Mustard) in the selected mango, guava and litchi orchards at field level. Research activities on mango based agroforestry with cauliflower and cabbage were conducted at FSRD site Ajoddhapur, Rangpur. Development of cropping pattern like Mustard-Sesame, Potato-T. *Aus*-T. *Aman* rice, and Letil-Mungbean-T. *Aman* rice with existing mango-based agroforestry system has been developed at Pabna, Rangpur and High Barind Tract Rajshahi. Mango-based agroforestry with shade tolerant perennial crops like Turmeric and Ginger has been developed at Pabna and Rangpur. In Patuakhali, different vegetables have grown in association with homestead trees, roadside trees and sorjan based fruit trees. In Bandarban, different creeper vegetables were grown in association with fruit trees in the hill slope. The activities under this sub-project seem encouraging for the farmers of

different locations. Average production of vegetables and fruits was achieved 513 kg and 469 kg per farm from homestead agroforestry which contributed higher family consumption (181 g head^{-1} day^{-1}), distribution and selling and total income (Tk. 6191 farm^{-1}). In Patuakhali, farm income increased 168% after intervention of homestaed agroforestry. System productivity of mango based agroforestry has increased by 74.06, 46.39, 30.18, 27.74 and 22% due to adoption of high value crops like field pea, radish, cabbage, cauliflower and tomato at Pabna. System productivity has also increased 2 to 3 fold under Litchi and Guava based agroforestry with pulse (Lentil, field pea and grasspea), and vegetable crop (cauliflower, cabbage, broccoli and tomato) at Pabna. In addition, fodder crop, cropping pattern, shade tolerant crop with mango-based agroforestry demonstrated encouraging production and farmers' income at different locations. In Banderban, BARI developed creeper vegetables with mango orchards exhibited encouraging return. Multistoried agroforestry was found more productive and profitable at Jashore and Khagrachari. However, rapid expanded fruit tree-based orchards are opening good scope for agroforestry based intensive production results in incremental yield and economic return per unit area. However, satisfactory improvement regarding production, consumption, family nutrition, women employment opportunity reflected due to development of agroforestry activities under this project. The results of all the activities under agroforestry system imply at five locations of the country are presented here and continuing to create the opportunity for the resource-poor farmers to improve their livelihood in different ecosystem.

Keywords: Agroforestry system, food security, homestead model, livelihood, plainland, coastal, rainfed, hill.

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<h1 style="text-align:center">PBRG Sub-project Completion Report (PCR)</h1>

A. Sub-project Description

1. **Title of the PBRG sub-project**

   Adaptation and Scaling up Agroforestry for Livelihood Improvement of farmers in Agricultural Ecosystem of Bangladesh

2. **Implementing organization**

   a. Component-I: On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701

   b. Component -II: Pomology Division, Horticulture Research Centre, BARI, Joydebpur, Gazipur-1701

3. **Name and full address with phone, cell and E-mail of Coordinator, Associate Coordinator and PI/Co-PI(s)**

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   Principal Investigator

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4. **Sub-project budget (Tk.)**
   4.1 **Total (in Tk. as approved):** Tk. 10000000/-
   4.2 **Latest Revised (if any):** Tk.10000410/-

5. **Duration of the sub-project:** May 2018 to April 2022
   5.1 **Start date (based on LoA signed):** May 2018
   5.2 **End date:** 15 April 2022

6. Background of the sub-project

The arable land of Bangladesh is shrinking at the rate of 86,000 hectares every year (BBS, 2008) due to high population density and enormous pressure on natural resources. In addition, climate change accelerated the intensity and frequency of occurrences of salinity, storms, drought, irregular rainfall, high temperature, flash floods, etc. eventually pose serious threat on crop production and food security. In such situation, a comprehensive research and development effort is needed to increase production per unit arable land through agroforestry. Agroforestry system can contribute stable income, food and nutrition security, savings and insurance and a potential means of risk management under climate change induced stress (Akter et al. 1989; Evans 1988). At present the research addressing soil and water conservation, reduce soil erosion, livestock feed management, fuel energy, tree-crop interaction for higher productivity and environmental benefit under integrated agroforestry system are getting high priority to combat climate change challenges (SAC, 2015). In hill ecosystem, agroforestry (contour hedgerows) on steep hill slopes (40-50%) can reduce soil erosion by 55-80% and runoff by 30-70% compared to shifting cultivation (Khisa, 2001).

BARI has developed Multi Strata Fruit Orchard (MSFO) suitable for preventing soil erosion and degradation and increased cropping intensity in hill areas (Paul and Hossain, 2001). On-Farm Research Division of Bangladesh Agricultural Research Institute (BARI) has developed homestead based agroforestry model through holistic approach in its 9 FSRD sites in different ecosystem increased production (50.93 and 146.56%), food intake (68.67 and 124%) farm net income (326% and 115%) from homestead agroforestry with year-round vegetables and fruits respectively over existing farmers practice (OFRD, 2015). Presently the research on screening of crops and their management under the niche of rapidly growing fruit orchard in rural areas is gaining increasing demand by the farmers.

The Bangladesh Agricultural Research Council (BARC) has identified new potential area of agroforestry research and development at cropland, homestead, hill, coastal, rainfed and charland under different ecosystem and given priority on coordinated research aiming food and nutrition security of peoples in those stress environments. Therefore, the proposed research concept is designed to conduct research aiming to find out innovative technologies and dissemination of developed agroforestry technologies in different ecosystem of Bangladesh.
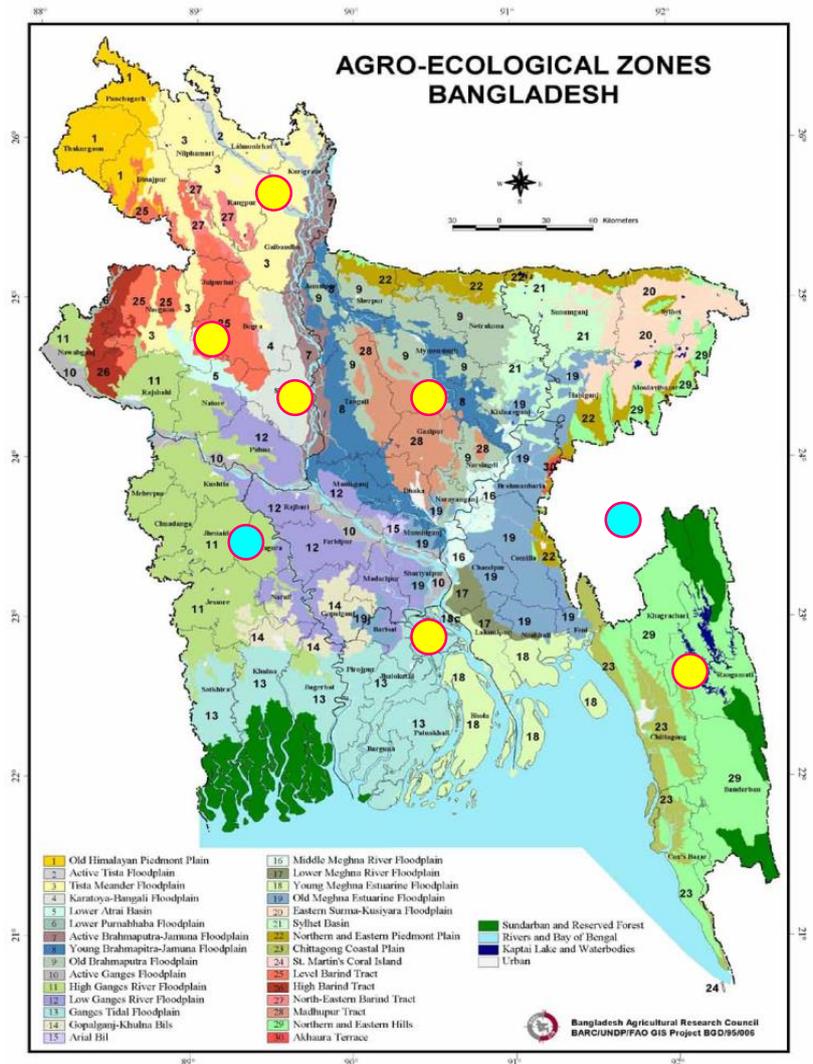
Fig. 1. Locations of implementation sites under the sub-project

Plain land ecosystem

Pabna area: The Pushpapara FSRD site is located 13 Kilometer east of Pabna town. It belongs to AEZ 11 (High Ganges River Floodplain) and AEZ 12 (Low Ganges River Floodplain). The land types are mainly medium high land (45.5%) and medium low land (35.3%). The increasing trend of fruit tree orchard in this area is opening scope of agroforestry based production. Farmers usually grow some perennial spices crops in association with fruit trees which requires long time for income generation. Recently agricultural land is shrinking sharply. Haphazard growing of some vegetable crops under the niche of fruit trees are practicing at the farmers' field. Many orchards are not under this practice. Homestead based year-round vegetables in association with quick growing fruits are opening better scope for income generation of

resource poor farm household. Growing high value vegetables and pulse crops in fruits orchards can be better options for higher productivity and income generations.

Rangpur area: The Ajoddhapur FSRD site of Rangpur belongs to AEZ 3 (Tista Meander Floodplain). In the site area, farmers are mostly resource poor. Due to poor management practice, lacks of quality seeds and saplings farmers usually get lower production and economic return. Growing of early vegetables (especially Tomato) is a common practice by the farmers which results in higher market price. Recently establishment of fruit orchards is gradually increasing in the area. Fruit orchards can be utilized for vegetable production under agroforestry system. Adoption of Eucalyptus, Sissoo and other trees in the crop land is very common which can be utilized as support for creeper vegetables. However, identification suitable crops/vegetables for growing with trees is limited. Suitable tree-crop combination can ensure higher productivity and economic benefit for resource poor farmers.

Rainfed ecosystem

Rajshahi area: The Kadamshahar FSRD site is 20 km far away from Rajshahi town. The land types are mainly high land and medium high land representing AEZ-26 (High Barind Tract). The rainfall is erratic and ranged from1200-1300 mm. Soil moisture sharply declines in winter season. In the rabi season crops are mainly grown in rainfed condition. Due to low yield and return from field crops farmers are adopting fruit trees in their crop field which results in more production and economic return. However, some field crops such as wheat, mustard, mungbean, potato are cultivating in tree orchards. But the suitable crops for agroforestry systems are still not well identified. In addition, year-round vegetables and fruits production, creeper vegetables in unproductive trees in agroforestry systems in homestead area can uplift income generation and family nutrition.

Jessore area: This area belongs to AEZ 11 (High Ganges River Floodplain) and has good scope for growing high value vegetables and fruits in the shape of agroforestry. The high land and medium high land is utilized for intensive high value vegetables. Rapidly increasing fruit orchards (mango, litchi, guava etc) can be utilized for growing different vegetables and spices crops. HRC, BARI taking initiative to grow vegetables in association with the existing fruit orchards.

Coastal ecosystem

Patuakhali area: The FSRD site represents AEZ 13 (Ganges Tidal Floodplain). The land escapes mainly clay dominant. Major soils are silty clay loam to silty clay (80%) and rest of the (20%) silt loam. The drainage condition is mainly poor. Soil reaction ranges from medium acidic to moderately alkaline (SRDI 2000). Seven types of major farming systems exist in the areas. Among the dominant farming systems Crops +Poultry + Fisheries + Agro forestry is one of them. The recognized items of income of the farmers are crop, livestock, fisheries, poultry, homestead, agro-forestry etc. Vegetable scarcity is dominant in the areas. Most of the farmers' produce vegetable in homestead condition using open sunny places, roofs, trellis, fences, fruit less trees etc. The homesteads of the localities are full of fruit trees and timber trees. Some farmers use these trees as trellis for cucurbit production.

Hill ecosystem

Banderban and Khagrachari area: The area represents AEZ 29 (Northern and Eastern Hills). There are many established fruit orchards in hill slope of Banderban and Khagrachari district which give only one crop in a year. There are ample opportunities to turn these perennial fruit orchards into two to three crops area and thus increase the productivity and cropping intensity. This area has great potentiality for growing different fruits and vegetables. Mixed crop cultivation is more profitable for the farmers than mono-crop fruit cultivation. Creeper

vegetables may be a good source of vegetables as well as to protect soil erosion through the hill slopes.

The proven technologies of agroforestry systems in crop land and homestead was included in the program. Strengthen inter-institutional cooperation and linkage through quick participations of research, extension & development agencies. Overall, the project is aimed to increase the production, income, employment opportunity, nutrition etc. and ultimately enhances livelihood status of the target farms towards poverty alleviation of the respective sites as mentioned above.

7. Sub-project general objective

Farmers' livelihood improvement and ensuring food security through adoption of innovative agro-forestry technologies.

8a. Sub-project specific objectives (OFRD, BARI Component)

(i) To develop innovative agroforestry technology through adaptive research in agriculture eco-system (rainfed, coastal, charland and hill) of Bangladesh

(ii) To adopt BARI developed homestead, cropland and hill agroforestry technologies in the respective eco-system through active participation of the stakeholders

(iii) To assess the productivity, income and environmental benefits of the developed agroforestry practices and its contribution to food security and poverty alleviation

8b. Sub-project specific objectives (Pomology Division, HRC, BARI Component)

(i) To identify potential agroforestry practices in Khagrachari and Jessore areas

(ii) To find out suitable lower and middle storied crops in fruits based agroforestry

(iii) To assess land utilization efficiency and economic return (BCR)

9. Implementing locations

Agroforestry systems research and development activities were carried out at FSRD site Pabna, Rangpur, Rajshahi, Patuakhali and Banderban under OFRD, BARI including plain land, rainfed, coastal and hill eco-systems. The activities were also conducted at Khagrachari and Jessore under Pomology Division, HRC, BARI. On the basis of farmer's traditional practices, their needs and choices, growing of high value vegetables crops, spices, cereals, pulses and other crops in association with existing fruits/unproductive trees in homestead and crop field the research and development program was incorporated under the project.

Component-1: OFRD, BARI

FSRD site Ganggarampur, Pabna

In Pabna, Pirpur, Kasarpur, Madhupur and Jafrabad villages under Pabna Sadar upazila of Pabna district were selected for agroforestry research and development activities Ganggarampur has a distance of eighteen km from the upazila head quarter and is located at the east side (24°03′ N latitude and 89°38′ E longitude; AEZ-11).
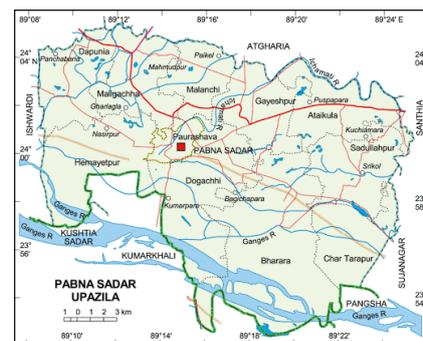
FSRD site Ajoddhapur, Rangpur

Two villages named South Ajoddhapur and Jhautary village under Rangpur Sadar upazila of Rangpur district were considered for FSRD activities. Ajoddhapur has a distance of sixteen km from the upazila head quarter and is located at the west side (25°40′ N latitude and 89°10′ E longitude; AEZ-3).
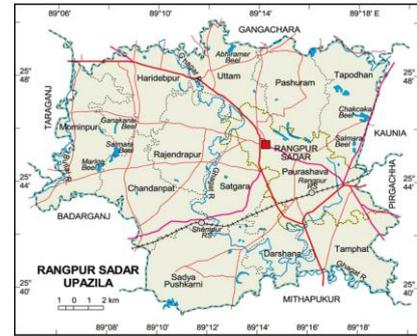
FSRD site Basantapur, Godagari, Rajshahi

The Agroforestry activities was conducted at farmers field of Farming System Research and Development site, Basantapur, Godagari, Rajshahi (Lat. 24°24′ N; long. 88°26′ E; 26 masl) This site was comprised of three villages viz., Dhatma, Udpur and Baslitala. The site belongs to the agro-ecological zone of High Barind Tract (AEZ-26).
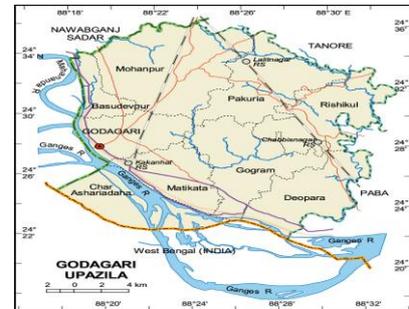
FSRD site Jamla, Dumki, Patuakhali
The project activities were undertaken in two FSRD site of coastal non-saline area at Jamla in Dumki Upazilla under Patuakhali districts. The site were located North-Eastern part (22°24′ N latitude and 90°23′ E longitude; AEZ-13) and 20 Km distance from the District head quarter.
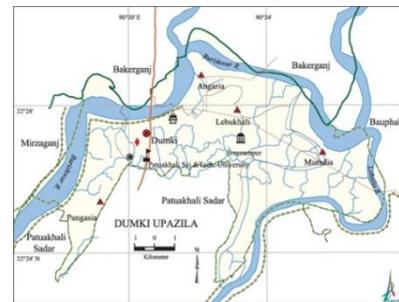
FSRD site Tukhung para, Bandarban

In Bandarban district, Tukhung para of sadar upazila and Tetulia para of Rowangchari upazila were selected for agroforestry research and development activities. Tukhung para has a distance of ten km from the upazila head quarter and is located at the northern side (22°24′ N latitude and 92°20′ E longitude; AEZ-29). Tetulia para has a distance of twelve km from the upazila head quarter and is located at the east side (22°17′ N latitude and 92°23′ E longitude; AEZ-29).

Component-2: Pomology Division, HRC, BARI

RARS Jessore and HARS, Khagrachari

The research activities under Pomology Division, HRC, BARI were conducted in two locations; one at RARS, Jashore and another at HARS, Khagrachari. The research field in RARS Jashore (AEZ-11) was located at 23°18′ N latitude and 89°19′ E longitude; and HARS, Khagrachari (AEZ-29) was 23°81′ N latitude and 92°03′ E longitude.

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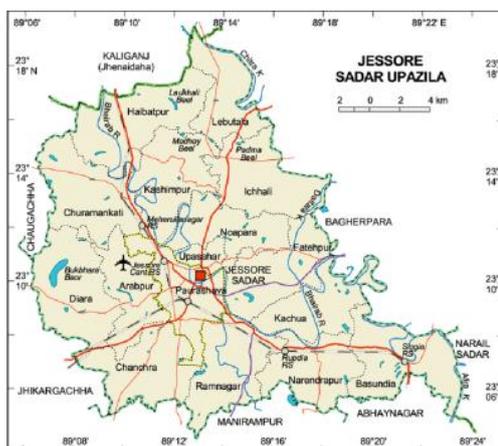
10. Methodology in brief

(a) Component-1: OFRD, BARI

Agroforestry systems research and development activities was carried out at FSRD site Pabna, Rangpur, Rajshahi, Patuakhali and Banderban of OFRD, BARI under plain land, rainfed, coastal and hill eco-systems and. The activities were carried out at Khagrachari and Jessore under Pomology Division, HRC, BARI. On the basis of farmer's traditional practices, their needs and choices, several alternatives of technologies of high value vegetables crops, spices, cereals, pulses and other crops in association with existing fruits/unproductive trees in homestead and field level have incorporated with active participation of the farmers. According to the aim of the project, suitable farmers from different categories viz. landless, marginal and small having major components of agroforestry systems and sizable homestead under single ownership were targeted and six farm households from each site which covered two villages was selected. Existing fruit orchards suitable for agroforestry research works was selected for each location. Prior to implement the project activities, a baseline survey of individual households was carried out. The detail information regarding livelihoods pattern of each household especially total resources inventory, liabilities, Agroforestry related technology used, level of input used, output obtained, income and expenditure status, labor availability of the farms of previous year was documented. Based on the potentials, suitable agroforestry based technological options were addressed to the farmers. Accordingly, farmers' selected suitable technology was adjusted with their need for livelihood improvement. Existing scenario/practices on vegetables, spices, cereals, pulses and fruits production in agroforestry systems, fruit tree management, marketing of the produce and some off-farm activities was identified as their major potential components. Integrated approach was followed for income generation and livelihood improvement of the farmers. The FSRD team of the respective sites and scientific staff of pomology division of HRC, BARI was facilitated the cooperators intend for technological intervention to maximize the productivity of the farm components. Local service provider (LSP) was developed for more sustainability. In case of technological adoption, some advanced methods/techniques were fine-tuned. Pilot production programs were taken in third year including new farmers with the fine-tuned appropriate technologies obtained suitable in first year interventions. Farm component wise data on production, farm level utilization, economic return, livelihood parameter and other socio-economic status was recorded from different locations and tabulated after appropriate statistical analysis.

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A. *Homestead Agroforestry Production System*

The farmers from different locations were selected on the basis of available resources and potentials for homestead based agroforestry systems. The trainings and suggestions were provided to the selected farmers by the OFRD team and scientific personnel of HRC on homestead agroforestry production systems following different models developed by OFRD, BARI in different eco-systems.

Plain land ecosystem

Activity-1: Development of homestead agroforestry with vegetables and fruits crops in Pabna areas under plain land ecosystem

Location: FSRD site Ganggarampur, Pabna Sadar, Pabna

Sustainable food and nutrition security for rural farm families is a growing concern and reflected in national agricultural policy of Bangladesh. Due to shrikage of agricultural cultivable land, homestead area of rural farming are being considered as an improtant production unit for food and nutrition security. In this connection agroforestry system based production approach was taking into concideration during 2019-20. Two co-operator farmers hometead area was selected for the development of homestead agroforestry. Scientific personnel of FSRD team provided training and necessary suggestions to the selected farmers on homestead agroforestry production systems. In case of homestead 1, around 19 decimal of homestead area was brought under homestead agroforestry system production which included fruit trees (mango) and high value vegetables whereas around 6 decimal area was brought under homestead agroforestry system production which included non fruit trees (mahogany) and high value vegetables for homestead 2. In homestaed 1, tomato, brinjal, country bean and bitter gourd was grown in association with mango trees with area coverage of 3, 3, 4 and 3 decimal of homestead area, respectively during 2019. Turmeric was grown in between mango trees with an area of 6 decimal. In homestead 2, elephant foot yam and country bean was grown in unutilized spaces of the trees. Standard management practices were followed for all crops and fruit trees.

Rainfed ecosystem

Activity-2: Development of homestead agroforestry with vegetables and fruits crops in Barind areas under rainfed ecosystem

Locations: Godagari, OFRD, Barind, Rajshahi

Available production niches of the homestead areas were brought under cultivation with the suggested vegetables and fruits following Barind model. This model has eight production units. Quick growing fruit trees (Guava, Papaya, Lemon, Ber, Banana, etc.) along with other existing fruit trees (Mango, Coconut, etc.) were managed through pruning, pest control, fertilization and irrigation.

SI No.	Spaces	Cropping patterns		
		Rabi (October- March)	**Kharif-I** (April-June)	**Kharif-II** (July-September)
1.	Open sunny land			
	Bed 1	Brinjal+Red amaranth	Kangkong	Kangkong
	Bed 2	Spinach-Spinach	Indian spinach	Red amaranth
	Bed 3	Radish-Red amaranth	Stem amaranth (Katua data)	Green Shak
	Bed 4	Cabbage	Onion	Red amaranth/Jute shak
	Bed 5	Cauliflower-Red amaranth	Okra	Red amaranth /Leafy Jute
2.	Fence	-	Bitter gourd, yard long bean	Sponge gourd
3.	Trellis	Country bean, bottle gourd	Pointed gourd, snake gourd, ridge gourd	sponge gourd
4.	Roof	Country bean, bottle gourd	Sweet gourd, White gourd	White gourd
5.	Tree support	-	White gourd, potato yam, sponge gourd	sponge gourd
6	Partial shady area	Coriander leaf	Turmeric, Aroids	Turmeric, Aroids
7.	Homestead boundary	Plantain banana Papaya Drumstick	Plantain banana Papaya Drumstick	Plantain banana Papaya Drumstick
8.	Pond/ ditch banks and slope	Bottle gourd	Snake gourd, Bitter gourd	-
9.	Others	-	Fodder, chewing sugarcane	Fodder, chewing sugarcane

Coastal ecosystem

Activity-3: Development of homestead agroforestry system through vegetable and fruits cultivation in coastal ecosystem

Locations: Jamla and Razakhali village under FSRD site, Dumki, Patuakhali

Available production niches of the homestead areas were brought under cultivation with the suggested vegetables and fruits following the below mentiond Lebukhali model.

Spaces	Cropping pattern for year round homestead vegetable production		
	Rabi (Oct.-March)	Kharif-I (April-June)	Kharif-II (July-Sep.)
Open sunny land			
Bed-1	Red amaranth + Brinjal	Brinjal	-
Bed-2	Red amaranth + Nolkhol	Okra	-
Bed-3	Coriander leaf + cabbage	Stem amaranth	-
Bed-4	Coriander leaf + Brinjal	Kangkong	-
Bed-5	Red amaranth + Tomato	Indian spinach	-
Fence	Bitter gourd	Yard long bean	-
Trellis	Cucumber, Bitter gourd	Ribbed gourd	-
Non-fruit trees	-	Sponge gourd/Potato Yam	-
Pond/ditch slope	Bottle gourd	Bitter gourd	-
Marshy land	Taro	Aroid (Latiraj)	

Four homesteads were selected used at FSRD site, Jamla, Patuakhali for vegetables and fruits production round year the during the study period. In open sunny place, four beds of each 8 m × 1.5 m were taken for growing vegetables round the year under Lebukhali model. A fence was made with bamboo. Other homestead spaces were also utilized following Lebukhali model. Vegetables were cultivated round the year one after another and necessary data was recorded. Different fruits trees *ie*., Mango, Jamrul, Jackfruits, Malta, Guava, Litchi and Lemon was grown in the homestead. Papaya and Drumstick plant were planted in the base of the house and homestead boundary to protect the saplings from the wind as well as water logging condition. BARI developed variety BARI Malta-1, BARI Aam-11, BARI Aam-4, and Papaya were planted under homestead agroforestry. Water hyacinth was used as mulch during dry season. Besides mulch, one small hole at the end of the plastic container (Five liters) filled with water was hanged by stick near the saplings (Mango) base for supplying water during dry season. Fertilizer was applied for vegetables and fruit trees as prescribed by Krishi Projukti Hatboi, 2018. Creeper vegetables like ridge gourd, snake gourd and potato yam were grown with the support of unproductive trees.

B. *Improvement of crop land agroforestry with suitable crops and cropping pattern*

On the basis of baseline survey of the respective FSRD and HRC sites, suitable crops (cereals, pulses, vegetables, and spices) and cropping pattern were tested under niches of existing fruit trees in each location for the improvement of crop land agroforestry.

Plain land ecosystem

Activity-4: Development of mango based agroforestry with pulse crop under plain land ecosystem

Location: FSRD site, Ganggarampur, OFRD, Pabna

Growing pulse crops in kharif season is really a challenge due to unfavourable climate. However, an effort was made to develop mango based agroforestry with kharif pulse specially blackgram. The experiment was carried out at farmers' field of FSRD site Ganggarampur, Pabna during 2020 to evaluate the performance of blackgram in agroforestry system and to increase productivity and farmers' income. About 5 years aged mango orchard (var. BARI Aam-4) was selected for the study. Blackgram was selected for growing with mango orchard in kharif season. The seeds of blackgram (*var*. BARI Mash-3) were broadcasted in the unutilized spaces of existing mango orchard on August 19, 2020. Application of fertilizers and other intercultural operation were made as per recommendation of pulse and fruit crops. The crop was harvested on November 05, 2020. The mango was harvested on July 05-07, 2020. The details of crop management practices are presented in Table 1. Data on yield of blackgram and mango fruits were recorded and necessary table were prepared with mean values.

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Table 1. Detail of crop management under existing fruit (Mango) orchard and Agroforestry system.

	Existing fruit orchard	Agroforestry system with existing fruit orchard	
		Blackgram	Mango
Crop	Mango	Blackgram	Mango
Variety	BARI Aam-4	BARI Mash-3	BARI Aam-4
Spacing	5 m x 5 m	Broadcast	5 m x 5 m
plot size (dec.)	132	132	132
Fertilizer dose (N-P-K-S-Zn-B kg/ha)	52-25-42-12-1.5-0.7	21-13-20-10-0-1.0	52-25-42-12-1.5-0.7
Date of sowing/planting	10.6.2017	19.8.2020	10.6.2017
Date of harvesting	5.7.2020 to 07.7.2020	5.11.2020	05.7.2020 to 07.7.2020

Activity-5: Feasibility of growing shade tolerant crops under mango based agroforestry system

Location: FSRD site, Ganggarampur, OFRD, Pabna

The experiment was conducted at FSRD site, Ganggarampur, Pabna during 2019-20 and 2020-21. Two management condition viz. a) agroforestry and b) open field along with five crops namely field pea (var. BARI Motor-3), radish (var. BARI Mula-1), cabbage (var. Atlas-70), cauliflower (var. Snow white) and tomato (var. BARI Tomato-19) were selected for growing under niche of mango orchard in this trial. The experiment was laidout in RCB factorial design with three replications. The plot size was 6m × 5m. The spacing was 30 cm × 10 cm for field pea, 40 cm × 15 cm for radish, 60cm × 45cm for cabbage and cauliflower and 75cm × 50cm for tomato. The crops were planted on November 17 to December 02 during the consecutive years. Fertilizers were applied as per recommendation of fertilizer recommendation guide (FRG'2018). The harvesting of pea, radish cabbage, cauliflower and tomato were March 24, January 31 to February 05, February 22 to March 10, February 15 to March 02 and March 01 to March 20, 2020, respectively during 2019-20. In the next year (2020-21) the harvesting of pea, radish cabbage, cauliflower and tomato were done on March 04-10, January 20 to February 15, February 15-28, March 01-10 and February 28 to March 15, respectively. Weeding was done on December 20, 2020. Other intercultural operations were done as and when required. The relevant data on different parameters were measured at respective stages and analyzed with R statistical software.

Activity-6: Development of litchi-based agroforestry with lentil

Location: Ganggarampur, OFRD, Pabna

The experiment was carried out during 2018-19 and 2019-20 to evaluate the performance of pulse crop in agroforestry system and to increase productivity and farmers' income. Among the pulse crops, lentil was selected for growing with litchi orchard in this study. The seeds of lentil (*var*. BARI Masur-8) were sown on November 07-30 (Table 2). Application of fertilizers and other intercultural operation were made as per recommendation of pulse and fruit crops. The crop was harvested on March 12-18. The litchi fruit was harvested on June 02-08. Data on yield of pulse crop and litchi fruits were recorded and necessary table were prepared with mean values.

Table 2. Crop management under the existing litchi orchard and agroforestry system

	Existing fruit orchard	Agroforestry system with existing fruit orchard	
Crop	Litchi	Lentil	Litchi
Variety	Local (Bombai)	BARI Masur-8	Local (Bombai)
Spacing	8m x 8m	Broadcast	8m x 8m
Plot size (Dec.)	40	40	40
Fertilizer dose (N-P-K-S-Zn-B kg ha^{-1})	86-63-94-7-2-1.5	19-16-20-9-0-1.5	86-63-94-7-2-1.5
Date of sowing/planting	July, 2019	November 07-30, 2018	July, 2019
Date of harvesting	June 01-08, 2020	March 12-18, 2020	June 02-08, 2020

Activity-7: Development of litchi-based agroforestry system with high value crops

Location: Ganggarampur, OFRD, Pabna

The experiment was carried out during the *rabi* season of 2019-20. Around eleven years aged litchi orchard was selected for the study. The kinds of vegetables were selected according to choice and preference of the co-operator farmers and agronomic feasibility. Cauliflower, cabbage and broccoli were chosen for planting with litchi trees. Thirty days old seedlings of cauliflower (*var*. Snow white), cabbage (*var*. Atlas 70) and broccoli (*var*. BARI Broccoli-1) were transplanted on November 29, 2019 with maintaining spacing of 60 cm x 45 cm for all vegetables. Application of fertilizers and other intercultural operation were made as per recommendation of individual crops. The harvesting of cauliflower was initiated on February 11 and continued up to February 18, 2020. The harvesting of cabbage was initiated on February 22 and continued up to March 10, 2020. The harvesting of broccoli was initiated on January 25 and continued up to February 08, 2020. The harvesting of litchi was initiated on May 24 and continued up to June 10, 2020. Data on yield of vegetables and guava fruits were recorded and necessary table were prepared with mean values.

Activity-8: Development of guava based agroforestry system with pulses Crops

Location: Ganggarampur, OFRD, Pabna

The experiment was carried out at extrapolation areas of FSRD site Ganggarampur, Pabna Sadar, Pabna during two consecutive years (2018-19 and 2019-20) to evaluate the performance of pulses crops in agroforestry system and to increase productivity and farmers income. Different pulse crops such as lentil, field pea and grasspea were selected for guava based agroforestry system in this study. The age of the guava trees was around 5 years. Seeds of lentil (var. BARI Masur-8), field pea (var. BARI Motor-3) and grass pea (var. BARI Khesari-3) were sown on November 11-30. All pulse crops were broadcasted in between spaces of guava trees. Application of fertilizers and other intercultural operation were made as per recommendation of individual crops (FRG' 2018). The date of harvesting of lentil, field pea and grass pea was March 08, February 22 and March 31, 2019 respectively. The harvesting of guava was initiated on November 2018 and continued up to March 15, 2019. In the next year, the harvesting of lentil, field pea and grass pea was March 16, March 12 and March 25, 2020, respectively. The harvesting of guava was initiated on November 15, 2019 and continued up to March 25, 2019. Data on yield of pulses crops and guava fruits were recorded.

Activity-9: Development of guava-based agroforestry system with high value crops

Location: Ganggarampur, OFRD, Pabna

The experiment was carried out at extrapolation areas of FSRD site Ganggarampur, Pabna Sadar, Pabna during three consecutive years (2018-19 to 2020-21) to evaluate the performance of high value crops in agroforestry system and to increase productivity and farmers' income. Different high value crops such as tomato, cauliflower and cabbage were selected for guava based agroforestry system in this study. Around 4 years aged guava (var. BARI Peyara-2) orchard was selected for the study during 2018. Thirty days old seedlings of tomato (var. BARI Tomato-19), cauliflower (var. Snow white) and cabbage (var. Atlas 70) were transplanted on November 19-December 05 during the consecutive years with maintaining spacing of 60 cm x 50 cm for tomato and 60 cm x 45 cm for both cauliflower and cabbage. Application of fertilizers and other intercultural operation were made as per recommendation of individual crops. The harvesting of tomato was initiated on February 12 and continued up to March 25. The harvesting of cauliflower was initiated on January 14 and continued up to March 11, 2021. The harvesting of cabbage was initiated on January 07 and continued up to March 15. The harvesting of guava was initiated on February 15 and continued up to March 25. Data on yield of vegetables and guava fruits were recorded and necessary table were prepared with mean values.

Activity-10: Performance of newly released late blight resistant potato variety at Rangpur under mango based agroforestry systems

Location: FSRD site Ajoddhapur, Rangpur

Late blight is the most devastating disease of potato in Bangladesh causes around 30-50% annual yield loss. Tuber Crops Research Center of BARI has developed two late blight resistant varieties viz. BARI Alu-46 and BARI Alu-53 which are higher yielder and resistant to late blight disease. These newly varieties need to be evaluated for their performance at different late blight prone areas under mango based agroforestry systems. The present studies were conducted to evaluate and popularize the variety under mango based agroforestry systems at farmer's field condition in Rangpur. The trial was conducted at farmers' field during the rabi season of 2020-2021 to promote and disseminate newly released late blight resistant potato variety, BARI Alu-46, BARI Alu-53 and BARI Alu-77. Potato was grown under niches of existing mango orchard maintaining standard management practices at farmers' field of Rangpur.

Activity-11: Development of mango based agroforestry with turmeric at farmers' field under plain land ecosystem

Location: FSRD site, Ganggarampur, OFRD, Pabna

Turmeric is a perrenial crop and can be grown easily under niche of mango orchards. Around 8-9 years aged mango orchard was selected for this study. Local turmeric variety was planted on May 15, 2020 under niche of the selected mango orchard. Recommended management practices were followed for turmeric and mango (Table 3).

Table 3. Detail of crop management under existing mango orchard and Agroforestry system

Topic	Existing fruit orchard	Agroforestry system with existing fruit orchard	
Crop	Mango	Turmeric	Mango
Variety	BARI Aam-3	Arani	BARI Aam-3
Spacing	4 m x 4 m	50 cm x 25 cm	4 m x 4 m
Plot size (dec.)	10	10	10
Fertilizer dose-NPKSZnB (kg/ha)	55-30-45-15-2-1	100-25-130-20-0-0.5	55-30-45-15-2-1
Date of sowing/transplanting	15.7.2016	15.5.20	15.7.16
Date of harvesting	20.6.20 to 25.6.20	20.12.20 to 25.12.20	20.6.20 to 25.6.20

Activity-12: Development of cropping pattern (Mustard-Sesame) with mango based agroforestry system

Location: FSRD site, Ganggarampur, OFRD, Pabna

Development of cropping pattern under agroforestry is considered for raising sustainable total production of the agroforestry system. In this regard, suitable cropping pattern was selected based on farmers' preferences and agronomic suitability for existing fruit orchard. Mustard-Sesame cropping pattern was selected for growing with existing mango orchard at FSRD site, Ganggarampur, Pabna during 2018-19 and 2019-20. The ages of the existing mango orchards (var. BARI Aam-4) of the selected orchard are about four years. The area of existing mango orchard is 66 decimal which was not utilized for crop production rather than sole mango in the previous year. However, for the development of cropping pattern mustard and sesame was grown in sequence with mango trees during two consecutive years. The variety of crops was BARI Sarisha-17 and BARI Til-4. The information of crop management practices is presented in Table 4.

Table 4. Details of crop management under existing mango orchard and improved agroforestry system

Topic	Existing mango orchard	Agroforestry system with existing fruit orchard		
Crop	Mango	Mustard	Sesame	Mango
Variety	BARI Aam-4	BARI Sarisha-17	BARI Til-4	BARI Aam-4
Spacing	5m x 5m	Broadcast	Broadcast	5m x 5m
Plot size (Dec.)	66	66	66	66
Fertilizer dose (N-P-K-S-Zn-B Kg ha^{-1})	38-17-32-8-1-0.5	120-34-43-27-2-2	46-30-25-22-2-2	38-17-32-8-1-0.5
Date of sowing/planting	June, 2016	Nov. 10-28	March 08-18	June, 2016
Date of harvesting	June 15-25	Feb. 17-March 03	June 12-21	June 15-25

Activity-13: Development of alternate cropping pattern Potato-T. *Aus*-T. *Aman* rice against *Boro*-Fallow-T. *Aman* rice under mango based agroforestry in plain land ecosystem

Location: Ajoddhapur, Rangpur Sadar, Rangpur

In Rangpur region *Boro*-Fallow-T. *Aman* rice cropping pattern is a common practice under the niches of mango orchards. In this study the variety of Boro, T. aman and mango was BRRI dhan28, Swarna and BARI Aam-4. In improved cropping pattern, Potato-T. *Aus*-T. *Aman* rice was tested under mango based agroforestry system. Standard crop management practices were followed for crops and fruit trees (Table 5).

Table 5. Details of existing and improved cropping pattern under mango based agroforestry system.

Pattern	Existing cropping pattern			Improved cropping pattern		
Crop	*Boro*	Fallow	T. *Aman*	Potato	T. *Aus*	T. *Aman*
Variety	BRRI dhan28	-	Swarna	BARI Alu-25	BRRI dhan48	BRRI dhan87
Field duration	133	-	112	87-89	90-95	90-100

Rainfed Ecosystem

Activity-14: Performance of pulses in mango based agroforestry system

Location: FSRD site, Barind, Rajshahi

High Barind Tract has 94% high land which can be a big scope to cultivate fruit in the main crop field. Cultivation of some pulse crops under agroforestry system will be a good option for increasing food production from the same piece of land.

The field experiment was conducted at Farming System Research and Development (FSRD) site, Basantapur, Godagari, Rajshahi during 2019-20 and 2020-21 to find out the performance of mango based agroforestry with pulse crops. The orchard with local popular variety of mango (*Khirshapat)* was selected for the study. Four pulses named, Chickpea (var. BARI Chola-5), Lentil (var. BARI Masur-8), Grass pea (var. BARI Kheshari-1) and Pea (var. BARI Motor-3) were tested in the mango orchard. Fertilizers were applied at the rate of 80-40-90-30-2 kg N-P-K-S-B ha^{-1} for pulses and mango cultivation. Chickpea, lentil, pea and grass pea seeds were broadcasted at 20-25 November. The pulse crops and mango were harvested on 10-26 March and 5-10 June, 2020 respectively.

Activity-15: Improvement of cropping pattern (Lentil-Mungbean-T. *Aman* rice) with mango based agroforestry system

Location: FSRD site, OFRD, Barind, Rajshahi

Cultivation of mango is very common and commercial agricultural practice in Rajshahi region. To make the the system more productive and profitable existing mango orchard were brought under agroforestry based production system. Lentil, mungbean and T. *Aman* rice were grown sequentially under niches of 8 yeras old mango orchard. The variety of lentil, mungbean and T. aman rice was BARI Masur-8, BARI Mug-6 and BRRI dhan51. Recommended management practices were followed for each crop and mango.

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Existing system: Sole mango

Improved system: Lentil (BARI Masur-8)-Mungbean (BARI Mung-6)-T. *Aman* rice (BRRI dhan51) with mango.

Coastal Ecosystem

Activity-16: Development of sorjan-based agroforestry system with quick growing fruits and vegetables in coastal ecosystem

Locations: Jamla village of FSRD site Dumki of Patuakhali

In coastal region farmers usually cultivate vegetables or timber trees in sorjan bed. In this study farmer's existing sorjan was renovated and cultivated high value vegetables and quick growing fruits in dyke in a sequential order round the year. The average size of sorjan was 30 decimal. This sorjan has three beds and two canals. The average length and wide of sorjan bed was 55 m × 24 m. Each bed was 2 m wide at the top and more or less 1 m height above ground level. Existing sorjan of cooperative farmers was renovated providing with all sorts of required inputs like seeds, fertilizers and pesticides. In *rabi* season, vegetables like red amaranth, brinjal and Bombay chili were cultivated. In *kharif-I* season, cucumber, snake gourd, ridge gourd, bottle gourd, Indian spinach, jute as vegetables and sweet gourd were cultivated. Quick growing fruits like Papaya, Guava and Banna were cultivated in sorjan bed. Seasonal fish like tilapia and Thai puti was cultivated within sorjan ditch in *kharif* season (Table 6). In *rabi* season irrigation was done for vegetables and fruits using ditch water of sorjan.

Table 6. Year round produced vegetables and fruits and seasonal fish in Sorjan of FSRD site Dumki of Paruakhali

Types	Year round vegetable & fruits in Sorjan		Remarks
	Rabi	*Kharif*	
Vegetables	Bottle gourd, Brinjal, chilli, sweet gourd	Cucumber, Snake gourd, Ridge gourd, Bottle gourd, Indian spinach, country bean etc.	Some vegetables already harvested and rest are now in sorjan bed
Fruits	Bannana, Papaya, Guava		Round the year
Fish	----	Seasonal fish like Telapia and Thaiputi	Telapia harvested with good condition

Hill Ecosystem

Activity-17: Performance of sweet gourd varieties under fruit tree based agroforestry system in hill slopes of Bandarban under hill ecosystem

Locations: Tetuli para hill slopes of Rowangchari Upazilla, Bandarban

Banderban hill tracts has great potentiality for growing different types of fruit specially mango, litchi, banana, pineapple, papaya, citrus etc. In this study performance of BARI released sweet gourd varieties under mango+papaya based agroforestry systems was observed. The experiment was conducted at the 2.5 years old mango gardens of the farmers' field of Tetulia para hill slopes in Bandarban during the rabi season of 2020-21. Average spacing of mango trees was 6 m × 4 m, clean bole height was 1.5 m, canopy spread was 2 m × 2 m and tree height was 2.5 m. So, there was much gaps between the tree canopy in the garden and direct sunlight may reach to the under storey crops. Three sweet gourd varieties viz. V_1=BARI Mistikumra-2, V_2=BARI Hybrid Mistikumra-2 and V_3=Hybrid Maya used as treatments under

Mango+Papaya based agroforestry system and the experiment was laid out in RCBD desing with three dispersed replications. The unit plot size was 6m×4m. The spacing was 4m×2m for each sweet gourd varieties. One papaya plant was planted in between two mango trees in a mango row to utilize the land more efficiently. Hence the distance between two papaya trees became 6m and average spacing of papaya trees was 6m×4 m. In this agroforestry plantation system, one bed of vegetable was cultivated maintaining 2m pit-pit distance. Pit size was 45cm×45cm×40cm and prepared by digging. Papaya seedlings were planted on 17 March to 18 March, 2020 and sweet gourd seeds were sown directly to the pits of different planting system on 11 November, 2020. Irrigation was provided when necessary. Insecticide and fungicide were sprayed to control the pest and diseases after leaf emergence. Data was recorded and analyzed by using Statistic 10 computer program.

Activity-18: Performance of different creeper vegetables under mango based agroforestry system in hill slopes of Bandarban

Location: Tetulia para hill slopes in Bandarban

The experiment was conducted at the 2 years old mango gardens of the farmers' field of Tukhung para and Tetulia para hill slopes of Sadar and Rowangchari upazila of Bandarban during the kharif season of 2019 and 2020 respectively. Average spacing of mango trees was 6 m × 4 m, clean bole height was 1.5-2 m, average canopy spread was 1.5 m × 1.5 m and tree height was 2-2.5 m. So, there was some gaps between the tree canopy in the garden, where direct sunlight may reach to the under storey crops. Sweet gourd, marpha and bottle gourd were used as under storey crop in this experiment. The experiment was laid out in Randomized Complete Block (RCB) Design with five dispersed replications. The unit plot size was 6 m × 4 m. The spacing was 4 m × 2 m for each vegetable. Pit-pit distance was 2 m. Pit size was 45 cm × 45 cm × 40 cm and prepared by digging. The seeds/seedlings were planted on 20-23 June, 2019 and 01 June, 2020. Insecticide and fungicide were sprayed as and when necessary to control the pest and diseases. Harvesting was done during 20 September to 30 October, 2019 and 20 July to 25 August depending upon the crop and location.

Activity-19: Performance of bitter gourd varieties under mango based agroforestry system in hill slopes of Bandarban

Locations: Tetuli para hill slopes of Rowangchari Upazilla, Bandarban

The experiment was conducted at the 2-3 years old mango gardens of the farmers' field of Tetulia para hill slopes in Bandarban during the kharif-1 season of 2020 and 2021. Average spacing of mango trees was 6 m×4 m, clean bole height was 1.5-2 m, canopy spread was 1 m×1 m and tree height was 2 m. So, there was some gaps between the tree canopy in the garden, where direct sunlight may reach to the under storey crops. Three varieties of bitter gourd viz. BARI Korola-3, BARI Korola-4 and Hybrid Tiya were used as under storey crop in this experiment. The experiment was laid out in Randomized Complete Block (RCB) Design with five dispersed replications. The unit plot size was 10 m × 8 m. The plant to plant spacing was 4 m × 1.5 m for each variety. Pit-pit distance was 1.5 m. Pit size was 45 cm × 45 cm × 40 cm and prepared by digging. The seeds were sown direct to the pit on 2 March, 2020 and 15 may, 2021. Insecticide and fungicide were sprayed as and when necessary to control the pest and diseases. Harvesting was done during 3 May to 1 July, 2020 and 10 July to 2 September, 2021.

C. *On-farm verification/Production program*

The On-farm verification or production programs was conducted at five FSRD sites under OFRD, BARI and two HRC, BARI sites with improved varieties of cereals, vegetables, spices,

pulses and other crops under the niche of trees to evaluate the performance of the crops in the respective FSRD and HRC, BARI sites for increasing area and production of the selected crops in agroforestry systems

Plain land Ecosystem

Activity-20: Upscaling mango based agroforestry with elephant foot yam at farmers' field

Location: FSRD site, Ganggarampur, OFRD, Pabna

The production program was carried out at FSRD site, Ganggarampur, Pabna during 2019-20. An existing 7 years aged unutilized mango orchard (var. Fazli) with an area of 30 decimal was selected for this study. Local variety (var. Madrazi) of elephant foot yam was used for this production program. The corms of elephant foot yam were planted in well prepared pit maintaining 100 cm x 75 cm spacing between the unutilized spaces of existing mango fruits on April 28, 2019 (Table 7). The spacing of mango fruit trees in the existing orchard was more or less 8m x 8m. Recommended fertilizer management was followed for fruits and elephant foot yam. Other management practices for fruits and elephant foot yam were done when required. Mango was harvested on July 10-20, 2020. Elephant foot yam was harvested on July 20-25, 2020.

Table 7. Details of crop management under existing mango orchard and agroforestry system

Topic	Existing fruit orchard	Agroforestry system with existing fruit orchard	
Crop	Mango	Elephant foot yam	Mango
Variety	Local (var. Fazli)	Local (var. Madrazi)	Local (var. Fazli)
Spacing	8m x 8m	100 cm x 75 cm	8m x 8m
Plot size (Dec.)	30	30	30
Fertilizer dose (N-P-K-S-Zn-B Kg ha^{-1})	115-50-62-45-4.5-2.3	160-50-100-36-4.0-2.0	115-50-62-45-4.5-2.3
Date of sowing/planting	July 2012	28 April 2019	July 2012
Date of harvesting	10-20 July 2020	20-25 July 2020	10-20 July 2020

Activity-21: Production of cauliflower under mango based agroforestry system

Location: FSRD site, Ajoddhapur, Rangpur

A field experiment was carried out at the agroforestory farm, Ajodhapur, FSRD site, under OFRD, BARI Rangpur during 2020-2021 to evaluate the performance of cauliflower under mango based agroforestry system. The experiment was conducted in newly established four years old Mango orchard where the spacing of tree saplings was 10 m×10 m. The experiment was laid out in RCBD with three dispersed replications. Before planting the seedlings of cauliflower, the land was fertilized by using fertilizer as per required doses. Seedlings of cauliflower were planted 5th November 2020 into the main plots. All P and K were applied at the time of final land preparation. N was applied in three equal. Plant protection measures were taken as required. Other intercultural operations were done when necessary. The crop was harvested from 01 to 7 February 2021. Production of cauliflower included costs of field preparation, planting, irrigation, organic manure and synthetic fertilizer, plant protection chemicals, and harvesting. Gross return under a treatment was calculated by multiplying the gross amount of cabbage produced by the farm-gate price. The gross margin was calculated by subtracting cost of production from the gross return.

Activity-22: Production of cabbage under mango based agroforestry system

Location: FSRD site, Ajoddhapur, Rangpur

A field experiment was carried out at the agroforestory farm, Ajodhapur, FSRD site, under OFRD, BARI Rangpur during 2020-2021 to evaluate the performance of Cabbage under mango based agroforestry system. The experiment was conducted in newly established four years old Mango orchard where the spacing of tree saplings was 10 m×10 m. The experiment was laid out in RCBD with three dispersed (Ferdous et al. 2018) replications. Before planting the seedlings of cabbage, the land was fertilized by using fertilizer as per required doses. Seedlings of cabbage were planted 10th November 2020 in to the main plots. All P and K were applied at the time of final land preparation. N was applied in three equal. Plant protection measures were taken as required. Other intercultural operations were done when necessary. The crop was harvested from 05 to 10 February 2021. Production of cabbage included costs of field preparation, planting, irrigation, organic manure and synthetic fertilizer, plant protection chemicals, and harvesting. Gross return under a treatment was calculated by multiplying the gross amount of cabbage produced by the farm-gate price. The gross margin was calculated by subtracting cost of production from the gross return.

D. *Fodder crops production under agroforestry system*

High yielding fodder crops was adapted at farm level. Different species of fodder crops have adapted at suitable agroforestry systems at field and homestead vicinity, pond bank at FSRD and HRC sites in each location. Multipurpose trees species have also been considered for feed management of livestock.

Plain land Ecosystem

Activity-23: Performance of Napier grass under mango based agroforestry system in plain land ecosystem

Location: Ajoddhapur, Rangpur sadar, Rangpur

Fodder crop Napier was grown under mango based agroforestry system at Ajoddhapur, FSRD site Rangpur during 2020-21. Cutting of Napier grass was planted on 28 May 2020. Harvesting of Napier grass was initiated on September 10 and continued at two months interval. Fertilizer management and other intercultural operations were done when required.

Activity-24: Production of fodder crop under mango based agroforestry system in plain land ecosystem

Location: FSRD site Ganggarampur, Pabna

The production program was carried out at farmers' field of FSRD site Ganggarampur, Pabna Sadar, Pabna during 2020-21. An existing 5 years aged unutilized mango orchard with an area of 33 decimals was selected at FSRD site, Ganggarampur, Pabna during 2020-21. The variety of mango of the selected orchard was BARI Am-4. Exotic variety (var. Pakchong) of Napier grass was used for this production program. The cuttings of napier grass was planted in between spaces of mango fruit trees maintaining spacing of 100 cm x 50 cm on December 10, 2018 (Table 8). Fertilizer management was done for fodder and fruit crops for better crop growth. Other management practices were done when required. The harvesting of fodder crop was initiated on July 15 and continued up to December 24, 2020. Mango fruit was harvested on July 5-12, 2020. The details of crop management practices are presented in Table 8.

Table 8. Details of crop management under existing fruit (mango) orchard and agroforestry system FSRD Site Gonggarampur pabna during 2020-21

Topics	Existing fruit orchard	Agroforestry system with existing fruit orchard	
Crop	Mango	Fodder	Mango
Variety	BARI Aum-4	Napier (Var. Pakchong)	BARI Aum-4
Spacing	5 m x 5 m	100 cm x 50 cm	5 m x 5 m
Plot size (dec.)	33	33	33
Fertilizer dose N-P-K-S-Zn-B	38-17-32-8-1-0.5	100-38-56.20-1.5-1.0	38-17-32-8-1-0.5
Date of sowing/planting	16.06.2020	10.12.2018	16.06.2016
Date of harvest	5.7.20 to 12.7.20	15.7.2020 to 24.12.2020	5.7.2020 to 12.7.2020

(b) Component-2: Pomology Div., HRC, BARI:

The activity of the project was carried out at the established fruit orchard to develop a sustainable model for fruit based Agroforestry. In the first year a benchmark survey was conducted to identify the traditional Agroforestry system usually practiced by the farmers in project areas. In second year, experiment was conducted with a view to identify the suitable vegetable or spices crops as the lower storied component along with the selection of suitable middle storied crop. The performance of all the crops grown in the Agroforestry system was done along with the utilization of resources and photosynthetically active radiation. Moreover, BCR and LER were determined to access whether the Agroforestry system is more profitable over control or not.

Research activity 1: Benchmark information

Justification**:** Existing cropping system of the project area was identified through Benchmark survey. The information through this study was helpful to identify the appropriate modern agroforestry system in the selected agro-eco system.

Objective(s**)**: 1. Identification of present practices of agroforestry system in the study area

The benchmark survey was conducted at the project area with the help of pretested questionnaire. Necessary data on demographic profile, different parameters on crops grown, meteprological information etc. were collected with participation of stakeholders.

Research activity 2: Productivity and profitability of mango based multistoried agroforestry system in Jessore and Khagrachari

Objective(s):

 i) Selection of lower and middle storied crops in mango based agroforestry
ii) To reduce yield gap by minimizing root shoot competition for light and nutrients of tree and crop through training and pruning management
iii) Economic study of crop in respect of BCR and LER
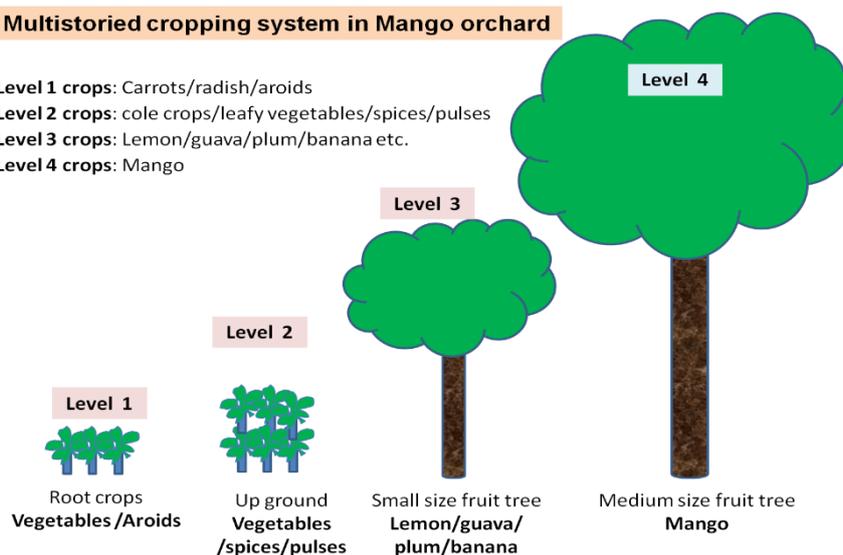
Fig: Multistoried cropping system in young mango orchard

There are many mango orchards in Jashore region and its demand is increasing day bay day where the fallow spaces can be utilized by planting different types of crops as a multistoried cropping system. Therefore, in view of proper utilization of spaces in new Mango orchards (3 years old) and to increase the tree coverage as well as the production of fruits, vegetables, spices, pulses and aroids, the present study has been undertaken to evaluate the performance of some fruits as middle layer and some vegetables, spices, pulses and aroids as lower layer crops to boast up the economy in Mango based four layered multistoried agroforestry system. Accordingly, an experiment was conducted in young mango orchards (2-5 years age) at Regional Agricultural Research Station (RARS), Jashore and Hill Agricultural Research Station, Khagrachari during July 2020 to June, 2021 to develop mango based multistoried agroforestry system. There were five treatments in the experiment viz; T_1 (Mango + Ber + Cabbage+Mung bean - Okra + Aroids (Oal kochu), T_2 (Mango + Lemon + Cauliflower+Mung bean - Yard long bean + Ginger), T_3 (Mango + Guava + Kohlrabi +Mung bean + red amaranth + Mukhi kochu), T_4 (Mango + Banana + Corriender+Mung bean - Indian spinach + Turmeric) and T_5 (Mango sole). The experiment was laid out in a Randomized Complete Block Design (RCBD) with 4 replications.

Unit plot size was 4.0 m x 4.0 m maintaining crop-wise plant spacing. The middle layer fruit plants (Banana, Ber, Guava and Lemon) were planted in May 2018. For the season 2020-2021, Kharif-2 lower layer vegetable crops (Okra, yard long bean, red amaranth and Indian spinach) were planted in 30 May 2020, Lower layer winter vegetable crops (Cabbage, cauliflower, kohlrabi and corriender) were planted in 25 October 2020, lower layer Kharif-1pulse crop (Mungbean) were planted in 27 February 2021 and lower layer year round crops (aroids, ginger and turmeric) were planted in 20 April 2020. The land and pants were fertilized with cowdung, urea, TSP, MoP and gypsum @ recommended doses respectively. All the intercultural operations including irrigations, wedding and disease or pest management were done as and when necessary. Data on yield parameter of all crops were recorded and economic analysis had also been done.

Research activity 3: Productivity and profitability of pummelo based multistoried agroforestry system in Jessore

Objective(s): i) Selection of lower and middle storied crops in pummelo based agroforestry
ii) To reduce yield gap by minimizing root shoot competition for light and nutrients of tree and crop through training and pruning management
iii) Economic study of crop in respect of BCR and LER

Pummelo is popular and commercially profitable fruit crops in Jashore region. There are fellow spaces between the rows and plants in pummel orchards which can be utilized by planting different types of crops as a multistoried cropping system. Therefore, in view of proper utilization of spaces in pummelo orchards (8 years old) and to increase the income the present study had been undertaken to evaluate the performance of some root crops to develop pummel based multistoried cropping system and to boast up the economy. Accordingly, an experiment was conducted in pummelo orchard (8 years old) at Regional Agricultural Research Station (RARS), Jashore during July 2020 to June, 2021. There were four treatments in the experiment viz; T_1 (Pummelo+Mukhi kochu), T_2 (Pummelo + Ginger), T_3 (Pummelo + Turmeric) and T_4 (Pummelo sole). The experiment was laid out in a Randomized Complete Block Design (RCBD) with 4 replications.

Necessary data on yield and yield contributing characters of lower, middle and upper storied crops, measurement of light intensity and soil moisture and major nutrient analysis of the soil under different agroforestry system was collected and analysed with statistical software.

11. Results and Discussion

Component-1: OFRD, BARI

A. Homestead Agroforestry Production System

Plain land Ecosystem

Activity-1: Development of homestead agroforestry with vegetables and fruits crops in Pabna areas under plain land ecosystem

Location: FSRD site Ganggarampur, Pabna Sadar, Pabna

The results of the hometead agroforestry are presented in Table 9. Total production of mango and vegetables/spice was 386 and 771 kg, respectively from fruit tree based homestead agroforestry (homestead 1). However, in case of homestead 2, total production of only vegetables was 345 from non-fruit tree based homestaed agroforestry. Regarding economic benefit, relatively higher gross return (Tk. 36920 ha^{-1}) and gross margin (Tk. 27740 ha^{-1}) was obtained from homestead 1 as compared with homestead 2 attaining gross return (Tk. 8625 ha^{-1}) and gross margin (Tk. 5425 ha^{-1}). Considering per unit economic benefit, growing bitter gourd, tomato and brinjal with mango orchard found more profitable. This result suggests that

fruit tree based homestead agroforestry is relatively more profitable than non-fruit tree based homestead agroforestry regarding total productivity and economic return.

Farmer's opinion

The co-operator farmers showed their satisfaction to homestead agroforestry system production

due to continuous income generation and family labour uitlization. Neighboring farmers frequently visited this technology and showed their interest to adopt this technology in their homestead vicinity in future.

Table 9. Yield and Economic performance of crops in homestead agroforestry system

Agroforestry practices in homestead	Area (dec.)	Production (kg)		Gross return (Tk.)	Total variable cost (Tk.)	Gross margin (Tk.)	Gross margin (Tk. decimal^{-1})
		Fruits	Vegetables/S pice				
Mango + Tomato	3	60	162	5679	951	4728	1576
Mango + Brinjal	3	66	186	6675	2049	4626	1542
Mango + Country bean	4	80	84	6500	1200	5300	1325
Mango + Bitter gourd	3	60	81	5664	900	4764	1588
Mango + Turmeric	6	120	258	12402	4080	8322	1387
Homestead 1 Total	*19*	*386*	*771*	*36920*	*9180*	*27740*	
Mahogany + Elephant foot yam	3	-*	180	4500	1700	2800	933
Mahogany + Country bean	3	-	165	4125	1500	2625	875
Homestead 2 Total	*6*		*345*	*8625*	*3200*	*5425*	

*The benefit of non fruit trees is not included in production.

Rainfed Ecosystem

Activity-2: Development of homestead agroforestry with vegetables and fruits crops in Barind areas under rainfed ecosystem

Locations: Godagari, OFRD, Barind, Rajshahi

Vegetable's production: Total vegetables production per homestead under homestead agroforestry was 513 kg during 2018-19 to 2020-21 (Table 10). Among the total production, own consumption, free distribution and selling were 333, 54 and 127 kg, respectively and the percentage of consumption, free distribution and selling were 64.91, 10.53 and 24.76%, respectively (Table 10). The average consumption per head per day was 181 g. From the above results, it was found that under homestead agroforestry intake of vegetables increased

to a significant level (on an average 181 g h^{-1} day^{-1} instead of 96 g h^{-1} day^{-1} bench mark), which helped the farmers to meet the demand of vegetables and to reduce the daily expenditure of vegetable purchase. Though the intake of 181 g h^{-1} day^{-1} was below than the recommended daily vegetable consumption (200 g h^{-1} day^{-1}), despite that wide spread malnutrition was reduced to a marked level, hence nutrition and food insecurity was marginalized.

Farmers also earned a small amount of cash income from vegetable selling after meeting their daily requirement and distributed a portion of vegetables among the relatives and neighbors. It was also found that total cash income was recorded Tk. 2531 per homestead which contributed to improve farmers' livelihood.

Table 10. Average vegetable production and disposal pattern per farm under homestead agroforestry at FSRD site, Barind, Rajshahi during 2018-19 to 2020-21

Months	Vegetable production (kg month^{-1})	Own consumption (kg month^{-1})	Own consumption (g h^{-1} day^{-1})*	Free distribution (kg month^{-1})	Sold (kg month^{-1})	Total cash income (Tk. month^{-1})
January	65.5	40.0	258.06	8.5	17	340
February	23.0	13.5	93.10	3.5	6.0	120
March	30.0	20.25	130.64	2.5	7.25	145
April	40.0	25.5	170.0	4.0	10.5	210
May	40.0	27.0	174.19	3.0	10.0	200
June	45.8	29.0	193.33	6.0	10.8	216
July	56.0	35.0	225.0	7.0	14.0	280
August	40.0	28.0	180.0	4.0	8.0	160
September	33.0	25.0	166.0	2.0	6.0	120
October	25.0	18.0	116.1	2.0	5.0	100
November	45.0	29.0	193.0	4.0	12.0	240
December	70.0	43.0	277.0	7.0	20.0	400
Total	**513**	**333 (64.91%)**	**181** (before intervention 96 g)	**54 (10.53%)**	**127 (24.76%)**	**2531**

* Five members in a family were considered. ** Figure in parenthesis indicates percentage

Fruits production: After intervention of the proven and improved technologies in the homestead, fruits production has increased significantly. Good amount of fruits production was found during the study period (469 kg homestead^{-1}) (Table 11). Using of improved technologies including judicious fertilizer management in fruits production has increased the yield tremendously.

Table 11. Average fruits production and disposal per farm pattern under homestead agroforestry at FSRD site, Barind, Rajshahi during 2018-19 to 2020-21

Total production (kg farm^{-1})	Total own consumption (kg farm^{-1})	Own consumption (g h^{-1} day^{-1})*	Free distribution (kg farm^{-1})	Sold (kg farm^{-1})	Total cash income (Taka farm^{-1})
469	289 (57.66%)	318	43 (9.48%)	122 (29.19%)	3660

* Five members in a family were considered. ** Figure in parenthesis indicates percentage

Utilization of fruits: The disposal pattern of different fruits produced under homestead agroforestry was recorded timely. The average of fruits intake per farm family during the study period was 289 kg (Table 11). After program intervention, the average distribution of fruits per farm was recorded as 43 kg and sell of fruits was 122 kg per farm. Increased production of fruits encouraged the farm families to distribute towards their relatives and neighbor, but the farmers were more interested to sell for getting some cash money.

Coastal Ecosystem

Activity-3: Development of homestead agroforestry system through vegetable and fruits cultivation in Coastal ecosystem

Locations: Jamla and Razakhali village under FSRD site, Dumki, Patuakhali

The performance of vegetable crops grown in different niches of homestead agroforestry is presented in Table 12. It was observed that per farm vegetable production was the highest during rabi season (107 kg) and the lowest in kharif-II season (51 kg). Average production of vegetables per farm was higher at sunny spaces (51 kg). Average production of vegetables and fruit per farm was 212 kg and 52 kg, respectively. The comparative study showed that total vegetable production and income increased 168% after intervention.

Table 12. Average vegetables and fruits production per farm from different places of homestead agroforestry at FSRD site, Jamla, Patuakhali from 2019-20 to 2020-21

Space		Rabi	Kharif-1	Kharif-II	Total
		October–March	April-June	July-September	(kg farm^{-1})
	Bed-1	12	10	07	29
Open sunny space	Bed-2	11	8	05	24
	Bed-3	13	7	04	24
	Bed-4	09	9	05	23
	Bed-5	06	5	05	16
Sub total		**51**	**39**	**26**	**116**
Trellis		27	08	15	50
Non-fruit trees		10	-	-	10
Pond/ditch slope		19	07	10	36
Total (vegetable)		107	54	51	212
Fruits		12	30	10	52
Total (vegetables + fruits)		**119**	**84**	**61**	**264**

Fig. Field views of homestead agroforestry at FSRD site of Patuakhali from 2019-20 to 2020-21

B. *Improvement of crop land agroforestry with suitable crops and cropping pattern*

Plain land Ecosystem

Activity-4: Development of mango based agroforestry with pulse crop under plain land ecosystem

Location: FSRD site, Ganggarampur, OFRD, Pabna

The results showed that agroforestry system with blackgram showed relatively higher productivity as compared to sole mango cultivation (Table 13). The fruit equivalent yield (FEY) of the agroforestry system with blackgram was 5.65 while relatively lower FEY (3.50) was recorded in sole mango culture. Higher gross return (Tk. 339000 ha^{-1}) and gross margin (Tk.274300 ha^{-1}) was also obtained from the agroforestry system. The results suggest that this agroforestry technology with mango and blackgram found more profitable and contributed to the higher production and economic return (MBCR: 3.44) as compared to famers traditional sole mango cultivation. Farmers were happy and convinced to this agroforestry system based production approach. Neighboring farmers were visited the plot and motivated to adopt this technology in their land.

Table 13. Yield and economics performance of existing fruit orchard and agroforestry system.

Production system	Crop yield (t ha^{-1})			Economic analysis (Tk. ha^{-1})			
	Blackgram	Mango	MEY	Gross return	Total variable cost	Gross margin	MBCR
Existing sole fruits (Mango)	-	3.50	3.50	210000	26600	183400	
Agroforestry system with pulse crop	1.29	3.50	5.65	339000	64100	274300	3.44

Market price (Tk kg^{-1}): Mango-60.00, Blackgram-100.00, MEY= Mango Equivalent Yield

Farmers' opinion: Farmers were happy and convinced to this agroforestry system based production approach. Neighboring farmers were visited the plot and motivated to adopt this technology in their land.

Conclusion: Mango-based agroforestry system with blackgram exhibited very encouraging results in view of total system productivity and economic return. This agroforestry technology with mango and blackgram can be recommended for wider scale extension at extrapolation areas.

Activity-5: Feasibility of growing shade tolerant crops under mango based agroforestry system

Location: FSRD site, Ganggarampur, OFRD, Pabna

The performance of different vegetables grown under agroforestry and open land condition is presented in Table 14. The results showed that all the tested crops exhibited significant difference in plant height under two growing environments except cabbage. Significantly higher plant height of field pea, radish, cauliflower and tomato was recorded in agroforestry system as compared with open land condition. Among the tested vegetables field pea, radish and cabbage showed significantly higher yield under open land condition whereas cauliflower and tomato did not demonstrate significant influence on yield due to two different growing conditions. However, lower yield of vegetables was attained from agroforestry system. The lower yield of vegetables especially field pea, radish and cabbage might be the reason of reduced light interception caused by trees canopy and reduced chlorophyll content. Regarding

system productivity, higher mango equivalent yield was noted for all vegetables under agroforestry system. This result suggests that though the yield of all vegetables is relatively low under agroforestry system, the cumulative benefit of fruits and vegetables production results in higher system productivity (Table 14). However, the system productivity increased by 74.06, 46.39, 30.18, 27.74 and 22% in case of field pea, radish, cabbage, cauliflower and tomato under agroforestry system during 2019-20 while system productivity increased by 13.58, 35.37, 84.50, 71.43 and 158.69% in case of field pea, radish, cabbage, cauliflower and tomato under agroforestry system as compared to sole mango cultivation during 2020-21.

Table 14. Performance of vegetables under open land and agroforestry system at FSRD site Ganggarampur, Pabna.

Vegetables	Growing environment	Plant height (cm)	Vegetables/ Seed yield (t ha⁻¹)	Fruit yield (t ha⁻¹)	Mango equivalent yield (t ha⁻¹)		System productivity increase (%)	
					2020-21	2019-20	2020-21	2019-20
Field pea	*Agroforestry*	169.73a	1.29b	9.50	10.79	7.75	13.58	74.06
	Open land	140.96b	2.13a					
	CV(%)	10.18	9.24					
	Level of signi.	*	*					
Radish	*Agroforestry*	32.63a	40.77b	9.84	13.32	64.87	35.37	46.39
	Open land	24.77b	56.06a					
	CV(%)	2.33	7.85					
	Level of signi.	*	*					
Cabbage	*Agroforestry*	33.20	65.42b	9.03	16.66	114.89	84.50	30.18
	Open land	30.33	80.91a					
	CV (%)	7.53	8.33					
	Level of signi.	ns	*					
Cauliflower	*Agroforestry*	66.53a	38.38	8.96	15.36	81.24	71.43	27.74
	Open land	58.07b	41.98					
	CV (%)	6.78	5.72					
	Level of signi.	*	ns					
Tomato	*Agroforestry*	130.10a	69.60	7.31	18.91	98.28	158.69	22.00
	Open land	78.73b	82.53	-				
	CV (%)	4.38	6.02					
	Level of signi.	*	ns					

Regarding economic benefit, in general higher gross return and gross margin was obtained from all the tested vegetables grown under agroforestry system as compared to open land condition. However, maximum gross return and gross margin was found from tomato, cabbage and cauliflower under agroforestry system (Table 15).

Table 15. Cost and return of vegetables under open land condition and mango based agroforestry system at FSRD site Ganggarampur, Pabna.

Vegetables	Gross return (Tk. ha⁻¹)		Total variable cost (Tk. ha⁻¹)		Gross margin (Tk. ha⁻¹)	
	Agroforestry	Open land	Agroforestry	Open land	Agroforestry	Open land
Field pea	647400	127800	106440	65940	540960	61860
Radish	793600	280300	112250	71750	681350	208550
Cabbage	999670	566370	180250	139750	819420	426620
Cauliflower	921400	419800	179450	138950	741950	280850
Tomato	1134500	825200	186850	146350	947650	678850

Price (Tk. kg⁻¹): Field pea- 60.00, Radish-5.00, Cabbage- 5.00, Cauliflower- 7.00 and Tomato-7.00

Activity-6: Development of litchi-based agroforestry with lentil

Location: Ganggarampur, OFRD, Pabna

The results showed that agroforestry system with lentil showed relatively higher productivity as compared to sole litchi cultivation. The litchi equivalent yield (LEY) of the agroforestry system with lentil was 5.51 and 7.71 while relatively lower LEY (4.32 and 6.50) was noted in sole litchi culture during 2018-19 and 2019-20 respectively (Table 16 and Table 17). Higher gross return (Tk. 551000 and Tk. 771000 ha⁻¹) and gross margin (Tk. 477000 and Tk. 693900 ha⁻¹) was also obtained from the agroforestry system during the successive years. The results suggest that this agroforestry technology with litchi and lentil found more profitable and contributed to the higher production and economic return as compared to famers' traditional sole litchi cultivation. Farmers were happy and convinced to this agroforestry system based production approach. Neighboring farmers were visited the plot and motivated to adopt this technolgy in their land.

Table 16. Yield and economic performance of existing litchi orchard and agroforestry system during 2018-19 at FSRD site Ganggarampur, Pabna.

Production system	Crop yield (t ha⁻¹)			Economic analysis (Tk. ha⁻¹)			
	Lentil	Litchi	LEY	Gross return	TVC	Gross margin	MBCR
Existing sole fruits (Litchi)	-	4.32	4.32	432000	35500	396500	-
Agroforestry system	2.25	4.27	5.51	551000	74000	477000	3.09

Price (Tk. kg⁻¹) = Urea-16, TSP-24, MP-16, Gypsum-10, Zinc Sulphate-230, Boric acid-460, Lentil seed-55, and Litchi-100. LEY= Litchi equivalent yield, TVC= Total variable cost, MBCR= Marginal benefit cost ratio

Table 17. Yield and economic performance of existing fruit orchard and agroforestry system during 2019-20 at FSRD site Ganggarampur, Pabna

Production system	Crop yield (t ha⁻¹)			Economic analysis (Tk. ha⁻¹)				Average
	Lentil	Litchi	LEY	Gross return	TVC	Gross margin	MBCR	MBCR
Existing sole fruits	-	6.50	6.50	650000	38600	611400	-	-
Agroforestry system	1.75	6.40	7.71	771000	77200	693900	3.13	3.11

Price (Tk. kg⁻¹) = Urea-16, TSP-24, MP-16, Gypsum-10, Zinc Sulphate-230, Boric acid-460, Lentil seed-75, and Litchi-100. LEY= Litchi equivalent yield, TVC= Total variable cost, MBCR= Marginal benefit cost ratio

Activity-7: Development of litchi-based agroforestry system with high value crops

Location: Ganggarampur, OFRD, Pabna

Maximum fruit equivalent yield was obtained from litchi+ cauliflower (13.21 t ha⁻¹) followed by litchi + cabbage (10.98 t ha⁻¹) and litchi + broccoli (9.18 t ha⁻¹) (Table 18). Regarding economic benefit, higher gross return (Tk. 1321000 ha⁻¹) and gross margin (Tk. 1162900 ha⁻¹) was achieved from litchi + cauliflower followed by litchi + cabbage and litchi + broccoli. All vegetables grown in litchi based agroforestry system exhibited remarkably higher gross return and gross margin compared to sole litchi orchard. However, litchi based agroforestry system with cauliflower demonstrated almost double return as compare to sole litchi orchard (Table 19).

Table 18. Performance of yield of vegetables and fruits in litchi based agroforestry system at FSRD site Ganggarampur, Pabna Sadar, Pabna during 2019-20

Treatment	Vegetables yield (t ha⁻¹)	Fruit yield (t ha⁻¹)	Fruit equivalent yield (t ha⁻¹)
Litchi + Cauliflower	40.70	7.10	13.21
Litchi + Cabbage	68.45	5.50	10.98
Litchi + Broccoli	16.65	5.85	9.18
Litchi	-	6.80	6.80

Price (Tk. kg⁻¹): Cauliflower: 15.0, Cabbage: 8.0, Broccoli: 20.0, Litchi: 100

Table 19. Cost and return of vegetables and fruits in litchi based agroforestry system at FSRD site Ganggarampur, Pabna Sadar, Pabna during the during 2019-20

Treatment	Gross return (Tk. ha⁻¹)	Total variable cost (Tk. ha⁻¹)	Gross margin (Tk. ha⁻¹)	MBCR
Litchi + Cauliflower	1321000	158100	1162900	5.36
Litchi + Cabbage	1098000	158100	939900	3.50
Litchi + Broccoli	918000	117100	800900	3.03
Litchi	680000	38600	641400	-

MBCR= Marginal Benefit Cost Ratio

Activity-8: Development of guava based agroforestry system with pulses crops

Location: Ganggarampur, OFRD, Pabna

Maximum guava equivalent yield was obtained from guava+ lentil (8.67 and 9.55 t ha^{-1}) followed by guava+ field pea and guava + grass pea during two consecutive years (Table 20 and Table 21). Regarding economic benefit, higher gross return (Tk. 318850 ha^{-1}) and gross margin (Tk. 212020 ha^{-1}) was achieved from guava + lentil followed by guava + grass pea and guava+ field pea. The results revealed that guava based agroforestry system with pulses crops demonstrated encouraging results in view of total system productivity and economic return (Table 22). All the tested pulses crops in agroforestry system exhibited relatively higher production and economic return as compared with sole guava. However, considering total system productivity and economic benefit guava+ lentil agroforestry system exhibited relatively better performance.

Table 20. Performance of pulses and fruits in guava based agroforestry system at FSRD site Ganggarampur, Pabna Sadar, Pabna during 2018-19.

Agroforestry practices	Pulse crop yield (t ha^{-1})	Fruit yield (t ha^{-1})	Guava equivalent yield (t ha^{-1})
Guava+ Lentil	1.7	6.0	8.67
Guava+ Field pea	1.4	5.9	8.10
Guava+ Grass pea	1.5	5.75	8.11
Guava (Sole)	-	6.2	6.2

Table 21. Performance of pulses and fruits in guava based agroforestry system at FSRD site Ganggarampur, Pabna Sadar, Pabna during 2019-20

Agroforestry practices	Pulse crop yield (t ha^{-1})	Fruit yield (t ha^{-1})	Guava equivalent yield (t ha^{-1})
Guava+ Lentil	1.75	5.80	9.55
Guava+ Field pea	1.50	5.65	7.79
Guava+ Grass pea	1.60	5.40	7.46
Guava (Sole)	-	5.95	5.95

Table 22. Cost and return of pulses and fruits in guava based agroforestry system at FSRD site Ganggarampur, Pabna Sadar, Pabna.

Agroforestry practices	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
Guava+ Lentil	318850	106830	212020	2.65
Guava+ Field pea	278075	107530	170545	1.61
Guava+ Grass pea	272475	102300	171175	1.69
Guava (Sole)	212625	66800	145825	-

Activity-9: Development of guava-based agroforestry system with high value crops

Location: Ganggarampur, OFRD, Pabna

The performance of different high value vegetable crops and fruits under guava based agroforestry system are presented in Table 23. Maximum fruit equivalent yield was obtained from guava+ tomato (22.18 t ha^{-1}) which was at par with guava + cauliflower (18.69 t ha^{-1}) and guava+ cabbage (15.86 t ha^{-1}). Minimum fruit equivalent yield was recorded in sole guava (4.49 t ha^{-1}). Regarding economic benefit, higher gross return (Tk. 938667 ha^{-1}) and gross margin (Tk. 783867 ha^{-1}) was achieved from guava + tomato followed by guava+ cauliflower and guava+ cabbage (Table 24). The results revealed that guava based agroforestry system with high value crops demonstrated very encouraging results in view of total system productivity and economic return. All the tested vegetables in agroforestry system exhibited three to four times' higher production and economic return as compared with sole guava. However, considering total system productivity guava + tomato agroforestry system exhibited relatively better performance.

Farmers' opinion: Farmers expressed their satisfaction to this agroforestry technology because:
- Increased production and economic benefit as compared to their sole guava cultivation
- More time harvesting and marketing generate cash income
- Intensive labour utilization
- Less pest and disease infestation
- Feel proud due to visit of neighboring farmers and govt. officials

Table 23. Average performance of vegetables and fruits in guava based agroforestry system at FSRD site Ganggarampur, Pabna Sadar, Pabna during 2018-19 to 2020-21

Treatment	Vegetables yield (t ha^{-1})	Fruit yield (t ha^{-1})	Guava equivalent yield (t ha^{-1})
Guava+ Tomato	60.08	4.17	22.18
Guava+ Cauliflower	58.51	4.81	18.69
Guava+ Cabbage	75.23	4.36	15.86
Guava	0	4.49	4.49

Table 24. Average cost and return of vegetables and fruits in guava based agroforestry system at FSRD site Ganggarampur, Pabna Sadar, Pabna during three consecutive years (2018-19 to 2020-21)

Treatment	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})
Guava+ Tomato	938667	154800	783867
Guava+ Cauliflower	755850	166467	589383
Guava+ Cabbage	659617	166467	493150
Guava	177767	78567	98200

Activity-10: Performance of newly released late blight resistant potato variety at Rangpur under mango based agroforestry systems

Location: FSRD site Ajoddhapur, Rangpur

The results reveal that BARI Alu-46 and BARI Alu-53 showed excellent performance against late blight under mango based agroforestry and produced higher tuber yield compared to BARI Alu-25 (Table 25). Farmers were happy to observe the performance of the varieties and demanded quality seed for next year cultivation.

Table 25. Yield of newly released late blight resistant potato variety at farmer's field under mango based agroforestry systems during 2020-2021

Location	Farmers (no)	Tuber yield of poatato varieties (t ha^{-1})			
		BARI Alu-53	BARI Alu-46	BARI Alu-77	BARI Alu-25 (Control)
Rangpur	F(1)	29.65	32.66	31.88	24.59
	F(2)	27.66	29.85	32.67	21.45
	F(3)	31.33	33.56	29.58	22.67
	F(4)	29.67	31.34	28.98	23.77
	Mean	29.12	31.17	30.77	22.49

Here, 'F' indicates 'Farmer'

Farmer's opinion: Farmers were happy to observe the performance of potato varieties BARI Alu-46, BARI Alu-53 and BARI Alu-77 under mango based agroforestry systems against Late Blight disease and higher yield potentials. They preferred BARI Alu-53 and BARI Alu-77 due to red color and higher market price. They demanded quality seed for (BARI Alu-53 and BARI Alu-77) next year cultivation.

Activity-11: Development of mango based agroforestry with turmeric at farmers' field under plain land ecosystem

Location: FSRD site, Ganggarampur, OFRD, Pabna

The results reveal that agroforestry system with turmeric showed remarkably higher productivity as compare to sole mango cultivation (Table 26). The higher system productivity in terms of mango equivalent yield (MEY) of the agroforestry system with turmeric was 8.02 t ha^{-1} while relatively much lower MEY (3.12 t ha^{-1}) in sole mango. The highest gross return (Tk. 401000 ha^{-1}) and gross margin (Tk. 260500 ha^{-1}) and satisfactory MBCR (2.13) was also obtained from agroforestry system. The results suggest that this agroforestry technology with mango and turmeric found more profitable and contributed to the higher production and economic return as compared to famers' traditional sole mango cultivation.

Co-operator farmers were happy and convinced to this agroforestry system based production approach.

Table 26: Yield and economics performance of existing mango orchard and agroforestry system.

Production system	Crop yield (t ha⁻¹)			Economic analysis (Tk. ha⁻¹)			MBCR
	Turmeric	Mango	MEY	Gross return	Total variable cost	Gross margin	
Existing sole fruits (Mango)	-	3.12	3.12	156000	25500	130500	2.13
Agroforestry system with Turmeric	12.25	3.15	8.02	401000	140500	260500	-

Market price (Tk kg⁻¹): Mango-50.00 Turmeric-20.00, MEY= Mango Equivalent yield

Activity-12: Development of cropping pattern (mustard-sesame) with mango based agroforestry system

Location: FSRD site, Ganggarampur, OFRD, Pabna

The results reveal that agroforestry system with cropping pattern showed remarkably higher productivity as compared to farmers' traditional sole mango cultivation (Table 27 and Table 28). The mango equivalent yield (MEY) of the agroforestry system was 5.95 and 6.86 t ha⁻¹ during 2018-19 and 2019-20 while relatively lower MEY (3.5 and 3.75 t ha⁻¹) was noted in sole mango cultivation. Higher gross return (Tk. 383830 and Tk. 411600 ha⁻¹) and gross margin (Tk. 259255 and Tk. 287025 ha⁻¹) and MBCR (2.04 and 2.12) was also obtained from agroforestry system during the successive years. The results suggest that development of cropping pattern in association with existing mango orchard found more profitable and contributed to the higher production and economic return. Co-operator farmers were happy and convinced to this agroforestry system based production approach.

Table 27. Yield and economic performance of existing fruit orchard and improved agroforestry system during 2018-19.

Production system	Crop yield (t ha⁻¹)				Economic analysis (Tk. ha⁻¹)			
	Mustard	Sesame	Mango	MEY	Gross return	TVC	Gross margin	MBCR
Existing sole fruits	-	-	3.5	3.5	210000	35625	183375	-
Agroforestry system	2.4	1.3	3.5	5.95	383830	120575	259255	2.04

MEY= Mango equivalent yield, TVC= Total variable cost, MBCR= Marginal benefit cost ratio

Table 28. Yield and economic performance of existing fruit orchard and improved agroforestry system with cropping pattern during 2019-20.

Production system	Crop yield (t ha⁻¹)				Economic analysis (Tk. ha⁻¹)				Avr.
	Mustard	Sesame	Mango	MEY	Gross return	TVC	Gross margin	MBCR	MBCR
Existing sole fruits	-	-	3.75	3.75	225000	36625	198375	-	-
Agroforestry system	2.10	1.47	3.75	6.86	411600	124575	287025	2.12	2.08

MEY=Fruit equivalent yield, TVC=Total variable cost, MBCR=Marginal benefit cost ratio,
Price (Tk. kg⁻¹): Urea=16, TSP=24, MoP=16, Gypsum=10, Zinc Sulphate=230, Boric acid=460, Mustard seed=43, Mustard stover=1.0, Sesame=62.5 and Mango=60

Activity-13: Development of alternate cropping pattern Potato-T. *Aus*-T. *Aman* rice against *Boro*-Fallow-T. *Aman* rice under mango based agroforestry in plain land ecosystem

Location: Ajoddhapur, Rangpur Sadar, Rangpur

In FSRD site Ajoddhapur, cropping pattern Potato-T. *Aus*-T. *Aman* rice was evaluated against existing *Boro*-Fallow-T. *Aman* rice under mango based agroforestry system. The yield of potato, T. *Aus* and T. *Aman* rice were recorded 23.45, 3.51 and 4.04 t ha⁻¹ whereas the yield of *Boro* and T. *Aman* rice was 4.73 and 3.26 t ha⁻¹ under agroforestry system.

Regarding economic benefit, higher gross margin (Tk. 192460 ha⁻¹) was obtained from Potato-T. *Aus*-T. *Aman* rice cropping pattern as compared to existing Boro-Fallow-T. aman pattern (Tk. 98640 ha⁻¹) (Table 29).

Farmers were very much impressed with their high yield as well as economic return obtained from the alternate pattern as compared to their existing one.

Farmers' opinion: Farmers prefer Potato-T. *Aus*-T. *Aman* rice cropping pattern due to its higher return and T. *Aus* rice is less irrigated water requiring crop compare to *Boro* and provide higher return.

Table 29. Performance of alternate and existing at FSRD site under mango based agroforestry systems.

Pattern	Existing cropping pattern			Improved cropping pattern		
Crop	*Boro*	Fallow	T. *Aman*	Potato	T. *Aus*	T. *Aman*
Variety	BRRI dhan28	-	Swarna	BARI Alu-25	BRRI dhan48	BRRI dhan87
Field duration	133	-	112	87-89	90-95	90-100
Turnaround time	12	-	10	13		
Grain or seed yield (t ha^{-1})	4.73	-	3.26	23.45	3.51	4.04
Straw or stover yield (t ha^{-1})	5.25	-	4.72	-	4.11	4.97
REY (t ha^{-1})	5.20	-	3.68	10.65	3.80	4.49
Whole pattern REY (t ha^{-1})	8.89			18.94		
Gross return (Tk. ha^{-1})	114560	-	79080	234500	85440	98820
Total variable cost (Tk. ha^{-1})	53200	-	41800	141400	43100	41800
Gross margin (Tk. ha^{-1})	61360	-	37280	93100	42340	57020
Whole pattern GM (Tk. ha^{-1})	98640			192460		

Rainfed Ecosystem

Activity-14: Performance of pulses in mango based agroforestry system

Location: FSRD site, Barind, Rajshahi

In general, mango orchard involving pulses produced significantly higher mango equivalent yield (MEY) than that having sole orchard. However, mango+lentil and mango+chickpea exhibited relatively higher MEY (11.52 and 11.30 t ha^{-1}) and economic return in terms of MBCR (4.10 and 3.95) during 2019-20. In 202-21, higher MEY (11.26 and 10.36) and MBCR (4.04 and 2.87) were also achieved from mango+chickpea and mango+lentil as compared to sole mango (Table 30 and Table 31). Therfore, chickpea and lentil are found suitable pulse crops to grow in mango-based agro-forestry system at High Barind Tract in respect of yield economic return which was economically profitable.

Farmer's reaction: Farmers obtained higher economic benefit from chickpea and lentil in mango based agroforestry system. Neighboring farmers visited the field and impressed to see the crop performance.

Table 30. Yield and economic performance of different pulses under mango based agroforestry system at FSRD sites, Barind, Rajshahi during 2019-20.

Agroforestry system	Mango (t ha^{-1})	Pulse (t ha^{-1})	MEY (t ha^{-1})	Gross return (Tk.ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk.ha^{-1})	MBCR
Mango + Pea	8.20	1.18	9.71	340099	85125	254974	3.16
Mango +Grass pea	8.32	1.26	10.12	354200	85500	268700	3.78
Mango+Chickpea	8.70	1.40	11.30	395500	95000	300500	3.95
Mango + Lentil	8.40	1.56	11.52	403200	95800	307400	4.10
Mango	7.85	-	7.85	274750	64500	210250	-

MEY=Mango equivalent yield

Input price (Tk.): Urea=16 kg^{-1}, TSP=22 kg^{-1}, MOP=15 kg^{-1}, Gypsum=6 kg^{-1}, ZnSO$_4$=120 kg^{-1}, Boric acid=150 kg^{-1}, powertiller (1 pass) = 2350 ha^{-1}, irrigation (1 time) = 950 ha^{-1} and Labour=400 day^{-1} (8 hours), Lentil seed=115 kg^{-1}, Pea seed=120 kg^{-1}, Pea seed=120 kg^{-1} and Grass Pea seed=95 kg^{-1}
Output price (Tk. kg^{-1}): Lentil=70, Pea=45, Chickpea=65 and Grass Pea=50, Mango= 35

Table 31. Yield and economic performance of different pulses under mango-based agroforestry system at FSRD sites, Barind, Rajshahi during 2020-21.

Agroforestry system	Mango yield (t ha^{-1})	Pulse yield (t ha^{-1})	Mango equivalent Yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR	Avr. MBCR
Mango + Pea	7.90	1.15	9.21	322350	84215	238135	2.41	2.785
Mango +Grass pea	8.05	1.25	9.30	325500	84400	241100	2.55	3.165
Mango + Chickpea	8.64	1.35	11.26	394100	94030	300070	4.04	3.995
Mango + Lentil	8.35	1.36	10.36	362600	95150	267450	2.87	3.485
Mango	7.85	-	7.85	274750	64500	210250	-	-

Price of Input (Tk.): Urea=16 kg^{-1}, TSP=22 kg^{-1}, MOP=15 kg^{-1}, Gypsum=6 kg^{-1}, ZnSO$_4$=120 kg^{-1}, Boric acid=150 kg^{-1}, power tiller (1 pass): 2350 ha^{-1}, Irrigation (1 time): 950 ha^{-1} and Labour: 400 day^{-1} (8 hours), Lentil seed=115 kg^{-1}, Pea seed = 120 kg^{-1}, Pea seed = 120 kg^{-1} and Grass Pea seed =95 kg^{-1}

Price of Output: Lentil=52 kg^{-1}, Pea= 40 kg^{-1}, Chickpea= 60 kg^{-1} and Grass Pea=35 kg^{-1}, Mango= 35 kg^{-1}

Field views of pulses (pea, grass pea, chickpea and lentil) with mango based agroforestry system

Activity-15: Improvement of cropping pattern (Lentil-Mungbean-T. *Aman* rice) with mango based agroforestry system

Location: FSRD site, OFRD, Barind, Rajshahi

The results exhibited that mango equivalent yield achieved from the Lentil-Mungbean-T. *Aman* rice cropping pattern under under agroforestry was satisfactory (14.31 t ha^{-1}) as compared to traditional sole mango cultivation (7.60 t ha^{-1}). Farmers were happy due to almost double productivity of the agroforestry sytem (Table 32).

Table 32. Productivity and economics of lentil-Mungbean-T. *Aman* rice cropping pattern in mango based agroforestry system during 2019-20.

Name of crops	Mango (t ha^{-1})	lentil (t ha^{-1})	Mungbean (t ha^{-1})	T. *Aman* (t ha^{-1})	Mango equivalent Yield (t ha^{-1})
Mango + lentil-Mung-T. Aman	8.20	1.40	1.65	4.90	14.31
Mango	7.60	-	-	-	7.60

Input price (Tk.): Urea=16 kg^{-1}, TSP=22 kg^{-1}, MoP=15 kg^{-1}, Gypsum=6 kg^{-1}, ZnSO$_4$=120 kg^{-1}, Boric acid=150 kg^{-1}, powertiller (1 pass) =2350 ha^{-1}, irrigation (1 time) = 950 ha^{-1} and Labour=400 day^{-1} (8 hours), Lentil seed=115 kg^{-1}

Output price (Tk kg^{-1}): Lentil=70, Mung=45, Rice=18.5 and Mango=35

Field views of Lentil-Mungbean-T. *Aman* rice with mango based agroforestry system

Coastal Ecosystem

Activity-16: Development of Sorjan-based agroforestry system with quick growing fruits and vegetables in coastal ecosystem

Locations: Jamla village of FSRD site Dumki of Patuakhali

The results revealed that Sorjan based agroforestry system with high value crops demonstrated very encouraging results in view of total system productivity and economic return. Cultivation of high value vegetables with quick growing fruits in sorjan based agroforestry system demonstrated satisfactory yield of vegetables per sorjan (865 kg and 230 kg) and fruits (220 kg and 245 kg sorjan^{-1}) during 2019-20 and 2020-21 which generated total gross return of Tk. 29950 and Tk. 14325 sorjan^{-1} and gross margin of Tk. 19050 and Tk. 10325 sorjan^{-1} respectively (Table 33 and Table 34). However, it can be concluded that cultivation of high value vegetables with quick growing fruits in sorjan bed is a good option to intensify cropping intensity compare to single cropping system. Moreover, additional income may be possible from fish cultivation in the sorjan ditch.

Table 33. Cost and return analysis from sorjan at FSRD site Jamla, Dumki of Patuakhali district during 2019-20.

Items (Crops)	Yield (kg sorjan^{-1})	Gross return (Tk. sorjan^{-1})	Total variable cost (Tk. Sorjan^{-1})	Gross margin (Tk. sorjan^{-1})
Red amaranth,Brinjal, Bombay chilli, Cucumber, Snake gourd, Ridge gourd, Bottle gourd, Indian spinach, Jute as vegetables, sweet gourd	865	17300/-	6500/-	10800/-
Banana, Papaya, Guava	220	7700/-	2,000/-	5700/-
Fish	45	4950/-	2400/-	2550/-
Total	**1030**	**29950/-**	**10900/-**	**19050/-**

***Average price of vegetable @ 20Tk. kg^{-1}, fruit @ 35Tk. kg^{-1}and Fish @ 110 Tk. kg^{-1}

Table 34. Cost and return analysis from sorjan at FSRD site Jamla, Dumki of Patuakhali district during 2020-21.

Items(Kharif-II)	Yield (kg sorjan^{-1})	Gross return (Tk. sorjan^{-1})	Total variable cost (Tk. Sorjan^{-1})	Gross margin (Tk. sorjan^{-1})
Bombay chilli, Cucumber, Snake gourd, Ridge gourd, Bottle gourd, Indian spinach and sweet gourd	230	5750/-	2500/-	3250/-
Banana, Papaya, Guava	245	8575/-	1500/-	7075/-
Fish	-	-	-	-
Total	**475**	**14325/-**	**4000/-**	**10325/-**

***Average price of vegetable @ 25tk kg^{-1}, fruit @ 35 Tk kg^{-1}

Farmers' reaction: Farmers are highly pleased to see the performance of crops like vegetables and fruits round the year from Sorjan. Seasonal fish cultivation may also be a good option for getting extra money. However vegetable production in Kharif-II season at coastal clay soil were so difficult but these methods were more helpful for successful crop production.

Sorjan-based agroforestry system with quick growing fruits and vegetables in coastal ecosystem

Hill Ecosystem

Activity-17: Performance of sweet gourd varieties under fruit tree based agroforestry system in hill slopes of Bandarban under hill ecosystem

Locations: Tetuli para hill slopes of Rowangchari Upazilla, Bandarban

Fruit number per plant, fruit length (cm), fruit breadth (cm), fruit weight (kg) and yield (t ha^{-1}) of sweet gourd at farmer's field is presented in Table 35. Mango equivalent yield was presented in Table 36.

Fruit number per plant: Per plant fruit number was significantly influenced in different sweet gourd varieties under mango+papaya based agroforestry system. The maximum fruits per plant (3.46) was observed in BARI Mistikumra-2 followed by BARI Hybrid Mistikumra-2 (3.01) and lowest number was found from Hybrid Maya variety (2.73) (Table 35).

Fruit length and breadth (cm): Significant variation in fruit length and breadth was not observed among these varieties but numerically higher fruit length and breadth was recorded from BARI Mistikumra-2 (13.41 cm and 19.70 cm) followed by BARI Hybrid Mistikumra-2 (13.39 cm and 19.44 cm) and lowest from Hybrid Maya variety (13.08 cm and 18.79 cm) (Table 35).

Fruit weight (kg): Fruit weight was found insignificant but BARI Mistikumra-2 (2.31 kg) showed numerically higher fruit weight followed by Hybrid Maya (2.04 kg) and lowest fruit weight from BARI Hybrid Mistikumra-2 (2.02 kg) (Table 35).

Fruit yield (t ha^{-1}): About 30% of mango tree produced fruit for the first time in this orchard and the average yield of mango was 2.08 t ha^{-1}. Average papaya yield for all intercrop combination was 18.72 t ha^{-1}. All sweet gourd varieties in mango+papaya based agroforestry system showed significant variation where higher yield was recorded from BARI Mistikumra-2 (11.89 t ha^{-1}) followed by BARI Hybrid Mistikumra-2 (9.00 t ha^{-1}) and lowest from Hybrid Maya variety (8.24 t ha^{-1}). The highest mango equivalent yield (25.00 t ha^{-1}) was obtained from mango+papaya+BARI Mistikumra-2 followed by mango+papaya+BARI Hybrid Mistikumra-2 (23.15 t ha^{-1}), mango + papaya + Hybrid maya (22.67 t ha^{-1}) and the lowest in sole mango (2.08 t ha^{-1}) (Table 36).

Economics of mango+papaya+sweet gourd based agroforestry system:

Cost of cultivation for mango, papaya and all sweet gourd varieties was Tk. 45000 ha^{-1}, Tk. 175000 ha^{-1} and Tk. 108000 ha^{-1} respectively. Highest gross return (Tk. 998210 ha^{-1}) was obtained from mango+papaya+sweet gourd (var. BARI Mistikumra-2) combination due to high yield of BARI Mistikumra-2 followed by mango+papaya+BARI Hybrid Mistikumra-2 (Tk. 925960 ha^{-1}), mango+papaya+ sweet gourd (var. Hybrid Maya) (Tk. 906960 ha^{-1}) and lowest in sole mango (Tk. 83200 ha^{-1}) (Table 37). The result revealed that the highest gross margin (Tk. 670210 ha^{-1}) and benefit cost ratio (3.04) was recorded in the mango + papaya + sweet gourd (var. BARI Mistikumra-2) intercrop combination followed by mango + papaya + sweet gourd (var. BARI Hybrid Mistikumra-2) (Tk. 597960 ha^{-1} and 2.82), mango + papaya + sweet gourd (var. Hybrid Maya) (Tk. 578960 ha^{-1} and 2.77) and lowest in sole mango (Tk. 38200 ha^{-1} and 1.85) (Table 38).

Pit preparation | Young stage | Vine stage

Flowering stage | Creeping field view | Fruiting stage

Farmer's opinion: Farmers preferred Mango+Papaya+ sweet gourd (var. BARI Mistikumra-2) in agroforestry system for high land use effeciency with higher yield and economic return over sole mango cultivation. They also liked sweet gourd var. BARI Mistikumra-2 due to its good color, size, yield and they stored seed for next year planting (open-pollinated variety).

Table 35. Yield contributing characters and average yield of different sweet gourd varieties under mango+papaya+sweet gourd based agroforestry system during the rabi season of 2020-21.

Varieties (Sweet gourd)	Fruit number per plant	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (kg)	Fruit yield (t ha^{-1})
BARI Mistikumra-2 (V_1)	3.46a	13.41	19.70	2.31	11.89a
BARI Hybrid Mistikumra-2 (V_2)	3.01ab	13.39	19.44	2.02	9.00ab
Hybrid Maya (V_3)	2.73b	13.08	18.79	2.04	8.24b
LSD (0.05)	0.26	NS	NS	NS	1.29
CV (%)	10.19	8.59	3.20	12.12	16.27

Table 36. Mango equivalent yield under mango+papaya based agroforestry system during the rabi season of 2020-21

Treatments	Yield (t ha^{-1})			
	Mango	Papaya	Intercrop	Mango equivalent
Mango+Papaya+Sweet gourd (var.BARI Mistikumra-2)	2.08	18.72	11.89	25.00
Mango+Papaya+Sweet gourd (var. BARI Hybrid Mistikumra-2)	2.08	18.72	9.00	23.15
Mango+Papaya+Sweet gourd (var. Hybrid Maya)	2.08	18.72	8.24	22.67
Sole Mango	2.08	-	-	2.08

Here, about 30% of mango tree produced fruit (1st harvest). Selling price: Mango- Tk. 40 kg^{-1}, Papaya- Tk. 33 kg^{-1} and Mistikumra- Tk. 25 kg^{-1} only

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Table 37. Cost of cultivation and gross return of mango+papaya+sweet gourd based agroforestry system

Treatment	Total variable Cost of cultivation (Tk. ha^{-1})				Gross return (Tk. ha^{-1})			
	Mango	Papaya	Sweet gourd	Total	Mango	Papaya	Sweet gourd	Total
Mango+Papaya+Sweet gourd (var.BARI Mistikumra-2)	45000	175000	108000	328000	83200	617760	297250	998210
Mango+Papaya+Sweet gourd (var. BARI Hybrid Mistikumra-2)	45000	175000	108000	328000	83200	617760	225000	925960
Mango+Papaya+Sweet gourd (var. Hybrid Maya)	45000	175000	108000	328000	83200	617760	206000	906960
Sole Mango	45000	-	-	45000	83200	-	-	83200

Here, Selling price: Mango- Tk. 40 kg^{-1}, Papaya- Tk. 33 kg^{-1} and Mistikumra- Tk. 25 kg^{-1} only.

Table 38. Net return and benefit cost ratio of mango+papaya+sweet gourd based agroforestry system

Treatment	Gross margin (Tk. ha^{-1})				Benefit cost ratio
	Mango	Papaya	Sweet gourd	Total	
Mango+Papaya+Sweet gourd (var.BARI Mistikumra-2)	38200	442760	189250	670210	3.04
Mango+Papaya+Sweet gourd (var. BARI Hybrid Mistikumra-2)	38200	442760	117000	597960	2.82
Mango+Papaya+Sweet gourd (var. Hybrid Maya)	38200	442760	98000	578960	2.77
Sole Mango	38200	-	-	38200	1.85

Activity-18: Performance of different creeper vegetables under mango based agroforestry system in hill slopes of bandarban

Location: Tetulia para hill slopes in Bandarban

Average yield and partial economic analysis of Sweet gourd, Marpha and Bottle gourd at farmer's field is presented in Table 39. Highest average yield (13.85 t ha^{-1}) was found from sweet gourd followed by marpha (10.58 t ha^{-1}) and lowest yield (8.81 t ha^{-1}) from bottle gourd under agroforestry system. Gross return, gross margin and BCR also followed the same trend like vegetables yield.

Field view   Vine stage   Papaya Fruiting
Fruiting stage   Fruiting stage

Farmer's opinion

Farmers preferred sweet gourd for their higher yield and economic return in mango-based agroforestry system. They also found Marpha and bottle gourd beneficial for increasing their farm yield and utilization of fallow land to fulfill their family requirements of different vegetables.

Table 39. Average yield and partial economic analysis of creeper vegetables under mango-based agroforestry system during the *kharif* season of 2019 and 2020.

Vegetables	Yield (t ha^{-1})			Gross return (Tk ha^{-1})	Total cost (Tk ha^{-1})	Net return (Tk ha^{-1})	BCR
	Kharif-1 (2019)	Kharif-1 (2020)	Average				
Sweet gourd	13.39	14.3	13.85	304700	110000	194700	2.77
Bottle gourd	9.41	8.2	8.81	140960	105000	35960	1.34
Marpha	10.25	10.9	10.58	158700	95000	58750	1.67
LSD (0.05)	0.67	0.61					
CV (%)	9.56	9					

Note: Sweet gourd, Bottle gourd and Marpha prices were 22, 16 and 15 Tk./kg only.

Conclusion: It may be concluded that Sweet gourd is the best among the three tested creeper vegetables in respect to the fresh yield in kharif season followed by marpha and bottle gourd.

Activity-19: Performance of bitter gourd varieties under mango based agroforestry system in hill slopes of Bandarban

Locations: Tetuli para hill slopes of Rowangchari Upazilla, Bandarban

Yield contributing characters, average yield and partial economic analysis of bitter gourd var. BARI Korola-3, BARI Korola-4 and Hybrid Tiya at farmer's field is presented in Table 40. Highest fruit number per plant was observed in BARI Korola-3 (25.08) followed by BARI Korola-4 (22.54) and lowest from Hybrid Tiya (14.39) where single fruit weight showed reverse value for BARI Korola-3, BARI Korola-4 and Hybrid Tiya (65.65 g, 99.83 g and 145.20 g respectively). Highest average fruit yield (7.49 t ha^{-1}) was found from BARI Korola-4 followed by Hybrid Tiya (7.44 t ha^{-1}) and lowest yield (5.43 t ha^{-1}) from BARI Korola-3 under agroforestry system. Gross return, gross margin and BCR also followed the same trend like their yield.

Farmer's Reaction: Farmers preferred bitter gourd var. BARI Korola-4 for their attractive color, size, higher yield and economic return and Hybrid Tiya for large size fruit under mango-based agroforestry system in kharif-1 season.

Table 40. Fruit yield and yield contributing characters of bitter gourd under mango-based agroforestry system with partial economic analysis during the kharif-1 season of 2020 and 2021.

Vegetables	Fruits plant^{-1} (no.)	Single fruit wt. (g)	Fruit yield (t ha^{-1})			Gross return (Tk ha^{-1})	Total cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})	BCR
			2020	2021	Av.				
BARI Korola-3	25.08	65.65	5.46	5.4	5.43	162900	90000	72900	1.81
BARI Korola-4	22.54	99.83	7.48	7.5	7.49	224700	90000	134700	2.50
Hybrid Tiya	14.39	145.20	6.97	7.9	7.44	223200	90000	133200	2.48
LSD (0.05)	1.17	4.15	0.39	0.42					
CV (%)	8.02	5.67	8.25	10.23					

Price of Bitter gourd (Tk. kg^{-1}): 30

C. *On-farm verification/Production program*

Plain land Ecosystem

Activity-20: Upscaling mango based agroforestry with elephant foot yam at farmers' field

Location: FSRD site, Ganggarampur, OFRD, Pabna

The results reveal that agroforestry system with elephant foot yam showed remarkably higher productivity as compare to sole mango cultivation. The higher system productivity in terms of fruit equivalent yield (FEY) of the agroforestry system with elephant foot yam was 25.85 while relatively much lower FEY (8.60) was noted in sole mango cultivation (Table 41). The highest gross return (Tk. 1292500 ha^{-1}) and gross margin (Tk. 963400 ha^{-1}) and MBCR (3.45) was also obtained from agroforestry system. The results suggest that this agroforestry technology with mango and elephant foot yam found more profitable and contributed to the higher production and economic return as compared to famers' traditional sole mango cultivation. Co-operator farmers were happy and convinced to this agroforestry system based production approach.

Table 41. Yield and economic performance of existing fruit orchard and improved agroforestry system

Production system	Crop yield (t ha^{-1})			Economic analysis (Tk. ha^{-1})			
	Elephant foot yam	Mango	MEY	Gross Return	Total variable cost	Gross margin	MBCR
Existing sole fruits	-	8.60	8.60	430000	79100	350900	-
Agroforestry system	28.75	8.60	25.85	1292500	329100	963400	3.45

Price (Tk. kg^{-1}): Urea=16, TSP=24, MoP=16, Gypsum=10, Zinc Sulphate=230, Boric acid=460, Mango=50.0, Elephant foot yam= 30.0. MEY= Mango equivalent yield.

Activity-21: Production of cauliflower under mango based agroforestry system

Location: FSRD site, Ajoddhapur, Rangpur

The cauliflower under mango based agroforestry system exhibited satisfactory yield (33.88 t ha^{-1}), gross return (Tk 271040 ha^{-1}) as well as the gross margin (Tk.109140 ha^{-1}) (Table 42). Agroforestry systems provide more output in terms of more biological yield than single cropping. The findings of the present investigation indicate that growing cauliflower as ground layer crop in Mango based orchard is a viable option for increasing income of farmers.

Table 42. Dates of all operations, yield, cost and return of cauliflower under mango based agroforestry

Crop	Planting date	Harvesting date	Cauliflower Yield (t ha^{-1})	Gross Return (Tk ha^{-1})	Total variable Cost (Tk ha^{-1})	Gross Margin (Tk ha^{-1})
Cauliflower	05 Nov 2020	01-07 Feb 2021	33.88	271040	161900	109140

Pest incidence: There was no remarkable disease or insect found during the growing period.

Activity-22: Production of cabbage under mango based agroforestry system

Location: FSRD site, Ajoddhapur, Rangpur

The cabbage under mango based agroforestry system demonstrated satisfactory yield (54.55 t ha^{-1}), gross return (Tk. 381850 ha^{-1}) as well as the gross margin (Tk.219950 ha^{-1}) (Table 43). Agroforestry systems provide more output in terms of more biological yield than single cropping. The findings of the present investigation indicate that growing cabbage as ground layers crops in Mango based orchard is a viable option for increasing income of farmers.

Pest incidence: There was no remarkable disease or insect found during the growing period.

Table 43. Dates of all operations, yield, cost and return of cabbage under mango based agroforestry

Crop	Planting date	Harvesting date	Head yield (t ha^{-1})	Gross Return (Tk ha^{-1})	Total variable Cost (Tk ha^{-1})	Gross Margin (Tk ha^{-1})
Cabbage	Nov. 10, 2020	Feb. 01-07, 2021	54.55	381850	161900	219950

D. *Fodder crops production under agroforestry system*

Plain land Ecosystem

Activity-23: Performance of Napier grass under mango based agroforestry system in plain land ecosystem

Location: Ajoddhapur, Rangpur sadar, Rangpur

The yield of Napier grass was 18.67 t ha^{-1} under mango based agroforestry system at The values in Table 1 indicate that the total cost of production was 25670 Tk. ha^{-1} in Mango + napier based agroforestry system and the gross return was 56010 Tk ha^{-1} as well as the gross margin 30340 from the napier grass (Table 44). The findings may be due to that in case of Agroforestry system more output was obtained as two crops produce more biological yield than single cropping. The findings of the present investigation indicate that diversification of farming system and growing Napier as ground layer crop in Mango based orchard is a viable option for increasing income of farmers.

Table 44. Dates of all operations, yield, cost and return, and farmers opinion

Variety	Planting date	Harvesting date	Fodder yield (t ha^{-1})	GR (Tk ha^{-1})	TC (Tk ha^{-1})	GM (Tk ha^{-1})
Napier grass	28-05-2020	harvesting continue	18.67	56010	25670	30340

Performance of Napier grass under mango based agroforestry system

Activity-24: Production of fodder crop under mango based agroforestry system in plain land ecosystem

Location: FSRD site Ganggarampur, Pabna

The results showed that agroforestry system with fodder crop showed relatively higher productivity as compare to sole mango cultivation. The mango equivalent yield (MEY) of the agroforestry system with fodder crop was 3.98 and 5.16 t ha^{-1} while relatively lower MEY (2.80 and 3.60 t ha^{-1}) was noted in sole mango cultivation during 2018-19 and 2019-20 respectively (Table 45 and Table 46). Higher gross return (Tk. 238800 and Tk. 309600 ha^{-1}) and gross margin (Tk. 163550 and Tk. 218260 ha^{-1}) was also obtained from agroforestry system during 2018-19 and 2019-20, respectively. The MBCR was recorded 2.14 and 1.87 under agroforestry with fodder during the successive years. The results indicated that this agroforestry technology with mango and fodder crop is found more profitable and contributed to the higher production and economic return as compared to famers' traditional sole mango cultivation. Co-operator farmers were happy and convinced to this agroforestry system based production approach. This agroforestry technology created a good impact among the rural farm families having livestock farming.

The results indicated that Mango-based agroforestry system with fodder crop demonstrated encouraging results in view of total system productivity and economic return.

Table 45. Yield and economic performance of existing fruit orchard and agroforestry system during 2018-19

Production system	Crop yield (t ha^{-1})			Economic analysis (Tk. ha^{-1})			
	Fodder (Biomass)	Mango	MEY	Gross return	TVC	Gross margin	MBCR
Existing sole fruits	-	2.80	2.80	160000	35500	124500	-
Agroforestry system	22.5	2.80	3.98	238800	72250	163550	2.14

Price (Tk. kg^{-1}) = Urea-16, TSP-24, MP-16, Gypsum-10, Zinc Sulphate-230, Boric acid-460, and Mango-60, Napier-3.00
MEY= Mango equivalent yield, TVC= Total variable cost, MBCR= Marginal benefit cost ratio

Table 46. Yield and economics performance of existing fruit orchard and agroforestry system during 2019-20

Production system	Crop yield (t ha^{-1})			Economic analysis (Tk. ha^{-1})			MBCR
	Fodder (Biomass)	Mango	MEY	Gross return	Total variable cost	Gross margin	
Existing sole fruits	-	3.60	3.60	216000	41140	174860	
Agroforestry system with fodder crop	26.81	3.6	5.16	309600	91300	218260	1.87

Market price (Tk kg^{-1}): Mango-60.00, Fodder-3.50, MEY= Mango equivalent yield

Component-2: Pomology Division, HRC, BARI

Activity 1: Benchmark information

The benchmark survey was conducted at the project area with the help of pretested questionnaire. Necessary data on demographic profile and different crops grown under existing mango and pummelo based agroforestry practices were collected. The findings of the study and interpretation of results with necessary discussion has been discussed below.

Age of the respondent

The age of the respondent was markedly varied. They were categorized into young (≤ 35), middle aged (36-50) and old (>50). Most (80%) of the respondents were middle aged to old aged and only 20% of the respondents were young aged. It is evident that middle aged to old aged people (80%) are more engaged in agroforestry practices (Table 47).

Table 47. Distribution of the respondents according to age

| Categories | Score (Year) | Respondent (N=100) | | Range | Mean | SD |
		Number	Percent			
Young	≤ 35	20	20			
Medium aged	36-50	51	51	31-69	45.29	9.75
Old	>50	29	29			
Total		100	100			

Educational qualification of the respondents

The education score of the respondents ranged from 1 to 16 with mean and standard deviation of 12.62 and 3.55, respectively (Table 48). On the basis of education, the respondents were categorized into five categories as shown in Table 2. It was revealed that majority (56%) of the respondents had Secondary education followed by higher secondary level (23%) and graduate and above level (12%). The lowest number of respondents (9%) had primary level of education and there were no illiterate respondents in the study area.

Table 48. Distribution of the respondents according to educational qualification

| Categories | Score (Year of schooling) | Respondent (N=100) | | Range | Mean | SD |
		Number	Percent			
Illiteracy	0	0	0	1-16	12.62	3.55
Primary	1-5	9	9			
Secondary	6-10	56	56			
Higher secondary	11-12	23	23			
Graduate and above	>12	12	12			
Total		100	100			

Family size of the respondents

The family size score of the respondents ranged from 2 to 6 with mean and standard deviation of 4.04 and 1.02, respectively (Table 49). Family size of the respondents were classified into small (1-3), medium (4-5) and large family (>5). Data presented in Table 3 indicate that majority (67%) of the respondents' family belonged to medium sized family followed by large sized family (21%) while only about 12% belonged to small sized family.

Table 49. Distribution of the respondents according to their family size

| Categories | Score (Number) | Respondent (N=100) | | Range | Mean | SD |
		Number	Percent			
Small	1-3	12	12	2-6	4.04	1.02
Medium	4-5	67	67			
Large	>5	21	21			
Total		100	100			

Experience in roof gardening of the respondents

The experience score of the respondents ranged from 2 to 12 with a mean and standard deviation of 7.14 and 8.19 respectively. Experience in roof gardening of the respondents were classified into low (≤10), medium (11-20) and high (>20) categories as shown in Table 50.

Table 50. Experience in roof gardening of the respondents

| Categories | Score (Year) | Respondent (N=100) | | Range | Mean |
		Number	Percent		
Low	≤10	79	79	2-36	7.14
Medium	11-20	21	21		
High	>20	0	0		
Total		100	100		

The majority of the respondents (79%) had short duration experience in agroforestry practices followed by medium experienced (21%) and no respondents had high experience (Table 50). As agroforestry practices is a modern concept that's why most of people had short term experience.

Annual income of the respondents

The annual income score of the respondents ranged from 240 ('000Tk) to 750 ('000Tk) with a mean and standard deviation of 493.91 and 154.137 respectively. On the basis of the annual income the respondents' family was classified into three categories as shown in Table 51.

Table 51. Distribution of the respondents according to annual income

| Categories | Score ('000Tk) | Respondent (N=100) | | Range ('000Tk) | Mean ('000Tk) | SD |
		Number	Percent			
Low	≤300	19	19	240-750	493.91	154.137
Medium	301-600	56	56			
High	>600	25	25			
Total		100	100			

It was found that majority (56%) of the respondents were in the category of medium income followed by high income (25%) and low income (19%). Findings indicate that medium income group peoples were more engaged in agroforestry practices.

Types of agroforestry practices by the respondents

Types of agroforestry practices by the respondents have been shown in Table 52. Most of the respondents (30%) had grown Mungbean under mango orchard followed by Mango-Banana-lentil (20%) and Mango-Ginger (15%). 12 % respondents followed Mango-turmeric system, 10 % Mango-red amaranth and 8% followed Mano-Guava system. However, the lowest (5%) number of respondents followed the other agroforestry system in the study area.

Table 52. Distribution of the respondents based on the types of plants grown in roof garden of the study area

Categories	Respondent (N=100)	
	Number	Percent
Mango-Mungbean	30	30
Mango-Banana-lentil	20	20
Mango-red amaranth	10	10
Mango-Guava	8	8
Mango-turmeric	12	12
Mango-Ginger	15	15
Others	5	5

The treatments for Activit-2 and activity-3 had been selected based on the benchmark information as well as including some innovations.

Activity 2: Productivity and profitability of mango based multistoried agroforestry system in Jessore and Khagrachari

The result showed that banana was found to be the most suitable middle layer fruit crop by considering mango equivalent yield (3.68 t/ha) followed by ber (2.09 t/ha) (Table 53) but the agroforestry system T_2 (Mango-Lemon) performed the best considering total mango equivalent yield (9.93 t/ha) and MBCR (4.78), which was closely followed by T_4 (Mango-Banana) by 9.21 t ha^{-1} and 3.41 respectively (Table 54).

Table 53. Performance of middle layer fruit crops in Mango based multistoried cropping system

Treatments (middle layer crop under Mango)	Fruit yield (t ha^{-1})	Mango equivalent Yield (MEY) (t ha^{-1})	Mango yield (t ha^{-1})	Total yield (t ha^{-1}) (Mango+MEY)
T_1 (Mango-Ber)	6.27	2.09	5.69	7.78
T_2 (Mango-Lemon)	1.71	1.71	8.22	9.93
T_2 (Mango-Guava)	4.86	1.62	4.20	5.82
T_3 (Mango-Banana)	5.52	3.68	5.53	9.21
T_5 (Mango sole) control			4.31	4.31

Here, Market price (Tk kg^{-1}): Mango=60, Ber = 20, Lemon= 60, Guava=20, Banana= 40

Table 54. Economic performance of middle layer fruit crops in Mango based multistoried cropping system

Treatments (middle layer crop under Mango)	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
T$_1$ (Mango-Ber)	466800	140500	351300	2.95
T$_2$ (Mango-Lemon)	595800	140500	480300	4.78
T$_3$ (Mango-Guava)	349200	140500	233700	1.29
T$_4$ (Mango-Banana)	552600	156340	426260	3.41
T$_5$ (Mango sole) control	258600	70000	188600	-

Field view of middle layer fruit crop in mango based multistoried agroforestry system

As a lower layer winter crop Cabbage performed the best on the basis of Mango equivalent yield (11.72 t/ha) and which was closely followed by Cauliflower (9.29 t/ha) (Table 55). However, the highest total MEY (17.51 t/ha) and MBCR (5.64) was obtained from the agroforestry system T$_2$ (Mango-Cauliflower) which was closely followed by T$_1$ (Mango-Cabbage) where, total MEY and MBCR were 17.41 t/ha and 5.59 respectively (Table 56).

Table 55. Performance of winter season lower layer vegetable crops in Mango based multistoried cropping system

Treatments (lower layer winter vegetable crops)	Vegetable yield (t/ha)	Mango equivalent Yield (MEY) (t/ha)	Mango yield (t/ha)	Total MEY (t/ha)
T$_1$ (Mango-Cabbage)	70.32	11.72	5.69	17.41
T$_2$ (Mnago-Cauliflower)	37.16	9.29	8.22	17.51
T$_3$ (Mango-Coriander)	7.23	2.41	4.20	6.61
T$_4$ (Mango-Kohlrabi)	21.00	3.59	5.53	9.12
T$_5$ (Mango sole) control			4.31	4.31

* Significant at 5% level   NS: Non significant

Here, Market price (Tk kg^{-1}): Mango=60, Cabbage = 10, Cauliflower= 15, Corriender=20, Kohlrabi= 10

Table 56. Economic performance of lower layer winter vegetable crops in Mango based multistoried cropping system

Treatments (middle layer crop under Mango)	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
T$_1$ (Mango-Cabbage)	1044600	210500	834100	5.59
T$_2$ (Mango-Cauliflower)	1050600	210500	840100	5.64
T$_3$ (Mango-Coriander)	396600	171250	225350	1.36
T$_4$ (Mango-Kohlrabi)	547200	210500	336700	2.05
T$_5$ (Mango sole) control	258600	70000	188600	-

Field view of winter season lower layer vegetable crops in Mango based multistoried cropping system

In respect of lower layer *kharif-2* vegetable crops, the highest mango equivalent yield (3.28 t/ha) was noted in the treatment T$_4$ (Indian spinach) followed by T$_1$ (okra) and T$_2$ (yard long bean) by 2.97 t/ha and 2.77 t/ha respectively (Table 57). However, the highest total MEY (10.99 t/ha) and MBCR (2.75) was obtained from the agroforestry system T$_2$ (Mango-Yard long bean) which was closely followed by T$_4$ (Mango-Indian spinach) and T$_1$ (Mango-Okra) where, total MEY were 8.81 t/ha and 8.66 t/ha respectively and MBCR were 1.85 and 1.17 respectively (Table 58).

Field view of kharif-2 season lower layer vegetable crops in Mango based multistoried cropping system

Table 57. Performance of *Kharif-2* season lower layer vegetable crops in Mango based multistoried agroforestry system

Treatments (lower layer *kharif-2* vegetable crops)	Vegetable yield (t ha⁻¹)	Mango equivalent Yield (MEY) (t ha⁻¹)	Mango yield (t ha⁻¹)	Total MEY (t ha⁻¹)
T₁ (Mango-Okra)	17.82	2.97	5.69	8.66
T₂ (Mango-Yard long bean)	13.85	2.77	8.22	10.99
T₃ (Mango-Red amaranth)	10.62	1.77	4.20	5.97
T₄ (Mango-Indian Spinach)	13.12	3.28	5.53	8.81
T₅ (Mango sole) control			4.31	4.31

Here, Market price (Tk kg⁻¹): Mango=60, Okra = 10, Yard long bean= 12, Red amaranth=10 and Indian Spinach= 15

Table 58. Economic performance of *Kharif-2* season lower layer vegetable crops in Mango based multistoried cropping system

Treatments (middle layer crop under Mango)	Gross return (Tk. ha⁻¹)	Total variable cost (Tk. ha⁻¹)	Gross margin (Tk. ha⁻¹)	MBCR
T₁ (Mango-Okra)	519600	292500	752100	1.17
T₂ (Mango-Yard long bean)	659400	215600	835000	2.75
T₃ (Mango-Red amaranth)	358200	165500	231050	1.04
T₄ (Mango-Indian Spinach)	528600	215600	331600	1.85
T₅ (Mango sole) control	258600	70000	188600	-

Mango equivalent yield (MEY), total MEY and alos MBCR were found the highest in treatment (agroforestry system) T₄ (Mango-Turmeric) by 6.63 t/ha, 12.16 t/ha and 5.61 respectively (Table 59 and Table 60).

Table 59. Performance of year round lower layer crops in Mango based multistoried cropping system

Treatments (lower layer year round crops)	Crop yield (aroids and spice) (t ha⁻¹)	Mango equivalent yield (MEY) (t ha⁻¹)	Mango yield (t ha⁻¹)	Total MEY (t ha⁻¹)
T₁ (Mango-Aroids- Oalkochu)	9.06	3.02	5.69	8.71
T₂ (Mango-Ginger)	4.86	2.43	8.22	10.65
T₃ (Mango-Aroids- Mukhikochu)	12.30	4.10	4.20	8.30
T₄ (Mango-Turmeric)	19.89	6.63	5.53	12.16
T₅ (Mango sole) control			4.31	4.31

Here, price (Tk/kg): Mango=60, Oalkochu = 20, Ginger = 30, Mukhi kochu=20 and Turmeric= 20

Table 60. Economic performance of *Kharif-2* season lower layer vegetable crops in Mango based multistoried cropping system

Treatments (lower layer year round crops)	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
T_1 (Mango-Aroids- Oalkochu)	522600	154000	388600	3.14
T_2 (Mango-Ginger	639000	165500	473500	3.98
T_2 (Mango-Aroids- Mukhikochu)	498000	165500	332500	2.50
T_3 (Mango-Turmeric)	729600	154000	575600	5.61
T_5 (Mango sole) control	258600	70000	188600	-

Field view of year round lower layer crops in Mango based multistoried agroforestry system

As a whole the effect of mango based multistoried agroforestry system on mango equivalent yield has been shown in table-9. According to the table, the highest mango equivalent yield (25.49 t/ha) was obtained from the agroforestry system T_1 (Mango + Ber + Cabbage+Mung bean - Okra + Aroids (Oal kochu) which was closely followed by T_2 (24.42 t/ha) and T_4 (22.71 t/ha) compared to T_5 (mango sole). However, the agroforestry system T_2 demonstrated the highest MBCR (2.67) closely followed by T_4 and T_1 by 2.65 and 2.46 respectively (Table 61).

Table 61. Effect of different Mango based multistoried agroforestry systems on Mango equivalent yield

Treatments (Agroforestry system)	Crop yield (t/ha)						Mango Equivalent Yield (t/ha)
T$_1$= (Mango + Ber + Cabbage+Mung bean - Okra + Aroids (Oal kochu)	Mango	Ber	Cabbage	Mungbean	Okra	Aroids (OalKachu)	25.49
	5.69	6.27	70.32	3.21	17.82	9.06	
T$_2$= (Mango + Lemon + Cauliflower+Mung bean - Yard long bean + Ginger)	Mango	Lemon	Cauliflower	Mung bean	Yard long bean	Ginger	24.42
	8.22	1.71	37.16	2.76	13.85	4.86	
T$_3$= (Mango + Guava + Kohlrabi +Mung bean + red amaranth + Mukhi kochu)	Mango	Guava	Kohlrabi	Mung bean	red amaranth	Mukhi kochu	14.10
	4.20	4.86	7.23	3.11	10.62	12.30	
T$_4$= (Mango + Banana + Corriender+Mung bean - Indian spinach + Turmeric)	Mango	Banana	Corriender	Mung bean	Indian spinach	Turmeric	22.71
	5.53	5.52	21.00	3.89	13.12	19.89	
T$_5$= (Mango sole)	Mango (Sole)						4.31
	4.31						

Price (Tk/kg): Mango=60, Ber = 20, Lemon= 60, Guava=20, Banana= 40, Cabbage = 10, Cauliflower= 15, Corriender=20, Kohlrabi= 10, Okra = 10, Yard long bean= 12, Red amaranth=10 and Indian Spinach= 15, Oalkochu = 20, Ginger = 30, Mukhi kochu=20 and Turmeric= 20

Table 62. Economic performance of different Mango based multistoried agroforestry systems

Treatments (Agroforestry system)	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
T$_1$	1529400	587500	941900	2.46
T$_2$	1465200	522100	943100	2.67
T$_3$	846000	472000	374000	1.46
T$_4$	1362600	487190	875410	2.65
T$_5$ (control)	258600	70000	188600	-

Here, T$_1$ = (Mango + Ber + Cabbage+Mung bean - Okra + Aroids (Oal kochu), T$_2$ = (Mango + Lemon + Cauliflower+Mung bean - Yard long bean + Ginger), T$_3$ = (Mango + Guava + Kohlrabi +Mung bean + red amaranth + Mukhi kochu) , T$_4$ = (Mango + Banana + Corriender+Mung bean - Indian spinach + Turmeric), T$_5$ = (Mango sole)

It can be concluded that, in mango based agroforestry system, banana and cabbage have been found to be the most suitable middle layer and lower layer winter vegetable crop by considering mango equivalent yield. In the case of lower layer kharif-2 and year round crop, Okra and turmeric was performed the best. As a whole, the treatment T$_1$ (Mango + Plum + Cabbage+Mung bean - Okra + Aroids (Oal kochu) was found to be the most suitable mango multistoried agroforestry system by considering mango equivalent yield and MBCR.

Field view of Mango based multistoried agroforestry system

Research activity 3: Productivity and profitability of pummelo based multistoried agroforestry system in Jessore

The effect of pummelo based multistoried agroforestry system on pummelo equivalent yield (PEY) has been shown in table-11. According to the table, the highest PEY (75.38 t/ha) was obtained from the agroforestry system T_3 **(Pummelo-Turmeric)** which was closely followed by T_1 (66.56 t/ha) and T_2 (63.23 t/ha) compared to T_4 (Pummeloo sole). However, the agroforestry system T_3 demonstrated the highest MBCR (6.52) (Table 63).

Table 63. Effect of different pummelo based multistoried agroforestry systems on pummelo equivalent yield

Treatments (Agroforestry system)	Crop yield (t/ha)		Pummelo Equivalent Yield (PEY) (t/ha)
T_1	Pummelo	Mukhi kochu	66.56
	20.42	23.07	
T_2	Pummelo	Ginger	63.23
	20.42	14.27	
T_3	Pummelo	Turmeric	75.38
	20.42	27.48	
T_4	Pummelo (sole)		20.42

Here, price (Tk/kg): Pummelo=10, Ginger = 30, Mukhi kochu=20 and Turmeric= 20

Table 64. Economic performance of different pummelo based multistoried agroforestry systems

Treatments (Agroforestry system)	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
T_1	665600	160500	505100	4.83
T_2	632300	160500	471800	4.48
T_3	753800	149300	604500	6.52
T_4 (control)	204200	65000	139200	-

So, it can be concluded that, in pummelo based agroforestry system turmeric have been found to be the most suitable crop and the agroforestry system T_3 (Pummelo+Turmeric) demonstrated the best option and the most profitable considering PEY and MBCR.

12. Research Highlights

1. DEVELOPMENT OF HOMESTEAD AGROFORESTRY WITH VEGETABLES AND FRUITS CROPS IN BARIND AREAS

Background: Homestead is considered as one of the important production unit for rural households of Bangladesh. There are about 2.0 crore homesteads in the country. Year round production of vegetables and fruits in different niches of homestead can play a vital role for food and family nutrition. Every homestaed in the country has unplanned fruit and non fruit trees. Growing of different vegetables in association with existing trees can mitigate the growing demand of food and nutriton security as well as increase family income. Regarding this concern development of homestead agroforestry is deemed imperative in barind areas.

Objectives:

i) to increase year round availability of vegetables and fruits in rainfed ecosystem
ii) to increase homestead production for food, nutrition and income generation

Methodology: Available production niches of the homestead areas were brought under cultivation with the suggested vegetables and fruits following Barind model. Quick growing fruit trees (Guava, Papaya, Lemon, Ber, Banana etc.) along with other existing fruit trees (Mango, Coconut etc.) were managed through pruning, pest control, fertilization and irrigation. Diffrent vegetables were grown under niches of existing fruit and un productive trees during rabi, kharif-I and kharif-II season following recommended management practices as per Barind Model.

Key findings:

➢ Satisfactory production of vegetables per homestead (513 kg) contributes 64.91, 10.53 and 24.76%, family consumption, distribution and sells respectively.

➢ The average consumption per head per day was 181 g. From the above results, it was found that under homestead agroforestry intake of vegetables increased to a significant level (on an average 181 g h^{-1} day^{-1} instead of 96 g h^{-1} day^{-1} base mark), which helped the farmers to meet the demand of vegetables and to reduce the daily expenditure of vegetable purchase.

➢ After intervention of the proven and improved technologies in the homestead, fruits production has increased significantly. Good amount of fruits production was found during the study period (469 kg $homestead^{-1}$)

Keywords: Homestead, agroforestry, vegetables, fruits, food and nutrition

2. DEVELOPMENT OF HOMESTEAD AGROFORESTRY SYSTEM THROUGH VEGETABLE AND FRUITS CULTIVATION IN COASTAL ECOSYSTEM

Background: Food and nutrition security in the coastal areas is great concern. Ther are deficiency of fruits and vegetables in the coastal ecosystem due to unfavourable climate and edaphic factors. Homestead is considered as one of the important production unit for rural households of Bangladesh. There are about 2.0 crore homesteads in the country. Year round production of vegetables and fruits in different niches of homestead can play a vital role for food and family nutrition. Every homestaed in the country has unplanned fruit and non fruit trees. Growing of different vegetables in association with existing trees can mitigate the growing demand of food and nutriton security as well as increase family income. Regarding this concern development of homestead agroforestry is deemed imperative in coastal areas.

Objectives:

i) to increase year round availability of vegetables and fruits in coastal ecosystem
ii) to increase homestead production for food, nutrition and income generation

Methodology: Available production niches of the homestead areas were brought under cultivation with the suggested vegetables and fruits following Lebukhali model. Lebukhali model has developed for producing year round vegetables and fruits in 6-7 production niches. Quick growing fruit trees (Guava, Papaya, Lemon, Ber, Banana etc.) along with other existing fruit trees (Mango, Coconut etc.) were managed through pruning, pest control, fertilization and irrigation. Diffrent vegetables were grown under niches of existing fruit and un productive trees during rabi, kharif-I and kharif-II season following recommended management practices as per Lebukhali model.

Key findings:

➢ Per farm vegetable production was the highest during rabi season (107 kg) and the lowest in kharif-II season (51 kg).

➢ Average production of vegetables per farm was higher at sunny open spaces (51 kg). Average production of vegetables and fruit per farm was 212 kg and 52 kg, respectively.

➢ The comparative study showed that total vegetable production and income increased 168% after intervention

Keywords: Coastal ecosystem, homestead, agroforestry, vegetables and fruits.

3. DEVELOPMENT OF HOMESTEAD AGROFORESTRY WITH VEGETABLES AND FRUITS CROPS IN PABNA AREAS UNDER PLAIN LAND ECOSYSTEM

Background: Sustainable food and nutrition security for rural farm families is a growing concern and reflected in national agricultural policy of Bangladesh. Due to shrikage of agricultural cultivable land, homestead area of rural farming are being considered as an improtant production unit for food and nutrition security. In this connection agroforestry system based production approach was taking into concideration

Objectives:

i) To increase year round availability of vegetables and fruits in plain land ecosystem
ii) To increase homestead production for food, nutrition and income generation

Methodology: Two co-operator farmers homtead area was selected for the development of homestead agroforestry. Scientific personnel of FSRD team provided training and necessary suggestions to the selected farmers on homestead agroforestry production systems. In case of homestead 1, around 19 decimal of homestead area was brought under homestead agroforestry system production which included fruit trees (mango) and high value vegetables whereas around 6 decimal area was brought under homestead agroforestry system production which included non fruit trees (mahogany) and high value vegetables for homestead 2. In homestaed 1, tomato, brinjal, country bean and bitter gourd was grown in association with mango trees with area coverage of 3, 3, 4 and 3 decimal of homestead area, respectively during 2019. Turmeric was grown in between mango trees with an area of 6 decimal. In homestead 2, elephant foot yam and country bean was grown in unutilized spaces of the trees. Standard management practices were followed for all crops and fruit trees.

Key findings:

➤ Total production of mango (var. BARI Aam-4) and vegetables (Tomato, Brinjal, Bitter gour and Country bean)/spice (Turmeric) was 386 and 771 kg, respectively from 3-4 decimal and 6 decimal fruit tree based homestead agroforestry (homestead 1).

➤ In case of homestead 2, total production of vegetables (Elephant foot yam and Country bean) was 345 kg from 3 decimal non-fruit tree based homestaed agroforestry.

➤ Regarding economic benefit, relatively higher gross return (Tk. 36920 ha^{-1}) and gross margin (Tk. 27740 ha^{-1}) was obtained from homestead 1 as compared with homestead 2 attaining gross return (Tk. 8625 ha^{-1}) and gross margin (Tk. 5425 ha^{-1}).

➤ Considering per unit economic benefit, growing bitter gourd (27 Kg dec.$^{-1}$), tomato (54 kg dec.$^{-1}$) and brinjal (62 Kg dec.$^{-1}$) with mango orchard is found more profitable.

Keywords: Homestead, agroforestry, vegetables and fruits.

4. DEVELOPMENT OF LITCHI-BASED AGROFORESTRY WITH LENTIL

Background: Litchi is popular and commercially profitable fruit crops in Pabna region. The increasing trend of litchi tree orchard in Pabna area is opening good scope of agroforestry based production. In most cases the ground space of litchi orchard is remain unused. So the unutilized space can be easily utilized with suitable crops. Nutrient enriched crops especially pulse crops are getting priority for family nutrition of rural household. Due to competition with other rabi crops, pulse growing area are gradually declining. Considering this issue growing lentil crop in association with litchi fruit orchards can be better options for higher productivity and income generation.

Objective:

➤ To increase system productivity and farmers' income in lentil based agroforestry system

Methodology: The experiment was carried out during 2018-19 and 2019-20 to evaluate the performance of pulse crop in agroforestry system and to increase productivity and farmers' income. Among the pulse crops, lentil was selected for growing with litchi orchard in this study. The seeds of lentil (*var.* BARI Masur-8) were sown on November 07-30. Application of fertilizers and other intercultural operation were made as per recommendation of pulse and fruit crops. The crop was harvested on March 12-18, 2019. The litchi fruit was harvested on June 02-08, 2020. Data on yield of pulse crop and litchi fruits were recorded.

Key findings:

➤ Agroforestry system with lentil showed relatively higher productivity with lentil (1.75 t ha^{-1}) and litchi (6.40 t ha^{-1}) as compare to sole litchi (6.50 t ha^{-1}) cultivation.

➤ The litchi equivalent yield (LEY) of the agroforestry system with lentil was 5.51 and 7.71 while relatively lower LEY (4.32 and 6.50) was noted in sole litchi culture during 2018-19 and 2019-20 respectively.

➤ Higher gross return (Tk. 551000 and Tk. 771000 ha^{-1}) and gross margin (Tk. 477000 and Tk. 693900 ha^{-1}) was also obtained from the agroforestry system during the successive years

Keywords: Litchi, lentil**,** agroforestry, litchi equivalent yield, gross return. gross margin

5. DEVELOPMENT OF LITCHI-BASED AGROFORESTRY SYSTEM WITH HIGH VALUE CROPS

Background: In most cases the ground space of litchi orchard is remain unused. So the unutilized space can be easily utilized with suitable crops. Development of agroforestry based production is deemed important for raising sustainable total production per unit area of land. High value vegetable crops specially cauliflower, cabbage, broccoli and others crops are getting priority for income generation and family nutrition of rural household. Considering this issue growing high value vegetable crops in association with litchi fruit orchards can be better options for higher productivity and income generation

Objective:

➢ To increase system productivity and farmers income in litchi based agroforestry system with high value crops

Methodology: The experiment was carried out during the *rabi* season of 2019-20. Around eleven years aged litchi orchard was selected for the study. The kinds of vegetables were selected according to choice and preference of the co-operator farmers and agronomic feasibility. Cauliflower, cabbage and broccoli were chosen for planting with litchi trees. Thirty days old seedlings of cauliflower (*var.* Snow white), cabbage (*var.* Atlas 70) and broccoli (*var.* BARI Broccoli-1) were transplanted on November 29, 2019 with maintaining spacing of 60 cm x 45 cm for all vegetables. Application of fertilizers and other intercultural operation were made as per recommendation of individual crops. The harvesting of cauliflower was initiated on February 11 and continued up to February 18, 2020. The harvesting of cabbage was initiated on February 22 and continued up to March 10, 2020. The harvesting of broccoli was initiated on January 25 and continued up to February 08, 2020. The harvesting of litchi was initiated on May 24 and continued up to June 10, 2020. Data on yield of vegetables and guava fruits were recorded.

Key findings:

➢ Litchi based agroforestry system with high value vegetable crops showed relatively higher productivity with cauliflower (40.70 t ha^{-1}), cabbage (68.45 t ha^{-1}), broccoli (16.65t ha^{-1}) and litchi (7.10, 5.50 and 5.85 t ha^{-1}) as compare to sole litchi (6.80 t ha^{-1}) cultivation
➢ Maximum fruit equivalent yield was obtained from litchi+ cauliflower (13.21 t ha^{-1}) followed by litchi + cabbage (10.98 t ha^{-1}) and litchi + broccoli (9.18 t ha^{-1}).
➢ Regarding economic benefit, higher gross return (Tk. 1321000 ha^{-1}) and gross margin (Tk. 1162900 ha^{-1}) was achieved from litchi + cauliflower followed by litchi + cabbage and litchi + broccoli.
➢ The tested vegetables grown in litchi based agroforestry system exhibited remarkably higher gross return and gross margin compared to sole litchi orchard.
➢ However, litchi based agroforestry system with cauliflower demonstrated almost double return as compare to sole litchi orchard.

Keywords: Litchi, cauliflower, cabbage, broccoli, litchi equivalent yield, economic return

6. DEVELOPMENT OF GUAVA BASED AGROFORESTRY SYSTEM WITH HIGH VALUE CROPS

Background: The increasing trend of fruit tree orchard in Pabna area is opening good scope of agroforestry based production. Guava is now a popular fruit and its off season fruiting and

handsome market price encourage the farmers to establish more guava orchards. For this reason, many farmers have established guava orchards. Guva trees have small canopy structure which favours more sunlight to the ground as compared to other densed canopy fruits. In some cases, farmers grow some perennial spices crops in association with fruit trees which requires long time for income generation. Many orchards are not under this practice. Growing high value vegetable crops in fruits orchards can be better options for higher productivity and income generation.

Objective:

➢ To increase system productivity and farmers' income in guava based agroforestry system with high value crops

Methodology: The experiment was carried out at extrapolation areas of FSRD site Ganggarampur, Pabna Sadar, Pabna during three consecutive years (2018-19 to 2020-21) to evaluate the performance of high value crops in agroforestry system and to increase productivity and farmers income. Different high value crops such as tomato, cauliflower and cabbage were selected for guava based agroforestry system in this study. Around 4 years aged guava (var. BARI Peyara-2) orchard was selected for the study during 2018.Thirty days old seedlings of tomato (var. BARI Tomato-19), cauliflower (var. Snow white) and cabbage (var. Atlas 70) were transplanted on November 19-December 05 during the consecutive years with maintaining spacing of 60 cm x 50 cm for tomato and 60 cm x 45 cm for both cauliflower and cabbage. Application of fertilizers and other intercultural operation were made as per recommendation of individual crops. The harvesting of tomato was initiated on February 12 and continued up to March 25. The harvesting of cauliflower was initiated on January 14 and continued up to March 11, 2021. The harvesting of cabbage was initiated on January 07 and continued up to March 15. The harvesting of guava was initiated on February 15 and continued up to March 25. Data on yield of vegetables and guava fruits were recorded.

Key findings:

➢ Guava based agroforestry system with high value vegetable crops showed relatively higher productivity with tomato (60.08 t ha^{-1}), cauliflower (58.51 t ha^{-1}), cabbage (75.23 t ha^{-1}) and guava (4.17, 4.81 and 4.36 t ha^{-1}) as compare to sole litchi (4.49 t ha^{-1}) cultivation.
➢ Maximum guava equivalent yield was obtained from guava+ tomato (22.18 t ha^{-1}) which was followed by with guava + cauliflower (18.69 t ha^{-1}) and guava+ cabbage (15.86 t ha^{-1}).
➢ Minimum guava equivalent yield was recorded in sole guava (4.49 t ha^{-1}). Regarding economic benefit, higher gross return (Tk. 938667 ha^{-1}) and gross margin (Tk. 783867 ha^{-1}) was achieved from guava + tomato followed by guava+ cauliflower and guava+ cabbage.

Keywords: Guava, cauliflower, cabbage, tomato, fruit equivalent yield, economic return

7. PERFORMANCE OF BITTER GOURD VARIETIES UNDER MANGO BASED AGROFORESTRY SYSTEM IN HILL SLOPES OF BANDARBAN

Background: Around 45866 ha area of land in Bandarban district is under year round mono-crop fruit cultivation. Introducing agroforestry system can be more profitable in this region. Incorporation of summer vegetables like bitter gourd at hill slope of Bandarban under mango based agroforestry system can be introduced. Cultivation can be done by making pit to minimize soil erosion. Hill farmers of Bandarban usually cultivate different local and hybrid varieties of bitter gourd. BARI has developed a good number of bitter gourd varieties which

are high yielding, tolerant to different pest and diseases and seed producing potentiality. Hence, the study is important one.

Objective:

➢ To evaluate the performances of different bitter gourd varieties under mango based agroforestry system and to increase production and economic return in hill slopes of Banderban

Methodology: The experiment was conducted at the 2-3 years old mango gardens of the farmers' field of Tetulia para hill slopes in Bandarban during the kharif-1 season of 2020 and 2021. Average spacing of mango trees was 6 m×4 m, clean bole height was 1.5-2 m, canopy spread was 1 m×1 m and tree height was 2 m. So, there was some gaps between the tree canopy in the garden, where direct sunlight may reach to the under storey crops. Three varieties of bitter gourd viz. BARI Korola-3, BARI Korola-4 and Hybrid Tiya were used as under storey crop. The experiment was laid out in Randomized Complete Block (RCB) Design with five dispersed replications. The unit plot size was 10 m × 8 m. The plant to plant spacing was 4 m × 1.5 m for each variety. Pit-pit distance was 1.5 m. Pit size was 45 cm × 45 cm × 40 cm and prepared by digging. The seeds were sown direct to the pit on 2 March, 2020 and 15 may, 2021. Insecticide and fungicide were sprayed as and when necessary to control the pest and diseases. Harvesting was done during 3 May to 1 July, 2020 and 10 July to 2 September, 2021.

Key findings:

➢ The highest fruit yield (7.49 t ha^{-1}) and maximum economic return was found from BARI Korola-4 followed by Hybrid Tiya (7.44 t ha^{-1}) and lowest yield (5.43 t ha^{-1}) from BARI Korola-3 under mango agroforestry system.

Keywords: Hill, Banderban, bitter gourd, mango based agroforestry, yield, and return

8. DEVELOPMENT OF MANGO BASED AGROFORESTRY WITH TURMERIC AT FARMERS' FIELD UNDER PLAIN LAND ECOSYSTEM

Background: Sustainable food and nutrition security for rural farm families is a growing concern and reflected in national agricultural policy of Bangladesh. Due to shrikage of agricultural land agroforestry system based production approach is taking into concideration. Turmeric is a perrenial crop and can be grown easily under niche of mango orchards.

Objective:

➢ To increase system productivity and farmers income in plain land ecosystem

Methodology: Around 8-9 years aged mango orchard was selected for this study. Rhizome of local turmeric variety was planted on May 15, 2020 maintaining spacing of 60 cm x 25 cm under niche of the selected mango orchard. Recommended management practices were followed for turmeric and mango.

Key findings:

➢ Mango agroforestry system with turmeric showed relatively higher productivity with turmeric (12.25 t ha^{-1}) and litchi (3.15 t ha^{-1}) as compare to sole mango (3.12 t ha^{-1}) cultivation.

➢ The higher system productivity in terms of mango equivalent yield (MEY) of the agroforestry system with turmeric was 8.02 t ha^{-1} while relatively much lower MEY (3.12 t ha^{-1}) in sole mango cultivation.

> ➤ The highest gross return (Tk. 401000 ha^{-1}) and gross margin (Tk. 260500 ha^{-1}) and satisfactory MBCR (2.13) was also obtained from agroforestry system.

Keywords: Mango based agroforestry, turmeric, plainland ecosystem, yield, and return

9. PERFORMANCE OF PULSES IN MANGO BASED AGROFORESTRY SYSTEM IN HIGH BARIND TRACT

Background: In Bangladesh, fruit orchards especially Mango, Litchi and Guava have increased considerably over last few years. As High Barind Tract has 94% high land, there is a big scope to cultivate fruit in the main crop field. Thus, vast area is going under orchard every year, which may be a threat for attaining self-sufficiency in food especially in vegetables and pulses. In these circumstances, cultivation of some pulse crops under agroforestry system could be a good option for increasing food production from the same piece of land. In the tropics and sub-tropics, rapid degradation of soil organic matter is a major problem, where through cereal production less chance to add biomass in the soil. To sustain productivity of soil, production of leguminous crops may be helpful. Keeping this view in mind, the present experiment has been undertaken to select pulse crop(s) suitable for agroforestry system.

Objectives:

i) To select suitable pulse crops in mango based agrofporestry system in high barind tract

ii) To increase productivity and farmers' income

Methodology: The field experiment was conducted at Farming System Research and Development (FSRD) site, Basantapur, Godagari, Rajshahi during 2020-21 to find out the performance of mango based agroforestry with pulse crops. The experimental area was high land of silty clay loam soils and belongs to the Amnura series of HBT under Agro Ecological zone 26 (Anonymous, 1988). About 8-10 years old mango orchard was selected for the trial. The orchard with local popular variety of mango (*Khirshapat)* was selected for the study. Four pulses named, Chickpea (var. BARI Chola-5), Lentil (var. BARI Masur-8), Grass pea (var. BARI Kheshari-1) and Pea (var. BARI Motor-3) were tested in the mango orchard. The experiment was laid out in a Randomized Complete Block Design with three dispersed replications. The land was prepared by ploughing and cross ploughing with power tiller. Fertilizers were applied at the rate of 80-40-90-30-2 kg N- P-K-S-B ha^{-1} for pulses and mango cultivation. Chickpea, lentil, pea and grass pea seeds were broadcasted at 25 November, 2020. During final land preparation, all the fertilizer was applied for pulses as recommended dose and fertilizer was applied on late-September for mango as ring placement. The pulse crops and mango were harvested on 8-26 March and 5-10 June, 2020 respectively. Data for pulses and mango were recorded plot wise and converted to ton per hectare. Recorded data were analyzed statistically using "Analysis of variance (ANOVA)" with open-source software R (R Core Team, 2019).

Key findings:

- The seed yield of pea, grass pea, chickpea and lentil was recorded 1.18, 1.26, 1.40 and 1.56 t ha^{-1} and fruit yield of mango was noted 8.20, 8.32, 8.70 and 8.40 in association with pulse crop under agroforestry system as compared to sole mango (7.85 t ha^{-1}).
- The mango+chickpea system was recorded the highest mango equivalent yield (MEY) (11.26 t ha^{-1}) than rest of the system.
- The mango+grass pea (9.30 t ha^{-1}) and mango+pea (9.21 t ha^{-1}) systems were found to be equally effective. However, the sole mango system recorded the lowest MEY (7.85 t ha^{-1}).

- Among the different system, mango + chickpea had a maximum gross return (Tk. 394100 ha^{-1}), gross margin (Tk. 300070 ha^{-1}) and MBCR (4.04) than all other system.
- The minimum gross return (Tk. 274750ha^{-1}) and gross margin (Tk. 210250 ha^{-1}) was found in sole crop of mango.

Keywords: Agro-forestry system, grass pea, chickpea, pea, mango equivalent yield, crop productivity

11. PRODUCTION OF FODDER CROP UNDER MANGO BASED AGROFORESTRY SYSTEM

Background: Intensive utilization of agricultural land for food based crops results in shrinkage of free grazing land for cattle. Production of fodder crops for feed management of cattle is now being considered as a priority issue for livestock sector. Establishment of fruit orchard is rapidly expanded in Pabna region. High land and medium high land is being brought under fruit cultivation. Development of high yield potential fruits varieties with dwarf canopy structure enhance increasing trend of fruit cultivation in rural areas. Development of agroforestry based production is deemed important for raising sustainable total production per unit area of land. Napier is a popular high yield potential fodder crop and can be grown under niches of fruit trees. For this reason, the production program was undertaken to increase fodder production and farmers' income.

Objectives:

To evaluate the performance of fodder crop in agroforestry system and to increase fodder production and farmers' income

Methodology: The production program was carried out at farmers' field of FSRD site Ganggarampur, Pabna Sadar, Pabna during 2020-21. An existing 5 years aged unutilized mango orchard with an area of 33 decimals was selected at FSRD site, Ganggarampur, Pabna during 2020-21. The variety of mango of the selected orchard was BARI Am-4. Exotic variety (var. Pakchong) of napier grass was used for this production program. The cuttings of napier grass was planted in between spaces of mango fruit trees maintaining spacing of 100 cm x 50 cm on December 10, 2018 (Table 1). Fertilizer management was done for fodder and fruit crops for better crop growth. Other management practices were done when required. The harvesting of fodder crop was initiated on July 15 and continued up to December 24, 2020. Mango fruit was harvested on July 5-12, 2020.

Key findings:

- The biomass yield of fodder crop and fruit yield of mango was recorded 22.5 and 2.80 t ha^{-1}, respectively under agroforestry system as compared to sole crop of mango (2.80 t ha^{-1}).
- The mango equivalent yield (MEY) of the agroforestry system with fodder crop was 5.16 while relatively lower MEY (3.60) was noted in sole mango cultivation.
- Higher gross return (Tk. 309600 ha^{-1}) and gross margin (Tk. 218260. ha^{-1}) was also obtained from agroforestry system with fodder crop.
- The results indicated that this agroforestry technology with mango and fodder crop found more profitable and contributed to the higher production and economic return as compared to famers traditional sole mango cultivation.

Keywords: Sole mango, fodder crop, mango equivalent yield, gross return, crop productivity.

12. DEVELOPMENT OF MANGO BASED AGROFORESTRY WITH PULSE CROP

Background: Mango is popular and commercially profitable fruit crops in Pabna region. The increasing trend of mango tree orchard in Pabna area is opening good scope of agroforestry based production. In most cases the ground space of mango orchard is remain unused. So the unutilized space can be easily utilized with suitable crops. Nutrient enriched crops specially pulse crops are getting priority for family nutrition of rural household. Due to competition with other crops, pulse growing areas are gradually declining. Growing pulse crops in kharif season is really a challenge due to unfavourable climate. However, an effort was made to develop mango based agroforestry with kharif pulse specially blackgram. Considering this issue growing pulse crops in association with mango fruit orchards can be better options for higher productivity and income generation.

Objectives:
- To evaluate the performance of pulse crop in agroforestry system
- To increase productivity and farmers' income

Methodology: The experiment was carried out at farmers' field of FSRD site Ganggarampur, Pabna during 2020 to evaluate the performance of pulse crop in agroforestry system and to increase productivity and farmers' income. About 5 years aged mango orchard (var. BARI Aam-4) was selected for the study. Blackgram was selected for growing with mango orchard in kharif season. The seeds of blackgram (*var.* BARI Mash-3) were broadcasted in the unutilized spaces of existing mango orchard on August 19, 2020. Application of fertilizers and other intercultural operation were made as per recommendation of pulse and fruit crops. The crop was harvested on November 05, 2020. The mango was harvested on July 05-07, 2020. The details of crop management practices are presented in Table 1. Data on yield of blackgram and mango fruits were recorded and necessary table were prepared with mean values.

Key findings:

- The seed yield of blackgram and fruit yield of mango was recorded 1.29 and 3.50 t ha^{-1}, respectively under agroforestry system as compared to sole crop of mango (3.50 t ha^{-1}).
- The mango equivalent yield (MEY) of the agroforestry system with blackgram was 5.65 while relatively lower MEY (3.50) was recorded in sole mango cultivation.
- Higher gross return (Tk. 339000 ha^{-1}) and gross margin (Tk. 274300 ha^{-1}) was also obtained from the agroforestry system.

Keywords: Blackgram, mango equivalent yield, crop productivity, farmers' income

13. FEASIBILITY OF GROWING SHADE TOLERANT CROPS UNDER MANGO BASED AGROFORESTRY SYSTEM

Background: In Pabna district, there is a scenario of increasing different fruits orchard at the farmers' field. About 3-4 years after planting of mango orchard farmers get some economic return from fruits of these orchards only during the fruiting seasons. The ground niches of these orchards are traditionally utilized with some spices sporadically or remain fallow. However, up to 6-7 years aged of mango orchard the ground niche can be successfully utilized with growing of different high value vegetables crops. So, cultivation of some shade tolerant crops under niche of fruit trees may be a good option for the farmers to produce more production and generate additional income from these fruit orchards. In this connection, suitable research is deemed imperative to screen some vegetable crops with regards to evaluate the magnitude of their shade tolerance capacity and productivity under niche of existing sole fruit orchards. Therefore, the present study was undertaken at farmer's field to find out some shade tolerant

crops which can be produced successfully in mango orchard and to increase total productivity and farmers' income.

Objectives:

To find out some shade tolerant crops which can be produced successfully in mango orchard and to increase total productivity and farmers' income.

Methodology: The experiment was conducted at FSRD site, Ganggarampur, Pabna during 2020-21. Two management condition viz. a) agroforestry and b) open field along with five crops namely field pea (var. BARI Motor-3), radish (var. BARI Mula-1), cabbage (var. Atlas-70), cauliflower (var. Snow white) and tomato (var. BARI Tomato-19) were selected for growing under niche of mango orchard in this trial. The experiment was laidout in RCB factorial design with three dispersed replications. The plot size was 6m × 5m. The spacing was 30 cm × 10 cm for field pea, 40 cm × 15 cm for radish, 60cm × 45cm for cabbage and cauliflower and 75cm × 50cm for tomato. The crops were planted on November 17, 2020. Fertilizers were applied as per recommendation of fertilizer recommendation guide (FRG'2018). The harvesting of pea, radish cabbage, cauliflower and tomato were done on March 04-10, January 20 to February 15, February 15-28, March 01-10 and February 28 to March 15, respectively. Weeding was done on December 20, 2020. Other intercultural operations were done as and when required. The relevant data on different parameters were measured at respective stages.

Key findings:

- The yield of field pea, radish, cabbage, cauliflower and tomato was recorded 1.29,40.77, 65.42, 38.38 and 69.60 t ha^{-1} which was relatively low under agroforestry system as compared to open land (2.13, 56.06, 80.91, 41.98 and 82.53 t ha^{-1}) but the system productivity increased by 13.58, 35.37, 84.50, 71.43 and 158.69% in case of field pea, radish, cabbage, cauliflower and tomato under agroforestry system.
- Regarding economic benefit maximum gross return (Tk. 1134500 ha^{-1}) and gross margin (Tk. 947650 ha^{-1}) was found from tomato followed by cabbage and cauliflower under agroforestry system.

Keywords: High value vegetables crops, tomato, cabbage, cauliflower, field pea, crop productivity and economic return

14. PERFORMANCE OF NEWLY RELEASED LATE BLIGHT RESISTANT POTATO VARIETY AT RANGPUR UNDER MANGO BASED AGROFORESTRY SYSTEMS

Background: Late blight is the most devastating disease of potato in Bangladesh. It causes around 30-50% annual yield loss. It may cause total loss of the crop if attack at early stage of the crop. Late blight can become epidemic within few days under favorable environmental conditions. Tuber Crops Research Center of BARI has developed two late blight resistant varieties viz. BARI Alu-46 and BARI Alu-53 which are higher yielder and resistant to late blight disease. These newly varieties need to be evaluated for their performance under different late blight prone areas under mango based agroforestry systems. The present studies were conducted to evaluate and popularize the variety under mango based agroforestry systems at farmer's field condition in Rangpur.

Objectives:

To find out the performance of newly released late blight resistant potato variety, among the potato growers of Rangpur under mango based agroforestry systems.

Methodology: Total six hundred (600) kg of seed tubers of potato var. BARI Alu-46, BARI Alu-53 and BARI Alu-77 were distributed among 4 farmers having mango orchard at FSRD site Ajoddhapur, Rangpur. Each farmer received 50 kg of quality seed tubers of each variety for cultivating 5 decimals of land which totally covered 15 decimals of mango orchard area where check farmers were cultivated BARI Alu-25. Plantings started on 28 November 2020 to 3 December 2020. TCRC standard fertilizer doses were applied and intercultural management practices were followed. Orientation was given to the farmers before and during the cropping season on improved seed production techniques as well as irrigation, disease management practices etc. Haulms were pulled after 80 days of planting. The crop was harvested on 23 February to 18 March 2021. The fruit bearing of mango trees were very little and did not count in this study. Finally, the yield data and diseases observation data were taken from the trial plots and farmers' fields and finally compared.

Key findings:

- Potato var. BARI Alu-46 and BARI Alu-53 showed excellent performance against late blight and produced higher yield compared to BARI Alu-25.
- Farmers were happy to observe the performance of the varieties and demanded quality seed for next year cultivation.

Keywords: Late blight resistant potato varieties, gross return, crop productivity.

15. PRODUCTION OF CAULIFLOWER AND CABBAGE UNDER MANGO BASED AGROFORESTRY SYSTEM

Background: The utilization of the nitches of mango orchard by growing vegetables may be an alternative avenue to overcome the increasing demand of vegetables for increasing population. Regarding this view, the present study was conducted with mango based agroforestry in association with cauliflower at farmers' field to assess the productivity and economic return.

Objectives:

To evaluate the performance of cauliflower and cabbage at mango based agroforestry systems at Ajodhapur, FSRD site Rangpur.

Methodology: A field experiment was carried out at the agroforestory farm, Ajodhapur, FSRD site, under OFRD, BARI Rangpur during 2020-2021 to evaluate the performance of cauliflower and cabbage under mango based agroforestry system. The experiment was conducted in newly established four years old Mango orchard where the spacing of tree saplings was 10 m×10 m. The experiment was laid out in RCBD with three dispersed replications. Before planting the seedlings of cauliflower and cabbage, the land was fertilized by using fertilizer as per required doses (FRG' 2018). Seedlings of cauliflower and cabbage were planted on 5-10 November 2020 in main plots. All P and K were applied at the time of final land preparation. N was applied in three equal. Plant protection measures were taken as required. Other intercultural operations were done when necessary. The crop was harvested from 01 to 10 February 2021. Production of cauliflower and cabbage included costs of field preparation, planting, irrigation, organic manure and synthetic fertilizer, plant protection

chemicals, and harvesting were included. The gross margin was calculated by subtracting cost of production from the gross return.

Key findings:

- The cauliflower (var. Snow white) and cabbage (var. Atlas-70) under mango based agroforestry system exhibited satisfactory yield (33.88 and 54.55 t ha^{-1}), gross return (Tk 271040 and Tk. 381850 ha^{-1}) as well as the gross margin (Tk.109140 and Tk. 219950 ha^{-1}).

Keywords: Mango equivalent yield, cauliflower, cabbage crop productivity, gross margin

16. DEVELOPMENT OF SORJAN-BASED AGROFORESTRY SYSTEM WITH QUICK GROWING FRUITS AND VEGETABLES IN COASTAL AREA

Background: In coastal areas agricultural production through Sorjan system is an age old traditional practice adopted by the farmers. Unplanned cultivation with low yielding varieties of vegetables and fruits and unutilized water bodies often results in lower production and economic. High yielding popular varieties of quick growing fruits and vegetables along with modern management practices would contribute higher production and income. In addition, seasonal fish culture in ditches also may be a good technology for poor farm households. Regarding this concern an integrated production system including fruits, vegetables, fishes through sorjan method is deemed imperative for sustainable production in coastal ecosystem like Patuakhali. Therefore, the present study was undertaken to increase production and income of farm households in Patuakhali.

Objectives:

To evaluate sorjan based agroforestry system with quick growing fruits and vegetables for increasing production and farmer's income.

Methodology: In coastal region farmers usually cultivate vegetables or timber trees in sorjan bed. In this study farmer's existing sorjan was renovated and cultivated high value vegetables and quick growing fruits in dyke in a sequential order round the year. The average size of sorjan was 30 decimals. This sorjan has three beds and two canals. The average length and wide of sorjan bed was 55 m × 24 m. Each bed was 2 m wide at the top and more or less 1 m height above ground level. Existing sorjan of cooperative farmers was renovated providing with all sorts of required inputs like seeds, fertilizers and pesticides. In kharif-II season, cucumber, snake gourd, ridge gourd, bottle gourd, Indian spinach, jute as vegetables and sweet gourd were cultivated. Quick growing fruits like Papaya, Guava and Banna were cultivated in sorjan bed. Seasonal fish like tilapia and thaiputi was cultivated within sorjan ditch in kharif season. The yield performance and cost return analysis of vegetables; fruits insorjan based agroforestry was recorded.

Key findings:

- Cultivation of high value vegetables with quick growing fruits in sorjan based agroforestry system showed satisfactory yield of vegetables (230 kg sorjan^{-1}) and fruits (245 kg sorjan^{-1}) during the study period which generated total gross return of Tk 14325 sorjan^{-1} and gross margin of Tk 10325 sorjan^{-1}.
- Moreover, additional income may be possible from fish cultivation in the sorjan ditch.

Keywords: Vegetables, fruits, crop productivity, farmer's income

18. PERFORMANCE OF SWEET GOURD VARIETIES UNDER FRUIT TREE BASED AGROFORESTRY SYSTEM IN HILL SLOPES OF BANDARBAN

Background: Chittagong hill tracts has great potentiality for growing different types of fruit specially mango, litchi, banana, pineapple, papaya, citrus etc. This region is about one tenth of the total area of Bangladesh and has great potentiality for growing different fruits and vegetables. Around 45866 ha area of land in Bandarban district is under fruit cultivation which may be increased more. The underneath fallow land of newly established fruit orchard in hill slope of Bandarban can be utilized to ensure high return. Agroforestry system can be more profitable than mono-crop fruit cultivation. But incorporation of all kind of vegetables at hill slope is not possible like plain land or valleys due to soil erosion. Therefore, introducing creeper vegetables is a good option where tillage practice can be avoided and plantation is done by making pit to check soil erosion. In this study performance of BARI released sweet gourd varieties under mango+papaya based agroforestry systems was observed. To use the land more efficiently, papaya was planted in between two mango trees in mango base agroforestry system to introduce mango+papaya based agroforestry system of 2-3 yeras old mango orchard. Papaya is a short duration fruit tree which can add extra farm income for 2-3 years at the early establishment period (0-3 years) of mango orchard. For this reason, present study was undertaken to find out the performance of BARI released sweet gourd varieties under mango+papaya based agroforestry system in the hill slopes of Bandarban.

Objectives:

To evaluate the performance of of different sweet gourd varieties in mango+papaya based agroforestry

Methodology: The experiment was conducted at the 2.5 years old mango gardens of the farmers' field of Tetulia para hill slopes in Bandarban during the rabi season of 2020-21. Average spacing of mango trees was 6 m × 4 m, clean bole height was 1.5 m, canopy spread was 2 m × 2 m and tree height was 2.5 m. So, there was much gaps between the tree canopy in the garden and direct sunlight may reach to the under storey crops. Three sweet gourd varieties viz. V_1=BARI Mistikumra-2, V_2=BARI Hybrid Mistikumra-2 and V_3=Hybrid Maya used as treatments under Mango+Papaya based agroforestry system and the experiment was laid out in RCBD desing with three dispersed replications. The unit plot size was 6m×4m. The spacing was 4m×2m for each sweet gourd varieties. One papaya plant was planted in between two mango trees in a mango row to utilize the land more efficiently. Hence the distance between two papaya trees became 6m and average spacing of papaya trees was 6m×4 m. In this agroforestry plantation system, one bed of vegetable was cultivated maintaining 2m pit-pit distance. Pit size was 45cm×45cm×40cm and prepared by digging. Papaya seedlings were planted on 17 March to 18 March, 2020 and sweet gourd seeds were sown directly to the pits of different planting system on 11 November, 2020. Irrigation was provided when necessary. Insecticide and fungicide were sprayed to control the pest and diseases after leaf emergence. Data was recorded and analyzed by using Statistic 10 computer program.

Key findings:

- The highest sweet gourd yield (11.89 t ha^{-1}), mango equivalent yield (25.00 t ha^{-1}), gross return (Tk. 998210 ha^{-1}), gross margin (Tk. 670210 ha^{-1}) and BCR (3.04) was obtained frommango+papaya+BARI Mistikumra-2 agroforestry system
- This might be suitable for the hilly areas of Bandarban because of higher crop productivity, better land and time utilization as well as economic return.

Keywords: Sweet gourd yield, Bandarban, crop productivity, mango equivalent yield

19. PERFORMANCE OF DIFFERENT CREEPER VEGETABLES UNDER MANGO BASED AGROFORESTRY SYSTEM IN HILL SLOPES OF BANDARBAN

Background: Chittagong hill tracts has great potentiality for growing different types of fruit specially mango, litchi, banana, pineapple, papaya, citrus etc. This region is about one tenth of the total area of Bangladesh and has great potentiality for growing different fruits and vegetables. There are many established fruit orchards in hill slope of Bandarban. Agroforestry system can be more profitable than mono-crop fruit cultivation. But incorporation of all kind of vegetables at hill slope is not possible like plain land or valleys due to soil erosion. Vegetables like sweet gourd, marpha and bottle gourd are being cultivated in traditional Jhum practice. The present study has been undertaken to evaluate the performances of these vegetables in mango+papay based agroforestry system to increase production and economic return.

Objectives:

To evaluate the performance of of different creeper vegetables in mango based agroforestry system

Methodology: The experiment was conducted at the 2.5 years old mango gardens of the farmers' field of Tetulia para hill slopes in Bandarban during the rabi season of 2020. Average spacing of mango trees was 6 m × 4 m, clean bole height was 1.5 m, canopy spread was 2 m × 2 m and tree height was 2.5 m. So, there was much gaps between the tree canopy in the garden and direct sunlight may reach to the under storey crops. Three creeper vegetables viz. sweet gourd, bottle gourd and marpha were used as under storey crop. The experiment was laid out in Randomized Complete Block (RCB) Design with three replications. The unit plot size was 6m×4m. The spacing was 4m×2m for each sweet gourd varieties. In Mango+Papaya based agroforestry system, one papaya plant was planted in between two mango trees in a mango row to utilize the land more efficiently. Hence the distance between two papaya trees became 6m and average spacing of papaya trees was 6m×4 m. In this agroforestry plantation system, one bed of vegetable was cultivated maintaining 2m pit-pit distance. Pit size was 45cm×45cm×40cm and prepared by digging. Papaya seedlings were planted on 17 March to 18 March, 2020 and seeds of sweet gourd, bottle gourd and marpha were sown directly to the pits of different planting system on 11 November, 2020. Irrigation was provided when required. Insecticide and fungicide were sprayed to control the pest and diseases after leaf emergence. Data was recorded and analyzed by using Statistic 10 computer program.

Key findings:

- Maximum vegetable yield (27.38 t ha^{-1}) was found from bottle gourd followed by sweet gourd (13.39 t ha^{-1}) and minimum yield (10.09 t ha^{-1}) from marpha under agroforestry system.
- Maximum mango equivalent yield was found from bottle gourd (27.79 t ha^{-1}), sweet gourd (25.89 t ha^{-1}), marpha (21.31 t ha^{-1}) and lowest in sole mango (2.08 t ha^{-1}).
- Maximum gross return, gross margin and BCR (Tk. 1111600 ha^{-1}, Tk. 786600 ha^{-1} and 3.42 respectively) was obtained from mango+papaya+bottle gourd combination.

Keywords: Creeper vegetables, gross return, crop productivity and economic return.

B. Implementation status

1. Procurement (Component wise):

Component-1: OFRD, BARI

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment	GD1				
1. Laptop Computer	1	60000	1	60000	
2. Desktop Computer	2	120000	2	120000	
3. UPS	1	10000	1	10000	100%
4. Laser printer	1	19930	1	19930	
5. Digital Camera	2	50000	2	50000	
(b) Field equipment	GD2				
1. Soil moisture meter	2	80000	2	80000	
2. pH meter	1	40000	1	40000	
3. Lux meter	1	45000	1	45000	100%
4. Digital hand refracto-meter	1	40000	1	40000	
5. Food and beverage analyzer	1	40000	1	40000	
Total		504930		504930	100%

Component-2: Pomology Division, HRC, BARI

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment	GD1				
(b) Field equipment	GD2				
Total					

The Pomology Division, HRC, BARI had no procurement procedure.

2. Establishment/renovation facilities**:**

Description of facilities	Newly established		U graded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

There was no project activity under this section.

3. Training/study tour/ seminar/workshop/conference organized:

Component-1: OFRD, BARI

Description	Number of participants			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training	120	60	180	1 day	Nine (09) trainings were conducted at five experimental sites of OFRD
(b) Workshop	50	10	60	1 day	Inception workshop was done on
(c) Others	-	-	-	-	-

Component-2: Pomology Division, HRC, BARI

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training	40	20	60	1 day	Two (02) farmers training
(b) Workshop					
(c) Others (if any)					

C. Financial and physical progress (Combined and Component wise)

Combined: Component-1 + Component-2

Figure in Tk.

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	1004889	742000	694500	47500	93.60	
b. Field research/lab expenses and supplies	4676862	4490437	4490437	0	100.00	
c. Operating expenses	1358392	1072132	1006082	66050	93.84	
d. Vehicle hire and fuel, oil & maintenance	1168400	1030400	1000400	30000	97.09	
e. Training/workshop/seminar etc.	703000	703000	613000	90000	87.20	
f. Publications and printing	330000	180000	80000	100000	44.44	
g. Miscellaneous	253937	195396	190396	5000	97.44	
h. Capital expenses	504930	504930	504930	0	100.00	
Total	10000410	8918295	8579745	338550	**89.20**	

Component-1: OFRD, BARI

Figure in Tk.

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	856599	675290	627790	47500	92.97	
b. Field research/lab expenses and supplies	3382350	3195925	3195925	0	100.00	
c. Operating expenses	1066650	925250	861995	63255	93.16	
d. Vehicle hire and fuel, oil and maintenance	935000	905000	875000	30000	96.69	
e. Training/workshop/seminar etc.	563000	563000	473000	90000	84.01	Due to pandemic
f. Publications and printing	280000	180000	80000	100000	44.44	Project completion workshop has not been done
g. Miscellaneous	177881	169340	164340	5000	97.05	
h. Capital expenses	504930	504930	504930	0	100.00	
Total	7766410	7118735	6782980	335755	88.54	

Component-2: Pomology Division, HRC, BARI

Figure in Tk.

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	148290	66710	66710	0	100.00	
b. Field research/lab expenses and supplies	1294512	1294512	1294512	0	100.00	
c. Operating expenses	291742	146882	144087	2795	98.10	
d. Vehicle hire and fuel, oil & maintenance	233400	125400	125400	0	100.00	
e. Training/workshop/seminar etc.	140000	140000	140000	0	100.00	
f. Publications and printing	50000	0	0	0	-	
g. Miscellaneous	76056	26056	26056	0	100.00	
h. Capital expenses	0	0	0	0	-	
Total	**2234000**	**17,99,560**	**1796765**	**2795**	**99.68**	

D. Achievement of Sub-project by objectives (Tangible form): Technology generated/ developed

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e., product obtained, visible, measurable)	Outcome (short term effect of the research)
a) General objective: Farmers' livelihood improvement and ensuring food security through adoption of innovative agro-forestry technologies	Development of innovative agroforestry technology: Mango+high value crops Litch+ high value crops Guava+ high value crops Mango+pulse crops Mango+Oil seed crops Mango+Fodder crops	-Enhancement of 2 to 3 fold production and income under agroforestry over sole fruit -	Higher income creates more acces to food and nutrition security
b) Specific objective: (i) To develop innovative agroforestry technology through adaptive research in agriculture eco-system (rainfed, coastal, charland and hill) of Bangladesh	Developpment of Agroforestry technologies in Rainfed, Coastal, Hill and Plainland ecosystem. 1. Mango based agroforestry with pulse crop for rainfed area 2. Mango, Litchi and Guva based agroforestry with high value vegetables crop for plainland 3. Homestaed agroforestry for Plainland, rainfed and coastal ecosystem 4. Mango based agroforestry with vegetables for Hill ecosystem	-Mango+ Lentil system increase 46.75% system productivity over sole mango -88.54% higher intake of vegetables under homestead agroforestry - System productivity increased by 74.06, 46.39, 30.18, 27.74 and 22% in case of field pea, radish, cabbage, cauliflower and tomato under mango based agroforestry system	-Higher production of vegetables and fruits -Hiigher family consumption -Higher income generation
(ii) To adopt BARI developed homestead, cropland and hill agroforestry technologies in the respective eco-system through active participation of the stakeholders	-BARI developed fruit varieties like BARI Aam-3, BARI Am-4 has been adopted in mango based agroforestry in plainland, rainfed, coastal and hill areas - BARI developed vegetables like BARI Tomato-19, BARI Motor-3, BARI Broccoli-1, BARI Mula-1 has been adopted in mango based agroforestry in different ceosystem -BARI developed pulse (BARI Masur-8) and oil seed crop (BARI Sarisha-17) -BARI Panikachu-1 with homestead fruit orchard -BARI Technology Mango+ elephant footyam agroforestry has been adopted successfully	-Rapid develop fruit orchards with BARI Aam-3, BARI Aam-4, BARI peyara-2 and BARI Malta-1 in rural areas. -Nearly 30 homestead agroforestry with BARI developed fruits and vegetables has been expanded in Pabna areas. -BARI Malta-1 became more available at urban and ryral market -Sorjan based agroforestry with BARI varieties gaining popularity in costal areas	More expansion of BARI fruit varieties and NARS institutes technology at the field level

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e., product obtained, visible, measurable)	Outcome (short term effect of the research)
(iii) To assess the productivity, income and environmental benefits of the developed agroforestry practices and its contribution to food security and poverty alleviation	-Recording of data on production, consumption, income	-Production of vegetables increase by129% -Consumption incresae 116% -Income increase174%	-Higher purchase capacity -Better health condition

E: Information/knowledge generated/policy generated

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
a) General objective: Farmers' livelihood improvement and ensuring food security through adoption of innovative agro-forestry technologies	-Provide foramal and informal training - Visit innovative agroforestry plot -Participatory planning	-Build up capacity of Scientists, DAE personnel and farmers -Gain knowledge on crop selection for agroforestry technology	-Motivated neighboring farmers adopted agroforestry technology
(ii) To adopt BARI developed homestead, cropland and hill agroforestry technologies in the respective eco-system through active participation of the stakeholders	-Joint planning with OFRD team, DAE personnel, NGO representative, farmers - Orientation of BARI developed varieties of fruit, vegetables, pulses, spices, oilsedd crop -Discussion on different technical issues of agroforestry technologies	- Co-operator farmers have been selected due to motivation	-Implemented agroforestry activities at the field level
(iii) To assess the productivity, income and environmental benefits of the developed agroforestry practices and its contribution to food security and poverty alleviation	-Regular observation on production and income	- Information on actual enhancement of production and income	-Improvement of livelihood of the farmers

F. Materials Development/Publication made under the Sub-project:

Component-1: OFRD, BARI

FSRD Site, Ganggarampur, Pabna

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	Leaflet-02		
Journal publication	Journal- 01		
Video clip/TV program	TV program-1		
News Paper/Popular Article			
Other publications, if any			

FSRD site, Ajoddhapur, Rangpur

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	Leaflet-01		
Journal publication	Journal-01		
Video clip/TV program			
News Paper/Popular Article			
Other publications, if any			

FSRD Site, Barind, Rajshahi

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	Leaflet-01		
Journal publication			
Video clip/TV program			
News Paper/Popular Article			
Other publications, if any			

FSRD Site, Patuakhali

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	Leaflet-02		
Journal publication	Journal- 01		
Video clip/TV program	Video clip-02		
News Paper/Popular Article			
Other publications, if any			

FSRD Site, Banderban

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	Leaflet-02		
Journal publication	Journal-01		
Video clip/TV program			
News Paper/Popular Article			
Other publications, if any			

Component-2: Pomology Div., HRC, BARI:

Jashore

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	Booklet-01		
Journal publication			
Video clip/TV program	Youtube video		
News Paper/Popular Article			
Other publications, if any			

Khagrachari

Publication	Number of publications		Remarks (e.g., paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	Leaflet-01		
Journal publication	Journal-01		
Video clip/TV program			
News Paper/Popular Article			
Other publications, if any			

G. Description of generated Technology/knowledge/policy:

(i). Technology Fact Sheet (title, introduction, description, suitable location/ecosystem, benefits, name and contact address of author)

Component-1: OFRD, BARI

Fact sheet-1

1. **Development of Mango based agroforestry with elephant foot yam in plain land ecosystem of Pabna**

Introduction: Establishment of fruit orchard is rapidly expanding in Pabna region. High land and medium high land are being brought under fruit cultivation. Development of agroforestry based production is deemed important for raising sustainable total production per unit area of land. Elephant foot yam is a popular high value vegetable and can be grown easily under partial

shady areas. In this regard, upscaling the mango based agroforestry technology with elephant foot yam may result in increased total system productivity and satisfactory income generation.

Description: An existing 5-7 years old unutilized mango orchard can be selected. The corms of elephant foot yam (var. Madrazi local) are sown on last week of April in well prepared pit maintaining spacing of 100 cm X 75 cm in a mango orchard (var. Fazi local) that maintain spacing of 8 m X 8 m. Fertilizers are applied at the rate of 160-50-100-36-4.0-2.0 N-P-K-S-Zn-B Kg ha^{-1} for elephant foot yam. Recommended fertilizers should be applied for mango trees The harvesting of elephant foot yam is initiated on mid-July and continued up to end of July. The mangos are harvested of mango during 10 to 20 July.

Suitable areas: Pabna and mango growing areas with similaer ecosystem of the country

Benefit of the technology: Mango based agroforestry system is more productive and profitable than sole mango orchard system. Considering total system productivity mango based agroforestry system exhibited relatively better performance with mango equivalent yield (25.85 t ha^{-1}) and gross margin of Tk. 963400 ha^{-1} with MBCR 3.45.

Fact sheet-2

2. Development of guava based agroforestry system with high value crops

Introduction: Guava is now a popular fruit and its off season fruiting and good market price encourage the farmers to establish more guava orchards. Guva trees have light canopy structure which favors more sunlight to the ground as compared to other densed canopy fruits. Growing high value vegetable crops (Tomato, cabbage, cauliflower) in guava orchards can be better options for higher productivity and income generation.

Description: Existing 3-4 years old unutilized guava orchard can be selected. Thirty days old seedlings of tomato (var. BARI Tomato-19), cauliflower (var. Snow white) and cabbage (var. Atlas 70) are transplanted on 1st week of December with maintaining spacing of 60 cm x 50 cm for tomato and 60 cm x 45 cm for both cauliflower and cabbage. Application of fertilizers and other intercultural operation are made as per recommendation of individual crops (FRG' 2018). The harvesting of tomato is initiated on March 12 and continued up to March 25. The harvesting of cauliflower is initiated on February 17 and continued up to March 10 and the harvesting of cabbage from February 20 and continued up to March 15. The harvesting of guava is initiated on February 17 and continued up to March 25.

Suitable areas: Pabna and guava growing areas with similar ecosystem of the country.

Benefit of the technology: All the tested vegetables in agroforestry system exhibited 3 to 4 time's higher production and economic return as compared with sole guava. Considering total system productivity guava + cauliflower agroforestry system exhibited better performance with fruit equivalent yield of 24.69 t ha^{-1} and gross margin of Tk. 678050 ha^{-1}. Guava+ Tomato

agroforestry system also perform better with guava equivalent yield of 21.68 t ha^{-1} and gross margin of Tk. 583300 ha^{-1}.

Fact sheet-3

3. **Development of Litchi based agroforestry with high value crops**

Introduction: The increasing trend of litchi tree orchard in Pabna area is opening good scope of agroforestry based production. In most cases the ground space of litchi orchard is remain unused. So, the unutilized space can be easily utilized with suitable crops. Development of agroforestry based production is deemed important for raising sustainable total production per unit area of land. Growing high value vegetable crops (Cauliflower, cabbage, broccoli) in litchi orchards can be better options for higher productivity and income generation.

Description: Existing 10-11 years old unutilized litchi orchard can be selected. Thirty days old seedlings of cauliflower (var. Snow white), cabbage (var. Atlas 70) and broccoli (var. BARI Broccoli-1) are transplanted on last week of November with maintaining spacing of 60 cm x 45 cm for all vegetables. Application of fertilizers and other intercultural operation are done as per recommendation of individual crops (FRG' 2018). The harvesting of cauliflower is initiated on February 11 and continued up to February 18. The harvesting of cabbage is initiated on February 22 and continued up to March 10 and the harvesting of broccoli from January 25 and continued up to February 08.

Suitable areas: Pabna and Litchi growing areas with similar ecosystem.

Benefit of the technology: All vegetables grown in litchi based agroforestry system exhibited remarkably higher production and economic return as compared to sole litchi. Considering total system productivity litchi + cauliflower agroforestry system exhibited relatively better performance with litchi equivalent yield of 13.21 t ha^{-1} and gross margin of Tk. 1162900 ha^{-1}. Litchi + Cabbage and Litchi + Broccoli agroforestry system also perform better with litchi equivalent yield 10.98 and 9.18 t ha^{-1} and gross margin of Tk. 939900 ha^{-1} and Tk.800900 ha^{-1} respectively.

Fact sheet-4

4. **Development of mango based agroforestry with high value vegetable crops in plain land ecosystem of Pabna**

Introduction: In Pabna district, different fruits (Mango) orchard has been established at the farmers' field. About 3-4 years after planting of mango orchard farmers get some economic return from fruits of these orchards. The ground niches of 6-7 years aged mango orchard can be successfully utilized with growing of different high value vegetables crops. In this connection, research is deemed imperative to screening some short duration crops (Pea, radish, cauliflower, cabbage and tomato) with regards to evaluate the magnitude of their shade tolerance capacity and productivity in relatively sole fruit orchards.

Description: Existing 5-7 years old unutilized mango orchard can be selected. Two management condition viz. a) agroforestry and b) open field along with five vegetables crops namely field pea (var. BARI Motor-3), radish (var. BARI Mula-1) cabbage (var. Atlas-70), cauliflower (var. Snow white) and tomato (var. BARI Tomato-19) are selected for growing under niche of mango orchard in this trial. The crops are sown/transplanted on last week of November maintaining recommended spicing for each crop and fertilizers are applied as per recommendation of FRG-2018.

Suitable areas: Pabna and mango growing areas with similar ecosystem.

Benefit of the technology: Considering total system productivity agroforestry system exhibited relatively better performance by 28-87 % over open land system. Considering higher economic return mango + tomato agroforestry system exhibited relatively better performance with gross margin of Tk. 771000 ha^{-1}. Considering total system productivity litchi + cabbage agroforestry system exhibited relatively better performance with cabbage equivalent yield of 114.9 t ha^{-1}.

Fact sheet-5

5. **Development of mango based agroforestry with fodder crops in plain land ecosystem of Pabna**

Introduction: Intensive utilization of agricultural land for food based crops results in shrinkage of free grazing land for cattle. Production of fodder crops is now being considered as a priority issue for livestock sector. High yield potential fruits varieties with dwarf canopy structure enhance increasing trend of fruit cultivation in rural areas. Napier is a high yield potential fodder crop and can be grown under niches of fruit trees.

Description: An existing 5-7 years old unutilized mango orchard can be selected. The cuttings of fodder crops (Napier var. Pakchong) are sown on mid Dicember maintaining spacing of 100 cm X 50 cm in a mango orchard (var. BARI Aam-4) with spacing of 5 m X 5 m. Fertilizers are applied at the rate of 100-38-56-20-1.5-1.0 N-P-K-S-Zn-B Kg ha^{-1} for the fodder crop (FRG' 2018). The harvesting of Napier is initiated on mid-July and continued up to end of December. The mangos are harvested of mango during 5 to 12 July.

Suitable areas: Pabna and mango growing areas with similar ecosystem.

Benefit of the technology: Mango based agroforestry system is more productive and profitable than sole mango orchard system. Considering total system productivity agroforestry system exhibited relatively better performance with mango equivalent yield (5.16 t ha^{-1}) and gross margin of Tk. 218260 ha^{-1} with 1.87 MBCR.

<u>**Fact sheet-6**</u>

6. **Development of Alternate Cropping Pattern Potato-T.** *Aus*-T. *Aman* rice against Boro-Fallow-T. Aman rice under Mango Based Agroforestry System

Introduction: Boro Fallow-T. Aman is a major cropping pattern in greater Rangpur region. Many farmers practice this cropping pattern in medium high land where potato and T. *Aus* rice can be grown under mango based agroforestry systems.

Description: Potato variety BARI Alu-25, Aus variety BRRI dhan-48 and T. *Aman* rice variety BRRI dhan-87 are used in the pattern. Potato are sown during 25 to 28 November, T. Aus is panted during 4-8 April and T. aman is transplanted during, 11 to 18 July in improved cropping pattern. In existing cropping pattern Boro is transplanted during 26 to 30 January and T. *Aman* rice is transplanted during 25 to 28, July, 2019. In Improved cropping pattern Potato, T. Aus and T. Aman can be harvested at 87-89 DAP, 90-95 DAP and 110-120 DAP respectively. Recommended fertilizer dose should be used for all crops (FRG' 2018). Intercultural operations should be done when necessary.

Suitable areas: Rangpur region and similar ecosystem

Benefit of the Technology: The total gross margin of the developed pattern is Tk. 192460 h^{-1} whereas in existing pattern Tk. 98640 h^{-1}. Farmers prefer Potato-T. *Aus*-T. *Aman* rice cropping pattern due to its higher return and T. *Aus* rice is less irrigated water requiring crop compare to Boro rice and provide higher return. Improved pattern gave Tk. 93820 ha^{-1} compared to existing pattern.

Fact sheet-7

7. Development of mango based agroforestry system with fodder (Napier)

Introduction: In Bangladesh, due to increasing burgeoning bovine population, which turned, to be 200 million in 2030 poses a big challenge to existing agriculture system for their fodder requirements. It is possible to bring unutilized land like the nitches of different orchard under fodder production by using latest technologies. So, integration of fodder grass like Napier and mango into agroforesty production system may be better option to overcome the increasing demand of fodder.

Description: Napier fodder can be harvested above the ground level (3-4 cm) after 30 days of planting. After 30 days of 1st harvest, the green fodder is harvested again after 60 days of planting. Then third time green fodder is harvested after 90 days of planting and in every cutting. The yield of napier grass 18.67 t ha^{-1} can be obtained from mango based agroforestry system. The total cost of production is about Tk. 25670 ha^{-1} in Mango + napier based agroforestry system and the gross return can be achieved Tk. 56010 ha^{-1} as well as the gross margin Tk. 30340 ha^{-1} from the napier grass at Ajodhapur FSRD site Rangpur.

Suitable Location: Rangpur region and similar ecosystem

Benefit of the Technology: The total cost of production was Tk. 25670 ha^{-1} in Mango+Napier based agroforestry system and the gross return was Tk. 56010 ha^{-1} as well as the gross margin Tk. 30340 ha^{-1} from the napier grass. Agroforestry system gave more output as two crops produce more biological yield than single cropping

Fact sheet-8

8. Production of mustard in mango based agroforestry system

Introduction: Huge area of land is cultivated with mango orchard in High Barind Tract. Normally farmer does not cultivate any crop under the mango orchard. There is a greater scope to cultivate mustard in the mango based agroforestry system up to 08-10 years of mango plant which can contribute to meet partial deficit of edible oil and earn extra income of farmer without hampering mango production.

Description: Age of mango (var. BARI Aam-3) orchard could be up to 08-12 years old. Short duration mustard varieties (BARI Sarisha-14, 15, 17) can be selected. Mustard should be sown 1st week of November using recommended fertilizer (FRG' 2018). One light irrigation may be done at vegetable stage. Dimethoate (insecticide) and Hiprodion 50 WP (fungicide) can be sprayed for controlling aphid and leaf blight, respectively. Crop is harvested at the end of January.

Suitable areas: Rajshahi region with similar ecosystem

Benefit of the technology: Farmers can earn higher gross margin (Tk. 215000 ha^{-1}) and BCR (3.26).

9. **Development of Lentil-T. Aman cropping pattern in mango based agroforestry system**

Introduction: Huge area of land is cultivated with mango orchard in High Barind Tract. Normally farmer does not cultivate any crop under the mango orchard. Lentil and T. Amam rice can be grown up to 08-10 years of mango orchard. As lentil is a leguminous crop it can contribute for maintaining soil health. Nevertheless, both two crops are helpful for earning extra income of farmer without hampering mango production.

Description: Lentil var. BARI Masur-8 and rice var. BRRI dhan51 can be used. Lentil can be planted on mid November and T. Aman on mid-July with recommended fertilizer application. Intercultural operations be done as per support of normal growth of crops. Lentil is harvested on 2nd week of March and T. Aman on 1st week of November.

Suitable areas: Rajshahi region with similar ecosystem

Benefit of the technology: Farmers can earn higher gross margin (tk.351800 ha^{-1}) and BCR (3.99).

Component-2: Pomology Div., HRC, BARI

Fact sheet preparation is under process

(ii) Effectiveness in Policy Support (if applicable)

Component-1: OFRD, BARI

➢ Development of multistoried agroforestry in different ecosystem can play a pivotal role regarding meetigation of climate change induced crop failure, enhancing vertical productivity for achieving SDGs.
➢ Crop land agroforestry system reduces green house effect through C sequestration by crops and trees.
➢ Integrated agroforestry system opens a greater scope for uplifting food and nutrition security and hence it will attract greater attention to formulate policy planning for poverty reduction.

H. Technology/Knowledge generation/Policy Support (as applied)

Component-1: OFRD, BARI

i. **Immediate impact on generated technology (commodity and non-commodity)**

➢ Increases 2 to 3 time's higher production and economic return in the same piece of land due to adoption of high value crops like vegetables, pulses, spices etc. with existing fruit orchards.
➢ Develop enterpreneurship to supply chain of seedling of fruit trees, vegetables, spices and oil seed crop for greater extension of agroforestry technologies.
➢ Homestead agroforestry open employment opportunity and enhance income generation for rural women.

ii. Generation of new knowledge that help in developing more technology in future

- Community based seedling raising by women could open new concept for community based nursery management and income generation
- Relatively safe food production under agroforestry technology can develop supply chain for safe food market outlets
- Due to higher production of vegetables and fruits create an opportunity for unemployed youth lead community market.
- Greater adoption of agroforestry system and eventual benefit could help efficient land use system
- Rapidly growing fruit orchards could open greater scope for adoption of NARS institutes technologies in the agroforestry system in future.

iii. Technology transferred that help increased agricultural productivity and farmers' income

- Guava based agroforestry system with high value vegetable crops like tomato, cauliflower, cabbage, broccoli
- Litchi based agroforestry system with high value vegetable crops like cauliflower, cabbage, broccoli
- Mango based agroforestry system with high value vegetable crops like tomato, cauliflower, cabbage, broccoli, field pea
- Integrated homestead agroforestry with year round fruits and vegetables
- Mango based agroforestry with pulse crops (Lentil) in rainfed area
- Sorjan based agroforestry (fruits+ vegetables) in coastal ecosystem
- Mango based agroforestry with vegetables in Hill ecosystem
- Mango based agroforestry with fodder crops

iv. Policy Support

- Development of multistoried agroforestry in different ecosystem can play a vital role regarding mitigation of climate change induced crop failure, enhancing vertical productivity for achieving SDGs.
- Crop land agroforestry system reduces green house effect through C sequestration by crops and trees.
- Integrated agroforestry system opens a greater scope for uplifting food and nutrition security and hence it will attract greater attention to formulate policy planning for poverty reduction.

Component-2: Pomology Div., HRC, BARI:

Write up under process

- Immediate impact on generated technology (commodity and non-commodity)
- Generation of new knowledge that help in developing more technology in future
- Technology transferred that help increased agricultural productivity and farmers' income
- Policy Support

I. Information regarding Desk and field Monitoring

i. Desk Monitoring [description and output of consultation meeting, monitoring workshops/seminars etc.):

ii. Field monitoring

FSRD site Ganggarampur, Pabna

Year	No of visit	Name and address	Remarks
2020	01	1. Dr. Md. Akkas Ali, CSO, OFRD, BARI, Gazipur 2. Dr. Md. Mazharul Anwar, PSO, OFRD, Region-1, Rajshahi 3. Dr. Jagadish Chandra Barman, PSO, Barind, Rajshahi 4. Dr. Md. Faruk Hossain, SSO, OFRD, BARI, Gazipur 5. Md. Akhtar hossain, SSO, OFRD, BARI, Gazipur 6. Dr. Jahan Al Mahmud, SSO, OFRD, Kushtia	Visitors express their high satisfactiontion and suggested for field trip of Scienitists, DAE, Farmers
2021	02	1. Dr. Debashis Sarker, Director General. BARI, Gazipur 2. Dr. Md. Nazirul Islam, Ex Director General. BARI, Gazipur 3. Dr. Md. Abdul Latif Akanda, Director, ORC, BARI, Gazipur 4. Dr. Rina Rani Saha, Director (P & E), BARI, Gazipur 5. Dr. Md. Akkas Ali, CSO, OFRD, BARI, Gazipur 6. Dr. Md. Faruk Hossain, SSO, OFRD, BARI , Gazipur 7. Dr. Taslima Zahan, SO, OFRD, BARI	Visitor's comment: -Excellent agroforestry activities -Honourable Agriculture Minister showed keen interest to see the agroforestry activities
2021	03	1. Dr. Akram Hossain Choudhuri, Chairman BMDA	Visitor being impressed and write a letter for concerning Honourable Prime Minister, Govt. of Bangladesh to adopt agroforestry technology for achieving SDGs

FSRD site, Ajoddhapur, Rangpur

Year	No of visit	Name and address	Remarks
2019	01	A S M Mahabubur Rhaman Farming system Expert, NATP, BARC	
2020	01	A S M Mahabubur Rhaman Farming system Expert, NATP, BARC	
	02	1.Dr. M. Akkas Ali, CSO, OFRD, BARI 2. Dr Md. Faruk Hossain, SSO, OFRD, BARI	
	03	A S M Mahabubur Rhaman, Farming system Expert, NATP, BARC	
	04	1.Dr. Quamrun Naher, SSO, OFRD, Gazipur 2. Md. Akhtar Hossain, SSO, OFRD, Gazipur	

FSRD Site, Barind, Rajshahi

Year	No of visit	Name and address	Remarks
2020	01	PIU-BARC, NATP-2 (Director, PIU)	Homestead, Field crop
	02	Executive Chairman, BARC	,,

FSRD Site, Patuakhali

Year	No of visit	Name and address	Remarks
2019	01	A S M Mahabubur Rhaman Farming system Expart, NATP, BARC	Homestead, Field crop, Livestock, Fisheries and Off-farm activities
2020	02	1.Dr. M. AkkasAli, CSO, OFRD, BARI 2. Dr Md. FarukHossain, SSO, OFRD, BARI	;;

FSRD Site, Banderban

Year	No of visit	Name and address	Remarks
2019	01	A S M Mahabubur Rhaman Farming system Expart, NATP, BARC	Research activities
2020	01	Dr. Munshi Rashid Ahmed, CSO, HRS, Khagracchari Dr. Taslima Zahan, SO, OFRD, BARI	,,
2021	01	1. Dr. M. Akkas Ali, CSO, OFRD, BARI 2. Dr Md. Faruk Hossain, SSO, OFRD, BARI	,,

iii. Weather data, Flood/salinity/drought level (if applicable) and natural calamities:

FSRD Site, Ajoddhapur, Rangpur

Flood: Continuous rainfall in September 2020 and Severe flood occurred during late September 2020.

Weather data of Rangpur during the years of February 2018 to December 2020.

Month	Temperature (ºC)						Avr. RH (%)			Total rainfall (mm)		
	Avr. Max			Avr. Min								
	2018-19	2019-20	2020	2018-19	2019-20	2020	2018-19	2019-20	2020	2018-19	2019-20	2020
February	26.77	26.35	26.08	14.16	14.45	12.93	69.59	70.82	70.59	0	119.60	0
March	30.99	30.14	30.09	18.98	17.56	17.94	6579	64.23	68.45	13.40	11.0	31.10
April	30.60	30.89	31.42	21.67	21.70	20.60	75.10	73.25	70.82	152.20	140.0	190.0
May	31.17	32.05	31.45	22.98	23.31	23.15	77.45	77.12	79.35	324.50	346.30	347.40
June	33.35	33.74	32.94	25.82	25.53	25.96	79.63	90.33	81.83	321.40	277.50	389.70
July	33.26	32.44	32	27.14	26.41	16.14	79.92	83.03	84.69	143.20	595.60	748.80
August	33.60	34.25	34.12	27.02	27.36	27.12	79.29	78.53	78.90	207.30	336.20	182.50
September	32.99	31.59	31.15	26.08	25.79	26.08	79.52	85.45	85.82	147.70	604.80	1036.60
October	30.80	30.53	33.10	22.30	23.15	24.80	77.02	79.76	78.03	32.30	174.40	119.0
November	29.25	29.44	29.48	17.38	19.51	17.93	71.07	74.87	68.72	0	0	0
December	25.68	23.55	25.08	12.62	12.71	14.34	70.26	75.84	75.72	7.6	0	0
January	25.69	22.50	-	11.79	11.92	-	66.85	77.26	-	0	8	-

FSRD Site, Ganggarampur, Pabna

Month	Temperature (°C)						Av. RH (%)			Total rainfall (mm)		
	Avr. Max			Avr. Min								
	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
January	17.80	25.60	23.20	12.80	10.50	11.29	76.10	81.70	100.50	00.00	0.00	21.30
February	20.20	33.40	26.40	16.80	26.80	26.00	73.50	79.30	80.60	00.00	276.10	0.00
March	20.20	32.20	31.40	16.90	17.80	17.80	69.90	70.90	75.30	168.40	00.00	0.00
April	31.80	34.10	34.20	20.90	22.90	21.70	81.40	79.80	81.30	212.30	00.00	13.20
May	32.00	35.70	33.60	24.60	25.70	24.10	79.90	79.00	81.80	144.50	1251.00	372
June	34.03	34.90	34.85	25.81	26.20	26.00	79.40	84.20	82.73	214.40	1679.00	-
July	33.99	34.00	34.10	27.36	26.60	26.74	80.60	86.80	84.94	540.50	297.10	-
August	33.44	33.90	33.92	26.85	26.80	26.82	82.70	86.20	82.74	356.50	158.5	-
September	33.54	32.70	33.24	25.99	26.30	26.00	81.70	88.90	83.70	270.50	192.9	-
October	31.45	31.40	31.44	22.80	22.90	22.12	80.70	91.90	85.72	75.80	191.2	-
November	28.80	29.70	29.60	18.20	18.50	18.60	82.50	90.80	76.73	2.60	69.1	-
December	25.0	24.2	24.52	13.2	19.8	18.20	71.3	89.8	62.50	7.2	6.0	-

FSRD Site, Barind, Rajshahi

Month	Temperature (°C)						Total rainfall (mm)		
	Avr. Max			Avr. Min					
	2018-19	2019-20	2020-21	2018-19	2019-20	2020-21	2018-19	2019-20	2020-21
July	33.93	34.50	34.50	26.71	26.48	26.48	238.2	261.1	261.5
August	34.65	34.52	34.59	26.97	26.94	27.18	83.9	114.6	143.7
September	34.35	33.45	34.09	26.14	26.21	26.83	118.2	187.7	214.8
October	41.13	31.40	33.63	21.71	23.01	25.01	81.5	173.8	98.3
November	29.97	29.99	30.23	16.73	18.30	17.39	0	3.4	0.2
December	25.22	23.67	25.17	11.64	11.70	13.01	17.2	0.2	0
January	25.46	23.33	23.75	10.41	11.45	11.44	0	16.2	0
February	27.62	26.72	29.09	13.38	12.56	12.85	47.1	0.6	0
March	32.08	31.61	34.57	17.45	18.05	19.27	67.6	3.5	0
April	34.53	34.44	37.52	22.95	21.69	22.85	113.9	32.7	15.3
May	35.92	33.80	34.63	32.29	24.18	24.40	146.8	187.3	196.6
June	35.81	35.81	-	26.35	26.35	-	121.8	121.8	-

FSRD Site, Patuakhali

Month	Temperature (°C)						Avr.Max. RH (%)			Total rainfall (mm)		
	Avr. Max			Avr. Min								
	2018-19	2019-20	2020	2018-19	2019-20	2020	2018-19	2019-20	2020	2018-19	2019-20	2020
July	32.6	31.84	33.80	26.30	27.29	26.30	96.33	95.77	98.00	1387	683.00	534.00
August	31.65	32.32	32.70	26.14	26.32	26.50	95.42	97.16	96.00	2431	470.00	586.00
September	32.26	30.40	32.30	26.40	24.20	26.30	40.55	96.83	97.00	277	838.00	459.00
October	33.07	31.83	31.90	26.35	24.15	25.70	97.03	98.48	98.00	390	394.00	443.00
November	31.41	30.14	30.4	23.21	20.13	19.8	98.81	99.20	98.00	162	249.00	240.00
December	30.16	26.45	27.1	19.07	14.92	15.1	97.73	97.90	98.00	6	5.00	0.00
January	26.24	24.89		13.96	13.35		98.10	98.26		0	64.00	
February	27.64	28.09		12.03	14.78		98.39	96.76		0	3.00	
March	30.95	32.84		34.14	20.50		90.77	98.00		61	30.00	
April	32.21	32.28		20.81	24.60		97.48	96.57		51	99.00	
May	33.93	33.72		24.16	25.57		93.13	95.13		51	135.00	
June	34.22	32.50		26.84	26.10		94.13	96.00		187.00	348.00	

FSRD Site, Banderban

Month	Temperature (°C)						Av. RH (%)			Average total rainfall (mm)
	Avr. Max			Avr. Min						
	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018-2020
February	29	32	24	19	21	18	53	50	70	13
March	32	34	30	22	24	22	76	60	56	46
April	35	34	31	26	26	24	73	77	80	65
May	31	34	31	26	28	27	75	78	78	232
June	32	33	31	27	26	27	84	85	80	416
July	33	32	30	27	26	26	82	83	83	435
August	32	31	28	27	26	27	83	84	87	334
September	32	30	29	26	26	27	84	86	86	292
October	30	30	31	24	25	26	80	81	80	186
November	30	31	29	22	22	23	72	79	75	45
December	23	28	27	22	19	19	61	69	58	16
January	24	27	24	17	18	19	70	57	68	5

Component-2: Pomology Div., BARI

i. Desk Monitoring [description and output of consultation meeting, monitoring workshops/seminars etc.): N/A

ii. Field monitoring

Year	No of visit	Name and address	Remarks
2019	01	1. Dr. Md. Monowar Karim Khan, Member Director, BARC 2. Dr. Susmita Das, Principal Documentation Officer, Agricultural Information Centre, BARC 3. Md. Ashequr Rahman, Assistant Manager Accounts, NATP-2, PIU-BARC	Experimental field visit and financial progress

J. Sub-project auditing (covers all types of audit performed)

Types of audit	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Foreign	No observation	-	-	-

K. Lessons Learned

  i. Agroforestry is the intensive production system which ensures year round crop production and cash income.
 ii. Rapidly growing fruit orchards can be brought under agroforestry system which could enhance total production and income generation of rural farming.
iii. Fallow land can be utilized in agroforestry system
 iv. Enhance development of enterpreneurship for seedling raising of fruit trees and different vegetables and their marketing.
  v. Motivational program/Training/Group discussion/Development of LSP would be helpful for widescale adoption of agroforestry technologies.

L. Challenges (if any)

1. Problems/ Constraints

   i. Lack of labour in crop growing season
   ii. Some difficulties faced in management of fruit trees due to standing associated crops
   iii. Land preparation with power tiller is difficult in some existing fruit orchards due to relatively dense planting of fruit trees
   iv. Delay in fund release hampers execution and set up of the experiments
   v. Lack of skillness of farmers on crop and fruit tree management in agroforestry system
   vi. Lack of quality seeds/seedlings of high yielding crop varieties at the field level
   vii. Lack of transport facilities for the agroforestry produce from the distant plot to the market
   viii. Lack of scientific staff having good understanding of necessary data collection from the agroforestry system at field level
   ix. Lack of training facility for farmers, scientific staff and scientific personnel on agroforestry technologies
   x. Sometimes lower market price of the produce make the farmers disinterested to the agroforestry system based production

M. Suggestions for future planning (if any)

- For successful adoption of agroforestry technologies Local Service Provider (LSP) needs to be established at each location for sustainable seed/seedling production and supply chain to the farmers.
- In situ training on efficient managment practices for crops and fruit trees in agroforestry system for capacity build up of the community farmers.
- Long-term project support needed to scale up viable agroforestry technologies in homestead and crop field.
- Multidisciplinary team including Agronomist, Soil Scientist, Entomologist, Pathologist Economist and Farmers should be engaged for the development of viable agroforestry technologies.
- Development of mini tillage machine could be helpful for land preparation in the fruit orchards in case of large scale adoption of agroforestry technologies.
- Strengthening of market linkage for the agroforestry produce in the community and urban level
- Safe food production technologies like environment friendly bio rational pesticides should be made available at the community level for producing safe fruits and vegetables under agroforestry system.

Signature of the Coordinator

Date ………………………….

Seal

Counter signature of the Head of the organization/ authorized representative

Date …………………………..

Seal