

## Integrated farming systems improves climate resilience and productivity of rainfed mango (*Mangifera indica*) orchards

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### ABSTRACT

Over six years (2016-2022), field experiments were carried out at the ICAR-Indian Institute of Horticultural Research in Bengaluru to evaluate the effects of a system approach on moderating microclimate, enhancing productivity, and increasing profitability in rainfed mango orchards (*Mangifera indica* L.). The approach involved rainwater harvesting, intercropping, resource recycling, bund intensification with fodder resources and dairy. The results indicated that intercropping with protective irrigation using water stored in farm ponds helped in slight modification in the microclimate. Among various intercropping systems, mango + brinjal registered the highest system productivity (22,468 kg/ha), followed by mango + sweet corn (10,864 kg/ha) and mango + pigeonpea (7,068 kg/ha). Intercropping in rainfed mango orchards on an average yielded net returns of Rs. 1,73,000/ha, significantly higher than mono-cropped rainfed mango. Further, integrating two dairy cows with brinjal intercropping, recycling farmyard manure (FYM), and maintaining a vermicompost unit resulted in a mean net return of Rs. 4,96,000 /ha/year. Continuous intercropping in mango orchards effectively enhanced soil organic carbon and nitrogen levels. The results demonstrated the modifications in microclimate, improved system productivity, economic returns and sustainability of mango orchard through an integrated farming system.

**Key words:** Climate resilience, Cropping diversity, Micro-climate, System productivity

Agricultural production is highly dependent on weather conditions, but recent shifts and increased frequency of extreme weather events have heightened its susceptibility to climate risks (Gangwar *et al.*, 2016). In India, rainfed agriculture accounts for 40% of the nation's food supply, supports 60% of its livestock, and sustains 40% of the population. Extreme weather events can significantly impact productivity in these areas (Anonymous, 2021). To secure food for a growing population and ensure the sustainability of natural resources, managing the impacts of climate change on crop production is crucial. Effective adaptation strategies are needed to counter adverse effects (Rao and Rao, 2016). While climate change is expected to reduce rainfed mango yields in drylands, this can be mitigated by applying knowledge on crop, soil, and water management.

Modifying the microclimate involves altering the local atmosphere's composition to improve crop growing con-

ditions, enhancing growth and yield (Mahi and Kingra, 2013). Integrated farming systems in tropical regions offer ecological benefits such as climate change mitigation, microclimate amelioration, water use efficiency, and sustainable land use (Kumar, 2016). Intercropping and mixed farming strategies improve farm resource efficiency and ensure sustainable crop production (Manjunath *et al.*, 2021). The overlap period between crops significantly impacts microclimate and resource efficiency. Protective irrigation at appropriate rates and timings helps to reduce heat stress, maximize yield, and improve water efficiency (Tesfaye *et al.*, 2006). Evaluating the impact of a system approach in rainfed mango is essential for sustainable productivity and profitability under changing climatic conditions. The present study aims to mitigate climate change impacts on rainfed mango yields through an integrated farming system approach.

### MATERIALS AND METHODS

The study was conducted over six years (2016-2022) at the ICAR-Indian Institute of Horticultural Research in Bengaluru, located at latitude 13°8'12" N and longitude 77°29'45"E. The region experiences maximum tempera-

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tures of 24°C to 36°C and minimum temperatures of 10°C to 22°C. March to May are the warmest months, while November to January are the coolest. The average annual rainfall is ~850 mm, with peaks in June-July and September-October. The soil was sandy loam with a pH 6.14, EC 0.067 dS per m, available N 152.4 kg/ha, available P 38.7 kg/ha, and available K 385.3 kg/ha. Soil moisture content at field capacity was 11.66% at 0-30 cm depth and 12.81% at 30-60 cm depth.

The system approach included rainwater harvesting for protective irrigation using solar pumps, boundary planting with forage grasses and legumes, selecting profitable intercrops, and integrating dairy and recycling resources through vermicomposting. A farm pond lined with silpaulin with a storage capacity of 5 lakh liters was constructed within a hectare catchment area to provide protective irrigation.

The feasibility of intercropping in a 30-year-old rainfed mango 'Totapuri' orchard, spaced 10 m x 10 m, was assessed. Eight intercrops were grown in fixed plots: pigeonpea 'BRG-5', forage grass 'hybrid napier BH-18', sweet corn 'Sugar 75', cowpea 'Goa Cowpea-3', drumstick 'PKM-1', finger millet 'GPU-28', field bean 'Hebbal Avare-3' and brinjal 'Arka Harshita', along with a control plot (no intercrop). Temperature and relative humidity were recorded monthly in the mango basin and interspaces at ground and canopy levels using a digital thermo-hygrometer. Recyclable materials produced in the mango orchard were quantified periodically and used for vermicomposting with mixed cultures of earthworms (*Eisinea foetida*, *Perionicus excavatus*, and *Eudrillus eugenia*). System productivity was calculated by convert-

ing intercrop yields to mango equivalents and economic analyses were conducted based on market values of inputs and produce. Statistical analyses of yield and economic data were performed using standard methods, with mean differences compared at 5% significance level.

## RESULTS AND DISCUSSION

### *Microclimate conditions in integrated farming system*

The six years of data on the impact of various intercropping systems on the annual mean temperature and relative humidity at both ground and canopy levels in rainfed mango orchards showed that intercropping with brinjal under protective irrigation from farm pond significantly influenced the microclimatic conditions. Brinjal, with its dense foliage under protective irrigation, recorded the lowest temperatures at both ground (29.64°C) and canopy levels (30.42°C) in the mango basin, and 29.62°C and 29.41°C, respectively in the interspace (Table 1). This cooler environment is likely due to the dense canopy and continuous moisture supply, which help to reduce soil temperature and minimize evaporation. Conversely, sweet corn, which is characterized by its tall stature and sparse coverage, resulted in the highest temperatures at the ground (33.54°C) and canopy levels (34.96°C) in the mango basin, and 34.28°C and 30.62°C, respectively in the interspace. The higher temperatures associated with sweet corn can be attributed to poor air circulation and reduced shading effect, leading to increased soil and air temperatures.

Relative humidity also varied significantly among the different intercropping systems. The intercropping involving brinjal consistently showed the highest relative humid-

**Table 1.** Annual mean temperature and relative humidity as influenced by different intercropping systems in rainfed mango (pooled data, 2016-2022)

Treatment	Temperature (°C)				Relative humidity (%)			
	Mango basin		Interspace		Mango basin		Interspace	
	Ground level	Canopy level	Ground level	Canopy level	Ground level	Canopy level	Ground level	Canopy level
Mango + Napier Grass	30.89	30.78	31.10	31.41	43.90	44.59	43.71	45.20
Mango + Pigeonpea	30.86	30.84	31.28	31.47	44.68	44.41	43.90	44.82
Mango + Sweet corn	33.54	34.96	34.28	30.62	43.52	43.61	42.90	44.20
Mango + Cowpea	30.91	32.15	34.02	33.47	42.17	41.19	40.90	44.98
Mango + Drumstick	30.97	31.07	31.22	31.56	44.26	45.18	43.83	44.76
Mango + Finger millet	30.78	31.16	31.39	31.59	43.59	44.14	43.20	44.49
Mango + Field bean	32.47	34.64	32.44	32.75	42.81	41.69	41.35	43.52
Mango + Brinjal	29.64	30.42	29.62	29.41	51.46	51.30	51.14	47.19
Mango alone (control)	32.87	34.02	33.32	32.31	44.78	45.55	43.99	45.69
SEm±	0.12	0.13	0.09	0.17	0.28	0.32	0.29	0.35
C.D (P=0.05)	0.36	0.37	0.27	0.49	0.83	0.93	0.84	1.02

ity levels, with values of 51.46% at the ground and 51.30% at canopy levels in the mango basin, and 51.14% and 47.19% respectively in the interspace. This high humidity with brinjal intercropping can be linked to effective ground coverage and protective irrigation, which maintain higher soil moisture and reduce evaporation rates. On the other hand, crops like cowpea, dolichos, and field bean recorded lower relative humidity levels, with cowpea/dolichos showing 42.17% and 41.19% at ground and canopy levels in the mango basin, and 40.90% and 44.98% respectively in the interspace. The reduced canopy coverage in these systems allowed greater light penetration causing higher temperatures, which in turn reduced the relative humidity. Closely grown, intensively irrigated crops can reduce temperature and increase humidity at the microclimate level, likely due to reduced soil temperature and moisture evaporation, increased water availability, and groundwater recharge from decreased runoff and increased infiltration (Chittapur, 2018; Tatarwal *et al.*, 2023). This emphasizes the importance of selecting appropriate intercrops to optimize microclimate conditions, thereby enhancing the overall system productivity and sustainability.

### Profitability in integrated farming system

#### Intercrops

Intercropping trials over six years period revealed that the mango + brinjal system recorded the highest system productivity (22,468 kg/ha), net returns (Rs. 4,36,252/ha), and benefit-cost ratio (2.8), followed by mango + sweet corn (10,864 kg/ha, Rs. 2,56,580/ha, and 4.7, respectively) and mango + pigeonpea (7,068 kg/ha, Rs. 1,42,310/ha, and 3.0, respectively) (Table 2). The higher productivity of the mango + brinjal and mango + sweet corn systems may be due to the high potential of the short-duration crops cultivated in these systems. Thus, it is evident that expanding the production system to include a sizable tree component protects against revenue risks brought on by climate unpredictability (Newaj *et al.*, 2016).

#### Integration with dairy

Finger millet stover, sweet corn green stover, *Sesbania* loppings, weeds from mango basin, and hybrid Napier forage grass formed a balanced diet for milch cows, which need 25-30 kg of green grass and 5-10 kg of dry grass daily. With proper storage, these resources can ensure a year-round fodder supply. The results demonstrated that 14.4 tonnes of fodder resources could be generated that can support two dairy cows. Feeding cows with farm-produced fodder significantly reduces feed costs and maintains sustainable milk production (Behera and France, 2016).

**Table 2.** System productivity and economics of rainfed mango based integrated farming systems (pooled data, 2016-2022)

Treatment	Yield of mango (kg/ha)	Yield of intercrop (kg/ha of mango garden)	Secondary produce of intercrop (kg/ha)	Mango equivalent yield of intercrop (kg/ha)	Total system productivity (kg mango/ha)	Total cost (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit-cost ratio
Mango+Forage grass	2,409	74,775	71,897	3,739	6,147	74,220	1,84,420	1,10,200	2.5
Mango+Pigeonpea	3,692	2,026	14,474	3,377	7,068	69,740	2,12,050	1,42,310	3.0
Mango+Sweet Corn	3,494	14,741	16,804	7,370	10,864	69,350	3,25,930	2,56,580	4.7
Mango+ Cowpea	4,368	432	219	720	5,088	54,300	1,52,630	98,330	2.8
Mango+ Drumstick	4,095	216	—	144	4,239	94,830	1,27,170	32,340	1.3
Mango+Finger millet	1,504	2,433	11,672	2,433	3,937	55,100	1,18,110	63,010	2.1
Mango + Field bean	956	7,891	—	5,261	6,216	78,170	1,86,490	1,08,320	2.4
Mango+ Brinjal	5,566	33,804	—	16,902	22,468	2,37,788	6,74,040	4,36,252	2.8
Mango alone (Control)	2,444	—	—	—	2,444	34,090	73,320	39,230	2.2

**Table 3.** Economics of integrated dairy maintenance (2 milch cows) in a year

Parameter	Particulars	Economics (Rs./ha)
Fixed cost	Cow purchase	1,60,000*
	Cowshed	20,000**
Variable cost	Feed	1,10,400
	Electricity	120
	Water	1,200
	Medicine	2,000
Total cost		1,31,720
Total returns	Milk yield 2910 liters/cow for a lactation period of 210 days @ Rs.29/litre	1,68,780
	Cowdung-22.48 tonnes @ Rs.630/tonne	14,160
Total gross returns		1,82,940
Net returns		51,200
The benefit-to-cost ratio		1.39

\*depreciated for a productive period of 15 years\*

\*\*depreciated for a life span of 20 years

With an average milk production of 9.7 liters per cow per day, gross monthly returns amounted to Rs. 15,245, while maintenance costs were reduced to Rs. 9,200 per month due to on-farm fodder supplies. This integration generated a consistent net return of Rs. 4,267 per month. Additionally, the cowdung produced (2.25 tonnes per month) contributed to the production of five tonnes of high-quality farmyard manure or compost annually (Table 3). Overall, this system provided regular income and employment for the farm family while enhancing farm sustainability.

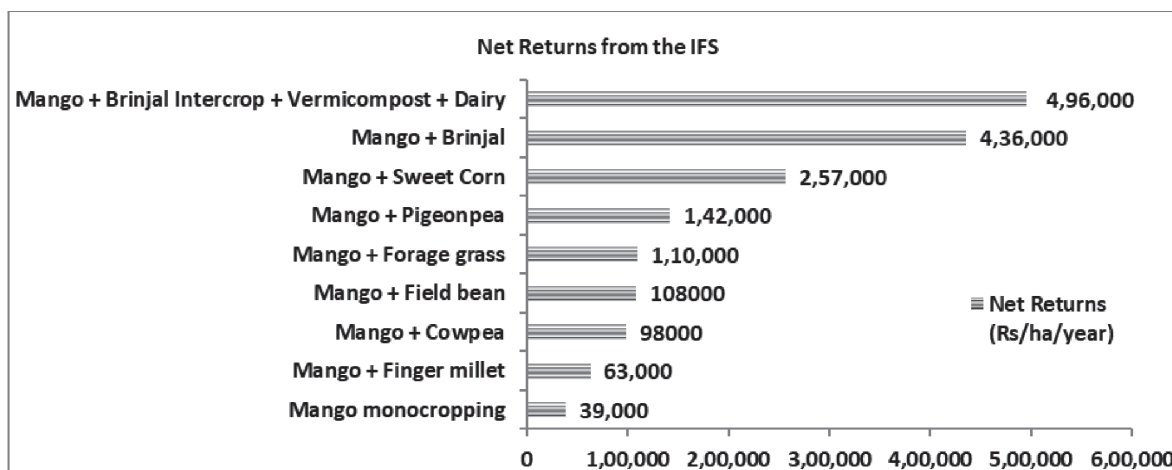
#### Resource recycling through vermicomposting

A low-cost vermicompost shed using silpaulin sheets produced an average of 467 kg of vermicompost per hectare annually from the 960 kg of crop residues and cow dung produced. The nutrient content of the vermicompost was 1.7% N, 0.30% P, and 4.5 % K. Recycling on-farm

generated resources through vermicomposting contributed significantly to the sustainability of the system by enhancing soil fertility and reducing the dependency on external inputs (Newaj *et al.*, 2016).

#### System productivity in the rainfed mango-based IFS

Integration of various crops in rainfed mango orchards yielded an average net return of Rs. 1,73,000 /ha compared to Rs. 39,000 /ha from monocropping (Fig 1). Integrating dairy and vermicompost units with brinjal intercropping resulted in mean net returns of Rs. 4,96,000 /ha/year, indicating the economic advantage of a diversified integrated system approach. This approach not only enhances farm income but also ensures a sustainable and resilient farming system by diversifying farm activities, reducing climate risks, and providing multiple sources of income and employment.



**Fig. 1.** Net returns from different aspects in the integrated farming system

**Table 4.** Recyclable resources and the on-farm generated vermicompost production during different years

Recyclable material	kg/ha/year					Mean yield
	2018	2019	2020	2021	2022	
Recyclable material (kg)	292	838	267	375	488	452
Cowdung (kg)	251	710	190	750	640	508
Total recycled (kg)	543	1,548	457	1,125	1,128	960
Total vermicompost produced (kg)	267	640	236	594	596	467
Recycled nutrients/ha/year (kg)						
Nitrogen	4.6	10.9	4.0	10.2	10.2	8.0
Phosphorus	0.8	1.9	0.7	1.8	1.8	1.4
Potassium	12.0	28.8	10.6	26.7	26.8	21.0

\*Considering the mean nutrient content of N (%) -1.7, P (%) - 0.3, K (%) – 4.5%.

### Sustenance of soil fertility

The soil test results of six years of continuous intercropping indicated that the organic carbon content of the soil was found to build up in the mango basin (0.54 % to 1.51 %). In the interspaces also, there was an increase in organic carbon from 0.42% (2017 initial) to 0.90% with intercropping. Among the intercrops, cultivation of pigeonpea accumulate marginally higher organic carbon (from 0.42 % to 0.81%). Compared to an initial status of 152.4 kg N/ha in the interspaces, the mean increase with six years of intercropping was 71 % (261 kg/ha). Further, among the intercrops pigeonpea added higher nitrogen in the soil (326 kg/ha) while forage grass removed higher nitrogen from the soil (178.5 kg/ha). In general, intercropping decreased the phosphorus content by 32 % (38.7 kg/ha to 29.3 kg/ha). The potassium content of the soil depleted with intercropping (385.3 kg/ha to 253 kg/ha), the highest depletion (105 %) being with forage grass intercropping.

The six-year study in rainfed mango orchards highlights the substantial benefits of integrated farming systems. The diversified integrated farming system notably increased net returns compared to monocropping, providing economic resilience, sustainable farm management, and improved livelihoods for farm families.

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