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Sustainable integration of banana in farming systems for enhanced income and nutritional security

Banana is a very popular fruit due to its low price and high nutritive value coupled with ample carbohydrates and vitamins. It has a short gestation period and higher potential. It is essentially a tropical plant requiring a warm humid climate. Almost all the parts of this plant viz. fruits, leaves, flower bud, trunk and pseudostem can be utilized effectively in a farming system. Banana plantation offer tremendous opportunities to efficiently increase the yield and income of farmers in a shorter time. Development of Banana-based farming systems involves cultivation of compatible intercrops along with the integration of enterprises like poultry, dairy, mushroom, fishery, crops, etc. Integration of banana in the system offers considerable scope for increasing production in lesser time and with high input-use efficiency. The wastes/by-products of crop/animals used as input for another component helps in increasing the nutrient efficiency at the farm level through nutrient recycling.

HORTICULTURE forms an integral part of Indian economy. A significant segment of the total agricultural production of a country is contributed by the horticultural crops. The role of horticulture is changing rapidly from traditional to high income generating activity. The horticultural crops are highly income intensive if improved management practices are adopted along with development of appropriate market linkages. The production of fruits and vegetables has a comparative advantage, particularly under conditions where arable land is scarce, labour is abundant and markets are accessible. Integrated farming system, a multidisciplinary whole-farm approach with special emphasis on natural resource conservation and their judicious utilization, is gaining immense importance now-a-days. With the increasing need for food and nutritional security under the changing climate and resource degradation due to faulty land use practices, horticulture-based farming system has emerged as important strategy to address this issue.

Horticulture based farming systems helps in effective utilization of resources and improvement of environment. Preservation of bio-diversity, diversification of cropping/farming system and maximum recycling is the base for success of the farming systems approach The wastes/by-products of crop/animals used as input for another component has increased the nutrient efficiency at the farm level through nutrient recycling. In the farming system approach, horticulture provides excellent opportunities in raising the income of the farmers even under abrasive conditions. The cultivation of fruit crops under horticulture based farming system (HBFS) plays an important role in the prosperity of a nation along with health, happiness, prosperity of the people and ensures sustainable farm income under abrasive climatic conditions. Integration of horticultural modules in farming systems enhances the productivity and profitability. Among different horticultural crops, banana is the one which can be a suitable crop to be integrated in the farming system along with high nutrition apart and income to the farm family. Banana is basically a tropical crop, which grows well in temperature range of 13°C–38°C with RH regime of 75-85%. The banana fruit itself is one of the most popular fruits and important diet due to its high nutritional contents.

In India, this crop is being cultivated in climate ranging from humid tropical to dry mild subtropics and currently India is the largest producer of banana in the world. Integration of banana in farming system in selected prototype models under All India Coordinated Research Project on Integrated Farming Systems (AICRP-IFS) across the country and has shown tremendous potential of banana.

Banana module in IFS (Modipuram, Uttar Pradesh)

An Integrated Farming System model of 0.70 ha has been developed for marginal farmers of Uttar Pradesh under irrigated conditions at ICAR-IIFSR, Modipuram, Meerut under AICRP-IFS (on station) programme. The primary components of the model are crops (0.38 ha), Horti-pasture system (0.18 ha), agri-horti system with

banana as main crop (0.04 ha), Dairy (1 B+1C) and boundary plantation with fruits like guava and karonda. The secondary components of this model are vermicomposting (0.005 ha) and value-addition of the marketable surplus. Under the cropping system module, three systems have been developed with a specific aim. To meet out the demand for family nutrition, Basmati rice-Wheat + Mustard/ Chickpea has been developed. For improving the soil health, *Sesbania*-Chickpea-Greengram, and for income generation Okra-Cauliflower-Babycorn + Cowpea have been developed as shown in Table 1. These systems are able to meet the demand of food, feed, and generation of income for the family (4-member household) along with the maintenance of soil health. The biofortified varieties of rice (CR Dhan 310) and wheat (WB 02) and plantation of napier grass (Co-5) as bunds were introduced in IFS module to ensure nutrition security of family members and livestock in IFS model. The horti-pasture module with 5 fodder crops, viz. sorghum, pearlmillet, maize, cowpea, and maize + cowpea in 5 strips (300 m^2 each) of kinnow plantation were evaluated and it was found that cultivation of fodder in 0.18 ha of kinnow plantation can supply green fodder to 1 cow and 1 buffalo for 158 days. Kinnow recorded 849 kg of fruits from 0.18 ha (27,416 kg/ha). And banana recorded yield of 580 kg from 0.04 ha (Table 2). The dairy unit with one buffalo (murrah) and one desi cow recorded milk 2328 l/year. Average daily dung production from dairy unit was 54 kg which works out to 19.7 tonnes/year. The 0.70 ha IFS model produced about 106 t/ha sugarcane equivalent yield annually with total 293 man days employment. Model could also ensure household level demand of cereals, pulses, oilseeds, milk, vegetables, and fruits compared to the existing system.

Table 1. Agri-horti based IFS model for marginal farmers developed at ICAR-IIFSR, Meerut

Module	Details
Cropping system (0.38 ha)	Basmati rice-Wheat + Mustard / Chickpea-Dhaincha Okra-Cauliflower-Baby corn + Cowpea Sesbania (Seed)-Chickpea -Greengram
Horti-pasture (0.18 ha)	1. Kinnow + Fodder crops
Agri-horti (0.04 ha)	1. Banana + Field crops
Boundary plantation	1. Karonda (Pink strain) 2. Guava (Allahabad Safeda)
Dairy (1 B + 1 C)	1. Buffalo (Murrah), 2. Cow (Gir)
Vermi-compost (50 $m^{2)}$	
Secondary agriculture	Value-addition of marketable surplus

Table 2. Production of different modules in 0.70 ha Agri-horti based IFS Model

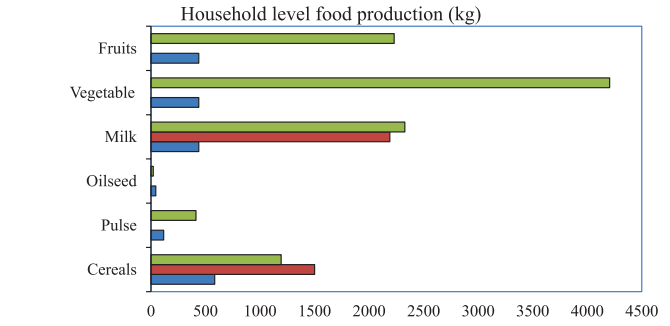
Module	Details	Crops	Production (kg)
Cropping system	Rice-wheat + mustard/ chickpea	Rice	518
		Wheat	675
		Mustard	20
		Chickpea	37
	Okra-cauliflower-baby corn + cowpea	Okra	1292
		Cauliflower	1380
		Baby corn	1114
		Cowpea	335
	Sesbania – chickpea- green gram	chickpea	312
		Green gram	81
Horti-pasture	Kinnow + fodder crops	Kinnow	849
		Fodder	4733
Agri-horti	Banana & Papaya + Intercrops	Papaya	91
		Banana	580
		Vegetable pea	84
		Soybean	42
Boundary plantation	Karonda and Guava	Karonda	206
		Guava	704
Dairy	1 B + 1 C	Milk (lit.)	2328
Total sugarcane equivalent yield (t/year)			106.08

Food and nutritional security of Agri-horti based IFS Model (0.70 ha)

The model could provide all the essential commodities to a farm family in terms of fruits, vegetables, milk, oilseeds, pulses and cereals. The Agri-horti model resulted in the production of cereals (1193 kg), Pulse (413 kg), Oilseeds (21.35 kg), Milk (2328 kg), Vegetables (4205 kg) and Fruits (2230 kg) and had been able to meet the demand of family for food and nutrition. The rest excess produce upon selling provided the farm family with the cash to meet their social demands.

Resource recycling and material flow through integration of Banana Module with other components of the farming system

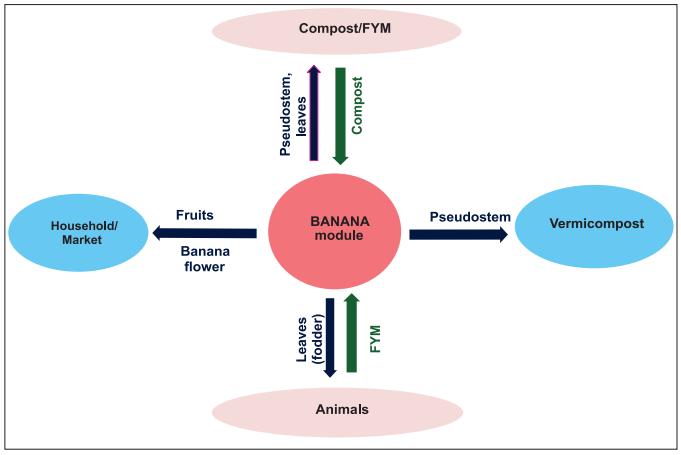
The integration of banana variety Monthan (Culinary purpose) in this model has provided the farmers with



	Cereals	Pulse	Oilseed	Milk	Vegetable	Fruits
Improved IFS	1193	413	21.35	2328	4205	2230
Existing system	1500	0	0	2190	0	0
Requirement (kg)	584	116	44	438	438	438

Food production in 0.70 ha IFS model

an alternative of planting banana as the main crop for diversification and higher income. The variety Monthan planted at a spacing of 2×2 m in the month of July starts bearing fruits in 13-14 months. Among the full grown plantation, intercropping with vegetables like pea and soybean has been done successfully. The interaction of different by-products has been studied and different by products have been utilized as input for others. The by-products of banana include suckers, leaves, pseudostem, fruits and banana flowers. The fruits and the flowers are utilized for home consumption or are sold in the market. The pseudostem and leaves are utilized for preparation of compost or vermicomposting. The chopped tender leaves and pseudostem are fed as fodder to animals as depicted below.



Interaction of different by-products in banana system

Integration of mushroom component in banana plantation

Fungi belonging to the *Pleurotus* genus, also known as oyster mushroom develop with efficiency in lignocellulosic wastes. They have specific enzymes that degrade lignocellulosic compounds present in those types of raw material. The waste from the banana tree is another material with high potential for utilization as substrate in edible mushroom cultivation. The substrates based on leaves of banana cultivar (Monthan) were used to evaluate the production of *Pleurotus florida* mushroom.

A huge amount of waste is generated after harvest. Both pseudostem and leaves of the banana tree have high content of lignolitic fibers with high potential for development of edible mushrooms. The cultivation technology of edible mushrooms in the Western Uttar Pradesh is still less developed and needs further refinement for successful integration in farming systems. Banana leaves can also be used as an alternative substrate for oyster mushroom production and this opens the avenues for recycling of banana residues within the farming system. Among the different substrates tested, the highest biological efficiency has been recorded for Rice straw (57.57%) with a yield of 575.70 g/kg of dry straw followed by Mustard straw (47.50 %) with a yield of 470.50 g/kg of dry straw and the lowest for straw prepared from banana leaves (43%) with a yield of 430.0 g/kg of dry straw (Table 2).

Oyster mushroom in Banana field

Table 2. Banana substrate for mushroom (*Pleurotus florida*) production

Substrate	Yield (g)/kg dry straw	Biological efficiency (%)
Rice straw	575.70	57.57
Mustard straw	470.50	47.50
Banana leaves	430.00	43.00

Nutrient saving through recycling of banana waste

Banana crop waste is a cheap source of nutrients, it increases organic matter, stimulates soil microbial life, enhances water holding capacity and increases crop yields. The process of composting offers many benefits including enhanced soil fertility and soil health (thereby increased agricultural production), improved soil biodiversity, and reduced environmental risks. It is suggested that banana crop residues can be recycled for compost with other organic sources. The pseudostem and leaves of banana after harvest are utilized for compost preparation and total of 8.07 kg of Nitrogen, 1.64 kg of Phosphorus and 18.12 kg of Potash can be saved by recycling from 0.04 ha. (Table 3). However, through the recycling of wastes from 0.7 ha model, the system can recycle 119.80 kg N, 33.50 kg P and 109.90 kg K. the share of recycling through banana module in the Model is 6.47% for N, 4.88% for P and 16.48% for K (Table 4). Thus Banana crop residues can be recycled for compost with other organic sources for better utilization of waste.

Value addition in Banana

Banana is considered to be one of the most important energy sources in the diet of people. The banana is a versatile fruit for preparing several processed foods

Banana chips

Banana pickles

Banana jam

Table 3. Nutrient saving through recycling of Banana wastes

Banana biomass from 0.04 ha	Fresh weight (kg)	Dry matter (kg)	N (kg)	P (kg)	K (kg)
Pseudostem	6200	1116	7.14	1.56	10.49
Leaves	305	61	0.93	0.07	7.63
Total	6505	1177	8.07	1.64	18.12

Table 4. Per cent share of recycling through Banana wastes

Parameter	N (kg)	P (kg)	K (kg)
System recycling (0.7 ha)	119.80	33.50	109.90
Recycling from Banana module (0.04 ha)	8.07	1.64	18.12
% Share	6.74	4.88	16.48

through simple processing methods. Monthan Banana is a versatile fruit that is a staple food and cannot be eaten as raw but has to be processed to a range of products such as chips, pickles, jam and squash for value addition and effective utilization and generating income through processing and value addition to the farm family (Table 5).

In case of banana sauce, matured green banana jam and green banana pickles, different blanching treatments (0, 2, 4, 6 and 8 min.) were considered. However among different treatments, banana jam prepared with 4 min blanching treatment recorded maximum overall sensory score (8.6) with final TSS (69.2°B) and banana pickles prepared with 2 min. blanching recorded the maximum overall sensory score (8.2), while, banana sauce prepared with 6 min. blanching treatment recorded the maximum sensory score (8.0).

Economics of agri-horti based IFS model (0.70 ha)

The Agri-horti model developed for a marginal farm can provide the Gross Returns of ₹ 344785 and Net Returns of ₹181324. Among all the modules integrated in the model, the horticulture module as the main crop or as the boundary plantation provided higher returns as compared to the others. The horticulture based farming system is capable of providing higher returns and benefits to the farmers along with the nutritional security. The cash flow generated helps in increasing investment in farming which is reflected in improvement in performance of other component also. Integration of horticultural crops provides the diversification, ensures resilience, enhances sustainability and provides great ecological services to the mankind. It ensures food, nutritional security, and gainful employment for farm families besides environmental

Table 5. Income generation through value addition in Banana

Processed products from Banana	Quantity of raw material of banana used (kg)	Cost of processing & value addition	Final quantity of processed product (kg)	Total income from processed product (₹)	Net income from processed product (₹)	Income improvement due to processing
Chips	10	425	1.5	600	175	0.8 times
Squash (ripe)	10	715	15	1500	785	2.6 times
Pickles	10	618	10	800	182	0.9 times
Jam	10	1085	20	2800	1715	8.5 times
Sauce	10	850	20	1600	750	3.7 times

Banana sauce

Banana squash

Table 6. Economics of 0.70 ha IFS model

Component	Sugarcane equivalent yield (kg)	COC (₹)	Gross return (₹)	Net return (₹)	B:C ratio
Cropping system	35192	28106	114375	86269	4.1
Horti-pasture	10109	6815	32877	26062	4.8
Agri-horti	5603	11700	18208	6508	1.6
Boundary plantation	10302	3000	33480	30480	11.2
Dairy	44875	113840	145845	32005	1.3
Total		163461	344785	181324	2.1

protection. The sustainability of production is well addressed in this system through efficient utilization of natural resources and biomass recycling.

The Agri-horti system including horti-pasture besides post-harvest processing and value addition of banana provided net returns of ₹ 39868 which is 22% of the net income of the model. The integration of banana system provided 8.07 kg N, 1.64 kg P and 18.12 kg K which is 6.74% for N, 4.88% for P and 16.48% for K of the total recycling done in the farming system model. This prevents an ultimate loss of huge amount of untapped biomass and environmental issues. It is important that all available by-products be turned into highly commercial outputs in order to sustain this renewable resource and provide additional income. Generating wealth from waste such as from the banana by-products should be regarded as one of the ways to create an eco-friendly environment for the sustainable farming systems.

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Integrated Farming System for Doubling Farm Income

Integrated farming system (IFS) model was developed with the concept of integration of multiple enterprises (crops, livestock's, beekeeping, fisheries etc.) in a single farm unit to ensure year-round income and employment for a farm family having 1 ha irrigated land. Net income of model was ₹ 3.87 lakh/year along with 628 man days engaged throughout the years. The highest net income (₹ 1.68 lakh/year) was obtained from livestock (3 crossbreed cows) enterprise followed by crop (₹ 1.06 lakh). Model depicted that the total carbon assimilation by the crop enterprises was 4,448 kg/annum. Carbon cycle assessed using farm design tool showed that total input of carbon from the crop enterprises to household and animal was 603 and 5,555 kg/annum respectively. The addition of carbon from crop and livestock manure to the soil was 256 and 1,698 kg/annum respectively. Overall accumulation of carbon in the soil was 1,955 kg per annum which ultimately enriches the organic matter pool of the soil.

Source: ICAR Annual Report (2020)